Skykomish River Temperature Total Maximum Daily Load Development

Water Quality Study Design (Quality Assurance Project Plan)

January 2013

Publication No. 13-03-104 (Ecology)

Publication No. Tt DCN QAPP 339 (Tetra Tech)

DEPARTMENT OF ECOLOGY
State of Washington

Publication and Contact Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

The plan for this study is available on the Department of Ecology's website at https://fortress.wa.gov/ecy/publications/summarypages/1303104.html

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Study Codes

Activity Tracker Code (Environmental Assessment Program) is 12-065.

Total Maximum Daily Load (TMDL) Study Code (Water Quality Program) is SkyR07TM.

Federal Clean Water Act 2008 and proposed 2010 303(d) Listings Addressed in this Study

Water body	Parameter	Medium	Listing ID	303(d) list
Bear Creek	Temperature	Water	35165	2008
	Temperature	Water	35163	2008
Beaver Creek	Temperature	Water	35166	2008
Olney Creek	Temperature	Water	35296	2008
Pekola Creek	Temperature	Water	35297	2008
Skykomish River	Temperature	Water	6569	2008
Unnamed Cr. (Tributary to Olney Cr.)	Temperature	Water	35169	2008
Wallace River	Temperature	Water	7435	2008

Cover photo: Skykomish River at the confluence with the North Fork

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Abstract

Segments of the Skykomish River watershed were included on the Washington State 2008 303(d) list of impaired water bodies for temperature violations of water quality standards. The Washington State Department of Ecology (Ecology) is required under Section 303(d) of the federal Clean Water Act to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters of the state. Shade and solar radiation will be modeled by Tetra Tech, using Ecology's Shade model, and wasteload allocations will be established for treatment plants and several municipal stormwater permittees. Existing data will form the basis for allocating contaminant loads to pollutant sources.

The goal of the TMDL project is to ensure that the Skykomish River watershed attains water quality standards for stream temperature. This Quality Assurance Project Plan (QAPP) describes the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the study, a Water Quality Improvement Report and Implementation Plan describing the results and corrective actions needed to attain standards will be published.

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act Requirements

The Clean Water Act established a process to identify and clean up polluted waters. The Act 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 (WQA) and the 303(d) List

Every two years, states are required to prepare a list of water bodies that do not meet water quality standards. This list is called the Clean Water Act 303(d) list. In Washington State, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. 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 WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list.

Category 1 – Waters that meet standards for parameter(s) for which they have 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 they:
- 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 that cannot be addressed by a TMDL, 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 website.

The Clean Water Act requires that a 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 water quality criteria.

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 strategy to control and reduce pollution sources and a monitoring plan to assess effectiveness of the water quality improvement activities. Together, the study and implementation strategy comprise the *Water Quality Improvement Report and Implementation Plan* (WQIR/WQIP).

Who Should Participate in this TMDL?

This TMDL will set nonpoint source pollutant load targets and point source wasteload allocations for the area shown in Figure 1. Nonpoint pollution comes from diffuse sources and all upstream watershed areas have potential to affect downstream water quality. All potential nonpoint sources in the watershed must use the appropriate best management practices to reduce impacts to water quality. Therefore, all landowners with the potential to contribute nonpoint pollution should participate in this TMDL.

Similarly, all point source dischargers in the watershed are regulated by NPDES permits that might be affected by this TMDL. These point source dischargers include stormwater from the cities of Everett, Monroe; Snohomish County; King County; the Washington State Department of Transportation; the Sultan wastewater treatment plant; the Monroe Sewage treatment plan; and any other general or individual National Pollution Discharge Elimination System (NPDES) permittees that are potential pollution sources.

Ecology also anticipates strong participation by a number of nonprofit organizations involved in instream and riparian restoration projects. Other stakeholder groups may also participate.

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 or stormwater collection and treatment system regulated by an

NPDES permit, that facility's share of the loading capacity is called a *wasteload allocation* (WLA). 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* (LA).

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 WLAs and LAs, any margin of safety, and any reserve capacity. The TMDL must be equal to or less than the loading capacity.

Surrogate Measures

To provide more meaningful and measurable pollutant loading targets, this TMDL may also incorporate *surrogate measures* other than daily loads. EPA regulations (40 CFR 130.2(i)) allow other appropriate measures in a TMDL. See the Glossary section of this document (Appendix A) for more information.

Potential surrogate measures for use in this TMDL are discussed below. The ultimate need for, and the selection of, a surrogate measure for use in setting allocations depends on how well the proposed surrogate measure matches the selected implementation strategy and how well the surrogate correlates to the water quality impairment.

The TMDL will use effective shade as a surrogate measure of heat flux to fulfill the requirements of the federal Clean Water Act Section 303(d) for a temperature TMDL. Effective shade is defined as the fraction of incoming solar shortwave radiation that is blocked by vegetation and topography from reaching the surface of the stream. This approach has been used consistently and successfully in Ecology's previous temperature TMDLs. For ease of implementation, LAs may be reported, where applicable, in terms of surrogates for solar radiation such as: shade, size of tree necessary in the riparian zone to produce adequate shade, channel width, channel width-to-depth ratio, or miles of active eroding stream banks. The final TMDL will include language that describes stream heating processes and all the factors involved.

Why is Ecology Conducting a TMDL Study in This Watershed?

Background

The Skykomish River watershed is impaired by high water temperatures, dioxin, dissolved oxygen (DO) content, and pH levels on its 2008 303(d) list and proposed 2010 303(d) list. Ecology addressed bacteria pollution problems stemming from the Skykomish River watershed's Woods Creek in the Snohomish River Tributaries Fecal Coliform Bacteria TMDL (Wright et al., 2001) and its implementation plan (Svrjcek, 2003). This project will address the temperature impairments.

High water temperature levels are detrimental to fish and other native species that depend on cool, clean, well-oxygenated water. Data on high water temperatures in the watershed have been taken in multiple locations over time, sometimes back to the early 1970s. These data sources resulted in water segments being included on the 303(d) list.

Several segments of the Skykomish River and its tributaries do not meet state water quality standards for temperature and therefore need to be addressed through TMDLs. Ecology has recently focused its temperature TMDL analysis on the development of riparian shade goals. This innovative TMDL approach focuses on the assessment of system potential mature riparian vegetation and resulting shade and does not include modeling of system potential temperatures throughout the Skykomish River. The relatively low levels of urbanization and other land use alterations in the Skykomish Watershed are not expected to result in hydrologic changes that significantly contribute to stream heating. Temperature impacts from the one major water withdrawal source in the watershed, the Henry M. Jackson Hydroelectric Project, are being addressed through a Clean Water Act Section 401 Water Quality Certification (PUD, 2011). Ultimately, riparian vegetation is considered the key environmental activity needed to maintain and, where necessary, improve stream temperatures because it increases the amount of shade to the stream. Point sources will also be addressed through a simple mixing equation, resulting in allocations protective of beneficial uses.

We recognize that factors other than shade, such as hydrologic changes, hydromodifications, and timber harvesting, also influence stream temperatures. However, based upon the relatively low level of human impact in the Skykomish River watershed, human influences on those factors are likely small compared to human modifications of riparian vegetation levels. Almost all temperature TMDL analysis done in this state to date has resulted in load allocation targets that are equal to system potential shade, even when these other factors are taken into account through water quality modeling. Ecology therefore chose a streamlined temperature TMDL analytical approach for the Skykomish. Although the basin-wide contribution of other factors will not be evaluated in this TMDL, the Implementation Plan will include best management practices that address these factors and their use in a targeted manner to improve stream temperatures.

Improving water quality in the Skykomish watershed benefits the health of resident salmon populations of Chinook, chum, coho, coastal cutthroat, and pink, as well as bull trout, steelhead trout, and mountain whitefish. These fish species are highly valued by the many state residents that depend upon them for cultural, recreational, or economic reasons. The current listing of Chinook salmon, bull trout, and steelhead trout as threatened species under the Endangered Species Act increases the urgency of correcting their habitat's water quality impairments.

The goal of this QAPP is to describe the study goals, objectives and methods that will be used to determine the TMDL for stream temperatures. The study results are designed to support the development of corrective actions needed to meet water quality standards for river water temperatures, which will be detailed in a Water Quality Improvement Report and Implementation Plan (WQIR/WQIP). The Improvement and Implementation Plan will help guide Ecology and other stakeholders in their work to restore and protect aquatic life uses set forth in Washington Administrative Code (WAC) 173-201A as well as implement the Puget Sound Action Agenda, the Water Resource Inventory Area (WRIA) 7 Chinook Salmon Recovery Plan, and the anticipated Threatened Steelhead Trout Recovery Plan currently under development.

Study Area

The study area for this TMDL is the Skykomish River watershed, which includes the North and South Fork Skykomish Rivers. These rivers converge to form the main fork of the Skykomish River. The Skykomish River eventually flows into the Snohomish River, which drains into Puget Sound near the city of Everett, WA (Figure 1). The watershed falls within WRIA 7.

Beneficial Uses

In the Washington State's water quality standards, aquatic-life-use categories are described using key species (e.g., salmon versus warm-water species) and life-stage conditions (e.g., spawning versus rearing) (WAC 173-201A-200; 2003 edition). The beneficial uses to be protected within the Skykomish River watershed include:

- Core Summer Salmonid Habitat (Skykomish River, May Creek, and tributaries, except those designated for char)
- Char spawning and rearing (North Fork Skykomish River, South Fork Skykomish River, Beckler River)
- Further protection for salmonid spawning and egg incubation along the Skykomish River, North Fork Skykomish River, South Fork Skykomish River, and some tributary reaches draining to these rivers (Ecology, 2011a)

See Figure 3 in the Water Quality Standards and Numeric Targets section.

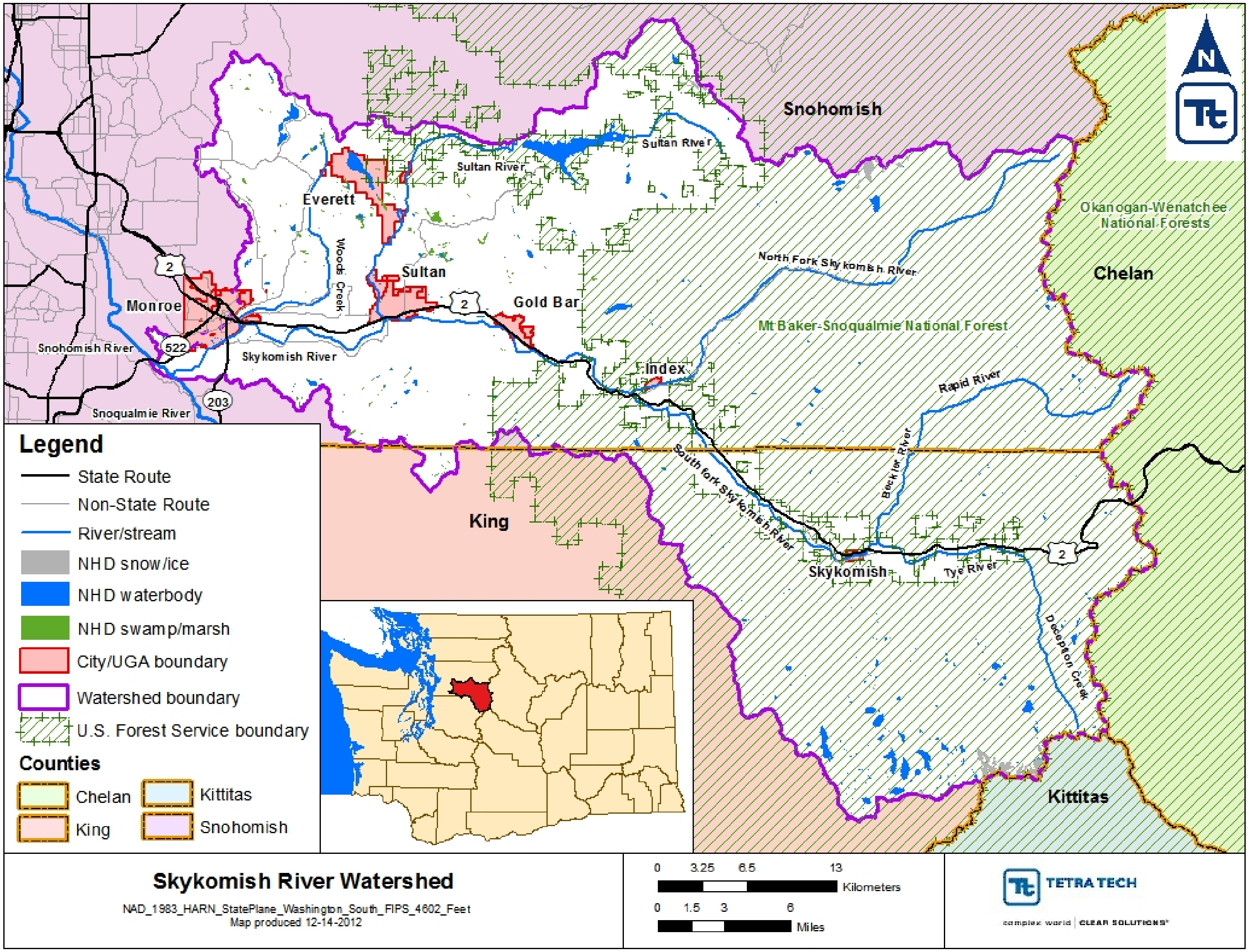

Figure 1. Study area for the Skykomish River Watershed TMDL.

Impairments Addressed by this TMDL

Washington State has established water quality standards to protect these beneficial uses. Table 1 lists the water bodies within the study area that, based on existing data, violate the temperature criteria established by the water quality standards (Ecology, 2009). This TMDL will address all known temperature impairments in the Skykomish Watershed outside of federal lands. Figure 2 displays a map of the water bodies impaired for temperature. In addition to temperature impairments, portions of the Skykomish River are also listed on the 303(d) list for DO and pH. This TMDL will only address temperature impairments. However, cooler temperatures can improve DO concentrations and moderate pH fluctuations.

Table 1. Study area water bodies in Category 5 for temperature in the 2008 and proposed 2010 Water Quality Assessments.

Water body	Parameter	Medium	Listing ID	303(d) list
Bear Creek	Temperature	Water	35165	2008, 2010
	Temperature	Water	35163	2008, 2010
Beaver Creek	Temperature	Water	35166	2008, 2010
Olney Creek	Temperature	Water	35296	2008, 2010
Pekola Creek	Temperature	Water	35297	2008, 2010
Skykomish River	Temperature	Water	6569	2008, 2010
Unnamed Creek (Tributary to Olney Creek)	Temperature	Water	35169	2008*
Wallace River	Temperature	Water	7435	2008, 2010

Note: Water body segments may be added or removed later in the development of this TMDL when Snohomish County data are fully evaluated for the 2010 WQ Assessment.

*Water body listed as Category 5 in 2008; it is currently under consideration for removal in 2010 Water Quality Assessment.

How Will the Results of This Study be Used?

A TMDL study identifies how much pollution needs to be reduced or eliminated to achieve water quality standards. This is done by assessing the situation and then recommending practices to reduce nonpoint pollution and establishing limits for NPDES-permitted facilities. Because the study will identify significant areas needing riparian restoration or instream improvements, Ecology and local partners will use these results to focus water quality improvement activities. The study might also suggest areas for follow-up sampling to further pinpoint sources of thermal pollution.

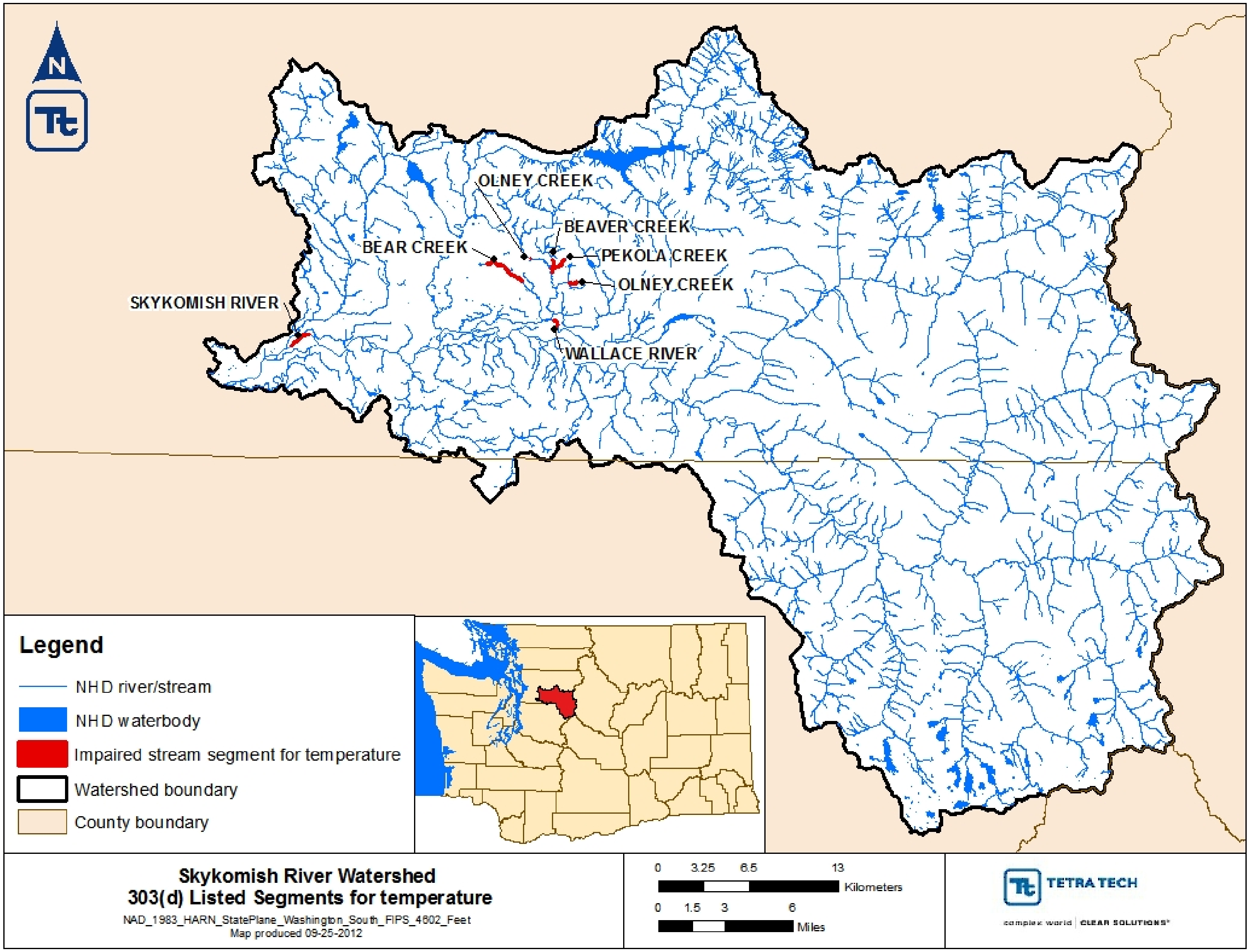

Figure 2. 303(d) listed segments for temperature in the Skykomish River watershed.

Water Quality Standards and Numeric Targets

The Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state. This section provides information on the temperature criteria in the standards that apply to the Skykomish River watershed.

In July 2003, Ecology made significant revisions to the state's surface water quality standards (WAC 173-201A). These changes included eliminating the classification system the state used for decades to designate uses for protection by water quality criteria (e.g., temperature, DO, turbidity, bacteria). Ecology also revised the numeric temperature criteria assigned to waters to protect specific types of aquatic life uses (e.g., native char, trout and salmon spawning and rearing, warm water fish habitat).

Ecology submitted the revised water quality standards regulation to the EPA for federal approval in July 2003. These standards were approved by EPA on February 11, 2008. The revisions to the existing standards are online at Ecology's water quality standards website: www.ecy.wa.gov/programs/wq/swqs. In this TMDL, the designated aquatic life uses to be protected are *core summer salmonid habitat* for the entire watershed (except the reaches designated for char) and *char spawning and rearing* in North Fork Skykomish River, South Fork Skykomish River, and Beckler River. The applicable water quality criteria are presented below.

Temperature

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

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

In the state water quality standards, aquatic life use categories are described using key species (salmonid or char versus warm-water species) and life-stage conditions (spawning versus rearing) (WAC 173-201A). In this TMDL, the designated aquatic life uses to be protected are *core summer salmonid habitat* and *char spawning and rearing.* For *core summer salmonid habitat*, the highest 7-DADMax temperature must not exceed 16 degrees centigrade (°C) more than once every ten years on average. For *char spawning and rearing*, the highest 7-DADMax temperature must not exceed 12°C more than once every ten years on average.

Portions of the Skykomish River and the tributaries shown in Figure 3 require supplemental protection for spawning and incubating salmonids. These waters have lower temperature requirements during spawning and incubation period during which the 7-DADMax temperatures must not exceed 13°C. The supplemental period is from September 15 to July 1 (Ecology, 2011a).

Washington State uses the criteria described above to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a water body is naturally warmer than the above-described criteria, the state provides a small allowance for 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 increase above the naturally higher temperature condition.

Water temperature increases as a result of increased heat flux loads. This assessment will use effective shade as a surrogate measure of heat flux from solar radiation. Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade values will be compared to system potential riparian vegetation that would naturally occur in the watershed. System potential will be determined through evaluation of various vegetation scenarios. Load allocations will be based on the selected system potential effective shade and will result in water temperatures that would occur under natural conditions, thereby achieving the natural conditions provision of the water quality standards.

In addition to the system potential effective shade, maximum effluent temperatures will be calculated using a mass balance equation (see Study Design section). This calculation ensures that the discharge will not raise the temperature of the river above the water quality standards at the edge of the mixing zone. If current effluent temperatures do not meet water quality numeric criteria at the edge of the mixing zone, Ecology will select an approach to calculate the WLA.

