Newaukum Creek
Temperature
Total Maximum Daily Load

Water Quality Improvement Report
and
Implementation Plan

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Newaukum Creek

Temperature Total Maximum Daily Load

Water Quality Improvement Report
and
Implementation Plan

by

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Abstract

Newaukum Creek is located in Water Resource Inventory Area (WRIA) 09 and flows 14 miles from its headwaters in the western slopes of the Cascade foothills, northeast of Enumclaw, to the stream's mouth at the confluence with the Green River. Portions of Newaukum Creek exhibit unhealthy temperature and oxygen conditions for fish. These streams serve as important migration corridors and spawning and rearing areas for several salmon species, including Puget Sound Chinook, bull trout, coho, chum, pink, sockeye, steelhead/rainbow, and cutthroat trout. These species all need cold oxygenated waters for optimum health during various stages of their lives.

Washington State Department of Ecology (Ecology), King County Department of Natural Resources and Parks, the Muckleshoot Indian Tribe and others initiated a cooperative effort in 2006 to conduct total maximum daily load (TMDL) studies for temperature in the Green River and Newaukum Creek basins (Roberts and Jack, 2006a). King County supported the development of the TMDL studies through in-kind laboratory analyses, field activities, and model development consistent with the county's interest in maintaining and enhancing regional water quality.

Stream temperature, streamflow, and conductivity data from the field monitoring effort fed development of the QUAL2Kw, a stream water quality model. The calibrated model helped to answer some management questions by predicting how different meteorological, shade, and flow conditions affect water quality in the river. These predictive models assisted Ecology in setting thermal pollution load reduction targets for Newaukum Creek.

This water quality improvement report documents the TMDL study and implementation plan for improving temperature in Newaukum Creek. The Green River mainstem is targeted for its own TMDL studies on temperature, which are documented in separate Ecology reports.

Acknowledgements

Thanks to Mindy Roberts of Ecology's Environmental Assessment Program (EAP) and Richard Jack of King County Department of Natural Resources (DNR) who both developed the Sampling and Analysis Plan and Quality Assurance Project Plan for the Green River and Newaukum Creek Temperature and Dissolved Oxygen studies in 2006.

Teizeen Mohamedali, Mindy Roberts, Trevor Swanson, Craig Homan of Ecology; and Richard Jack, Jean Power, and Stephanie Hess of King County participated in the data collection and helped author the Green River and Newaukum Creek Temperature and Dissolved Oxygen Total Maximum Daily Load Study Data Summary Report in 2007.

Greg Pelletier of Ecology's Environmental Assessment Program provided technical advice and helped ensure that issues such as changes in canopy density were fully considered in the temperature modeling scenarios.

Thanks to Carla Carlson and others at Muckleshoot Indian Tribe Fisheries Division for analyzing historical impacts of development and water management on streamflows and baseflow scenarios for Newaukum Creek, and for providing valuable comments on the report.

Josh Kahan, King County Watershed Steward for Newaukum Creek basin is currently coordinating and managing stream restoration projects which constitute a significant component of implementation for this TMDL.

Curtis DeGasperi and David Funke of King County Department of Natural Resources conducted extra flow measurements in Newaukum Creek in summer of 2010.

Finally, special thanks to riparian property owners in Newaukum Creek Basin who are cooperating in stream restoration projects to improve stream habitat and help keep stream temperatures cool.

Executive Summary

Newaukum Creek basin is located in western Washington State in Water Resource Inventory Area (WRIA) 09. It drains about 27 square miles of land area, and includes portions of King County and the city of Enumclaw. Newaukum Creek flows 14 miles from its headwaters in the western slopes of the Cascade foothills, northeast of Enumclaw, to the stream's mouth at the confluence with the Green River.

Portions of Newaukum Creek exhibit unhealthy stream temperature and oxygen conditions that do not meet Washington State water quality standards. This water quality improvement report (WQIR) contains the studies and implementation plan for improving stream temperatures in Newaukum Creek. The WQIR consists of the total maximum daily load (TMDL) study and a plan to implement the TMDL. The TMDL study identifies pollution problems in the watershed, and then specifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology, local governments, agencies, and the community developed a plan that describes actions to control thermal pollution and promotes monitoring to assess the effectiveness of the water quality improvement actions.

The Green River and its major tributaries, including Newaukum Creek, serve as important migration corridors and spawning and rearing areas for several salmon species, including Puget Sound Chinook; bull trout; coho; chum; pink; sockeye; steelhead/rainbow; and cutthroat trout. These species all need cold, oxygenated waters for optimum health during various stages of their lives. TMDL studies and modeling, conducted in 2006, show that Newaukum Creek and its tributaries are not meeting water quality standards for temperature at all times. The critical time of year, combining annual minimum flow and annual maximum temperature in Newaukum Basin, typically occurs in late July and early August. Maximum predicted temperatures in Newaukum Creek, during the critical period, under current conditions do not exceed the 22^{O} C lethal level for salmon, but do exceed the core summer salmon habitat standard of 16^{O} C over the lower 14 km (8.7 miles) of stream length.

Establishing mature riparian vegetation for shade is expected to improve stream temperatures and increase the stream's oxygen-carrying capacity. Modeling showed that Newaukum Creek could meet the 16^{O} C temperature standard over most of the stream length, except for the last 2 km of the mainstem, with the combined effects of added streamside trees with overhanging vegetation and riparian microclimate. Modeling also showed the middle plateau reach of Newaukum Creek as the reach currently needing the most additional shade, ranging from 11.9 to 63.4% required additional shade. Some riparian restoration projects are already underway on the plateau reach to help reduce this shade deficit. More restoration projects are needed on the Newaukum Creek mainstem and its tributaries.

Modeling also showed that Newaukum Creek could meet the 16^{O} C temperature standard over the entire stream length with the combined effects of restored baseflows, added streamside trees with overhanging vegetation, and riparian microclimate. Restoring historical stream baseflows will involve limiting water withdrawals from springs and shallow aquifers feeding the creek, and infiltrating stormwater and/or reclaimed water to the maximum extent feasible. Restored baseflows were modeled by adding 5.9 cubic feet per second (cfs) to Newaukum Creek streamflow in accordance with estimates of baseflow loss from impervious surfaces and water withdrawals (Carlson, 2011). Restored baseflows are predicted to decrease maximum stream temperature by 0.5 ^{O} C (on average) below system potential.

Some actions recommended by the WRIA 9 Green-Duwamish Salmon Recovery Council affect stream temperatures and are included in this TMDL implementation plan. Salmon-related implementation actions include riparian restoration of Newaukum Creek mainstem up to stream mile 14.3, and re-alignment and restoration of Newaukum Creek tributary Big Spring Creek. These actions will improve stream temperatures as well as salmon habitat.

Newaukum Creek and its tributaries should meet water quality standards for temperature by 2040, given that stream restoration and stormwater management projects proceed on schedule. Long-term progress toward meeting temperature TMDL goals will be measured by re-evaluating riparian shade and modeling to determine how much of the stream length is exceeding standards. Re-evaluation will occur approximately every five years. If the modeled length of stream channel falls behind the implementation schedule, the rate and type of restoration projects should be altered in accordance with the adaptive management section of this plan.

Funding for TMDL implementation projects is available through EPA; Ecology's Centennial Clean Water Fund, Coastal Protection Fund, and other sources; King County's Grant Exchange Programs; King Conservation District Programs; the state Salmon Recovery Funding Board; and various other funding sources.

What is a Total Maximum Daily Load (TMDL)

Federal Clean Water Act requirements

The Clean Water Act (CWA) established a process to identify and clean up polluted waters. The CWA requires each state to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) criteria, usually numeric criteria, to achieve those uses.

The Water Quality Assessment and the 303(d) List

States are required to prepare a list of water bodies every two years that do not meet water quality standards. This list is called the CWA 303(d) list. In Washington State, this list is part of the water quality assessment (WQA) process.

Washington State Department of Ecology (Ecology) compiles its own water quality data to develop the WQA along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

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

Category 2 – Waters of concern.

Category 3 – Waters with no data or insufficient data available.

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

- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, culverts.

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

Further information is available at Ecology's Water Quality Assessment web site.

The CWA requires that a total maximum daily load (TMDL) be developed for each of the water bodies on the 303(d) list. A TMDL is a numerical value representing the highest pollutant load a surface water body can receive and still meet water quality standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. 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, with the assistance of local governments, tribes, agencies, and the community then develops a plan to control and reduce pollution sources and a monitoring plan to assess effectiveness of the water quality improvement activities. Together, the study and implementation plan comprise the *water quality improvement report and implementation plan*.

Who should participate in this TMDL?

Many government agencies, citizen groups, and tribes in the watershed have regulatory authority, influence, information, resources, or other involvement to protect and restore the stream health of Newaukum Creek. King County has lead roles and regulatory authority in stream restoration and protection and regional salmon recovery. The city of Enumclaw has municipal stormwater permit coverage. The Muckleshoot Indian Tribe has resource interests in the Newaukum Creek basin and contributed technical analysis to this TMDL.

Nonpoint source pollutant load targets have been set in this TMDL and are described in Table 8. Because nonpoint pollution comes from diffuse sources, all upstream watershed areas have potential to affect downstream water quality. Therefore, all potential nonpoint sources in the watershed must use the appropriate best management practices to reduce impacts to water quality. Similarly, all point source dischargers in the watershed must also comply with the TMDL. The area subject to the TMDL is shown in Figure 3 as the Newaukum Creek watershed subbasin to the Middle Green River Watershed.

Elements the Clean Water Act requires in a TMDL

Loading capacity, allocations, seasonal variation, margin of safety, and reserve capacity

A water body's *loading capacity* is the amount of a given pollutant that a water body can receive and still meet water quality standards. 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 *wasteload* or *load* allocation. If the pollutant comes from a discrete (point) source subject to a National Pollutant Discharge Elimination System (NPDES) permit, 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 diffuse (non-point) sources not subject to an NPDES permit, such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation*.

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

Surrogate measures

This TMDL incorporated *surrogate measures* other than the listed parameter of temperature to provide more meaningful and measurable pollutant loading targets. EPA regulations [40 CFR 130.2(i)] allow other appropriate measures, or surrogate measures, in a TMDL where numeric load allocations are impractical or where the impairment cannot be attributed to a single traditional "pollutant". Discussion of potential surrogate measures for use in this TMDL follows. The ultimate need for, and the selection of, a surrogate measure for use in setting allocations depends on how well the proposed surrogate measure correlates with the listed parameter and matches the selected implementation approach.

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 being violated, heat is considered the pollutant. Processes that affect the heat load in the Newaukum Creek basin include:

- Riparian vegetation disturbance that affects stream surface shading and microclimate.
- Reduced exchange of cool groundwater.
- Reduced summer baseflows (reducing the volume and velocity 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 to a measure which can be used for TMDL implementation. Planting for riparian shade is the major implementation action used in most temperature TMDLs. Other factors influencing heat flux and water temperature were also considered, including microclimate, channel geometry, groundwater recharge, and instream flow.

This TMDL recommends restoration and protection of summer stream baseflows in Newaukum Creek. The volume of summer baseflows directly influences stream temperatures by absorbing heat from solar radiation. The greater the summer baseflow stream discharge, the more water is avalible to absorb heat loads during the critical period.

Why Ecology Conducted a TMDL Study in this Watershed

Ecology conducted 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 for the Newaukum Creek basin is in accordance with that prioritization.

Ecology, King County, the Muckleshoot Indian Tribe, and others initiated a cooperative effort to develop a temperature and dissolved oxygen (DO) TMDL in this basin in the summer of 2006. The effort included water quality monitoring in Newaukum Creek. 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.

Data collected were used to develop water quality models for Newaukum Creek. The models are used to understand factors contributing to elevated temperature and low dissolved oxygen in the system and to develop load reduction targets necessary to meet the water quality standards throughout the system.

Impairments addressed by this TMDL

This TMDL was originally intended to address both temperature and DO impairments in Newaukum Creek Basin. At this point in time the TMDL was narrowed to address only temperature because additional data and information are needed to refine the model used to simulate dissolved oxygen. The dissolved oxygen and temperature models can be decoupled so that temperature effects can be addressed now and dissolved oxygen effects can be addressed in the future when additional data and information are available.

The main uses to be protected by this TMDL are aquatic life uses for core summer salmonid habitat and salmonid spawning, rearing, and migration in Newaukum Creek. Washington State established water quality standards to protect these beneficial uses. The uses will be protected by reducing heat to the water body. Table 1 includes the 303(d) listing for temperature impairment in Newaukum Creek.

Table 1. Segment of Newaukum Creek on the 2008 303(d) list for temperature.

Water body	Parameter	Listing ID	Township	Range	Section
Newaukum Creek	Temperature	48233	21N	06E	29

This watershed has other water quality impairments not addressed in this Newaukum Creek Temperature TMDL (Table 2).

Table 2. Additional 2008 303(d) listings not addressed by this Newaukum Creek Temperature TMDL.

Water body	Parameter	Listing ID	Township	Range	Section
Newaukum Creek	DO	12700	21N	06E	33
Newaukum Creek	DO	47454	20N	06E	15
Newaukum Creek	DO	47455	20N	06E	14
Newaukum Creek	Fecal coliform	13157	21N	06E	28
Newaukum Creek	Fecal coliform	13165	21N	06E	33
Newaukum Creek	Fecal coliform	13166	20N	06E	10
Newaukum Creek	Fecal coliform	13971	20N	06E	12
Newaukum Creek	Fecal coliform	13972	20N	07E	07
Newaukum Creek	Fecal coliform	13981	20N	07E	07
Newaukum Creek	Copper	13765	21N	06E	28
Newaukum Creek	Copper	13839	21N	06E	33

Fecal coliform listings in Newaukum Creek watershed are being addressed through a 'Straight to Implementation' plan currently underway with Ecology's Northwest Regional Office.

Water Quality Standards

Temperature and dissolved oxygen affect 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. Stream temperature is critically important to aquatic organisms because it regulates their survival, metabolism, reproduction, growth, and behavior. Permanent shifts in temperature can cause stream organisms to abandon habitat that would otherwise be suitable. Accordingly, stream temperature is closely regulated; heat is considered a pollutant under Section 502(6) of the Clean Water Act.

The health of fish and other aquatic species also depends upon 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. Oxygen is added to the stream through mixing with the atmosphere and absorbed across the air-water interface, but also is produced by photosynthetic aquatic plants. Low oxygen conditions result when the plant material dies and decomposes or result from diel shifts in plant metabolism (King County, 2007). 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.

Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (Ecology, 2006), include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state.

Designated aquatic life uses

Aquatic life use categories are described in the state water quality standards 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 Newaukum Creek basin include (1) Core Summer Salmonid Habitat and (2) Salmonid Spawning, Rearing, and Migration (Figure 1).

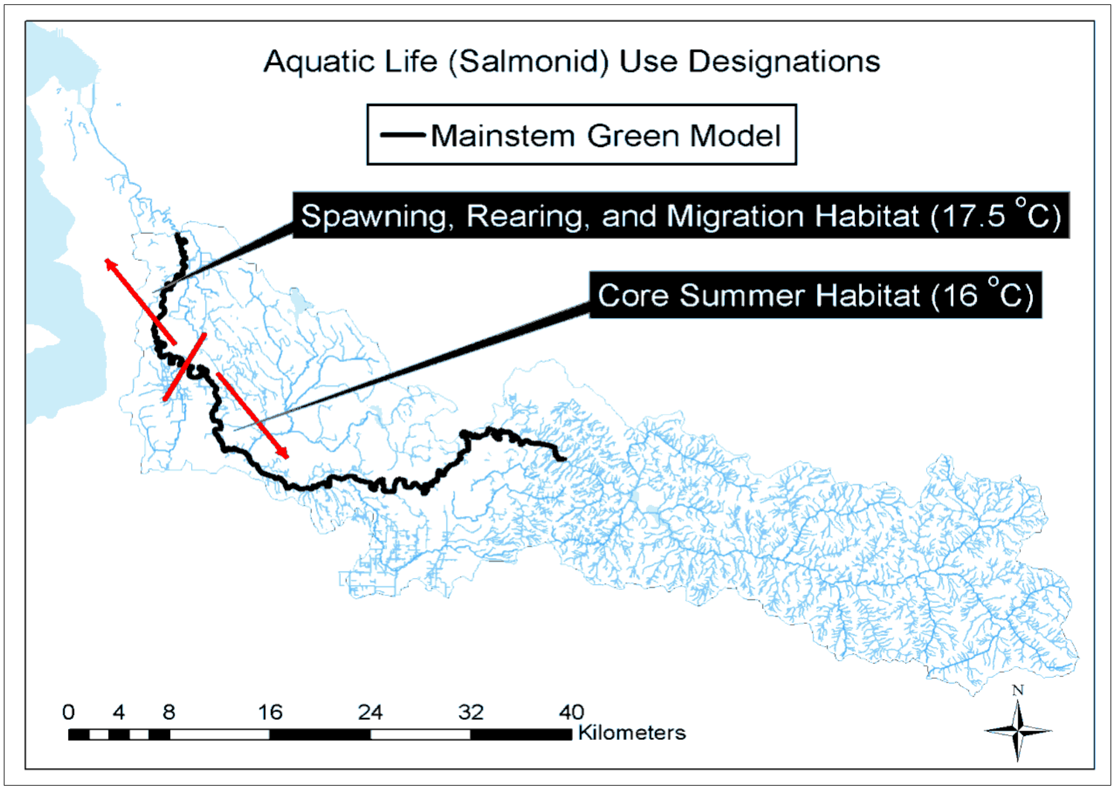

Figure 1. Aquatic life use designations and temperature criteria for Green River. *Newaukum Creek is tributary to mainstem Green River approximately midway on the Core Summer Habitat designated reach.*

These designated aquatic life uses are defined in WAC 173-201A-200 as:

- *Core summer salmonid habitat* **-** this use protects summer season, defined as 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.

Each beneficial use designation has associated water quality criteria. The relevant temperature criteria that apply to the Newaukum Creek are summarized below.

Temperature criteria

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 seven-day average of the daily maximum temperatures (7-DADMax) occurring in a water body.

The applicable temperature criteria [WAC 173-201A-200(c) and 173-201A-602] for the designated uses are:

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.

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

Supplemental temperature standards

Special consideration is also required to protect spawning and incubation of salmonid species. In addition to protecting core summer salmonid habitat June 15 through Sept 15, Newaukum Creek must not exceed 13°C between September 15 and July 1 for spawning and incubation. This study was designed to evaluate summer peak temperatures; other conditions are not evaluated explicitly.

The salmonid populations targeted for the additional spawning and incubation protection are those that have eggs and embryos developing in the stream bed in late spring to early fall. Salmonid populations, which begin spawning in late, fall or whose young have emerged from the stream gravels before late spring do not require added protection.

A spawning temperature of 13°C (as a seven-day average of daily maximum temperatures) is used to protect summer reproduction areas for salmon and trout, and a criterion of 9°C (as a seven-day average of daily maximum temperatures) is used to protect summer reproduction by native char species (bull trout and Dolly Varden). Figure 2 shows the reaches in Green River Watershed including Newaukum Creek where these criteria are to be applied during September 15 to July 1.

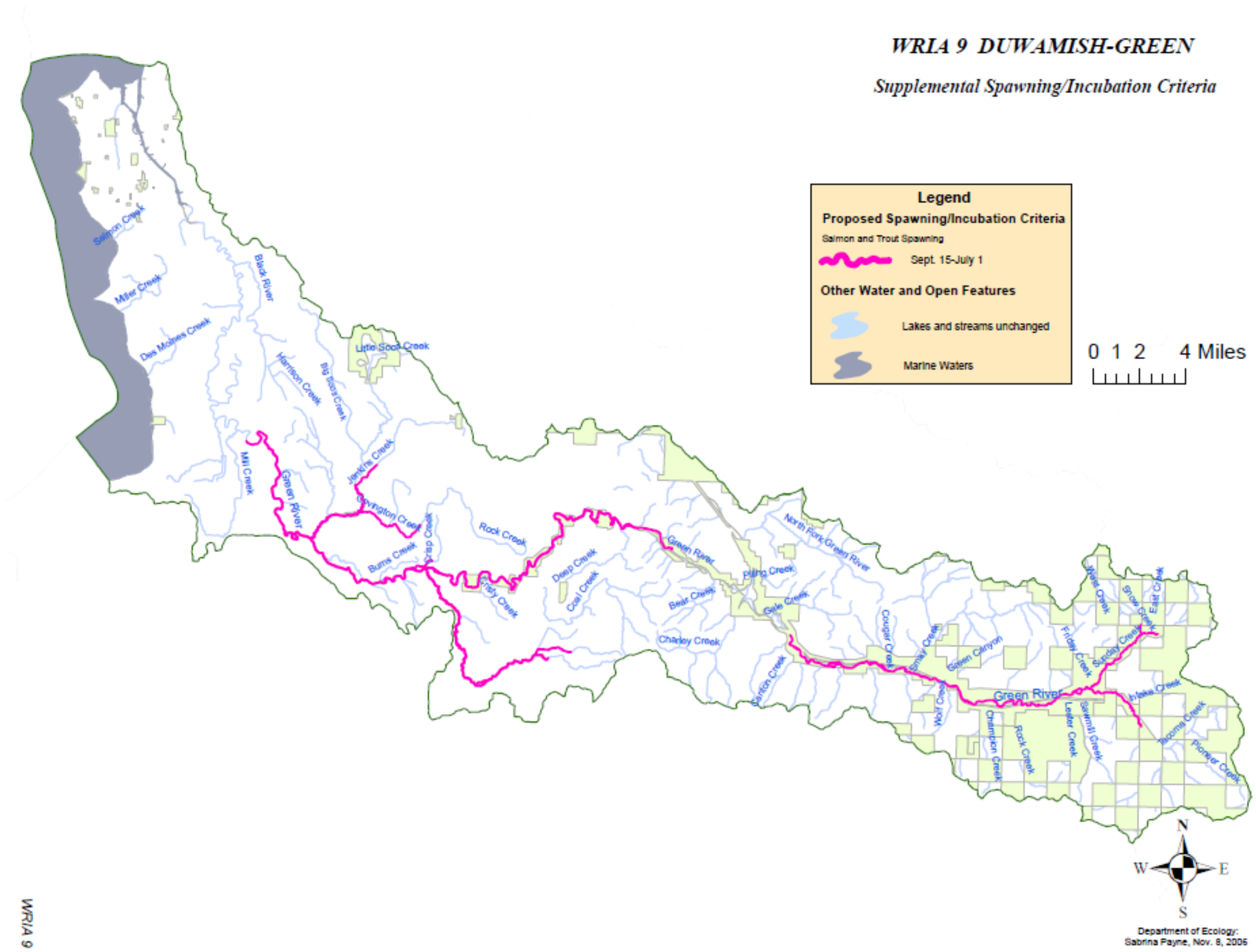

Figure 2. Application of supplemental spawning and incubation criteria in WRIA 9. *Newaukum Creek is the southern tributary to the lower-middle Green-Duwamish Watershed.*

Watershed Description

Newaukum Creek

Newaukum Creek is located in Water Resources Inventory Area (WRIA) 09 Green-Duwamish Watershed. It has 27.5 miles of stream length that drains a 27.4 square mile region north of the city of Enumclaw. Mainstem Newaukum Creek flows 14.0 miles from its headwaters in the western slopes of the Cascade foothills, northeast of Enumclaw, to the stream's mouth at river mile 40.7 of the Green River. The remaining 13.5 miles of Newaukum Creek stream length are in the eight tributaries to the mainstem.

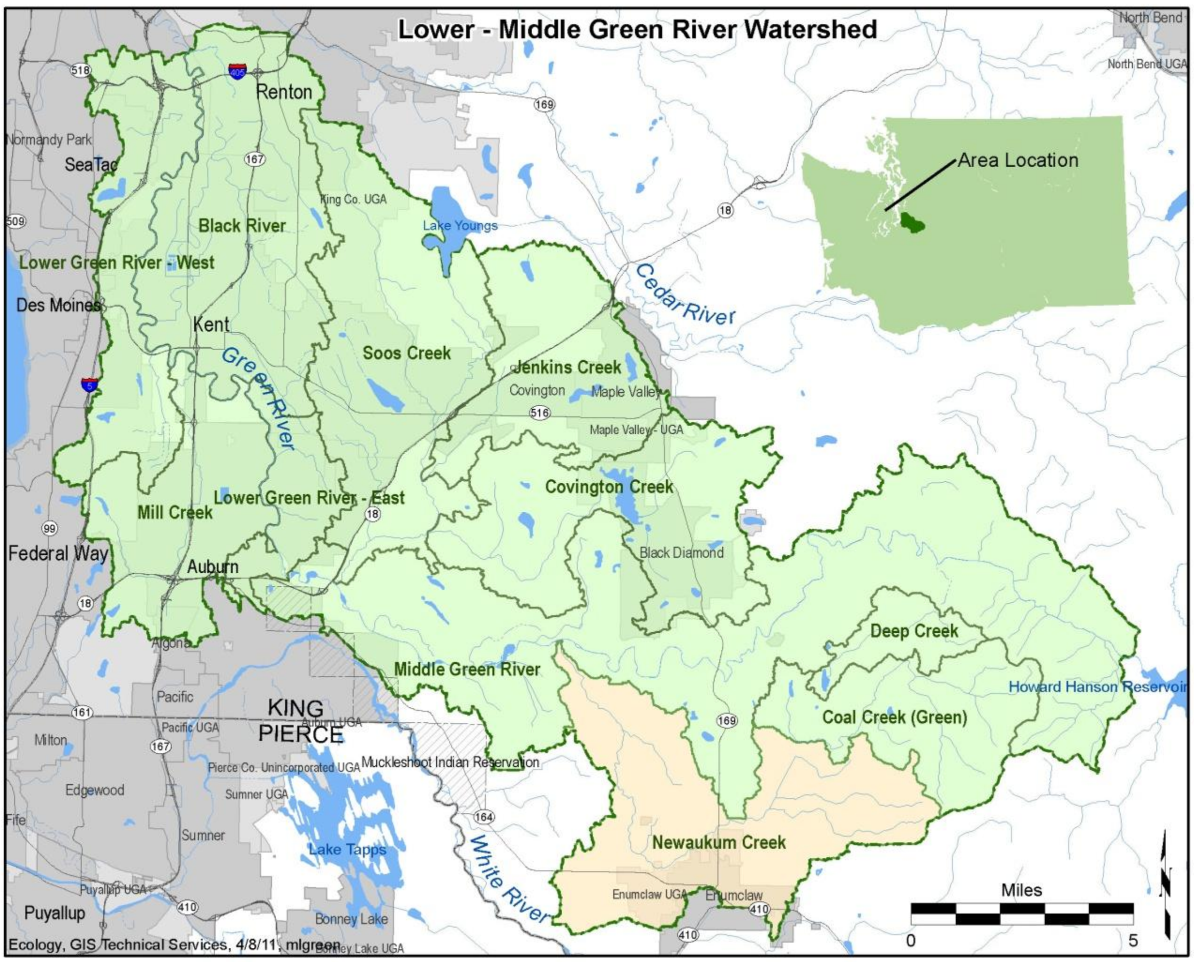

Figure 3. Newaukum Creek watershed in Middle Green River Basin.

Basin characteristics

Physical features and climate

Newaukum Creek watershed can be topographically divided into three subbasins: the upper subbasin in the Cascade foothills; the middle subbasin on the Enumclaw plateau; and the lower subbasin, a downward grade to the confluence with the Green River. In the upper subbasin, Newaukum Creek flows from Boise Ridge through the second growth forests on the western flank of the Cascade foothills, down to the farmlands of the Enumclaw plateau. Topography in Newaukum Creek basin is most pronounced (steep and uneven) in the upper basin, relatively level and even across the plateau, and steep and uneven in the v-shaped ravine of the lower subbasin. Elevations range from 153 feet at the stream mouth to 2,980 feet along Boise Ridge (King County, 2007).

Rain is the dominant form of precipitation in Newaukum Creek Basin, though snow plays an important role in the upper basin near Boise Ridge. The amounts and form of precipitation are strongly influenced by air temperature and 'orographic effects' caused by the Cascade foothills (King County, 2007).

Middle Newaukum Creek subbasin occupies most of the Enumclaw plateau, a relatively flat plain at elevation 500-750 ft. formed by the Osceola Mudflow from Mount Rainier (Crandell, 1971). The surficial geology of the Enumclaw plateau is primarily made up of the poorly permeable silt and clay matrix of the mudflow, which tends to limit infiltration of surface water and causes 'perched' streams, lakes, and wetlands. The Osceola Mudflow is at least 50 feet thick on the Enumclaw plateau and flowed over older glacial deposits of Vashon till and melt-water sand and gravel outwash.

Newaukum Creek enters the lower subbasin and begins a 150 foot/mile descent through a steep ravine to the Green River. As Newaukum Creek flows northwest off the plateau and drops down into the lower subbasin, it traverses more permeable outwash deposits that underlie the Osceola Mudflow layer. The streamflow analyses associated with this TMDL study assume losing and gaining reaches within the lower portion of Newaukum Creek based on the subsurface geology of the lower basin.

Streamflows and groundwater use

Newaukum Creek has a continuously-recording streamflow gage, USGS gage #12108500-Newaukum Creek near Black Diamond, operated by the U.S. Geological Survey since 1952 (USGS, 2005). The gage station is located 0.8 miles above the mouth of Newaukum Creek downstream from West Whitney Hill Road and is 310 feet in elevation. Average stream discharge for the 58-year period of record is 59.4 cubic feet per second (cfs); maximum discharge was 2,640 cfs on Feb 8, 1996, and late summer low flows typically drop to 9-10 cfs.

The city of Enumclaw has three water supply sources located to the east of the city: Boise Springs, Watercress Spring and Well, and the PC Johnson Wellfield. The latter two sources are located within the Newaukum Creek Basin. The city also has an emergency intertie connection with Tacoma Water pipeline, but it has not been used since 2003. Water use by the city increased substantially between 1962 and 2003. In 1962, estimated annual consumption for the city was 330 million gallons (Luzier, 1969). Enumclaw water use reached a peak of 1,254 million gallons in 1998. Approximately 50% of this supply was derived from Watercress Springs and 2% was from the P.C. Johnson groundwater wellfield. The estimated yearly consumption in 2003 was 787 million gallons, with 40% from Watercress Springs and 2% from groundwater wells (city of Enumclaw, 2006). It should be noted that this consumption is for municipal supply only and does not include additional water used for agricultural irrigation and commercial water use purposes.

In addition to the city of Enumclaw's public water supply sources, there are also single domestic supply wells within the Newaukum Creek basin. The Department of Ecology estimated there were 381 single domestic wells in Newaukum Basin in 2000, based on water right and well log information (NHC, 2005). It should be noted that this approach typically underestimates the actual number of single domestic wells because of unreported wells installed prior to the development of the well log database.

Water developed for city of Enumclaw is exported from the Newaukum Creek basin in one of two ways: potable water as part of the city's water supply system, and wastewater as part of the city's wastewater treatment system. The estimated exported volume in 2000 was 340 million gallons per year or 2.1 cfs. Approximately two-thirds of this (1.4 cfs) was exported as part of the public water supply system and approximately one-third (0.7 cfs) was exported as wastewater.

Land uses and vegetation cover

Land use in the upper Newaukum Creek sub-basin is primarily timber production and harvesting practices. Dairy and cattle farming, and rural, single-family housing are the main land uses in the middle and lower subbasins (WRIA-09, 2005). Farming and rural residential land uses have induced channelization of some Newaukum Creek tributaries; construction of ditches for stormwater conveyance; use of manure lagoons and field application of manure as fertilizers; and installation of private septic systems for rural residences.

Newaukum Creek's stream banks in the upper and lower sub-basins support deciduous vegetation offering shade and protection for fish. Primarily, the stream banks in the flat farmlands (RM 5.0 to RM 10.0) are deeply cut by erosion and void of significant stretches of natural vegetation. Whereas long riffles and short pools are present on the plateau, rapids and riffles are dominant in stream reaches in the ravine and foothill regions of the basin.

Aquatic life resources

Protection and enhancement of coldwater habitat for salmon and trout species is the primary driver behind the need for the temperature TMDL for Newaukum Creek. Historically, runs of Chinook (spring and summer/fall stocks); pink; coho; chum salmon; winter steelhead; and cutthroat trout were present. Summer steelhead was also likely present in low numbers (Kerwin and Nelson, 2000). Recent studies in the Green/Duwamish Basin have determined that spring Chinook are extinct, chum at high risk of extinction, and coho presence is depressed (Nehlsen et al., 1991).

Puget Sound Chinook salmon (including the Green River population) are currently listed as a Threatened species under the federal Endangered Species Act (ESA). Although the early-run (spring) population of Green River Chinook is considered extinct, the late-run (summer/fall) population is generally one of the larger runs in Puget Sound – greater than an average of 10,000 returning adults over the period 2000-2004 (Shared Strategy for Puget Sound, 2007). Puget Sound bull trout and steelhead have also been listed as ESA Threatened species.

Chinook, coho, sockeye, and chum salmon, as well as winter steelhead have been observed spawning in Newaukum Creek (Kerwin and Nelson, 2000). This sub-basin of the Green-Duwamish watershed is considered to be a major producer of winter steelhead, coho and chinook salmon. In the farmlands of Newaukum Creek basin, the gravel composition is ideal for spawning habitat (WRIA-09, 2005). Coho have been observed as far upstream as RM 11.5 of Newaukum Creek, where the stream flows from the Cascades foothills onto the plateau's farmlands. The presence of coho has been observed in five of Newaukum Creek tributaries.

Potential pollutant sources and factors

Many human activities can have adverse effects on the natural environment. Recognized water quality problems in Newaukum Creek basin are high water temperatures, low dissolved oxygen, excess bacteria levels, and excess copper. This TMDL addresses only temperature. Other water quality parameters in Newaukum Creek are not addressed. Following is a discussion of possible sources of pollution that affect stream temperature.

Loss of riparian habitat

Riparian habitat plays a valuable role in stream 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 shade water for cooler temperatures and filter out a variety of pollutants. Direct shading from trees is a critical component affecting stream temperatures. Trees and shrubs insulate the stream from solar radiation, reducing the heat load and allowing cool streams to stay cool (King County, 2007). When wooded stream buffers are removed to create lawns, establish pasture or cropland, or make room for development, water temperatures increase because greater portions of the stream are exposed to warm air and sunlight.

Removal of large riparian vegetation also reduces the amount of large organic debris reaching the stream and increases the solar radiation to the stream. Solar radiation, in the form of heat, is considered a pollutant when it causes stream temperatures to reach levels that are harmful to fish or other aquatic life. Increases in heat loads can result in the loss of fish habitat and increases in summer water temperatures. The *Newaukum Creek Basin Characterization Report* (King County, 2007) identified lack of shade and overhang cover along the stream as key limiting factors for salmon. In addition, temperature plays an important role in determining how much oxygen water can hold.

Other human actions, such as adding riprap or 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.

Groundwater, lakes, and wetlands can also influence heat in a receiving stream or river. The stream is cooled in the downstream direction via groundwater inflow, input from cooler spring-fed tributaries, and hyporheic exchange. The amount of downstream cooling depends on groundwater and tributary inflow temperatures and volume, and the amount of riparian vegetation available to reduce solar radiation and prevent additional heating.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in the stream. In addition to natural filtering of pollutants through riparian vegetation, streamside trees also reduce solar radiation reaching the stream surface.

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

Ecology regulates municipal separate storm sewer systems (MS4s) as point sources under the National Pollutant Discharge Elimination System (NPDES) Municipal Phase I and II Stormwater Management Program. The entire Newaukum Creek watershed is covered by municipal stormwater Phase I and Phase II permit jurisdictions (Table 3). The Washington State Department of Transportation was issued a separate Municipal Stormwater Permit in 2009. This permit regulates stormwater discharges from state highways and related facilities contributing to discharges from MS4s owned or operated by WSDOT within areas covered by Phase I and II Municipal Stormwater Permits.

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 are likely to contribute to Newaukum Creek temperature impairments. Several local sites are covered by general permits for sand, gravel, and construction stormwater.

Table 3. Facilities covered under permits within Newaukum Creek basin.

Type of Permit	Permit Holder	Ecology Permit Number
Individual		
Phase I stormwater	King County	WAR04-4501
Phase II stormwater	City of Enumclaw	WAR04-5514
Highway Stormwater	Washing State Department of Transportation	WAR043000A
General		
Sand and Gravel	(Varies over time)	--
Construction Stormwater	(Varies over time)	--
General CAFO Permit		
Dairy CAFO	Allan Thomas Dairy	WAG011051B
Dairy CAFO	Krainick Dairy	WAG018006B

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 via natural processes wherever adequate soils and vegetation are retained (Figure 4).

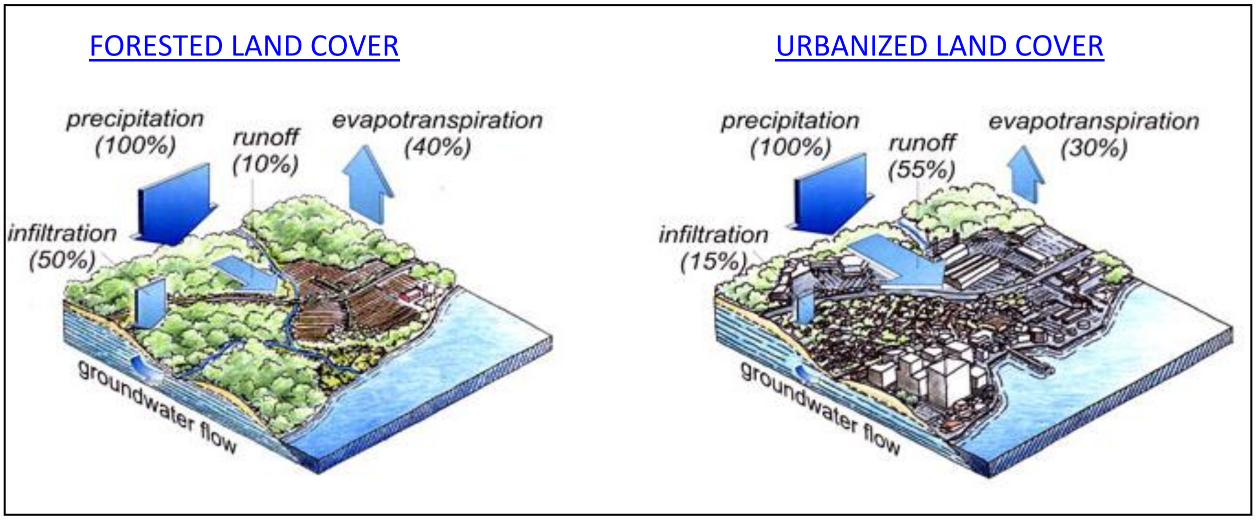

Figure 4. Hydrologic effects of urbanized land cover. Altered hydrology includes roads, rooftops, and sidewalks, which change the percentage of water transported in different processes of the hydrologic cycle (EOEA, 2004).

Figure 4 illustrates how changes in land use and increases in urban and residential development can alter the natural hydrologic regime. Increasing the amount of impervious surface can limit groundwater infiltration and subsequent recharge to streams during summer low-flow conditions. Stormwater management facilities that infiltrate stormwater runoff help offset reduced groundwater recharge due to impervious surfaces.

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). The effects of impervious surface and water management (groundwater withdrawals) on baseflows in Newaukum Creek were evaluated by Carla Carlson of the Muckleshoot Indian Tribe Fisheries Division (2011) and are shown in Table 4.

Table 4. Estimates of altered hydrology within Newaukum Creek basin.

Baseflow losses	Newaukum Creek
Baseflow loss due to EIA	
reported value (cfs)	2.6
reported value (m^3/sec)	0.0736
Baseflow loss due to water management	
reported value (cfs)	3.4
reported value (m^3/sec)	0.0963
Net baseflow loss	
reported value (cfs)	6.0
reported value (m^3/sec)	0.1700

Effective impervious area (EIA) is the component of total impervious area that is connected to a stream channel and contributes to streamflow. Estimates of EIA for Newaukum Basin were 10% in 2002, causing an estimated baseflow loss of 2.6 cfs compared to undeveloped conditions. Baseflow loss from water management was estimated at 3.4 cfs based on city of Enumclaw water withdrawal data. Small community wells, permit exempt wells, and unauthorized wells are not included in the water management estimates. A future land use scenario (about 2022) and a longer–term future condition were estimated by Carlson (2011) to result in future baseflow losses of 3.2 cfs and 3.7 cfs due to EIA, respectively. Impacts to stream temperature for these scenarios were not modeled for this TMDL.

Parts of the Newaukum Creek watershed on the Enumclaw Plateau are drained by agricultural drainage ditches and drainage tiles. Some areas, such as the Enumclaw Plateau (most of the Newaukum Creek watershed), are not well-suited for stormwater infiltration because of water table or geologic conditions. In order for land on the Enumclaw Plateau to be successfully farmed, excess water was historically drained by modifying and straightening existing waterways and constructing drainage ditches.

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Goals and Objectives

Project goals

The project goals are (1) to conduct TMDL studies on temperature and dissolved oxygen impairments in the Newaukum Creek basin during critical low-flow conditions, (2) to determine loading capacity and allocate the loading capacity among various sources and stream reaches influencing stream temperature in Newaukum Creek, and (3) to develop an implementation plan for meeting water quality standards in this basin.

Study objectives

The objectives are to:

- Characterize stream temperatures and processes governing the thermal regime in the Newaukum Creek during critical conditions.
- Develop predictive temperature models of the Newaukum Creek basin under critical conditions. Apply the models to determine load allocations for effective shade and other surrogate measures, as appropriate, to meet temperature water quality standards. Identify the areas influenced by lakes and wetlands and, if necessary, estimate the natural temperature regime.
- Characterize stream temperature model sensitivity to changes in buffer width, streamflow, riparian vegetation, and other factors that may affect stream temperature.

Implementation plan objectives

The objectives of the temperature TMDL implementation plan are to:

- Identify water quality targets and priority areas needing riparian restoration.
- Identify key restoration projects and responsible agencies and organizations involved in restoration and water quality improvement.
- Define schedule and how progress toward meeting stream temperature standards will be measured.
- Describe potential funding sources for restoration projects and public education efforts.

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Analytical Approach

Study area

Newaukum Creek has 27.5 miles of stream length that drains a 27.4 square mile region north of the city of Enumclaw. Mainstem Newaukum Creek flows 14.0 miles from its headwaters in the western slopes of the Cascade foothills, northeast of Enumclaw, to the stream's mouth at river mile 40.7 of the Green River. The remaining 13.5 miles of Newaukum Basin stream length are in the eight tributaries to the mainstem.

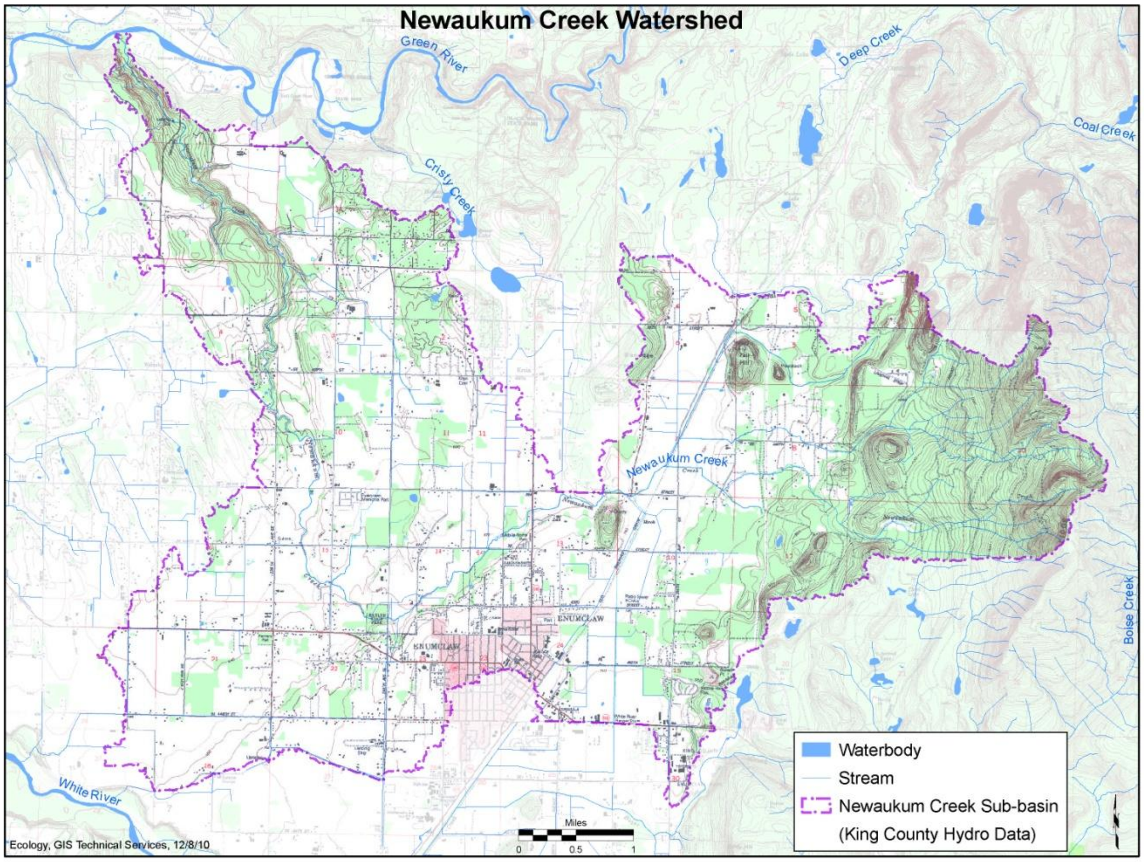

Figure 5. Study area of the Newaukum Creek basin.

Modeling framework

Three models were used to evaluate the temperature loading capacity of Newaukum Creek and to determine the allocations necessary to meet water quality standards. These models are TTools, Shade, and QUAL2Kw. Data collection, compilation, and assessment were based on the data requirements of the three models, which are described below.

TTools

TTools is an ArcView extension developed by the Oregon Department of Environmental Quality (ODEQ, 2001) to develop GIS-based data from polygon coverages and grids. The tool develops vegetation and topography perpendicular to the stream channel, and samples longitudinal stream channel characteristics such as the near-stream disturbance zone and elevation.

Shade model

Shade.xls (Ecology 2003a) was used to calculate effective shade along Newaukum Creek and was calculated at 20-meter intervals along Newaukum Creek. The Shade.xls model requires physical and vegetation parameters, some of which were assembled from the field monitoring surveys.

QUAL2Kw model

The QUAL2Kw is a one-dimensional river and stream water quality model used to calculate the components of the heat budget and simulate water temperatures. It simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw was applied by assuming that flow remains constant for a given condition such as a one-day or seven-day period, but key variables are allowed to vary with time over the course of a day.

Field monitoring methods

A variety of data are needed to develop and test water quality models. The primary source of water quality, streamflow, and meteorological data for establishing model inputs and model testing are from the field monitoring conducted during summer low-flow conditions in 2006. Data collection, compilation, and assessment were governed by the data requirements of the temperature and DO models as described in the *Sampling and Analysis Plan/Quality Assurance Project Plan* (QAPP) for the Green River and Newaukum Creek Temperature and Dissolved Oxygen TMDL studies (Roberts and Jack, 2006a). During summer low-flow and high temperature conditions from July to October 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 measurements in the stream and HemiView photographs of riparian canopy.

This TMDL was originally intended to address both temperature and DO impairments in Newaukum Creek. The TMDL was narrowed to address only temperature because additional data and information are needed to refine the model used to simulate dissolved oxygen. Appendix B describes the monitoring locations and the type of data collected at each station.

Study Results and Discussion

From July through October 2006, Ecology, King County, and others participated in a cooperative effort to conduct a series of short-term water quality monitoring surveys (Roberts and Jack, 2006a; and Swanson et al., 2007). Field data included pH, conductivity, dissolved oxygen, temperature, relative humidity, flow, periphyton biomass, and riparian shade. Laboratory data included total nitrogen, total phosphorus, dissolved nutrients, chlorophyll a, total organic carbon, dissolved organic carbon, and alkalinity. The data supplemented the routine ambient monitoring done by Department of Ecology, King County, U.S. Army Corps of Engineer, and others.

Details on the sampling and measurement procedures and quality assurance evaluation can be found in the *Data Summary Report* (Swanson et al., 2007). Monitoring locations in Newaukum Creek watershed for the different sampling programs are shown in Figure 13.

Field monitoring results

All data that passed quality control checks are available in Ecology's EIM database under User Study ID MROB003. All collected data are presented in the form of plots and tables in the *Data Summary Report* (Swanson, et al., 2007). Since field monitoring in Green River and Newaukum Creek was coordinated together, the results for both basins are summarized below.

Continuous temperature

Continuous temperature data were recorded throughout the summer. Except for Ecology's water temperature logger at the mouth, temperature loggers in Newaukum Creek were not deployed during the hottest period of the summer. Table 5 provides a summary of the temperature data in terms of the highest seven-day average of daily maximum temperatures recorded throughout the Green-Newaukum watershed during the summer 2006. Eighteen of 19 locations in the Green River and 2 of 9 locations in Newaukum Creek violated state water quality standards for temperature.

One obvious trend in the temperature data is downstream warming along the Green River. The upper Green River stations starting below the Tacoma Water Headworks Diversion Dam were less warm than the rest of the mainstem Green River. Water temperatures in the Green River and its major tributaries were relatively cool in late June at the start of monitoring. Hottest air and water temperatures, representative of the summer's critical conditions, were recorded between July 25 and 31.

Mullen Slough and Mill Creek, both in lower Green River sub-basin, were the warmest tributaries to the Green River. In the middle Green River sub-basin, Soos Creek and Newaukum Creek provided cooler water to the Green River. Crisp Creek in the middle Green River sub-basin is also a source of cooling to the Green River with water temperatures within standards throughout the summer.

Again, temperature loggers in Newaukum Creek were not deployed during the hottest period of the summer. Results for Newaukum Creek and its tributaries in Table 5 captured the highest 7-DADMax after the critical condition period.

Table 5. Highest seven-day of daily maximum temperature recorded in the Green River and Newaukum Creek basins during summer 2006.

Station ID	Station Description	Temperature (^oC) Highest 7-DADMax	WQ Standard
Upper Green River			
09-GRE-DAM	Below Tacoma Water Headworks Diversion Dam	17.76	16.0
09-GRE-KAN	At Cumberland-Kanaskat Rd.	19.22	16.0
09-GRE-FLA	@ Flaming Geyser Park, nr end of SE Flam.Geys. Rd.	19.74	16.0
Middle Green River			
09-GRE-WHI	At 212th Way SE (Whitney Bridge)	21.83	16.0
09-GRE-GRE	At Green Valley Rd.	21.58	16.0
09-GRE-8TH	At 8th St. NE in Auburn	20.98	16.0
09-GRE-277	Off Green River Rd. under 277th St. bridge	20.94	16.0
09-GRE-167	Upstream of Mill Ck. Under Hwy 167 bridge	21.42	16.0
Lower Green River			
09-GRE-OLD	At Meeker St. near the “Old Fishin’ Hole”	21.59	16.0
09-GRE-212	At S. 212th St.	22.16	16.0
09-GRE-180	At SE 180th St. (SW 43rd St.)	22.61	16.0
09-GRE-FOR	Under Interurban Ave. bridge near Fort Dent	22.84	16.0
09-GRE-COM	Under 42nd Ave. S bridge at Tukwila Comm. Cntr	23.14	16.0
Green River Tributaries			
09-NEW-MOU	At mouth of Newaukum Creek	18.45	16.0
09-CRI-GRE	Crisp Ck at Green Valley Rd.	15.68	16.0
09-SOO-USG	Soos Ck at USGS gauging station upstream of hatchery	19.14	16.0
09-MIL-WAS	Mill Ck at Washington Ave.	21.97	16.0
09-FRA-FRA	Mullen Slough at Frager Rd	23.50	16.0
Newaukum Creek and Tributaries			
09-X322	Newaukum Ck near the mouth off of 358th SE	15.30	16.0
09-E322	Newaukum Ck at SE 400 St bridge	14.81	16.0
09-AC322	Trib upstream of confluence with Newaukum Ck at 236th St SE	13.25	16.0
09-AN322	Newaukum Ck just upstream of confluence with trib at 236th St	13.86	16.0
09-G322	Newaukum Ck at bridge on SE 424th St	13.55	16.0
09-R322	Newaukum Ck off 416th St down pipeline trail	15.77	16.0
09-N322	Newaukum Ck at Veazie Cumberland Rd crossing	13.72	16.0
09-Q322	Newaukum trib off Veazie Cumberland Rd, ditch north of TPU trail	17.91	16.0

Streamflows

Ecology measured instantaneous streamflows at all wadable sites during the synoptic sampling event. Discharge was calculated by measuring velocities and depths in 20 or more divisions of a cross-section (Ecology, 1993). Fewer divisions were measured if necessary on small streams. USGS also maintains a continuous recording streamflow gage on the lower mainstem of Newaukum Creek. During the productivity and synoptic flow studies, discharge at the Green River USGS gage in Auburn was 310 cubic feet per second (cfs).

Streamflow measurements taken in Newaukum Creek on August 2, 2006 and Sept 15, 2006 characterized Newaukum Creek as a losing reach between flows measured on the plateau and flows recorded at the USGS gauging station. Given equipment and personnel making observations in 2006 were different than the USGS, additional synoptic measurements were conducted August 4, 2010. Minimizing any bias, the same equipment and personnel were used to take measurements at both locations. Results from this attempt characterized Newaukum Creek as slightly gaining with approximately 10% flow accretion between the two locations. However, a storm passed through early that day such that flow rates were measured during the falling limb of the hydrograph.

During a storm event, groundwater response can be delayed and could possibly have been still increasing during measurements generating a gaining reach condition. Moreover, the accuracy of flow measurements at the USGS site are characterized as "fair" which equates to an error of +/- 10%. These considerations along with permeable outwash soils in the channel between stream kilometers 10 and 15 further confound a firm conclusion that the stream is gaining (albeit more likely). Thus for the purposes of this study and accounting for these characterized conditions in 2006 and 2010, the modeling of Newaukum Creek was assumed to be neither losing or gaining net flow rates for the last 6 kilometers of the system.

QUAL2Kw water quality model

Data collected during the field monitoring studies were used to simulate temperature in Newaukum Creek 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).

The QUAL2Kw model assumes steady-state flow and hydraulics; however, 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 seven-day or one-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 kinetic formulations for components of the surface water heat budget that are described in Chapra (1997).

Hydrology parameters

Manning's 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 Manning's 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).

The above equation was rearranged to solve for n at field locations gauged during the TMDL study:

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

Temperature parameters

In addition to hydrologic parameters, other parameters that affect stream temperature include effective shade, solar radiation, air temperature, cloud cover, relative humidity, and headwater temperature, as well as tributary point source and diffuse inflow temperatures. These were all specified or simulated as time-varying functions (changing over the course of a day) in QUAL2Kw using a finite difference numerical method at 300-meter intervals along Newaukum Creek. In addition, QUAL2Kw uses light and heat parameters and surface heat transfer models that govern the temperature regime of the system being modeled.

Effective shade analysis

Link between effective shade and temperature

Shade is an important parameter that controls stream heating derived from solar radiation. 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. Stream temperature represents the concentration of heat in the water. If heat loads gained by a stream reach exceed heat losses, the stream 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 channel morphology, and in turn, reduce shade. Loss of shade to the stream surface can significantly add more heat to the stream and stream bed. 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:

- 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 analysis to determine percent effective shade involves:

- Digitizing and sampling current stream channel and riparian vegetation.
- Deriving vegetation heights using LiDAR, and
- Generating effective shade from current riparian vegetation and topography.

System potential effective shade

Primary factors that affect shade are near stream vegetation height and channel width (i.e. bankfull width). The maximum level of shade practical at a particular site is termed the "system potential" effective shade level (Ketcheson, et al., 2003). 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.* System Effective Potential Shade occurs when:

1. Near stream vegetation is at a mature life stage
    - Vegetation community is mature and undisturbed from anthropogenic sources;
    - Vegetation height and density is at or near the potential expected for the given plant community;
    - Vegetation is sufficiently wide to maximize solar attenuation; and
    - Vegetation width should accommodate channel migrations.

2. Channel width reflects a suitable range for hydrologic process given that near stream vegetation is at a mature life stage
    - Stream banks reflect appropriate ranges of stability via vegetation rooting strength and floodplain roughness;
    - Sedimentation reflects appropriate levels of sediment input and transport;
    - Substrate is appropriate to channel type; and
    - Local high flow shear velocities are within appropriate ranges based on watershed hydrology and climate.

The Puget Sound River History Project 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. Geographic Information Systems (GIS) soils datasets are often linked to an index with values of 50-year old tree heights that the soils in the area can support. Both the Natural Resources Conservation Service and the Washington State Department of Natural Resources provide soils coverages for the state of Washington, which lead to distinguishing ecoregions and system potential tree heights in the Green-Duwamish Watershed (Figure 6).

Sources of determining system potential tree height for the Newaukum Basin include:

1. Refer to historical accounts of vegetation in the area
2. Analyze soils data: GIS Soil data layers often have a database with “SITE INDEX” values representing the 50-year old tree heights that the soil can support
3. Observe tallest existing vegetation in non-degraded areas
4. Evaluate LiDAR data from comparable nearby Puget Sound watersheds

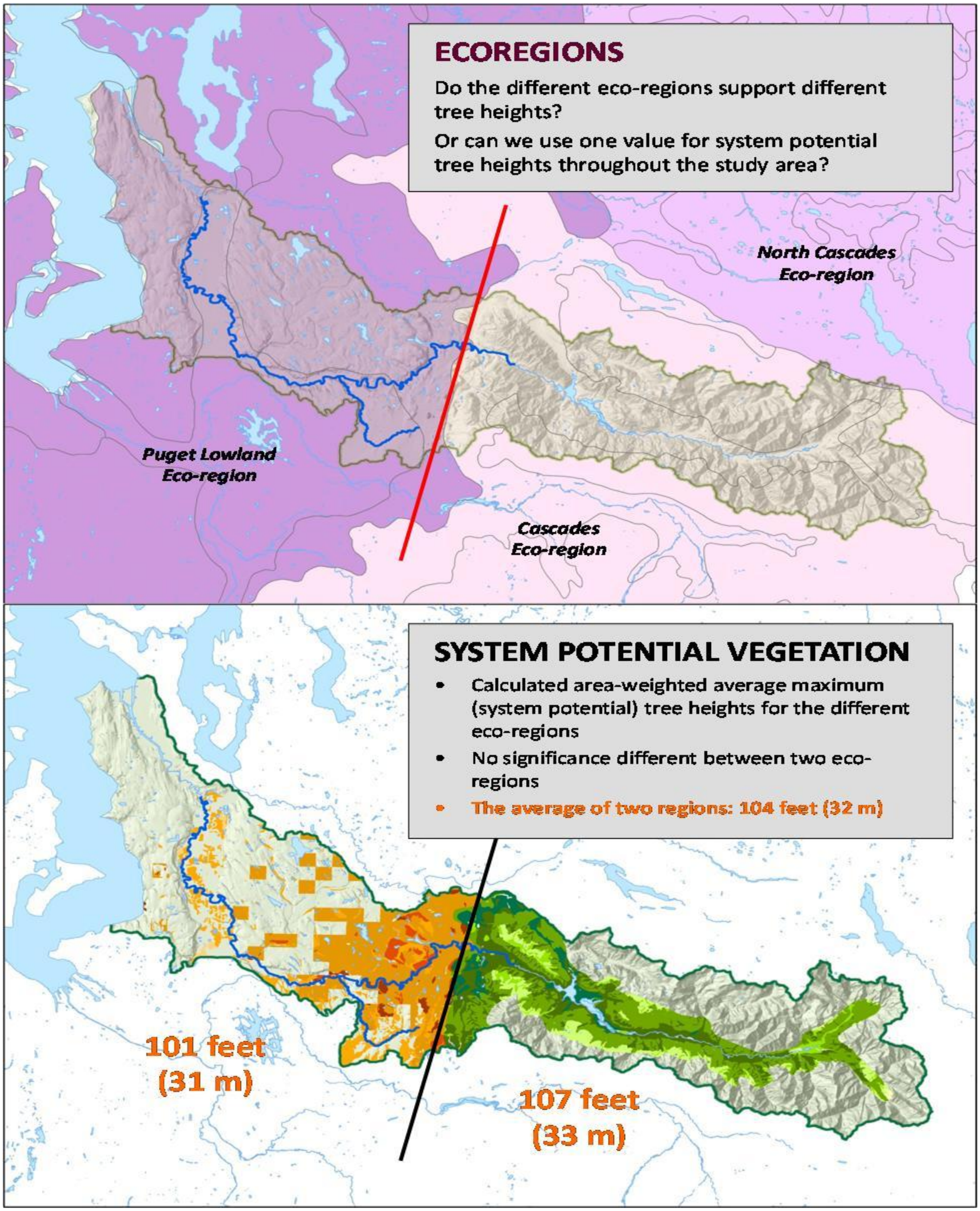

Figure 6. System potential vegetation in Green-Duwamish Watershed.

A historical account of vegetation based on Kerwin and Nelson (2000) describes the following observations:

- Middle Green: young early successional deciduous species (willow, red alder, black cottonwood) on exposed bar surfaces
- Lower Green: coniferous dominated, forested wetlands & swampy meadows on exposed bar surfaces
- Terraces/stable floodplain surfaces: older stands of mixed coniferous & deciduous trees
- Other: bigleaf maple, Sitka spruce, western hemlock
- Western red cedar and Douglas-fir are reported to be the most common indigenous forest species.

Additionally, LiDAR data indicate that Near Stream Vegetation Heights show 90th percentile height values of 37m for current vegetation. Published temperature TMDLs for nearby Puget Sound watersheds have used tree height values ranging from 37–55 meters (Table 6).

Table 6. System potential vegetation in nearby Puget Sound watersheds.
Tree height and density based on published Ecology temperature TMDLs.

Watershed	WRIA	Height	Density
Skagit River Basin	4	37-53m	75%
Stillaguamish River	5	45m	85%
Bear-Evans Creeks	8	50m	85%
South Prairie Creek	10	55m	90%

In summary, historical accounts provide tree species and basal areas from which approximate tree heights can be derived. NRCS soil data analysis (50 index-year) provides a value of 104 feet (32 m) based on the average system potential vegetation in Cascades and Puget Lowland Eco-regions. It is possible that the system potential vegetation in Newaukum Basin may actually be taller than 32 meters. However, a sensitivity analysis done on a comparably small stream system (Bear-Evans Creeks) indicated a small difference in terms of effective shade and temperature effects between 50-meter and 70-meter trees planted within a 100-meter riparian buffer (Mohamedali and Lee, 2008). The Bear-Evans analysis showed a difference in average effective shade ranging from 0.22% to 1.91%. This difference is insignificant in terms of effective shade and temperature effects for relatively small streams such as Newaukum Creek. Assuming a 32-meter tree height as representative of mature vegetation is appropriate throughout the Newaukum Creek watershed.

TMDL Analysis for Temperature

Multiple remotely sensed data sets were translated into GIS elements used to derive a shade model for Newaukum Creek. Types of data used include orthographically corrected photographs (Washington State DNR 2006) taken in 2006 with resolution of 12-inch pixels and compressed using MrSID (an industry wide standard proprietary technique for compressing raster images). Digital elevation models built on LiDAR technology were also used, and more recent high resolution imagery obtained by King County with 6-inch resolution and much lower compression rate of MrSID improving image quality and interpretation.

Stream centerlines were originally delineated by King County in 2001/2002, with a significant level of effort updating the accuracy of the coverage in 2005/2006. Updates performed included reanalysis of the topography using LiDAR and visual photograph interpretation. Manual adjustments were made adhoc as field information became available. Channel cross-sections were coarsely surveyed at multiple stations in the basin. In general, Newaukum Creek channel geometry begins in the Enumclaw foothills with deeply incised channels. Channels gain in width from less than 3 meters at Cumberland Road to over 7 meters wide near the mouth and become more trapezoidal with side slopes of 1:1 progressing downstream. Using the 2006 ortho imagery, visually determining stream widths was not feasible given the scale of the stream system. Stream width characteristics are not readily identifiable for much of the basin as shown in the recently obtained high resolution 2007 imagery (Figure 7).

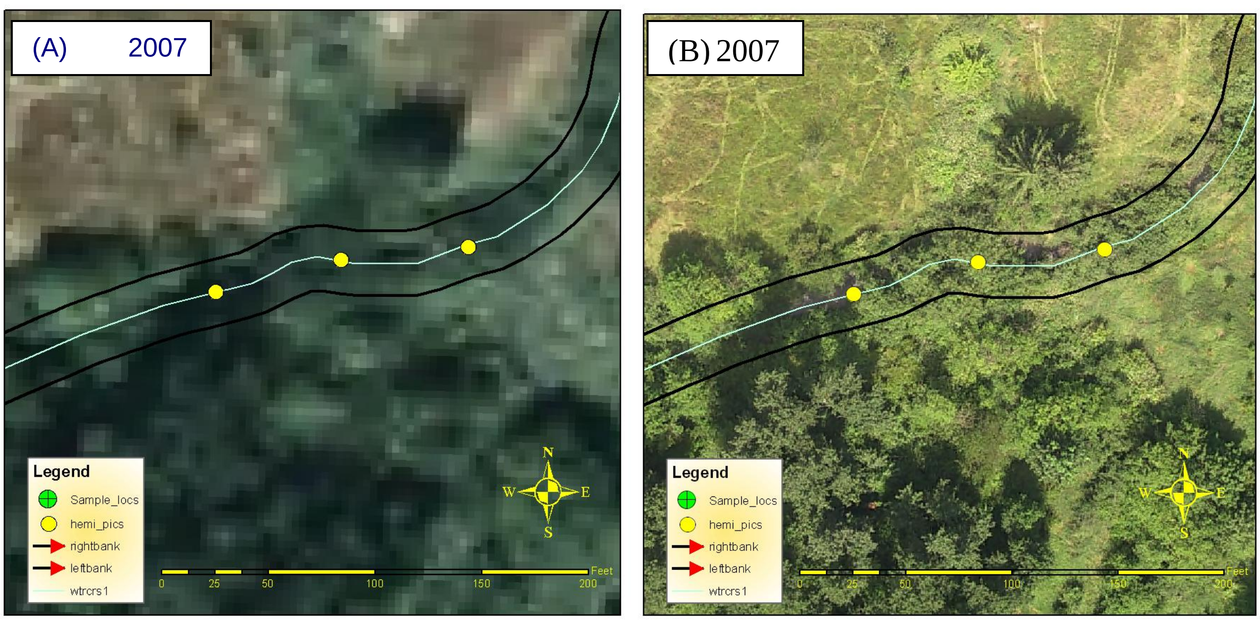

Figure 7. Defining stream centerlines and streambanks using photo interpretation. *Image (A) corresponds to 2006 data set with a resolution of 12-inches, while image (B) corresponds to 2007 imagery with 4x pixel resolution at 6-inches. Both images are at comparable scale; with stream centerline shown in blue, and streambanks shown in black.*

As previously described, Newaukum Creek channel geometry starts deeply incised in the headwater tributaries and gradually becomes more trapezoidal moving downstream either under natural conditions or with some bank armoring. Given available data, stream wetted and bank widths were defined by starting with known geometries of 1.5-meter wetted width and 2-meter bank width at the headwaters, and ending with 7.5-meter wetted width and estimated bank widths of 14-meters. Widths along the stream length were defined using linear interpolation based on longitudinal distance traveled between end points. However, field observations at a few cross-sections suggest a more constant width should be applied for areas where the channel traverses the plateau for large reach lengths. Consequently, at those locations bottom widths were adjusted to more closely match field data (Figure 8). Using spot field measurements of channel geometry can promote some error, given that cross-sections are typically taken near road crossings, which can be unrepresentative of general channel conditions.