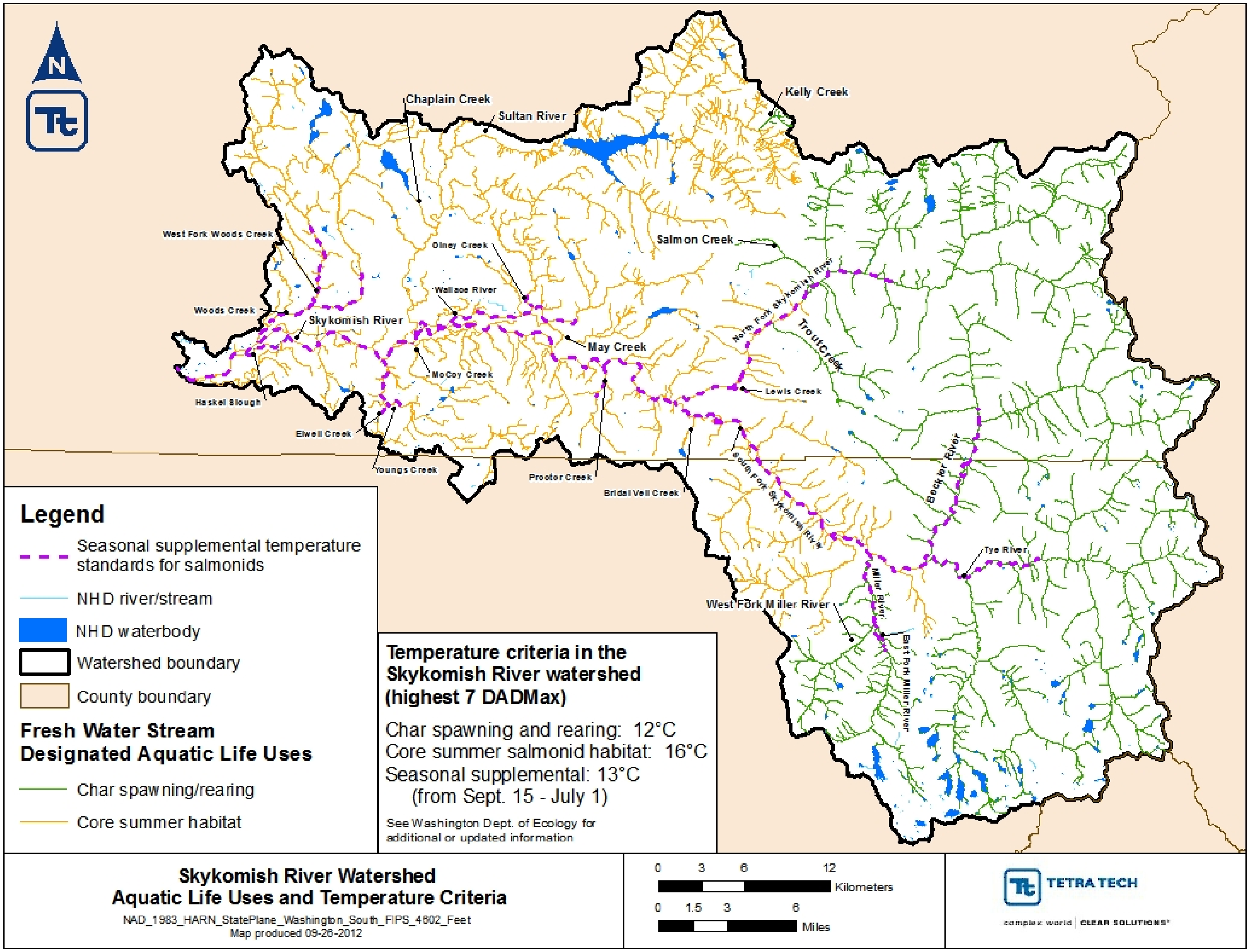

Figure 3. Aquatic life designated uses and applicable water quality criteria in the Skykomish River watershed.

Global Climate Change

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005).

Ten climate change models were used to predict the average rate of climatic warming in the Pacific Northwest (Mote et al., 2005). The average air temperature warming rate is expected to be in the range of 0.1–0.6°C per decade, with a best estimate of 0.3°C (Mote et al., 2005). Eight of the ten models predicted proportionately higher summer air temperatures, with three of the models indicating summer temperature increases of at least two times higher than winter increases.

The predicted changes to our region’s climate highlight the importance of protecting and restoring the mechanisms that help to cool stream temperatures. Stream temperature improvements obtained by growing mature riparian vegetation corridors along stream banks, reducing channel widths, and enhancing summer baseflows may all help to minimize the changes anticipated from global climate change. It will take considerable time, however, to reverse human actions that contribute to elevated stream temperatures. The sooner such restoration actions begin and the more complete they are, the more effective the program will be in offsetting some of the detrimental effects on our stream resources.

Restoration efforts might not cause streams to meet the numeric temperature criteria everywhere or in all years. However, they will maximize the extent and frequency of healthy temperature conditions, creating long-term and crucial benefits for fish and other aquatic species.

Ecology is conducting this TMDL to meet Washington State’s surface water quality standards using current climatic patterns. Potential changes in stream temperatures associated with global climate change may require further modifications to human-source allocations at some future time.

Watershed Description

The Skykomish River watershed is in northeastern King County/southeastern Snohomish County, Washington and is a subsection of WRIA 7 (Figure 1). The watershed is approximately 835 square miles (mi^2), and includes the North and South Fork tributaries. The forks flow down from the Northern Cascades and converge just downstream of the town of Index. The Skykomish River then joins the Snohomish River approximately 15 miles above where it flows into the Puget Sound (Pentec and NW GIS, 1999).

Evergreen forest and grassland areas dominate the watershed, as a large portion is managed by the U.S. Forest Service (USFS) and Washington State Parks and Recreation (Figure 4). Some development is present (approximately 4 %), including the cities of Index, Skykomish, Gold Bar, Sultan, and Monroe. Most of the urban area is located along the mainstem of the Skykomish River, after the confluence of the north and south forks. The remainder of this section presents details on the watershed characteristics that may impact water quality. Land ownership within the Skykomish River watershed is shown in Figure 4.

Geographic Setting

Hydrology

The Skykomish River is comprised of two major forks and numerous tributaries. The North Fork drains the Henry M. Jackson Wilderness area. Its major tributaries include West Cady, Silver, and Trout creeks. This fork's watershed is largely an Inventoried Roadless Area in USFS Wilderness Area. The South Fork originates in King County and is formed from the union of the Tye, Foss, and Beckler rivers near the town of Skykomish. Other tributaries include the Miller River and Money, Barclay, and Index creeks. The South Fork and its tributaries flow through USFS land. Both Forks and their tributaries help to drain the Mt. Baker-Snoqualmie National Forest (Ecology, 2011b; Marshall, 1914).

Near the town of Index, the north and main forks of the Skykomish River flow through Washington State Parks and Recreation land. Moving southwest, the main fork passes through agricultural areas and the cities of Gold Bar, Sultan, and Monroe. The Wallace and Sultan rivers join the Skykomish from the north in Sultan. The Wallace River flows through mostly undeveloped, evergreen forested land including the Wallace Falls State Park. The Sultan River flows from Spada Lake, which is a municipal water source, through USFS land of evergreen and mixed forest. Woods Creek joins from the north at Monroe after flowing through forest, then agricultural and urban residential lands (Ecology, 2002, 2011b).

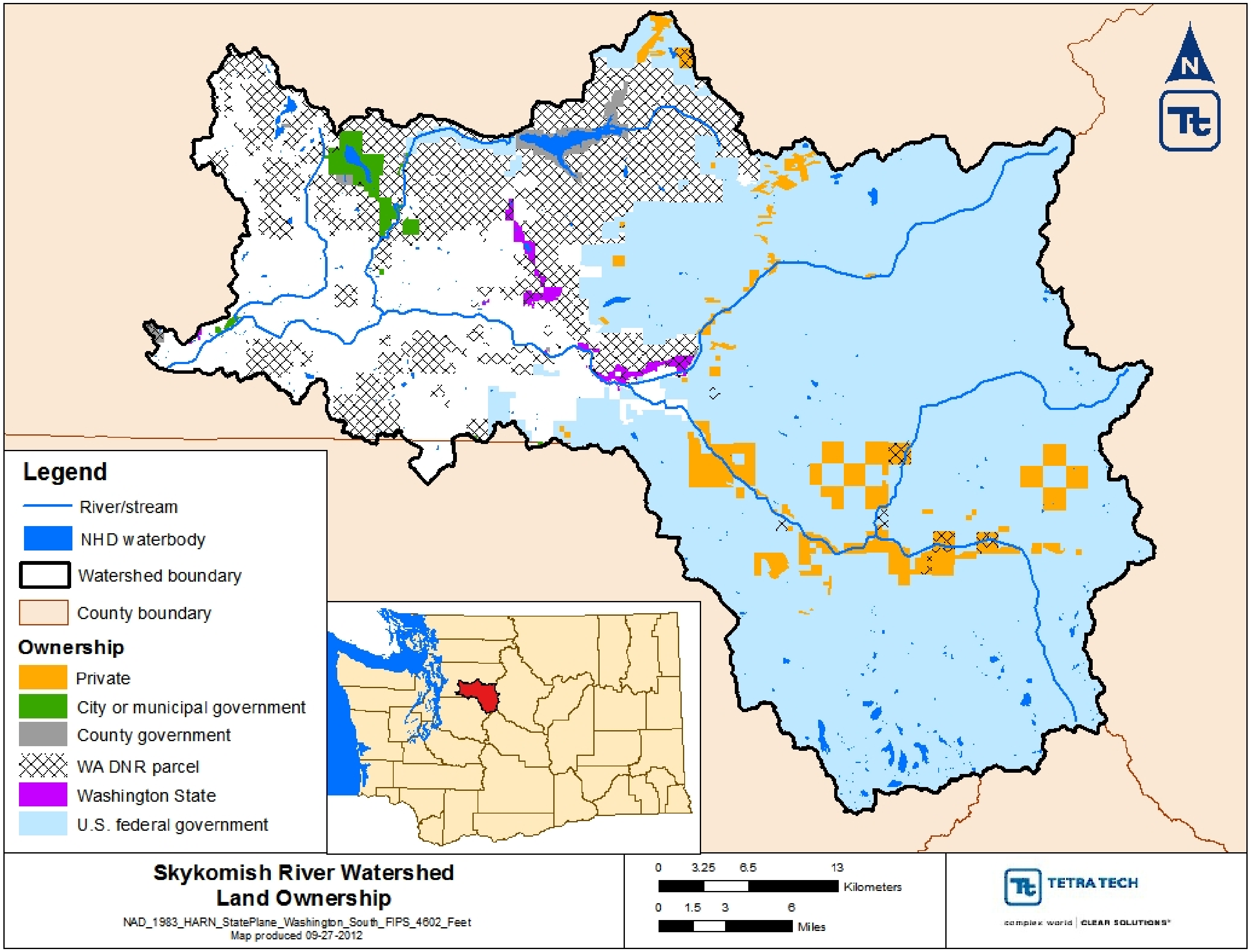

Figure 4. Land ownership within the Skykomish River watershed.

Geology

Most of the Skykomish River watershed east of the Sultan River is composed of thin soils over granite, granodiorite, tonalite, intrusive igneous rocks, and some andesite and basalt volcanic bedrock. The soil retains little water and the bedrock is impermeable, so precipitation drains quickly off into surface waters. In the region west of the Sultan and along the mainstem of the Skykomish River, soils rest on glacial drifts composed of Olympia gravels and Vashon deposits, which make more effective aquifers. The U-shaped Skykomish River valley was formed by alpine glaciers and is now underlain by alluvium (Pentec and NW GIS, 1999). These deposits supply municipal water to communities in the area.

Land Use and Land Cover

Land cover data for the Skykomish watershed was obtained from 2006 National Land Cover Database (NLCD 2006). The assessment includes 16 types of land cover, mapped at a resolution of 30 meters. The 16 land cover types were consolidated into eight categories for this assessment (Table 2 and Figure 5). Snohomish County, King County, and Ecology all have additional land use files for the watershed that can be accessed during TMDL development, if necessary. In particular, the Snohomish County land use data will be evaluated as it covers the most urbanized and developed land in the study area.

Table 2. NLCD land cover in the Skykomish River watershed.

NLCD 2006 land cover	Aggregated land cover category	Percent of total watershed
11- Open water	Water	1.20%
12- Perennial ice/snow	Perennial ice/snow	0.28%
21- Developed, open space	Developed	4.00%
22- Developed, low intensity		
23- Developed, medium intensity		
24- Developed, high intensity		
31- Barren land (rock/clay/sand)	Barren	2.82%
41- Deciduous forest	Forest	74.81%
42- Evergreen forest		
43- Mixed forest		
52- Shrub/scrub	Grassland/shrub/scrub	14.16%
71- Grassland/herbaceous		
81- Pasture/hay	Agriculture	1.06%
82- Cultivated crops		
90- Woody wetlands	Wetland	1.66%
95- Emergent herbaceous wetlands		

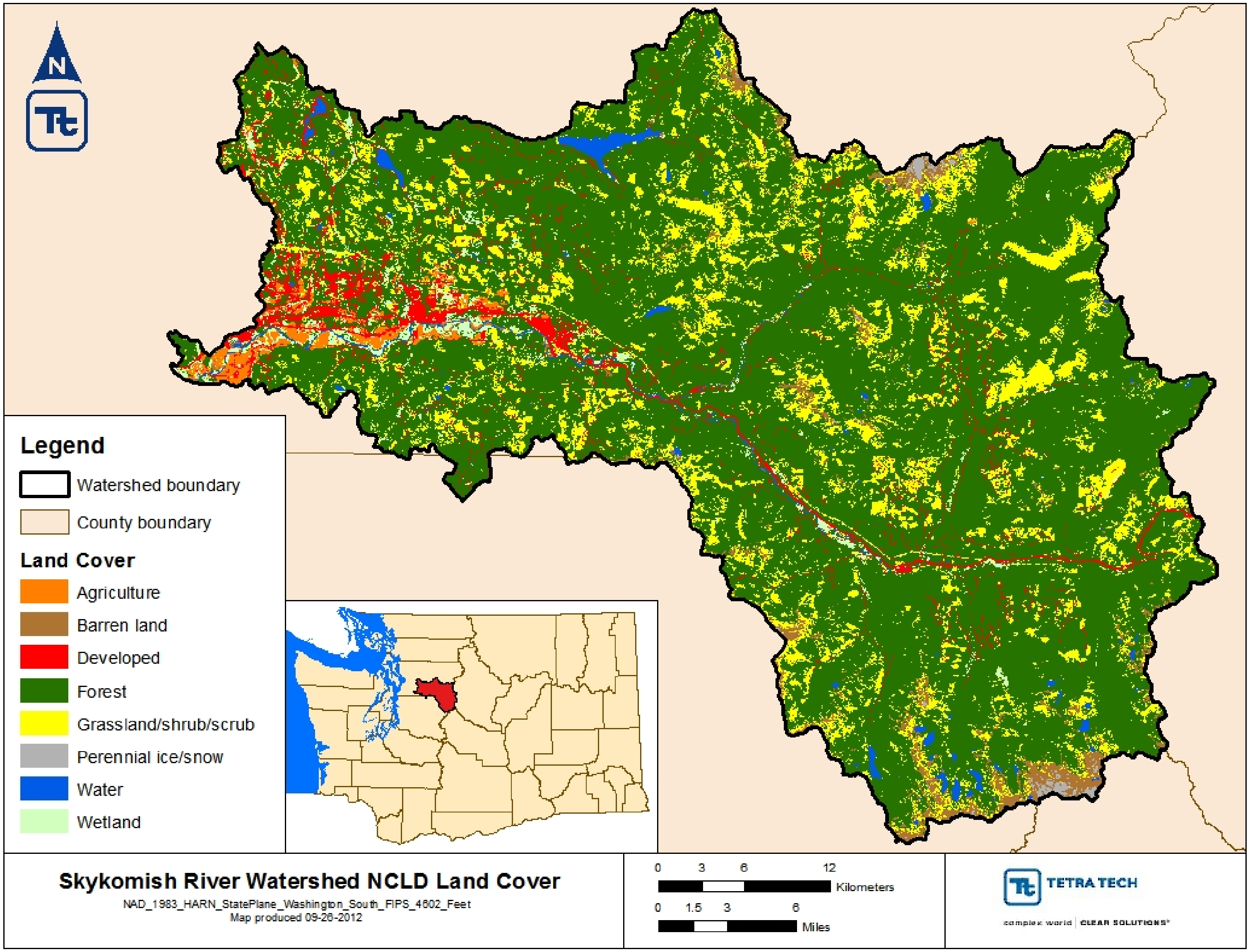

Figure 5. Skykomish River watershed land cover.

Undeveloped and agricultural land comprises 96.0 % of the Skykomish watershed. Of this, 77.9 % (624.32 mi^2) is deciduous, evergreen, or mixed forest, and 14.8 % (118.13 mi^2) is grassland or scrub/shrub land. 3 % (23.54 mi^2) of the watershed is barren, compared with 1 % (8.85 mi^2) devoted to agricultural production. Wetlands comprise 1.7 % (13.86 mi^2). Most of the undeveloped, nonagricultural land coincides with the Cascade Mountains and the Mt. Baker-Snoqualmie National Park and is managed by USFS.

Developed areas comprise 4 % of the watershed and are concentrated along the South Fork and mainstem of the Skykomish. The South Fork Skykomish River includes the cities of Index and Skykomish, while the cities of Gold Bar, Sultan, and Monroe are along the mainstem. Even within the developed areas, the majority (56 %) of the land is classified as *Developed - Open Space*, which includes lawns, golf courses, and parks with no more than 20 % impervious surfaces. Low intensity development, including single family housing units with 20 to 49 % impervious surfaces, comprises another 38.4 % of the developed land. Medium intensity development, with 50 to 79 % impervious surfaces, is 4.9 % of the developed land.

Climate

The climate of the Skykomish River watershed is characterized as temperate marine due to its year-round precipitation and moderate temperatures (Pentec and NW GIS, 1999). The Pacific Ocean provides both a cooling effect in the summer and a warming effect in the winter, while the Cascade ranges buffer the region from the extreme temperatures of continental air masses (Seliskar et al., 1983). January has the coldest temperatures, dipping to lows around 33 degrees Fahrenheit (°F), while in July temperatures peak around 77°F (WRCC, 2006b). Winters are wetter than the summers, with snowfall less common than rainfall. Only 25 to 33 % of total precipitation falls between April and September. Annual precipitation increases from west to east across the watershed, from 48 inches in Monroe (in the western watershed) to 89 inches in Index (in the center of the watershed) (WRCC, 2006a, 2012).

Wildlife

The Skykomish and its tributaries support wild populations of native and non-native salmonids including Chinook salmon, chum salmon, coho salmon, coastal cutthroat salmon, pink salmon, bull trout/Dolly Varden, steelhead trout, and mountain whitefish (Drucker, 2006; Haring, 2002). Stocked salmonids include Chinook and coho (Pentec and NW GIS, 1999). Adequate flow during the summer months, cool temperatures, deep pools, sediment-free gravel, high DO content, and unobstructed migration routes are all important habitat conditions that affect the life cycle of these fish (Pentec and NW GIS, 1999).

It is important to note that the Puget Sound Chinook salmon, bull trout, and steelhead have been listed as threatened under the Endangered Species Act. This is actually an improvement, as the Chinook was formerly listed as endangered. The coho, once a candidate for listing, is not currently listed.

Other fish observed in the Skykomish River and its tributaries include largescale sucker, threespine stickleback, and sculpin (Drucker, 2006).

A large part of the watershed is located in the Mt. Baker-Snoqualmie National Park, which is largely designated as a sensitive habitat region by the Washington Department of Fish and Wildlife (WDFW). The watershed streams as well as large portions of the watershed are designated as protected habitat regions. The watersheds also provide habitat for many animal species. Several birds in the region are listed as endangered, threatened, or species of concern, including bald eagles, northern goshawks, trumpeter swans, and pileated woodpeckers (NPWRC, 2006). The gray fox and the grizzly bear are among the many other endangered species that find refuge in the Skykomish watershed (WDFW, 2008).

Vegetation

Before Euro-American settlement, western Washington was completely forested except in areas above the alpine timberline and in prairies and wetlands. Post-settlement, the percentage of forested land decreased, while the evergreen conifer-dominated regions increased in deciduous and mixed stands (Turley et al., 2010).

The remaining forested areas, which cover nearly 75 % of the Skykomish watershed, fall into four vegetative zones: alpine (non-forested), mountain hemlock, Pacific silver fir, and western hemlock. The vegetative zones are listed in high to low altitude order, and are named for their potential climax tree species (Turley et al., 2010). The western hemlock zones are located in the lowest-altitude regions, and are dominated by western hemlock, Douglas fir, and western red cedar. Pacific silver fir zones outline the mountains, and support populations of western hemlock, noble fir, Douglas fir, western red cedar, and western white pines. Ericaceous shrubs form the understory. Mountain hemlock zones are the highest tree lines, composed of mountain hemlock, mountain cypress, and Pacific silver firs (Franklin and Dyrness, 1973).

A large part of the Skykomish watershed has been preserved as forested area because of the USFS, which maintains the Mt. Baker-Snoqualmie National Forest, and private landowners in the timber-production industry. Despite significant declines in the volume of timber harvested in the past 20 years, Washington is ranked second among all states in softwood lumber production. The Skykomish watershed produces predominantly Douglas fir, western hemlock, western red cedar, and red alder (Turley et al., 2010).

Hydromodifications

Hydromodifications on the Skykomish River and its tributaries include the destruction and isolation of the characteristic side streams and channels that provide ideal conditions for anadromous salmonids. Dikes, levees, roads, and railroads cut off natural habitat areas throughout the watershed, particularly on the mainstem, and also impair floodplain function. A flood hazard management plan for the Skykomish floodplain was drafted in 1995, but only informally implemented as repairs became necessary (Haring, 2002).