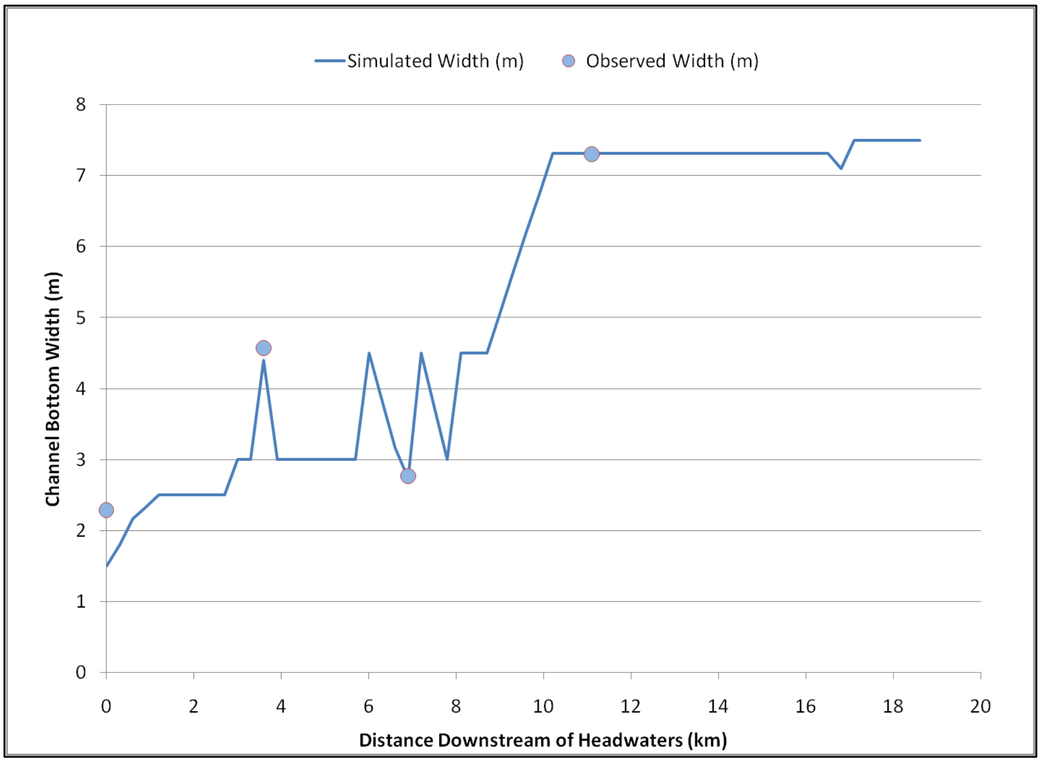

Figure 8. Model defined channel bottom widths with observed locations.

Digital ground and surface (i.e. top of vegetation) LiDAR data sets were used to define the stream channel, nearby vegetation heights, and topographic relief within 10-kilometers proximity. LiDAR is a remote sensing system used to generate digital elevation data. LiDAR sensors mounted on an airborne device emit laser pulses that hit the ground or tree top and 'return' back to the sensor where they are recorded. The timing and speed of pulses are used to calculate the distance between the sensor and the ground (i.e., elevation).

King County LiDAR resolution is defined as having 1.8-meter (6-feet) horizontal accuracy and grid resolution. While the laser sensor records measurements with errors less than 1.0-

millimeter; true measurements of ground surfaces and vegetation heights have greater inaccuracies due to sensor measurements not actually taking readings of the intended targets. Error analysis of the LiDAR results yielded estimates of vertical accuracies for ground elevations of RMSE = 0.30-meters (approximately 1-foot) in low density vegetated areas, and RMSE = 0.60-meters (approximately 2-feet) in densely vegetation. Errors associated with vegetation heights are derived from sensor measurements not hitting top elements of the vegetation, but rather partially penetrating slightly lower elevations, thus biasing true vegetation heights to be underestimated.

Comparing estimated stream channel geometries generated by LiDAR with observed, it was necessary to impose a channel definition technique to more accurately represent true values. Given the heavily vegetated stream banks and narrow channels in Newaukum Creek, much of the defined stream channel elevations were representative of bank elevations and not channel bottom. To counterbalance this error, a local minimum nearest neighbor method was used to define stream channel bottom elevations (aka wetted surface elevations for this study). Bank elevations were based on absolute values of the digital ground model (i.e. no nearest neighbor technique used).

The causes of LiDAR error for small densely vegetated areas require further modification of wetted surface elevations by defining a minimum relative difference between top of bank and stream bottom. Field observations show relative stream bottom elevations are generally 1-meter or lower from top of bank. Consequently, where calculated differences were less than 1-meter in elevation, channel depths (i.e. incision) were assigned as 1-meter. Similarly, vegetation heights were re-calculated using 9-cell (at 6-feet cell size) local maxima nearest neighbor technique.

Stream width, aspect, topographic shade angles (west, east, and south), elevation, and riparian vegetation were sampled with TTools version 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 (subsequently to v9.2). Newaukum Creek was sampled every 20 meters (65.6 feet) along its length to generate a longitudinal profile of stream aspect and width, elevation, and topographic and riparian vegetation elevations. All these parameters were input into Ecology's Shade model to generate effective shade profiles (Ecology, 2003a).

Generating effective shade from current riparian vegetation

Ecology's Shade model (Ecology, 2003a) 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 for the Shade model to generate longitudinal effective shade profiles for Newaukum Creek. The Shade model was run for multiple one-day conditions used for QUAL2Kw model calibrations and validations. The list of days run include: August 1, 2006, August 2, 2006, August 20, 2006, and September 15, 2006.

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 20-meter. Results were then averaged for fifteen segments to create shade characteristics for 300-meter reaches, which were input into the QUAL2K model discussed later.

A recent study done by King County (King County 2005) led by Curtis DeGasperi demonstrated that using LiDAR to estimate ground elevations and vegetation heights with a 90-percent constant canopy density gave comparable results to field reconnaissance and photographic interpretations categorizing types and heights of vegetation. Modifications were made to Ecology's Shade model to employ this new technique (*see Green River Temperature TMDL Water Quality Improvement Report*).

Figure 9 illustrates the current longitudinal effective shade profile for Newaukum Creek generated from the modified Shade model and field HemiView shade measurements. For illustrative purposes, the solid blue line shows effective shade at 20-meter segments rather than the 300-meter averages input into QUAL2Kw. Given that three HemiView observations were widely different than predicted, an accuracy assessment was done to verify reasonableness of the model (Appendix C).

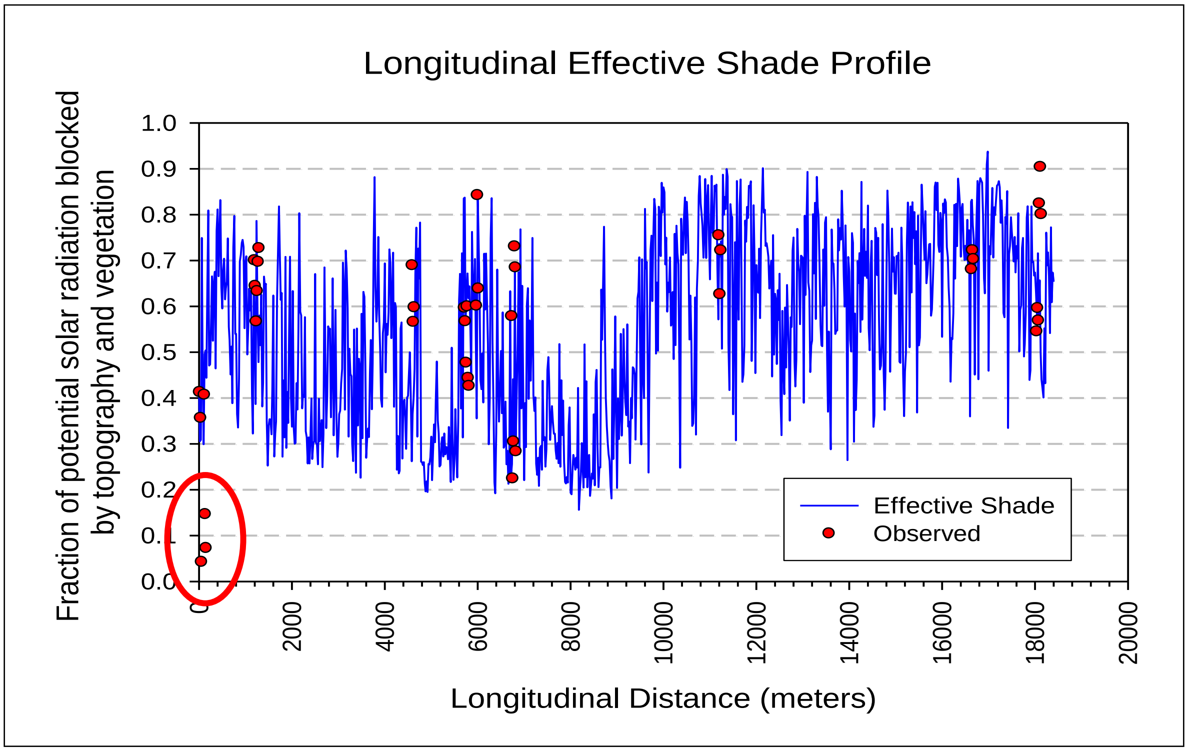

Figure 9. Longitudinal estimates of observed and simulated effective shade. *Simulated shade shown as continuous blue line and observed shade shown as point estimates with red dots. Distances increase going downstream. Suspect observed data points are circled in red.*

Shade model accuracy

Multiple sets of three HemiView photographs were taken approximately 60-feet apart at various stream segments in the Newaukum Creek basin. As previously mentioned in the longitudinal shade figure (Figure 9), three HemiViews differed widely from the predicted shade profile. Those same three sampling points are also highlighted below in the Figure 10 map.

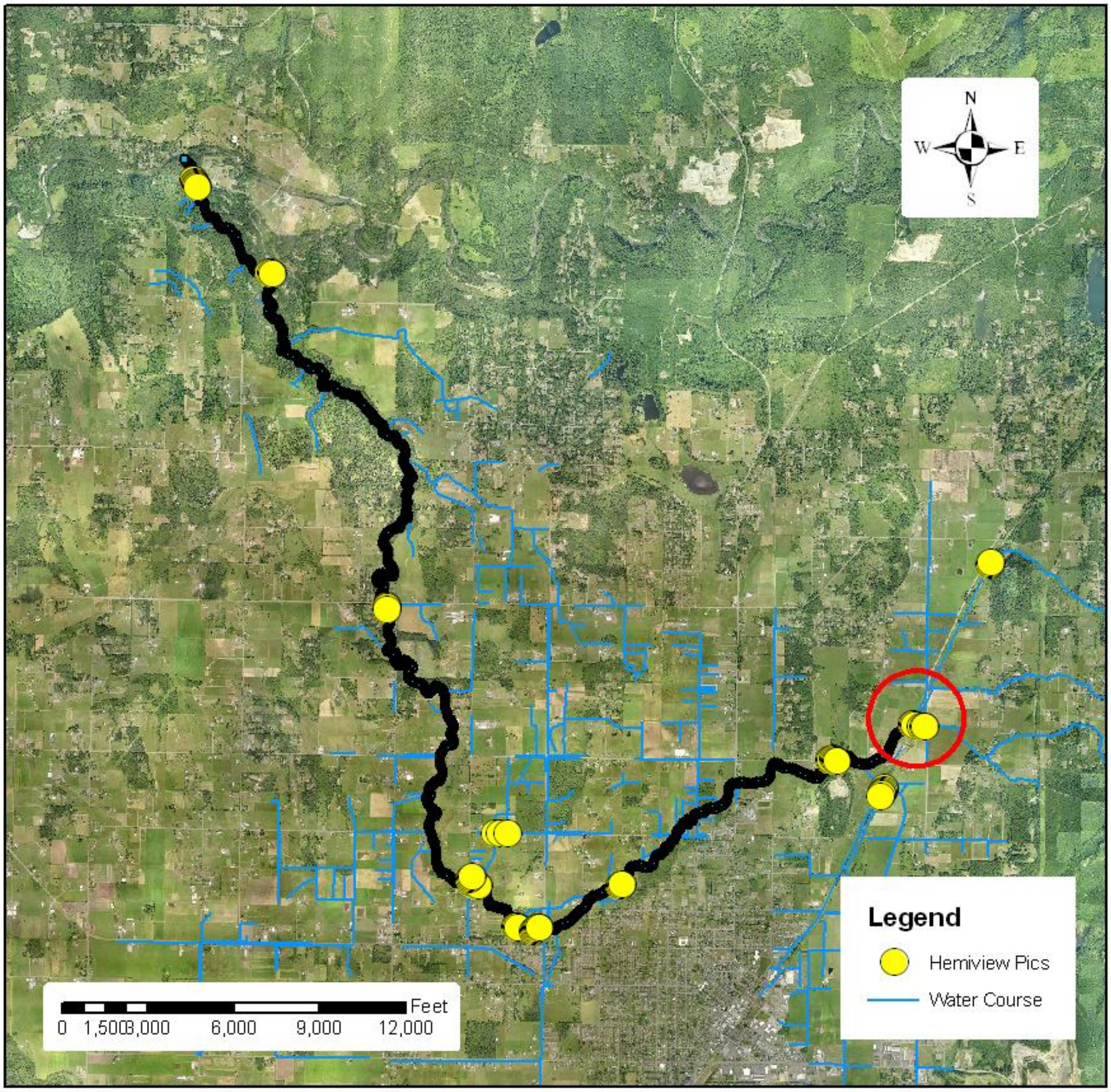

Figure 10. Sampling locations for hemispherical shade photographs. *Photo sites are shown in yellow dots. Water courses are shown in blue lines with the mainstem shown in black. Only hemispherical photos taken in the mainstem (black line) were analyzed.*

To represent values used in QUAL2Kw, sets of three HemiView sampling points were averaged together to represent shade estimates for those segments. Average observed estimates are then plotted against simulated estimates for the corresponding reach segments. An assessment of the Shade model accuracy was conducted and results are shown in Appendix C.

An example HemiView photograph taken at site Newk40 is shown in Figure 11. The image shows the solar pathway on August 2, 2006 overlain on the HemiView photograph representing the shade conditions at site Newk40 on that day. Aside from tall grass on the stream banks providing shade on the fringes, most of the sky is open to the stream. The magnetic north and true compass directions are indicated on the circumference of the photograph. The tree circled in red in the photograph is located west and slightly north of the sampling site.

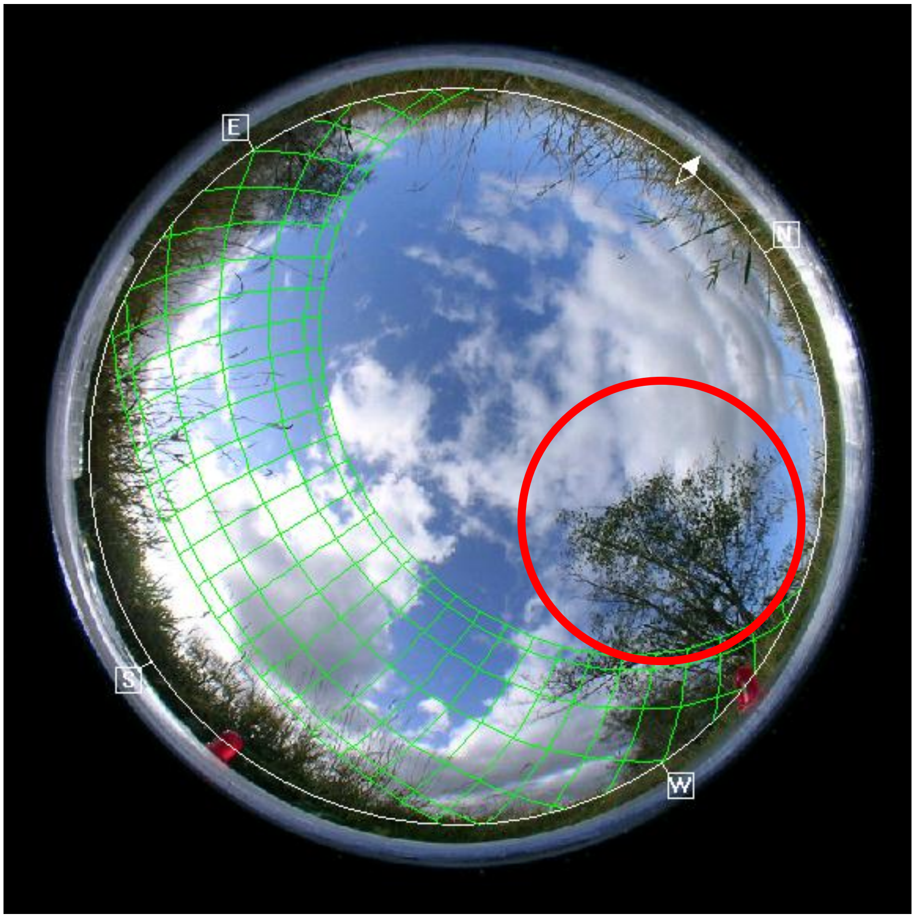

Figure 11. Hemispherical image for site Newk40 with solar path for August 2. *The tree circled in red is visible in the satellite image for site Newk40 (Figure 12).*

More recent orthographic imagery obtained (circa 2007) for site Newk40 provides clarity to the discrepancy of simulated versus observed shade at this point and provides similar clarity for the other two suspect sampling sites. In Figure 12, the same tree estimated to be in the HemiView photograph of Figure 11 is circled in red. The proximity of the tree to the photograph site is considerably closer than was interpreted in the composition of the HemiView image. Hence, it assumed that the recorded GPS coordinates for these points are inaccurately obtained. One possible explanation, albeit unsubstantiated, was an inadequate number of acquired satellites necessary to provide adequate accuracy of position.

Figure 12. High resolution image of station Newk40. *Newly available (circa 2007) high resolution (6-inch pixels) images clarify the point of interest (Newk40) and verify that vegetation should be providing more shade than what is interpreted in the hemispherical photograph.*

QUAL2Kw model for Newaukum Creek

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. Newaukum Creek was segmented into 300-meter segments/reaches for the model. Three model runs were developed for each creek in the following order: a calibration run, a flow validation run, and a temperature validation run. Model calibration was accomplished using the genetic algorithm for automatic QUAL2Kw calibration. The genetic algorithm is described in more detail in Pelletier et al. (2006). During model validation, all parameters 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:

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

Model calibration for Newaukum Creek

The period of the synoptic survey, August 2, 2006, was used as the calibration period for temperature. 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, as described in more detail below.

Hydrology parameters for Newaukum Creek

Field streamflow and cross-sectional geometry measurements taken in Newaukum Basin provided the necessary information to derive values for model parameters S_o, A_c, Q and P. Since streamflow measurements were taken at three stations (G322, AN322, E322, and gage data was available for USGS stream gage 12108500) distributed across the length of the stream and typically located at road crossings (Figure 13), calculated Manning's coefficients (n-values) were used as a guide to adjust the individual reach segment values. 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). Where calibration points existed, n-values were gradually adjusted in 0.01 to 0.02 increments. When no information was available, n-values were held constant for the reach segment.

Manning's 'n' values calibrated for Newaukum Creek ranged from 0.06-0.11 over the total 18.6 kilometer stream length. Manning values for various open channel surfaces in this model are higher than normal for this type of stream, which typically range from 0.03-0.08 (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 Newaukum Creek basin. Significant amounts of the channel can be heavily vegetated slowing down velocities and increasing depths beyond otherwise expected values. See Figure 14 for examples of channel and seasonal flow characteristics for Newaukum Creek.

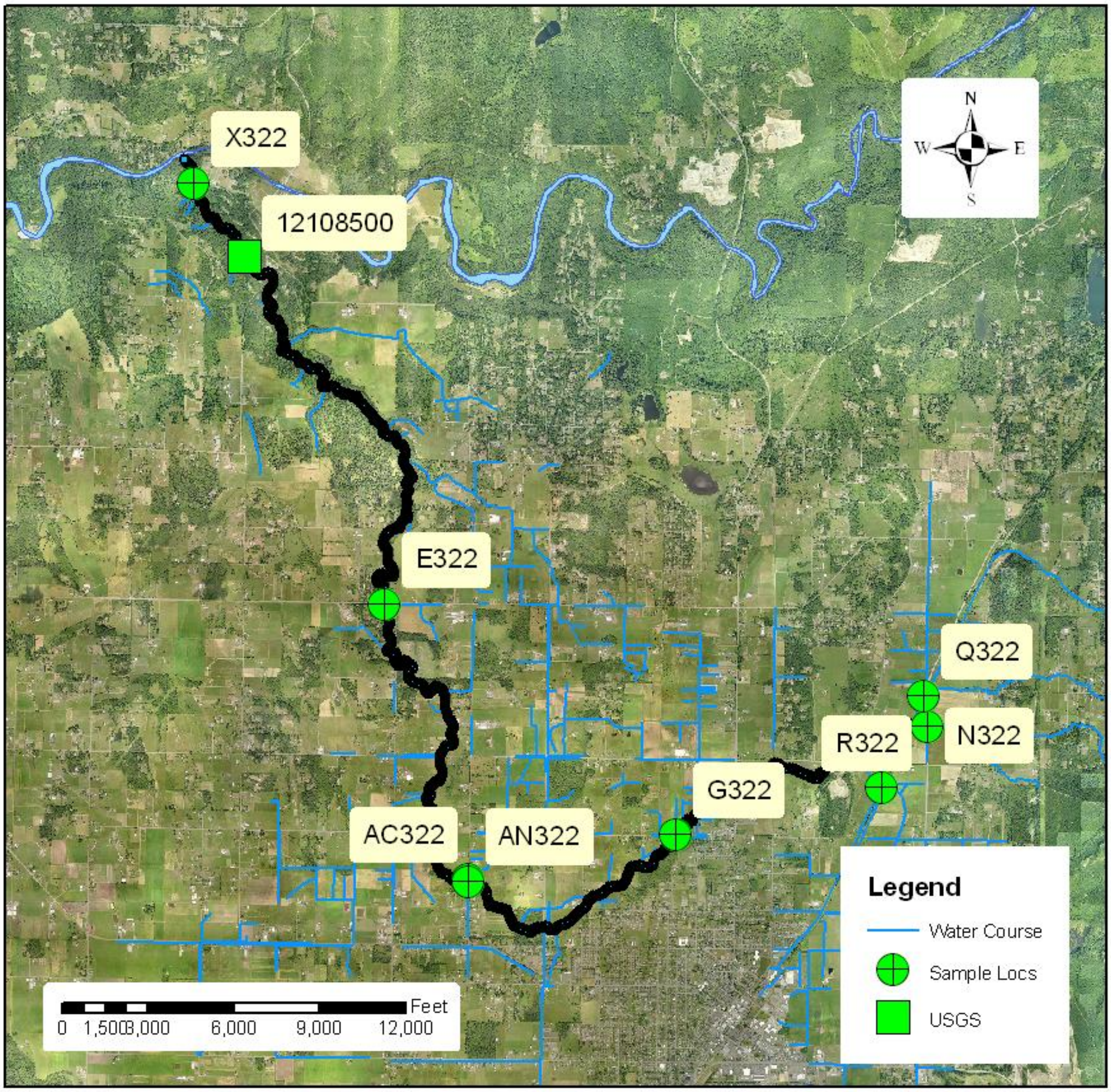

Figure 13. Water quality sampling locations used for modeling. *USGS streamflow gage STATION 12108500 was used for discharge and water temperature. Linear stream distance between the USGS gage station and site X322 is approximately 3,400 feet.*

Stream bottom widths and side slopes, required by QUAL2Kw when using the Manning equation, were derived from GIS calculations previously described in the Shade section and corrected to reflect reach-specific conditions where needed.

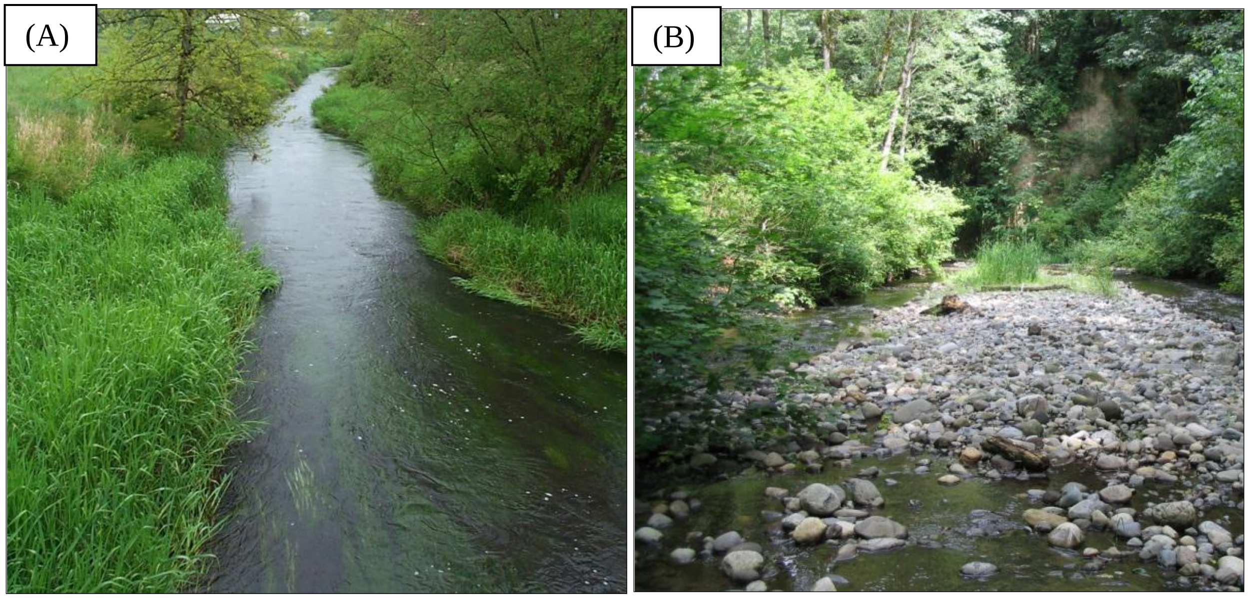

Figure 14. Comparison of channel and seasonal flow conditions in Newaukum Creek. *(A) shown in winter base flow conditions characteristic of middle section of the basin. (B) lower reach near the mouth during summer time conditions.*

Examples of seasonal changes in flows and channel characteristics in Newaukum Creek are shown in Figure 14. Figure 14 (A) shows winter base flow with instream vegetation affecting channel roughness. Figure 14 (B) shows lower Newaukum Creek during summer with high channel roughness from cobbles and boulders that were transported during higher flows.

Flow balances for the calibration run were developed for the time of the synoptic survey using measured headwater and tributary inflows. For one tributary where flow measurements were not taken, flows were estimated by scaling flows using a comparable neighboring watershed with similar land cover where flows were measured. Residual flows were entered into the model as distributed diffuse groundwater inflows and/or outflows. Synoptic flow measurements generally show an increase in flows downstream as basin area accumulates. However, decreasing flows were measured between station E322 and six kilometers downstream near the mouth at USGS gage 12108500 (Figure 13). Flow rates were not measured during the calibration period at water quality sampling site X322, 3,400 feet downstream of the USGS gage.

Loss of streamflow in the lower reach was again suggested by a second set of synoptic flow measurements taken September 15, 2006. However, later synoptic measurements made in August 2010 measured a gain of 10 percent in flow between E322 and the USGS gage. Gaining and losing reaches are not uncommon in stream systems where shallow groundwater levels are low enough that stream flows infiltrate to the hyporheic zone. In extreme cases, temporary losses to deep groundwater tables may transfer water to a completely different stream system, or reintroduce flow back to the same system lower down in the basin (i.e. creating a gaining reach). Given the contradictory progression of measured flow rates between 2006 and 2010, the modeled flow rates are assumed to remain constant for the last 6 kilometers of the system.

In practice, developing robust (representative of variable conditions) models with highly sensitive parameters, and in this case a boundary condition, minimal adjustments are made and parameters are kept as constant as possible unless other supporting information suggests otherwise. This paradigm was employed throughout the model development and calibration process. While it may be possible to improve model calibration to a set of conditions, validating the model becomes even more critically important to prove robustness, and not strip the model of any predictive capabilities.

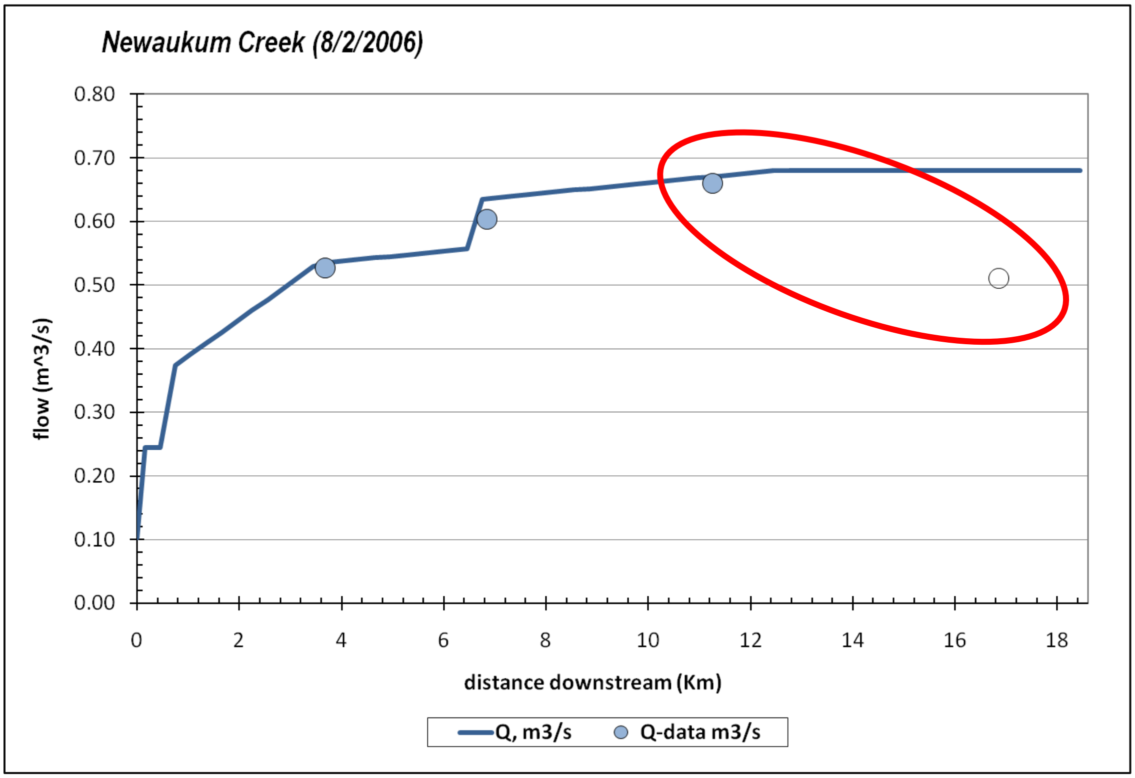

Figure 15. Longitudinal profile of streamflow rates for August 2, 2006. *Measured flow rates indicate an apparent "losing" reach for the last few kilometers (circled in red), however modeling conditions assumed constant flow rates based on subsequent spot check in summer 2010.*

Another good measure for identifying gaining or losing reaches is longitudinal measurement of conductivity in the stream. Conductivity in groundwater is significantly higher than in surface water. A gaining reach is expected to increase in conductivity downstream as groundwater is added and becomes a greater proportion of the surface flow. Losing reaches are expected to experience a near constant level of conductivity. Conductivity was evaluated as part of the mass balance calibration for flows in Newaukum Creek. Measured conductivity levels in 2006 increased progressing downstream, indicative of a gaining reach, yet flow measurements including flows measured independently by USGS indicated a losing reach below stream km 11 (Figure 15). Conversely, flows measured in 2010 indicated a gaining reach (with previously stated caveats). Therefore, measured conductivity levels in 2006 were used to define a zero net loss or gain exchange of diffusive flow rates between the hyporheic zone and the stream channel while replicating the measured increase in conductivity levels downstream.

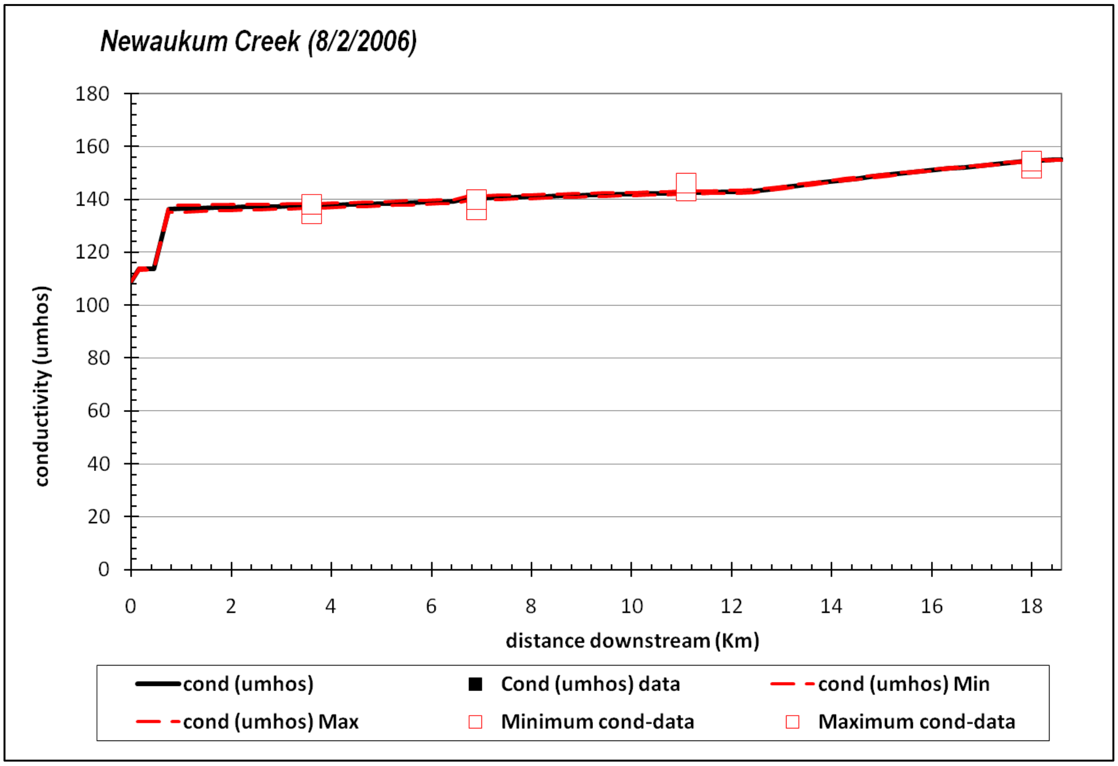

Figure 16. Longitudinal profile of stream conductivity for August 2, 2006. *Conductivity generally increases progressing downstream.*

Conductivity measurements taken in 2006 show conductivity levels in Newaukum Creek were stable and slightly rising at around 140 umhos/cm^2 over the Enumclaw Plateau to stream km 11. Conductivity increased at a higher rate although only slightly between stream km 11 and 18 to about 155 umhos/cm^2.