Salmonid habitats are also degraded by channelization and streambed dredging, which is common along agricultural lands. This type of hydromodification might also affect sediment loads and floodplain function (Haring, 2002).

The mainstem tributaries are peppered with culverts which often block salmonid migration, and might also impair floodplain function and normal sediment transport patterns.

There are two dams and reservoirs in the watershed (see Figure 6). The most significant is the City of Everett diversion dam, which has blocked salmonid migration on 6.8 miles of the Sultan River since the early 1900s (Haring, 2002). The installation of fish ladders was considered in the last construction phase but deemed unnecessary because the upstream habitat has natural limits to salmonid productivity and the dam improves downstream habitat by normalizing flow (Haring, 2002). The dam stores water in the Chaplain Reservoir, which supplies municipal water to Everett residents. The second dam, Culmback Dam, is upstream of the diversion dam and also on the Sultan River. It stores water in the Spada Lake Reservoir. Renovation of the Culmback Dam in 1984 added hydroelectric and flood control functions to the dam (PUD, 2011). Since the Culmback Dam is upstream of the diversion dam, there is no need for a fish ladder. Furthermore, there is not sufficient historical evidence to suggest that the reaches upstream of the Culmback Dam were ever salmonid breeding grounds (Haring, 2002).

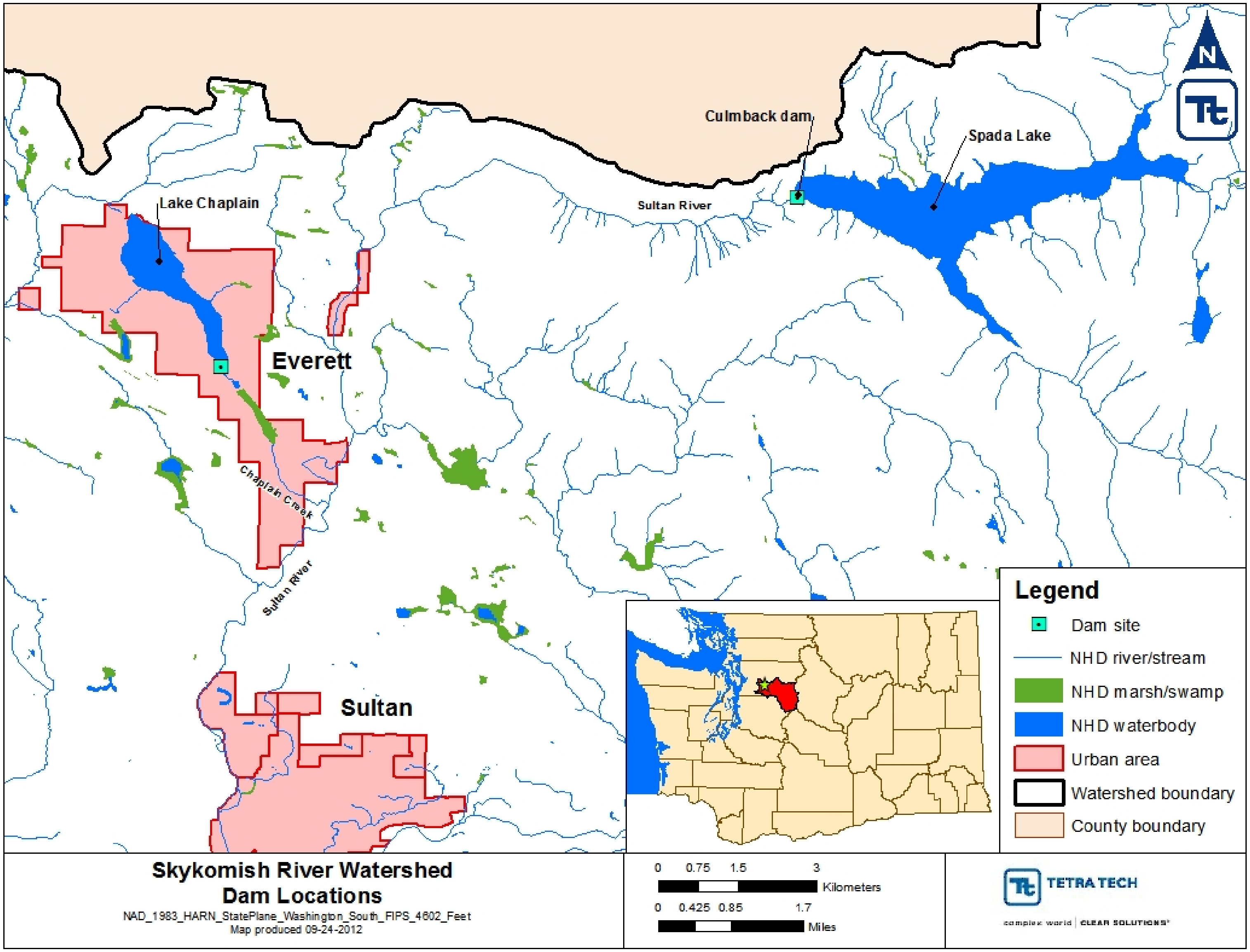

Figure 6. Dam sites in the Skykomish River watershed.

Potential Sources of Contamination

Point Sources of Pollution

Point sources of pollution are described below. The first section describes all non-municipal stormwater sources, and the subsequent section describes entities that operate municipal separate storm sewer systems (MS4s).

Non-stormwater and Stormwater General Permit Sources

There are 27 active, permitted facilities within the Skykomish River watershed. Table 3 summarizes permitted facility information by permit type. Figure 7 shows the spatial distribution of these facilities. Permitted facility information comes from Ecology's permit database, PARIS (2007). Preliminary screening has been performed on the 27 permitted facilities. Facilities potentially relevant to water temperature are shown in Table 4. During TMDL development, discharge monitoring report data and permit limits will be reviewed in detail for the facilities that are potentially relevant to water temperature. This information will then be used to develop WLAs, as needed, for these facilities. Phase I and Phase II MS4 stormwater permits are discussed separately in the following section.

There are no other permitted point sources in the study area, although there might be unknown, illicit discharges in the watersheds. Furthermore, although they do not hold NPDES permits, Chaplain and Spada Lake Reservoirs manage discharges through Federal Energy Regulatory Commission licensing and Washington State's program to implement the federal Clean Water Act Section 401 Water Quality Certification Program.[1] These systems alter downstream stream geometry and flow rate, thereby potentially impacting stream temperatures (Haring, 2002; Cristea and Kardouni, 2006).

[1] www.ecy.wa.gov/programs/wq/ferc/existingcerts/Jackson401CertOrder101810.pdf . Accessed September 21, 2012.

Table 3. Permitted discharger information in the Skykomish River watershed.

Permit ID	Facility Name	Permit type	Number of active permits
WAR125317	Reiter Foothills Forest Recreation Motorized Trail System	Construction Stormwater General Permit	9
WAR007140	Skykomish Habitat Mitigation Bank		
WAR125445	CPD WSDOT SR 522 Snohomish River Bridge Replacement Communication Relocations		
WAR125557	Sultan River Side Channel Enhancement & LWD Project		
WAR125457	US 2 Rice Rd Intersection Safety Improvements		
WAR124861	WA DOT Wagleys Creek Tributary Fish Passage		
WAR007442	Cascade Breeze Estates		
WAR007452	Skoglund Estates		
WAR009041	Hidden Ridge II		
WA0030465	AAA Monroe Rock Corp	Industrial NPDES Individual Permit	1
Unknown[1]	Skykomish Drop Box	Industrial Stormwater General Permit	3[1]
WAR004433	Sultan Post & Pole		
WAR004362	East Teak Fine Hardwoods		
WA0020486	Monroe STP	Municipal NPDES Individual Permit	2
WA0023302	Sultan WWTP		
WAG503217	Meridian Aggregates Miller River	Sand and Gravel General Permit	9
WAG503074	Cemex Proctor Creek		
WAG503041	Scarsella Bros Cascade Quarry		
WAG503148	Cadman Rock Inc Sky River Pit		
WAG503326	Scarsella Bros.		
WAG503364	Cadman Inc Gold Bar		
WAG503351	Seamount Resources		
WAG503322	Lakeside Industries Woods Creek Quarry		
WAG503382	Far Point Sand & Gravel		
WAG133005	WA DFW Reiter Ponds	Upland Fish Hatchery General Permit	2
WAG133006	WA DFW Wallace River Hatchery		
WAG643009	Everett Water Filtration Plant	Water Treatment Plant General Permit	1

1 Listed in PARIS database as “No Permit”; however, the facility is listed as active status.

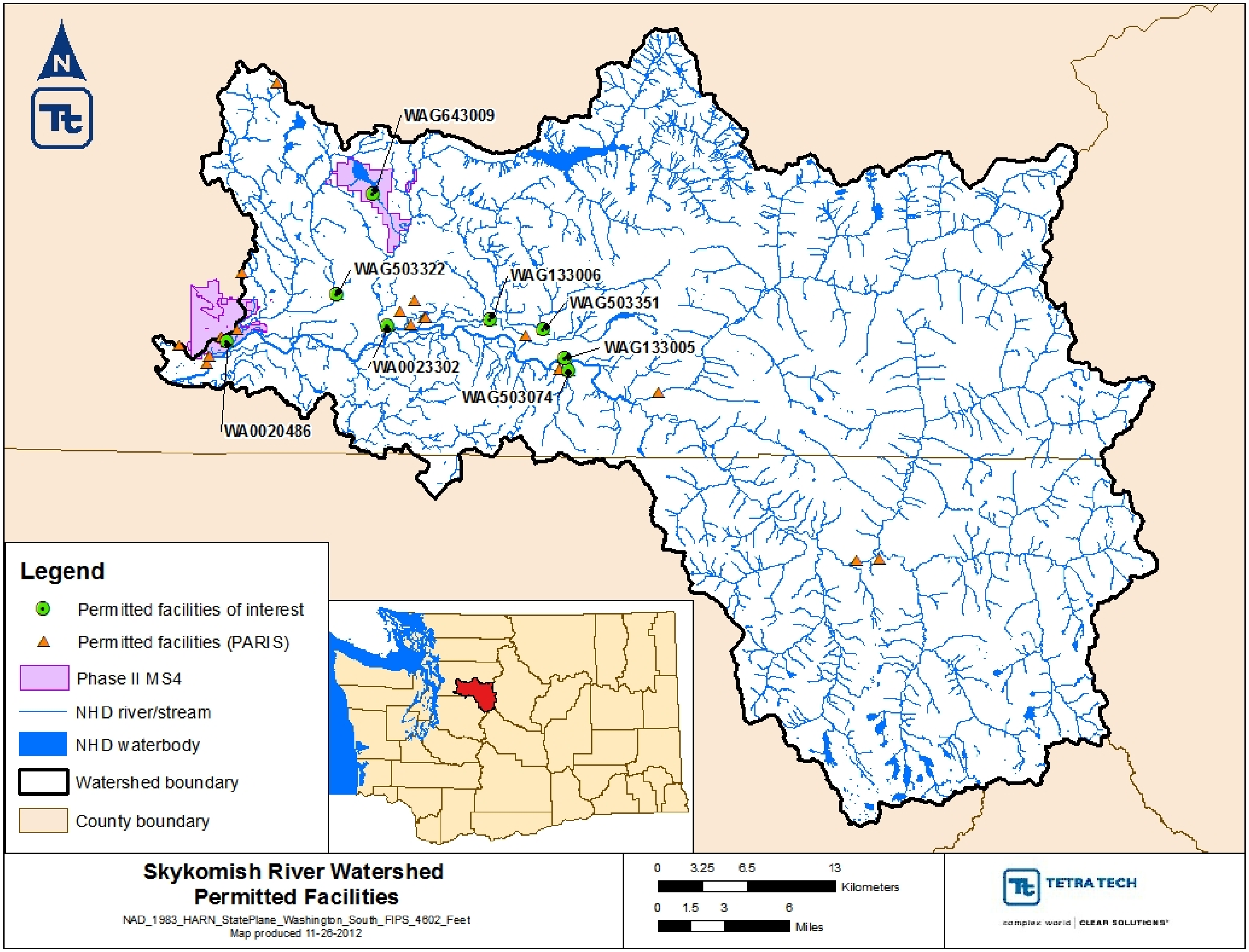

Figure 7. Permitted discharger locations within the Skykomish River watershed.

The projects listed in Table 4 are the most likely permitted facilities to have some influence on the temperature of the Skykomish River and its tributaries (see Figure 7, *Permitted facilities of interest*). General permit construction projects were excluded from Table 4 because the temporal, short-term, and stormwater-driven nature of surface water discharges make the calculation of WLAs for these facilities infeasible. With the exception of these construction projects, we reviewed Ecology's permit database and interviewed the Ecology sand and gravel facility inspector and determined that only the facilities in Table 4 are expected to discharge to surface waters during the months of July, August, and September. These include three treatment plants (one drinking water treatment plant and two municipal wastewater plants) and three sand and gravel processing facilities that currently hold NPDES permits. During TMDL development, these facilities will be evaluated in detail to determine whether WLAs are necessary. This process and the results will be documented in the TMDL report and the facilities in question are described in greater detail below.

Table 4. Permitted facilities of interest in the Skykomish River watershed.

Program ID	Facility name	Permit description	Facility description
WAG503074	Cemex Proctor Creek	Sand and Gravel General Permit	Sand and gravel facility
WAG503322	Lakeside Industries Woods Creek Quarry	Sand and Gravel General Permit	Sand and gravel facility
WAG503351	Seamount Resources	Sand and Gravel General Permit	Sand and gravel facility
WA0020486	Monroe STP	Municipal NPDES Individual Permit	Sewage treatment plant
WA0023302	Sultan WWTP	Municipal NPDES Individual Permit	Wastewater treatment plant
WAG643009	Everett Water Filtration Plant	Water Treatment Plant General Permit	Water filtration plant
WAG133005	WA DFW Reiter Ponds	Upland Fish Hatchery General Permit	Fish hatchery
WAG133006	WA DFW Wallace River Hatchery	Upland Fish Hatchery General Permit	Fish hatchery

When completed, the two construction projects might have a positive effect on water temperatures. The Skykomish habitat mitigation bank (habitat restoration) project will make environmental improvements along the mainstem Skykomish near the City of Monroe (approximately 2.5 miles upstream of the confluence with the Snohomish and Snoqualmie Rivers) including riparian channel and floodplain creation or enhancement. The project is led by Skykomish Habitat LLC and supported by Ecology (Tallent, 2006). Similarly, the Sultan River Side Channel Enhancement and Large Woody Debris Project will repair fish and wildlife habitat along the Sultan River. This effort is part of a settlement agreement associated with the Henry M. Jackson Hydroelectric Project (PUD, 2011). Riparian restoration will have a direct effect on water temperature by reducing the amount of solar radiation that reaches the water body, potentially cooling existing stream temperatures.

In the previous Sand and Gravel General Permit, facilities were required to take spot measurements of discharge temperatures during summer months. This information will be evaluated during preparation of the TMDL. Based on the overall information received during that first permit cycle, Ecology determined that temperature limits were not needed in the revised Sand and Gravel General Permit.

The fish hatcheries (Reiter Ponds and Wallace River) redirect water into man-made systems which might have less riparian cover, unnaturally high fish populations, and/or alternative geometries and flows. Therefore, these facilities have the potential to alter downstream water temperatures. However, cool water is a requirement for successful hatchery operation. Previous Ecology studies have determined that temperature limitations are not necessary for these facilities because they require cool water and because discharge is not expected to contribute to elevated stream temperatures. In addition, there is no permit requirement to monitor temperature in the discharged water, so the discharge monitoring reports for the hatcheries do not contain temperature data. These facilities will be evaluated in greater detail during TMDL development to determine if WLAs are necessary.

MS4 Stormwater Pollution

During rain events, rainwater washes the surface of the pavement, rooftops, and other impervious surfaces. This stormwater runoff accumulates and transports pollutants and contaminants via stormwater drains to receiving waters and can degrade water quality. Ecology issues NPDES permits to larger entities that operate MS4s responsible for collecting, treating, and discharging stormwater to local streams and rivers.

Under the NPDES stormwater program, operators of large, medium, and regulated small MS4s must obtain authorization to discharge pollutants. The Stormwater Phase I Rule (USEPA, 1990) requires all operators of medium and large MS4s to obtain an NPDES permit and develop a stormwater management program. The permit regulates stormwater discharges to waters of Washington from the permittees' MS4s in compliance with Washington Water Pollution Control Law (Chapter 90.48 RCW) and the federal Clean Water Act (33 USC, Section 1251 et seq.). Medium and large MS4s are defined by the size of the population within the MS4 area, not including the population served by combined sewer systems. A medium MS4 has a population between 100,000 and 249,999; a large MS4 has a population of 250,000 or more.

Phase II requires a select subset of small MS4s to obtain an NPDES stormwater permit. A small MS4 is any MS4 not already covered by the Phase I program as a medium or large MS4. The Phase II rule automatically covers all small MS4s in urbanized areas (UAs), as defined by the Bureau of the Census, and also includes small MS4s outside an UA that are so designated by NPDES permitting authorities, case by case (USEPA, 2000).

Snohomish County and King County each hold one active Phase I MS4 permit in the watershed, as does the Washington State Department of Transportation (WSDOT). In addition, the cities of Monroe and Everett each hold a Phase II MS4 permit.

Snohomish and King Counties

Ecology issued an NPDES Phase I Municipal Stormwater Permit to Snohomish County, King County, and other western Washington jurisdictions in January 2007. The permit was subsequently revised in June 2009 and recently reissued on August 1, 2012 (effective September 1, 2012 – July 31, 2013). The updated 2013-2018 Phase I permit was also reissued and will become effective on August 1, 2013.

More information on Phase I permits can be found at www.ecy.wa.gov/programs/wq/stormwater/municipal/phaseIpermit/phipermit.html or www.ecy.wa.gov/programs/wq/stormwater/municipal/Phase1equivalentstormwatermanualsWestern.html.

Snohomish County has a Stormwater Management Plan that outlines the county's responsibilities to protect water through stormwater management. The Plan can be found at www.co.snohomish.wa.us/documents/Departments/Public_Works/surfacewatermanagement/water_quality/permit2010swmp.pdf.

King County has a Stormwater Management Program that is updated and resubmitted to Ecology on an annual basis. The 2012 copy of the program was submitted on March 30, 2012 and can be found at www.kingcounty.gov/environment/wlr/sections-programs/stormwater-services-section/stormwater-program.aspx.

Ecology's five-volume Stormwater Management Manual, revised and updated in 2012, is available on the Internet at http://www.ecy.wa.gov/programs/wq/stormwater/manual.html.

Washington State Department of Transportation (WSDOT)

In March 2012, Ecology issued a new modified permit to WSDOT. This permit addresses stormwater discharges from WSDOT MS4s in areas covered by the Phase I and Phase II municipal MS4s. WSDOT highways, maintenance facilities, rest areas, park and ride lots, and ferry terminals are covered by this permit when a WSDOT MS4 conveys the discharges. State highways in the Skykomish River watershed include State Route (SR) 203 and 522.

More information on the WSDOT permit can be found at www.ecy.wa.gov/programs/wq/stormwater/municipal/wsdot.html.

WSDOT has a 2011 Highway Runoff Manual that provides tools for designing stormwater collection, conveyance, and treatment systems for transportation-related facilities. This manual has been approved by Ecology as functionally equivalent to the Stormwater Management Manual for Western Washington and is available at www.wsdot.wa.gov/Environment/WaterQuality/Runoff/HighwayRunoffManual.htm

Cities of Everett and Monroe

Two cities located in the Skykomish River watershed hold Phase II MS4 Permits (Cities of Everett and Monroe). Outside of the city boundaries, Snohomish and King County must follow Phase I of the NPDES municipal stormwater guidelines to manage stormwater before it discharges to surface water.

Ecology issued the Western Washington Phase II Municipal Stormwater Permit in January 2007 and modified it in June 2009. Ecology reissued it unmodified on August 1, 2012 to be effective through July 31, 2013. The updated 2013-2018 Phase II permit was also reissued and will become effective on August 1, 2013. Under the Phase II permit, the cities must follow the prescribed guidelines to manage stormwater before it discharges to surface water. Permit requirements fall under five basic categories: public education and outreach, public involvement and participation, illicit discharge detection and elimination, the control of runoff from development, and pollution prevention. General information on the Phase II permit is available at www.ecy.wa.gov/programs/wq/stormwater/municipal/phaseIIww/wwphiipermit.html.

Nonpoint Pollution Sources

Nonpoint pollution sources are dispersed and thus not controlled through discharge permits. Activities that have the following effects can result in water temperature increases and are classified as nonpoint sources:

- Riparian vegetation disturbance
- Hydrologic changes (including altered streamflow patterns from urban and timber harvest areas resulting in increased spring runoff and decreased summer-base flows)
- Hydromodifications that affect stream geometry and flow rate (Cristea and Kardouni, 2006)

It is important to understand the ways in which natural riparian and groundwater systems have been changed and how these changes affect water temperature. Temperature is most directly impacted by the removal of riparian zone vegetation, which increases solar radiation reaching the stream surface. This reduction of riparian zone vegetation reduces the available shade, which increases sunlight to the stream surface and subsequently increases water temperature.

Timber harvest, which still occurs in the watershed, is a significant nonpoint pollution source. It can:

- directly reduce riparian cover along water bodies
- increase erosion by destabilizing stream banks
- increase spring runoff by fostering snow accumulation in cleared areas
- reduce infiltration and subsequent groundwater recharge
- decrease summer flows by leaving the winter snowpack exposed to early season rays.

Agricultural activities have similar effects, with the additional impacts of overgrazed stream banks, livestock use of water bodies, and channelization of waterways (Haring, 2002).