Surficial geology is another important element to consider in characterizing gaining/losing stream reaches. Porous channel substrate (i.e. high permeability sand and gravels) provides greater potential for appreciable rates of infiltration and exfiltration in a stream system. Surficial geology in Newaukum Creek channel suggests glacial outwash material begins to appear in the lower channel reaches at approx 10 kilometers downstream of the headwater boundary (i.e. Cumberland Road) and continues down to stream km 15 (Figure 17). Sampling station E322 is located at 11.1-km from headwaters on outwash channel. Newaukum Creek flows over five km past station E322 in permeable outwash channel before reaching USGS gauging station 12108500 at approximately stream km 16.8. This length of permeable outwash channel enables possible exchange of surface and subsurface flows that could be gaining or losing while still allowing conductivity to increase downstream.

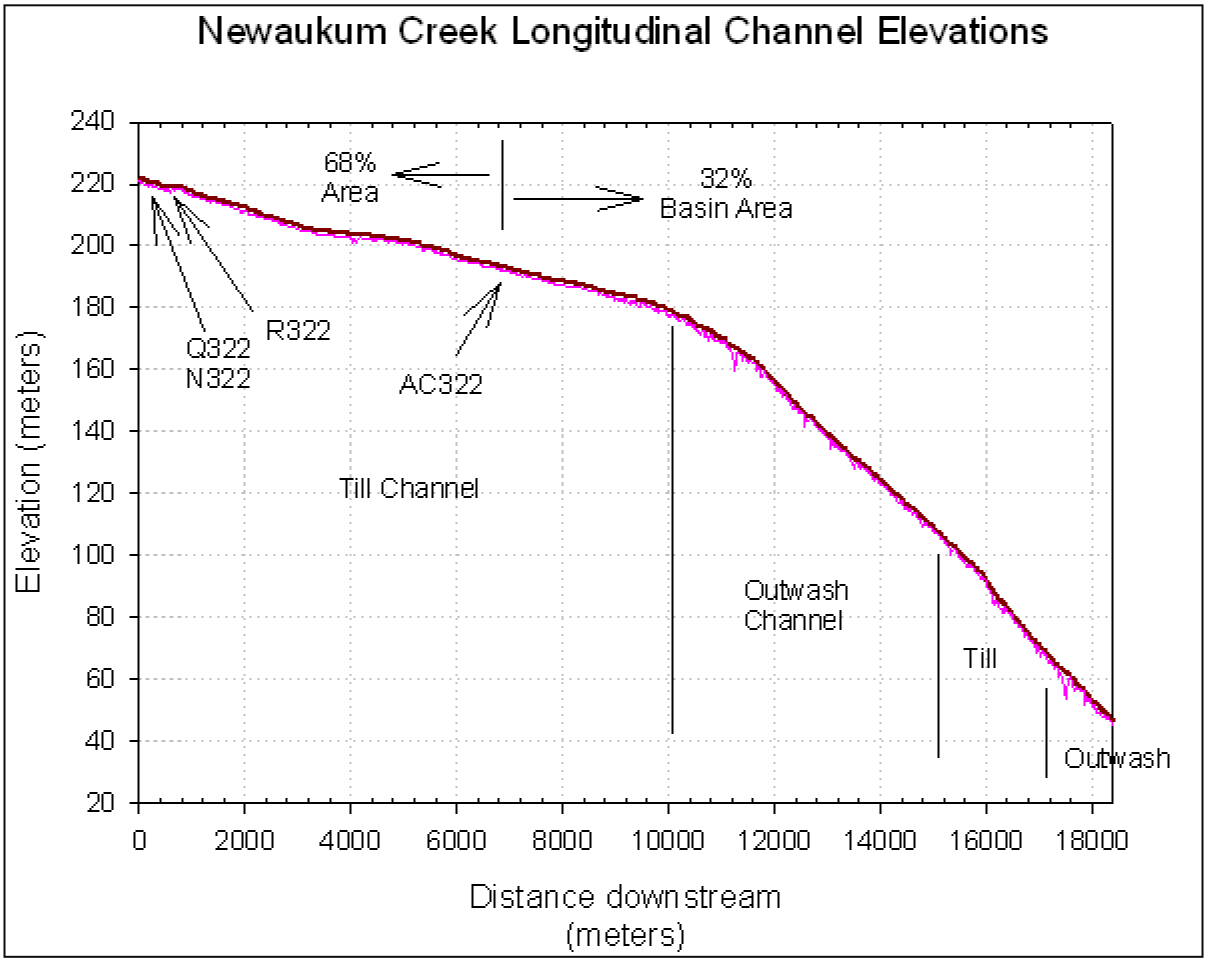

Figure 17. Longitudinal elevation profile with generalized channel surficial geology. *Apparent losing stream reach is located between stream km 11 and 16.8.*

Given this geologic description in conjunction with measured flow rates and conductivity, mass balances done with source exchanges via diffuse sources were defined to generally coincide with boundaries of outwash geologic conditions. These characterizations support observed conditions with constant flow rates and increasing conductivity. Consequently, diffuse exchanges were defined as stream abstractions (i.e. losing reach) and stream inflows (i.e. gaining reach) with zero net loss but an exchange of 0.32 cubic meters per second (cms) (or 11.3 cfs) streamflow to attain mass balance with measured streamflows. A summary of these adjustments for losing and gaining conditions relative to their stream reach location in Newaukum Creek is graphically depicted in Figure 18.

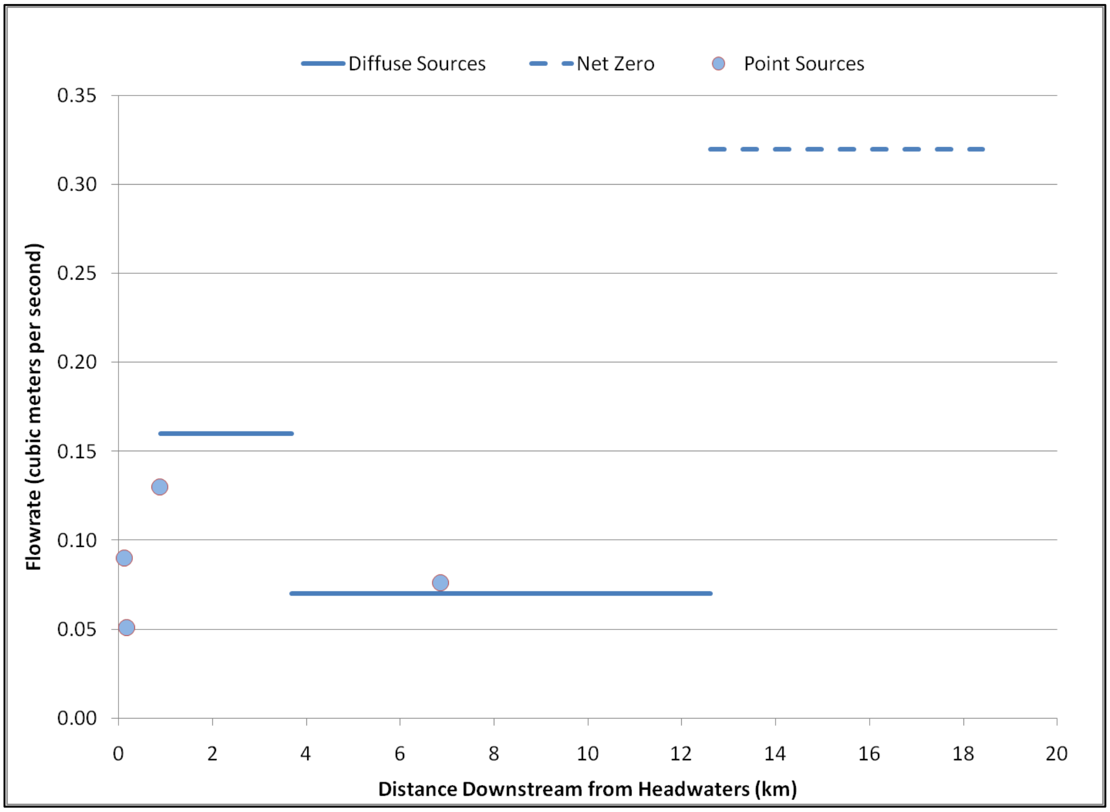

Figure 18. Defined flow rate point and diffuse sources.

After mass balance of stream flow rates, channel roughness was adjusted to better match simulated velocities and depths to observed conditions. Keeping consistent with previously defined methods of channel characterization, channel roughness was adjusted to more closely match observed conditions. Water velocity profiles are shown in Figure 19. Stream velocities were highly variable between 0.32 and 0.54 meters per second (m/s) in the upper two thirds of the watershed. Velocities were less variable around 0.45 m/s in the lower third.

Stream channel depth profiles are shown in Figure 20. Stream depths were similarly more variable in the upper watershed around 0.31 m and decreased in the lower watershed to around 0.13 m. Validation measurements of Newaukum Creek water velocity and channel depth taken on September 15, 2006 are shown in Appendix C.

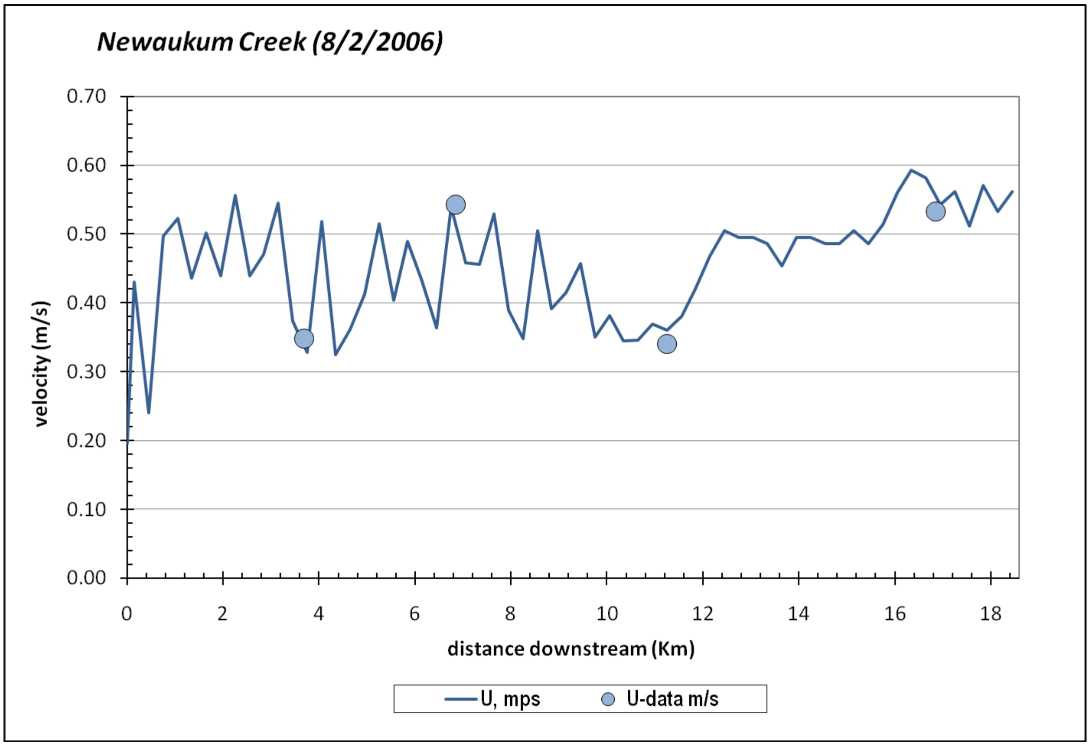

Figure 19. Longitudinal profile of stream velocities for August 2, 2006.

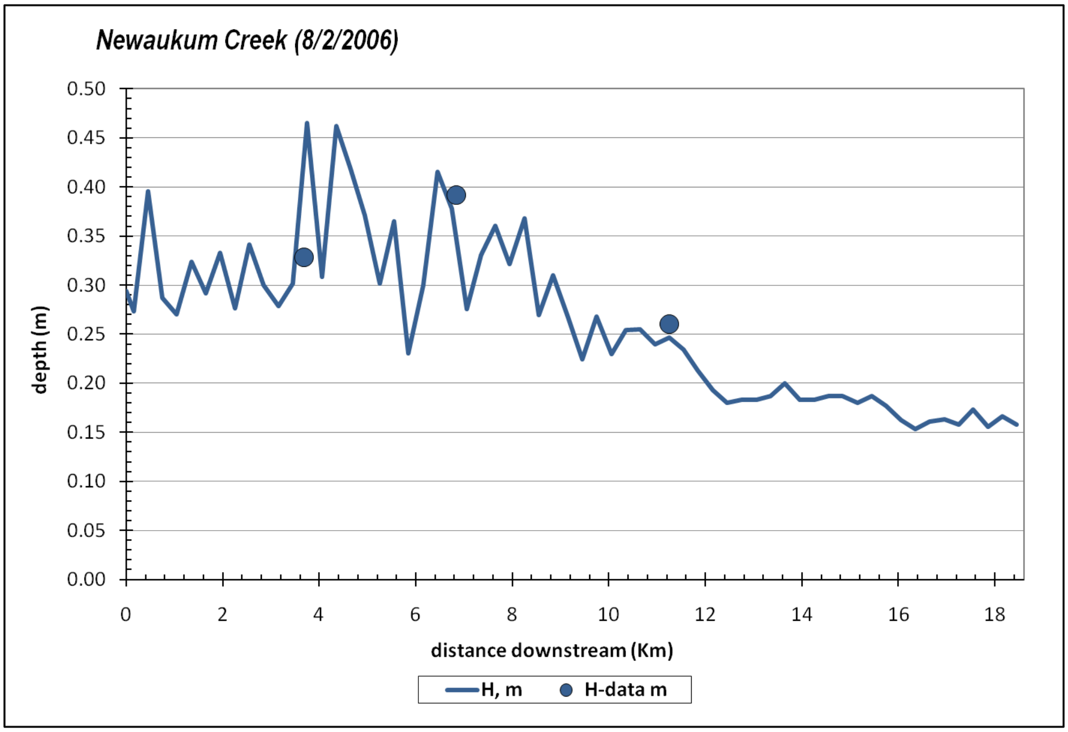

Figure 20. Longitudinal profile of stream depths for August 2, 2006.

Temperature parameters for Newaukum Creek

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 300-meter intervals along the stream system. 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 August 2, 2006, from the most upstream station on Newaukum Creek. Continuous temperature data were input as hourly values.
- Sediment thermal properties were based on literature values for mud/sand and wet sand, gravel, and cobbles. Values were varied from upstream to downstream to reflect the change from siltier upstream reaches to cobble 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). This calibration point moderates the diurnal temperature range along with other more constant parameters.
- Air temperature data were established from continuous air tidbit data measured in the field on August 2, 2006. A single air temperature record was used to characterize conditions for the whole stream reach.
- Dewpoint temperature was established from continuous relative humidity data for August 2, 2006. Similarly, a single stations record was used for the whole stream system.
- Wind speed and hourly cloud cover data were retrieved for August 2, 2006 from the National Climatic Data Center for Sea-Tac International Airport for use in the model.
- Shade values were established by running the Shade model on August 2 using current riparian conditions.
- 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 source temperatures were initially assigned values typical of shallow groundwater temperatures measured throughout King County. Diffuse inflows/outflows were assumed to be dominated by groundwater, which has temperatures often similar to the mean annual air temperature. During model calibration, groundwater temperatures were adjusted and values were assigned within the range of King County's ambient groundwater monitoring data in the

Green River basin area for shallow groundwater wells. King County groundwater data are summarized in Appendix C.

Figure 21 illustrates the model-predicted and observed temperatures for Newaukum Creek for August 2, 2006. The root-mean-square-error (RMSE) for this calibration run was less than one-half degree at 0.37 degrees Celsius.

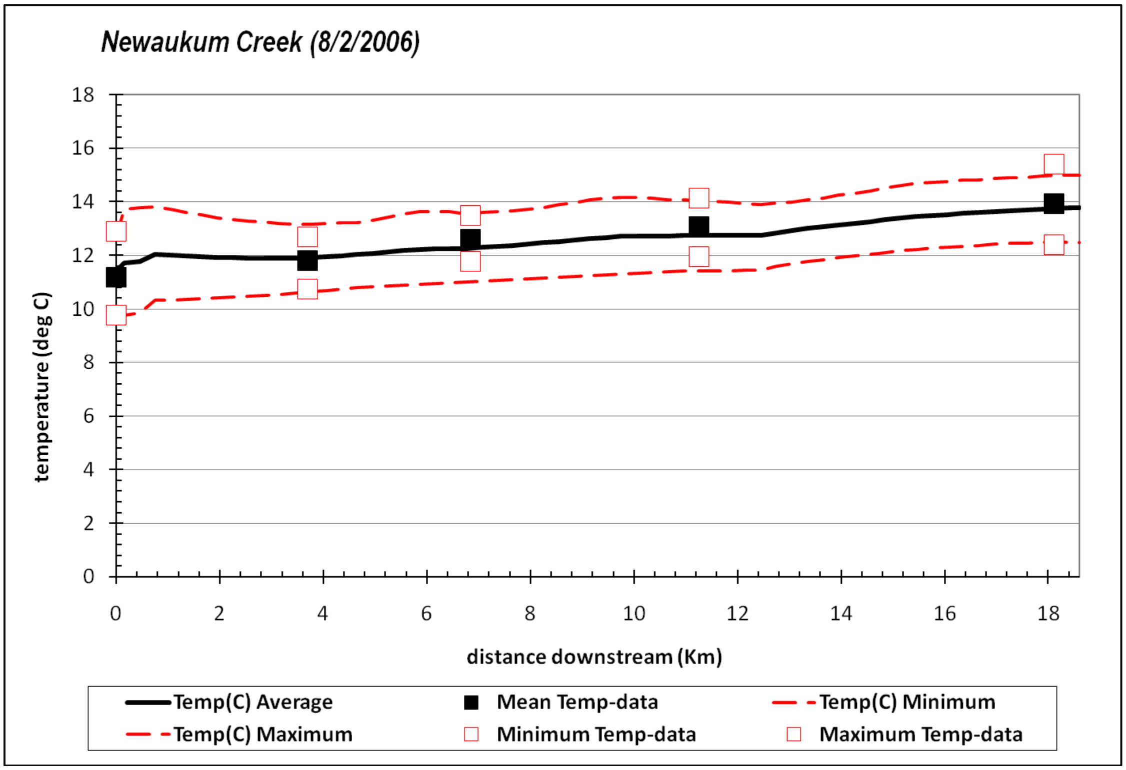

Figure 21. Longitudinal profile for water temperature on August 2, 2006. *Average stream temperatures gradually increased moving downstream from 11 to 14 degrees C.*

Interestingly, near the headwaters of the modeled system at station Q322, thermal loads into Newaukum Creek were a-typically large relative to all other tributary point sources. This may be partially attributable to north-south trending agricultural drainage ditches above site Q322 with little or no riparian vegetation to provide shade. Figure 22 illustrates 24-hour diurnal temperature swings at station Q322 for August 2, 2006 (the calibration period), and for validation periods August 1 and August 20. Water temperature loads at this station range from 10 to 18 degrees Celsius for August 2, and for the warmest day of the year in 2006 (August 20), temperatures peaked at over 19-degrees Celsius.

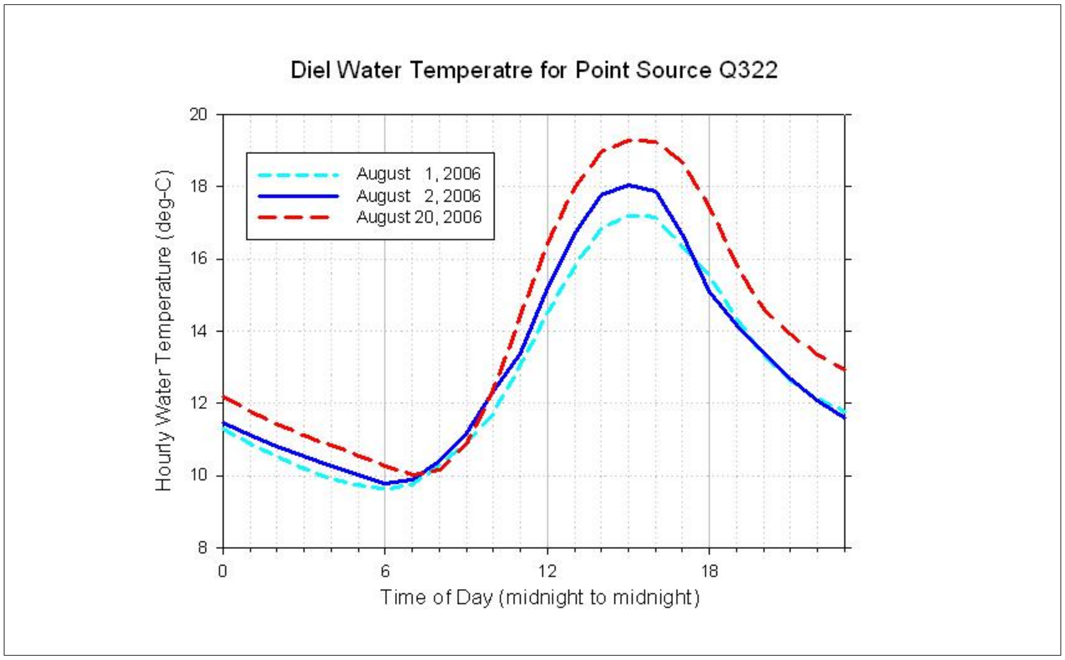

Figure 22. Hourly observed water temperature at point source station Q322 for Aug 1, 2, and 20.

Model validation, sensitivity and error analysis

Temperature validations for Newaukum Creek

Various portions of synoptic or other types of data were collected between August 1 and September 15, 2006. However besides August 2, 2006[1] used as the calibration period, there were no other days with a complete set of data available to perform a true validation of all parameters. Consequently, various aspects of the model development were validated with models setup to available data.

To confirm the hydraulic variables defined in the calibration run, only those variables that changed with time were adjusted. This included headwater and tributary temperatures, air and dewpoint point temperature, wind speed, cloud cover, and shade.

Flow validation

Synoptic flows were not only measured on the calibration day, but also on September 15, 2006. A QUAL2Kw flow rate model was constructed with the same set of hydraulic reach parameters. Flow rates during that day were 32 percent less downstream than at the headwater boundary. Consequently, diffuse source inflows and outflows were adjusted to attain mass balance. Additionally, with the obvious growth of vegetation in the channel at numerous sections of the reach and smaller flows, Manning's roughness adjustments were increased 30-percent for the upper two thirds to better match observed velocities and depths where gradients are relatively flat.

[1] Gaps were filled in as needed.

As an example of the effects of vegetation on streamflow, rating curves were done in the Sammamish River at a flow gage where vegetation growth continues until onset of fall (Appendix C). The two rating curves (one for winter and one for summer) show channel geometry remaining constant while the water level versus discharge relation is changed by vegetation growth in the channel; thus, an increase in roughness. This suggests that when applying the model, some adjustment (possibly validation as well) should be performed on the hydraulics of the model if flow rates are much different from the calibration set.

Other adjustments were minimally different from calibrated conditions for August 2, 2006. The character of the base flow progression was also similar in nature, such that the validation was determined adequate for purposes of the study. No other flow data were available for validation.

Temperature validation

The hottest single day for the year in 2006 for water temperature was measured on August 20, 2006, with water temperatures reaching above 16.0-degrees Celsius on the mainstem and exceeding 19.0-degrees Celsius on the warmest point source tributary. Continuous water temperature probes were recording during this period and a water temperature QUAL2Kw model was developed with conditions reflective of this day. Flow rates were not measured on August 20 other than at the USGS recording station near the mouth, which was approximately 28 percent lower (.142 cms) than measured on August 2, 2006. This relative decrease in flow rates was applied to all point and diffuse inflows and outflows.

Certainly, the validation could be better if more flow rates were measured and a better thermal load defined. However, it would then jeopardize the legitimacy of the validation (even if not all necessary data are available). Again accounting for all hourly observed water temperatures for August 20, 2006 at all stations resulted in an RMSE equal to 0.58-degrees Celsius (Figure 23). Given the lack of all necessary data, relative characteristics of the profile were nevertheless maintained with an acceptable level of accuracy and deemed adequate for this study.

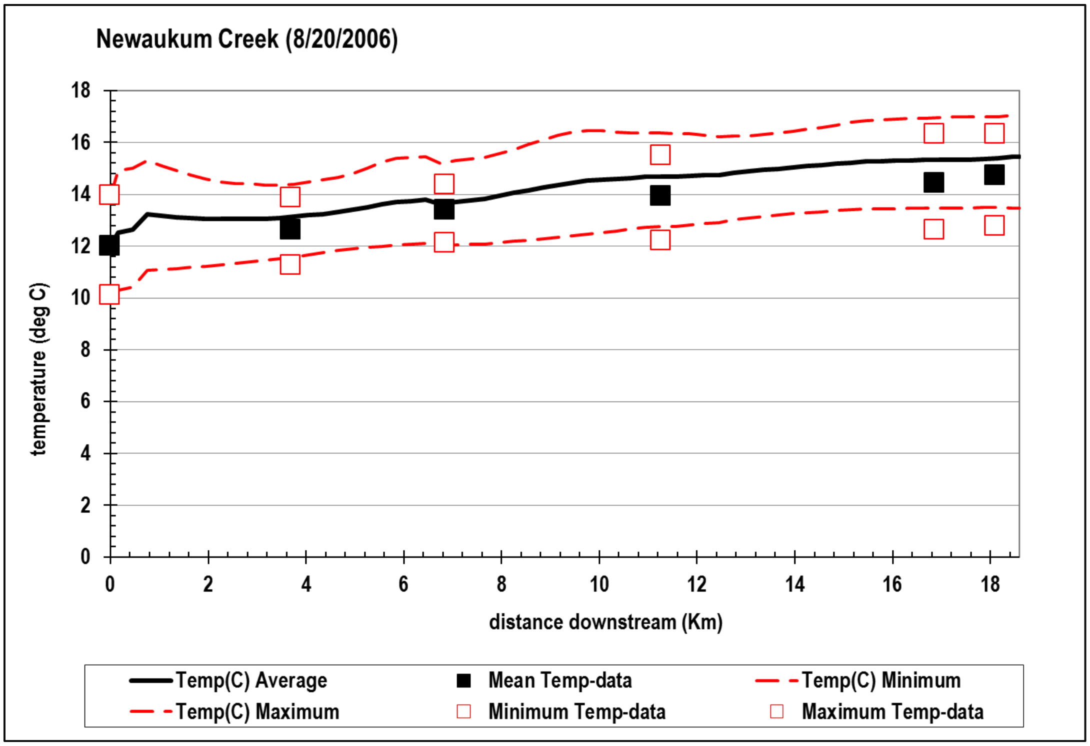

Figure 23. Water temperature longitudinal profile validation run for Aug 20, 2006. *August 20 was the hottest day of season for 2006. RMSE = 0.58 degrees Celsius (includes all diel data for all reaches with observed data).*

Conditions measured in Newaukum Creek on August 1, 2006 were less extreme and closer to calibrated conditions compared to August 20. Most of the necessary data for the model (sans flow rates) was measured on August 1 and was setup to validate calibrated parameters derived for August 2, 2006 conditions. Model accuracy improved on August 1 using calibrated parameters derived for August 2. Accounting for all hourly water temperature data for that day, model error (RMSE) equaled 0.32-degrees Celsius (Figures 24 and 25). However, given how tightly correlated the input conditions are between August 1 and August 2, a third test was performed combining the two days of data collection and averaging them—while it was assumed flow rates were identical between the two days. Evaluation results for the combined August 1 and 2 data were very similar to evaluating the days individually.

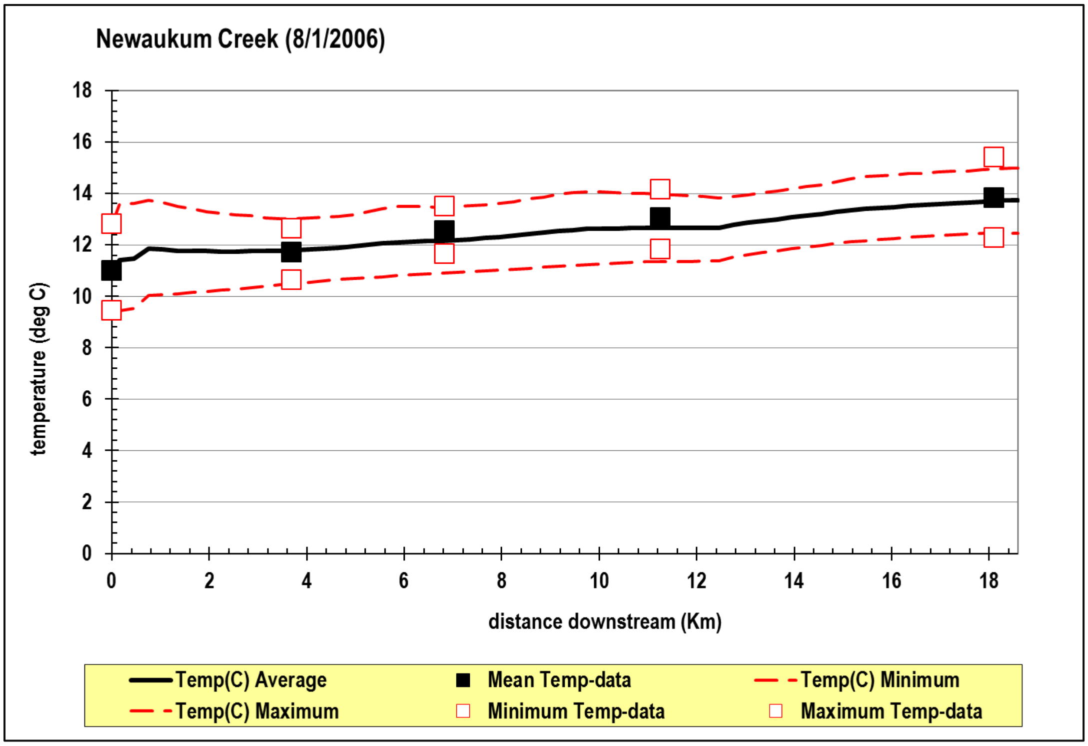

Figure 24. Water temperature longitudinal profile validation run for August 1, 2006*. RMSE = 0.32 degrees Celsius (includes all diel data for all reaches).*

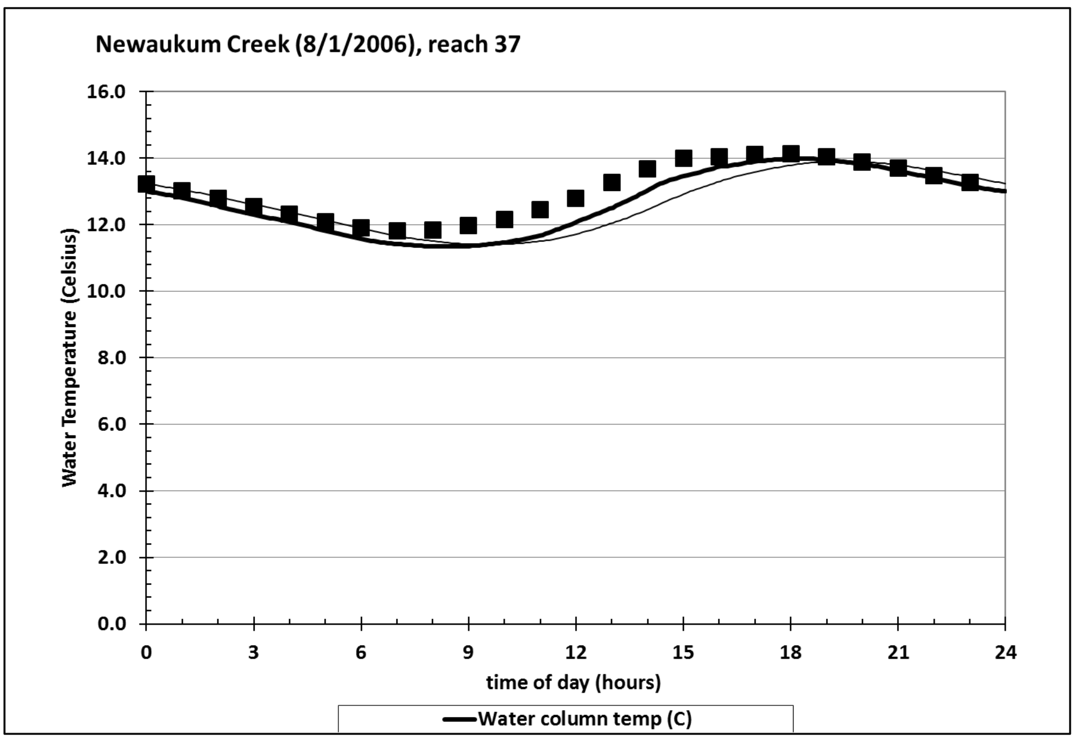

Figure 25. Example water temperature diel validation (reach with greatest error) run at reach 37 for Aug 1.

System potential effective shade

A System Potential tree height of 32 meters (as presented in a previous section) was used in the shade model to estimate system potential effective shade along the mainstem Newaukum Creek. If the existing tree height at a particular location along the channel was greater than 32 m, the taller existing tree height (up to 56 m) was used instead to model system potential effective shade. As in the shade model developed to best match model-predicted effective shade for existing conditions, riparian extinction was turned off and a fixed canopy density of 90 percent was used. This is also consistent with other shade model testing done on the Green River and Sammamish River (King County 2005). Figure 26 compares the calibrated QUAL2Kw model reach-averaged effective shade representing existing conditions and system potential effective shade assuming a minimum 32 m riparian tree height and a fixed 90% canopy density.

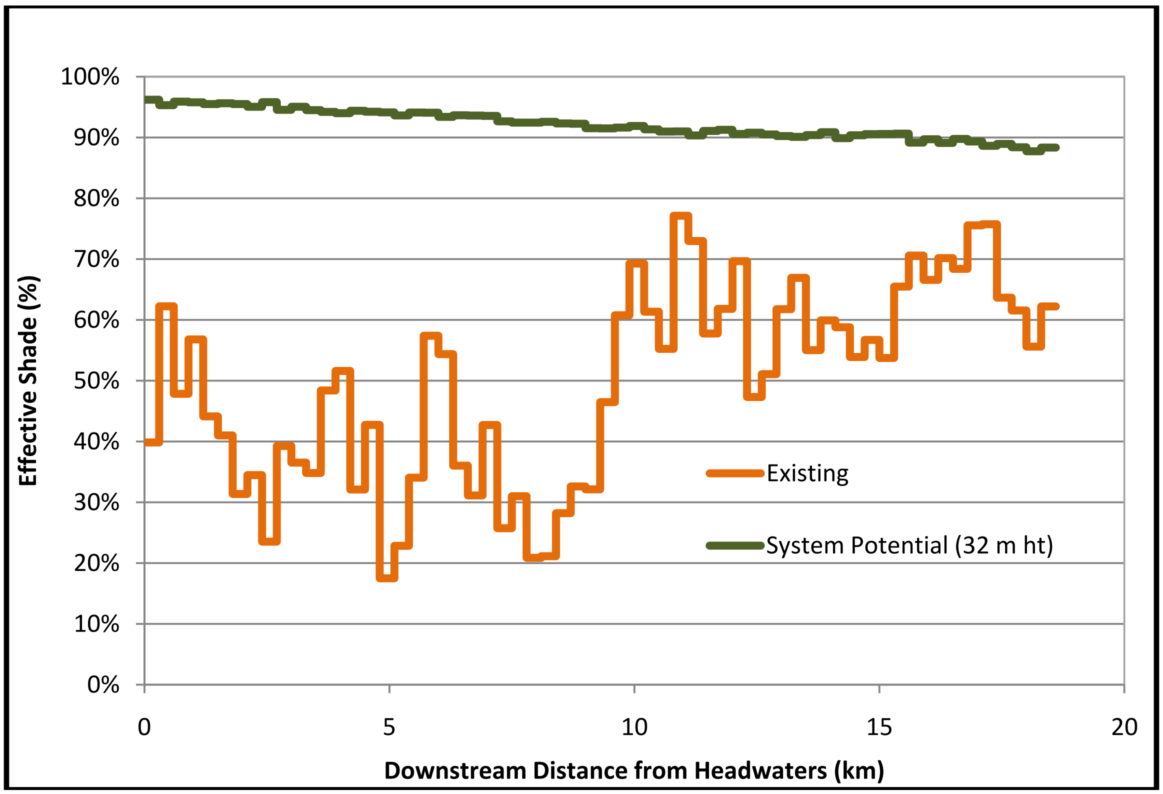

Figure 26. Current and system potential effective shade profiles for Newaukum Creek. *The greatest potential to improve effective shade is on the plateau reach within 10 stream kilometers of Cumberland Road.*

Sensitivity to overhang

Relative channel widths of Newaukum watershed streams are narrow enough that overhang from a mature tree canopy can completely overlap the water surface providing significant additional shade. Assuming a mature tree canopy can overhang the stream by 3 meters on either side, there is an average 5 percent increase of effective shade resulting from the inclusion of overhang, assuming 90 percent canopy density. The added effectiveness from the overall tree canopy diminishes as relative stream width increases, either when overhang is less or as cumulative drainage area increases and stream banks widen downstream (Figure 27).

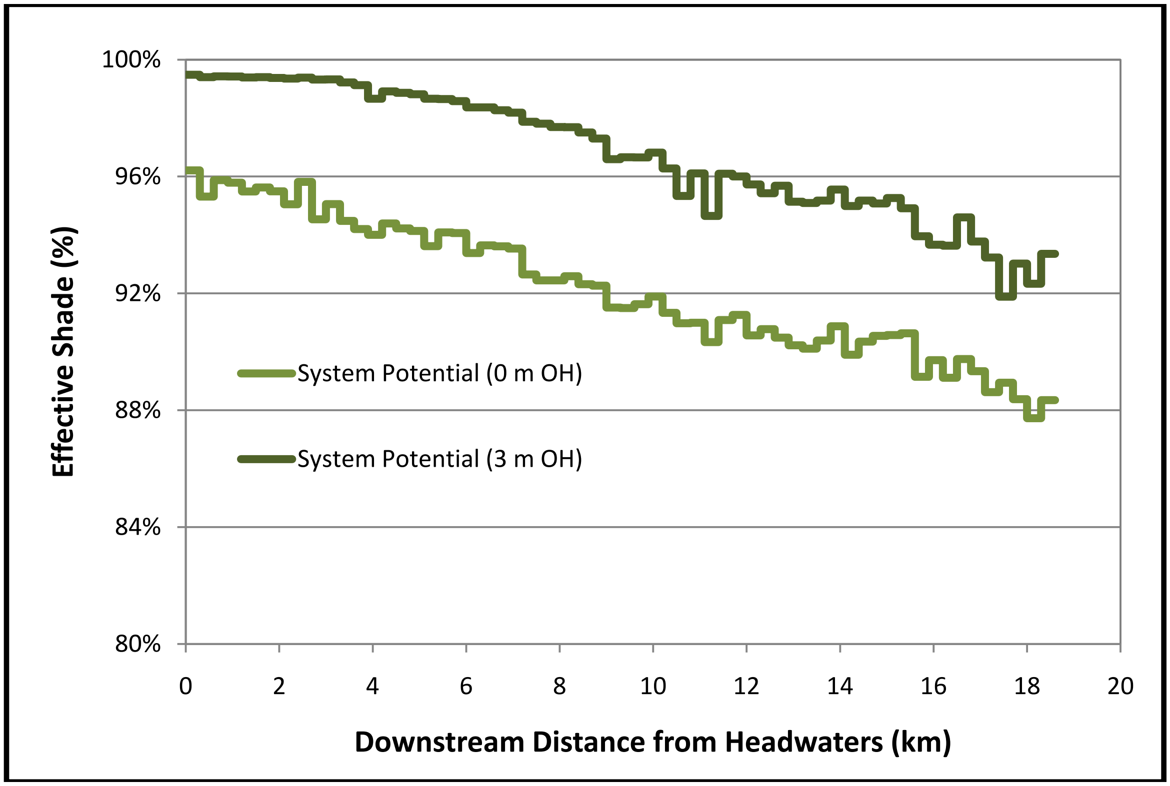

Figure 27. System potential effective shade based on 0 m and 3 m overhang from tree canopy. *Effective shade is improved 3 – 5% by including 3 m canopy overhang.*

Sensitivity to buffer width

During development of the Newaukum Creek shade model, turning off riparian extinction and using a fixed canopy density of 90% resulted in the best fit of the shade model to the observed levels of effective shade (see Model Calibration section above). However, testing stream temperature sensitivity to buffer widths required the inclusion of riparian extinction (changes in canopy density with buffer width). Canopy density was modified for each buffer based on canopy density as a function of buffer width found in Beschta et al. (1987). Accounting for riparian extinction and system potential tree heights of 32 meters, system potential shade is reduced from the assumed 90% density as well as when buffer widths are hypothetically narrowed. A reduction of buffer width from 45 meters to 15 meters reduces effective shade 24 to 29 percent with assumed 0 meters of overhang. The lower most 7 km of the stream reach is generally more sensitive to buffer width with a 28 percent average loss of effective shade due to reduced buffer (Figure 28).

Including the presence of overhang (3 m) along the stream bank increases overall effective shade but reduces the sensitivity of buffer widths with differences ranging from 3 to 17 percent between 15 and 45 meter buffers (Figure 28). Canopy density drops from 90% at 45 m buffer width to 73% with 15 m buffer width. However, a 15 m buffer with overhang provides more effective shade than a 45 m buffer with no overhang. As the stream banks become farther apart the effect on shade from overhang progressively loses effectiveness.

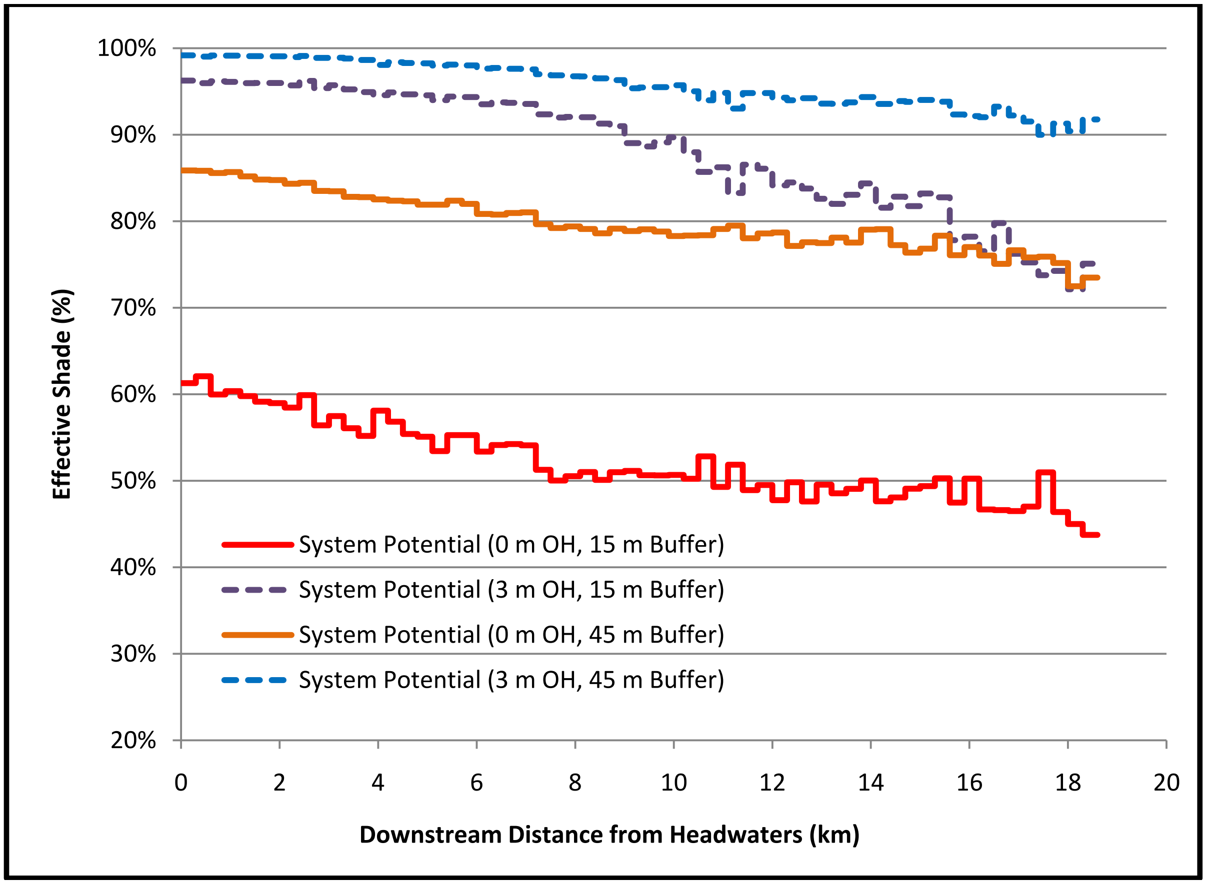

Figure 28. System potential effective shade based on 0 m and 3 m overhang from tree canopy and buffer widths of 15 and 45 meters.

In previous Ecology temperature TMDL studies, a minimum buffer width of 46 m has been recommended in consideration of the minimum riparian cover needed to maintain a river/stream microclimate (Mohamedali and Lee, 2008). Riparian areas also serve other important physical functions such as erosion control and channel stability, as well as ecological functions that are dependent on adequate buffer widths. The implementation plan associated with this TMDL recommends a minimum buffer width with riparian plantings that are designed (i.e., dense enough) to achieve 90 percent reduction of incoming solar radiation during the summer regardless of the planting buffer width.

System potential model

Critical flow

System Potential Flow in temperature TMDL models is typically set to the 7Q10 (7-day average flow with a 10 percent chance of occurring in any year) flow condition when stream temperatures are typically at their peak – generally July to August in the Puget Lowlands.

However, annual 7-day low flows in Newaukum Creek on average occur near the end of September (i.e. September 22) and have occurred 13 times in the last 65 years in the month of August. Annual low flows have occurred in October or later in 23 of the last 65 years. Given this amount of shift in timing between annual minimum low flow and annual maximum temperature, the 7Q10 was recalculated to coincide with the same months as the maximum temperature (July through August). The timing of these occurrences predominately occurs in late August (August 24) with none occurring in July. The 7Q10 flow rate using this time window is 0.336 cms (11.86 cfs), while the true 7Q10 that generally occurs in late September is 0.302 cms (10.68 cfs), or about 10 percent less.

It has been documented that there is a distinct and significant downward trend (-.003 cms/year) in annual minimum 7-day flow rates (e.g. King County 2007, King County 2010, Konrad and Booth 2002, and Ecology 1995) since the 1950s. The cause of this trend is likely the result of a combination of: loss of infiltration potential with added impervious surfaces over time, consumptive use for irrigation and water withdrawals for domestic and other uses with population increases, and possibly to a lesser extent changes in precipitation (Carlson, 2011). Therefore, full restoration of baseflows was simulated by increasing the 7Q10 by 0.167 cms (5.9 cfs) equal to 0.503 cms.

The QUA2Kw model was defined with four significant tributary point sources, 1) headwater boundary inflow, and 2) reaches of diffuse sources of inflows. Flow rates for the 7Q10 were estimated using the USGS stream gage (USGS 12108500) near the mouth of Newaukum Creek (1.7 km from the mouth) and two methods were used to adjust inflows to the model to simulate 7Q10 conditions. The first method was adjusting surface input sources only (i.e. diffuse sources remained the same from the calibration period), and the second was to adjust all input sources proportionally. The second method for adjustments was introduced because of the significant shift in timing of low flows between the calibration period in August (8/2/2006) at 0.680 cms and the true occurrence of the low flow (.302 cms) for that year in September (9/10/2006), which coincidentally was equal to the true 7Q10 using the entire period of record.

Critical weather

The calibrated model was also modified to represent critical meteorological conditions. These changes included:

- Setting cloud cover to zero
- Setting wind speed to zero
- Scaling Sea-Tac air temperature to locally observed conditions, and
- Adjusting the air and dew point temperatures to represent critical conditions

Air and dew point temperatures were adjusted by calculating the seven-day moving average of the daily maximum temperature recorded at Sea-Tac International Airport from 1949 to 2010 and finding the maximum seven-day maximum air temperature for each year during the July-August period. The same was done with data from a local air temperature gauge (KC 44u) located within the Newaukum Creek subbasin for its period of record (1998 through 2011). A linear regression (KC 44u = 1.07*SeaTac - 0.95) was used on the annual maximum seven-day averages to scale the Sea-Tac data to better represent local conditions. These temperatures were then ranked to calculate the seven-day maximum temperature with a ten percent chance of occurrence in any year. Once the critical temperature period was identified, the hourly air and dew point temperature data represented by the critical seven-day period were averaged to create an hourly data set to represent the critical hourly temperature in the model (Figure 29).

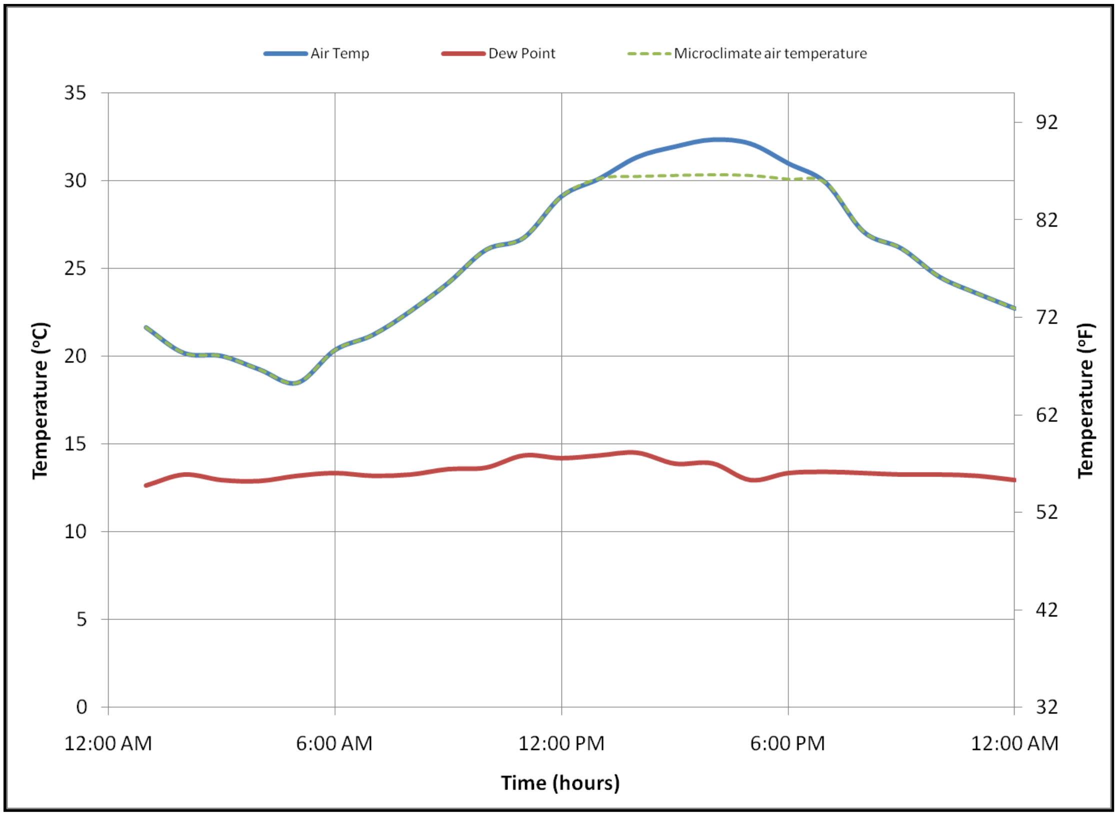

Figure 29. Hourly air and dew point temperatures used to represent critical weather conditions in the QUA2Kw system potential model.

The peak air temperature was also reduced by 2°C and smoothed to represent a microclimate effect created by system potential vegetation. The hourly air temperature series adjusted to account for a riparian microclimate is shown in Figure 29.

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 in the Newaukum 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. System potential temperature is based on our best estimates of mature riparian vegetation, riparian microclimate, and natural base flows. The system potential temperature does not replace the numeric criteria and does not invalidate the need to meet numeric criteria at other times of year and at 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 critical low flows based on a combination of instream flow targets and tributary 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. Records used to calculate these conditions dated as far back as 1944 for flows and 1949 for air temperature. 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 mature riparian vegetation that would naturally occur along the Newaukum Creek mainstem. Mature vegetation was represented by a riparian vegetation width of 45 meters on each side of the stream (upwards of 50x the width of the plateau stream channel). In this scenario, tributaries and the upstream boundary condition were not assumed to be well shaded and meeting temperature standards where they discharge into the mainstem of the creek.

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 results of these scenarios, they provide additional information about the system and indicate other important factors that affect stream temperature.

- Sensitivity to buffer width. Riparian vegetation widths of 45 m and 15 m were modeled.
- Sensitivity to overhang from mature tree canopy. Vegetation overhanging the stream by 3 m on both sides was modeled.
- Restoration of baseflows assuming full potential infiltration from impervious surfaces and discontinued exportation of groundwater withdrawals (Carlson, 2011)
- Microclimate improvements. Increases in buffer width and vegetation height are expected to result in localized decreases in air temperature. In order to evaluate the effect of microclimate on water temperature, the daily maximum air temperature was reduced by 2°C based on the summary of literature presented by Bartholow (2000).

The current 7Q10 critical condition results in daily maximum water temperatures that are warmer than 16°C at a confluence of a tributary near the headwaters for two-thirds of kilometer then continuously starting at 3.75 km downstream from Cumberland Road. Most of the increases in stream temperatures occur on the Enumclaw Plateau where existing shade is minimal. When streambank vegetation becomes more consistent (approximately stream kilometer 8) and topographic shading of the ravine (shading from increases of ground elevations relative to stream channel) occurs, the rate of temperature increase is subdued such that for the last 9 km, the increase in temperature is less than 1^{o}C (Figure 30).

The 22°C threshold for fish lethality is 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."

No portions of Newaukum Creek are currently above the 22°C lethal level during the critical period (Figure 30). However, 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).

Temperature improvements

Reductions in water temperature compared to current shade conditions are predicted for the system potential shade condition described above and presented in Figure 30.

Meeting salmonid spawning, rearing, and migration, and salmonid rearing and migration only (17.5°C) requirements

Figure 30 presents the results of the different temperature modeling scenarios for Newaukum Creek. Significant temperature reductions are predicted with system potential mature riparian vegetation, but very minor improvements accounting for riparian microclimate. Increases in effective shade from mature riparian vegetation have the potential to decrease water temperatures across all reaches, and meets compliance with the 17.5°C water quality standard protecting salmonid spawning, rearing, and migration uses when buffer widths are sufficient enough to generate 90% effective shade. Stream temperatures exceed 17.5°C in the lower third of the system when buffer widths generate less than 90% density (e.g. 15 m buffer width).

The effect of either restoring baseflows or additional shading from overhang was similar—both generally reduced maximum stream temperatures by an additional 0.5°C. Moreover, either adjusting surface water inputs only or adjusting all surface and subsurface water inputs averaged less than 0.2°C difference between the methods for all scenarios. Depending on the scenario, the changes either showed minor decreases or minor increases in stream temperatures according to the relative contribution of surface point sources and diffuse groundwater inflows to the stream reach. Thus, all scenarios presented are based on adjusting point source surface inflows only.

Meeting core summer salmonid habitat (16°C) requirements

Stream temperatures were below 16°C with assumed system potential vegetation and buffer widths of 90% density except for the lower 4 stream kilometers. Narrowing buffer widths (e.g. 15 m) diminishes restoration of stream temperatures such that temperatures exceed 16°C for over half the stream system (System Potential – 15m Buffer). Restored baseflows were modeled by adding 0.167 cms (5.9 cfs) to Newaukum Creek streamflow in accordance with estimates of baseflow loss from water withdrawals and impervious surfaces (Carlson, 2011).

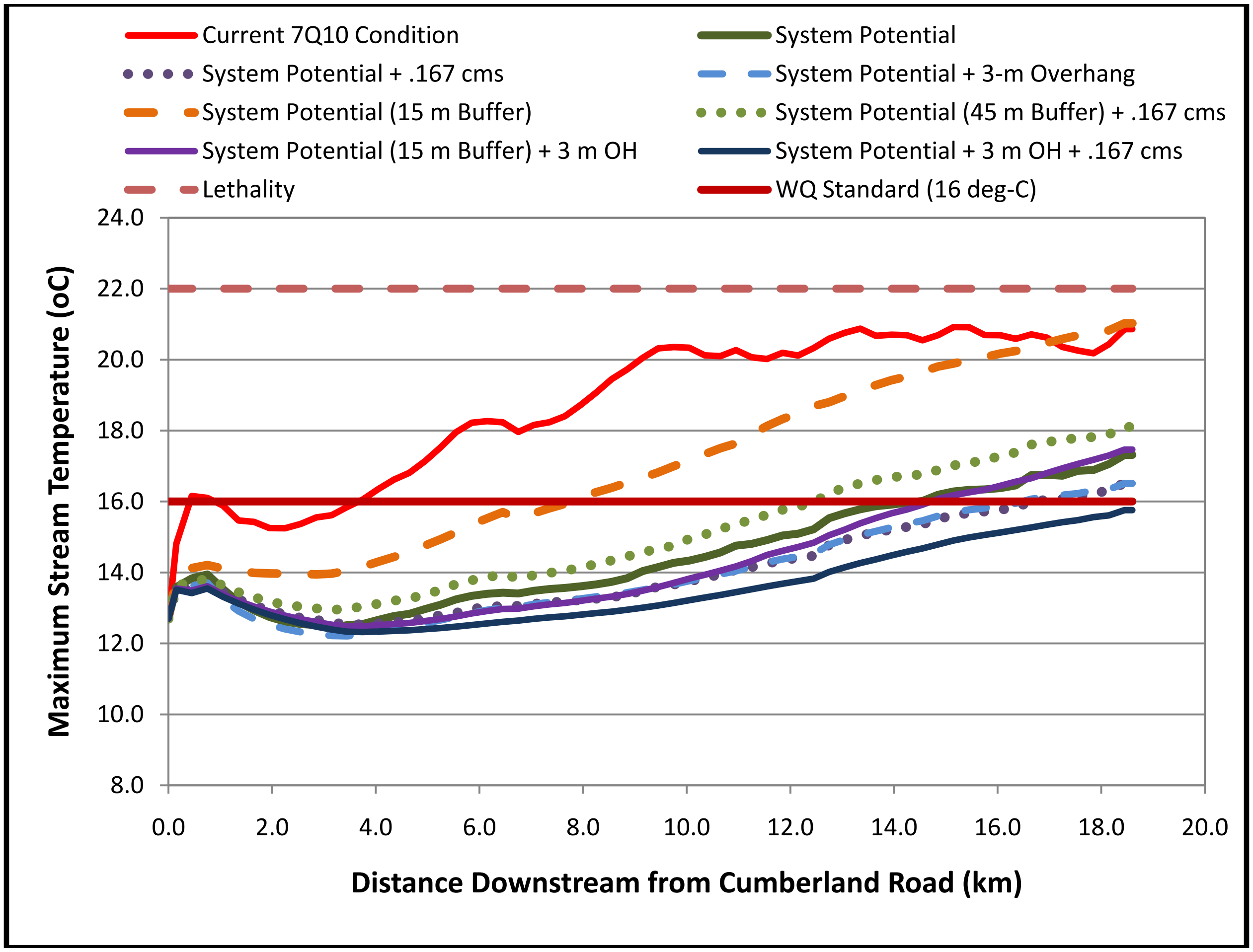

Figure 30. Maximum predicted Newaukum Creek temperatures with current, system potential (mature) riparian vegetation, and restored baseflows under critical summer conditions.

With restored baseflows or added overhang vegetation, temperatures are predicted to decrease an additional 0.5°C (on average) below system potential, causing stream temperatures to not exceed 16°C until the last 2 kilometers of the mainstem. The added effects of microclimate were negligible in both these scenarios. Combining all the effects of system potential vegetation with overhang, restored baseflows, and microclimate kept stream temperatures below the 16° C standard all the way to the mouth of Newaukum Creek (System Potential + 3 m OH + .167 cms).

A summary of temperature improvements in Newaukum Creek for various implementation actions represented by model scenarios is shown in Table 7.

Table 7. Predicted decreases in average and maximum 7Q10 temperatures with improvements in Newaukum Creek. *Improvements include implementation of mature riparian vegetation, tree canopy overhang, restoration of baseflows, and microclimate improvements.*

Model Scenario	T_{avg}	T_{max}	ΔT_{max}*	Length of stream in compliance with 16°C WQ Std.
	(^oC)	(^oC)	(^oC)	
Newaukum Creek				
current conditions	19.0	20.9		3.5 km
mature riparian vegetation	14.5	17.2	2.7	8.8 km
mature veg + microclimate	14.4	17.2	2.7	9.0 km
mature veg + overhang	14.0	16.5	4.4	16.5 km
no net baseflow loss	14.0	16.5	4.4	16.5 km
mature veg + overhang + no net baseflow loss + microclimate	13.5	15.8	5.1	18.5 km

* Change from current T_{max}

Mature riparian vegetation with microclimate is predicted to cool maximum temperatures in Newaukum Creek, during critical conditions, by 2.7° C. This is estimated to lengthen the amount of mainstem meeting the 16.0° C water quality standard from 3.5 km to 9.0 km. Adding the effects of either overhang from tree canopy or restoration of baseflows improves maximum stream temperatures by 4.4° C and lengthens the amount of mainstem in compliance with water quality standards to 16.5 km. Finally, combining all these temperature improvement measures lowers maximum stream temperature a total of 5.1° C and brings the entire mainstem into compliance with the 16.0° C standard.

Load and Wasteload Allocations

Load Allocations

The load allocations for temperature in Newaukum Creek are the effective shade that would occur from system potential mature riparian vegetation in each stream reach (Table 8).

Table 8. Effective shade and solar load allocations on July 23 to improve temperature conditions in Newaukum Creek. *(Potential effective shade is based on establishing system potential mature riparian vegetation to a height of 32 meters and a buffer width greater than 45 meters to attain 90% effective shade.)*

Station ID	Distance from upstream boundary to end of reach (km)	Existing reach averaged effective shade (%)	Existing reach averaged solar heat load (W/m2)	POTENTIAL reach averaged effective shade (%)	POTENTIAL reach averaged solar heat load (W/m2)	Load Allocation	
						REQUIRED increase in effective shade (%)	REQUIRED decrease in solar load (W/m^2)
284th AVE SE-N322	0.3	54.20%	100	96.80%	6.9	42.70%	92.7
	0.6	68.80%	68	96.00%	8.8	27.10%	59
	0.9	59.20%	89	96.50%	7.6	37.30%	81
SE 416th	1.2	63.60%	79	96.40%	7.8	32.90%	71.4
	1.5	54.70%	98	96.20%	8.3	41.50%	90.1
	1.8	52.00%	104	96.30%	8.1	44.30%	96.2
	2.1	46.20%	117	96.20%	8.3	49.90%	108.5
	2.4	46.90%	115	95.80%	9.2	48.90%	106.3
264th AVE SE	2.7	40.50%	129	96.50%	7.6	56.00%	121.7
	3	49.60%	110	95.30%	10.2	45.70%	99.4
	3.3	51.50%	105	95.90%	8.9	44.40%	96.4
SE 424th - G322	3.6	45.50%	118	95.20%	10.4	49.70%	107.9
	3.9	55.40%	97	95.00%	10.9	39.60%	86.1
	4.2	58.60%	90	94.90%	11.1	36.20%	78.7
	4.5	43.30%	123	95.20%	10.4	51.90%	112.8
	4.8	51.70%	105	95.10%	10.7	43.40%	94.2
252nd AVE SE	5.1	31.60%	149	95.00%	10.9	63.40%	137.6
	5.4	36.00%	139	94.50%	11.9	58.50%	127.1
244th AVE SE	5.7	45.30%	119	95.00%	10.9	49.70%	108
	6	66.40%	73	95.00%	10.9	28.50%	62
	6.3	61.50%	84	94.30%	12.3	32.80%	71.3
	6.6	46.40%	116	94.50%	11.8	48.10%	104.6
236 Ave SE-AN322	6.9	42.60%	125	94.60%	11.8	51.90%	112.8
	7.2	52.00%	104	94.50%	12	42.50%	92.3
	7.5	36.20%	139	93.60%	13.9	57.40%	124.8
SE 424th	7.8	40.30%	130	93.40%	14.2	53.20%	115.5

Station ID	Distance from upstream boundary to end of reach (km)	Existing reach averaged effective shade (%)	Existing reach averaged solar heat load (W/m2)	POTENTIAL reach averaged effective shade (%)	POTENTIAL reach averaged solar heat load (W/m2)	Load Allocation	
						REQUIRED increase in effective shade (%)	REQUIRED decrease in solar load (W/m^2)
	8.1	32.60%	146	93.50%	14.1	60.90%	132.4
	8.4	32.90%	146	93.60%	13.9	60.70%	131.9
SE 416th	8.7	38.40%	134	93.30%	14.5	54.90%	119.3
	9	42.90%	124	93.30%	14.5	50.40%	109.6
	9.3	42.70%	125	92.70%	15.8	50.10%	108.7
	9.6	53.40%	101	92.60%	16	39.20%	85.2
	9.9	66.90%	72	92.80%	15.6	25.90%	56.2
	10.2	73.70%	57	93.00%	15.1	19.30%	42
	10.5	69.20%	67	92.60%	16	23.40%	50.9
	10.8	64.40%	77	92.30%	16.7	27.90%	60.6
SE 400th - E322	11.1	80.30%	43	92.20%	16.9	11.90%	25.9
	11.4	77.60%	49	91.80%	17.8	14.20%	30.8
	11.7	66.20%	73	92.30%	16.6	26.10%	56.7
	12	70.20%	65	92.50%	16.3	22.30%	48.5
	12.3	74.10%	56	91.80%	17.8	17.70%	38.4
	12.6	58.30%	91	92.10%	17.1	33.80%	73.4
	12.9	59.10%	89	91.80%	17.8	32.70%	71
	13.2	67.00%	72	91.60%	18.3	24.60%	53.4
	13.5	71.20%	62	91.40%	18.6	20.20%	43.9
	13.8	62.90%	81	91.70%	18	28.80%	62.7
	14.1	66.80%	72	92.20%	17	25.40%	55.1
	14.4	65.40%	75	91.30%	18.9	25.90%	56.2
	14.7	62.40%	82	91.80%	17.9	29.40%	63.9
	15	65.50%	75	91.80%	17.8	26.40%	57.3
	15.3	63.90%	78	91.90%	17.5	28.10%	61
	15.6	71.90%	61	91.90%	17.5	20.10%	43.6
	15.9	75.00%	54	90.70%	20.2	15.70%	34.1
	16.2	73.00%	59	91.10%	19.4	18.00%	39.2
212th Ave SE	16.5	75.20%	54	90.50%	20.5	15.30%	33.3
USGS Gage 12108500	16.8	72.90%	59	91.20%	19	18.40%	39.9
	17.1	79.60%	44	90.60%	20.4	11.10%	24
	17.4	80.10%	43	90.10%	21.6	10.00%	21.8
	17.7	70.80%	63	90.70%	20.3	19.90%	43.2
X322	18	67.70%	70	90.00%	21.8	22.30%	48.4
	18.3	61.50%	84	89.40%	23	27.90%	60.7

The load allocations shown in Table 8 are not entirely representative of natural conditions since they do not account for baseflow loss. The natural condition would be characterized by both system potential effective shade and restored summer baseflows, resulting in even cooler stream temperatures.