Infrastructure along the waterways, particularly SR 2 and the Burlington Northern and Santa Fe (BNSF) railway, constricts the riparian zone, reduces pervious surface cover, and requires modification of water body channels. Both SR 2 and the BNSF run along the Skykomish River South Fork and the mainstem for significant distances. Residential and urban developments have similar results.

Groundwater influences, instream flows, water withdrawals, hyporheic flow, and stream channel geometry also influence stream temperature. Groundwater tends to maintain a constant temperature that can warm a stream in winter and cool it in the summer. As mentioned in the Geology section, most of the Skykomish watershed east of the Sultan River lies on impermeable bedrock that does not allow aquifer formation (but may have influence from hyporheic flow); however, the lowlands along the Skykomish River valley contain aquifers formed from alluvium and glacial deposits.

Historical Data Review

The following section gives a brief summary of existing Skykomish River watershed data. Since this is an innovative temperature TMDL (i.e., no temperature model will be developed), existing temperature data is not needed for modeling but helps confirm existing water quality problems. Other available data will also be useful to characterize current and system potential vegetation, and other relevant watershed characteristics.

Water Temperature Data

Water quality, specifically water temperature, in the Skykomish River watershed is monitored regularly by Snohomish County (SnoCo), Snohomish County Public Utilities District (SnoPUD), Ecology, USGS, and King County (Ecology, 2012a, 2012b; King County WLRD, 2012; USGS, 2012), among others. Available and pertinent data from these agencies are described below. Table 5 summarizes the available discrete monitoring data. Most of these data were collected monthly; however, the frequency varied by source and site as some data were collected daily. Table 6 summarizes the continuous temperature monitoring data. Data were obtained from multiple sources. Ecology's EIM database contains records from monitoring locations throughout Washington including physical, chemical, and biological data (Ecology, 2012a). Data in the database are submitted by Ecology (including their contractors), grant recipients, local governments, and volunteers. The data from Snohomish County were obtained via personal communication with Snohomish County staff (Flynn Adams, Snohomish County, personal communication in connection with the French Creek and Pilchuck River TMDL, March 14, 2012). All monitoring stations identified to date are illustrated in Figure 8. The legend for the map is based on the source, so the EIM stations represent multiple sources, which are specified in the second column of Table 5.

Table 5. Discrete water temperature data for the Skykomish River watershed.

Source	Site ID	Site name	Start date	End date[1]	Count	Water temperature (° C)		
						Minimum	Maximum	Average
EIM [2]	07C070 (Ecology)	SKYKOMISH RIVER AT MONROE	11/30/70	03/21/11	1,338	0	21	9
	07C090 (Ecology)	Skykomish R @ Sultan	11/30/70	09/25/74	44	1.8	17.3	7.8
	07C120 (Ecology)	Skykomish R nr Gold Bar	08/25/47	09/19/01	242	0.6	19	9
	07C170 (Ecology)	Skykomish R nr Miller R	10/11/76	09/19/77	24	2.3	17	8.8
	07F055 (Ecology)	Woods Cr @ Monroe	11/30/70	09/16/96	68	2.4	19.1	10
	07E055 (Ecology)	Sultan R @ Sultan	07/20/60	09/19/01	110	2.9	21.3	9.2
	benth222 (Ecology)	WOODS CR ABV WOODS CR RD.	09/16/97	09/13/99	3	11.9	12.2	12.1
	benth223 (Ecology)	WOODS CR AT CALHOUN RD	09/17/97	09/17/97	1	12.8	12.8	12.8
	FB200 (Ecology)	Snohomish Watershed Forest 200	10/17/09	07/06/10	11	5.31	13.8	9.26
	FB203 (Ecology)	Snohomish Watershed Forest 203	10/17/09	07/06/10	13	5.62	15.7	9.5
	RILEY(SITEA) (Ecology)	RILEYSLOUGH(SITEA)	04/26/00	06/26/03	43	1.9	16	9.1
	RILEY(SITEB) (Ecology)	RILEYSLOUGH(SITEB)	04/26/00	04/22/03	40	1.3	28.4	13
	RILEY(SITEC) (Ecology)	RILEYSLOUGH(SITEC)	04/26/00	04/22/03	41	1.3	19.4	11
	RILEY(SITED) (Ecology)	RILEYSLOUGH(SITED)	05/11/00	04/22/03	35	1.1	18	10
	RILEY(SITEE) (Ecology)	RILEYSLOUGH(SITEE)	04/26/00	06/26/03	34	1.1	17.2	10
	RILEY(SITEG) (Ecology)	RILEYSLOUGH(SITEG)	12/18/01	04/22/03	18	3.6	16.6	8.0
	ROBB DN (Ecology)	ROBB DN ((KISSEE CR)	05/18/00	12/27/02	17	4.4	15.7	9.2
	ROBB UP (Ecology)	ROBB UP ((KISSEE CR)	05/18/00	12/27/02	17	4.5	17	9.4
	ROESN11 (Ecology)	ROESIGER (NORTH ARM) (SNOHOMISH) 1	05/24/93	08/19/99	250	4.4	24.6	11
	ROESN23 (Ecology)	ROESIGER (SOUTH ARM) (SNOHOMISH) 3	06/03/97	08/19/99	94	4.9	24.6	12
	SITE C1 UP (Ecology)	SITE C1 UP (UNNAMED STREAM)	06/16/00	09/24/02	28	4.2	13.2	9.4
	SITE C2 DN (Ecology)	SITE C2 DN (UNNAMED STREAM)	06/16/00	09/24/02	28	4.1	14	10
	SNOCOOUTFALL 418 (SnoCo)	HOFSTRA DITCH	04/11/05	04/11/05	1	9.78	9.78	9.78
	SNOCOOUTFALL 419 (SnoCo)	HORSESHOE CULVERT UNDER RR	04/11/05	04/11/05	1	10.57	10.57	10.57
	SNOCOOUTFALL 420 (SnoCo)	PERCHED RR CULVERT	04/11/05	04/11/05	1	11.47	11.47	11.47
	SNOCOOUTFALL 438 (SnoCo)	BEAVER DAM KOSTERLAND DAIRY	04/13/05	04/13/05	1	8.74	8.74	8.74

Source	Site ID	Site name	Start date	End date[1]	Count	Water temperature (° C)		
						Minimum	Maximum	Average
	SNOCOOUTFALL 439 (SnoCo)	UP A SLOUGH W/O A PADDLE	04/11/05	04/11/05	1	10.18	10.18	10.18
	SNOCOOUTFALL 440 (SnoCo)	SULTAN PARK	04/11/05	04/11/05	1	9.42	9.42	9.42
	SNOCOOUTFALL 461 (SnoCo)	MONROE	04/26/05	04/26/05	1	12.12	12.12	12.12
	Snodry1 (Ecology)	Skykomish River (SKY01)	08/16/93	08/17/93	2	13.7	14.7	14.2
	Snodry2 (Ecology)	Skykomish River (SUL02)	08/16/93	08/17/93	2	12.1	12.2	12.1
	Snodry3 (Ecology)	Skykomish River (SKY03)	08/17/93	08/17/93	1	14.2	14.2	14.2
	Snodry5 (Ecology)	Skykomish River (SKY05)	08/16/93	08/17/93	2	13.5	14	14
	Snodry6 (Ecology)	Woods Creek (WOD06)	08/16/93	08/17/93	2	14.2	14.5	14.3
	Snodry7 (Ecology)	Skykomish River (SKY07)	08/16/93	08/17/93	2	14	15.3	15
	SOMM DN (Ecology)	SOMM DN (NR SKYKOMISH RV)	12/20/01	12/27/02	8	4	14.9	8
	SOMM UP (Ecology)	SOMM UP (NR SKYKOMISH RV)	12/20/01	12/27/02	9	3.9	21	11
	WCDN (Ecology)	WOODS CREEK MAINSTEM (WCDN)	02/13/96	04/09/96	6	4.4	12.6	7
	WCMF (SnoCo/Ecology)	WOODS CREEK MAINSTEM (WCMF)	02/13/96	09/07/06	74	0.7	16.09	10
	WCUP (Ecology)	WOODS CREEK MAINSTEM (WCUP)	02/13/96	04/09/96	5	4.2	11	7.0
	WCWF (SnoCo/Ecology)	WOODS CREEK WEST FORK (WCWF)	02/13/96	09/07/06	74	0.8	16.5	10
King County	SKYKOMISH	Skykomish- King County	02/15/11	05/14/12	16	2.1	11.6	5.8
City of Monroe	Al Borlin	Woods Creek @ Al-Borlin Park	3/11/08	7/7/12	53	3.9	16.3	8.8
	Albertsons	Woods Creek behind Albertsons	3/11/08	7/7/12	53	4.9	13.7	9.8
	Eagles Park	Woods Creek @ Eagles Park	3/11/08	7/7/12	53	4.8	14.9	10.2
City of Sultan	Sultan WWTP	Sultan WWTP	Data currently unavailable, anticipated in future,					

[1] The frequency of data collection varied for different sources and different monitoring locations from daily to monthly measurements.
[2] Data collection agency or study sponsor is identified in the Site ID column.

Table 6. Continuous water temperature data in the Skykomish River watershed.

Source	Site name/location	Start date	End date	7-day average day count[1]	Water temperature (°C)		7-DADMax exceeding temperature criteria	
					Max 7-DADMax	Mean 7-DADMax	Count	Percent
Mainstem Monitoring Locations								
City of Monroe	Monroe WWTP	Data currently unavailable, but has potential for future use. WWTP discharges to Skykomish River mainstem.						
Ecology	Skykomish River at Monroe (07C070)	7/23/2001	9/19/2001	53	20.0	17.0	42	79.2%
		7/22/2002	9/18/2002	53	18.3	16.5	32	60.4%
		7/22/2003	9/22/2003	57	21.3	19.0	54	94.7%
		7/13/2004	9/30/2004	74	21.1	17.2	48	64.9%
		7/14/2006	9/15/2006	58	20.3	18.6	58	100%
SnoCo	North Fork Skykomish River Mainstem 2	7/7/2010	10/6/2010	86	20.0	13.8	15	17.4%
SnoPUD[2]	Skykomish Above	1/4/2011	5/17/2012	430	14.7	7.5	10	2.3%
SnoPUD[2]	Skykomish Below	1/1/2011	5/17/2012	497	16.7	7.5	21	4.2%
Tributary Monitoring Locations								
SnoCo	Carpenter Creek at N Carpenter Rd	7/10/2008	8/26/2008	42	17.2	15.4	10	23.8%
		7/10/2009	10/2/2009	79	20.4	15.8	28	35.4%
		6/1/2010	10/22/2010	138	17.7	14.5	26	18.8%
SnoCo	Carpenter Creek Up (CARPUP)	6/1/2009	9/23/2009	109	19.6	16.6	64	58.7%
		6/1/2010	10/1/2010	117	19.2	15.5	46	39.3%
		6/1/2011	10/1/2011	117	17.2	15.1	30	25.6%
SnoCo	Carpenter Creek upstream of N Carpenter Rd	7/2/2008	8/26/2008	50	17.4	15.3	16	32.0%
		7/10/2009	10/2/2009	79	17.4	14.2	8	10.1%
		6/1/2010	10/26/2010	135	19.4	14.4	34	25.2%
SnoCo	McCoy Creek	6/30/2008	10/13/2008	100	19.2	16.5	71	71.0%
		6/14/2010	9/29/2010	102	19.9	16.9	77	75.5%
		6/22/2009	9/14/2009	79	18.8	14.9	22	27.8%
SnoCo	Olney Creek	7/10/2008	10/12/2008	89	16.5	13.8	6	6.7%
		7/7/2010	10/6/2010	86	17.1	14.3	19	22.1%
SnoCo	Wallace River 3	7/10/2008	10/8/2008	88	17.2	14.0	13	14.8%
		7/7/2010	10/6/2010	86	19.9	15.8	61	70.9%
SnoCo	Wallace River at Startup	7/10/2008	10/13/2008	90	20.0	15.6	38	42.2%
		7/7/2010	9/29/2010	79	18.4	14.8	28	35.4%
SnoCo	East Fork Woods Creek at Florence Acres Rd	7/8/2008	10/22/2008	101	18.7	16.0	37	36.6%
		6/1/2009	9/30/2009	116	18.8	15.4	83	74.8%
		6/1/2010	9/25/2010	111	21.6	16.8	89	76.7%
SnoCo	West Fork Woods Creek @ Yaeger Rd	7/8/2008	10/22/2008	101	19.2	16.5	47	46.5%
		6/1/2009	9/23/2009	109	22.6	17.6	102	93.6%

Source	Site name/location	Start date	End date	7-day average day count[1]	Water temperature (°C)		7-DADMax exceeding temperature criteria	
					Max 7-DADMax	Mean 7-DADMax	Count	Percent
		6/16/2009	9/23/2009	94	19.1	15.6	46	48.9%
		6/1/2010	9/30/2010	116	19.1	15.8	88	75.9%
SnoCo	Wood Creek - Woods Creek Rd	6/1/2009	9/23/2009	109	19.0	15.6	60	55.0%
		6/16/2009	9/23/2009	94	22.6	17.6	87	92.6%
		6/1/2010	10/1/2010	117	17.5	14.6	52	44.4%
		6/1/2011	10/1/2011	117	16.1	14.2	28	23.9%
SnoCo	Woods Creek - 211th Ave	6/1/2009	9/23/2009	109	22.0	17.1	100	91.7%
		6/1/2010	9/30/2010	116	18.6	15.2	76	65.5%
		6/1/2011	10/1/2011	117	17.4	15.0	58	49.6%
SnoCo	Woods Creek Old Owen	6/1/2010	10/1/2010	117	20.4	16.4	94	80.3%
USGS	USGS 12137290, S. Fork Sultan River	10/1/2009	9/30/2011	723	14.8	6.4	0	0.0%
USGS	USGS 12137800, Sultan River	10/1/1993	9/29/1994	155	14.1	9.8	0	0.0%
		9/30/2009	06/12/2012[3]	748	13.8	7.9	0	0.0%
USGS	USGS 12138160, Sultan River	8/10/1995	10/18/2011	4,622	16.1	8.1	2	<1.0%
SnoPUD[2]	Sultan RM 15.8	1/1/2011	5/17/2012	497	7.9	4.6	0	0.0%
SnoPUD[2]	Sultan RM 14.3	1/1/2011	5/17/2012	497	10.2	5.7	0	0.0%
SnoPUD[2]	Sultan RM 12.8	1/1/2011	5/17/2012	497	10.6	5.8	0	0.0%
SnoPUD[2]	Sultan RM 11.3	1/1/2011	5/17/2012	417	12.43	6.9	0	0.0%
SnoPUD[2]	Sultan RM 9.8	1/1/2011	5/17/2012	450	14.0	7.3	0	0.0%
SnoPUD[2]	Sultan RM 4.9	1/1/2011	5/17/2012	360	14.9	7.8	0	0.0%
SnoPUD[2]	Sultan RM 4.3	4/3/2012	5/17/2012	39	9.9	6.7	0	0.0%
SnoPUD[2]	Sultan RM 0.2	1/1/2011	5/17/2012	497	18.2	7.3	7	1.4%
SnoPUD[2]	Big Four	1/1/2011	5/17/2012	366	14.7	7.5	0	0.0%
SnoCo	Barr Ck @ Ben Howard Rd BARR)[4]	6/8/2000	9/21/2000	100	18.7	15.3	31	31.0%
SnoCo	Creswell Cr @ Creswell Rd (CRESWELL)[4]	6/17/2004	9/14/2004	84	22.2	19.2	84	100.0%
SnoCo	Elwell Cr @ Ben Howard Rd bridge (ELWELL) [4]	6/26/2000	9/21/2000	82	21.0	16.8	56	68.3%
SnoCo	Kissee Cr @ Ben Howard Rd (KISSEE)[4]	6/8/2000	9/21/2000	100	17.4	14.6	14	14.0%
SnoCo	Lk Roesiger Outlet (WOODSLR) [4]	8/5/1998	11/10/1998	92	14.9	12.0	0	0.0%
SnoCo	Carpenter Cr @ 211th Ave SE (CARP211)[4]	6/1/2004	9/14/2004	100	19.1	16.5	63	63.0%
SnoCo	Carpenter Cr @ 47th St SE (CARP47)[4]	6/1/2004	9/14/2004	100	17.5	15.4	43	43.0%

Source	Site name/location	Start date	End date	7-day average day count[1]	Water temperature (°C)		7-DADMax exceeding temperature criteria	
					Max 7-DADMax	Mean 7-DADMax	Count	Percent
SnoCo	Carpenter Creek Up (CARPUP)[4]	06/01/04	09/14/04	101	16.7	15.1	17	16.8%
EIM [5]	WESTF SITE 000699 DOWNSTREAM WATER (ERST_WF000699DW), Olney Creek[4] (Ecology)	7/3/2008	10/2/2008	80	14.9	12.8	1	1.2%
		6/22/2009	9/14/2009	79	19.1	15.2	23	29.1%
EIM [5]	WESTF SITE 000699 UPSTREAM WATER (ERST_WF000699UW), Olney Creek [4] (Ecology)	7/3/2008	10/2/2008	86	15.6	12.9	0	0.0%
SnoCo	Richardson Cr @ 132nd St SE (RICHARD)[4]	8/6/1998	11/10/1998	91	26.0	14.2	37	40.7%
		6/1/2004	9/14/2004	100	19.9	17.4	80	80.0%
SnoCo	Richardson Cr @ Upper Ingraham Rd (RICHUP) [4]	6/1/2004	9/15/2014	101	19.3	17.2	80	79.2%
SnoCo	Richardson Cr @ Woods Cr Rd (RICHMOUTH) [4]	6/1/2004	9/14/2004	100	18.8	16.6	66	66.0%
SnoCo	Roesiger Cr @ Middle Shore Rd (ROESIGER) [4]	6/1/2004	9/14/2004	100	25.1	22.4	100	100.0%
SnoCo	Sister of Friar Cr @ 116th St SE (FRSIS116) [4]	6/1/2004	7/12/2004	36	19.6	17.2	25	69.4%
SnoCo	Sister of Friar Cr @ Pipeline Rd (FRSISPIPE) [4]	6/1/2004	9/15/2004	102	21.2	15.8	27	26.5%
SnoCo	Sister of Friar Cr @ Woods Cr Rd (FRIARSIS) [3]	8/12/1998	10/19/1998	63	15.3	13.4	0	0.0%
SnoCo	Sorgenfrei Cr @ Dubuque Rd (SORGEN) [4]	8/7/1998	11/10/1998	90	15.3	12.5	0	0.0%
SnoCo	Timber Cr @ Forestry Rd (TIMBER) [4]	8/9/1998	11/10/1998	88	22.4	12.1	4	4.6%
SnoCo	Woods Cr @ Bridge 446 (WOODSCKRD)[4]	6/1/2004	9/14/2004	100	16.4	14.3	27	27.0%
SnoCo	Woods Cr @ Pipeline Rd (WOODPIPE) [4]	6/1/2004	9/15/2004	101	18.7	16.4	72	71.3%
SnoCo	Woods Cr @ Woods Cr Rd (WOODSUP) [4]	6/1/2004	9/14/2004	100	15.2	14.0	19	19.0%
SnoCo	Woods Cr @ Yaeger Rd (WCMF) [4]	6/1/2004	9/14/2004	100	20.7	17.8	92	92.0%
SnoCo	Woods Cr WF @ Bridge 298 (WOODS298) [4]	6/1/2004	9/14/2004	100	18.5	16.4	83	83.0%
SnoCo	Woods Cr WF @ Yaeger Rd (WCWF) [4]	6/1/2004	9/14/2004	100	21.1	18.1	97	97.0%

See next page for Notes for Table 6

Notes for Table 6:

[1] 7-day average day count is the number of times that a summary statistic has been calculated from the data set based on a rolling 7-day period.
[2] SNOPUD data associated with Henry M. Jackson Hydroelectric Project.
[3] Data were downloaded on June 12, 2012, and more recent data may be available.
[4] Data set does not meet Ecology's data QA protocol and will not be used in TMDL calculations.
[5] Data collection agency or study sponsor is identified in the Site name/location column.

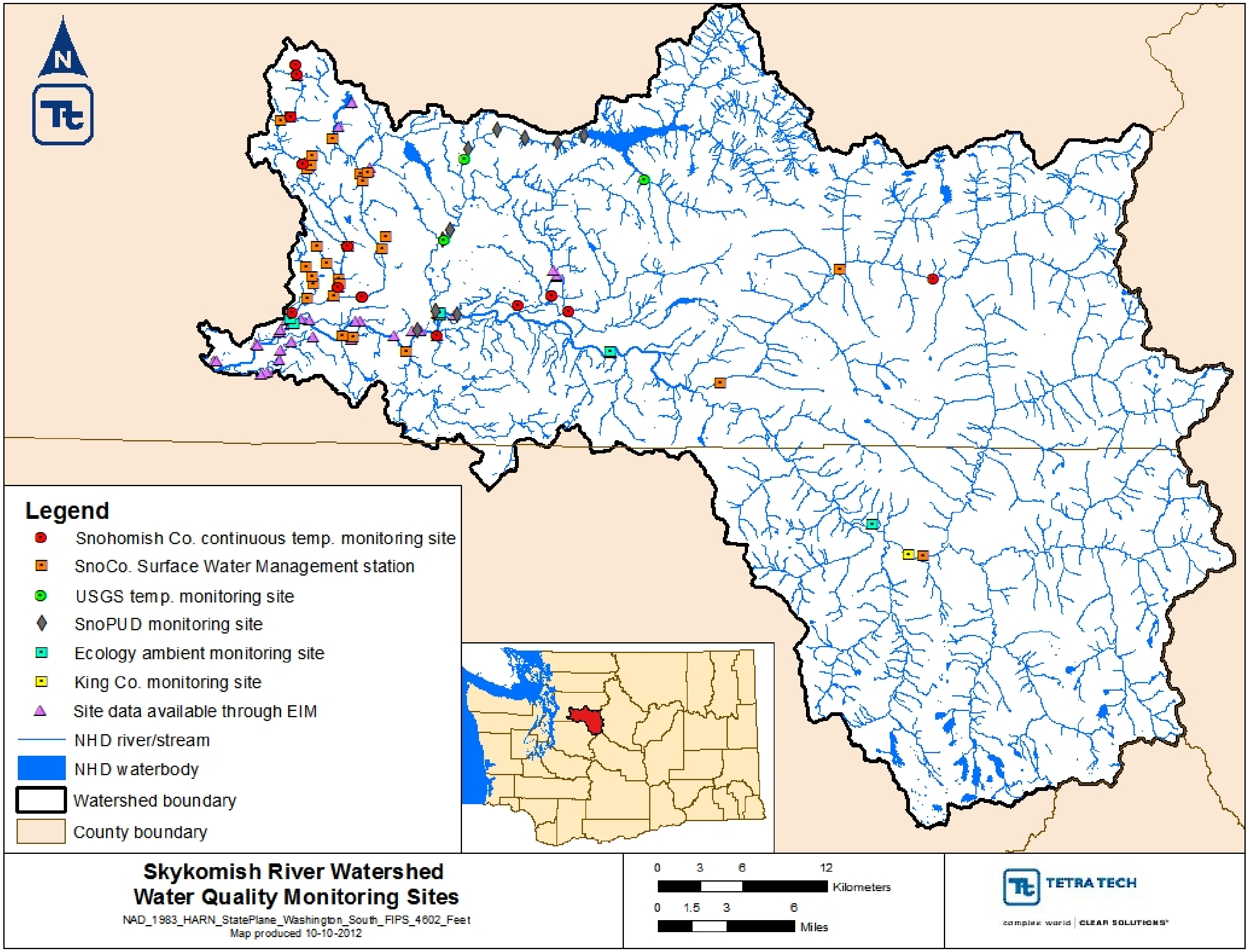

Figure 8. All discrete and continuous Skykomish River watershed monitoring stations.

The discrete monitoring stations in Table 5 may be useful to evaluate specific conditions during a snapshot in time on a particular reach that is not continuously monitored. The continuous data in Table 5 may be used in more detailed analyses because these data provide a more thorough representation of stream temperature conditions. These continuous data have been compared to the requirements in Ecology's credible data policy (www.ecy.wa.gov/programs/wq/qa/wqp01-11-ch2_final090506.pdf) and those data sets that do not meet the quality requirements have been flagged and excluded from further assessment (see Table 6 footnote). The data in Table 6 have also been separated into tributary and mainstem stations for additional analyses.

The suite of continuous data that meet the data quality requirements and are used in the historical data analyses are illustrated in Figure 9, which also identifies the stations as tributary or mainstem. The SnoPUD station locations have been estimated because latitudes and longitudes were not available when this document was developed; the location of the SnoPUD Big Four site is unknown and is not represented on the map.

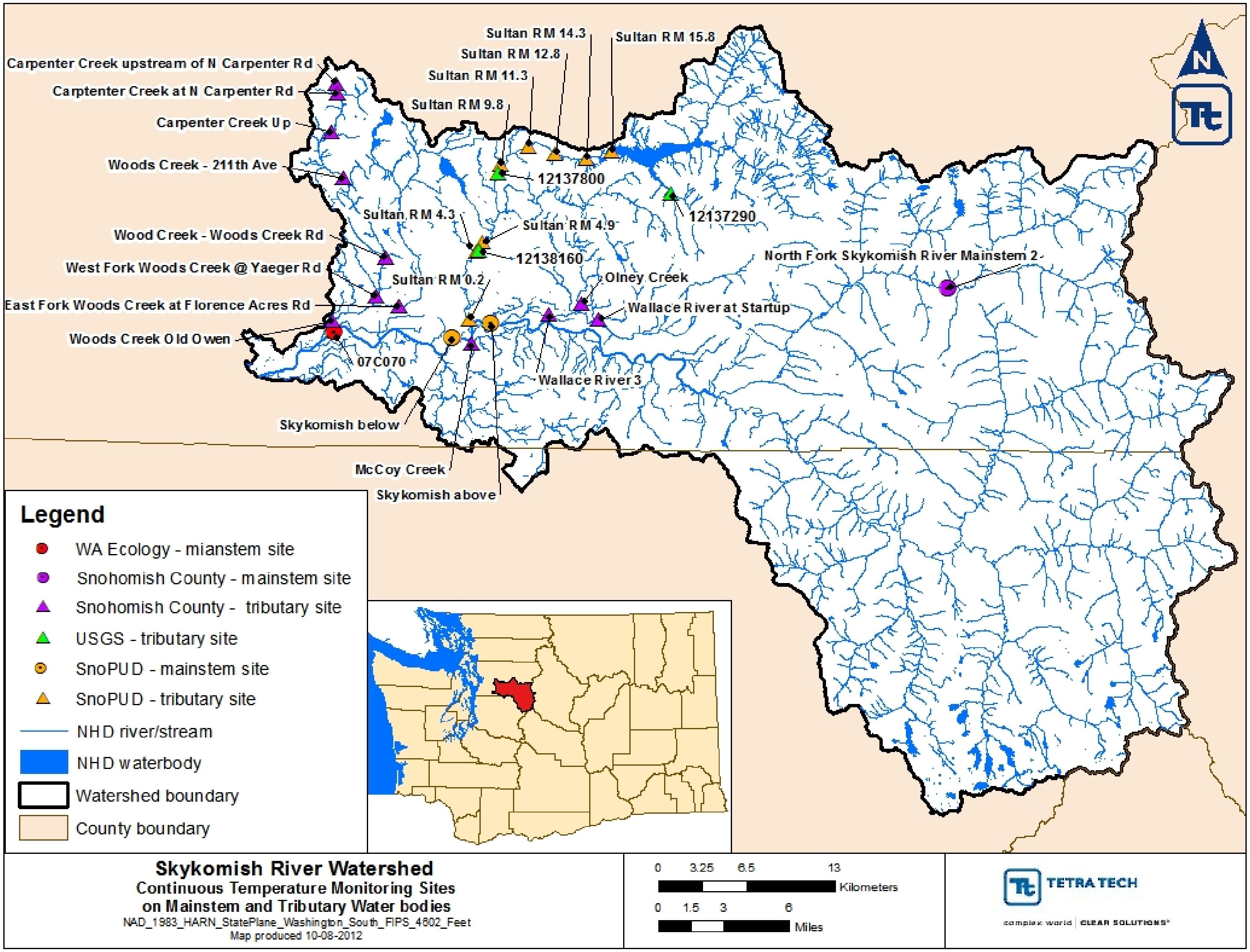

Figure 9. Skykomish River watershed continuous monitoring stations used for water quality assessment.

Mainstem Temperature Data Summary

Continuous water temperature data are available for four stations on the main river channel. Site 07C070 is on the Skykomish River mainstem at Monroe, upstream of the Monroe STP. A plot of 7-DADMax temperatures versus time for Site 07C070 appears in Figure 10. During all of the available sample years (2001, 2002, 2003, 2004, 2006), the average 7-DADMax exceeds 16 °C, with 100 % of the calculated 7-DADMax values exceeding 16 °C in 2006. Figure 11 illustrates the sampling locations in the watershed along with percent exceedances during the most recent year of data (100 % in 2006). Site 07C070 is near the watershed outlet and has the highest observed exceedance rates. There is an additional Snohomish County continuous monitoring station on the North Fork Skykomish River (North Fork Skykomish River Mainstem 2). Data are only available for the summer of 2010 at this station and the overall exceedance frequency was 17.4 %. Since data at this station was not collected for the same time periods as at station 07C070, a direct comparison between the two stations is not possible. However, there are fewer exceedances at this station during 2010 are than at station 07C070 from 2001-2006. The site at Monroe is farther downstream (Figures 11 and 12).

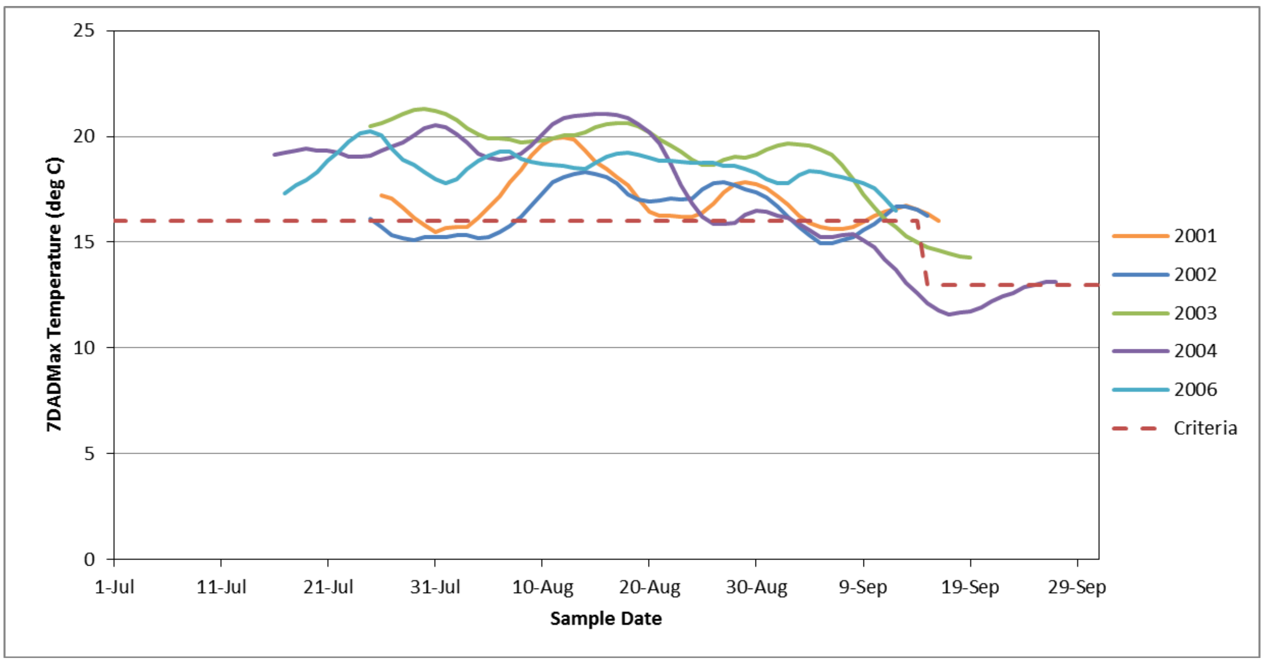

Figure 10. 7-DADMax temperatures for the 07C070 Ecology continuous temperature monitoring site.

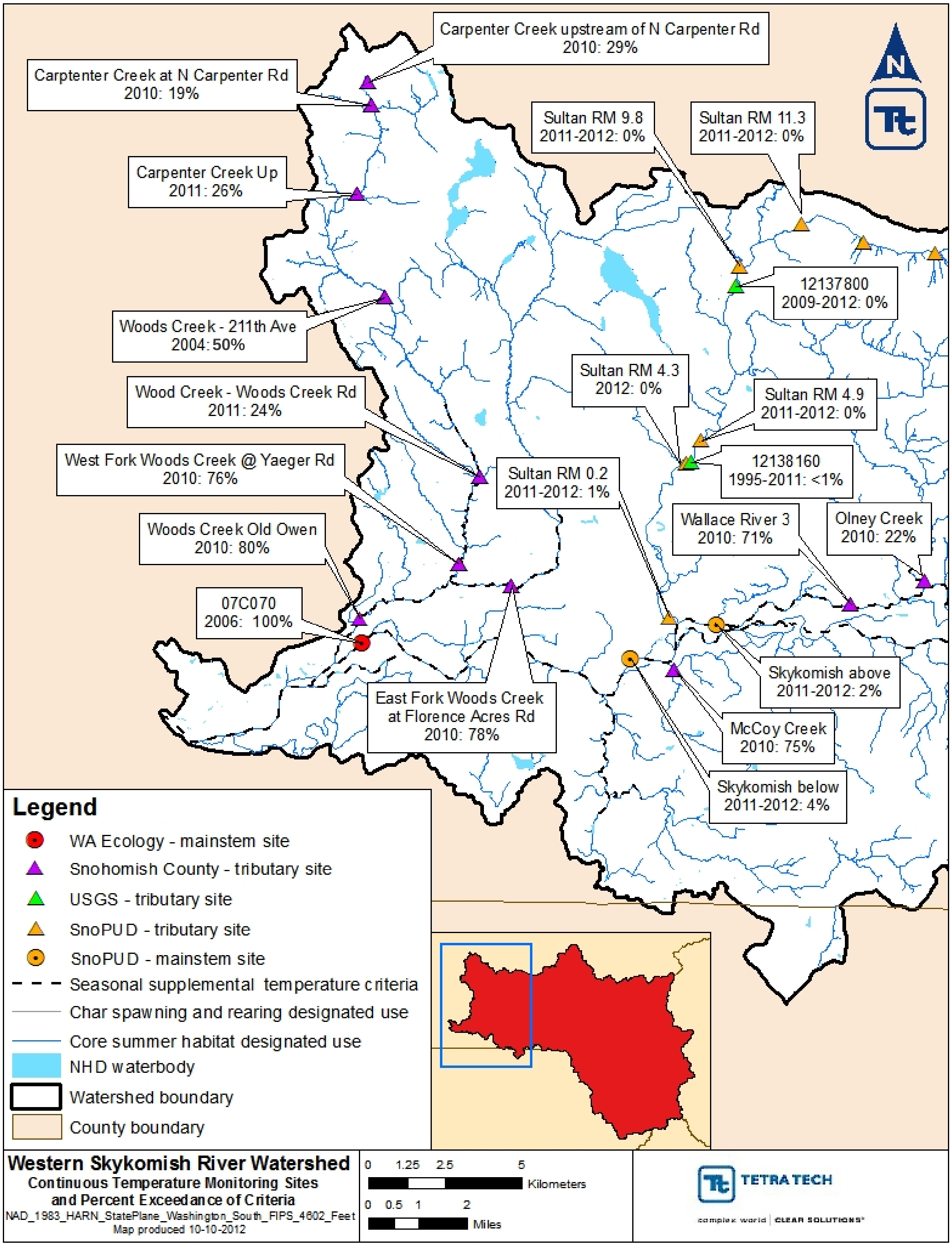

Figure 11. Percent exceedance at continuous temperature monitoring sites (western watershed).

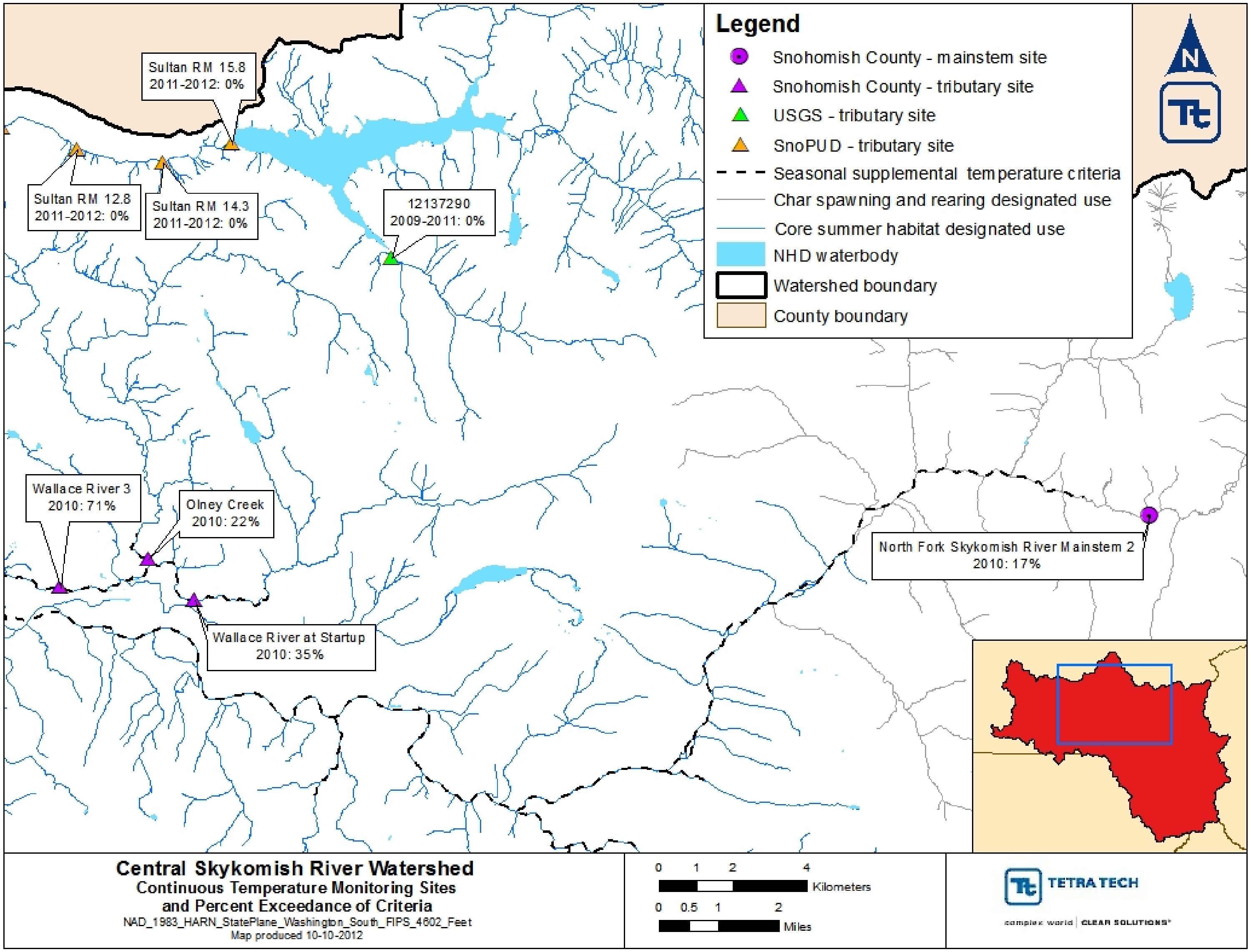

Figure 12. Percent exceedance at continuous temperature monitoring sites (central watershed).

SnoPUD has two monitoring stations on the Skykomish River near the confluence of the Sultan River. The exact locations of these stations are unknown; however, based on the station name, they are assumed to be on the Skykomish River immediately upstream and downstream of the Sultan River input. In 2011, the station below the confluence of the Sultan River exceeded the 16 °C water quality standard in September (Figure 13). The supplemental water quality standard of 13 °C applies at these stations beginning on September 15 and the station below the confluence exceeds this criterion at the end of September and into October 2011. The station above the confluence is below the water quality standards at all times during 2011 except for a few days after the seasonal criterion is applied in mid-September.

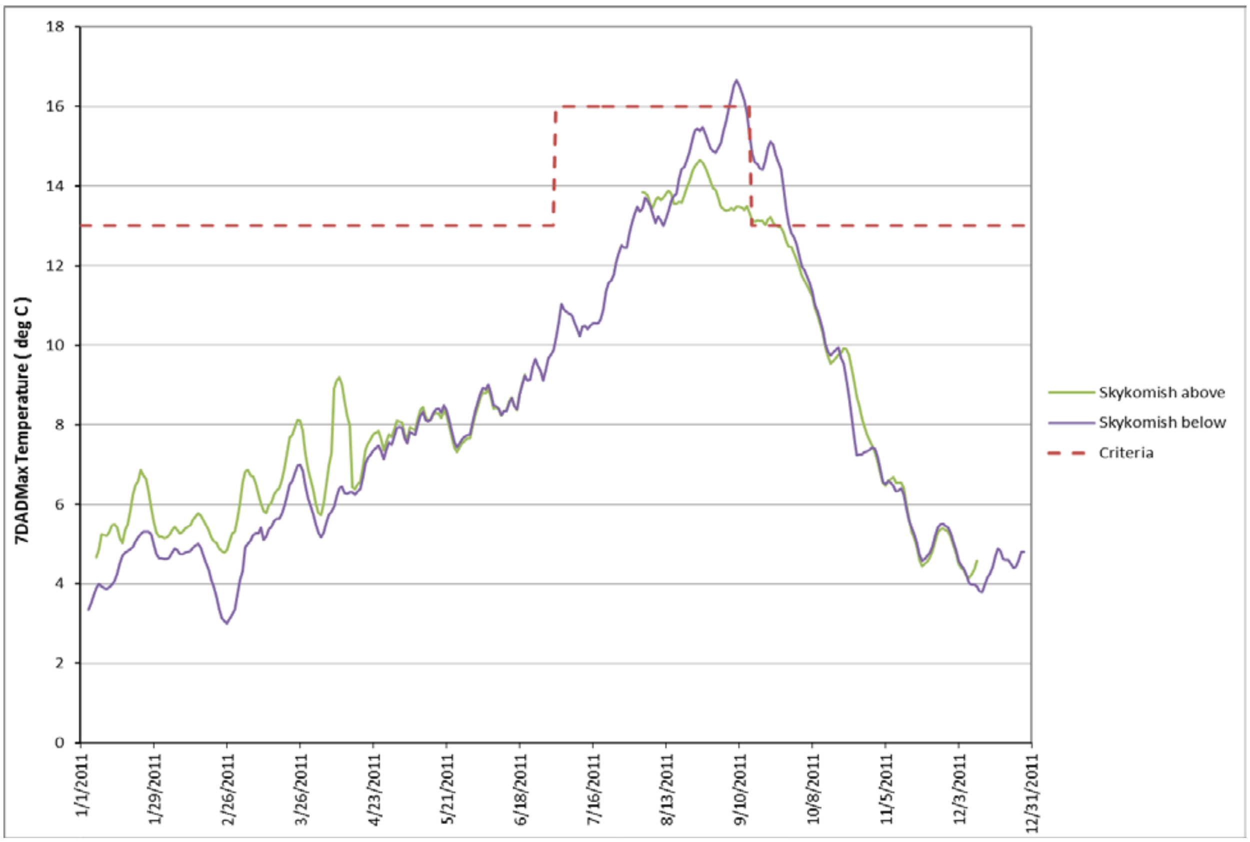

Figure 13. 7-DADMax temperatures for the SnoPUD Skykomish River continuous temperature monitoring sites.