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.

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 streamside 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 Newaukum Creek can potentially increase the heat load as they discharge into the mainstem of the creek. 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 32-meter tree heights and 90% density. Improving shade along these tributary streams can potentially reduce temperatures in the mainstem.

Wasteload allocations

Wasteload allocations (WLAs) are necessary for permitted facilities if they are found to be sources of pollutant loading to the stream. Ecology regulates municipal separate storm sewer systems (MS4s) as point sources under Ecology's NPDES Municipal Stormwater Program. Newaukum Creek basin has permitted stormwater sources that discharge into the mainstem or to tributaries of Newaukum Creek, but no specific sampling or modeling of stormwater inputs to Newaukum Creek was done for this TMDL study. Municipal Stormwater Permit holders within the Newaukum Creek watershed are shown in Table 9.

Table 9. Municipal Stormwater Permittees within Newaukum Creek basin.

Type of Permit	Permit Holder	Ecology Permit Number
Phase I stormwater	King County	WAR04-4501
Phase II stormwater	City of Enumclaw	WAR04-5514
Highway Stormwater	Department of Transportation	WAR043000A

Ecology does not consider stormwater discharges *significant direct* sources of thermal pollution during the summer critical period. However, stormwater runoff could potentially contribute to thermal loading during infrequent summer rainstorms. Precipitation that occurs in late spring to early fall that runs off or across heated surfaces can be initially quite warm. However, runoff cools rapidly during long rain events and is not expected to cause greater than a 0.2°C increase of the seven-day average daily maximum temperature as limited by state water quality standards (see Chapter 173-201A-200(1)(c)(i) WAC). Since these stormwater sources may have some effect on the mainstem or tributaries of Newaukum Creek, WLAs for municipal stormwater permittees are established in this TMDL. WLAs are expressed as:

- Cumulative stormwater discharges from all permitted sources may not cause the 7DADMax receiving water temperature to increase more than 0.2 degrees C (0.36° F).
- All appropriate best management practices required in the stormwater permit for controlling thermal loadings to surface waters are applied to the discharge to protect designated aquatic life uses.

Recent studies carried out in the Snoqualmie watershed may be informative for generalizing conditions and estimating stormwater effects in Newaukum Creek basin. Results from the Snoqualmie River TMDL study (Stohr, et al., Draft 2011), based on one year of data, show that precipitation during the critical period months is limited in occurrence and intensity, and it is unlikely that stormwater runoff would raise stream temperatures. It is further projected that weather conditions that would produce periods of stormwater runoff would be associated with cooler air temperatures and cloud cover. The dataset used to make these projections is admittedly small, and further study needs to be completed to fully understand and quantify the relationship between stormwater runoff and Newaukum Creek temperatures during critical, high temperature periods.

Temperature monitoring of representative stormwater outfalls that originate from large areas of impervious surfaces that are prone to solar heating may be appropriate in the future. If it is determined through future monitoring and studies in Newaukum Creek or other Puget Sound watersheds that there are significant stormwater heat discharges to rivers, an evaluation of the sources will be completed and appropriate allocations or monitoring requirements will be made. At this time any additional monitoring requirements for permittees on mainstem Newaukum Creek will be addressed through future permit requirements and not in this TMDL. Compliance with the permit constitutes compliance with the goals of this TMDL.

Ecology’s next round of municipal stormwater permits will be issued in mid-2012. These permits are anticipated to require new development and redeveloped areas to implement low impact development (LID) practices to the maximum extent feasible. This new requirement will minimize the generation of new stormwater and should capture a large percentage of the stormwater generated by the smaller storms that occur from June through September. In addition, the new municipal stormwater LID requirement will help infiltrate winter stormwater which will increase groundwater recharge and help restore summer baseflows. Much of the existing storm sewer systems in outlying areas transport stormwater in grass-lined ditches that already infiltrate stormwater.

The supplemental standard of 13°C applies in Newaukum Creek from September 15 to July 1, outside the critical period, to protect spawning and incubation of salmonid species (Figure 2). 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.

Stormwater runoff during the wet winter months is indirectly related to stream temperature impairment through reduced groundwater recharge and subsequent reduced baseflows. However, Ecology is not establishing an infiltration-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 disperse and infiltrate stormwater using site design, pervious paving, and retention of forests and mature trees. As part of the implementation plan, this TMDL stresses the importance of infiltrating stormwater and reducing effective impervious area throughout Newaukum Creek watershed where feasible. The Municipal Stormwater General Permit currently requires permit holders to develop local ordinances that allow LID and provide education and outreach on LID techniques to developers, engineers, land use planners, contractors, and others.

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Seasonal Variation

Load allocations for this TMDL were determined using a model that considered conditions that would describe a "worst case scenario". Low flow, high air temperature, and high solar loads were included in the calculations. These conditions typically occur in the summer months of July and August. Since the load allocations resulting from the summer model runs resulted in requiring the maximum riparian protection to the stream, a fall scenario was not performed. Fall temperature criteria for salmon begin September 15. If a model evaluation were performed, it would need to be done with September climate conditions, an annual 7Q10 flow, and an estimate of the shade produced by the vegetation on September 15. Additional modeling would not change the resulting load allocation. If the resulting water temperature were below the state standard, the summer load allocation for effective shade would still need to be met to comply with the summer critical condition. If the resulting fall water temperature were greater than the state standard, the load allocation would still be the maximum potential shade.

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 implicitly addressed by using critical climatic conditions in the modeling analysis. The factors of margin of safety in this TMDL are:

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

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Implementation Plan

Introduction

This implementation plan was developed jointly by Ecology and interested groups and responsible parties, and describes what will be done to improve temperatures in Newaukum Creek watershed. It explains the roles and authorities of restoration partners (those organizations with jurisdiction, authority, or direct responsibility for water quality improvement), along with the programs or other means through which they will address these water quality issues.

The plan describes and prioritizes specific actions to improve water quality and achieve water quality standards.

What needs to be done?

This implementation plan summarizes actions that will help improve water quality in Newaukum Creek watershed. After the U.S. Environmental Protection Agency (EPA) approves this *Newaukum Creek Temperature TMDL/Water Quality Improvement (TMDL) Report and Implementation Plan*, interested and responsible parties will work together to implement the *Plan*. The plan describes and prioritizes specific actions to improve water quality and achieve water quality standards for temperatute. 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. Ecology typically contributes funding to support local efforts and prioritizes grant projects that are consistent with TMDL implementation plans.

Several agencies and groups in Newaukum Creek watershed actively conduct educational and stream restoration projects that help remediate the water quality impacts to these creeks. State and local governments, King Conservation District, and others actively plan and develop stream restoration and other watershed activities that will help improve stream temperatures in Newaukum Basin.

This plan also summarizes and incorporates many actions recommended by other restoration plans for Newaukum Creek watershed: Newaukum Creek Basin Characterization Project Report **(**King County, 2007), and WRIA 9 Salmon Habitat Plan (WRIA 9, 2005). In addition, Ecology incorporated valuable input from Newaukum Creek watershed stakeholders into this plan.

The TMDL study evaluated several approaches to reducing temperature in Newaukum Creek Basin, 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, restored baseflows, and microclimate improvements 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 45 meters (148 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 many years, 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.

Figure 31. Newaukum Creek near station AN322.

Maintaining or enhancing groundwater recharge through the use of 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. In most areas on the Enumclaw Plateau, infiltrating water is especially challenging because of underlying, poorly-permeable mudflow deposits. With this in mind, LID and infiltration of stormwater are recommended in Enumclaw and the Enumclaw Plateau, where feasible.

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. Human population growth and increasing development within the Urban Growth Area and in rural areas around the city of Enumclaw are expected to exacerbate existing ecological impairments and further constrain restoration opportunities in the basin (King County, 2007). 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, minimizing livestock impacts, and groundwater interactions) would help improve stream temperature and help protect core salmonid life stages. Table 10 is a summary of implementation actions and timeframes to improve temperature in Newaukum Creek watershed. Ecology will discuss these and related activities with the key parties and will adaptively manage the list of priority actions during the implementation process.

Table 10. Summary of implementation actions and timeframes to improve temperature in Newaukum Creek watershed.

Actions	Schedule
Provide more shade and improve riparian areas	
Assess potential planting sites along Newaukum Creek and tributaries.	2011 - 2020
Promote invasive plant removal and plant colonizing species.	2011 - 2040
Enforce local ordinances to minimize livestock impacts to streams.	2011 - 2040
Incorporate TMDL actions into local regulatory programs and policies.	2011 - 2040
Protect cool groundwater and enhance current summer baseflows	
Promote Low Impact Development (LID) practices.	2011 - 2040
Consider TMDLs during SEPA and other land use planning reviews.	2011 - 2040
Infiltrate stormwater and/or reclaimed water to the maximum extent possible.	2011 - 2040
Restore and/or create beneficial wetlands.	2011 - 2040
Increase water conservation.	2011 - 2040
Consider economically-feasible alternative water sources.	2011 - 2040
Reduce unauthorized water withdrawals through enforcement.	2011 - 2040
Monitoring	
Conduct in-stream water quality & flow monitoring.	2011 - 2040
Incorporate stormwater sampling/temperature monitoring in fall.	Fall 2011
Effectiveness monitoring	2025, 2040

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 for instream habitat. 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.
The effective and potential shade shown in Table 8 identifies reaches along the mainstem of Newaukum Creek with the greatest lack of shade (45-61%). 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 stream deriving temperature benefits. Riparian restoration and preservation of existing high-value habitat should also be focused upstream from identified high-shade deficit reaches.

Summary of actions

- **Assess potential planting sites along mainstem Newaukum Creek and tributaries, particularly in the high shade deficit areas.**

  The greatest need for increased shade on the Newaukum Creek mainstem is at 264th Avenue Southeast (SR 169), the 1 km reach below 252nd Ave SE, and the 2.5 km below 236th Ave SE. All three of these reaches are located on the plateau portion of the Newaukum Basin.

  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 150 foot (46m) buffer zone around Newaukum Basin streams 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. 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.

  Improvements in sensitive area regulations for all jurisdictions should require buffers of at least 150 feet 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 Newaukum Creek system benefits 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 Newaukum Basin should be protected and recharged to maintain hydrologic integrity and a temperature regime that supports core salmonid life stages.

In general, human activities can change stream hydrology by reducing baseflows. 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 baseflow losses within Newaukum Creek Basin due to effective impervious areas (EIA) and water management activities (e.g. consumptive water use and withdrawals) were made by Carlson (2011) in a streamflow analysis for this TMDL.

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 Newaukum 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 Enumclaw withdraws the largest water volumes from the Newaukum Basin. The city is 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 existing legal water rights.

Exempt wells also use groundwater for domestic purposes. These wells can provide up to 5,000 gallons of water per day for a single home or small group of homes and do not require a state water right permit. The estimated number of exempt wells in the Newaukum Creek basin in 2000 was 381 and the estimated withdrawal from these wells was 18.3 million gallons or 0.08 cfs (NHC, 2005). More recent estimates have not been developed.

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. As demand for water supply increases, it will be important to minimize the degradation to groundwater recharge that could continue to occur as a result of population growth and development.

Summary of actions

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

  Municipalities should evaluate their stormwater drainage systems (municipal separate storm sewer systems, or MS4s) for opportunities to infiltrate stormwater, where feasible, rather than directly discharging to creeks. To promote more stormwater infiltration, Ecology's current Western Washington Manual on Stormwater best management practices (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.

  To help reduce the effect of new and existing stormwater discharges, local government should advance the use of low impact development (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, 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 systems. Correcting "infiltration" of extraneous groundwater that enters sewer systems 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 landscaping 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 King Conservation District 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 safe drinking water to their respective communities. All water purveyors should be compliant with water conservation rules and support efforts to enhance groundwater recharge. In assessing alternative sources to augment local groundwater sources, potential impacts to the baseflows in other important salmon-bearing streams, such as Boise Creek and the White 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, golf courses, and for routine city maintenance of storm drainage systems, such as street sweeping and cleaning drains. However, importing reclaimed water to Newaukum Creek 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 a more economically-feasible option for using reclaimed water in the basin.

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

  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 Big Spring Creek Natural Area is being managed to protect the cool groundwater source of Big Spring Creek tributary to Newaukum Creek. The important

Newaukum Creek headwaters and tributary sub-basins should also be preserved for the benefit of aquatic habitat.

- **Increase water conservation in Newaukum Creek 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. 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 structures 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 requires significantly less water for irrigation.

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

  This TMDL encourages projects that 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 closed Green River and its tributaries, including Newaukum Creek, to any further consumptive surface water diversions in 1980. 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 in 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 encourages developers to not 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 in water rights. Ecology requires that water right holders install flow meters and maintain metering records to make sure permitted volumes are not exceeded.

Salmon recovery projects

Numerous salmon habitat programs and projects already identified by the WRIA 9 Watershed Ecosystem Forum will also help implement temperature improvement in Newaukum Creek (WRIA 9, 2005). Programmatic actions include increasing natural yard-care programs for landscapers and single-family homeowners and supporting King County's Natural Resource/Basin Steward Programs. Other watershed-wide programs recommended for the Green – Newaukum Basins are increased use of LID and porous concrete, and developing a coordinated acquisition program for natural areas.

Salmon habitat actions that are specific to the Newaukum Creek sub-basin include Newaukum Creek riparian planting and restoration between stream mile 0.0 and 14.3, and Big Spring Creek re-alignment and restoration. The Newaukum Creek riparian restoration and re-alignment of Big Spring Creek will re-locate approximately 4,000 linear feet of Big Spring Creek (tributary to Newaukum Creek) from the current ditched system into a channel consistent with its historic route. The stream re-alignment will restore about 80 acres of riparian area and will reduce pollution coming from road ditches and a dairy and connect the stream and nearby wetland to improve off-channel rearing areas and help lower temperatures in Newaukum Creek. The project will enhance riparian conditions by planting conifers and creating off-channel wetland connections to the stream, especially the pastured wetland to the south of Southeast 424th Street. The project will also fence areas adjacent to the stream to exclude livestock and protect riparian vegetation (WRIA 9, 2005).

The following programs and projects recommended in the WRIA 9 Green/Duwamish Salmon Habitat Plan (August 2005) are incorporated here as Newaukum Creek temperature TMDL implementation. Newaukum Creek is a Priority Salmon Habitat Protection Area up to SR 169. More detail on these programs and actions is available in the WRIA 9 Salmon Habitat Plan.

Table 11. WRIA 9 Salmon Recovery Projects included in Newaukum Creek temperature TMDL.
Watershed-Wide programs intended to compliment on-the-ground habitat restoration and protection projects:

WW-3	Increase/expand Natural Yard Care Programs for Landscapers
WW-4	Increase/expand Natural Yard Care Programs for Single Family Homeowners
WW-5	Promote Planting of Native Trees
WW-8	Increase Involvement of Volunteers in Habitat Stewardship
WW-10	Support/Expand the Natural Resource/Basin Stewardship Programs
WW-13	Increase Use of Low Impact Development and Porous Concrete
WW-14	Provide Incentives for Developers to Follow Built Green Guidelines
WW-15	Develop Coordinated Acquisition Program for Natural Areas
WW-16	Develop Salmon Restoration Tools Consistent with Agricultural Land Uses

Middle Green Projects specific to Newaukum Creek:

MG-6	Newaukum Creek riparian planting and large woody debris placement between stream miles 0.0 – 14.3 (both banks)
MG-7	Big Spring Creek restoration project
MG-8	Newaukum Creek mouth riparian planting and large woody debris between stream miles 0.0 – 4.3 (both banks)

Agricultural drainage assistance projects

Most of the Enumclaw Plateau was designated by King County as an Agricultural Protection District (APD) in 1985. The Enumclaw Plateau APD is the largest of the five APDs in King County with over 20,000 acres. The county established the Agricultural Drainage Assistance

Program (ADAP) to help farmers navigate the permitting process for improvement and maintenance of agricultural drainage systems. ADAP was also established to provide assistance in the implementation of best management practices (BMPs) required by federal, state, and local regulations (King County, 2010). Some of the implementation measures supported by ADAP will assist in maintaining Newaukum Creek baseflows and should help implement temperature improvements in Newaukum Creek.

Forest practices

The state's forest practices regulations will be relied upon to bring waters in private and state forested lands into compliance with the load allocations established in this TMDL. This strategy, referred to as the Clean Water Act Assurances, was established as a formal agreement to the 1999 Forests and Fish Report (http://www.dnr.wa.gov/Publications/fp_rules_forestsandfish.pdf).

The state's Forest practices rules were developed with the expectation that the stream buffers and harvest management prescriptions were stringent enough to meet state water quality standards for temperature and turbidity, and provide protection equal to what would be required under a TMDL. As part of the 1999 agreement, new forest practices rules for roads were also established. These new road construction and maintenance standards are intended to provide better control of road-related sediments, provide better stream bank stability protection, and meet current best management practices.

To ensure the rules are as effective as assumed, a formal adaptive management program was established to assess and revise the forest practices rules, as needed. The agreement to rely on the forest practices rules in lieu of developing separate TMDL load allocations or implementation requirements for forestry is conditioned on maintaining an effective adaptive management program. Consistent with the directives of the 1999 Forests and Fish agreement, Ecology conducted a formal 10-year review of the forest practices and adaptive management programs in 2009.

Ecology noted numerous areas where improvements were needed, but also recognized the state's forest practices program provides a substantial framework for bringing the forest practices rules and activities into full compliance with the water quality standards. Therefore, Ecology decided to conditionally extend the CWA assurances with the intent to stimulate the needed improvements. Ecology, in consultation with key stakeholders, established specific milestones for program accomplishment and improvement. These milestones were designed to provide the public with confidence that forest practices in the state will be conducted in a manner that does not cause or contribute to violations of the state water quality standards.

SEPA reviews

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 stream temperatures 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's focus sheet on TMDLs and SEPA impact analysis, threshold determinations, and mitigation (http://www.ecy.wa.gov/biblio/0806008.html) may help. Additionally, the TMDL should be considered in the issuance of land use permits by local authorities.

Monitoring

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

- **Continue existing monitoring efforts throughout the watershed.** King County currently has robust stream monitoring programs in the watershed. Data from these monitoring programs not only track trends in stream quality in the Newaukum Creek 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 Newaukum Creek from September 15 to July 1 to protect spawning and incubation of salmonid species. Data collected for this TMDL showed stream temperature exceedances during the critical period but not 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 water temperatures throughout the year.

- **Effectiveness monitoring** for streams in Newaukum Creek watershed will tell us whether actions to improve temperature are effective. 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 available water quality data. Depending on available data and resources, Ecology may conduct additional monitoring to assess current water quality conditions. This allows us to see what is working, what is not working, and what changes may be needed to improve water quality.

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 Newaukum Creek watershed.

Federal, tribal, and state entities

U.S. Environmental Protection Agency

The 1997 Memorandum of Agreement between the Environmental Protection Agency, Region 10 and Ecology requires that EPA and Ecology jointly evaluate the implementation of TMDLs in Washington. These evaluations address whether interim targets are being met, whether implementation measures such as BMPs have been put into effect, and whether 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 stormwater 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 Green-Duwamish watershed (WRIA 9), which includes Newaukum Creek, is within Ecology's Northwest Region. The Northwest Regional Office (NWRO) has one TMDL lead covering TMDL projects in WRIAs 8 and 9, one municipal stormwater engineer and two municipal stormwater specialists who provide technical assistance and auditing activities for Phase I and Phase II municipal stormwater permits. Ecology's headquarters also has several staff that help administer TMDLs and permits and distribute education and outreach materials to stormwater permit holders.

Ecology's Water Quality Improvement Lead is assigned to the implementation of the Newaukum Creek Temperature TMDL who will track implementation and assist the stormwater permit holders and other environmental agencies and groups. 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 range of funding opportunities offered through Ecology is discussed under the section "Funding Opportunities." Ecology's Grant Specialists assist local government in the development, funding, and implementation of stream restoration and water quality improvement projects.

Ecology will be responsible for organizing meetings of stakeholder workgroups 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. WSDOT actively participates in TMDL processes where WSDOT facilities or operations are important contributing sources to the pollutants being addressed in the TMDL.

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; including the Green-Duwamish watershed. The Newaukum Creek system is part of the Green-Duwamish 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.

In December, 2008, the Partnership produced the 2020 Action Agenda that establishes science-based goals to achieve recovery and protection. The 2020 Action Agenda addresses 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. Newaukum Creek watershed of Water Resource Inventory Area 09 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 9 Watershed Ecosystem Forum

The WRIA 9 Watershed Ecosystem Forum is comprised of representatives of 32 local governments, businesses, community groups, and state and federal agencies that have worked together since 2000 to protect and restore salmon habitat. King County and 20 cities in the watershed pooled resources to develop the WRIA 9 Salmon Habitat Plan which was ratified by all 20 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.

Newaukum Creek watershed, mostly in rural King County, is among the most important basins in the Green-Duwamish basin for salmon habitat. In the WRIA 9 Salmon Habitat 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 Newaukum Creek and the WRIA 9 watershed is the Big Spring Restoration Project. The project will relocate a major section of Big Spring Creek from the current ditched system into a channel consistent with its historical route; add large woody debris; and restore riparian conditions.

Local government resources

City of Enumclaw

The City of Enumclaw Public Works Department is preparing a Stormwater Management Program (SWMP) as required by their National Pollutant Discharge Elimination System (NPDES) Phase II Municipal Stormwater Permit. The City submits annual reports on its stormwater activities and annual updates to its SWMP Plan for future stormwater activities. To mitigate for impacts associated with stormwater runoff, the City requires that stormwater management practices be designed, constructed, operated and maintained in accordance with Ecology's Stormwater Management Manual for Western Washington.

In addition to the Ecology Manual, surface water impacts can be mitigated through green building practices or Low Impact Development (LID) practices. Green building and LID practices are not just for new development, but can be considered for redevelopment projects.

Enumclaw's Water Utility operates a water supply system serving over 5,500 customers within the city and portions of unincorporated King County encompassing approximately 37 square miles. Two of the City's three water-supply sources are located in the Newaukum Creek watershed.

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, and water quality monitoring. Following are the program descriptions.

- The *WRIA 9 Basin Steward* serves as a liaison between residents and cities, King County, state, federal, and tribes in stewardship and restoration projects in Newaukum Creek watershed. 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 Newaukum Creek has been very effective at initiating and coordinating significant acquisition and restoration projects in the Newaukum Basin.

- The *Natural Resources Lands Program* of King County manages the Big Spring Natural Area in Newaukum Basin, an area owned by the city of Enumclaw, and adjacent conservation easements in Newaukum Creek watershed all totaling over 150 acres. These natural areas contain extensive wetland systems, numerous springs, and one of the highest quality salmon-bearing streams in the Newaukum Creek drainage basin. In 2011, Ecology awarded King County $30,000 in Coastal Protection Funds as part of a $113,000 project to fence and revegetate 6,500 linear feet of Newaukum Creek riparian zone on the Enumclaw Plateau. King County's long-term goal is to revegetate the plateau reach from RM 5 to RM 9 over a ten-year period.

- 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 *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 (K.C.C. 21A.30), 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. The Ordinance requires landowners to implement BMPs to minimize nonpoint pollution from livestock. The Ordinance also recommends the development and implementation of Farm Plans for farms with livestock.

- *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 *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 or connections to the storm drainage system.

- 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, decreases the costs of conveying and treating wastewater, and leaves more groundwater in shallow aquifers to assist stream baseflows.

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; designs and installs stream enhancement projects; holds classes; conducts farm tours; and provides financial assistance.

KCD advises farm owners on practices that help improve water quality and protect fish and wildlife habitat through the development of farm plans. 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 numerous small farm plans within Newaukum Creek watershed over the last 10 years. The more recent planning efforts address water quality concerns on these farms.

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 general 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 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.

Nonprofit and volunteer organizations

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 streams, rivers, fish, and stream environments in Snohomish and King Counties and to restore 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.

AASF conducts culvert fish barrier and pollution identification surveys which are sometimes funded through Centennial Clean Water Fund grants from Ecology. They spend 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 staff provides education to the public on ways to address stream problems such as stream bank erosion, native riparian vegetation planting, flooding/drainage issues, and habitat creation for fish and wildlife.

Stewardship Partners

Stewardship Partners helps private landowners restore and preserve the natural landscapes and waterways 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 collaborates 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 Salmon-Safe label is gaining national recognition and appears on a variety of products including dairy, produce, wine, and fruit. The Salmon Safe certification program may be expanded to include city parks and golf courses.

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.

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

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 for the past 10 years. 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 Conservation Districts, natural resource agencies, extension offices, environmental groups, horse organizations, and other equine professionals.

Educational presentations are given 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. 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. In turn, local businesses can be partners in increasing public awareness on the local water quality issues in Newaukum Creek Basin. 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 streams.

Local citizens

Local citizens play a critical role in improving the water quality of Newaukum Creek. Many citizens can have an immediate impact on local water quality by allowing stream restoration projects on their riparian property and changing certain land use practices. Property owners can take it upon themselves to enhance streamside riparian vegetation, minimize runoff of nonpoint sources of pollution from their yards, and repair leaky on-site septic systems. 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 Newaukum Creek watershed.

Schedule for achieving water quality standards

There is currently general warming in Newaukum Creek as it flows downstream in late summer (Figure 30). Under current conditions, Newaukum Creek exceeds the 16^{O} C water quality standard during the summer critical period over the lower 14 km of stream. This implementation plan proposes to reduce the length of stream exceeding standards to 0 km by the year 2040, according to the general schedule shown in Figure 32.

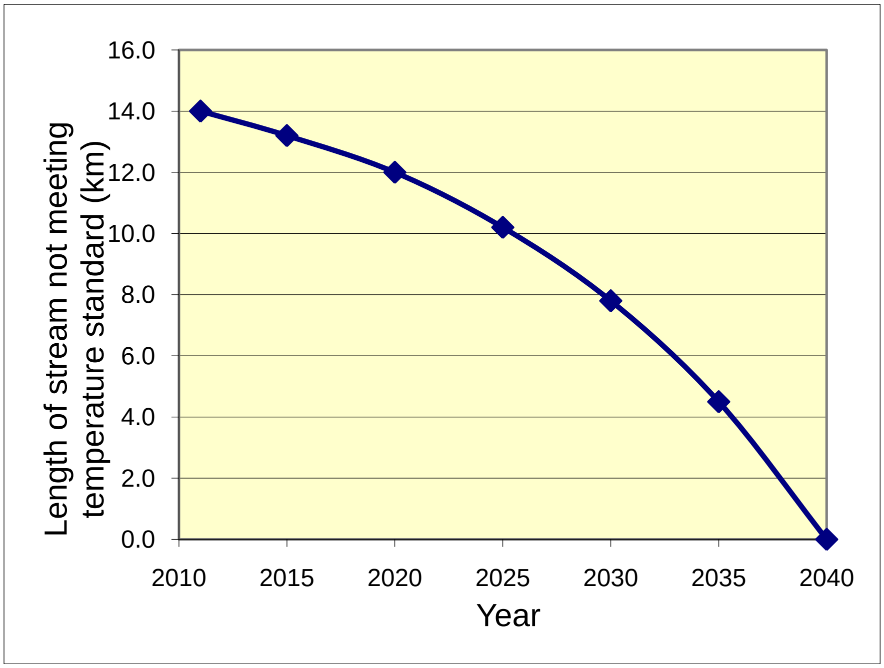

Figure 32. Schedule for reducing stream length exceeding standards during critical period. *Dates are estimates and may change depending on implementation constraints.*

Modeling associated with this TMDL study indicates that with system potential vegetation with overhang, or restored baseflows, Newaukum Creek temperatures will meet the 16^{O} C standard except for the lower 2 kilometers of the mainstem. With both optimal stream restoration and restored baseflows, Newaukum Creek will meet the 16^{O} C standard over its entire stream length (Figure 30). This implementation schedule focuses on meeting water quality standards over the entire length of stream during summer low flows by the year 2040. Water Quality Standards may be attained in Newaukum Creek during critical periods sooner than 2040 depending on the pace of LID, planting projects, and time needed to establish mature riparian vegetation.

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Measuring Progress toward Goals

Monitoring progress

A monitoring program for evaluating progress is an important component of any implementation plan. Monitoring is needed to keep track of what activities have or have not been done, measure the success or failure of implementation actions, and evaluate improvements in water quality. Monitoring should also be done after water quality standards are achieved (compliance monitoring) to ensure that standards continue to be met.

King County monitors the ecological health of Newaukum Creek in a variety of ways including collecting and analyzing water, sediment, sampling for benthic invertebrates, and taking stream temperature measurements. Water quality samples have been collected monthly by the county in Newaukum Creek since 1972 at a location 1 mile upstream of the mouth at station 0322, located at the USGS gauging station near 312th Street. In addition, King County maintained several other water temperature gages in Newaukum Basin between 2001 and 2009. The county intends to continue monitoring at station 0322 and at least three other sites in the foreseeable future.

Overall stream health in terms of temperature should be measured after initial riparian planting projects have had time to mature and provide shade. Mainstem vegetation and shade should be re-evaluated and the QUALKw model re-run during the period between 2015 and 2020. The model results will be used to assess length of lower Newaukum Creek exceeding the 16^{O} C temperature standard under current vegetation and 7Q10 flow conditions. The stream length indicated by the model results will be compared to the schedule for achieving critical period water quality standards shown in Figure 32.

This comparison using model results with current riparian shade data should be conducted for Newaukum Creek mainstem approximately every five years between 2020 and 2040. The rate and/or type of restoration will be altered in accordance with the adaptive management section of this plan if the modeled length of stream channel meeting standards falls behind schedule as shown by the implementation goals in Figure 32.

Monitoring implementation actions and how they will be maintained

Implementation projects will be inventoried by Ecology in terms of location, length of streambank restored, buffer width, and year of planting. Those conducting restoration projects or installing best management practices (BMPs) are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing. GIS mapping of implementation projects may also prove helpful in identifying areas that have been successfully restored and areas that still need work.

Entities with enforcement authority are responsible for following up on any enforcement actions. Stormwater permittees and point source permittees are responsible for meeting the requirements of their permits. Compliance monitoring will be needed when water quality standards are believed to be achieved.

Adaptive management

Adaptive management involves testing, monitoring, evaluating applied strategies, and incorporating new knowledge into management approaches that are based on scientific findings. Natural systems are complex and dynamic and the way a system will respond to human management activities is often unknown and can only be described as probabilities or possibilities. In the case of TMDLs, Ecology uses adaptive management to assess whether the actions identified as necessary to solve the identified pollution problems are the correct ones and whether they are working. As these actions are implemented, the system will respond and change. Adaptive management allows us to fine-tune our actions to make them more effective, and to try new strategies given evidence that a new approach could help us to achieve compliance.

The Newaukum Creek temperature TMDL reductions should be achieved by 2040. These targets will be described in terms of percent shade, percent reductions in solar loading, concentrations, and implementation activities. A key measure of TMDL progress will be modeled stream length of Newaukum Creek exceeding standards during the critical period as shown in Figure 32. Partners will work together to monitor progress toward these goals, evaluate successes, obstacles, changing needs, and make adjustments to the implementation strategy as needed.

Ecology will use adaptive management when water monitoring data show that the TMDL targets are not being met or implementation activities are not producing the desired result. A feedback loop (Figure 33) consisting of the following steps will be implemented:

Step 1. The activities in the water quality implementation plan are put into practice.

Step 2. Programs and (best management practices) BMPs are evaluated for technical adequacy of design and installation.

Step 3. The effectiveness of the activities is evaluated by assessing new monitoring data and comparing it to the data used to set the TMDL targets.

> Step 3a. If the goals and objectives are achieved, the implementation efforts are adequate as designed, installed, and maintained. Project success and accomplishments should be publicized and reported to continue project implementation and increase public support.
>
> Step 3b. If not, then BMPs and the implementation plan will be modified or new actions identified. The new or modified activities are then applied as in Step 1.

Additional monitoring may be necessary to better isolate heat sources and identify needed shade so that new BMPs and restoration projects can be designed and implemented to improve temperatures in Newaukum Basin streams.

It is ultimately Ecology's responsibility to assure that implementation is being actively pursued and water standards are achieved.