Tributary Temperature Data Summary

Numerous continuous monitoring stations are located on tributaries to the Skykomish River; however, only stations with multiple years of data have been further evaluated. Data are available on Carpenter Creek[2], Woods Creek, Sultan River, Olney Creek, McCoy Creek, and Wallace River. Some of these water bodies are subject to the seasonal temperature water quality standard, while the 16 °C water quality standard applies year-round to other water bodies. Graphs of the 7-day DADMAX compared to the applicable water quality standards are presented below along with maps illustrating the exceedance rates for several groups of tributary stations.

For Carpenter Creek[2], the 16 °C water quality standard applies year-round. As shown in Figure 14, all three stations on the creek had exceedances of the criterion during the summer of 2010. 2010 was selected for illustration because it had data for multiple stations on Carpenter Creek (Table 6). The most downstream station (Carpenter Creek Up) had the highest temperatures during this summer period, but not in the spring. Figure 11 illustrates the percent exceedance at these stations for the most recent year of data. Overall, the exceedances at nearby stations were similar.

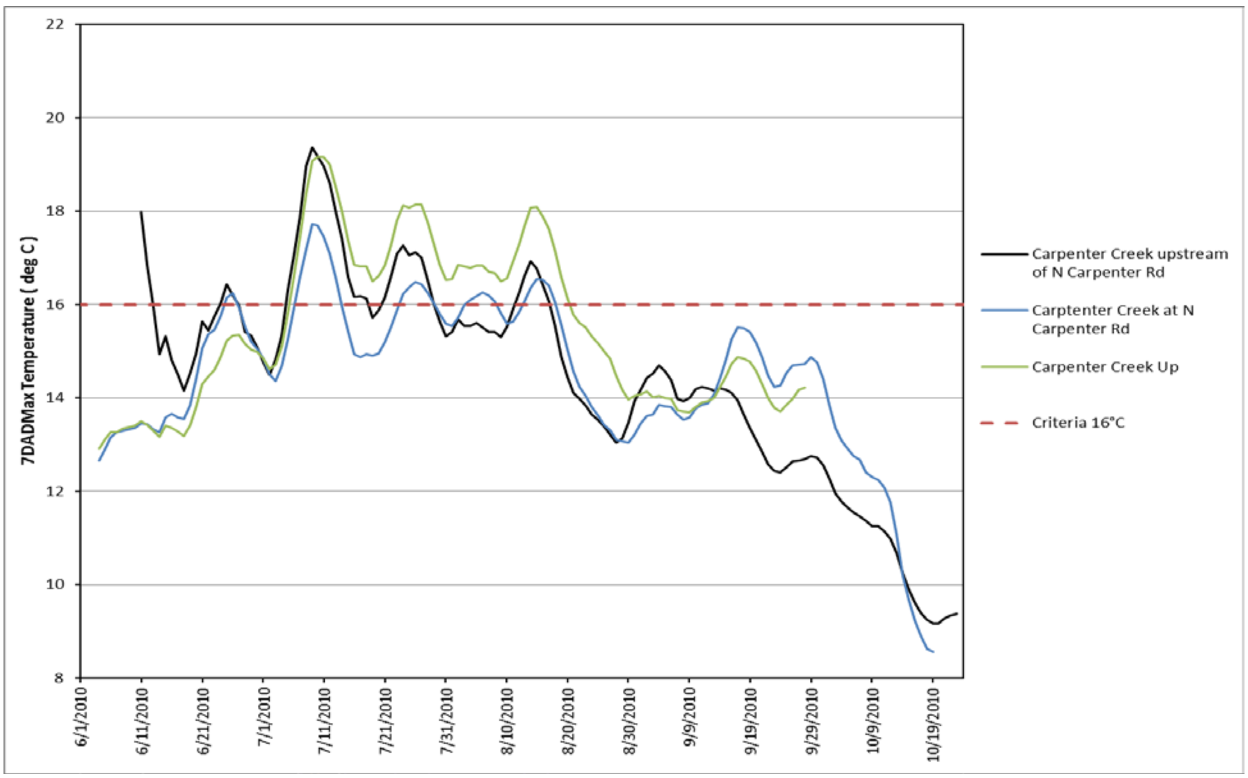

Figure 14. Water temperature at continuous monitoring stations on Carpenter Creek.

(note: Carpenter Creek is the headwaters to Woods Creek.)

[2] Carpenter Creek is the headwaters to Woods Creek.

Data for Woods Creek, which is downstream of Carpenter Creek, are illustrated in Figure 15. All stations except Woods Creek – 211th Avenue are subject to the seasonal criteria illustrated in the graph. The 16 °C water quality standard applies year-round to this station. All stations along Woods Creek (or its east and west fork) exceeded their criteria throughout the summer of 2010. 2010 was the year with greatest overlap between the various stations near Woods Creek. Woods Creek Old Owen is the most downstream station and had the highest temperatures and the highest percent exceedance for the most recent year of data (Figure 11). The spatial representation of the percent exceedances generally illustrates higher exceedances at the downstream stations in the Woods Creek drainage; however, exceedances for Woods Creek at 211th Avenue were higher than those of sites farther downstream.

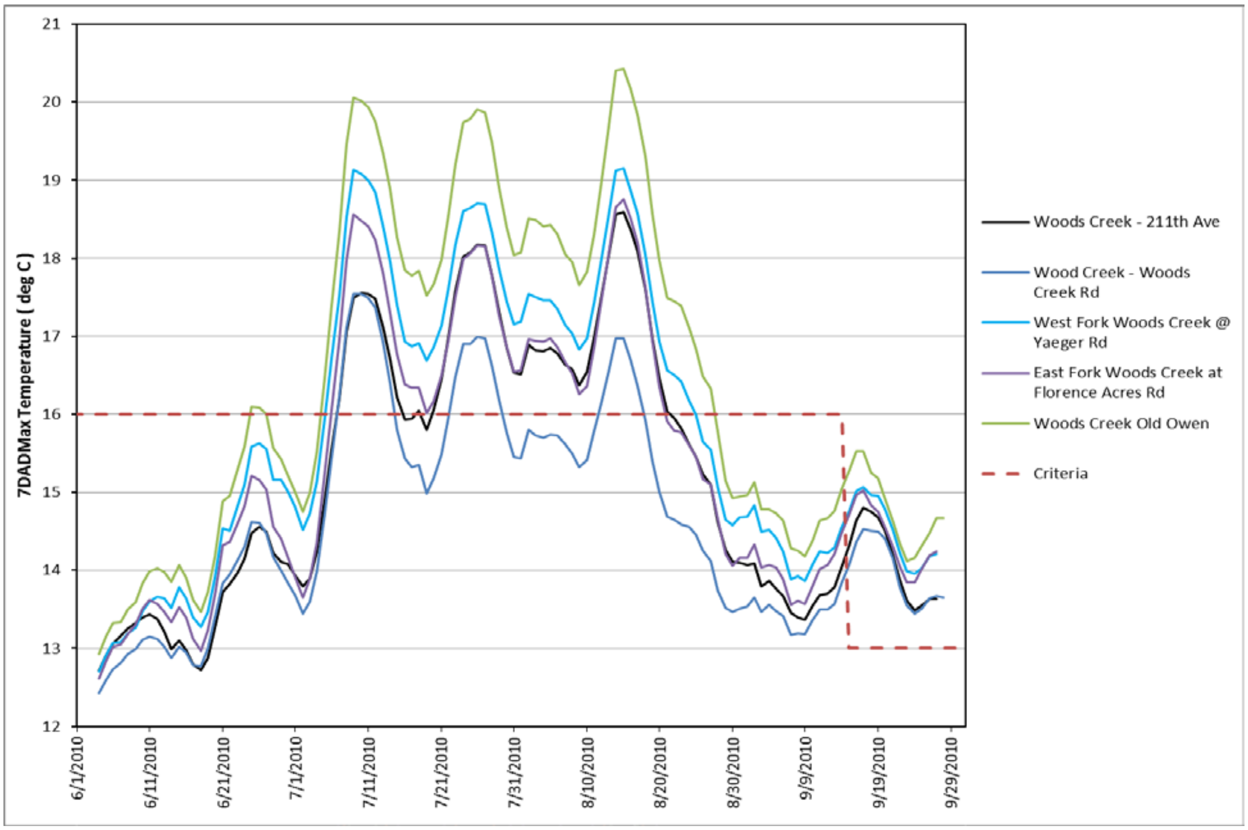

Figure 15. Water temperature at continuous monitoring stations on Woods Creek.

Several stations are monitored by SnoPUD and USGS on the Sultan River and are subject to year-round 16 °C water temperature criterion. Three of the U.S. Geological Service (USGS) stream gages discussed in the Streamflow section below also monitor for water temperature (USGS, 2012). The stations are on the Sultan River and the South Fork of the Sultan River. Station 12137290 is upstream of both dams, station 12137800 is downstream of Culmback Dam, and station 12138160 is downstream of both dams. SnoPUD stations at river mile 15.8, 12.8, and 9.8 are downstream of Culmback Dam and the remaining SnoPUD stations are downstream of both dams. During 2011, only the most downstream station exceeded the criterion for a brief period in September. 2011 is presented in the graphs because it has the most overlap between stations. All other stations were consistently below the criterion (Figure 16). SnoPUD station at river mile 15.8 has a fairly constant and low temperature as it is located immediately downstream of a dam. Figure 11 illustrates the percent exceedance at these stations for the most recent year of data. When comparing stations in this drainage, exceedances were similar and low.

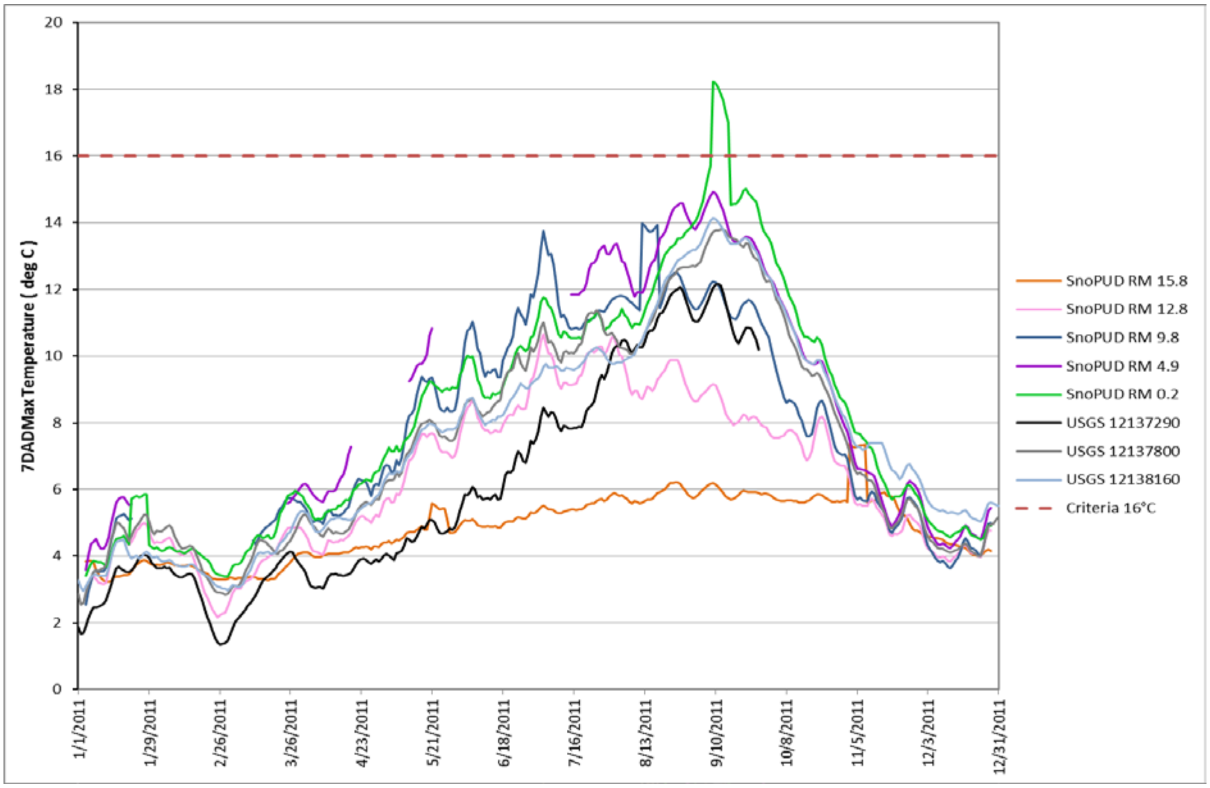

Figure 16. Water temperature at continuous monitoring stations on the Sultan River.

Several other creeks east (upstream on the Skykomish River) of the Sultan River confluence are monitored for water temperature. These creeks include McCoy Creek, Olney Creek, and Wallace River. The monitoring stations on each of these creeks are subject to the seasonal water quality criteria. McCoy Creek had the highest temperatures of these smaller creeks; however, temperatures at Wallace River 3 were similar during much of the summer of 2010 (Figure 17). At each of the stations, the stream temperatures decreased in late August 2010; however, the 13 °C water temperature criterion effective September 15 was exceeded at several stations (Figure 17). As shown in Figures 11 and 12, the percent exceedance at these stations for the most recent year of data reflect the results presented in Figure 17, as 2010 was the most recent year of data for each of these stations.

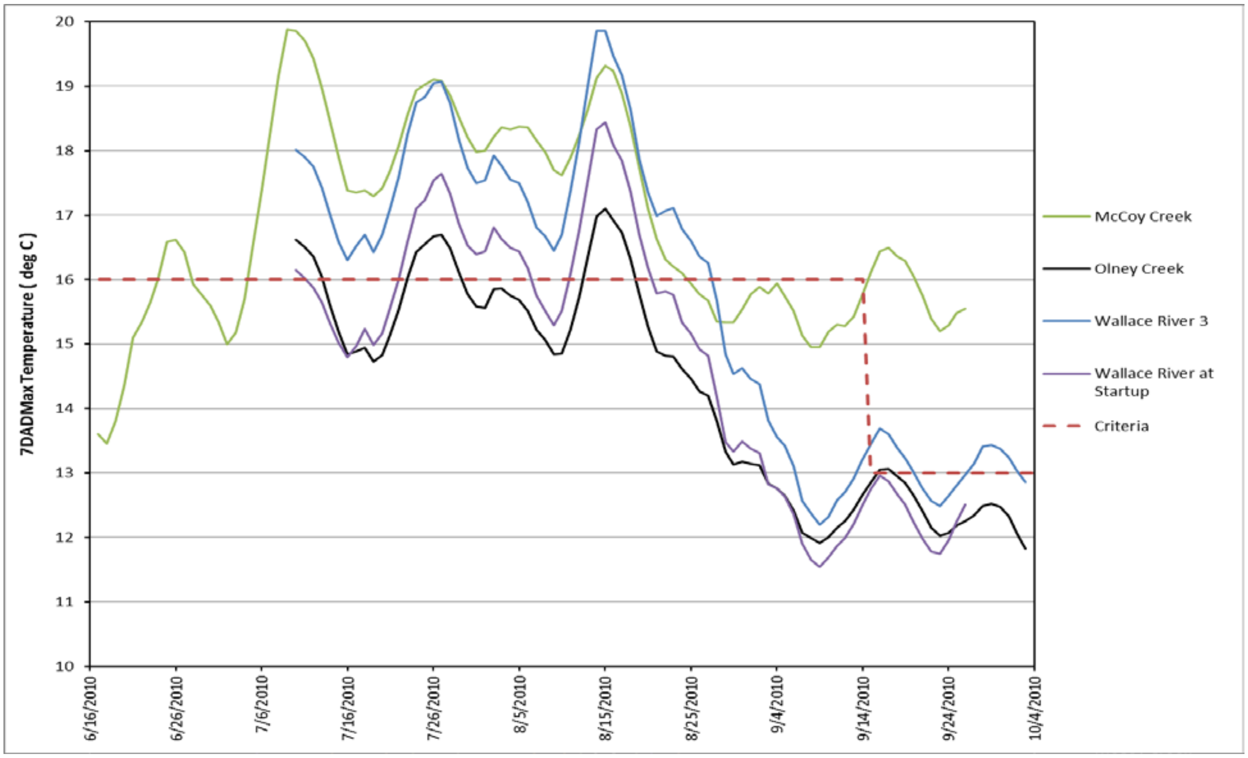

Figure 17. Water temperature at continuous monitoring stations on McCoy and Olney Creeks and on Wallace River.

In addition to the traditional continuous water quality data, other ambient monitoring data, often collected as part of special studies, can be used to characterize trends and describe conditions. For example, water temperature and air temperature data can be evaluated together to describe the relationship between these parameters. Continuous water temperature data are available at two tributary sites on Olney Creek (ERST_WF000699DW and ERST_WF000699UW). Figures 18 and 19 show plots of 7-DADMax temperatures and daily average air temperatures versus time for the sites on Olney Creek. At both sites, the water temperatures were generally higher in 2009 than 2008, which correlates with average air temperatures. Table 7 summarizes the air temperature data available for the Skykomish River watershed (Ecology, 2012a).

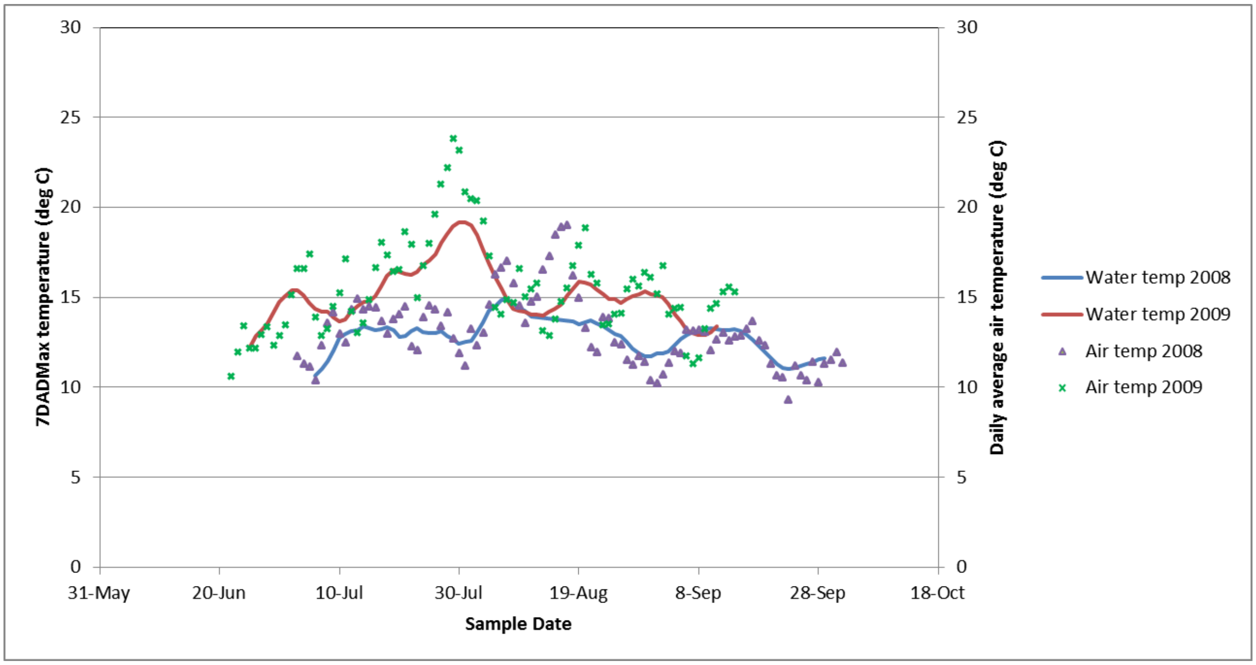

Figure 18. Water temperatures for the ERST_WF000699DW continuous temperature monitoring site.

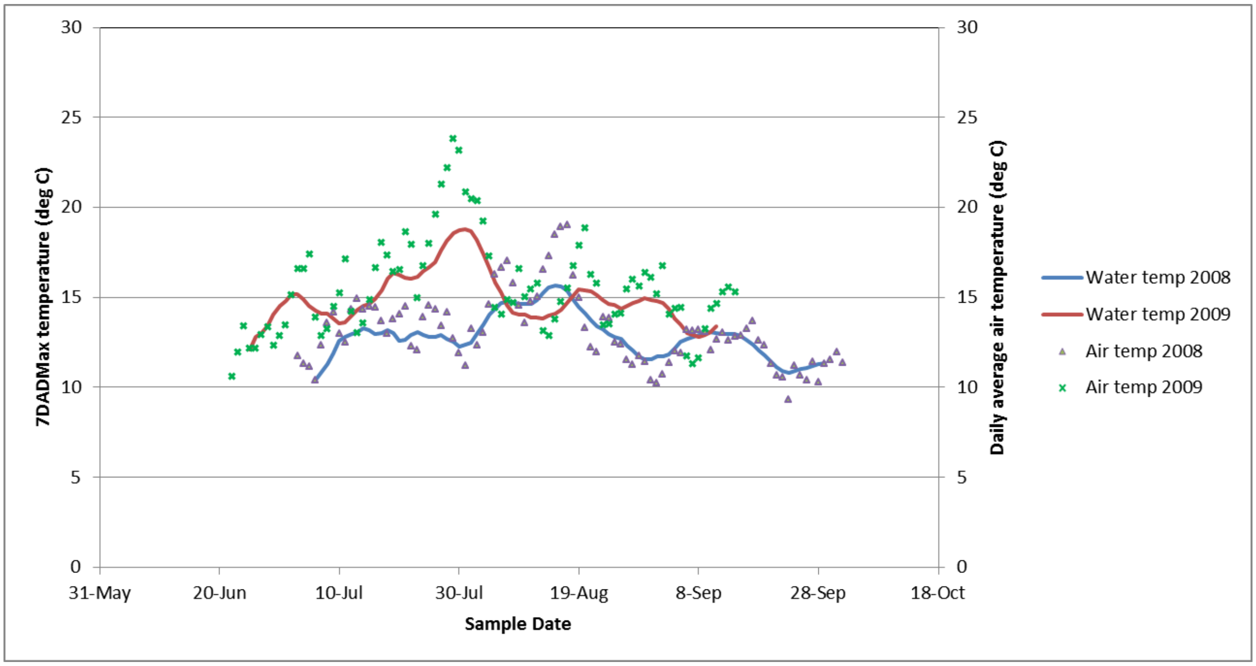

Figure 19. Water temperatures for the ERST_WF000699UW continuous temperature monitoring site.

Table 7. EIM air temperature monitoring data in Skykomish River watershed.

			Air temperature (°C)			
Site	**Start date**	**End date**	**Minimum**	**Maximum**	**Average**	**Count**
07C070[1]	07/23/01	09/30/04	5.8	31.4	16.33	783
ERST_WF000699DA[1]	07/03/08	09/14/09	4.23	31.06	14.29	177
RILEY(SITEA)	04/26/00	06/26/03	1	25	14.17	42
RILEY(SITEB)	04/26/00	04/22/03	1	32	16.35	40
RILEY(SITEC)	04/26/00	04/22/03	-2	32	15.65	40
RILEY(SITED)	05/11/00	04/22/03	-1	30	15.75	37
RILEY(SITEE)	04/26/00	04/22/03	-1	27	13.68	40
RILEY(SITEG)	12/18/01	04/22/03	4	21	10.22	18
ROBB DN	05/18/00	12/27/02	1.5	26	13.59	17
ROBB UP	09/05/01	12/27/02	1.5	26	13.59	16
SITE C1 UP	07/10/00	09/24/02	3	24	14.38	27
SITE C2 DN	07/10/00	09/24/02	4	22	13.73	27
SOMM DN	12/20/01	12/27/02	1.5	21	9	8
SOMM UP	12/20/01	07/22/02	4	26	13.38	8

[1] Continuous monitoring. Data are reported in EIM as daily min, max and average. (Ecology, 2006)

Streamflow Data

Ecology has monitored stream stage and flow at six stations along the Skykomish (Ecology, 2012b). Only one of these stations has data within the last 10 years. Additionally, the USGS has maintained nine flow gauges in the watershed since approximately 1980, but only four have data within the last 10 years (USGS, 2012). Four additional sites documenting streamflow were found on Woods Creek within Ecology's EIM database (Ecology, 2012a) – two of these only have streamflow data for a few months in 1996, while two of them have data from 1996-2006. Table 8 lists streamflow monitoring stations in the study area and summarizes the available data.

During the TMDL development process, it might be necessary to expand the available flow record. This can be done by establishing relationships between flows at long-term flow monitoring stations (07C070 and USGS 12134500, 12137290, 12137800, and 12138160) and flows at the other short-term flow monitoring stations. All flow monitoring stations in the watershed are shown in Figure 20. In addition, Snohomish County's SWMD has maintained three stations in the Skykomish River watershed to monitor staff depth: two sites on the North Fork at Index and Galena and one on the South Fork at Skykomish. The data from these stations cannot be downloaded at this time, but could be requested if deemed necessary.

Table 8. Discharge monitoring stations in the Skykomish River watershed.

Agency/ source	Station ID	Name	Start date	End date	Count	Discharge (cfs) Minimum	Discharge (cfs) Maximum	Discharge (cfs) Average
USGS	12133000	South Fork Skykomish River near Index, WA	01/01/80	09/30/82	1,004	378	36,200	2,392
	12134500	Skykomish River near Gold Bar, WA	01/01/80	06/12/12	11,852	303	88,400	3,978
	12135000	Wallace River at Gold Bar, WA	07/30/80	09/30/99	3,924	11	2,990	123
	12137200	Elk Creek near Sultan, WA	01/01/80	11/10/83	1,410	7.9	1,800	125
	12137260	Williamson Creek near Sultan, WA	01/01/80	11/10/83	1,399	17	4,040	181
	12137290	South Fork Sultan River near Sultan, WA	10/01/91	06/12/12	7,561	5	5,300	128
	12137800	Sultan River below Diversion Dam near Sultan, WA	05/01/83	06/12/12	10,636	35	16,600	197
	12138150	Sultan River below Champlain Creek near Sultan, WA	01/01/80	10/16/84	1,751	42	13,500	708
	12138160	Sultan River below power plant near Sultan, WA	10/01/83	06/12/12	10,483	157	20,100	754
Ecology[1]	07C070	Skykomish R. @ Monroe	11/30/70	03/21/11	1,260	490	59,400	6,019
	07C090	Skykomish R @ Sultan	08/09/71	09/25/74	28	965	41,900	6,371
	07C120	Skykomish R nr Gold Bar	08/25/47	09/19/01	229	327	23,700	3,697
	07C170	Skykomish R nr Miller R	10/11/76	09/19/77	24	420	5,400	1,290
	07F055	Woods Cr @ Monroe	07/12/71	09/25/74	29	20	2,110	335
	07E055	Sultan R @ Sultan	08/09/71	09/21/92	40	153	14,500	1,132
EIM	WCDN	Woods Creek Mainstem	02/13/96	04/09/96	6	82.6	308	298
	WCMF	Woods Creek Mainstem	02/13/96	09/07/06	10	39.4	148	100
	WCUP	Woods Creek Mainstem	02/13/96	04/09/96	5	14.8	51.1	35
	WCWF	Woods Creek West Fork	02/13/96	09/07/06	10	35.4	140	94

1 Some data points missing/low quality from this data set.

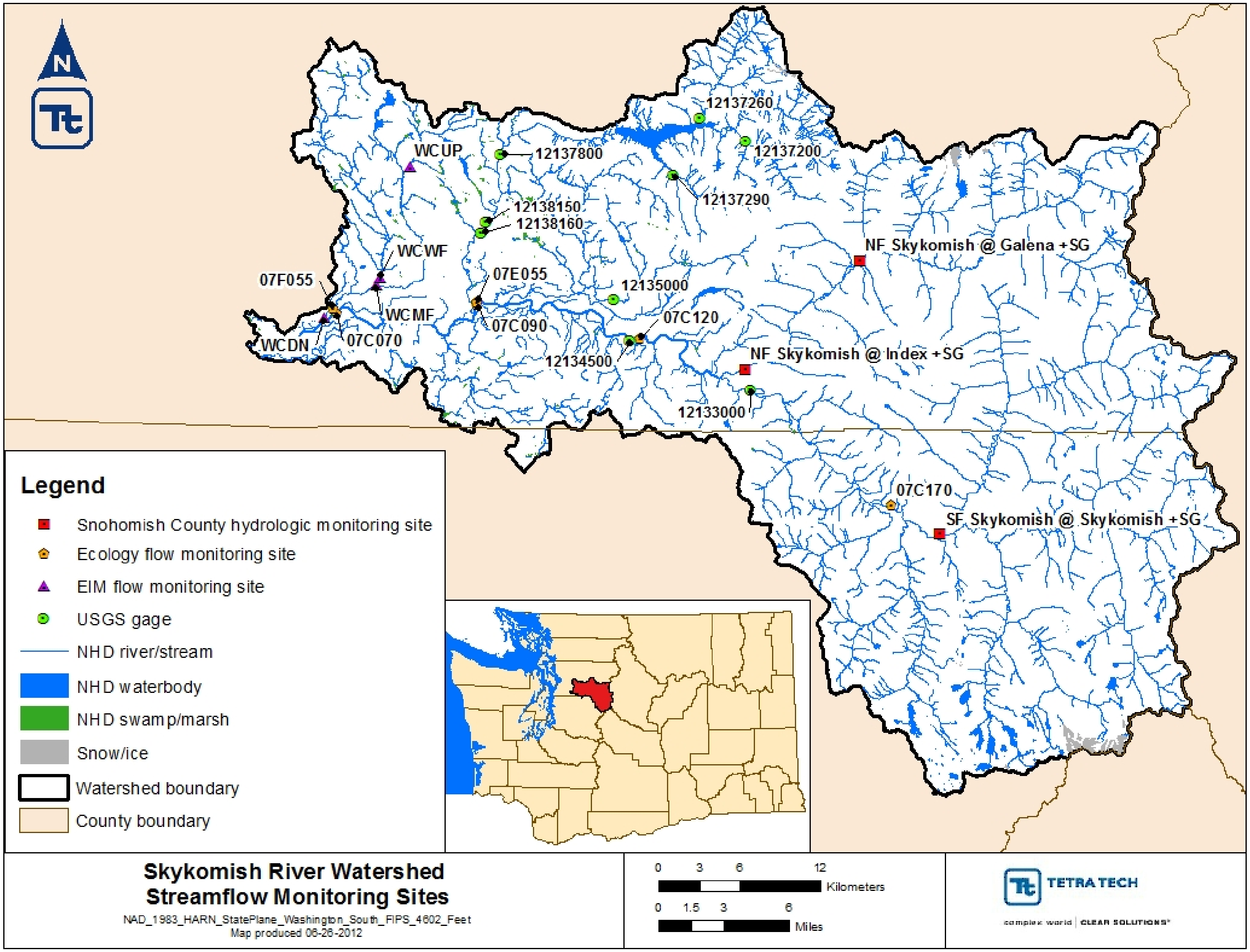

Figure 20. Skykomish watershed streamflow monitoring stations.

LiDAR Data

Light Detection and Ranging (LiDAR) is a technology used to develop high resolution topography data (PSLC, 2011). For this study, topography of the bare earth and vegetation height will be used in the Shade modeling (see *Model Calibration and Validation* section). LiDAR data from various sources and years are available for the Skykomish River watershed, as shown in Figure 21. Coverage includes the Skykomish River main branch, and portions of major tributaries, including Woods Creek. LiDAR data have been provided by Snohomish (2004) and King County (2011) (Teizeen Mohamedali, Ecology, personal communication, May 30, 2012). Additional data were downloaded from the Puget Sound LiDAR Consortium (PSLC). The following describes the available data sets, including source and year:

1. **Skykomish Mainstem (2004)**
- (Source: PSLC and Snohomish County)
- Covers lower Skykomish River and lower portions of the North and South Forks.
- Bare-earth (PSLC) and first return data (Snohomish County) is available.

2. **Skykomish Floodplain (2004)**
- (Source: PSLC)
- Only bare-earth data is available.

3. **Snohomish County Partial (2005-06)**
- (Source: PSLC)
- Covers northwest portion of the watershed.
- Bare-earth and first return data is available.

4. **Skykomish (2007)**
- (Source: PSLC)
- Covers the lower half of the North Fork Skykomish River.
- Bare-earth and first return data is available.

5. **SF Skykomish (2011)**
- (Source: King County)
- Covers most of the South Fork Skykomish River.
- Bare-earth and first return data is available.

The mainstem of the Skykomish River as well as the North and South Forks of the Skykomish River are covered by the LiDAR data. Some of the data are from 2004, which overlaps with the area in the watershed that has the most development (Figure 5). More recent data would better characterize the current shade conditions; however, the 2004 LiDAR data will be used if more recent data are not available at the time of the Shade modeling.

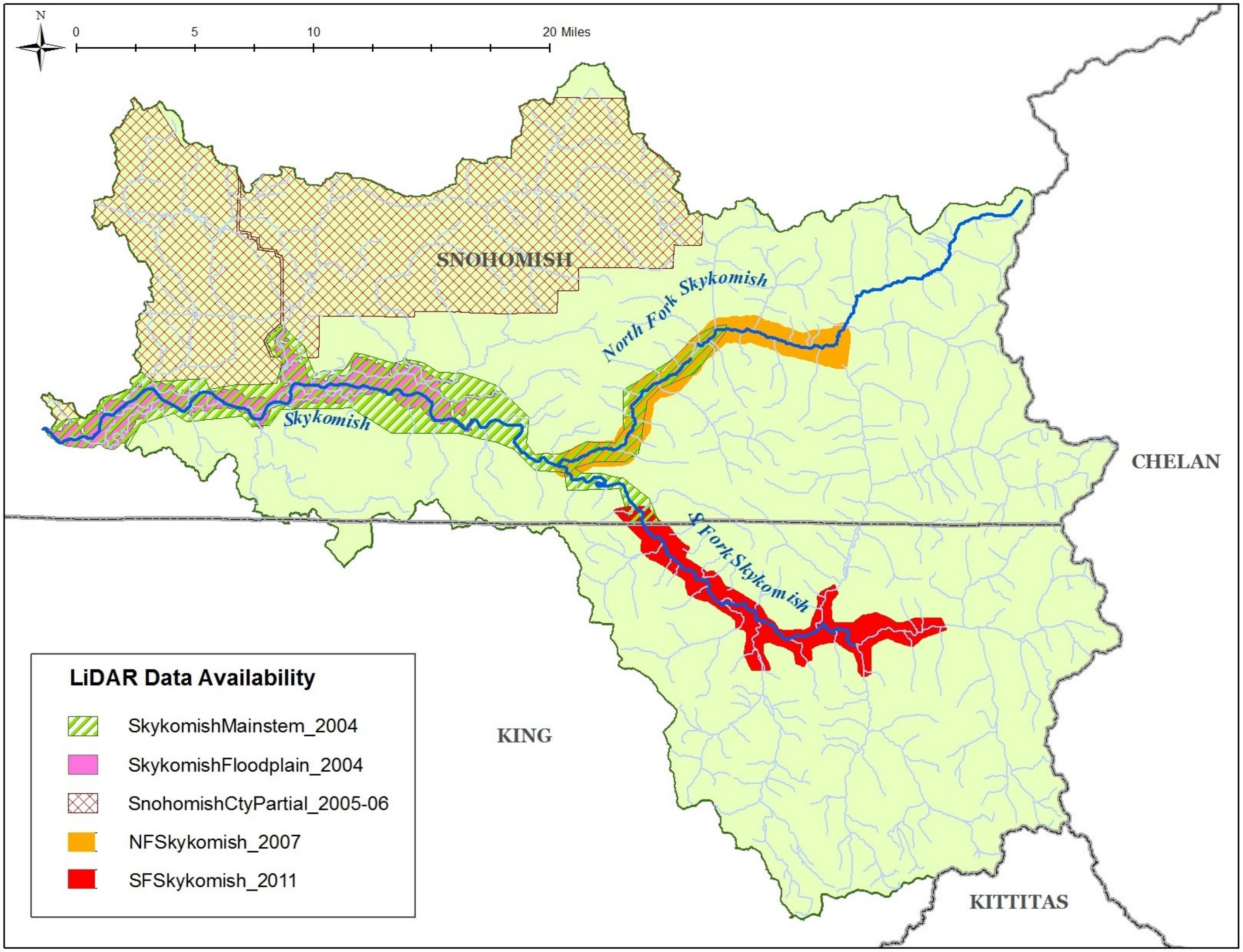

Figure 21. LiDAR availability in the Skykomish River watershed.

Goals and Objectives

Project Goal

The goal of this study is to address temperature problems in the Skykomish River watershed so that water quality is improved and beneficial uses are restored. More specifically, the goal is for the Skykomish River and its tributaries to meet state temperature water quality criteria through the identification of current and potential shade and the development of a Water Quality Improvement Report and Implementation Plan.

Study Objectives

The objectives of this study are to determine system potential mature riparian vegetation for the Skykomish River and its tributaries and to develop wasteload allocations for point source dischargers. Current vegetation along the mainstem (and key tributaries, if data are available) will be analyzed to help identify riparian areas that can be prioritized for vegetation plantings.

Objectives of the TMDL study are to:

- Evaluate existing temperature data for confirmation of impairments and for the historical data review.
- Characterize stream temperatures and processes governing the thermal regime in the Skykomish River watershed.
- Characterize current (if sufficient data are available) and system potential vegetation along the riparian zone of the Skykomish River and its major tributaries, focusing on those areas with documented impairments.
- Develop a Shade model for Skykomish River watershed to be used to develop shade allocations.
- Establish WLAs for relevant point sources, using a simple mixing equation.
- Establish a TMDL for temperature in the Skykomish River watershed.

Study Design

Overview

The temperature of a stream reflects the amount of heat energy in the water. Changes in water temperature within a particular segment of a stream are induced by the balance of heat exchange between the water and the surrounding environment during transport through the segment. If there is more heat energy entering the water in a stream segment than there is leaving, then the temperature will increase. If there is less heat energy entering the water in a stream segment than leaving, the temperature will decrease.

In the past, Ecology's temperature TMDL studies have typically recommended implementation of system potential shade to achieve temperature water quality criteria. Because the Skykomish watershed is relatively not urbanized and undeveloped these shade prescriptions can be calculated in the absence of developing a water temperature model. This approach has been coined by Ecology as an "innovative temperature TMDL", and will be used in this TMDL, focusing on the assessment of system potential mature riparian vegetation and resulting shade. Riparian vegetation is typically the key environmental component for maintaining cool stream temperatures by improving the shade received by the stream. Ecology and EPA will discuss other needed best management practices as needed in the final Water Quality Improvement Report and Implementation Plan.

Technical Analysis Framework

Addressing the principal study questions requires a technical framework that can estimate the conditions affecting water temperature, including effective shade. To predict relative thermal conditions throughout the Skykomish River watershed and to assess relationships with riparian vegetation characteristics and topography, the geographical information system (GIS)-based Shade model will be applied. The Shade model uses the relationships between sun position, stream location, date, stream orientation, and local topography with the riparian vegetation characteristics to compute a time-series of effective shade levels. Effective shade is defined as the fraction or percentage of the total possible solar radiation heat energy that is prevented from reaching the surface of the water.

The Shade model will evaluate increasing solar radiation levels at the stream surface due to anthropogenic causes resulting from the following conditions:

- Channel widening (increased width-to-depth ratios) that increases the relative stream surface area exposed to energy processes.
- Riparian vegetation disturbances that reduces stream surface shading through reductions in riparian vegetation height and density. (Shade is commonly measured as percent effective shade.)

The Shade model cannot evaluate potential changes in flow conditions (groundwater, flow, or velocity) or air temperature. Specifically, it does not represent reduced summer baseflows resulting from instream withdrawals, wells in hydraulic continuity with the stream, or altered streamflow patterns due to land-use practices that increase runoff instead of storage. However, reducing solar radiation to the channels is expected to be the most important source influencing stream temperature.

In addition to the nonpoint sources associated with riparian shade, point sources of heat are also present in the watershed. Specifically, the three treatment plants (one for drinking water and two for municipal wastewater) and stormwater (see Point Sources of Pollution section) have the potential to heat downstream waters. The heat contribution from point sources will be evaluated using a simple mixing equation considering both the volume of water discharged and the receiving water characteristics or other technical analyses. Analyses will be based upon a review of each facility's potential for causing significant stream heating, using temperature data upstream of the facility, the water quality standards, and specific effluent temperature data for each facility that is analyzed. Mixing equations and other technical analyses will be included and discussed in the TMDL.

The sources of increased stream temperatures will be examined as part of the Skykomish River watershed temperature TMDL to produce a loading capacity and load and wasteload allocations for the heat sources. The load allocations based on system potential shade are considered sufficient to attain the water quality standards, resulting in stream temperatures that are equivalent to natural conditions. Wasteload allocations, expressed as an allowable discharge temperature, will be calculated for each relevant point source to ensure water quality standards are met in the receiving waters.

Summary of the Technical Framework

The work described in this QAPP does not involve creating new simulation modeling software. Rather, it involves developing and applying an existing model—Shade.xls—to evaluate effective shade and applying a mixing equation to evaluate point source effluent. The rationale for selecting the proposed framework is described below.

The Shade model was selected to evaluate solar radiation along the streams using watershed-specific GIS-based data derived with the TTools ArcView extension, developed by Oregon Department of Environmental Quality (ODEQ). It was designed to develop GIS-based data from polygon and grids coverages. It specifically used these coverages to develop vegetation and topography data perpendicular to the stream channel and longitudinal stream channel characteristics such as the near-stream disturbance zone and elevation. Typical inputs into TTools are LiDAR data, digital elevation models (DEMs), and forward-looking infrared imaging systems (FLIR) temperature data. Stream width, aspect, topographic shade angles, elevation, and riparian vegetation will be sampled with TTools for incorporation into the Shade model. The riparian vegetation coverage will contain four specific attributes: vegetation height, general species type or combinations of species, percent vegetation overhang, and average canopy density of the riparian vegetation.

Ecology's Shade model (Shade.xls—a Microsoft Excel spreadsheet available for download at www.ecy.wa.gov/programs/eap/models.html) was adapted from a program that ODEQ developed as part of its HeatSource model version 6 (Ecology, 2003). Shade.xls calculates shade using one of two methods. The first is Chen's method, based on the FORTRAN program, HSPF SHADE. Y.D. Chen developed the method for his 1996 Ph.D. dissertation at the University of Georgia (Chen, 1996). It is further documented in the Journal of Environmental Engineering (Chen, et al. 1998a, 1998b). The second method is ODEQ's original method from the HeatSource model version 6. Documentation of ODEQ's HeatSource model is at www.heatsource.info and www.deq.state.or.us/wq/TMDLs/TMDLs.htm. The Shade model quantifies the potential daily solar load and generates the percent effective shade. Effective shade is the fraction of shortwave solar radiation that does not reach the stream surface because vegetative cover and topography intercept it. Effective shade is influenced by latitude/longitude, time of year, stream geometry, topography, and vegetative buffer characteristics, such as height, width, overhang, and density.