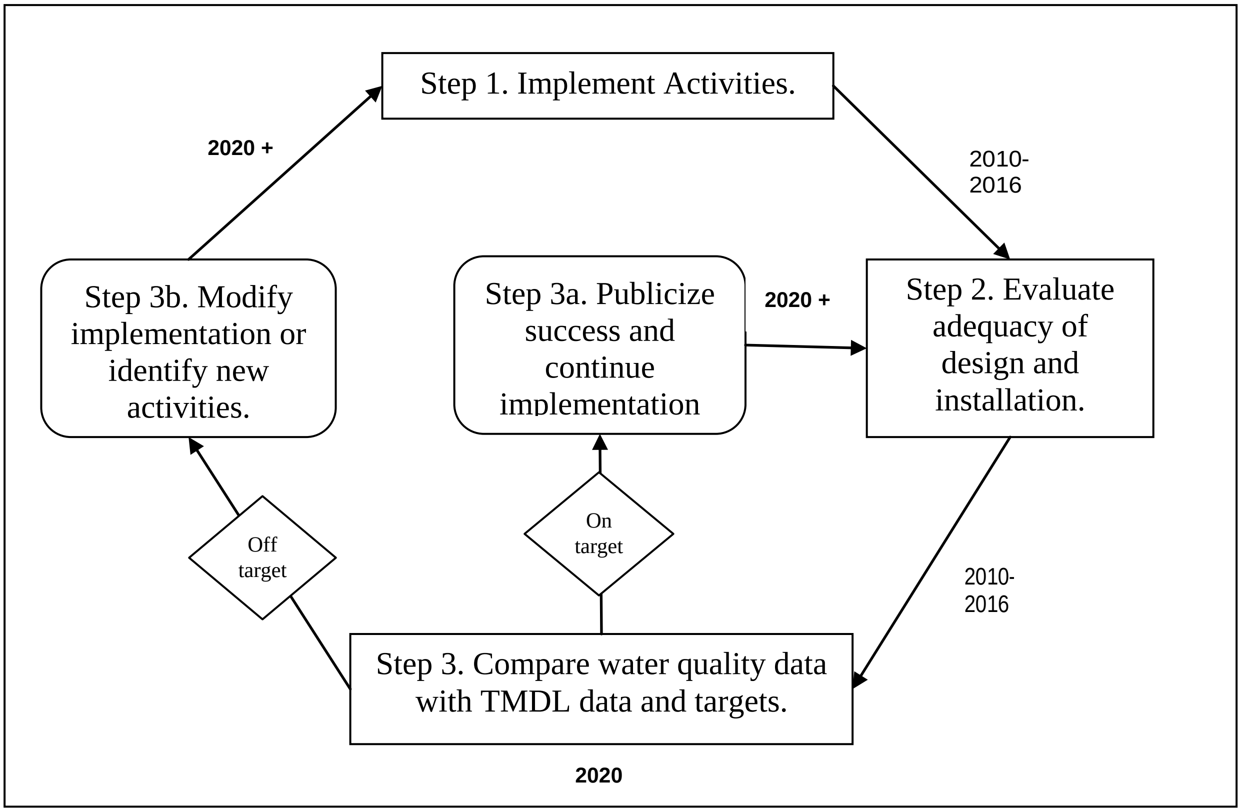

Figure 33. Feedback loop for determining need for adaptive management. *Dates are estimates and may change depending on resources and implementation status.*

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Potential Funding Sources

Several possible funding sources available to implement activities necessary to correct water quality problems in Newaukum Creek watershed are shown in Table 12. 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 12. 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	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, restoring stream riparian areas. ▪ 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	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.
King Conservation District	CREP – Conservation Reserve Enhancement Program CRP – Conservation Reserve Program EQIP – Environmental Quality Incentives Program LIP – Landowners Incentives Program	CREP – rental, incentive, maintenance, & cost share for forested buffers along streams CRP – rental, & cost share pmts to establish cover on cropland EQIP – technical assistance & cost share for livestock owners LIP – incentive payments for on-the-ground conservation practices

Environmental Protection Agency

Environmental Education Grants Program

Education institutions, environmental and educational public agencies, and not-for-profit organizations are eligible for this funding, which supports environmental education projects. These grants require non-federal matching funds for at least 25 % of the total cost of the project. If project requests are $5,000 or less through a Regional Office or $100,000 or less through EPA Headquarters, chances of being funded increase. For more information contact Diane Berger @ (202) 260-8619, berger.diane@epa.gov, or on the Internet @ www.epa.gov/enviroed.

Ecology Funding Opportunities

Centennial/SRF/319 Fund

These three funding sources are managed by Ecology through one combined application program. Centennial and 319 funds are grants and the State Revolving Fund (SRF) is a low interest loan program and each is available to public entities. Grants require a 25 % match and may be used to provide education/outreach, technical assistance, for specific water quality projects, or as seed money to establish various kinds of water quality related programs or program components.

At the time of this report, grant funds are available for riparian fencing, riparian re-vegetation, and alternative stock watering methods to assist riparian restoration. Funds are generally not available for making capital improvements to private property. However, eligibility rules can change so one should check at the beginning of each grant cycle.

Low-interest loans are available to public entities for all the above uses, and have also been used as "pass-through" to provide low-interest loans to homeowners for agricultural best management practices. Ecology's grant and loan cycle kicks off in September of each year with public meetings held throughout the state. See Ecology's webpage for more information on Ecology financial assistance opportunities as well as other funding sources.
http://www.ecy.wa.gov/programs/wq/links/funding.html

Coastal Protection Fund

Since July 1998, water quality penalties issued under Chapter 90.48 RCW have been deposited into a sub-account of the Coastal Protection Fund. A portion of this fund is made available to regional Ecology offices to support on-the-ground environmental restoration and enhancement projects. Local governments, tribes, and state agencies must propose projects through Ecology staff. Projects seeking to reduce bacterial pollution are encouraged. Contact an Ecology Water Cleanup specialist to investigate fund availability and to determine if your project is a good candidate.

Salmon Recovery Funding Board (SRFB)

The Salmon Recovery Funding Board (SRFB) provides grants to local governments, tribes, nonprofit organizations, and state agencies for salmon habitat restoration, land acquisition, and habitat assessments. Projects and programs must produce sustainable and measurable benefits for fish and fish habitat. Most projects designed to improve salmon habitat also provide water quality benefits.

USDA Programs

Conservation Reserve Enhancement Program (CREP)

The CREP is a voluntary program to establish forested buffers along streams where streamside habitat is a significant limiting factor for salmonids. It helps landowners implement conservation practices on their property while offsetting the burden of property taxes through land rental payments. In addition to providing habitat, the buffers improve water quality and increase stream stability. Land must be on a salmon or steelhead stream to be eligible.

Land enrolled in CREP is removed from production and grazing under 10-15 year contracts. In return, landowners receive annual rental, incentive, maintenance, and cost share payments. Other program highlights include:

- Annual payments can equal 100% of the weighted average soil rental rate (incentive is 110% in areas designated by Growth Management Act).
- Annual soil rental rates in King County for 2011 vary greatly (from about $100/acre[2] to $232/acre) depending on the quality of soil and type of crops typically raised on them.

Landowners can enter a 10-15 year rental agreement with the United States Department of Agriculture. Additional incentives offered through the program include a signing bonus, fencing cost-share for livestock owners, watering facilities, and other land improvements for qualifying landowners. CREP is administered by the King Conservation District in cooperation with the USDA Farm Service Agency.

Conservation Reserve Program (CRP)

The CRP is a voluntary program that offers annual rental payments, incentive payments for certain activities, and cost-share assistance to establish approved cover on eligible cropland. Administered by King Conservation District, assistance is available in amounts equal to not more than 50% of the participant's costs in establishing approved practices; contract duration between 10-15 years.

Environmental Quality Incentives Program (EQIP)

This federally funded program is managed by King Conservation District and has the following features:

- Provides technical assistance, cost share payments and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm.
- 75% cost sharing but allows 90% if producer is a limited resource or beginning farmer or rancher.
- Program funding divided 60% for livestock-related practices, 40% for crop land.

[2] CREP buffers can range from 15 feet to 180 feet wide. A small agricultural watercourse with a 15 foot wide buffer on each side generates an acre of CREP income every 1,450 feet.

- Contracts are one to ten years.
- NO annual payment limitation; sum not to exceed $450,000 per individual/entity.

King Conservation District Funds

Funding of on-the-ground watershed improvement projects by the King Conservation District (King CD) is critical to the success of the Newaukum Creek Temperature TMDL. The King CD provides over $4M annually across King County to support of on-the-ground conservation projects and environmental education programs. King CD funds are provided through several programs in the Newaukum Creek Watershed.

Landowner Incentive Program

The Landowner Incentive Program (LIP) has been developed by the King CD to address soil and water resource concerns in King County by funding on-the-ground conservation projects. The King CD LIP is intended to promote stewardship by enabling landowners to implement best management practices (BMPs) on their land. A landowner will be required to have either an approved farm plan, forest stewardship plan, or be currently receiving technical assistance from the King CD in order to apply. Typical LIP grants focus on forest health management, aquatic buffer plantings, waste storage facilities and other activities involving the implementation of best management practices.

The King CD LIP is an incentive based program that can fund 50-90% of the project cost with the remainder to be provided by the applicant. The list of funded practices includes both agricultural related BMPs and non-agricultural BMPs. There is no lifetime maximum on the number of BMPs a landowner can fund through the King CD LIP. However, the landowner must complete and receive reimbursement for a funded practice before another application to fund additional practices or BMPs will be considered.

Summary of Public Involvement Methods

Ecology engaged the public in several ways in the TMDL process to address temperature problems in the Newaukum Creek watershed. Beginning in spring 2006, Ecology staff met with key stakeholders in the basin including King County, the Muckleshoot Indian Tribe, the city of Enumclaw, King Conservation District and others.

The public comment period for the draft TMDL ran from May 25 to June 23, 2011 and gave the public, including key stakeholders, a chance to review and provide feedback on the proposed final draft report. A public meeting was hosted by Ecology on the Newaukum Creek Temperature Total Maximum Daily Load at Auburn City Hall from 6:30 p.m. to 9:00 p.m. on June 14, 2011. In advance of the public meeting, the following outreach steps were taken to involve public.

A newspaper display ad notifying public of a combined meeting on the Green River and Newaukum Creek temperature TMDLs was published in five local papers down the Newaukum Creek and Green River watersheds (Appendix E). The ad appeared on Friday, May 20; Wednesday, May 25; and Friday, June 10.

In addition, the Draft Newaukum Creek Temperature Total Maximum Daily Load report was delivered in-person on May 25, 2011 to the Muckleshoot tribal offices and libraries at:

- Enumclaw
- Covington
- Auburn
- Kent
- Foster (Tukwila)

Other notifications:

- As relevant WQ documents were developed, links were established and appeared on our updated Green and Newaukum web pages.
- The public comment period and public meeting appeared on Ecology's public events calendar available by the internet.
- Information about the TMDLs was distributed by Ecology stormwater specialists to stormwater staff at nine local government offices on May 26, 2011.

During the week of May 30, 2011, Ecology's Communication Manager sent a news release to several local-area newspapers. On May 27, 2011, a message from Chris Coffin, with an attached copy of the newspaper display ad, and the enclosed four-page paper "Focus on Green River Watershed" (see Appendix E) was sent to approximately 150 addresses composed of individuals and organizations that had participated in some fashion or expressed interest in Ecology's activities regarding these projects.

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Conclusions

Portions of Newaukum Creek and its tributaries have water quality impairments for temperature. Newaukum Creek basin is an important subbasin of the Green River Watershed and supports several salmon species, including Puget Sound Chinook, bull trout, Coho, chum, pink, sockeye, steelhead/rainbow, and cutthroat trout.

TMDL studies and modeling, conducted in 2006, show that Newaukum Creek and its tributaries are not meeting water quality standards for temperature at all times. The critical time of year, combining annual minimum flow and annual maximum temperature in Newaukum Basin, typically occurs in late July and early August. Maximum predicted temperatures during the critical period, under current conditions, do not exceed the 22^{O} C lethal level for salmon, but do exceed the core summer salmonid habitat standard of 16^{O} C over the lower 14 km (8.7 miles) of stream length.

Establishing mature riparian vegetation for shade is expected to improve stream temperatures and increase the stream's oxygen-carrying capacity. Modeling showed that Newaukum Creek could meet the 16^{O} C temperature standard over the entire stream length with the combined effects of system potential vegetation with overhang, restored baseflows, and riparian microclimate. Modeling also showed the middle plateau reach of Newaukum Creek as the reach needing the most shade improvement, ranging from 11.9 to 63.4% required additional shade. Some riparian restoration projects are already underway on the plateau reach to help reduce this shade deficit. More restoration projects are needed on the Newaukum Creek mainstem and its tributaries.

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. Implementation actions include riparian planting for shade, infiltration of stormwater and/or reclaimed water to the maximum extent possible, restoring stream baseflows to the extent feasible, and incorporating consideration of TMDL actions into local regulatory programs and policies. To help evaluate temperature exceedances outside the critical period, stream and stormwater temperature monitoring should be conducted in mainstem Newaukum Creek between September 15 and July 1.

Newaukum Creek and its tributaries should meet water quality standards for temperature by 2040, given restoration projects proceed on schedule. Long-term progress toward meeting goals will be measured by re-evaluating riparian shade and modeling to determine stream length exceeding standards approximately every five years. If the modeled length of stream channel meeting standards falls behind the implementation schedule, the rate and type of restoration projects should be altered in accordance with the adaptive management section of this plan.

Funding for TMDL implementation projects is available through EPA; Ecology's Centennial Clean Water Fund, Coastal Protection Fund, and other sources; King County's Grant Exchange Programs; King Conservation District Programs; the state Salmon Recovery Funding Board; and various other funding sources.

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Appendices

Appendix A. Glossary, Acronyms, and Abbreviations

Appendix B. Site descriptions and monitoring locations

Appendix C. Additional Data on Newaukum Basin models and analysis

Appendix D. Global climate change

Appendix E. Record of public participation

Appendix F. Responses to public comments

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Appendix A. Glossary, acronyms, and abbreviations

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Glossary, acronyms, and abbreviations

Baseflow: streamflow during rainless periods. Stream baseflows are normally fed by wetland drainage, springs, and groundwater seepage.

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

Buffer: An area of intact vegetation maintained between human activities and a particular natural feature, such as a stream. The buffer reduces potential negative impacts by providing an area around the feature that is unaffected by this activity.

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, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background.)

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 (see definition) flow event unless determined otherwise by the department.

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 (for example, 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.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

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 units per 100 milliliters of water (cfu/100mL).

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

Impervious surface: An impermeable ground coverage or surface such as a paved road, roof, sidewalk, or structure that alters the natural flow and quality of water.

Load allocation: The portion of a receiving water's 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.

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): (1) 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 (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) 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 and revising permits, as well as imposing and enforcing pretreatment requirements, under the Clean Water Act. The NPDES permit program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

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

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 five 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 are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

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

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

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.

Surrogate measures: To provide more meaningful and measurable pollutant loading targets, EPA regulations [40 CFR 130.2(i)] allow other appropriate measures, or surrogate measures in a TMDL. 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.

System potential: The design condition used for TMDL analysis.

System potential channel morphology: The more stable configuration that would occur with less human disturbance.

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

System potential riparian microclimate: The best estimate of air temperature reductions that are expected under mature riparian vegetation. System potential riparian microclimate can also include expected changes to wind speed and relative humidity.

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

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum and minimum thermometers or continuous monitoring probes having sampling intervals of 30 minutes or less.

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.

7Q2 flow: A typical low-flow condition. The 7Q2 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every other year on average. The 7Q2 flow is commonly used to represent the average low-flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

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 10 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 the months of July and August as these typically represent the critical months for temperature in our state.

Acronyms and abbreviations

Following are acronyms and abbreviations used frequently in this report.

ADAP	Agricultural Drainage Assistanec Program
BMPs	Best management practices
cfs	cubic feet per second
cfu	colony forming units
CWA	Clean Water Act
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency

GIS	Geographic Information System software
LA	Load Allocation
LID	Low Impact Development
LiDAR	Light Detection And Ranging
m/s	meters per second
m^3/sec	cubic meters per second (also cms)
NPDES	National Pollution Discharge Elimination System
NSDZ	Near-stream disturbance zones
RM	River mile
RMSE	Root mean squared error
SEPA	State Environmental Policy Act
TIR	Thermal infrared radiation
TMDL	Total maximum daily load (water cleanup plan)
USFS	United States Forest Service
USGS	United States Geological Survey
W/m^2	Watts per square meter
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WLA	Wasteload Allocation
WQA	Water Quality Assessment
WRIA	Water Resources Inventory Area
WWTP	Wastewater treatment plant

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Appendix B. Site descriptions and monitoring locations

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Table B-1. Site identification codes and descriptions. *"x" indicates that monitoring occurred.*

Station ID	River Mile	Description	Water temp	Air temp	RH	Hemi/ shade	Periphyton	Continuous DO/pH	Nutrients	Flow
Green River										
09-GRE-DAM	60.9	below Tacoma Water Headworks Diverson Dam	x		x	x	x	x	x	x
09-GRE-KAN	57.6	at Cumberland-Kanaskat Rd	x	x		x	x	x	x	x
09-GRE-GOR		at Green River Gorge Rd							x	
09-GRE-FLA	43.1	at Flaming Geyser Park, near end of SE Flaming Geyser Rd.	x			x			x	x
09-GRE-WHI	41.4	at 212th Way SE (Whitney Bridge)	x		x	x	x	x	x	x
09-GRE-GRE	35.0	at Green Valley Rd.	x		x	x	x	x	x	x
09-GRE-8TH		at 8th St. NE in Auburn	x	x		x			x	
09-GRE-277	27.9	off Green River Rd. under 277th St. bridge	x			x	x		x	x
09-GRE-167	24.0	upstream of Mill Ck. under HWY 167 bridge	x	x		x		x	x	x
09-GRE-OLD	21.5	at Meeker St. near the "Old Fishin' Hole"	x			x			x	x
09-GRE-212		at S 212th St.	x	x		x			x	
09-GRE-180	14.4	at SE 180th St. (SW 43rd St.)	x			x	x		x	x
09-GRE-FOR		under Interurban Ave. bridge near Fort Dent	x		x	x		x	x	
09-GRE-COM		under 42nd Ave. S bridge at Tukwila Community Center	x			x			x	
09-GRE-BOE		downstream of 102nd Ave. at Boeing foot bridge	x			x			x	
Green River Tributaries										
09-CRI-GRE	40.1*	Crisp Ck. at Green Valley Rd.	x			x			x	x
09-SOO-USG	33.8*	Soos Ck. at USGS gaging station upstream of hatchery	x			x	x	x	x	x
09-MIL-WAS	23.9*	Mill Ck. at Washington Ave.	x			x	x	x	x	x
09-FRA-FRA	21.7*	Mullen Slough at Frager Rd.	x			x			x	x
Newaukum Creek (King County stations)										
X322	40.7*	Newaukum Ck. near the mouth off of 358th SE	x				x	x	x	x
E322		Newaukum Ck. at SE 400 St. bridge	x				x	x	x	
AC322		Trib. upstream of confluence with Newaukum Ck.at 236th St. SE	x				?	x	x	
AN322		Newaukum Ck. just upstream of confluence with trib. at 236th St.	x				x	x	x	
G322		Newaukum Ck at bridge on SE 424th St.	x				x	x	x	
R322		Newaukum Ck. off 416th St., down pipeline trail	x				x	x	x	
N322		Newaukum Ck. at Veazie Cumberland Rd. crossing	x	x			x	x	x	
Q322		Newaukum trib. off Veazie Cumberland Rd., ditch north of TPU trail	x				?	x	x	

*Green River river mile where creek enters

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Appendix C. Additional data on Newaukum Basin models and analysis

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Shade Model Accuracy Assessment

As shown in Figure C-1 below, a linear regression (shown as a black line in the figure) shows a near 1:1 (red line) relationship (0.94) with a root-mean-square-error (RMSE) of 0.15 (i.e., 15-percent error in shade estimates). The three suspect sampling sites highlighted in Figure 10 of the report were included in the accuracy assessment shown in Figure 1. A sense of scale of this error is shown in the cumulative distribution of observed and simulated shade. Approximately 80-percent of the Newaukum Creek sampling locations quantified shade greater than 50-percent shade (Figure C-2).

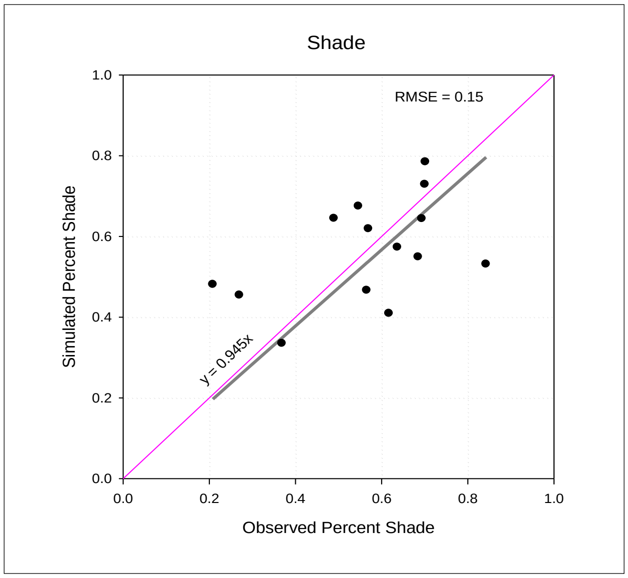

Figure C-1. Scatter Plot of simulated versus observed shade. *Red line is a reference line representing a 1:1 relationship (i.e. perfect model). Black line is a representation of the slope coefficient for the linear regression between observed and simulated (0.94), with an RMSE = 0.15.*

Analytical techniques used to calculate observed canopy density using HemiView software provides an accurate and robust estimate of stream shade when done correctly. As previously mentioned, using the modified Ecology shade model has also been demonstrated to give comparable results to field measurements.

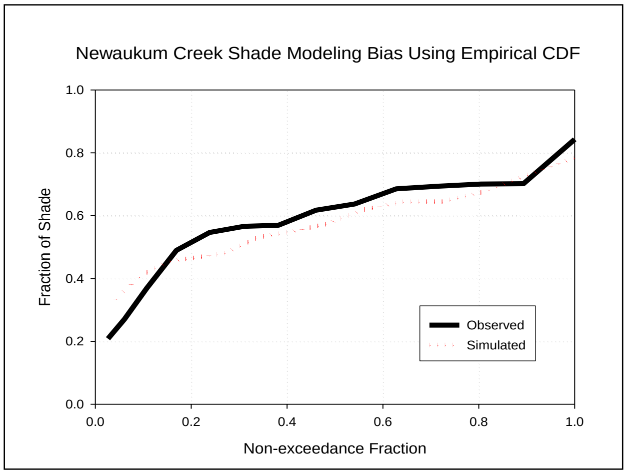

Figure C-2. Empirical cumulative distributions for observed and simulated shade. *Overall, the hade model slightly underestimates observed shade.*

The digital height model (i.e. calculated vegetation height) at one of the sampling locations (Newk40) shows vegetation surrounding the location north, west, and southwest. With vegetation heights ranging from 9-feet above ground (southwest quadrant) to over 29-feet (northwest quadrant) above ground (Figure C-3). Given the longitude/latitude, aspect, and solar path for the time of year (August 2, 2006), sensitive areas for shade on the stream would be realized on the East, West, and South quadrants (hence any inaccuracies in the shade model will not be realized on northern direction of sampling locations).

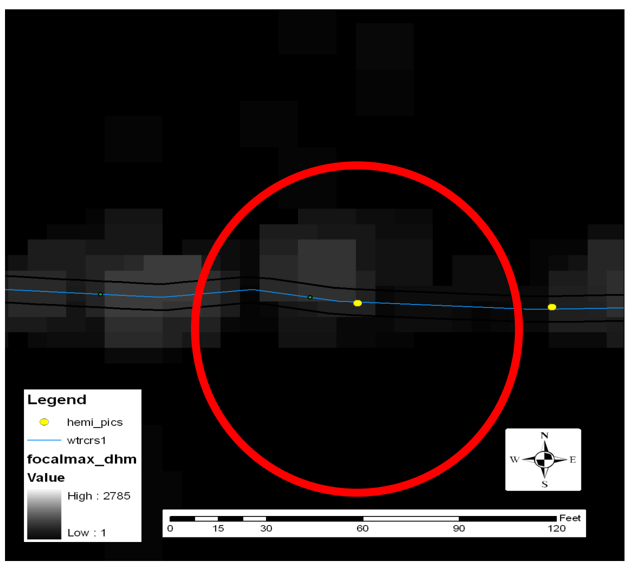

Figure C-3. Digital height model zoomed in on calibration site Newk40. *Location of calibration point in discrepancy is the yellow dot circled in red. Vegetation elevations are shown in various densities of grey, within the red circle subtle greys are approximately 9-feet southwest of the yellow dot, and vegetation elevations progress northwest up to 29-feet in height above the ground.*

Continuing this review, the HemiView photograph taken at site Newk40 illustrates a different interpretation of expected results. As can be seen below in Figure 4, the solar pathway on August 2, 2006 has been overlaid on the HemiView photograph representing the shade conditions at site Newk40 on August 2. Aside from tall grass on the stream banks providing shade on the fringes, most of the sky is open to the stream. Circled in red is a tree that is located west and slightly north of the sampling site. The magnetic north and true compass directions are indicated on the circumference of the photograph.

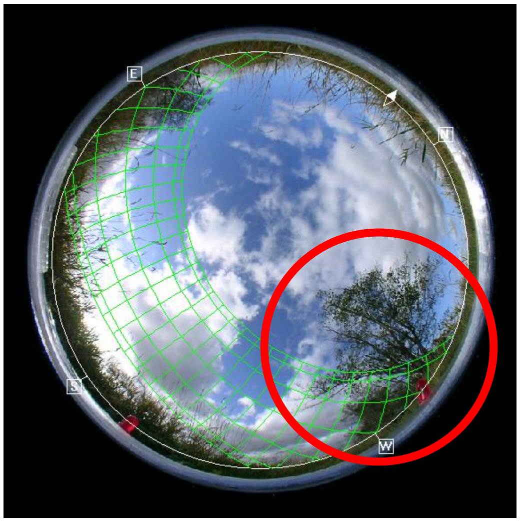

Figure C-4. Hemispherical image for site Newk40 with solar path for August 2. *The tree circled in red is visible in the satellite image for site Newk40 (Figure 6).*

Clearly, the sampling location for the photograph does not match with the estimated vegetation height. Further review of the orthographic image originally available during this study (Figure 5) was inconclusive; although there is apparent vegetation west and north of the sampling site using color gradations as a guide.

Figure C-5. Orthographic image (WA 2006) for calibration point location Newk40. Apparent vegetation coincides with digital elevation model shown in Figure C-3.

More recent orthographic imagery obtained (circa 2007) for site Newk40 provides clarity to the discrepancy of simulated versus observed shade at this point and provides similar clarity for the other two suspect sampling sites. In Figure 12, the same tree estimated to be in the HemiView photograph of Figure 4 is circled in red. The proximity of the tree to the photograph site is considerably closer than was interpreted in the composition of the photograph. Hence, it assumed that the recorded GPS coordinates for these points are inaccurately obtained. One possible explanation, albeit unsubstantiated, was a less than adequate number of satellites necessary to provide adequate accuracy of position.

Figure C-6. High resolution image of station Newk40. *Newly available (circa 2007) high resolution (6-inch pixels) images clarify the point of interest (Newk40) and verify that vegetation should be providing more shade than what is interpreted in the hemispherical photograph. This suggests that the actual location of the hemispherical photograph is incorrectly stated in GIS coordinates.*

Additional Newaukum Basin Data

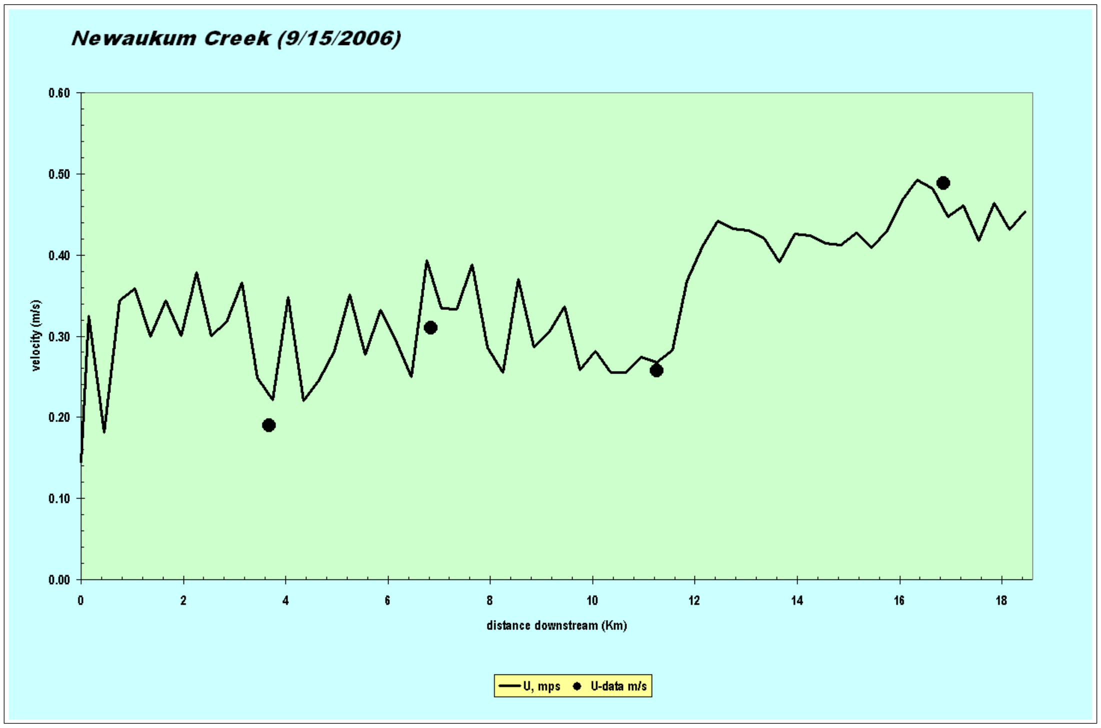

Figure C-7. Velocity validation longitudinal profile for September 15, 2006.

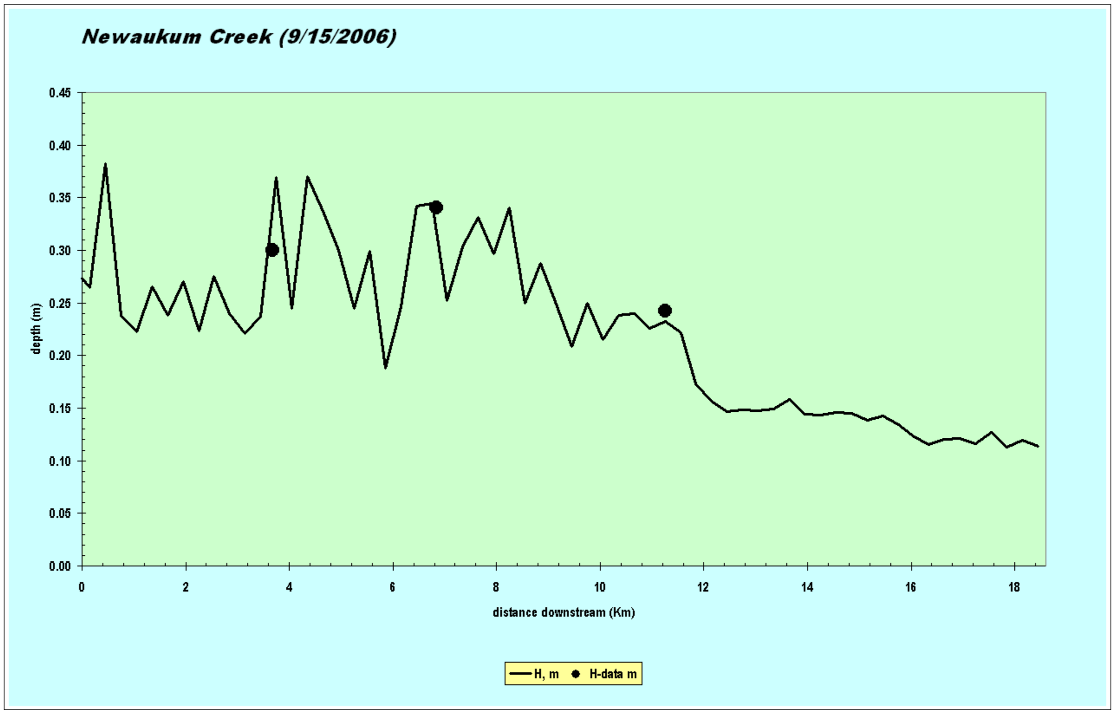

Figure C-. Depth validation longitudinal profile for September 15, 2006.

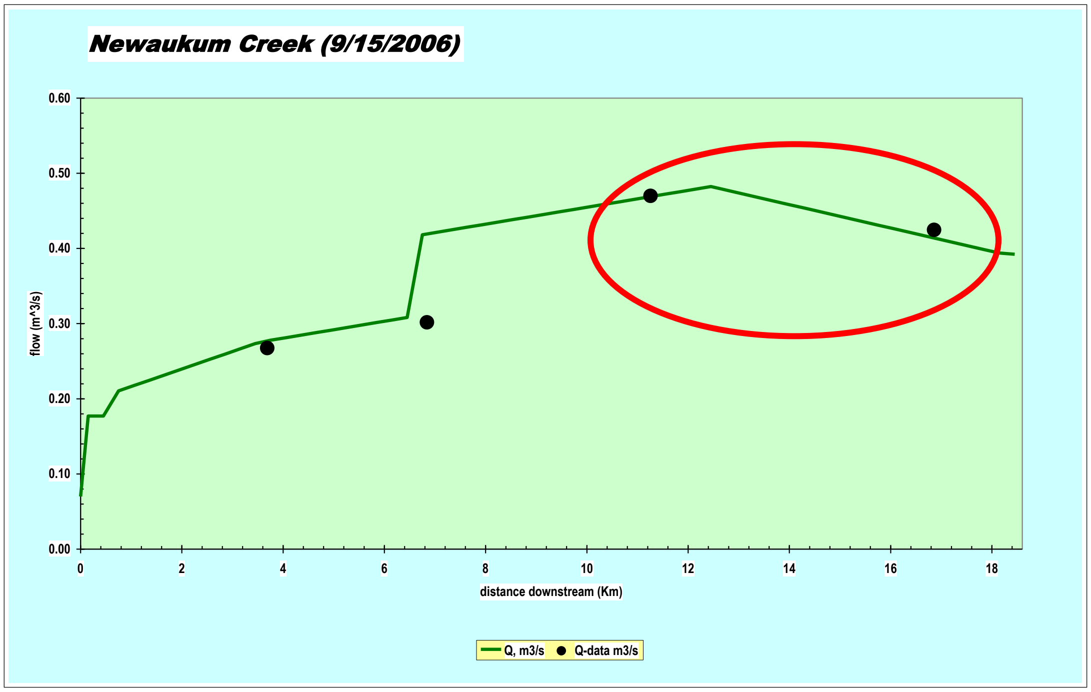

Figure C-9. Flow rate validation longitudinal profile for September 15, 2006. *Measured discharges confirm losing reach between X322 and USGS gage 12108500 (circled in red).*

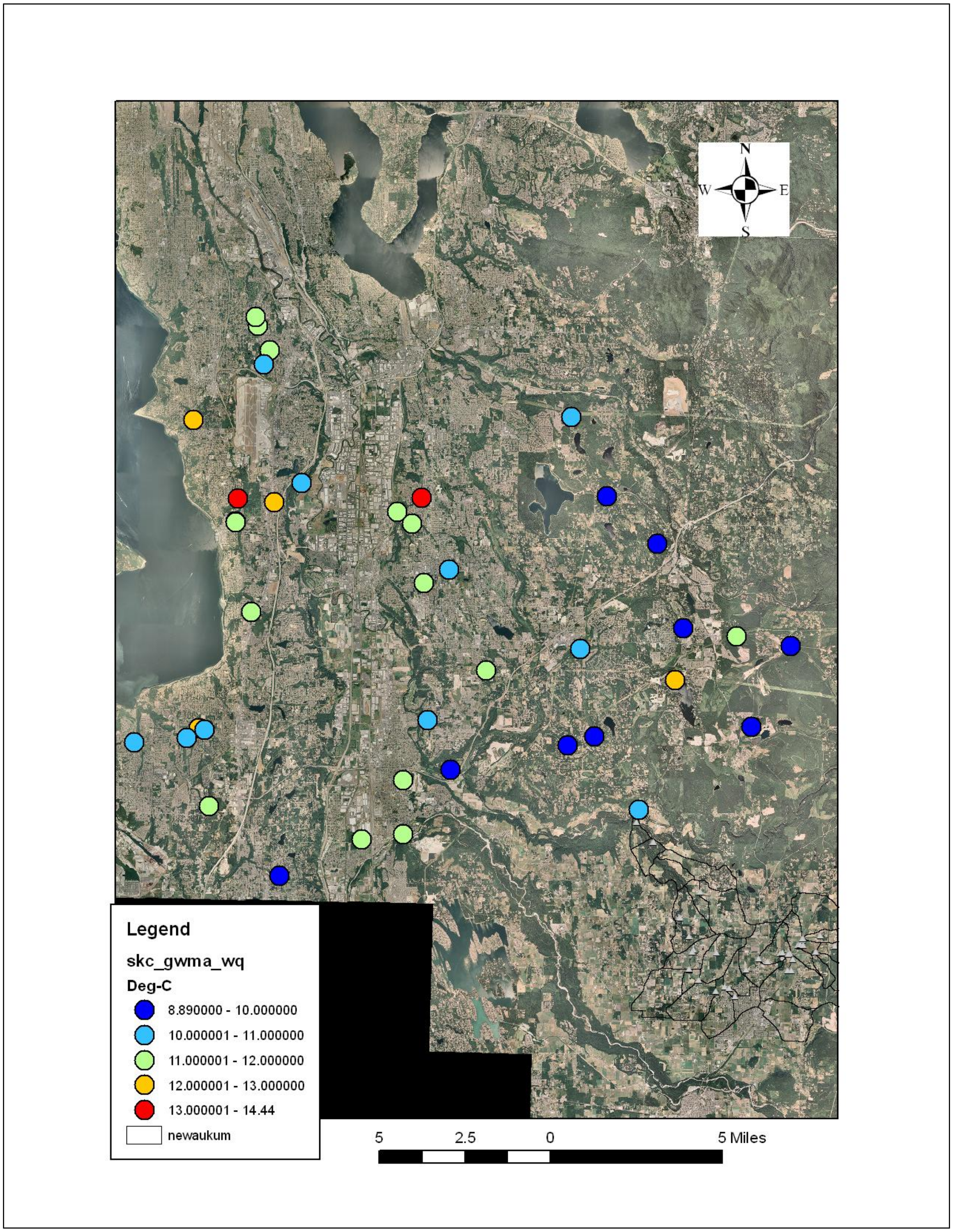

Figure C- 10. Spatial distribution of groundwater temperatures in South King County.

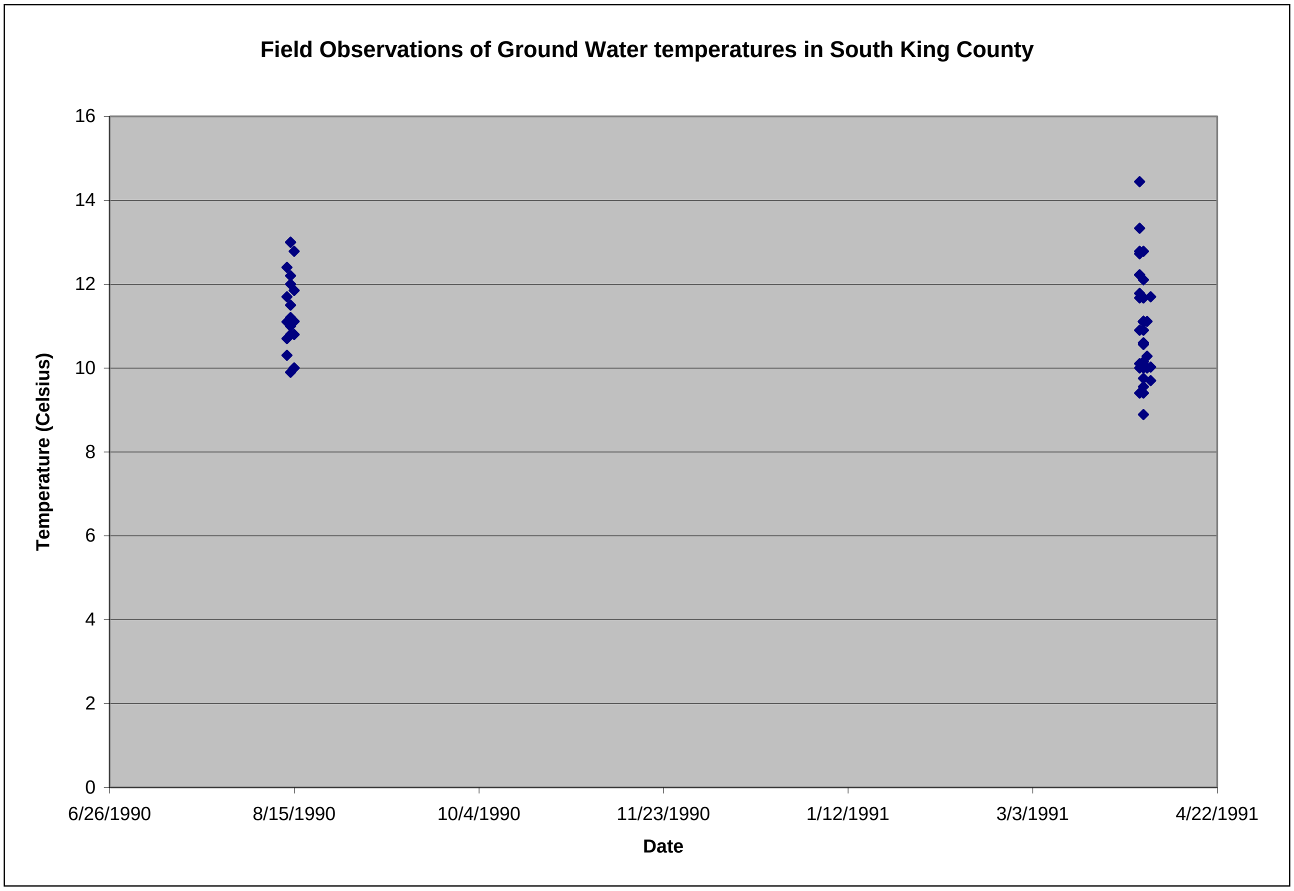

Figure C- 11. Summary of groundwater temperatures taken in South King County.

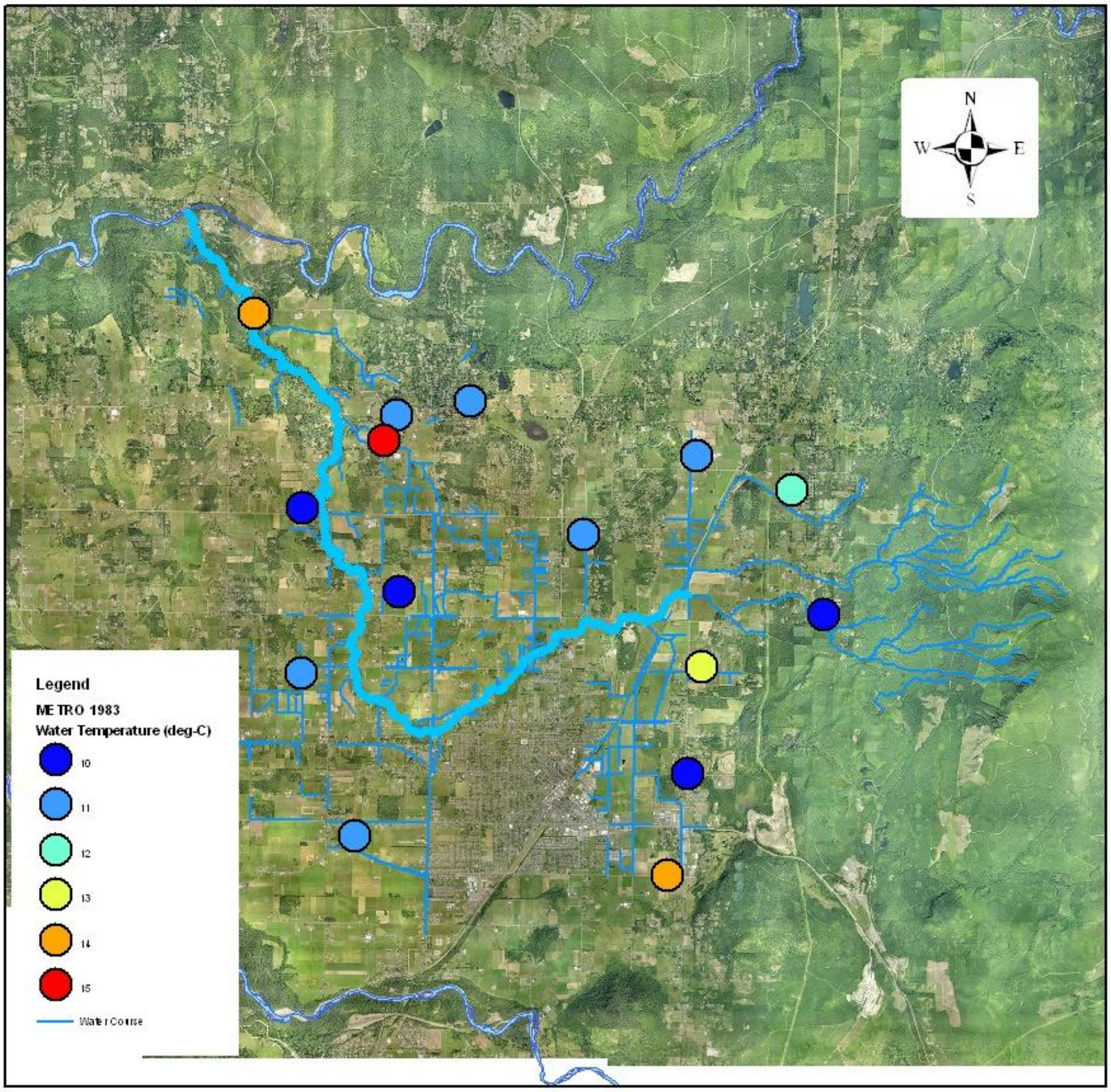

Figure C-12. Water Temperature-Newaukum Groundwater Observations (METRO 1983).

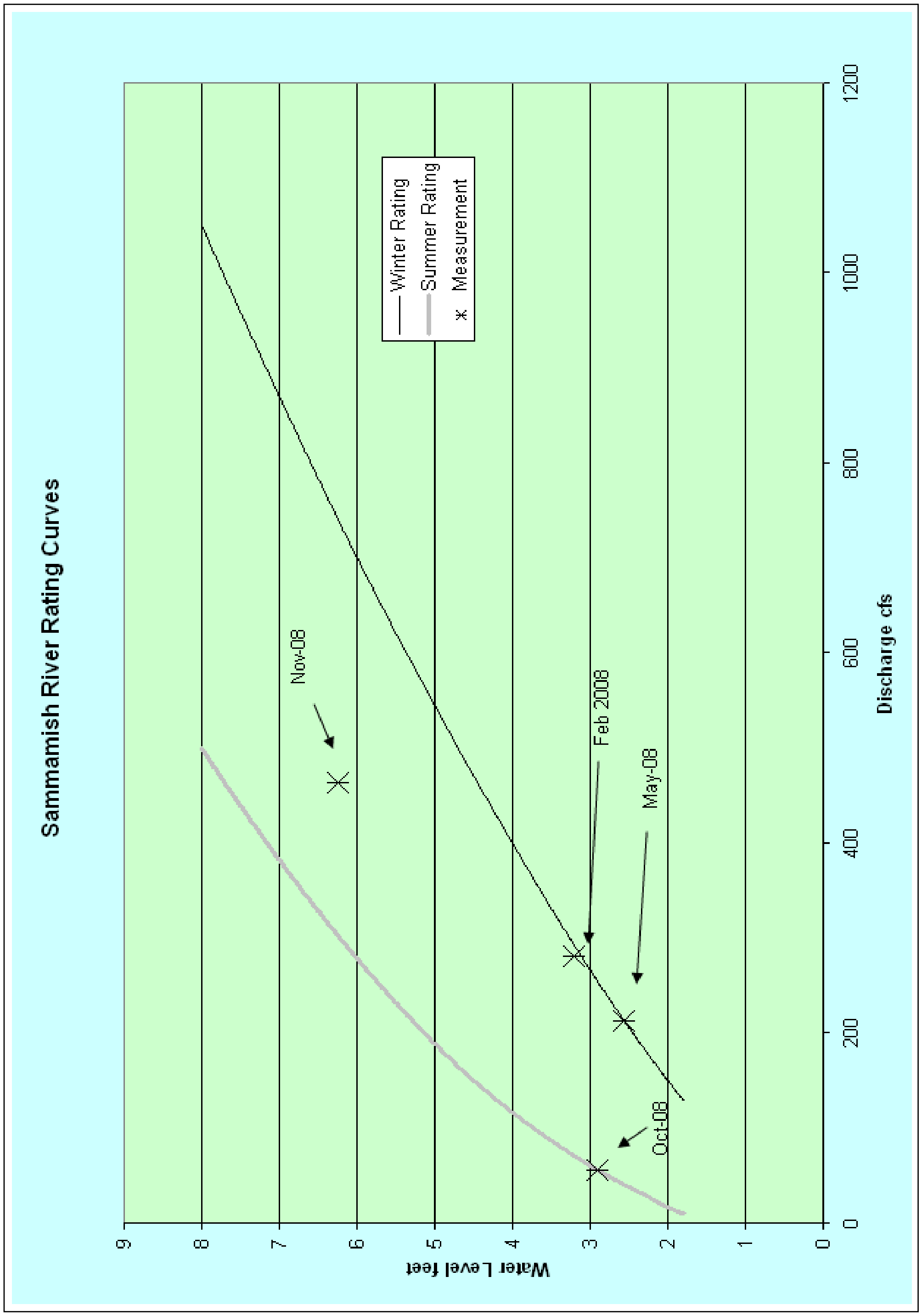

Figure C-13. Example of two rating curves for the same location depicting increases in water level as a result of vegetation growth in the Sammamish River

Appendix D. Global climate change

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Global climate change

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005). Summer streamflows depend on the snowpack stored during the wet season. Studies of the region's hydrology indicate a declining trend in snow water storage coupled with earlier spring snowmelt and earlier peak spring streamflows. Factors affecting these changes include climate influences at both annual and decadal scales. Increases in air temperatures result in more precipitation falling as rain rather than snow and earlier melting of the winter snowpack.

Ten climate change models used to predict the average rate of climatic warming in the Pacific Northwest estimated the average warming rate to be 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). 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 global climate change. Recent studies have highlighted the likelihood of future changes in the timing, type, and amount of precipitation and increasing air temperatures in the Pacific Northwest attributed in part to human-induced climate modifications (Casola *et al*., 2005). Research has identified increasing air temperatures, decreasing spring mountain snow pack, earlier timing of spring runoff, and lower summer flows in basins like the Green River due to reduced snowpack and earlier timing of snow melt.

Overall, there are a number of factors that ultimately determine summer water temperatures, but the key features that can potentially be managed include instream flows, riparian vegetation, floodplain and hyporheic zone dynamics, and channel morphology. A holistic approach founded on an understanding of the historical stream channel, riparian zone, and alluvial aquifer systems is recommended as the proper context for successful ecological restoration of stream ecosystems.

The potential 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 help offset the changes expected from global climate change – keeping conditions from getting worse. The sooner such restoration actions begin the more effective we will be in offsetting some of the detrimental effects on our stream resources.

These efforts will maximize the extent and frequency of healthy temperature conditions, creating long-term benefits for fish and other aquatic species. As climate change progresses, the thermal regime of the stream may 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.

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Appendix E. Record of public participation

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Record of public participation

Ecology engaged the public in several ways in the TMDL process to address temperature problems in the Newaukum Creek watershed. Beginning in spring 2006, Ecology staff met with key stakeholders in the basin including King County, Muckleshoot Indian Tribe, City of Enumclaw, King Conservation District and others.

The public comment period for the Draft TMDL ran from May 25 to June 23, 2011 and gave the public, including key stakeholders, a chance to review and provide feedback on the proposed final draft report. A public meeting was hosted by Ecology on the Newaukum Creek Temperature Total Maximum Daily Load at Auburn City Hall from 6:30pm to 9:00pm on June 14, 2011. In advance of the public meeting:

The newspaper display ad below was placed in five local papers down the Newaukum Creek and Green River watersheds:

Dept. of Ecology Public Meeting & Comment Period -- Stream Temperature

Green River & Newaukum Creek
Temperature Reduction Action Plans

The State Department of Ecology would like your comments on two draft documents that include technical information and plans to address high-temperature problems in the Green River and in Newaukum Creek.

These reports outline actions that are already underway--or are still needed--to lower temperatures in these waters. The goal is to lower temperature levels in these streams and meet the State's Water Quality Standards. We want your comments on these reports and welcome you to share your thoughts with us and your neighbors.

A public meeting will be held June 14 at Auburn City Hall,
25 W Main Street, Auburn WA 98001-4998
Open house, presentations, & discussion begin at 6:30 pm

♦ A 30 day comment period will run from May 25th through June 23rd 2011.

♦ For a *Report* copy after May 24, call local library reference, or 425-649-7110.

♦ To submit written comments (must be received by June 23), go to:

http://www.ecy.wa.gov/programs/wq/tmdl/GreenRvrTMDLsummary.html

Or, contact the Ecology Department office: c/o Chris Coffin, Dept. of Ecology, 3190 160th Ave SE, Bellevue WA 98008-5452; email: ccof461@ecy.wa.gov

If you have special accommodation needs or require this publication in an alternate format please contact: DouGlas Palenshus at (425) 649-7041 (Voice) or (425) 1-800-833-6388 (TTY).

The display ad was shown a total of nine times in local newspapers throughout the subject watersheds;

- Friday May 20: display ad placements in each of four newspapers in middle & lower Green River watershed: Auburn Reporter (circulation: 24,738), Kent Reporter (circulation: 27,650), Maple Valley & Covington Reporter (circulation: 24,184), and the Renton Reporter (circulation: 30,035).

- Wednesday May 25: display ad ran in the Enumclaw Courier-Herald newspaper (circulation: 13,116).
- Friday June 10: additional display ad placements in the four newspapers in Auburn , Kent, Maple Valley/Covington, and Renton.
- May 25, 2011, the Draft Newaukum Creek Temperature Total Maximum Daily Load report was delivered in-person on to the Muckleshoot tribal offices and libraries at:
    - Enumclaw
    - Covington
    - Auburn
    - Kent
    - Foster (Tukwila)
- Other notifications:
    - As relevant WQ documents were developed, links were established and appeared on our updated Green and Newaukum web pages.
    - The public comment period and public meeting appeared on Ecology's public events calendar available by the internet.
    - May 26, 2011, information about the TMDLs was distributed by Ecology stormwater specialists to stormwater staff at nine local government offices on.
- During the week of May 30, 2011, Ecology's Communication Manager sent a news release to several local-area newspapers.
- On May 27, 2011, a message from Chris Coffin, with an attached copy of the newspaper display ad, and the enclosed four page paper "Focus on Green River Watershed" (see below) was sent to approximately 150 addresses composed of individuals and organizations that had participated in some fashion or expressed interest in Ecology's activities regarding these projects.

- Focus sheet (4 pages) on temperature problems in Green River and Newaukum Creek watersheds.

Focus on Green River Watershed

DEPARTMENT OF ECOLOGY
State of Washington

Water Quality Program **May 2011**

Water in Green River and Newaukum Creek is Too Warm

Streams in these watersheds need your help!

Cool streams are important for water quality in the Middle and Lower Green River Watersheds. Water quality standards are established to protect the most sensitive beneficial uses of local waters: salmon and trout spawning, rearing of young, and fish migration. As water temperatures heat up, typically during summer lower-flow periods, fish become physically stressed and are more likely to get diseases. This can also affect fish respiration because warm water doesn't hold as much oxygen—critical for salmonid life stages, as colder water. If temperatures get above the lethal limit (77°-78°F), most salmonids will die or become dangerously stressed.

Federal and state laws require corrective actions for impaired waters. More importantly, most Washington citizens take seriously our responsibility to protect and restore our waterways now and for those in the future.

What affects stream temperature?

Factors that affect stream temperature can occur from both natural and human-causes in the watershed. These include:

- Solar radiation—related to latitude, time of year, time of day, cloud cover, and how much shade is available to block the sun which heats both water and air.
- Stream depth and width, flow rate, and overall volume of water.
- Availability of cooler groundwater flowing into streams.

WHY IT MATTERS

Warm water holds less oxygen and can harm fish and other aquatic creatures. Parts of the Green River and its tributaries, including Newaukum Creek, serve as important migration corridors and spawning and rearing areas for salmon species that require cold waters for optimum health and survival. Additionally, warm water may be a factor in the presence of bacteria, viruses, and other human pathogenic organisms.

These water bodies are too warm, fail Washington's water quality standards, and cause thermal stress to fish during various life stages. Affected species include Puget Sound Chinook and Bull Trout (both "threatened" under the Endangered Species Act), coho, chum, pink, sockeye, and steelhead/rainbow and cutthroat trout.

Ecology is seeking comment on the plans for improving these water bodies thru June 23, 2011. We will hold a public meeting at 6:30 p.m. at the Auburn City Hall on June 14.

Contact information

Chris Coffin
425-649-7110
Chris.coffin@ecy.wa.gov

Special accommodations

If you need this document in a format for the visually impaired, call the Water Quality Program at 425-649-7105.

Persons with hearing loss, call 711 for Washington Relay Service. Persons with a speech disability, call 877-833-6341.

Streamside vegetation is the key!

Trees and shrubs create important shade. Their removal increases the amount of sun that can hit and warm water, and reduces cool microclimate zones near streams and rivers. In considering the many decisions we make in choosing our watershed land management activities, the absence of such plants is the *major* factor that increases stream temperatures. *Tree removal reduces the amount of shade on the water and allows more sun to heat the stream.*

Erosion: Another problem related to tree removal is the erosion arising from poorly-managed forest lands, agricultural areas, or construction sites that results in bank deterioration and landslides. These events can cause heavy sediment loads and flooding as they make streams shallower and wider. All this allows more sun on the water, reduces available high quality salmon spawning habitat, and affects how well colder groundwater interacts with surface waters to cool streams.


Tributary to Newaukum Creek

Water withdrawals: There are other human caused factors that increase stream temperatures too. Less water means warmer water. Water withdrawals for various purposes, including irrigation, reduce the amount of cool water stored in the ground to feed the local creeks during the summer when flows are already critically low. Reduced flows make streams slower and shallower, allowing them to become warmer during the dry summer months.

Impervious surfaces and wetland destruction: Areas of impervious surface such as pavement and wetland destruction, allow more runoff water to heat up and flow directly to waterways. (Remember the *hot tin roof* effect, and going barefoot over hot blacktop in the summertime?). And as wetlands disappear, the sponge effect that helps store precipitation and that contributes cool water in summer seasons is lost. This can also worsen seasonal floods.

Green River issues

The middle and lower sections of the river need more shade. Currently, the system of levees, low water flow, warm weather, and summer water temperatures create impacts that can become lethal for salmonids. Portions of the river below Howard Hanson Dam and upstream from Auburn need improvement, but below Auburn conditions worsen. Levees, roads, and development too near the banks of the river create serious problems. These areas fail to provide cooling vegetation and shade to block heat from the sun, have lost the capacity to provide habitat functions, and generally inhibit good water quality. Shade will help.

The Green was one of the most productive salmon rivers in the state, but at least one major salmon run has gone extinct and others are suffering.

Modeling results were used to help develop effective solutions that the local community can act on to lower stream temperatures during critical periods. These steps will improve water quality and help prevent loss of threatened and endangered fish species and other sensitive organisms.

What can we *all* do to reduce stream temperatures?

Citizens and organizations, including local governments, can act now to help protect and restore water quality in the Green River Watershed by taking at least one of the following actions to help reduce water temperatures in streams.

- **Protect and restore streamside vegetation:** Get involved in restoration projects to improve streamside (riparian) areas where streams have been straightened and channelized and trees have been removed. Trees shade the water, create cool microclimates, and increase stream bank stability. Restoration projects help prevent stream shallowing from sedimentation and widening from erosion, and can help re-establish connections with the natural floodplain and with cool groundwater resources. Woody debris, native plant material, and insects that fall into water can also provide food and habitat for fish.
- **Plant tree borders:** Streamside landowners can plant trees that shade streams and help reduce air temperatures by providing a cool microclimate near the stream. Plants also filter excessive amounts of sediments, fertilizers, or other nutrients from lawns and agricultural areas.
- **Conserve water:** Increased flow in streams helps keep the water cool. 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. 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.
- **Reduce impervious areas:** Less pavement near streams for roads or parking lots reduces precipitation becoming heated by the sun and allows a greater proportion to infiltrate cooler soils. This recharges and conserves water in the ground for dryer seasons. Water allowed to infiltrate during storms does not run off to waterways so quickly and helps reduce flooding.

Developing action plans for the Green and Newaukum watersheds

Ecology's plans to bring down stream temperatures for each of these watersheds were developed with help from local agencies, Native-American tribes, businesses, and residents. The coordinated and sustained efforts of all these groups are needed for these plans to be effective.

Review copies are also at local libraries for comment until June 23, 2011.
Send comments to:
Chris Coffin 3091 160th Ave. SE, Bellevue, WA 98008-5452
Email: chris.coffin@ecy.wa.gov
See: http://www.ecy.wa.gov/programs/wq/tmdl/GreenRvrTMDLsummary.html

Please consider coming to a public meeting to learn more:
Auburn City Hall Council Chambers June 14 at 6:30 p.m.

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Appendix F. Response to public comments

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Response to public comments

The following summarized comments were received during the public comment period for the Newaukum Creek Temperature TMDL Water Quality Improvement Report and Implementation Plan.

1. **Comment:** Since shading has been modeled as the solution to the thermal problem in the stream, and stormwater has not been identified as part of the problem, it seems inappropriate to emphasize infiltration to this degree with regard to the TMDL.

   ***Response*:** *The primary emphasis of the TMDL is riparian shade to block solar heating of the stream. However, stream heating has been amplified due to baseflow loss and will be further exacerbated if flows diminish below current baseflow levels. Therefore, restoring baseflows through measures such as infiltration is also included as a component of the TMDL. Efforts to restore baseflows may also help offset the anticipated effects of climate change*.

2. **Comment:** All load and wasteload allocations are required to be expressed as daily loads regardless of parameter type.

   Response: *Table 8 shows effective shade and solar load allocations for July 23 (the day used for model development of critical summer conditions). The required decrease in solar load is expressed in Watts per square meter (W/m^2) by 300-meter stream reach which is a daily load allocation having been derived for the calibration day July 23. The required solar load reductions are also translated into required increases in percent effective shade by reach. The categorical wasteload allocation for all permitted stormwater discharges is expressed as an allowable increase (0.2^oC) to the 7-day average of the daily maximum temperatures (7DADMax). This term also incorporates daily values, which constitute the required daily loading term for the TMDL. The report narrative was revised in accordance with this comment.*

3. **Comment:** The Implementation Plan should outline what actions Ecology will implement when voluntary measures fail to protect and restore riparian vegetation buffers.

   Response: *TMDLs are founded in the federal Clean Water Act and compliance with TMDLs continues to be mandatory. We do not anticipate failure in reaching the TMDL temperature goals for Newaukum Creek. Ecology initially intends to use approaches that cultivate cooperation of riparian property owners, such as technical assistance, grant funding, and our ability to refer property owners to programs such as Conservation Reserve Enhancement Program (CREP) which provides rental rates for acreage placed in forested buffers along streams. If TMDL implementation progress falls behind schedule or effect however, Ecology will assess its options at that time.*

4. **Comment:** Please provide additional detail on the proposed Big Spring Creek re-alignment project in Newaukum Creek watershed.

__Response:__ Big Spring Creek is an important major cold-water tributary to Newaukum Creek. The proposed Big Spring Creek re-alignment and restoration project will re-align approximately 4,000 linear feet of Big Spring Creek and restore and re-vegetate about 80 acres of adjacent riparian area. Additional detail was added to the TMDL Implementation Plan describing the proposed Big Spring Creek salmon recovery project.

5. **Comment:** It would be helpful to include information on the general width of Newaukum Creek.

   __Response:__ Newaukum Creek channel generally ranges from less than 3 meters wide at Cumberland Road to over 7 meters wide near the mouth. The TMDL report narrative associated with Figure 8 was revised in response to this comment.

6. *__Comment:__ The Implementation Plan should prescribe Low Impact Development (LID) measures as a requirement for all jurisdictions in the Newaukum Creek basin, with incentives and/or grant funding to help fund the resources needed to implement these methods.*

   __Response:__ The TMDL Implementation Plan recommends that Low Impact Development (LID) measures that lead to infiltration of stormwater be employed wherever feasible. For jurisdictions with municipal stormwater permits, LID is becoming a more important requirement over time. Ecology and other agencies do offer incentives and grant funding to help fund the resources needed to implement these methods.

7. **Comment:** The discussion of King County's Livestock Management Ordinance (K.C.C. 21A. 30) should cite the Ordinance specifically and state that the Ordinance requires land owners to implement best management practices to minimize nonpoint pollution from livestock.

   __Response:__ The discussion of the county's Livestock Ordinance and Program was revised in accordance with this comment.

8. **Comment:** The expected changes due to regional climate change support a combined approach of restoring net baseflows in addition to establishing mature riparian vegetation for water temperatures in Newaukum Creek.

   __Response:__ The Newaukum Creek temperature TMDL recommends a combined approach of restoring baseflows and riparian planting for shade. The current emphasis on riparian shade may shift more to streamflows in the future if diminishing baseflows are found to be more of a limited factor for stream temperatures.

9. **Comment:** The TMDL should discuss potential impacts of future growth on reducing baseflows and increasing stream temperatures. Carlson (2011) analyzed baseflow loss due to potential increases in effective impervious area (EIA) for two possible land use scenarios. The TMDL should include a section on future growth to discuss the potential impacts to reduced baseflows from EIA, including the baseflow losses estimated by Carlson (2011) for the two future land use scenarios.

Response: *A discussion of the future growth and EIA scenarios provided by Carlson (2011) was added to the 'Altered hydrology/loss of baseflows' section of the TMDL report.*

10. **Comment:** Consider adding a summary table showing the temperature improvement scenarios and corresponding stream temperature changes.

    Response: *A summary table (Table 7) was added showing temperature changes and changes in stream length in compliance with water quality standards corresponding to various modeled water quality improvement scenarios.*

11. **Comment:** We question why stormwater point sources are required to receive wasteload allocations or even be a part of this TMDL, given various statements in the report related to stormwater not being considered a significant source that impacts temperature. We request that WSDOT be removed from this TMDL.

    Response: *While stormwater is not considered a significant contributing factor to thermal loading during the late summer critical period, there may be summer storms, which do cause stormwater thermal waste loads to Newaukum Creek. Accordingly, WSDOT is included in the categorical wasteload allocation (WLA) for permitted stormwater in the Newaukum Creek temperature TMDL.*

12. **Comment:** Suggest revising the "Measuring Progress toward Goals" section to clarify who will be responsible for performing monitoring. We believe Ecology should be responsible for compliance monitoring.

    Response: *This section mentions current monitoring conducted in Newaukum Creek watershed by King County. Ecology will inventory implementation projects and exercise its water quality regulatory authority where needed. Ecology may also conduct effectiveness monitoring after riparian plantings have naturalized. Ecology may conduct compliance monitoring in the future or might rely on existing data if it is available to assess compliance with the temperature TMDL.*

13. **Comment:** Suggest removing all references to oxygen conditions and dissolved oxygen throughout the document. These references are misleading and confusing because this is not a TMDL for dissolved oxygen.

14. ***Response:*** *Some, but not all references to dissolved oxygen (DO) were removed from the TMDL report. The Newaukum Creek TMDL study was designed to address temperature and DO. While the temperature and DO models were decoupled because more data are needed to refine the DO model, DO is still partially dependent on stream temperature and warrants some acknowledgement in the temperature TMDL.*

15. **Comment:** To be consistent with regulations and guidelines used to establish TMDLs, we feel it is Ecology's responsibility to characterize the sources of pollution and assign numeric WLAs only when there is credible, site specific data or information indicating that WSDOT facilities are a significant source or contributor of the pollutant of concern. In the absence of site specific stormwater outfall data, a numeric WLA assigned to WSDOT is presumptuous and without just cause.

Response: *Federal regulations state that it is reasonable to express allocations for NPDES-regulated stormwater discharges from multiple point sources as a single categorical wasteload allocation when data and information are insufficient to assign each source or outfall individual WLAs. See 40 C.F.R. § 130.2(i). Discharges from WSDOT facilities are included in the categorical WLA for permitted stormwater in Newaukum Basin because, although rare, late summer stormwater discharges can and do occur.*

16. **Comment:** Suggest deleting the numeric WLA. WSDOT suggests the WLA be assigned in the form of actions since site-specific data is not available to assign numeric WLAs.

    Response*: Wasteload Allocations (WLAs) and Load Allocations (LAs) must be expressed in numeric form in TMDLs.*

17. **Comment:** Suggest replacing "All appropriate best management practices in the stormwater permit for controlling thermal loadings to surface waters are applied to the discharge to protect designated aquatic life uses" with the following: "Compliance with the permit constitutes compliance with the goals of this TMDL." The action as previously stated is vague and this revision would provide clarity and consistency with the last sentence in the third paragraph on page 64.

    Response: *The last sentence in the third paragraph on page 64 of the draft is "Compliance with the permit constitutes compliance with the goals of this TMDL." The previous bullet does not conflict with the compliance statement since the bullet refers to BMPs "in the stormwater permit". Compliance with the permit is being called out with special attention to any BMPs that may help control thermal loadings to surface waters. The Newaukum Creek temperature TMDL is not recommending any additional actions for municipal stormwater permittees beyond compliance with the permit.*