The Shade model requires physical and vegetation parameters such as stream width, aspect, topographic shade angles, elevation, and riparian vegetation to be sampled using the TTools GIS extension. Most data inputs for the Shade model are easily available (e.g., by aerial imagery and digital elevation models). TTools output will be used as input for the Shade model to generate longitudinal effective shade profiles. Riparian vegetation, stream aspect, topographic shade angles, and latitude/longitude will be used to estimate effective shade. The Contractor will determine system potential mature riparian vegetation using the *System Potential Vegetation Guidance* document developed by Ecology and calculate current (if available) and potential shade using Ecology's Shade model.

System potential mature riparian vegetation is defined as the vegetation that would naturally grow and reproduce on a site, given climate, elevation, soil properties, plant biology and hydrologic processes. Soils data are particularly useful to determine system potential mature vegetation and are available from Washington State Department of Natural Resources for a portion of the watershed. The soils layer site index provides the tree heights associated with system potential vegetation. During analyses, if the soils data are not adequate to determine system potential vegetation, the additional steps outlined in the *System Potential Vegetation Guidance* document will be followed. This guidance document describes the process used by Ecology in most temperature TMDLs throughout the state to date.

While the entire watershed will be evaluated to ensure all listings (including those on USFS lands) are addressed, LiDAR data are only available for the mainstem of Skykomish River and along several tributaries in the northwest portion of the watershed. Therefore the TMDL will focus on the mainstem of the Skykomish, Woods Creek, and the Sultan River. In addition, shade allocations based on curves of effective shade will be developed on the non-modeled tributary streams, including an analysis of soil types (using United States Department of Agriculture Natural Resources Conservation service soil survey data) to determine where similar vegetation can grow along the tributaries. Where LiDAR data are more than 5 years old, the Contractor will work with Ecology to obtain and incorporate data from the WDFW Habitat Work Schedule. The Contractor will document the actual or estimated current vegetation heights and density in the riparian zone.

The Contractor will calculate preliminary WLAs for point sources in the study area, using either mixing or loading equations as applicable for each discharge scenario. The specific approach taken for each point source will be detailed in the final WQIR/WQIP. If the approach selected by Ecology requires the calculation of the system potential temperature, it is anticipated that the rTemp water temperature model (Ecology, 2004) or other appropriate water temperature model will be used to perform this analysis.

Model inputs and outputs will be evaluated carefully and will take into consideration the surrounding, especially upstream, areas to ensure that highly localized characteristics (input parameters to the rTemp model) do not cause unrealistic results for the water body. The Contractor will document its WLA calculations, current and potential shade and natural temperatures.

Model Calibration

Environmental simulation models are simplified mathematical representations of complex real-world systems. Models cannot accurately depict the multitude of processes occurring at all physical and temporal scales. Models can, however, make use of known interrelationships among variables to predict how a given quantity or variable would change in response to a change in an interdependent variable or forcing function. In this way, models can be useful frameworks for investigating how a system would likely respond to a perturbation from its current state. To provide a credible basis for predicting and evaluating mitigation options, the ability of the model to represent real-world conditions should be demonstrated through a process of model calibration and corroboration (CREM, 2009).

Objectives of Model Calibration Activities

Model calibration is designed to ensure that the model is adequate to provide appropriate input to answer the study questions. The objective of this TMDL is to develop temperature TMDLs. The principal study questions to be addressed by modeling in this project are:

1. What are the sources of increased temperature in the Skykomish River watershed during critical summer low-flow conditions?
2. What are the TMDL allocations needed in the Skykomish River watershed to meet temperature standards?

Model Calibration Procedures

The GIS and modeling analysis will be conducted using specialized software tools:

- Ecology's TTools extension for ArcView will be used to sample and process GIS data for input to the Shade model.
- Ecology's Shade model (Ecology, 2003) will be used to estimate effective shade along the segments with LiDAR data (mainstem, Woods Creek, and the Sultan River). Effective shade

will be calculated at 50- to 100-meter intervals along the streams (and then may be averaged over 500- to 1000-meter intervals for final analyses).

Estimated system potential shade will also be developed. The TTools extension for ArcView will be used to sample and process GIS data for input to the Shade model.

While the Shade model will be developed only for the mainstem and selected tributaries, a shade curve will be used to represent the load allocations for all tributaries/streams in the rest of the watershed. Shade curves are an output of the Shade model and show how much effective shade can be achieved in streams within the watershed which have different channel widths and aspects (for a given system potential vegetation height and density). The TMDL and shade load allocations, therefore, cover the entire watershed, both listed and unlisted segments.

Given the limited observed data for comparison with Shade model output (such as hemispheric photographs), there is uncertainty associated with the model results. The effective shade results along various reaches will be assessed in several different ways. First, the reaches will be evaluated to ensure that results are meaningful. For example, streams with similar aspect, width, and tree heights within the watershed will be compared to ensure the predicted shade levels are similar to one another, i.e., within 20 % effective shade. In addition, stream results similar in aspect, width, and vegetation height and with observed monitoring data in nearby watersheds will be compared to reach results in the Skykomish watershed to ensure that the effective shade results are similar. Available 2006 canopy cover and land cover data for Western Washington (www.ecy.wa.gov/services/gis/data/landcover/landcover.htm) will also be used for comparison with the effective shade results. Newer data will be used if they become available. Although uncertainty exists due to the limited field data and calibration of the shade model to current conditions, the shade load allocations will be based on system potential effective shade for streams with different widths and aspects and not on current conditions.

Sampling Procedures

No water quality sampling will be conducted as part of this study.

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Measurement Procedures

No water quality field monitoring will be conducted as part of this study.

Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to address project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness. Quality objectives apply equally to laboratory and field data collected by Ecology, to data used in this study collected by entities external to Ecology, and to modeling and other analysis methods used in this study.

Measurement Quality Objectives

No water quality field monitoring will be conducted as part of this study.

Representative sampling

No water quality field monitoring will be conducted as part of this study.

Completeness

No water quality field monitoring will be conducted as part of this study.

Quality Objectives for Modeling or other Analysis

To help guide the interpretation of the technical information provided by the Shade model, several methods can be used to evaluate model results. These methods include:

- Graphical comparison for visual inspection.
- Statistical methods quantifying the comparison with nearby, similar streams that are calibrated for effective shade.

Specific numeric acceptance criteria are not specified for the model. Appropriate uses of the model will be determined by the project team after assessing the types of decisions to be made, the model performance, and the available resources. Model results will be compared to observed hemisphere photos or other data, if available.

Quality Control

No water quality field sampling or monitoring will be conducted as part of this study. Data quality will be evaluated as part of the EIM data submission process or through review of QAPPs for data used by Snohomish County Public Utility District (SNOPUD) or other entities.

Laboratory

No water quality field sampling will be conducted as part of this study.

Field

No water quality field monitoring will be conducted as part of this study.

Corrective Actions

No water quality field sampling or monitoring will be conducted as part of this study.

Data Management Procedures

Data Management for Environmental Data

All continuous data will be stored in a project database that includes station location information and data quality assurance (QA) information. This database will facilitate summarization and graphical analysis of the temperature data and also create a temperature data table for uploading to the EIM geospatial database. Any existing data or non-Ecology data used in the TMDL analysis must meet the same precision and bias criteria as data collected by Ecology.

Data Management for Modeling or other Analysis

The modeling software to be used for this project consists primarily of Ecology's Shade and rTemp models. Executables for the Shade and rTemp models are available as part of Ecology's *Environmental Assessment Program Models for Total Maximum Daily Load Studies* (www.ecy.wa.gov/programs/eap/models.html).

The Contractor will maintain and provide the final version of the model input, output, and executables to Ecology and EPA for archiving at the completion of the task. Electronic copies of the data, GIS, and other supporting documentation will be supplied to Region 10 with the final report. The Contractor will maintain copies in a task subdirectory (subject to regular system backups) and on disk for a maximum period of 3 years after task termination, unless otherwise directed by EPA.

Most work conducted by the Contractor for this task requires the maintenance of computer resources. The Contractor's computers are either covered by on-site service agreements or serviced by in-house specialists. When a problem with a microcomputer occurs, in-house computer specialists diagnose the problem and correct it if possible. When outside assistance is necessary, the computer specialists call the appropriate vendor. For other computer equipment requiring outside repair and not covered by a service contract, local computer service companies are used on a time-and-materials basis.

Routine maintenance of microcomputers is performed by in-house computer specialists. Electric power to each microcomputer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes.

All computer users have been instructed on the importance of routinely archiving work assignment data files from hard drive to compact disc or server storage. The office network server is backed up on tape nightly during the week. Screening for viruses on electronic files loaded on microcomputers or the network is standard company policy. Automated screening systems have been placed on all contractor computer systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

Audits and Reports

The Task Order Leader (TOL), or designee, will provide monthly progress reports to EPA. As appropriate, these reports will inform EPA of the following:

- Adherence to project schedule and budget.
- Deviations from the approved QAPP, as determined from project assessment and oversight activities.
- The impact of any deviations on model application quality and uncertainty.
- The need for and results of response actions to correct any deviations.
- Potential uncertainties in decisions based on model predictions and data.
- Data quality assessment findings regarding model input data and model outputs.

Data Quality (Usability Assessment)

Usability of Results from Modeling or Other Analysis

From a decision context, the primary function of a model is to predict the response of pollutants to changes in management. As such, an important input to the decision-making process is information on the degree of uncertainty that is associated with model predictions. In some cases, the risks or *costs* of not meeting water quality standards could be substantially greater than the costs of over-protection, creating an asymmetric decision problem in which there is a strong motivation for risk avoidance. Further, if two scenarios produce equivalent predicted results, the scenario with the smaller uncertainty is often preferable. Therefore, an uncertainty analysis of model predictions is essential.

As with any mathematical approximation of reality, the shade model is subject to significant uncertainties. Direct information on the aggregate prediction uncertainty will arise from the model corroboration exercise; however, further diagnostics are needed to understand the sources and implications of uncertainty.

The major sources of model uncertainty include the mathematical formulation and boundary conditions data uncertainty (e.g., LiDAR and DEM data). In many cases, a significant amount of the overall prediction uncertainty is due to boundary conditions, which, in this case, are largely related to the resolution of the collected data. These sources of uncertainty are largely unavoidable, but they do not invalidate the use of the model for decision purposes. Uncertainties in the mathematical formulation are usually of greater concern for decision purposes because they describe the relationships in the calibrated model.

For the Skykomish River TMDL project, the code for the Shade model has a history of testing and application, so outright errors in the coding of the models are unlikely. A simulation model, however, is only a simplified representation of the complexities of the real world. The question is not whether the model is *right* in the sense that it represents all processes, but rather whether it is useful, in the sense that it represents the important processes to a sufficiently correct degree to be useful in answering the principal study questions.

Additional aspects of model quality assessment are described below, including model development, software development, surveillance of project activities, and overall model output assessment and model usability.

Model Development Quality Assessment

This QAPP and other supporting materials will be distributed to all personnel involved in the work assignment. The designated quality control (QC) officer will ensure that all tasks described in the work plan are carried out in accordance with the QAPP. The Contractor will review staff performance throughout each development phase of each case study to ensure adherence to task protocols.

Quality assessment is defined as the process by which QC is implemented in the model development task. All modelers will conform to the following guidelines:

- All modeling activities including data interpretation, calculations, or other related computational activities are subject to audit or peer review. Thus, the modelers are instructed to maintain careful written and electronic records for all aspects of model development.
- If historical data are used, a written record on where the data were obtained and any information on their quality will be documented in the final report. A written record about the data's location on a computer or backup media will be maintained in the task files.
- If new theory is incorporated into the model framework, references for the theory and how it is implemented in any computer code will be documented.
- Any modified computer codes will be documented, including internal documentation (e.g., revision notes in the source code) and external documentation (e.g., user's guides and technical memoranda supplements).

The QC Officer will periodically conduct surveillance of each modeler's work. Modelers will be asked to provide verbal status reports of their work at periodic internal modeling work group meetings. The Contractor TOL or his/her designee will make monthly detailed modeling documentation available to members of the modeling work group.

Software Development Quality Assessment

New software development is not anticipated for this project. If any such development is required, the QC officer (or designee) will conduct surveillance on software development activities to ensure that all tasks are carried out in accordance with the QAPP and satisfy user requirements. Staff performance will be reviewed throughout the project to ensure adherence to task procedures and protocols.

Surveillance of Project Activities

Internal peer reviews within the Contractor's organization will be documented in the project file and QAPP file. Documentation will include the names, titles, and positions of the peer reviewers; their report findings; and the project management's documented responses to their findings. The Contractor TOL could replace a staff member if it is in the best interest of the task to do so.

Performance audits are quantitative checks on different segments of task activities. The Contractor QC officer (or designee) will be responsible for overseeing work as it is performed and for periodically conducting internal assessments during the data entry and analysis phases of the task. The Contractor TOL will perform surveillance activities throughout the duration of the task to ensure that management and technical aspects are being properly implemented according to the schedule and quality requirements specified in the data review and technical approach documentation. These surveillance activities will include assessing how task milestones are achieved and documented; corrective actions are implemented; budgets are adhered to; peer reviews are performed; data are managed; and whether computers, software, and data are acquired in a timely manner.

Output Assessment and Model Usability

Departures from Quality Objectives

The model developed for the project will be used to assess a series of study objectives, as summarized in the *Goals and Objectives* section. Quality objectives for the model are described in the *Quality Objectives for Modeling or Other Analysis* section.

Written documentation will be prepared under the direction of the relevant QC Officer addressing the calibrated model's ability to meet the specified criteria and provided to the TOL and QA Officer for review. If a model does not meet quality objectives, the QC Officer will first direct efforts to bring the model into compliance. If, after such efforts, the model still fails to meet the criteria, the Contractor will conduct a thorough exposition of the problem and potential corrective actions (e.g., additional data collection or modification of model code) and provide them to Ecology and EPA. The Contractor will also provide an analysis of the degree to which any model that does not fully meet quality objectives might still be useful for addressing study questions.

Reconciliation with User Requirements

Appropriate uses of the model will be determined by the project team on the basis of an assessment of the types of decisions to be made, the model performance, and the available resources. If the project team determines that the quality of the model calibration is insufficient to address the project goal and study objectives, the Contractor will consult with Ecology, EPA, and other team members, as appropriate, as to whether the levels of uncertainty present in the models can allow user requirements to be met, and, if not, the actions needed to address the issue.

A detailed evaluation of the ability of the modeling tools to meet user requirements will be provided in either the TMDL report or in internal technical memoranda between the contractor and Ecology, which may ultimately be included as an appendix to the TMDL report.

External Data Usability

Any water quality data that will be used in the TMDL analysis will meet the requirements of the agency's credible data policy (www.ecy.wa.gov/programs/wq/qa/wqp01-11-ch2_final090506.pdf). Note that this requirement does not apply to non-water quality data such as flow or meteorological data, as the credible data policy does not discuss the quality of flow or meteorological data.

External data (also referred to as secondary data) are data previously collected that are used for water body assessment as well as model development and calibration. Other secondary data will be assembled from other sources. Table 9 lists the secondary sources that are anticipated to be used as part of this project. The sections below provide details regarding how such secondary data will be identified, acquired, and used for this task.

Table 9. Sources of key secondary data.

Data type	Source
Water quality observations	Snohomish County Surface Water Management Division; Ecology; USGS; King County Water and Land Resources Division
Point source data	Discharge Monitoring Reports (Ecology)

Water Quality Observations

Water quality observations are required for TMDL development in addition to overall water body assessment (see Historical Data Review section). The Contractor has compiled and reviewed water quality monitoring data for Skykomish River watershed collected by Snohomish County SWMD, King County WLRD, Ecology, and USGS. Specifically, as noted in the Historical Data Review, monitoring included in situ, continuous data and instantaneous values.

Monitoring parameters include those identified in the temperature impairment listing. Data available from Snohomish County were downloaded from EIM and from the County's Surface Water Online Database (http://198.238.192.103/spw_swhydro/index.asp). All data obtained have associated data quality codes for QC purposes.

Any water quality data that will be used in the TMDL analysis will meet the requirements of the agency's credible data policy (www.ecy.wa.gov/programs/wq/qa/wqp01-11-ch2_final090506.pdf) and these data will be presented in the final TMDL. This ensures that the data for the TMDL analyses can be combined, compared, and analyzed comprehensively, resulting in a complete suite of data and information to characterize the study area.

Point Source Discharges

Several types of NPDES permitted facilities or activities exist in the Skykomish River watershed, as described above in the Watershed Description section. The most numerous is the construction and mining general permits, with nine construction permits and nine sand and gravel permits throughout the watersheds.

Snohomish and King Counties and WSDOT hold Phase I MS4 permits in the watershed. In addition, two communities (Everett and Monroe) hold Phase II MS4 permits. Those permits do not stipulate limits for temperature or flow. During this project, all available monitoring data from EPA Region 10 and Ecology will be assembled. When data from other sources are used, the project team will review the relevant QA protocols and document the results in the final TMDL report.

Quality Control for Secondary Measurements

The majority of the secondary measurements will be obtained from quality-assured sources. Associated water quality data will be verified using Ecology's Credible Data Policy before inclusion in TMDL analyses. For non-water quality data, the project team will determine how much effort should be made to find reports or metadata that might contain measurement performance criteria information and will perform general quality checks on the transfer of data from any source databases to another database, spreadsheet, or document.

Where non-water quality data are obtained from sources lacking an associated quality report, the Project Manager will evaluate data quality of such secondary data before using it. Additional methods that might be used to determine the quality of secondary data are:

- Verifying values and extracting statements of data quality from the raw data, metadata, or original final report.
- Comparing data to a checklist of required factors (e.g., analyzed by an approved laboratory, used a specific method, met specified data quality objectives, validated).

If it is determined that such searches are not necessary or that no quality requirements exist or can be established, but the non-water quality data must be used in the task, a disclaimer will be added to the deliverable indicating that the quality of the secondary data is unknown.

Project Organization

Table 10 shows the roles and responsibilities of USEPA, Ecology, and selected EPA contractor staff.

Table 10. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
U.S. Environmental Protection Agency (USEPA) Region 10		
Laurie Mann Phone: (206) 553-1583 mann.laurie@epa.gov	USEPA Technical Lead	Provides project oversight for this study as the USEPA Region 10 technical lead. Provides oversight for selection of analytical tools used to support TMDL development, data selection, and adherence to project objectives.
Jayne Carlin, Phone: (206) 553-8512 carlin.jayne@epa.gov	USEPA Task Order Manager	USEPA Region 10 Task Order Manager (TOM). Provides coordination of the technical and QA resources of the Agency and its contractors in executing this project.
Gina Grepo-Grove Phone: (206) 553-1632 grepo-grove.gina@epa.gov	Regional Quality Assurance Manager	USEPA Region 10 Quality Assurance Manager (QAM), or her designee. Reviews and approves the QAPP and any other deliverables, as requested by the TOM.
Washington State Department of Ecology (Ecology)		
Ralph Svrjcek Ecology, WQP, NWRO Phone: (425) 649-7165 rsvr461@ecy.wa.gov	Ecology Project Lead	Acts as point of contact between EAP staff and interested parties. Coordinates information exchange. Forms technical advisory team and organizes meetings. Reviews the QAPP.
Teizeen Mohamedali Ecology, EAP, NWRO Phone: (360) 715-5209 tmoh461@ecy.wa.gov	Modeling and technical support	Provides modeling and technical expertise for the project. Reviews the QAPP.
Tetra Tech, Inc.		
Amy King Phone: (720) 881/5874 amy.king@tetratech.com	Tetra Tech QAPP Author/ Task Order Leader	Writes sections of the QAPP. Coordinates with EPA TOM on technical and QA resources.
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EAP: Environmental Assessment Program.
QAPP: Quality Assurance Project Plan.
NWRO: Northwest Regional Office.
HQ: Headquarters.
WQP: Water Quality Program.

Project Schedule

Table 11 shows the anticipated project schedule for the Skykomish River TMDL project.

Table 11. Proposed schedule for TMDL report.

Final TMDL (WQIR) report: To be declared by EPA and the contractor

Laboratory Budget

No water quality field sampling will be conducted as part of this study.

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Appendix. Glossary, Acronyms, and Abbreviations

Glossary

Char: Fish of genus *Salvelinus* 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.

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.

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

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

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

Load allocation (LA): 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 (MS4s): 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, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Near-stream disturbance zone (NSDZ): The active channel area without riparian vegetation that includes features such as gravel bars.

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 NPDES 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.

Parameter: Water quality constituent being measured (analyte).

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

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

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

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

Salmonid: 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 water courses within the jurisdiction of Washington State.

System potential: The design condition used for TMDL analysis.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

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

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

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

Acronyms and Abbreviations

°C	degrees centigrade
7-DADMax	(See Glossary above)
BNSF	Burlington Northern and Santa Fe
cfs	cubic feet per second
DO	dissolved oxygen
DEM	digital elevation model
EAP	Washington State Department of Ecology Environmental Assessment Program
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FLIR	forward-looking infrared imaging systems
GIS	Geographic Information System software
LiDAR	Light Distance And Ranging
LA	(See Glossary above)
MS4	(See Glossary above)
NLCD	National Land Cover Database
NPDES	(See Glossary above)
ODEQ	Oregon Department of Environmental Quality
PSLC	Puget Sound LiDAR Consortium
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
SR	state route
SWMD	Surface Water Management Division
TMDL	(See Glossary above)
TOL	Task Order Leader
UA	urbanized area
USFS	United States Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WLA	(See Glossary above)
WQA	Water Quality Assessment
WQIP	Water Quality Implementation Plan
WQIR	Water Quality Improvement Report
WQP	Washington State Department of Ecology Water Quality Program
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation