WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Wind River Watershed Temperature Total Maximum Daily Load

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WASHINGTON STATE
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ECOLOGY

Wind River Watershed Temperature Total Maximum Daily Load

by

Greg Pelletier

Washington State Department of Ecology
Environmental Assessment Program

March 2002

Water Body Numbers: WA-29-1010, -1025, -1026, -1028, -1030, and -1040

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Abstract

The Wind River watershed covers 582 km^2 and supports a fifth-order stream system that discharges to the Columbia River near the town of Carson, Washington. The 303(d) listings for temperature in streams in the Wind River basin include Bear Creek, Eightmile Creek, and Trout Creek. Temperatures in the lower portion of Trout Creek have frequently been measured near or above the lethal limit for steelhead of about 24 degrees C.

This technical assessment uses effective shade as a surrogate measure of heat flux to fulfill the requirements of the federal Clean Water Act Section 303(d) for a Total Maximum Daily Load for temperature. Effective shade is defined as the fraction of incoming solar shortwave radiation above the vegetation and topography that is blocked from reaching the surface of the stream.

In addition to the load allocations for effective shade, other management activities are recommended for compliance with water quality standards for water temperature, including measures to reduce channel widths and water withdrawals.

Acknowledgements

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- Dustin Bilhimer and Tara Galuska (Ecology) for their analyses of GIS and other environmental data.
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- Joan LeTourneau for formatting the final report.

Introduction

Section 303(d) of the federal Clean Water Act mandates that the state establish Total Maximum Daily Loads (TMDLs) for surface waters that do not meet standards after application of technology-based pollution controls. The U.S. Environmental Protection Agency (EPA) has promulgated regulations (40 CFR 130) and developed guidance (EPA, 1991) for establishing TMDLs.

Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses. When a lake, river, or stream fails to meet water quality standards after application of required technology-based controls, the Clean Water Act requires the state to place the water body on a list of "impaired" water bodies and to prepare an analysis called a Total Maximum Daily Load (TMDL).

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the water body and still meet standards, the loading capacity, and allocates that load among the various sources. If the pollutant comes from a discrete source (referred to as a point source) such as an industrial facility's discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If it comes from a diffuse source (referred to as a nonpoint source) such as a farm, that facility's share is called a load allocation.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. The sum of the individual allocations and the margin of safety must be equal to or less than the loading capacity.

Pollutants and Surrogate Measures

The Wind River basin TMDL is developed for heat (i.e., incoming solar radiation). Heat is considered a pollutant under Section 502(6) of the Clean Water Act. Heat generated by solar radiation reaching the stream provides energy to raise water temperatures. Elevated summertime stream temperatures may result from anthropogenic influences (Figure 1). The following processes affect water temperatures in the Wind River watershed:

- Riparian vegetation disturbance that compromises stream surface shading, through reductions in riparian vegetation height and density (shade is commonly measured as percent effective shade)
- Channel widening (increased width-to-depth ratios) that increases the stream surface area exposed to energy processes, namely solar radiation
- Reduced summertime baseflows that result from instream withdrawals or from wells in hydraulic continuity with the stream.

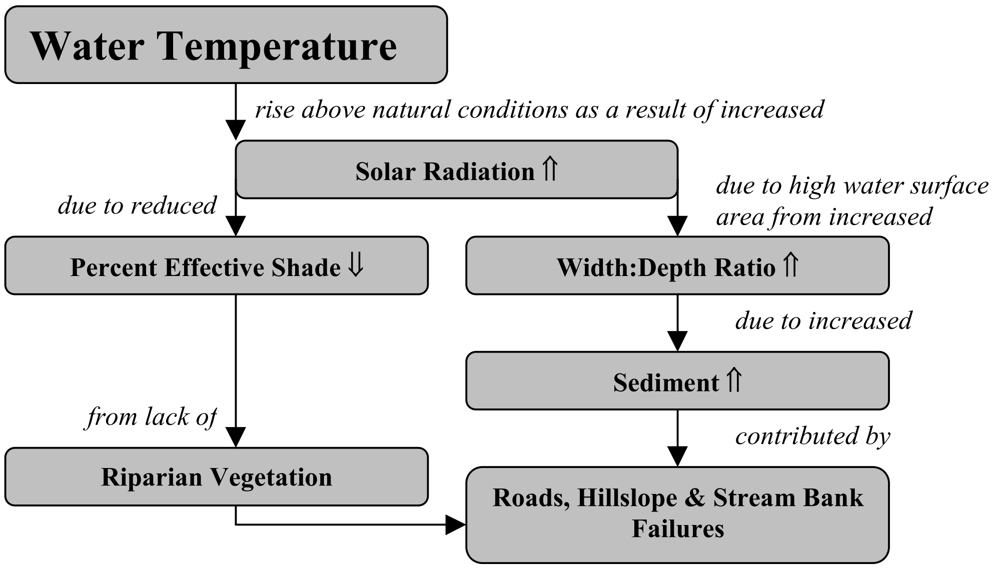

Figure 1. Shade and channel characteristics that impact water temperature (Boyd and Park, 1998)

Figure 2 shows the heat energy processes or fluxes that control heat energy transfer to and from a given volume of water.

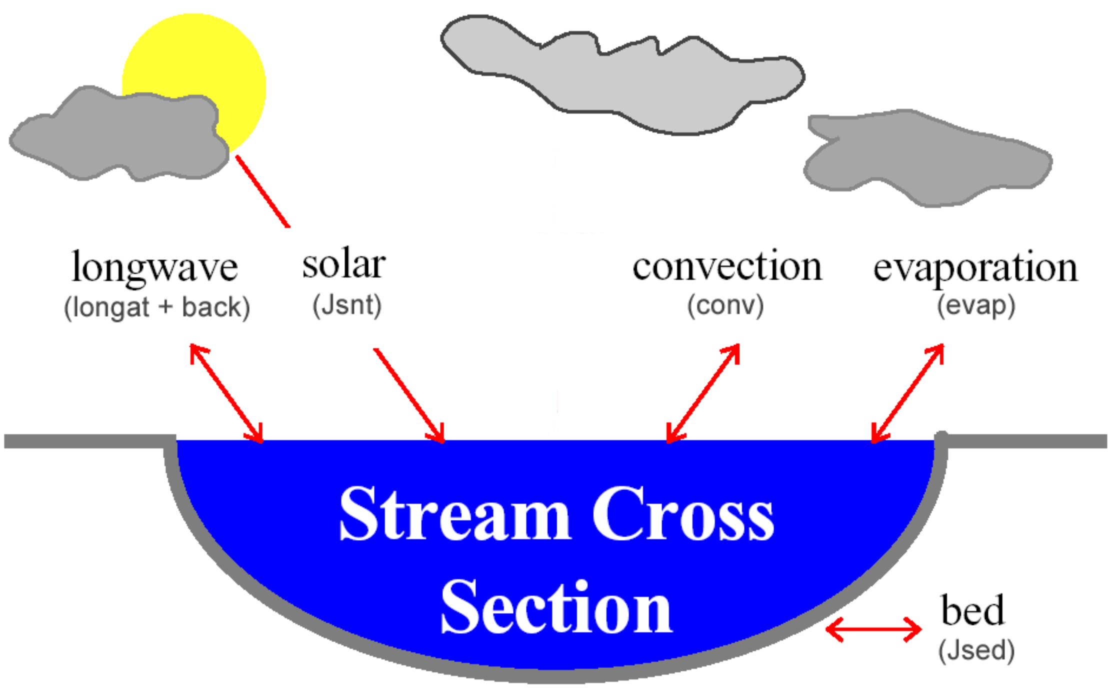

Figure 2. Heat transfer processes in the QUAL2K model that affect water temperature (net heat flux = solar + longwave atmosphere + longwave back + convection + evaporation + bed).

Figure 3 shows the relative importance of the fluxes in the heat budget for the Wind River near Carson for the current condition of riparian vegetation and the potential condition of riparian vegetation with a tree height of 160 feet with 85% canopy density.

The solar shortwave radiation flux is typically the dominant component of the heat budget in unshaded streams. The daily changes in water temperature typically follow the same pattern as solar radiation delivered to a stream. The solar shortwave flux can be controlled by managing vegetation in the riparian areas adjacent to the stream. Shade that is produced by riparian vegetation can reduce the solar shortwave flux (Figure 3). The net heat flux to a stream can be managed by increasing the shade from vegetation, which reduces the shortwave solar flux and causes a reduction in the water temperature in a stream.

Other processes, such as longwave radiation and convection, also introduce energy into a stream but at much smaller rates when compared to solar shortwave radiation (Beschta and Weatherred, 1984; Boyd, 1996). If streamflow increased the volume of water available, these same heat processes would be in place but would result in a smaller temperature gain to the stream.

This TMDL technical assessment for the Wind River uses riparian shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d). 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 accounts for the interception of solar radiation by vegetation and topography.

Heat loads to the stream are calculated in this TMDL in a numerical model (in units of calories per square centimeter per day or $cal/cm^2/day$). However, heat loads are of limited value in guiding management activities needed to solve identified water quality problems. Shade is used as a surrogate to thermal load as allowed under EPA regulations (defined as “other appropriate measure” in 40 CFR §130.2(i)). A decrease in shade due to inadequate riparian vegetation causes an increase in solar radiation and thermal load upon the affected stream section. Human-caused activities that contribute to lack of shade include livestock grazing, recreation, agriculture, and logging. Other factors influencing the distribution of the solar heat load have also been assessed, including increases in the wetted width-to-depth ratios of stream channels and instream flow.

The “Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program” (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

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

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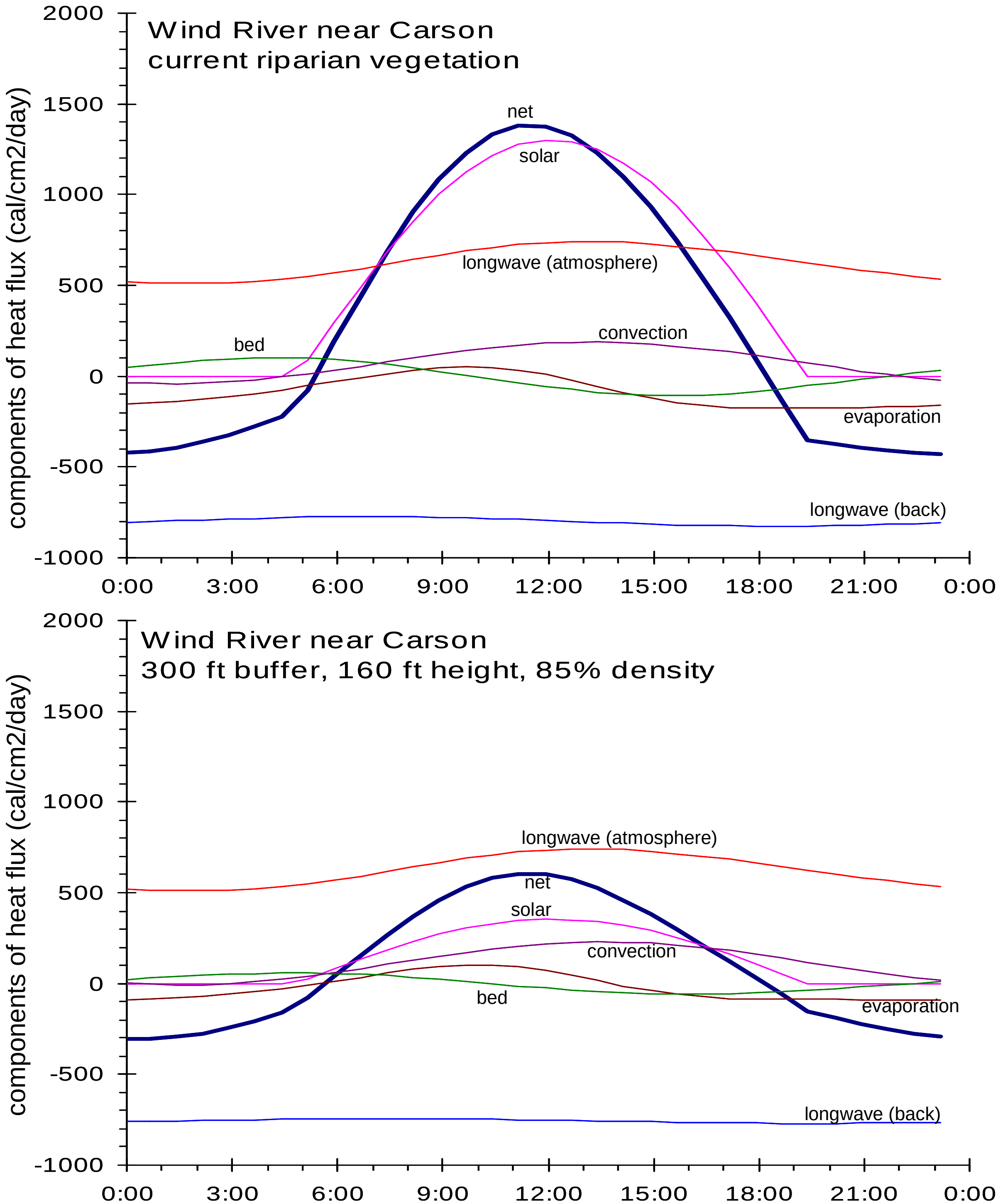

Figure 3. Heat fluxes for conditions of current and potential riparian vegetation (Wind River near Carson, UCD station wr-1, August 1 of a typical year).

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Background

The Wind River watershed covers 582 km^2 and supports a fifth-order stream system that discharges to the Columbia River near the town of Carson, Washington. The largest tributaries in the watershed are Trout Creek (88 km^2) and Panther Creek (107 km^2), which are each third-order systems (Figure 4). Elevations range from 22 m (74 ft) at the mouth of the Wind River to 910 m (2,985 ft) at the headwater of the Wind River. The climate in the watershed is a temperate marine climate. Most of the average annual precipitation of 280 cm (110 inches) occurs between November and April. Precipitation in the winter is mostly rain in the lower elevations and snow in the higher elevations.

Land Ownership

Land ownership in the Wind River watershed is a mixture of public and privately owned forest land (Figures 4, 5, and 6). Most of watershed is owned by the U.S. Forest Service (USFS) in a portion of the Gifford Pinchot National Forest (88% of the Wind River watershed). Approximately 9% of the watershed is privately owned, including the riparian area of the lower 27 km of the Wind River, the lower 2 km of Trout Creek, the lower 3 km of Panther Creek, and other downstream tributaries. The state of Washington Department of Natural Resources owns another 2.5% of the watershed in the southern part of the watershed, west of the mainstem of the Wind River.

The federally owned portion of the watershed is divided into four categories of management by the USFS according to the Forest Plan as follows (Figure 5):

- *Congressionally Withdrawn Areas* are managed to preserve the wilderness character. These areas are managed to allow for natural processes and provide opportunities for solitude, challenge, and inspiration. Within these objectives, and following a policy of nondegradation management, these areas provide for appropriate levels of recreational, scenic, educational, scientific, and in some cases, historical uses.

- *Administratively Withdrawn Areas* include wildlife, recreation, visual, and other areas not managed to provide timber outputs.

- *Late-Successional Reserves* are designated to protect and enhance conditions of late-successional and old-growth forest ecosystems, which serve as habitat for late-successional and old-growth related species including the northern spotted owl. These reserves are designed to maintain and enhance late-successional forests as a network of existing old-growth forest ecosystems, although their size, distribution, and management vary. These reserves represent a network of existing old-growth forests that are retained in their natural condition with natural processes, such as fire, allowed to function to the extent possible. The reserves are designed to serve a number of purposes. First, they provide a distribution, quantity, and quality of old-growth forest habitat sufficient to avoid foreclosure of future management options. Second, they provide habitat for populations of species that are associated with late-successional forests. Third, they will help ensure that late-successional species diversity will be conserved.

- The *Matrix* consists of those federal lands outside of the other USFS categories of designated areas. Most scheduled timber harvest not taking place in Adaptive Management Areas (none are in the Wind River watershed) will occur in the Matrix. The Matrix includes non-forested areas and forested areas that are technically unsuitable for timber production.

Wind River Watershed Council

There is an ongoing comprehensive watershed restoration effort that involves a high degree of multi-entity collaboration. All stakeholders in the basin, including public agencies, citizens, and private landowners are integrated in this restoration effort (Connolly, 2001). In 1997 the U.S. Fish and Wildlife Service provided funding to the Underwood Conservation District (UCD) to establish a pilot watershed project in the basin. A stakeholder group called the Wind River Action Committee (AC) was formed and was responsible for selecting demonstration restoration projects on private lands. The AC decided to establish a permanent position in the basin and was renamed the Wind River Watershed Council to better describe its operation. A Technical Advisory Committee (TAC) made up of specialists in fisheries, water quality, forestry, geomorphology, and education was created to provide technical support to the Council.

USFS Forest Plan

Forest plans are required by the National Forest Management Act (NFMA) for each National Forest. These plans establish land allocations, goals and objectives, and standards and guidelines used by land managers, other government agencies, private organizations, and individuals.

In 1990, the Gifford Pinchot National Forest published its first Land and Resource Management Plan (Forest Plan) developed under the NFMA and the National Environmental Policy Act (NEPA). The Forest has made several amendments to the plan since 1990.

In April 1993, President Clinton convened a Forest Conference in Portland, Oregon to address the human and environmental needs served by the federal forests of the Pacific Northwest and Northern California. President Clinton directed his cabinet to craft a balanced, comprehensive, and long-term policy for the management of Forest Service and BLM lands within the range of the northern spotted owl. The Northwest Forest Plan, completed in April 1994, amended 19 Forest Service and 7 BLM plans within the range of the northern spotted owl to include a comprehensive ecosystem management strategy. The Gifford Pinchot National Forest adjusted its 1990 Forest Plan in February 1995 to incorporate the amendment.

The Forest Plan requires establishment of Riparian Reserves, which are portions of watersheds where riparian-dependent resources receive primary emphasis and where special standards and guidelines apply. Riparian Reserves include those portions of a watershed directly coupled to

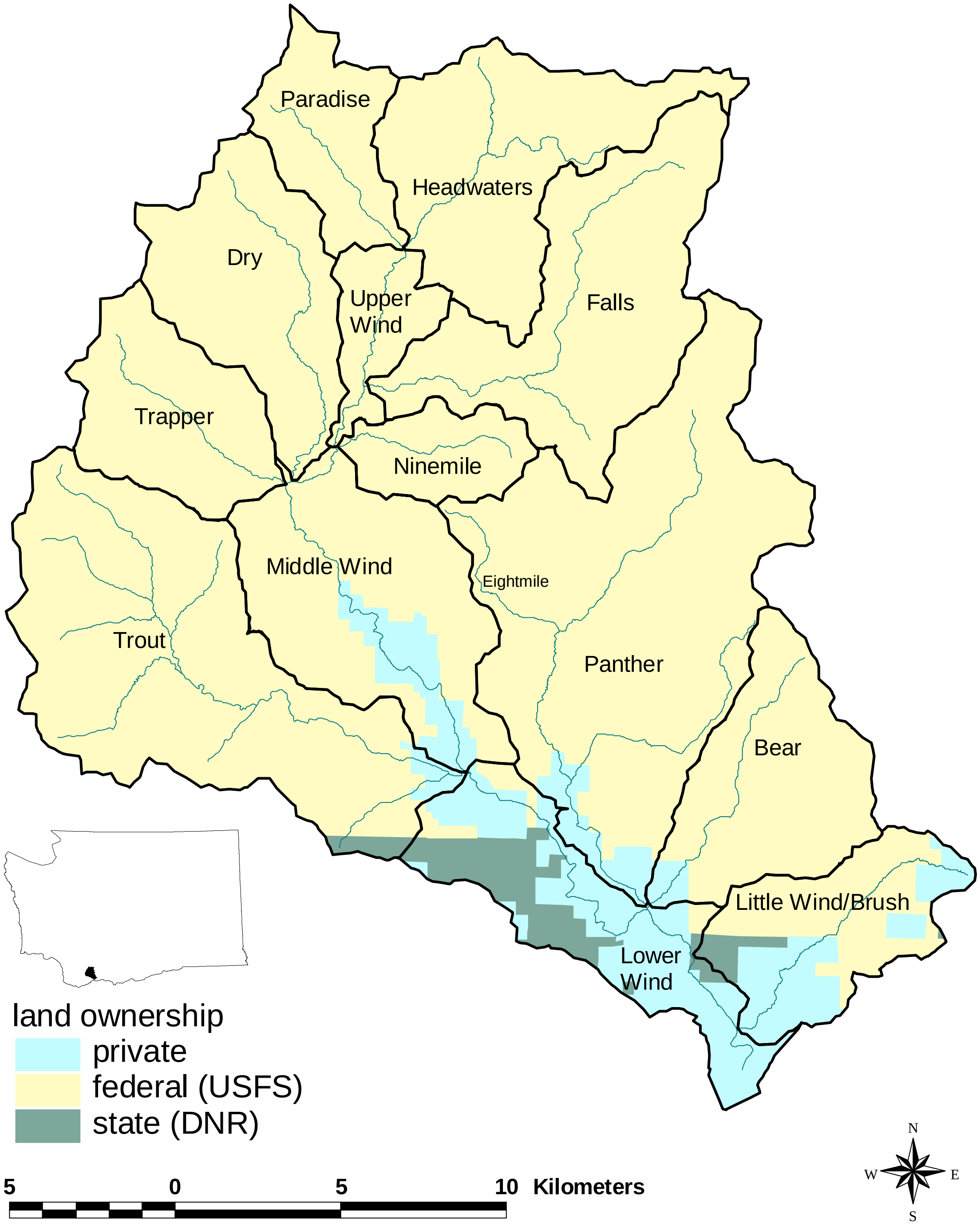

Figure 4. Land ownership in the Wind River watershed.

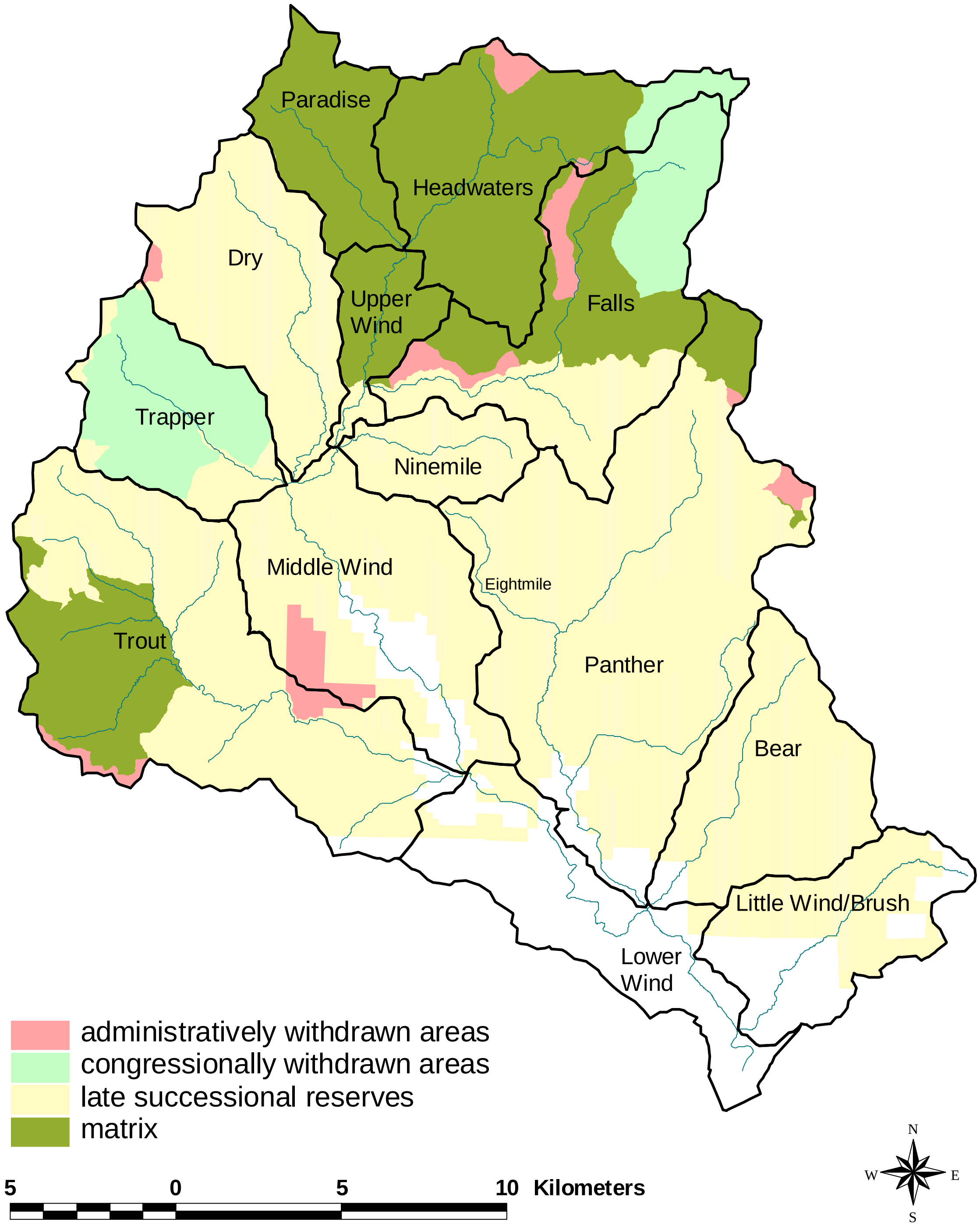

Figure 5. Land management in the Gifford Pinchot National Forest.

Figure 6. False color Landsat image of the Wind River watershed from July 7, 1991 (TM bands 5,4, and 3).

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streams and rivers. Riparian Reserves are required for maintaining hydrologic, geomorphic, and ecological processes that directly affect standing and flowing water such as lakes and ponds, wetlands, streams, stream processes, and fish habitats. Riparian Reserves include primary source areas for wood and sediment such as unstable and potentially unstable areas in headwater areas and along streams. Riparian Reserves occur at the margins of standing and flowing water, intermittent stream channels, ephemeral ponds, and wetlands. Riparian Reserves generally parallel the stream network but also include other areas necessary for maintaining hydrologic, geomorphic, and ecological processes.

Riparian Reserves are specified for categories of streams or water bodies as follows:

- Fish-bearing streams - Riparian Reserves consist of the stream and the area on each side of the stream extending from the edges of the active stream channel to the top of the inner gorge, or to the outer edges of the 100-year flood plain, or to the outer edges of riparian vegetation, or to a slope distance equal to the height of two site-potential trees, or 300 feet slope distance (600 feet total, including both sides of the stream channel), whichever is greatest.

- Permanently flowing nonfish-bearing streams - Riparian Reserves consist of the stream and the area on each side of the stream extending from the edges of the active stream channel to the top of the inner gorge, or to the outer edges of the 100-year flood plain, or to the outer edges of riparian vegetation, or to a slope distance equal to the height of one site-potential tree, or 150 feet slope distance (300 feet total, including both sides of the stream channel), whichever is greatest.

- Specific riparian buffer zones ranging from 100 to 300 feet of slope distance are also specified for the following categories of riparian areas: constructed ponds and reservoirs, and wetlands; lakes and natural ponds; seasonally flowing or intermittent streams, wetlands less than one acre, and unstable and potentially unstable areas; wetlands and meadows less than one acre in size.

In 1996, the USFS published the Watershed Analysis for the Wind River (USFS, 1996). This analysis enables watershed planning that achieves Aquatic Conservation Strategy objectives of the Forest Plan. The Watershed Analysis provides the basis for monitoring and restoration programs and the foundation from which Riparian Reserves were delineated.

TFW and the Forests and Fish Report

In 1986, as an alternative to competitive lobbying and court cases, four caucuses (the Tribes, the timber industry, the state, and the environmental community) decided to try to resolve contentious forest practices problems on non-federal land through negotiations. This resulted in the first Timber Fish Wildlife (TFW) agreement in February 1987. Recent events have caused the TFW caucuses to once again come together at the policy level to address a new round of issues. Under the Endangered Species Act, several salmonid populations have been listed or considered for listing. In addition, over 660 Washington streams have been included on a 303(d) list identifying stream segments with water quality problems under the Clean Water Act.

In November 1996, the caucuses - now expanded from the original four to six with the addition of federal and local governments - decided to work together to develop joint solutions to these problems. The Forests and Fish Report was presented to the Forest Practices Board of the state Department of Natural Resources and the Governor's Salmon Recovery Office in February 1999 (www.wa.gov/dnr/htdocs/fp/fpb/forests&fish.html). The goals of the forestry module of the Forests and Fish Report are fourfold:

- Provide compliance with the Endangered Species Act for aquatic and riparian-dependent species on non-federal forest lands
- Restore and maintain riparian habitat on non-federal forest lands to support a harvestable supply of fish
- Meet the requirements of the Clean Water Act for water quality on non-federal forest lands
- Keep the timber industry economically viable in the State of Washington.

To achieve the overall objectives of the Forests and Fish initiative, significant changes in current riparian forest management policy are prescribed. The goal of riparian management and conservation as recommended in the Forests and Fish report is to achieve restoration of high levels of riparian function and maintenance of these levels once achieved. For west-side forests such as the Wind River watershed, the Forests and Fish Report specifies riparian silvicultural treatments and conservation measures that are designed to result in "desired future conditions." Desired future conditions are the stand conditions of a mature riparian forest, agreed to be 140 years of age, and the attainment of resource objectives. These desired future conditions are a reference point on the pathway to restoration of riparian functions, not an endpoint of riparian stand development.

The riparian functions addressed by the recommendations in the Forests and Fish report include bank stability, the recruitment of woody debris, leaf litter fall, nutrients, sediment filtering, shade, and other riparian features that are important to both riparian forest and aquatic system conditions. The diversity of riparian forests across the landscapes is addressed by tailoring riparian prescriptions to the site productivity and tree community at specific sites.

Load allocations are included in this TMDL for forest lands in the Wind River Basin in accordance with the section of Forests and Fish entitled “TMDLs produced prior to 2009 in mixed use watersheds”. Also consistent with the Forests and Fish agreement, implementation of the load allocations established in this TMDL for private and state forestlands will be accomplished via implementation of the revised forest practice regulations. The effectiveness of the Forests and Fish rules will be measured through the adaptive management process and monitoring of streams in the watershed. If shade is not moving on a path toward the TMDL load allocation by 2009, Ecology will suggest changes to the Forest Practices Board.

Washington State Department of Natural Resources (DNR) is encouraged to condition forest practices to prohibit any further reduction of stream shade and not waive or modify any shade requirements for timber harvesting activities on state and private lands. Ecology is committed in assisting DNR in identifying those site-specific situations where reduction of shade has the potential for or could cause material damage to public resources.

New emergency rules for roads also apply. These include new road construction standards, as well as new standards and a schedule for upgrading existing roads. Under the new rules, roads must provide for better control of road-related sediments, provide better streambank stability protection, and meet current Best Management Practices. DNR is also responsible for oversight on these activities.

Water Withdrawals

Actual water withdrawals at any given time from streams in the Wind River watershed are not known, but information from the Water Rights Application Tracking database system (WRAT) was used as an indicator of the amounts of water that may be withdrawn (Tracy et al, 2001). The water quantity potentially withdrawn from surface waters for consumptive use is about 1.2 m^3/sec. Irrigation represents the majority of the consumptive withdrawal from surface waters.

A majority of water rights certificates, permits, claims, and applications in the WRAT database lie in Trout Creek, Panther Creek, middle Wind River, and lower Wind River watersheds (Table 1). The existing water rights could theoretically result in withdrawal and consumption of up to 76% of the flow in Trout Creek, 46% of the lower Wind River, 14% of the middle Wind River, and 13% of Bear Creek during low flows (Tracy et al, 2001). The bulk of the water appropriations in Trout Creek and Bear Creek are associated with two facilities: 1) the Wind River Nursery and Work Center on Trout Creek; and 2) the City of Carson's municipal water supply intake on Bear Creek.

Table 1. Estimated water use in the Wind River watershed (Tracy et al, 2001).

	estimated total surface water use (cms)	consumptive surface water use (cms)	estimated groundwater use (cms)
Upper Wind	0.014	0.014	0.000
Falls	0.000	0.000	0.000
Dry	0.003	0.003	0.000
Middle Wind	2.863	0.108	0.030
Trout	0.864	0.665	0.270
Panther	0.125	0.011	0.003
Bear	0.057	0.057	0.003
Lower Wind	3.775	0.365	0.056
Entire basin	7.699	1.223	0.362

Applicable Water Quality Criteria

This report and the subsequent TMDL are designed to address impairments of characteristic uses caused by high temperatures. The characteristic uses designated for protection in Wind River basin streams are as follows (Chapter 173-201A WAC):

> *"Characteristic uses. Characteristic uses shall include, but not be limited to, the following:*
> *(i) Water supply (domestic, industrial, agricultural).*
> *(ii) Stock watering.*
> *(iii) Fish and shellfish:*
> *Salmonid migration, rearing, spawning, and harvesting.*
> *Other fish migration, rearing, spawning, and harvesting.*
> *Clam and mussel rearing, spawning, and harvesting.*
> *Crayfish rearing, spawning, and harvesting.*
> *(iv) Wildlife habitat.*
> *(v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).*
> *(vi) Commerce and navigation."*

The state water quality standards describe criteria for temperature for the protection of characteristic uses. Streams in the Wind River basin are designated as either Class AA or Class A. The area of the watershed owned by the USFS that is contained in the Gifford Pinchot National Forest is designated Class AA. The other watershed areas downstream from the USFS land are designated Class A. These classes have different temperature criteria to protect the characteristic uses.

The temperature criteria for Class AA waters are as follows:

> *"Temperature shall not exceed 16.0°C…due to human activities. When natural conditions exceed 16.0°C…, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C."*

The temperature criteria for Class A waters are as follows:

> *"Temperature shall not exceed 18.0°C…due to human activities. When natural conditions exceed 18.0°C…, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C."*

During critical periods, natural conditions may exceed the numeric temperature criteria mandated by the water quality standards. In these cases, the antidegradation provisions of those standards apply.

> *"Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria."*

Water Quality and Resource Impairments

The 1996 and 1998 303(d) listings for temperature in the Wind River watershed are as follows:

- WA-29-1025 BEAR CREEK Temperature (listed in 1996 and 1998)

  Yakama Indian Nation data (submitted by Carroll Palmer on 2/28/96) show 6 excursions beyond the criterion in 1994.

- WA-29-1028 EIGHTMILE CREEK Temperature (listed in 1996 and 1998)

  Yakama Indian Nation data (submitted by Carroll Palmer on 2/28/96) show 7 excursions beyond the criterion in 1994.

- WA-29-1030 TROUT CREEK Temperature (listed in 1996, not listed in 1998 because of missing quality assurance data in Ecology's files).

  108 excursions beyond the criterion at USFS STORET station 03090502, at the NFS boundary, between 7/1/87 and 7/1/91.

The 303(d) listings for temperature are also confirmed by the recent and ongoing monitoring program by the USGS, USFS, and UCD (Figures 7 and 8, Appendix A). Temperatures in excess of the water quality standards have been observed between 1998 and 2000 throughout the watershed at numerous locations, including the following watercourse segments (identified by stream name, township, range, and section):

- Bear Cr (T03N R08E Sec05)
- Bear Cr (T04N R08E Sec33)
- Cedar Cr (T04N R075E Sec25)
- Compass Cr (T04N R06E Sec11)
- Crater Cr (T04N R06E Sec11)
- East Fork Trout Cr (T04N R06E Sec11)
- Eightmile Cr (T04N R075E Sec12)
- Eightmile Cr (T04N R075E Sec13)
- Falls Cr (T05N R07E Sec21)
- Layout Cr (T04N R06E Sec14)
- Little Wind R near mouth (T03N R08E Sec22)
- Martha Cr (T04N R07E Sec27)
- Ninemile Cr (T05N R07E Sec28)
- Planting Cr (T04N R07E Sec19)
- South Fork Falls Cr (T05N R07E Sec24)
- Trout Cr (T04N R06E Sec13)
- Trout Cr (T04N R06E Sec24)
- Trout Cr above Hemlock Dam (T04N R07E Sec27)

- Trout Cr below Hemlock Dam (T04N R07E Sec27)
- Trout Cr near mouth (T04N R07E Sec26)
- Wind R above Falls Cr (T05N R07E Sec21)
- Wind R above Paradise Cr (T05N R07E Sec03)
- Wind R below Paradise Cr (T05N R07E Sec03)
- Wind R headwater (T06N R07E Sec26)

While a simple TMDL that addresses only the listed segments could be done, due to the large amount of data that are available it is more efficient to develop the present TMDL to address water temperature in perennial streams in the entire watershed.

The Trout Creek watershed is of particular concern because temperatures often exceed the preferred range for steelhead trout of 10 to 13 degrees C (Figures 7 and 8; Jezorek and Connolly, 2001). The warmest temperatures in the Wind River watershed have been recorded in Trout Creek in the vicinity of Hemlock Dam. Temperatures in the lower portion of Trout Creek have frequently been measured near or above the lethal limit for steelhead of about 24 degrees C. Trout Creek should have been included in the 1998 303(d) list. It was not listed in 1998 because of missing USFS quality assurance data in Ecology's files.

Seasonal Variation

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

Existing conditions for stream temperatures in the Wind River watershed reflect seasonal variation. Cooler temperatures occur in the winter, while warmer temperatures are observed in the summer. Figures 7 and 8 summarize the highest daily maximum and the highest seven-day average maximum water temperatures of each year for 1998, 1999, and 2000. The highest temperatures typically occur from July through August. This time frame is used as the critical period for development of the TMDL.

Seasonal estimates for stream flow, solar flux, and climatic variables for the TMDL are taken into account to develop critical conditions for the TMDL model. The critical period for evaluation of solar flux and effective shade was assumed to be August 1, because it is the mid-point of the period when water temperatures are typically at their seasonal peak.

Critical stream flows for the TMDL were evaluated as the lowest 7-day average flows with a 2-year recurrence interval (7Q2) and 10-year recurrence interval (7Q10) for the months of July and August. The 7Q2 stream flow was assumed to represent conditions that would occur during a typical climatic year, and the 7Q10 stream flow was assumed to represent a reasonable worst-case climatic year.

The minimum and maximum air temperatures that occurred on the hottest days of 1987 and 1998 (median year and highest summer air temperatures on record, respectively) represented critical conditions for air temperature. The design years for the median and worst-case climatic conditions (1987 and 1998) were selected based on the distribution of maximum 1-day-average-daily-maximum air temperatures for each year of observation at the Carson Fish Hatchery from 1977 through 1999.

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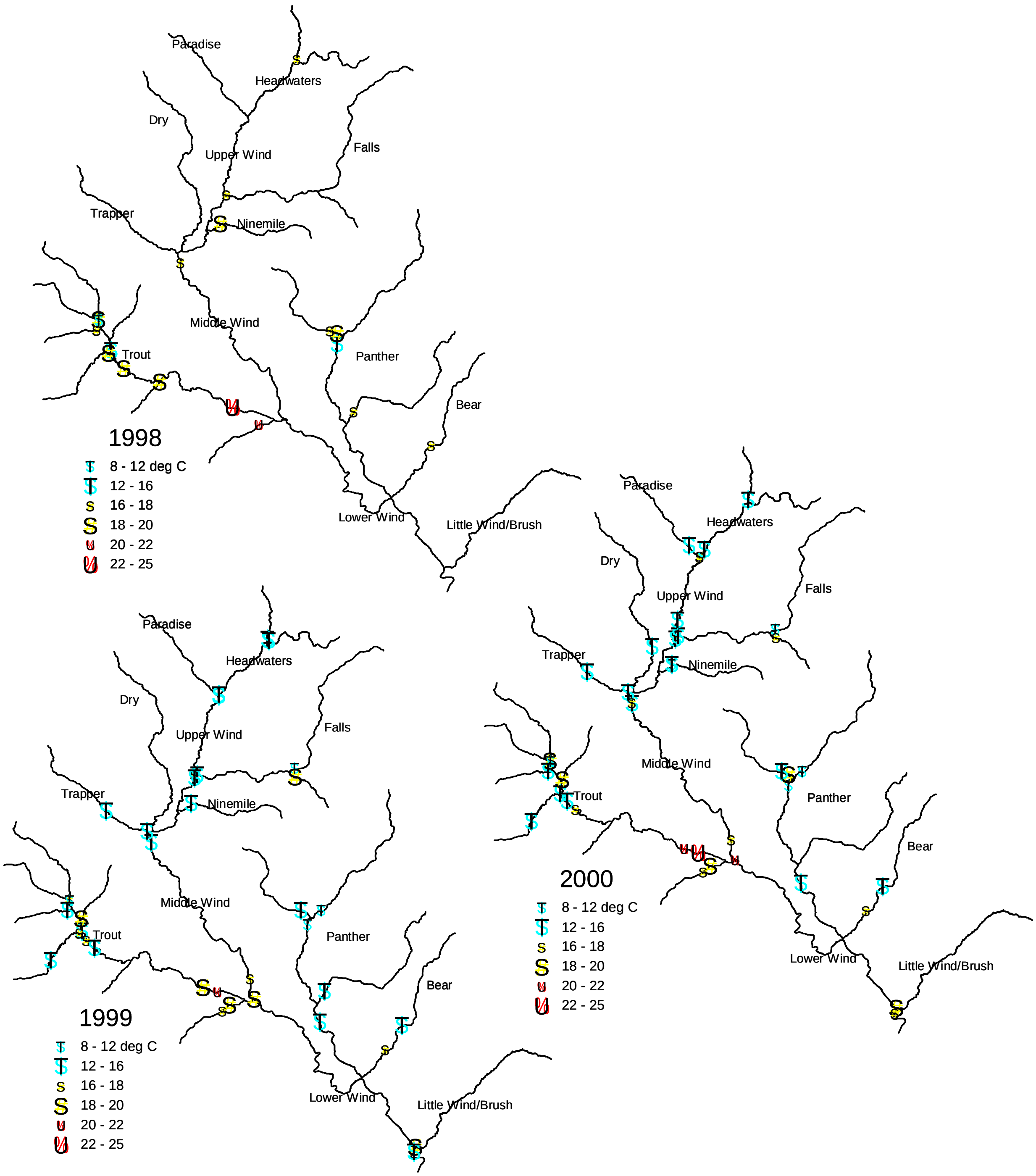

Figure 7. The highest daily maximum temperatures in the Wind River and its tributaries in 1998, 1999, and 2000 on the hottest day of the year for each station.

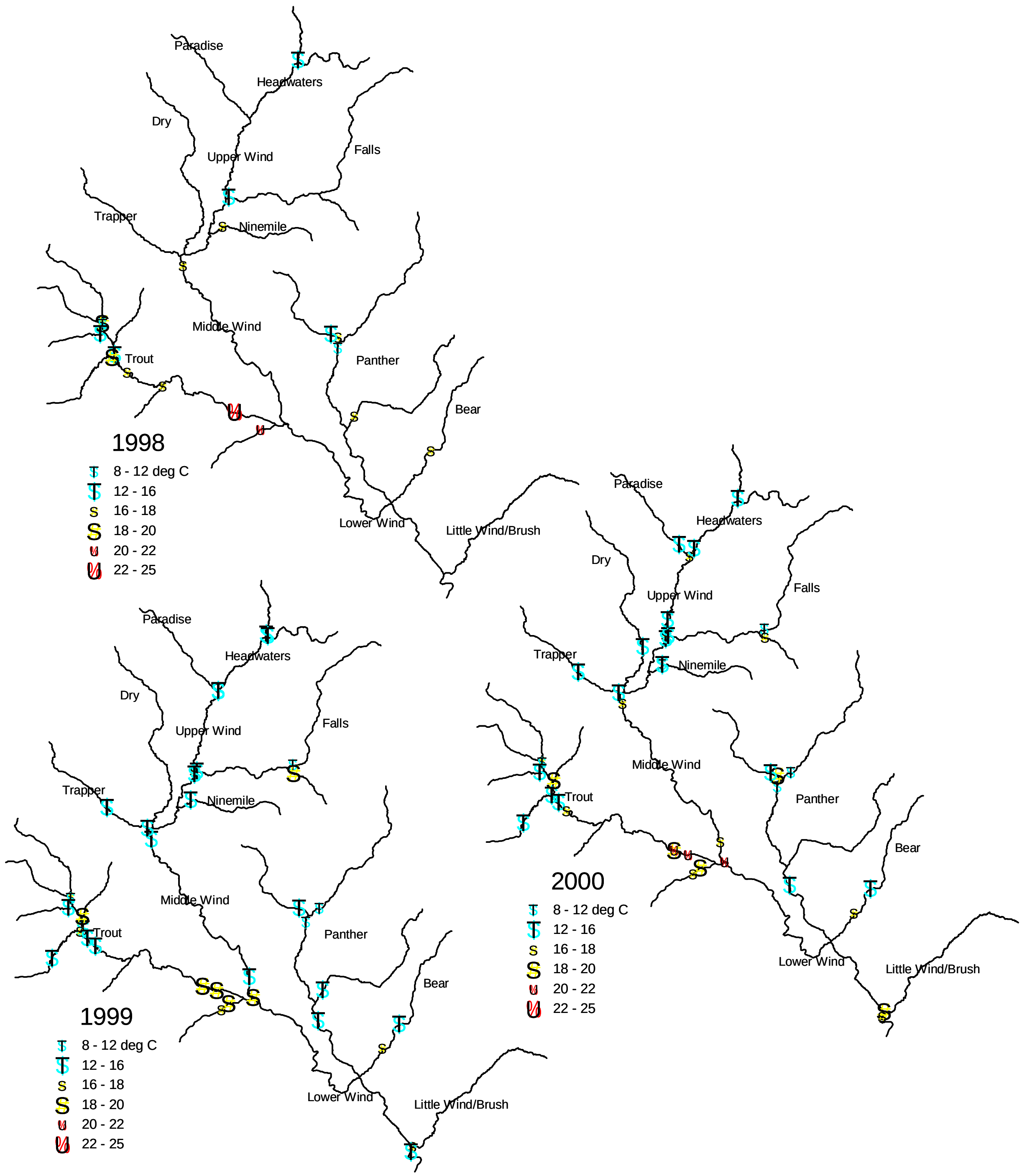

Figure 8. Maximum 7-day-averages of daily maximum temperature in the Wind River and its tributaries in 1998, 1999, and 2000.

Technical Analysis

Stream Heating Processes

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by land use activities. Specifically, the elevated summertime stream temperatures attributed to anthropogenic sources in the Wind River basin result from the following:

- Riparian vegetation disturbance reduces stream surface shading via decreased riparian vegetation height, width, and/or density, thus increasing the amount of solar radiation reaching the stream surface. Several causes of reduced shade include past riparian timber harvest, development for residential housing or recreation, and agricultural uses for orchards and nurseries (Tracy et al, 2001).
- Channel widening (increased width to depth ratios) increases the stream surface area exposed to energy processes, namely solar radiation. Several causes of channel widening include past riparian harvest, splash dams, road building, and harvest related landslides (Tracy et al, 2001). A significant widening of the natural channel for a portion of Trout Creek was caused by the construction of Hemlock Dam. The shallow reservoir created by Hemlock Dam is approximately 180 meters wide and 430 meters long, with little shading at the margins. Widening of the near-stream disturbance zone (NSDZ) throughout the Wind River watershed also decreases the effectiveness of potential shading from near-stream vegetation.
- Reduced summertime base flows may result from instream withdrawals and hydraulically connected groundwater withdrawals. Reducing the amount of water in a stream can increase stream temperature (Brown, 1972). Within the Wind River watershed, the cumulative water rights of significant magnitude to alter low flows and consequently affect stream temperatures exist in the Trout Creek, Bear Creek, middle Wind River, and lower Wind River watersheds (Tracy et al, 2001).

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

- latitude and longitude
- time of year
- stream aspect and width
- vegetation buffer height, width, overhang, and canopy density
- topographic shade angles

In the Northern Hemisphere, the earth tilts on its axis toward the sun during summertime months allowing longer day length and higher solar altitude, both of which are functions of solar declination (i.e., a measure of the earth's tilt toward the sun). Geographic position (i.e., latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation. Riparian height, width, and density describe the physical barriers between the stream and sun that can attenuate and scatter incoming solar radiation (i.e., produce shade). The solar position has a vertical component (i.e., altitude) and a horizontal component (i.e., azimuth) that are both functions of time/date (i.e., solar declination) and the earth's rotation (i.e., hour angle). While the interaction of these shade variables may seem complex, the math that describes them is relatively straightforward geometry, much of which was developed decades ago by the solar energy industry.

Percent effective shade is perhaps the most straightforward stream parameter to monitor/ calculate and is easily translated into quantifiable water quality management and recovery objectives. Using solar tables or mathematical simulations, the potential daily solar load can be quantified. The measured solar load at the stream surface can easily be measured with a hemispherical photography or estimated using mathematical shade simulation computer programs (Boyd, 1996). Effective shade was calculated for the Wind River, Trout Creek, and Panther Creek using the HeatSource model developed by the Oregon Department of Environmental Quality (ODEQ, 2000).

Current Conditions

Available Water Temperature Data

A network of continuous temperature dataloggers has been developed and maintained in the Wind River watershed by the U.S. Geological Survey (USGS) Columbia River Research Laboratory, the Underwood Conservation District (UCD), and the USFS (Figures 7 and 8, Appendix A). The lower segment of Trout Creek typically exhibits the warmest temperatures. Data from 1998, 1999, and 2000 show that water temperatures in excess of 18 degrees C are common throughout the watershed. Air temperatures during the summer of 1998 were the hottest recorded in the watershed at the Carson Fish Hatchery since 1977. Water temperatures in excess of 22 degrees C have been observed in Trout Creek upstream from Hemlock Dam. Cooler maximum temperatures of less than 16 degrees C have also been observed at many sites, especially the upper segments of most tributaries including Trout Creek.

Stream Flow Data

The Department of Ecology installed a network of flow measurement stations during 1999 (Figure 9 and Appendix B1). The Ecology stations included a continuous stage recorder at the Wind River near Carson from 7/7/99 through 9/22/99. Instantaneous flow measurements at all stations were made on three days during the summer of 1999 to represent the range of flows in the basin during this period. Rating curves to estimate the continuous flows at each station were developed by applying power curves using linear regression of log-transformed stage and discharge (Appendix B2).

The USGS Columbia River Research Laboratory also measured instantaneous flows at a network of stations starting in 1996 (Figure 9). The USGS measured instantaneous flows at intervals of approximately 2 weeks at nine of the stations shown in Figure 8 during 1999: Crater Creek, upper Trout Creek, lower Layout Creek, upper Layout Creek, Martha Creek, Trapper Creek, Paradise Creek, lower Dry Creek, and upper Dry Creek.

Hydraulic Geometry

The width (w), depth (d), and velocity (u) of a stream are typically related to discharge (Q) by power functions (Leopold, 1994) as follows:

- $w = aQ^b$ (b is approximately 0.26 at a station)
- $d = cQ^f$ (f is approximately 0.40 at a station)
- $u = kQ^m$ (m is approximately 0.34 at a station)

The coefficients are also related to each other by continuity such that the product of the coefficients (a * c * k) should equal 1 and the sum of the exponents (b + f + m) should equal 1.

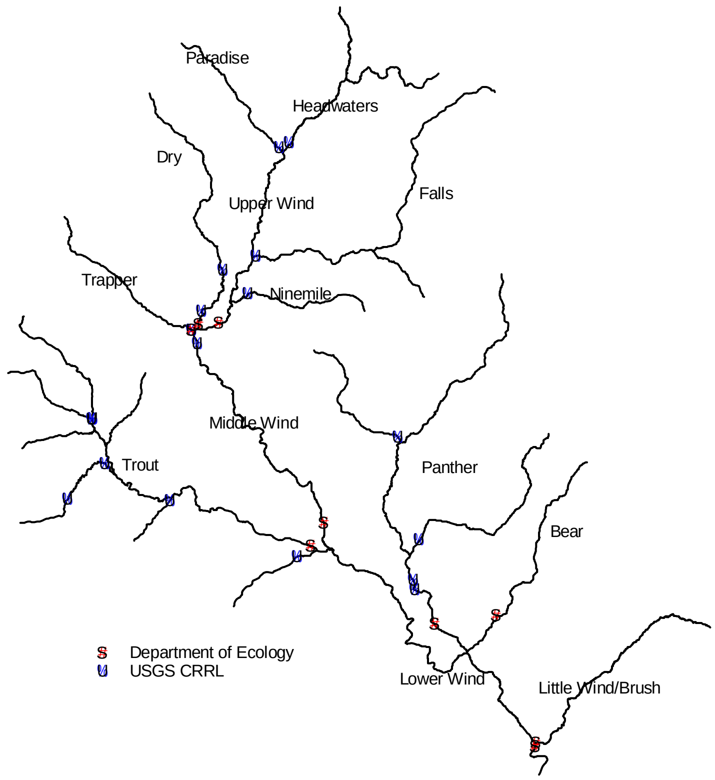

Figure 9. Stream flow stations.

The channel width and the ratio of width/depth also have an important influence on the sensitivity of water temperature to the flux of heat. Approximate stream widths at low flow have been estimated by the USFS for segments of streams in the Wind River basin (Table 2, unpublished data from personal communication with Ruth Tracy and Brian Bair, USFS). The USFS used the Rosgen stream morphology classification system (Rosgen, 1996) to describe the channel characteristics for streams in the Wind River basin.

Manning's equation is commonly used to estimate depth (d) from flow (Q), Manning's roughness coefficient (n), width (w), and slope (S), assuming the hydraulic radius equals the depth and the width is large compared to the depth (Lindeburg, 1989; metric units):

- $d = [(n * Q)/(S^{0.5} * w)]^{0.6}$

If the flow (Q), width (w), and depth (d) are known, then the continuity equation can be used to estimate velocity (u):

- $u = Q / (w * d)$

Table 2. Channel width, Rosgen classification, and width/depth ratios.

Stream name	Segment downstream boundary (Km from mouth)	Segment upstream boundary (Km from mouth)	Approximate width at low flow (m)	Rosgen channel classification	Approximate Rosgen width/depth ratio
Panther	0.00	3.30	9.14	A	<12
Panther	3.30	5.70	10.15	B	**>12**
Panther	5.70	7.40	13.66	B/C	**>12**
Panther	7.40	9.17	14.20	A/B	**>12**
Panther	9.17	10.14	20.60	-	-
Panther	10.14	11.10	11.09	-	-
Panther	11.10	12.60	9.14	-	-
Panther	12.60	14.81	8.96	-	-
Trout	0.00	0.70	3.05	-	-
Trout	0.70	1.50	9.75	-	-
Trout	1.50	2.90	9.75	-	-
Trout	2.90	4.00	9.17	B	**>12**
Trout	4.00	4.51	11.73	B	**>12**
Trout	4.51	7.40	9.81	A	<12
Trout	7.40	10.94	10.64	C	**>12**
Trout	10.94	14.00	10.09	C	**>12**
Trout	14.00	15.13	6.86	B	**>12**
Trout	15.10	16.80	6.10	-	-
Wind	8.90	10.00	22.86	-	-
Wind	10.00	14.50	18.29	-	-
Wind	14.50	22.50	9.14	-	-
Wind	22.50	28.60	12.80	-	-
Wind	28.60	32.80	12.74	D	**>40**
Wind	32.80	35.00	11.83	D	**>40**
Wind	35.00	37.60	8.35	C	**>12**
Wind	37.60	42.80	6.71	D	**>40**
Wind	42.80	45.50	6.49	B	**>12**
Wind	45.50	47.30	5.33	B	**>12**
Wind	47.30	47.80	3.85	A	<12
Wind	47.80	48.60	5.07	D	**>40**
Wind	48.60	49.10	4.57	-	-
Wind	49.10	50.00	3.05	-	-
Wind	50.00	51.50	1.52	-	-

Manning’s n typically varies with flow and depth (Gordon et al, 1992). As the depth decreases at low flow, the relative roughness increases. Typical published values of Manning’s n, which range from about 0.02 for smooth channels to about 0.15 for rough natural channels, are representative of conditions when the flow is at the bankfull capacity (Rosgen, 1996). Critical conditions of depth for evaluating the period of highest stream temperatures are generally much less than bankfull depth, and the relative roughness may be much higher. Values of Manning’s n of nearly 1 were measured at flow gaging stations in the basin (Figure 10).

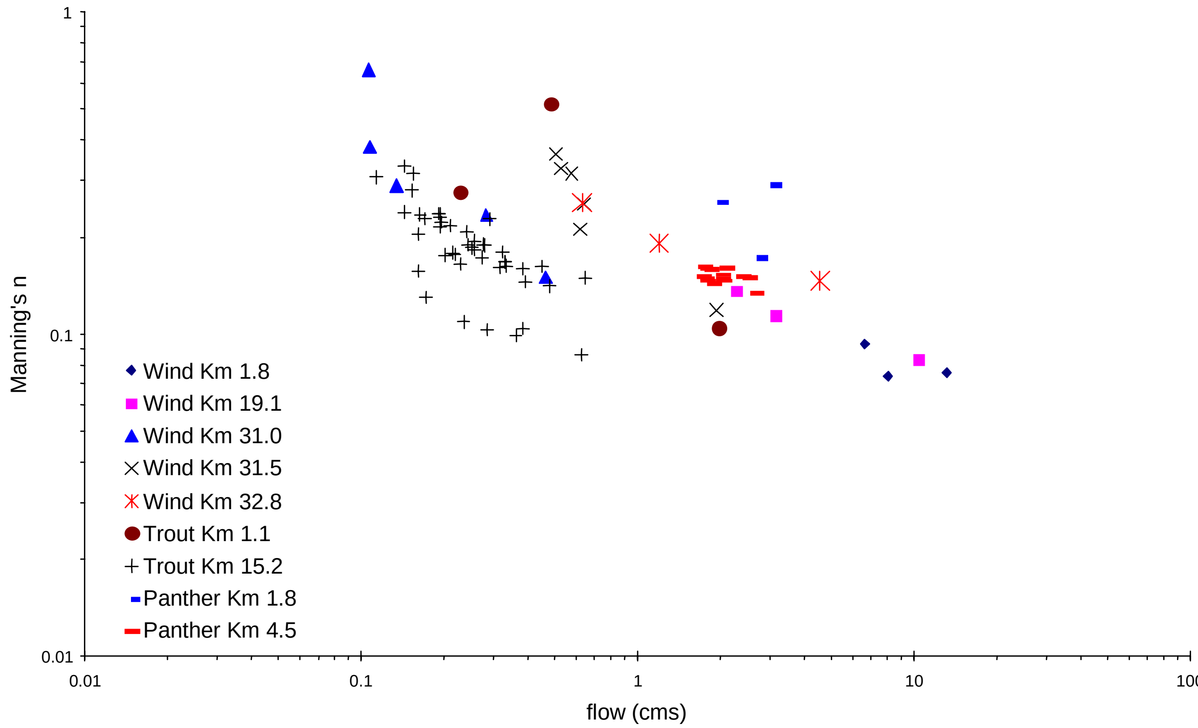

Figure 10. Relationship between Manning's n and flow at stations in the Wind River, Trout Creek, and Panther Creek.

Reach-averaged values of Manning’s n may be higher than those measured at the gaging stations because the locations of the cross-sections for flow measurements were typically selected for laminar flow conditions that occur in channels that are deeper and narrower than average. Reach-averaged depth may be considerably less than the depth at the flow measurement stations. Therefore, reach-averaged relative roughness is likely to be greater than the measured roughness at the flow stations.

Riparian Vegetation and Effective Shade

The Gifford Pinchot National Forest maintains a collection of GIS databases that includes detailed descriptions of vegetation (http://www.fs.fed.us/gpnf/gis/). GIS coverages were obtained from the USFS to describe the vegetation species, tree heights, and percent of canopy closure (Figure 11).

Figure 11. Example of the vegetation coverage for the Hemlock Lake portion of Trout Creek in the Wind River basin. A 4-digit code "hhdd" was assigned to vegetation polygons (e.g. a code of 4090 denotes vegetation height of 30-40 meters and canopy density of 80-90%; a code of 110 denotes vegetation height of 0-1 meter and density of 0-10%.)

Effective shade was calculated using the HeatSource model (ODEQ, 2000; Figure 12 and Appendix C). Riparian vegetation size and density was sampled from the GIS coverages along the stream at 100-meter intervals along the Wind River and Panther Creek, and at 50-meter intervals along Trout Creek using the Ttools extension for Arcview that was developed by ODEQ (ODEQ, 2001). At each stream transect location the vegetation grid was sampled orthogonal to the stream at 10-meter-wide riparian zone intervals between the wetted edge and 91 meters (300 feet) away from each bank of the stream. Other spatial data that were estimated at each transect location includes stream aspect, and topographic shade angles to the west, south and east. Stream widths were estimated from USFS data (Table 2).

Effective shade calculations were made for three scenarios of vegetation:

- Current vegetation based on spatial data for height and canopy density
- Current vegetation based on spatial data for height but assuming that the canopy density is 85%. This scenario was evaluated based on the recommendation of the USFS (personal communication with Ruth Tracy, USFS).

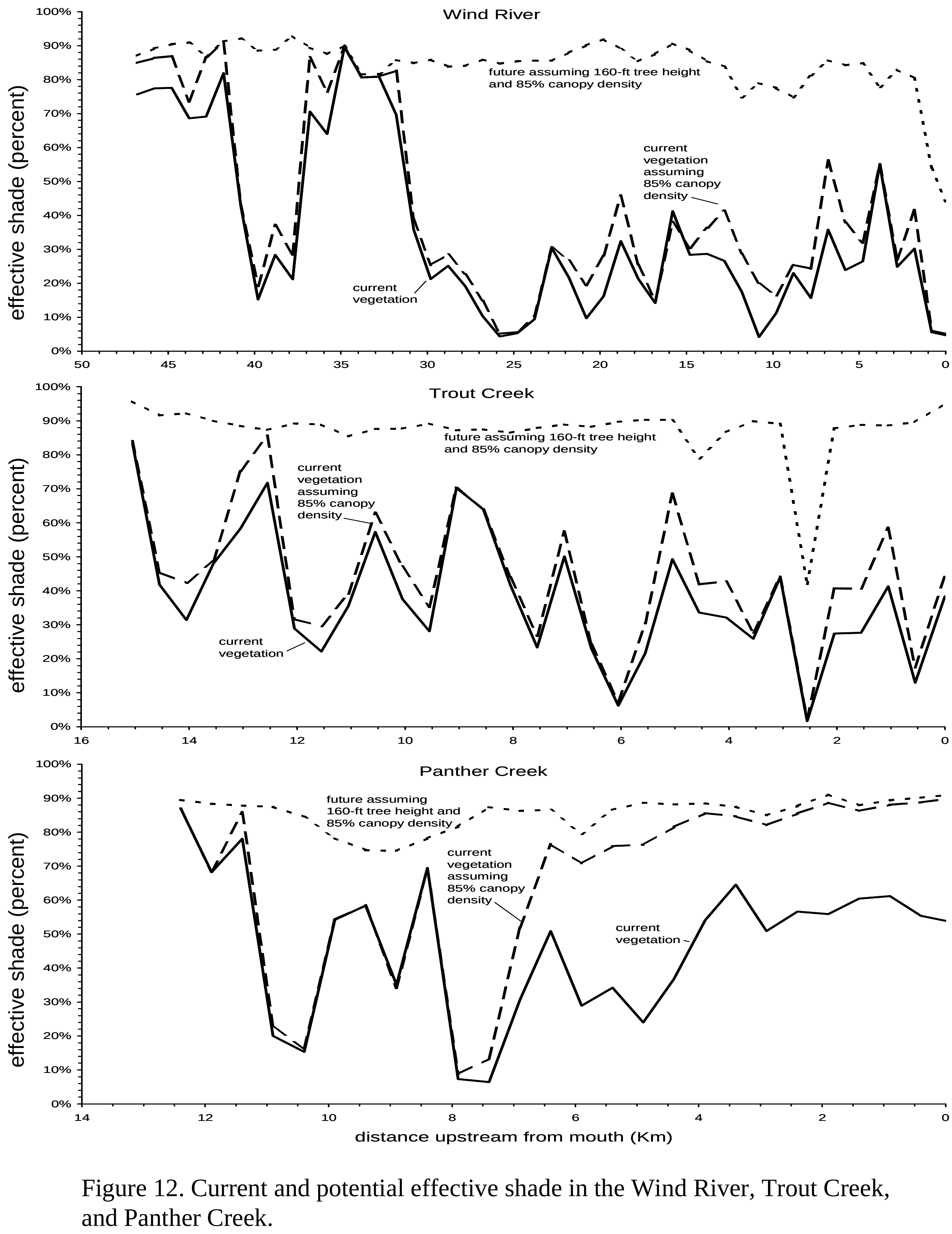

Figure 12. Current and potential effective shade in the Wind River, Trout Creek, and Panther Creek.

- Maximum effective shade from mature riparian vegetation. The potential future vegetation was assumed to be a tree height of 48.8 meters (160 feet) and canopy density of 85%. This is the same potential maximum future vegetation scenario that was evaluated by the USFS for their shade analysis for the Forest Plan.

Analytical Framework

Data collected during this TMDL effort has allowed the development of a temperature simulation methodology that is both spatially continuous and which spans full-day lengths (quasi-dynamic steady-state diel simulations). The GIS and modeling analysis was conducted using three specialized software tools:

- ODEQ's Ttools extension for Arcview (ODEQ, 2001) was used to sample and process GIS data for input to the HeatSource and QUAL2K models.

- ODEQ's HeatSource model (ODEQ, 2000) was used to estimate effective shade along the mainstems of the major tributaries in the Wind River basin (Figure 12). Effective shade was calculated along the mainstems of the Wind River, Trout Creek, Panther Creek, Eightmile Creek, and Bear Creek using the HeatSource model. Effective shade was calculated at 50 to 100-meter intervals along the streams and then averaged over 500 to 1000-meter intervals for input to the QUAL2K model.

- The QUAL2K model (Chapra, 2001) was used to calculate the components of the heat budget and simulate water temperatures. QUAL2K simulates diurnal variations in stream temperature for a steady flow condition. QUAL2K was applied by assuming that flow remains constant for a given condition such as a 7-day or 1-day period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures were specified or simulated as diurnally varying functions. QUAL2K uses the kinetic formulations for the components of the surface water heat budget that are shown in Figure 2 and described in Chapra (1997). Diurnally varying water temperatures at 500 to 1000-meter intervals along the streams in the Wind River basin were simulated using a finite difference numerical method. The components of heat flux were calculated along the mainstems of the Wind River, Trout Creek, Panther Creek, Eightmile Creek, and Bear Creek. The water temperature model was calibrated to in-stream data along the mainstems of the Wind River, Trout Creek, and Panther Creek. The water temperature model was not calibrated to observed data for Eightmile Creek and Bear Creek because of limited available data.

All input data for the HeatSource and QUAL2K models are longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments. Model input data were determined from available GIS coverages using the Ttools extension for Arcview, or from data collected by Ecology, USFS GPNF, USGS CRRL, or the Underwood Conservation District, or other data sources. Detailed spatial data sets were developed for the following parameters for model calibration and verification (for the mainstems of the Wind River, Trout Creek, Panther Creek, Eightmile Creek, and Bear Creek):

- Rivers and tributaries were mapped at 1:3,000 scale from 1-meter-resolution Digital Orthophoto Quads (DOQ).

- Riparian vegetation size and density were mapped at 1:15,840 scale, and sampled from the GIS coverage along the stream at 100-meter intervals along the Wind River and Panther Creek, and at 50-meter intervals along Trout Creek. At each stream transect location the vegetation grid was sampled orthogonal to the stream at 10-meter intervals starting at the wetted edge and progressing to 300 feet from each side of the stream.

- Near-stream disturbance zone (NSDZ) widths were digitized at 1:3000 scale (Hemlock Lake and the lower 2 km of the Wind River only).

- West, east, and south topographic shade angle calculations were made from the 10-meter DEM grid using ODEQ's Ttools extension for Arcview.

- Stream elevation and gradient were sampled from the 10-meter DEM grid with the Arcview Ttools extension. Gradient was estimated from the topographic contours on the USGS 7.5-minute Quad maps.

- Aspect (stream flow direction in decimal degrees from north) was calculated by the Ttools extension for Arcview.

- The daily minimum and maximum observed temperatures for the boundary conditions at the headwaters and tributaries were used as input to the QUAL2K model for the calibration and verification periods. The QUAL2K model was calibrated and verified using data collected during July and August 1999 (Figure 13).

- Flow balances for the calibration and verification periods were estimated from field measurements of flow made by Ecology and the USGS CRRL (Figure 14). The lowest 7-day-average flows during the July-August period with recurrence intervals of 2 years (7Q2) and 10 years (7Q10) were estimated based on low flow statistics from the Wind River near Carson (USGS station 14128500, period of record from 1935-1977, July-August 7Q2= 5.90 m^3/sec, July-August 7Q10=4.72 m^3/sec). The 7Q2 and 7Q10 at various other locations were estimated by scaling the estimates at the USGS gage according to the sub-watershed areas weighted by annual average precipitation. A flow balance spreadsheet of the stream networks for the Wind River, Trout Creek, and Panther Creek was constructed to estimate groundwater inflows or outflows by differences between the gaging stations.

- Hydraulic geometry (wetted width, depth, and velocity as a function of flow) was estimated from USFS data, Manning's equation, and the Leopold power functions. Stream width at low flow was estimated from USFS data (Table 2). The Leopold power functions were used to extrapolate the hydraulic geometry to various river flow regimes. The coefficients for the Leopold power functions were estimated by assuming that the exponents were equal to 0.26, 0.40, and 0.34 for width, depth, and velocity (Leopold, 1994). The first step was to estimate the Leopold coefficient for width. The USFS width data was assumed to represent the flow regime for the calibration period in July 1999. The Leopold coefficient for width was then determined assuming the Leopold exponent for width was 0.26. The next step was to estimate depth from Manning's equation. Next the Leopold coefficient for depth was determined assuming an exponent of 0.40. Finally, the velocity was estimated by the continuity equation (flow = width * depth * velocity), and the Leopold coefficient for velocity was determined assuming an exponent of 0.34. The values for Manning's n were selected during model calibration to provide the best fit of the model to the observed water temperatures during the calibration period of 7/30/1999 - 8/5/1999. The values of Manning's n that produced the best fit for prediction of water temperatures were n=0.19 for the Wind River, n=1.3 for Trout Creek, and n=0.41 for Panther Creek. The calibration values for Manning's n are within the range of observed values with the exception of the value for Trout Creek. The observed values for Manning's n in Trout Creek are available from only two locations, which may not be representative of reach-averaged conditions, but appear to be capable of approaching the calibration value at low flow (Figure 10).

- The temperature of groundwater is often assumed to be similar to the mean annual air temperature (Theurer et al, 1984). The mean annual air temperature at the Carson Fish Hatchery weather station is approximately 8.7 degrees C. Although there is very limited data, the temperature of groundwater in the Wind River watershed is known to be spatially variable. For example, there are numerous hot springs adjacent to the mainstem of the Wind River. In contrast to the hot springs near the Wind River, groundwater temperatures maintain cooler temperatures at the headwaters of Trout Creek and Panther Creek. During July and August, the headwaters of Trout and Panther creeks are relatively constant averages of approximately 6.5 degrees C and 7.2 degrees respectively. The mean daily range in temperatures of the headwaters of Trout Creek and Panther Creek during July-August are approximately 5.8 to 7.7 degrees C and 6.6 to 8.2 degrees C, respectively. Temperatures of groundwater inflows to the mainstems of the Wind River, Trout Creek, and Panther Creek during July-August were estimated during model calibration as 12 degrees C, 6.5 degrees C, and 7.2 degrees C, respectively.

- Air temperature, relative humidity, and cloud cover were estimated from meteorological data. The observed minimum and maximum air temperatures at the Carson Fish Hatchery were used to represent the conditions for the calibration and verification periods. Relative humidity and cloud cover data are not available from within the Wind River watershed and were estimated from reported data at the National Weather Service station at The Dalles, Oregon.

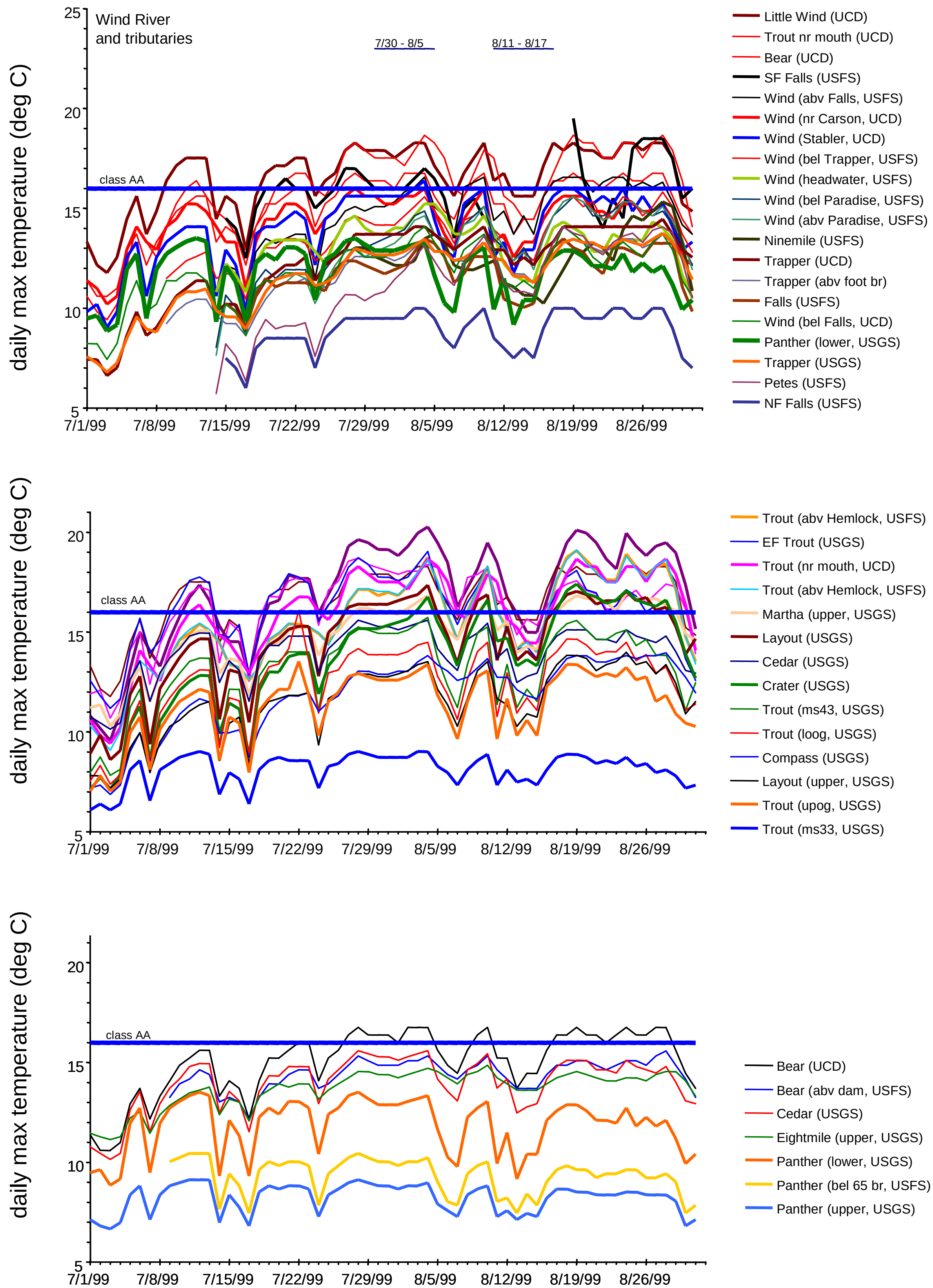

Figure 13. Daily maximum temperatures in the Wind River, Trout Creek, and Panther Creeks during July-August 1999.

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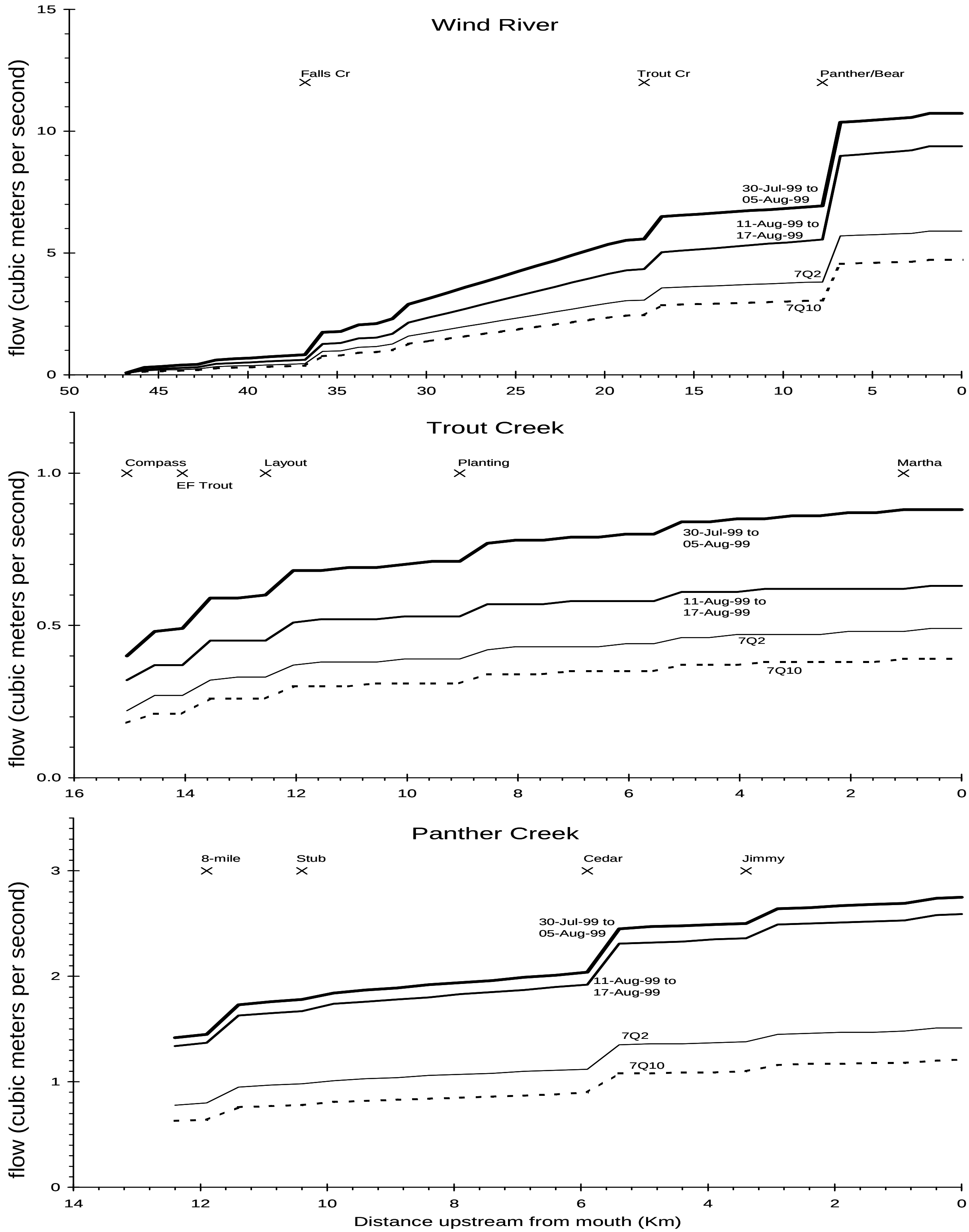


Figure 14. July-August flows in the Wind River, Trout Creek, and Panther Creek.

Calibration and Verification of the QUAL2K Model

The hottest 7-day period of 1999 occurred from July 30th through August 5th and was used for calibration of the QUAL2K model (Figure 15). The coolest 7-day period of August 1999, the 11th through 17th, was used for verification to test the model calibration (Figure 16).

The uncertainty of the predicted temperatures from the QUAL2K model was assessed by calculating the root mean squared error (RMSE) of the predicted versus observed maximum and minimum temperatures. For the calibration period, the RMSE of the predicted versus observed daily maximum temperatures in the Wind River, Trout Creek, and Panther Creek were 0.6, 0.7, and 0.04 degrees C. For the verification period, the RMSE of the predicted versus observed daily maximum temperatures in the Wind River, Trout Creek, and Panther Creek predictions was 1.0, 0.7, and 0.8 degrees C.

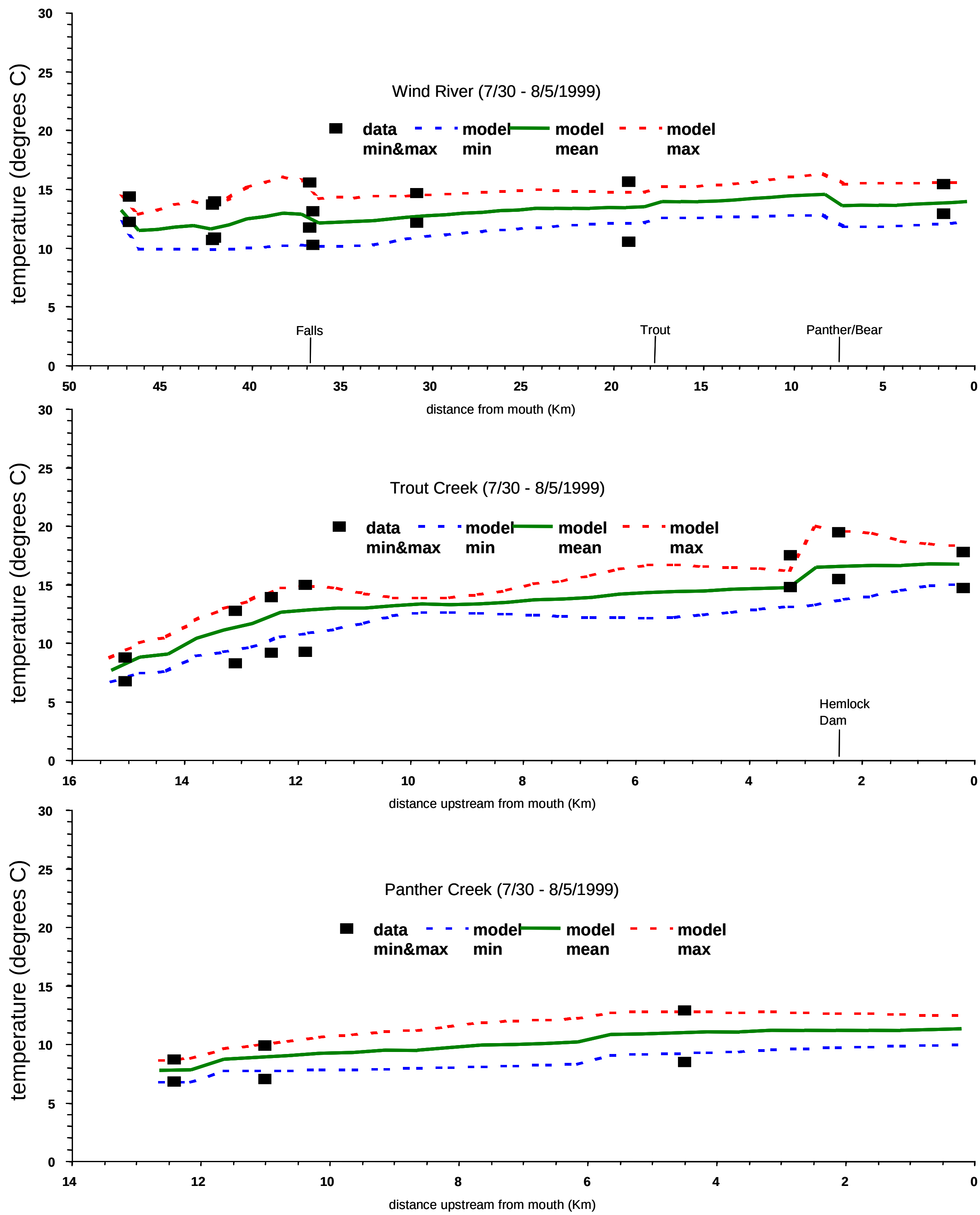


Figure 15. Comparison of predicted and observed minimum and maximum temperatures for the Wind River, Trout Creek, and Panther Creek for the period of 7/30/99 through 8/5/99.

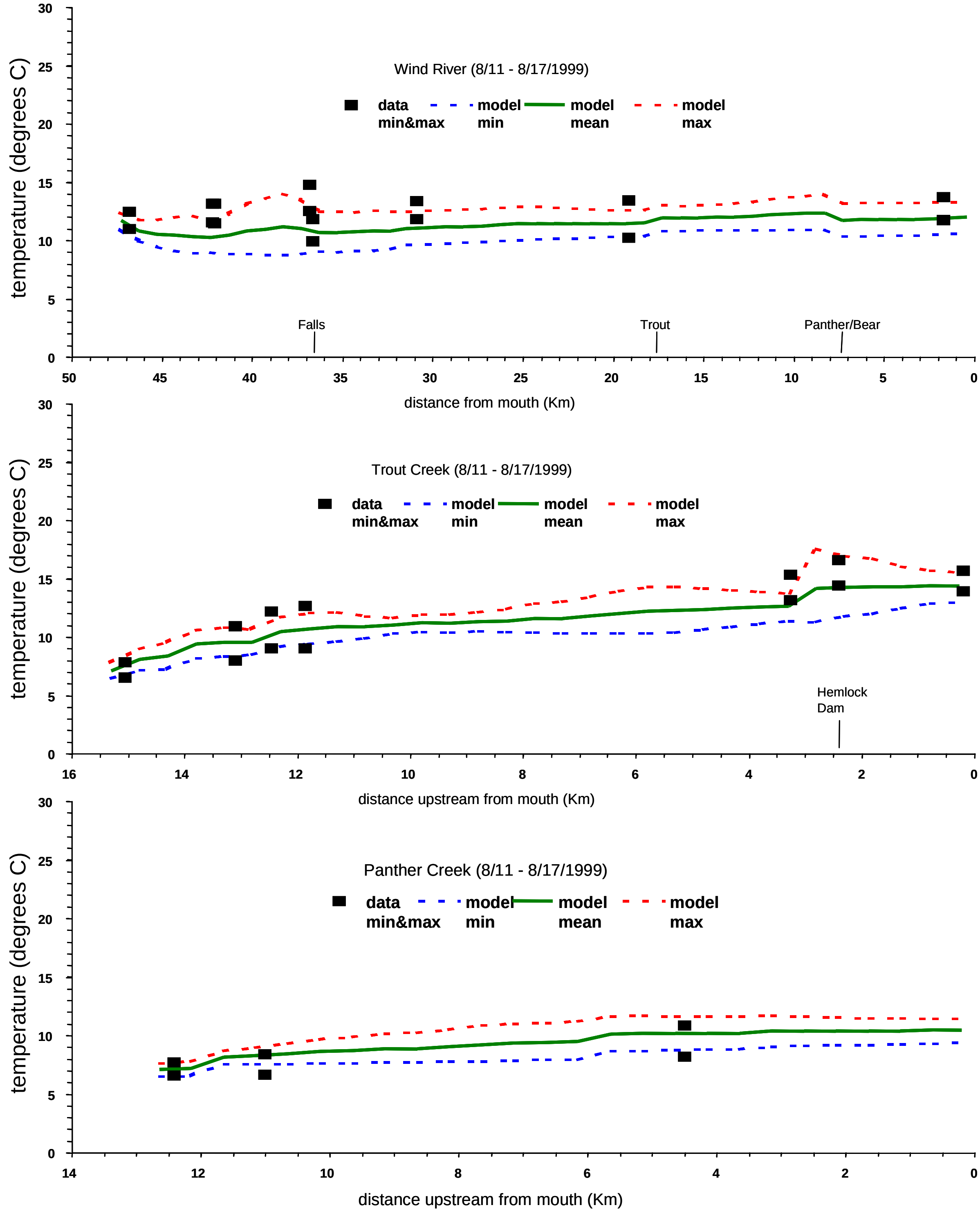


Figure 16. Comparison of predicted and observed minimum and maximum temperatures for the Wind River, Trout Creek, and Panther Creek for the period of 8/11/99 through 8/17/99.

Loading Capacity

The calibrated QUAL2K model was used to determine the loading capacity for effective shade for streams in the Wind River basin. Loading capacity was determined based on prediction of water temperatures under typical and extreme flow and climate conditions combined with a range of effective shade conditions.

The 7Q2 low flow was selected to represent a typical climatic year, and the 7Q10 low flow was selected to represent a reasonable worst-case condition for the July-August period. Air temperatures for the 7Q2 condition were assumed to be the same as those observed on the hottest day of 1987, which was the median condition from the historical record at the Carson Fish Hatchery. The air temperatures for the 7Q10 condition were assumed equal to the hottest day of the hottest year of record in 1998.

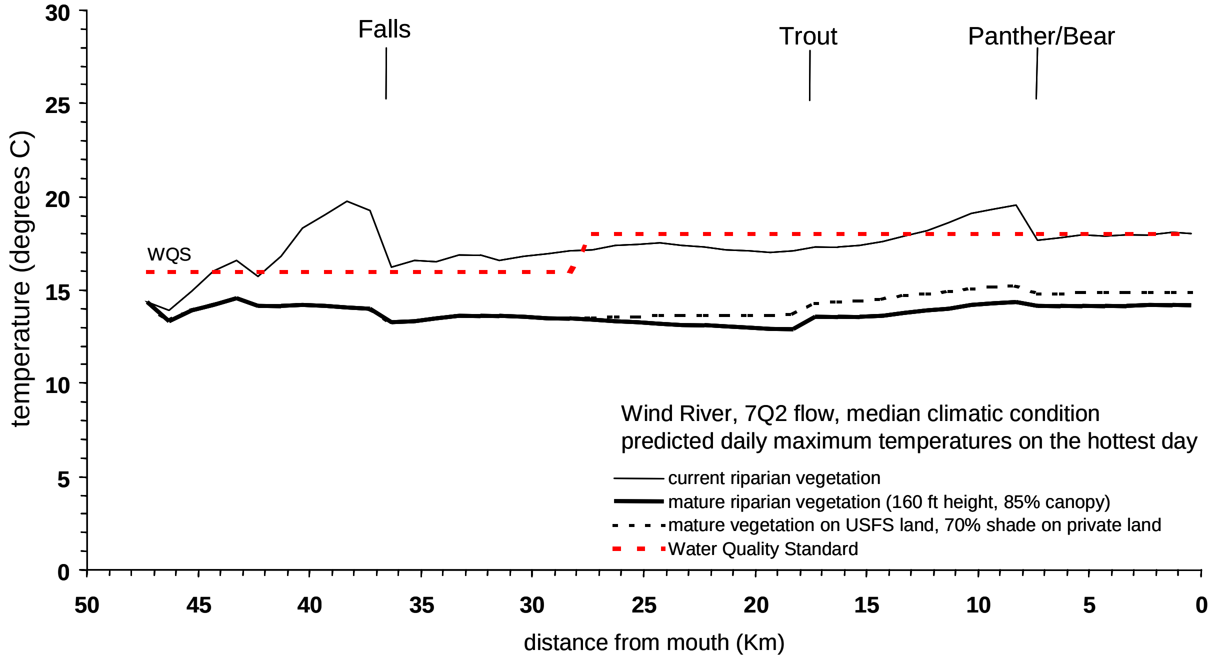
The following scenarios for effective shade were evaluated for the 7Q2 and 7Q10 flow and climate conditions:

- Effective shade that is produced by the current condition of vegetation.
- Maximum potential effective shade from mature riparian vegetation that would naturally occur in the Wind River watershed. The potential future vegetation was assumed to be represented by a tree height of 48.8 meters (160 feet) and canopy density of 85%. This is the same potential maximum future vegetation scenario that was evaluated by the USFS for their shade analysis for the Forest Plan.
- Maximum potential effective shade from mature riparian vegetation on USFS land and 70% effective shade on non-USFS land for perennial streams. Mature riparian vegetation on private forest land was assumed to produce a maximum effective shade of at least 70% based on the lower bound of the range that was estimated by Ecology for the Humptulips River TMDL (Ecology, 2001). Ecology estimated a range of 70-85% for potential effective shade for Forests and Fish buffers on the west side of the Cascades.

Additional critical scenarios were evaluated for Trout Creek, including removal of Hemlock Dam and reduction of width-to-depth ratios.

Wind River

Figure 17 shows the predicted water temperature in the Wind River for the lowest 7-day average flow during July-August with a 2-year recurrence interval (7Q2) and a 10-year recurrence interval (7Q10). Figure 17 shows that increases in effective shade from mature riparian vegetation has the potential to produce water temperatures that would meet the water quality standard in the mainstem of the Wind River. Effective shade of 70% from riparian vegetation is sufficient to meet the water quality standard for temperature in the segment of the Wind River that is downstream from the boundary of Gifford Pinchot National Forest.



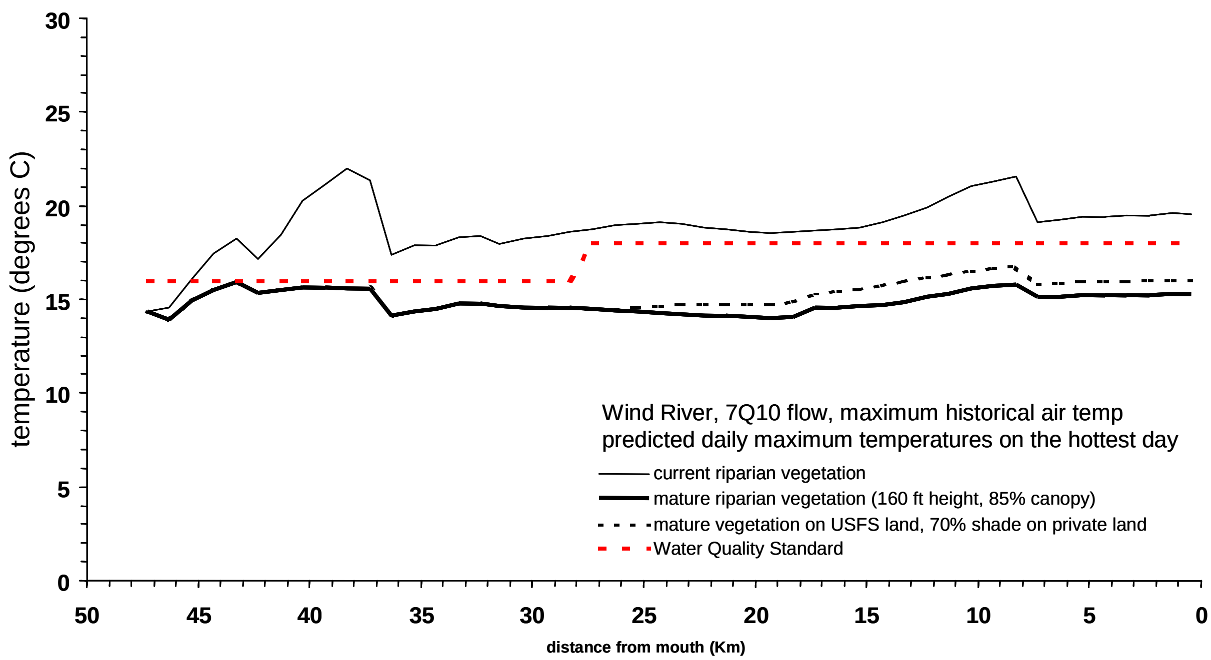


Figure 17. Predicted daily maximum temperature in Wind River under critical conditions for the TMDL.

Trout Creek

Figure 18 shows the predicted water temperature in Trout Creek for the 7Q2 and 7Q10 conditions. The same three riparian vegetation conditions were evaluated for Trout Creek as was done for Wind River. The results for the maximum potential shade from mature riparian vegetation showed that the water quality standard for temperature would be exceeded in the vicinity of Hemlock Dam.

The Forest Service is proposing to remove Hemlock Dam, partially dredge the reservoir, restore 2000 feet of the original creek channel, and revegetate the affected riparian areas with native plants (Federal Register, Vol. 66, No. 159). The Forest Service will prepare an environmental impact statement to restore migratory fish passage, and aquatic and riparian habitat at Hemlock Dam on Trout Creek. Removal of Hemlock Dam was predicted to result in significant reduction of temperature and possible compliance with the temperature standard (Figure 18).

The shallow reservoir above the Hemlock Dam is about 430 meters long and 180 meters wide (Figure 11). Increases in water temperature in water flowing from the upstream to the downstream end of the reservoir were observed in 1999 and 2000. The greatest observed increases in temperature through the reservoir were nearly 2 degrees C in the summer of 2000. Flows during this period were significantly higher than normal (70 to 80% greater than 7Q2 based on the Lewis River as a reference). Air temperatures were cooler than normal in the summer of 1999 and 2000. Increases in water temperature of significantly greater than 2 degrees C through the reservoir are likely when flows are lower and climate conditions are warmer (Figure 18).

Reductions of stream width-to-depth ratios would also be recommended for Trout Creek to further reduce the water temperatures and provide a greater probability of meeting the Class AA standard within Gifford Pinchot National Forest. Figure 18 also shows the predicted water temperature for the 7Q10 condition if a 30% reduction in width-to-depth ratio could be achieved in addition to increasing effective shade and removing Hemlock Dam. Effective shade of 70% from riparian vegetation is probably sufficient to meet the water quality standard for temperature in the segment of Trout Creek that is downstream from the boundary of Gifford Pinchot National Forest.

Panther Creek

Figure 19 shows the predicted water temperature in Panther Creek for the 7Q2 and 7Q10 conditions. Effective shade from mature riparian has the potential to produce water temperatures that would meet the water quality standard in the mainstem of Panther Creek. Effective shade of 70% from riparian vegetation is sufficient to meet the water quality standard for temperature in the segment of Panther Creek that is downstream from the boundary of Gifford Pinchot National Forest.

Estimated Solar Flux at the Loading Capacity for Effective Shade

The loading capacity in terms of the flux of shortwave solar radiation to the water surface was estimated as the flux that would occur at the effective shading that was evaluated (Figures 20 and 21, and Tables 3, 4, 5, and 6).

For perennial streams on USFS land, the loading capacity was translated into the solar flux that would occur with mature riparian vegetation. The potential future vegetation was assumed to be represented by a tree height of 48.8 meters (160 feet) and canopy density of 85%. This is the same potential maximum future vegetation scenario that was evaluated by the USFS for their shade analysis for the Forest Plan. For private land, the loading capacity was translated into the solar flux that would occur with effective shade of at least 70% for perennial streams.

The estimated solar flux at the loading capacity for effective shade in the Wind River, Trout Creek, Panther Creek, Bear Creek, and Eightmile Creek is presented in Figures 20 and 21 and Tables 3, 4, 5, and 6. The recommended load allocations for effective shade are predicted to result in significant reductions of the flux of solar radiation to streams in the Wind River basin.

Load Allocations

The Load Allocations for effective shade for the Wind River, Trout Creek, Panther Creek, Eightmile Creek, and Bear Creek are presented in Tables 3, 4, 5, and 6. The solar flux estimated for August 1 at the Load Allocations for effective shade is presented in Figures 20 and 21. In general, the load allocations for effective shade in the Wind River watershed are as follows:

- For perennial streams on USFS land, the load allocation for effective shade is the maximum potential effective shade that would occur from mature riparian vegetation. Load allocations for effective shade are quantified for the evaluated reaches in Tables 3, 4, 5, and 6. For other areas on USFS land the effective shade that would be produced from mature riparian vegetation is generally estimated to be greater than approximately 70%.
- For perennial streams on non-USFS land, the load allocation for effective shade from riparian vegetation and topography is 70%, or shade produced by mature riparian vegetation, whichever is less.

In addition to the load allocations for effective shade, the following management activities are recommended for compliance with the water quality standards for water temperature:

- For U.S. Forest Service land, the riparian reserves in the Northwest Forest Plan are recommended for establishment of mature riparian vegetation.
- For privately owned forest land, the riparian vegetation prescriptions in the Forests and Fish Report are recommended for all perennial streams. Load allocations are included in this TMDL for forest lands in the Wind River Basin in accordance with the section of Forests and Fish entitled “TMDLs produced prior to 2009 in mixed use watersheds”.
- Reduction of sediment loading to the Wind River and its tributaries is recommended according to the Water Quality Restoration Plan (Tracy et al, 2001).
- Removal of Hemlock Dam in the Trout Creek watershed is recommended to reduce stream widths and increase effective shade.
- Channel restoration projects are recommended according to the Water Quality Restoration Plan (Tracy et al, 2001) to reduce stream width-to-depth ratios and also reduce the width of the near-stream disturbance zone.
- Reduction of consumptive water use withdrawals are recommended according to the Water Quality Restoration Plan (Tracy et al, 2001).
- Decommissioning of forest roads is recommended according to the Water Quality Restoration Plan (Tracy et al, 2001) to reduce runoff and sediment loading from roads and improve channel conditions.
- Special studies of Bear Creek are recommended according to the Water Quality Restoration Plan (Tracy et al) to determine the relationship between water withdrawal by the City of Carson and water temperature in Bear Creek. Special studies should also be conducted to characterize the channel geometry, and determine the flow and temperature of distributed inflows along the reach downstream from the USFS temperature station.

Table 3. Effective shade and solar flux for the Wind River.

						Load Allocations (1)	
	Distance from mouth to upstream segment boundary (Km)	Distance from mouth to downstream segment boundary (Km)	Current condition effective shade from HeatSource model using current vegetation estimates	Estimated daily average solar flux to water surface on August 1 with current vegetation (cal/cm2/day)	Site potential effective shade from HeatSource model using minimum 160-ft tree height and 85% canopy density	Load allocation for effective shade assuming mature riparian vegetation on USFS land (160-ft tree height and 85% canopy density), and effective shade of 70% or shade produced by mature riparian vegetation, whichever is less, on non-USFS land. For Trout Creek the proposed LA is also based on removal of Hemlock Dam.	Estimated daily average flux of shortwave solar radiation to the water surface on August 1 at the load allocation for effective shade (cal/cm2/day)
Wind River:	46.8	45.8	77%	165	89%	89%	77
Wind River:	45.8	44.8	78%	158	90%	90%	69
Wind River:	44.8	43.8	69%	222	91%	91%	65
Wind River:	43.8	42.8	69%	222	87%	87%	94
Wind River:	42.8	41.8	82%	129	91%	91%	62
Wind River:	41.8	40.8	43%	408	92%	92%	57
Wind River:	40.8	39.8	15%	609	89%	89%	82
Wind River:	39.8	38.8	28%	516	89%	89%	80
Wind River:	38.8	37.8	21%	566	93%	93%	51
Wind River:	37.8	36.8	71%	208	89%	89%	75
Wind River:	36.8	35.8	64%	441	88%	88%	89
Wind River:	35.8	34.8	90%	329	90%	90%	71
Wind River:	34.8	33.8	81%	368	82%	82%	132
Wind River:	33.8	32.8	81%	368	82%	82%	132
Wind River:	32.8	31.8	70%	415	86%	86%	102
Wind River:	31.8	30.8	36%	458	85%	85%	108
Wind River:	30.8	29.8	21%	566	86%	86%	101
Wind River:	29.8	28.8	25%	537	84%	84%	116
Wind River:	28.8	27.8	19%	580	84%	84%	114
Wind River:	27.8	26.8	10%	645	86%	70%	215
Wind River:	26.8	25.8	4%	688	85%	70%	215
Wind River:	25.8	24.8	5%	680	85%	70%	215
Wind River:	24.8	23.8	9%	652	86%	70%	215
Wind River:	23.8	22.8	30%	501	86%	70%	215
Wind River:	22.8	21.8	22%	559	88%	70%	215
Wind River:	21.8	20.8	10%	645	90%	70%	215
Wind River:	20.8	19.8	16%	602	92%	70%	215
Wind River:	19.8	18.8	32%	487	89%	70%	215
Wind River:	18.8	17.8	21%	566	85%	70%	215
Wind River:	17.8	16.8	14%	616	88%	70%	215
Wind River:	16.8	15.8	41%	423	91%	70%	215
Wind River:	15.8	14.8	28%	516	89%	70%	215
Wind River:	14.8	13.8	29%	509	85%	70%	215
Wind River:	13.8	12.8	27%	523	84%	70%	215
Wind River:	12.8	11.8	18%	587	75%	70%	215
Wind River:	11.8	10.8	4%	688	79%	70%	215
Wind River:	10.8	9.8	11%	637	78%	70%	215
Wind River:	9.8	8.8	23%	551	75%	70%	215
Wind River:	8.8	7.8	16%	602	81%	70%	215
Wind River:	7.8	6.8	36%	458	86%	70%	215
Wind River:	6.8	5.8	24%	544	84%	70%	215
Wind River:	5.8	4.8	26%	530	85%	70%	215
Wind River:	4.8	3.8	55%	322	78%	70%	215
Wind River:	3.8	2.8	25%	537	83%	70%	215
Wind River:	2.8	1.8	30%	501	81%	70%	215
Wind River:	1.8	0.8	6%	673	54%	54%	330
Wind River:	0.8	0.0	5%	680	44%	44%	400

(1) The surrogate load allocations for effective shade on privately owned land are proposed as estimated targets. Actual effective shade from Forest and Fish buffers is expected to be greater than 70%.

Table 4. Effective shade and solar flux for Trout Creek.

	Distance from mouth to upstream segment boundary (Km)	Distance from mouth to downstream segment boundary (Km)	Current condition effective shade from HeatSource model using current vegetation estimates	Estimated daily average solar flux to water surface on August 1 with current vegetation (cal/cm2/day)	Site potential effective shade from HeatSource model using minimum 160-ft tree height and 85% canopy density	Load Allocations (1): Load allocation for effective shade assuming mature riparian vegetation on USFS land (160-ft tree height and 85% canopy density), and effective shade of 70% or shade produced by mature riparian vegetation, whichever is less, on non-USFS land. For Trout Creek the proposed LA is also based on removal of Hemlock Dam.	Load Allocations (1): Estimated daily average flux of shortwave solar radiation to the water surface on August 1 at the load allocation for effective shade (cal/cm2/day)
Trout Creek:	15.1	14.6	42%	417	92%	92%	60
Trout Creek:	14.6	14.1	31%	491	92%	92%	56
Trout Creek:	14.1	13.6	48%	372	90%	90%	72
Trout Creek:	13.6	13.1	58%	507	89%	89%	82
Trout Creek:	13.1	12.6	72%	459	87%	87%	91
Trout Creek:	12.6	12.1	29%	613	89%	89%	77
Trout Creek:	12.1	11.6	22%	558	89%	89%	79
Trout Creek:	11.6	11.1	36%	462	85%	85%	105
Trout Creek:	11.1	10.6	57%	306	88%	88%	89
Trout Creek:	10.6	10.1	38%	447	88%	88%	88
Trout Creek:	10.1	9.6	28%	515	89%	89%	77
Trout Creek:	9.6	9.1	70%	213	87%	87%	92
Trout Creek:	9.1	8.6	64%	258	88%	88%	90
Trout Creek:	8.6	8.1	42%	418	87%	87%	97
Trout Creek:	8.1	7.6	23%	549	88%	88%	87
Trout Creek:	7.6	7.1	50%	357	89%	89%	79
Trout Creek:	7.1	6.6	23%	551	88%	88%	85
Trout Creek:	6.6	6.1	6%	672	90%	90%	74
Trout Creek:	6.1	5.6	22%	561	90%	90%	69
Trout Creek:	5.6	5.1	49%	363	90%	90%	70
Trout Creek:	5.1	4.6	34%	476	79%	79%	151
Trout Creek:	4.6	4.1	32%	486	87%	87%	95
Trout Creek:	4.1	3.6	26%	531	90%	90%	72
Trout Creek:	3.6	3.1	44%	401	89%	89%	78
Trout Creek:	3.1	2.6	2%	704	42%	89%	78
Trout Creek:	2.6	2.1	27%	520	88%	70%	215
Trout Creek:	2.1	1.6	28%	518	89%	70%	215
Trout Creek:	1.6	1.1	41%	420	89%	70%	215
Trout Creek:	1.1	0.6	13%	623	90%	70%	215
Trout Creek:	0.6	0.0	38%	441	95%	70%	215

(1) The surrogate load allocations for effective shade on privately owned land are proposed as estimated targets. Actual effective shade from Forest and Fish buffers is expected to be greater than 70%.

Table 5. Effective shade and solar flux for Panther Creek.

						Load Allocations (1)	
	Distance from mouth to upstream segment boundary (Km)	Distance from mouth to downstream segment boundary (Km)	Current condition effective shade from HeatSource model using current vegetation estimates	Estimated daily average solar flux to water surface on August 1 with current vegetation (cal/cm2/day)	Site potential effective shade from HeatSource model using minimum 160-ft tree height and 85% canopy density	Load allocation for effective shade assuming mature riparian vegetation on USFS land (160-ft tree height and 85% canopy density), and effective shade of 70% or shade produced by mature riparian vegetation, whichever is less, on non-USFS land. For Trout Creek the proposed LA is also based on removal of Hemlock Dam.	Estimated daily average flux of shortwave solar radiation to the water surface on August 1 at the load allocation for effective shade (cal/cm2/day)
Panther Creek:	12.4	11.9	68%	226	88%	88%	82
Panther Creek:	11.9	11.4	78%	156	88%	88%	86
Panther Creek:	11.4	10.9	20%	566	88%	88%	88
Panther Creek:	10.9	10.4	15%	601	85%	85%	110
Panther Creek:	10.4	9.9	54%	325	78%	78%	154
Panther Creek:	9.9	9.4	58%	297	75%	75%	179
Panther Creek:	9.4	8.9	35%	460	75%	75%	180
Panther Creek:	8.9	8.4	70%	212	78%	78%	154
Panther Creek:	8.4	7.9	7%	658	82%	82%	129
Panther Creek:	7.9	7.4	6%	665	87%	87%	89
Panther Creek:	7.4	6.9	31%	488	86%	86%	97
Panther Creek:	6.9	6.4	51%	347	87%	87%	95
Panther Creek:	6.4	5.9	29%	502	80%	80%	145
Panther Creek:	5.9	5.4	34%	467	87%	87%	95
Panther Creek:	5.4	4.9	24%	538	89%	89%	80
Panther Creek:	4.9	4.4	37%	446	88%	88%	83
Panther Creek:	4.4	3.9	54%	325	89%	89%	81
Panther Creek:	3.9	3.4	65%	248	88%	88%	88
Panther Creek:	3.4	2.9	51%	347	85%	70%	212
Panther Creek:	2.9	2.4	57%	304	88%	70%	212
Panther Creek:	2.4	1.9	56%	311	91%	70%	212
Panther Creek:	1.9	1.4	60%	283	88%	70%	212
Panther Creek:	1.4	0.9	61%	276	89%	70%	212
Panther Creek:	0.9	0.4	55%	318	90%	70%	212
Panther Creek:	0.4	0.0	54%	325	91%	70%	212

(1) The surrogate load allocations for effective shade on privately owned land are proposed as estimated targets. Actual effective shade from Forest and Fish buffers is expected to be greater than 70%.

Table 6. Effective shade and solar flux for Bear Creek and Eightmile Creek.

						Load Allocations (1)	
	Distance from mouth to upstream segment boundary (Km)	Distance from mouth to downstream segment boundary (Km)	Current condition effective shade from HeatSource model using current vegetation estimates	Estimated daily average solar flux to water surface on August 1 with current vegetation (cal/cm2/day)	Site potential effective shade from HeatSource model using minimum 160-ft tree height and 85% canopy density	Load allocation for effective shade assuming mature riparian vegetation on USFS land (160-ft tree height and 85% canopy density), and effective shade of 70% or shade produced by mature riparian vegetation, whichever is less, on non-USFS land. For Trout Creek the proposed LA is also based on removal of Hemlock Dam.	Estimated daily average flux of shortwave solar radiation to the water surface on August 1 at the load allocation for effective shade (cal/cm2/day)
Bear Creek:	#REF!	9.2	56%	320	88%	88%	87
Bear Creek:	9.2	8.7	91%	65	92%	92%	58
Bear Creek:	8.7	8.2	93%	49	93%	93%	49
Bear Creek:	8.2	7.7	89%	79	89%	89%	78
Bear Creek:	7.7	7.2	85%	109	91%	91%	65
Bear Creek:	7.2	6.7	60%	291	88%	88%	88
Bear Creek:	6.7	6.2	83%	122	87%	87%	97
Bear Creek:	6.2	5.7	20%	580	87%	87%	91
Bear Creek:	5.7	5.2	19%	590	95%	95%	39
Bear Creek:	5.2	4.7	64%	265	91%	91%	66
Bear Creek:	4.7	4.2	29%	519	93%	93%	54
Bear Creek:	4.2	3.7	76%	176	92%	92%	56
Bear Creek:	3.7	3.2	82%	131	90%	90%	73
Bear Creek:	3.2	2.7	83%	122	90%	90%	76
Bear Creek:	2.7	2.2	74%	189	92%	92%	60
Bear Creek:	2.2	1.7	73%	194	91%	70%	218
Bear Creek:	1.7	1.2	73%	199	90%	70%	218
Bear Creek:	1.2	0.7	81%	142	92%	70%	218
Bear Creek:	0.7	0.0	58%	303	92%	70%	218
Eightmile Creek:	5.1	4.6	98%	12	99%	99%	8
Eightmile Creek:	4.6	4.1	78%	161	93%	93%	52
Eightmile Creek:	4.1	3.6	83%	127	93%	93%	51
Eightmile Creek:	3.6	3.1	83%	126	94%	94%	42
Eightmile Creek:	3.1	2.6	86%	103	94%	94%	42
Eightmile Creek:	2.6	2.1	93%	51	95%	95%	39
Eightmile Creek:	2.1	1.6	89%	78	94%	94%	44
Eightmile Creek:	1.6	1.1	67%	237	94%	94%	42
Eightmile Creek:	1.1	0.6	95%	39	95%	95%	39
Eightmile Creek:	0.6	0.0	95%	38	95%	95%	38

(1) The surrogate load allocations for effective shade on privately owned land are proposed as estimated targets. Actual effective shade from Forest and Fish buffers is expected to be greater than 70%.

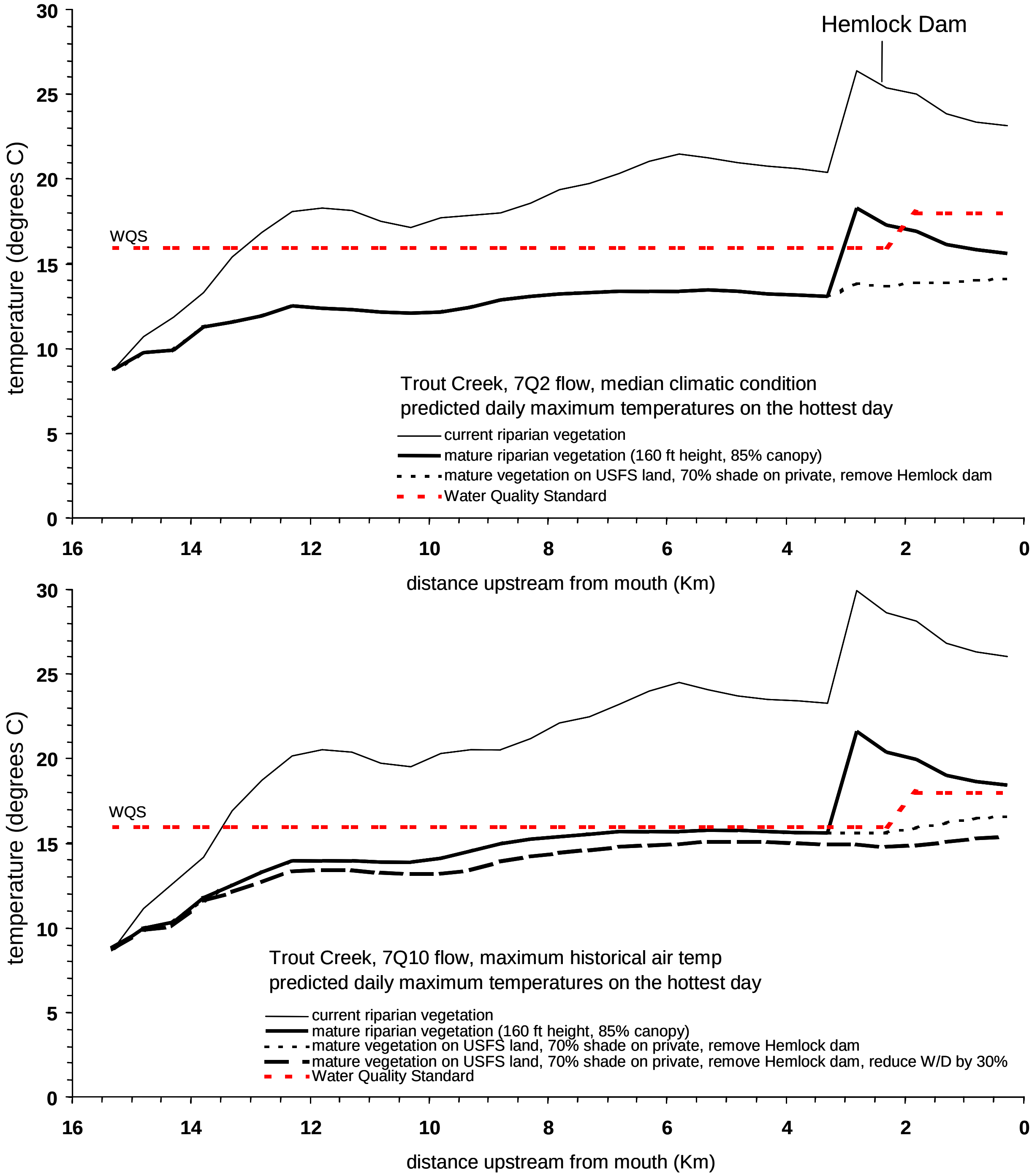


Figure 18. Predicted daily maximum temperature in Trout Creek under critical conditions for the TMDL.

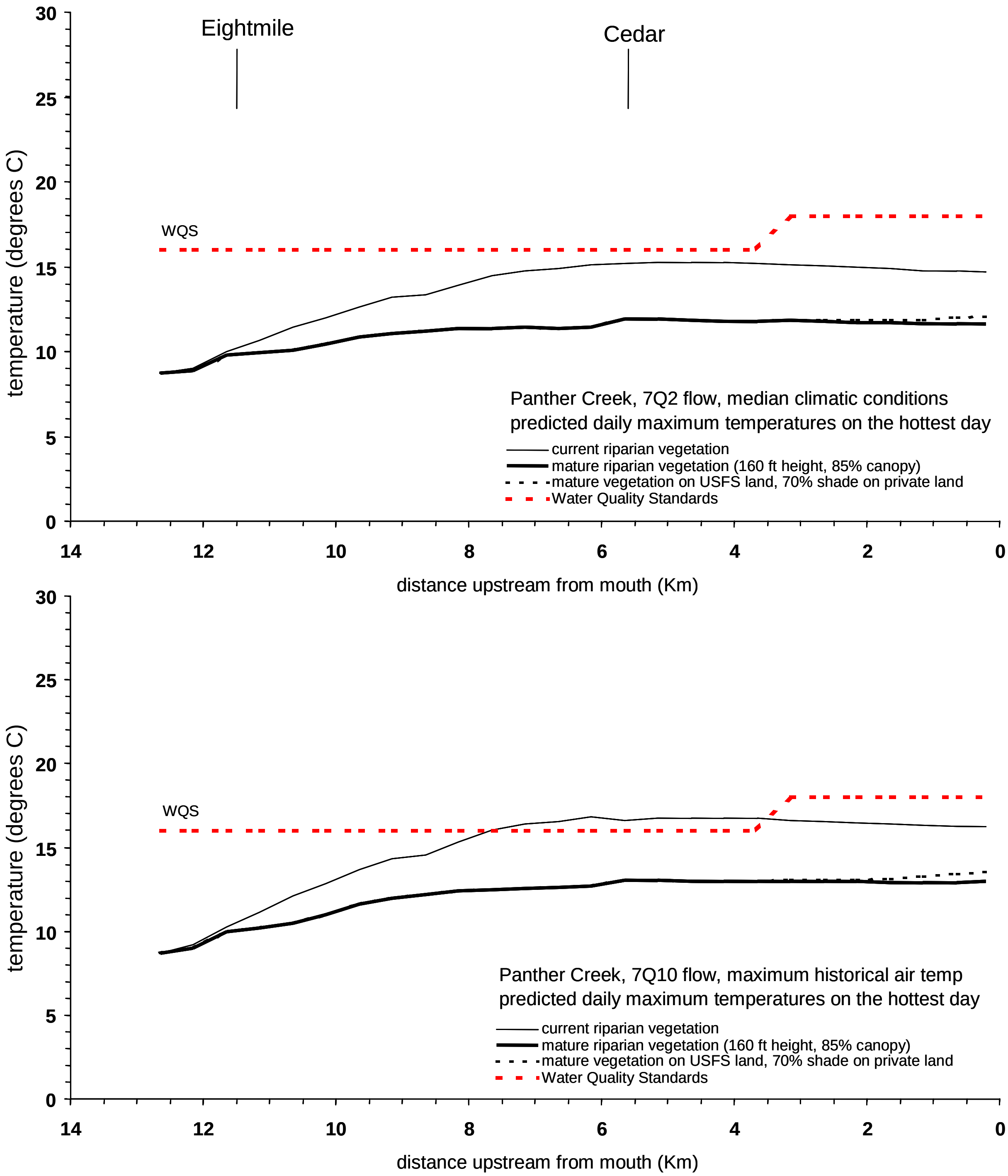


Figure 19. Predicted daily maximum temperature in Panther Creek under critical conditions for the TMDL.

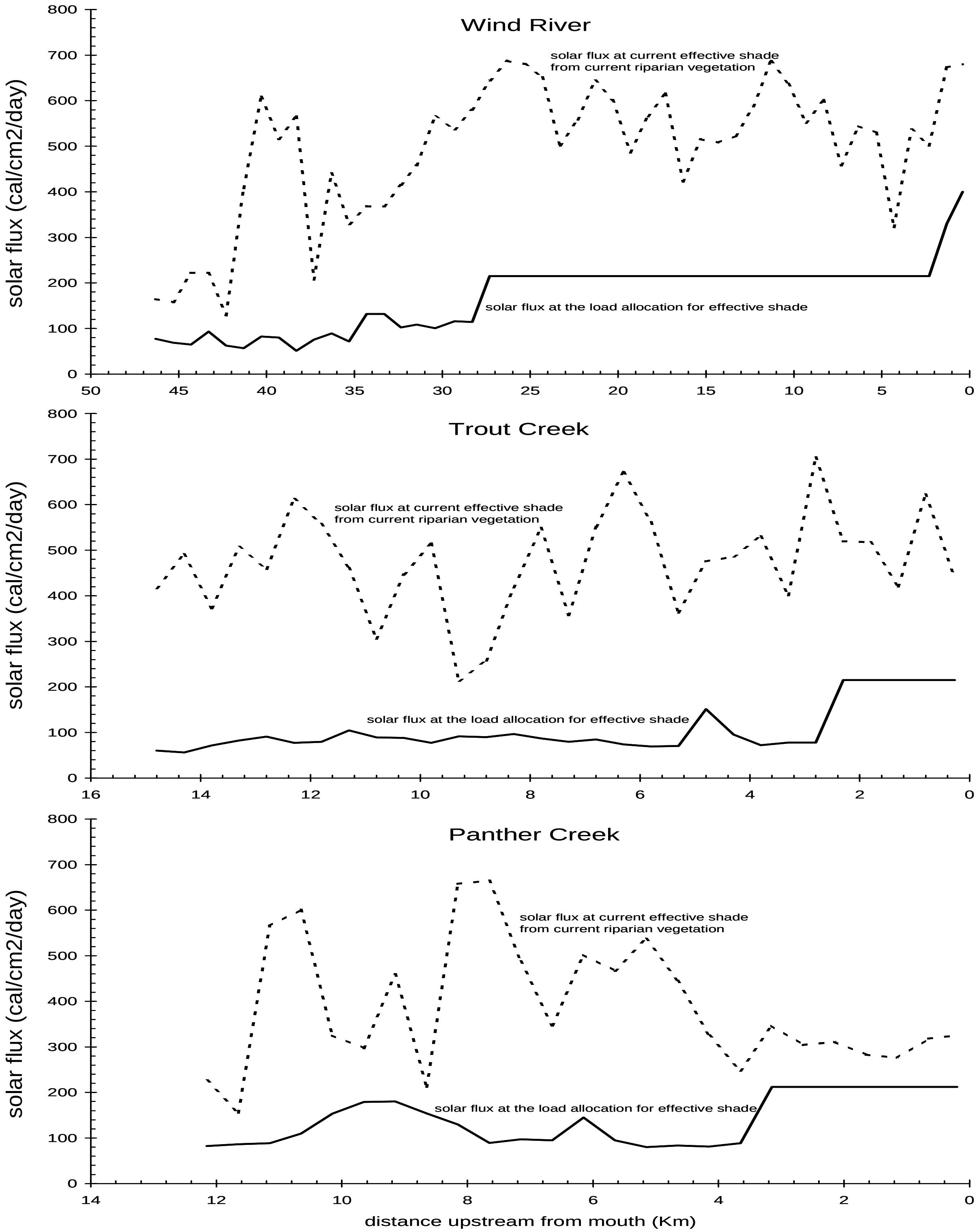


Figure 20. Loading capacity for solar flux to the water surface on August 1 at the load allocations for effective shade for the Wind River, Trout, and Panther Creek (at 7Q10 low flow conditions and maximum historical air temperatures).

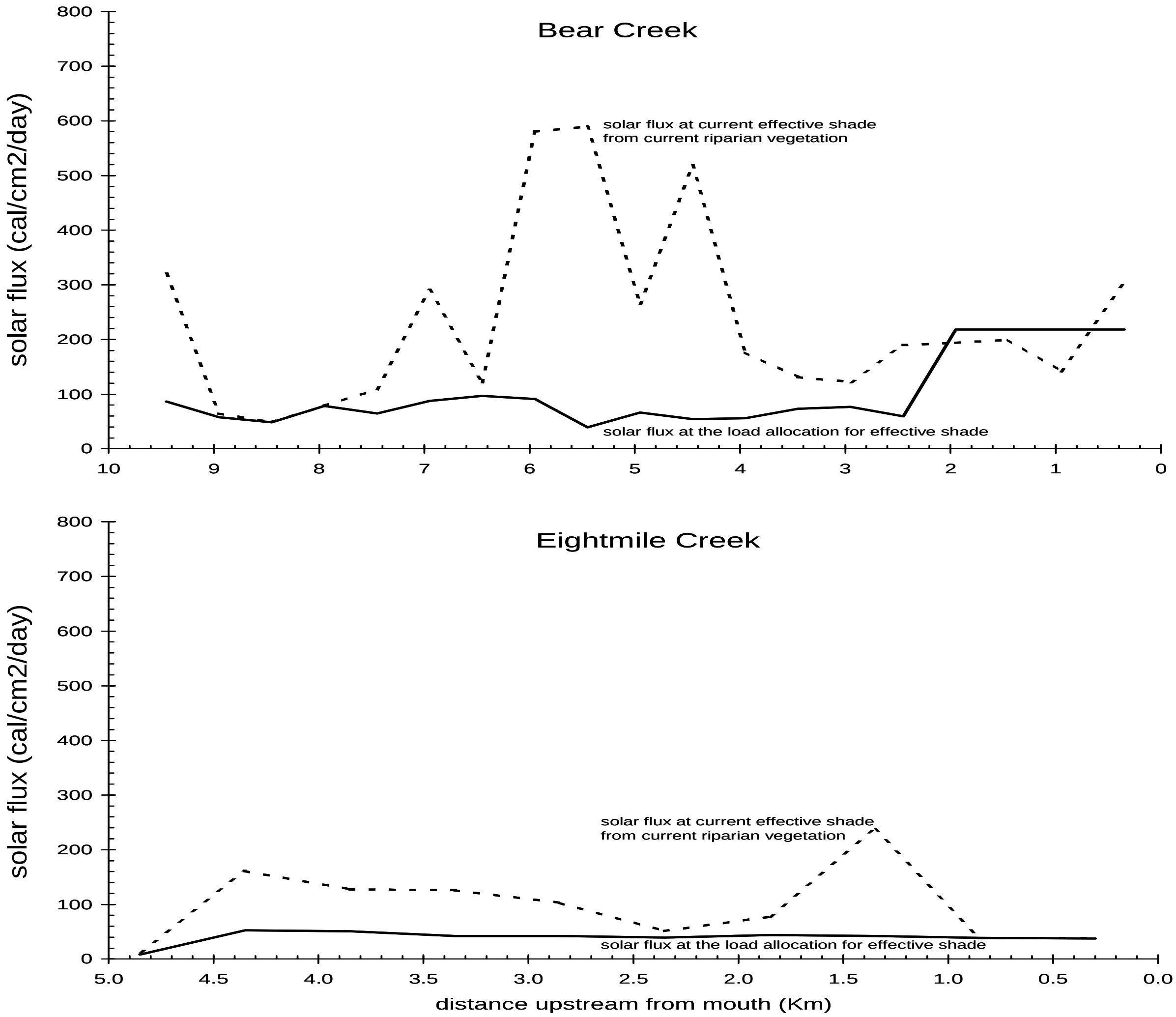


Figure 21. Loading capacity for solar flux to the water surface on August 1 at the load allocations for effective shade for Bear and Eightmile Creeks (at 7Q10 low flow conditions and maximum historical air temperatures).

Margin of Safety

The margin of safety accounts for uncertainty about pollutant loading and water-body response. In this TMDL, the margin of safety is addressed by using critical climatic conditions in the modeling analysis. Conservative assumptions for critical conditions include the following:

- Climatic conditions measured during 1998, the hottest year of record at the Carson Fish Hatchery, were used to represent reasonable worst case conditions.

- 7Q10 low flow conditions were used to represent reasonable worst-case conditions in this analysis. Typical conditions were evaluated using 7Q2 low flow conditions.

- The effective shade that would be produced by mature riparian vegetation throughout the watershed was conservatively estimated to be 70%. The TMDL analysis predicts that the actual effective shade from mature riparian vegetation is likely to be greater than 70% in most locations.

- Model uncertainty was assessed by estimating the RMSE of model predictions compared with observed temperatures during model verification. The upper 75^{th} percentile prediction limits for water temperatures that were predicted by QUAL2K were estimated using the RMSE of the model verification results as an estimate of the standard deviation of the model predictions. The 75^{th} percentile prediction limits of water temperature were used to determine whether the water quality standard would be met for the proposed load allocations. The 75^{th} percentile prediction limits of water temperature under the critical 7Q10 flow and climate condition and at the proposed load allocations were predicted to meet the water quality standards for temperature in the Wind River, Trout Creek, and Panther Creek.

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Appendices

Appendix A. Summary of maximum daily maximum temperatures in the Wind River basin for 1998, 1999, and 2000.

					Maximum 7-day-average daily maximum			Maximum daily maximum		
Station Id	Name	Data Source	Station Start Date	Station End Date	Water Temp. (degC)	7-day Start Date	7-day End Date	Water Temp. (degC)	Date	Peak Hourly Change on that day (degC/hr)
WR-1	Wind (nr Carson, UCD)	UCD	7/16/99	10/6/99	15.6	7/27/99	8/2/99	16.0	7/28/99	0.64
WR-1	Wind (nr Carson, UCD)	UCD	7/16/99	10/6/99	15.6	7/28/99	8/3/99	16.0	8/4/99	0.63
WR-1	Wind (nr Carson, UCD)	UCD	7/16/99	10/6/99	15.6	7/29/99	8/4/99	16.0	8/10/99	0.64
WR-1	Wind (nr Carson, UCD)	UCD	6/19/00	10/2/00	16.8	7/29/00	8/4/00	17.5	7/31/00	0.64
WR-1	Wind (nr Carson, UCD)	UCD	6/19/00	10/2/00	16.8	7/30/00	8/5/00			
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99	16.5	7/28/99	8/3/99	16.8	7/28/99	0.64
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99	16.5	7/29/99	8/4/99	16.8	8/2/99	0.96
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99	16.5	8/22/99	8/28/99	16.8	8/3/99	0.64
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99				16.8	8/4/99	0.63
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99				16.8	8/10/99	0.64
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99				16.8	8/19/99	0.64
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99				16.8	8/24/99	0.64
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99				16.8	8/27/99	0.63
WR-1a	Bear (UCD)	UCD	6/15/99	10/7/99				16.8	8/28/99	0.63
WR-1a	Bear (UCD)	UCD	6/19/00	10/2/00	17.5	7/30/00	8/5/00	17.9	7/31/99	0.63
WR-1a	Bear (UCD)	UCD	6/19/00	10/2/00	17.5	7/31/00	8/6/00			
WR-1d	Wind (nr Carson, UCD)	UCD	6/15/99	10/7/99	14.5	7/9/99	7/15/99	15.2	7/11/99	0.65
WR-1d	Wind (nr Carson, UCD)	UCD	6/15/99	10/7/99				15.2	7/12/99	0.65
WR-1d	Wind (nr Carson, UCD)	UCD	6/15/99	10/7/99				15.2	7/21/99	0.64
WR-1d	Wind (nr Carson, UCD)	UCD	6/15/99	10/7/99				15.2	7/22/99	0.64
WR-1d	Wind (nr Carson, UCD)	UCD	6/19/00	10/2/00	16.7	7/28/00	8/3/00	17.1	7/30/00	0.64
WR-1d	Wind (nr Carson, UCD)	UCD	6/19/00	10/2/00	16.7	7/29/00	8/4/00	17.1	7/31/00	0.64
WR-1d	Wind (nr Carson, UCD)	UCD	6/19/00	10/2/00	16.7	7/30/00	8/5/00			
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99	18.0	7/28/99	8/3/99	18.3	7/28/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99	18.0	7/29/99	8/4/99	18.3	8/3/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99	18.0	8/19/99	8/25/99	18.3	8/4/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99	18.0	8/21/99	8/27/99	18.3	8/10/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99	18.0	8/22/99	8/28/99	18.3	8/17/99	0.95
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99	18.0	8/23/99	8/29/99	18.3	8/19/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99				18.3	8/24/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99				18.3	8/25/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99				18.3	8/27/99	0.63
WR-2	Little Wind (UCD)	UCD	6/15/99	10/7/99				18.3	8/28/99	0.63
WR-2	Little Wind (UCD)	UCD	6/19/00	10/2/00	18.8	7/29/00	8/4/00	19.4	7/31/99	0.63
WR-2	Little Wind (UCD)	UCD	6/19/00	10/2/00	18.8	7/30/00	8/5/00			
WR-2	Little Wind (UCD)	UCD	6/19/00	10/2/00	18.8	7/31/00	8/6/00			
WR-4	Trout (nr mouth, UCD)	UCD	6/15/99	10/5/99	18.1	8/18/99	8/24/99	18.7	8/4/99	0.95
WR-4	Trout (nr mouth, UCD)	UCD	6/15/99	10/5/99	18.1	8/19/99	8/25/99	18.7	8/19/99	0.63
WR-4	Trout (nr mouth, UCD)	UCD	6/15/99	10/5/99	18.1	8/23/99	8/29/99	18.7	8/28/99	0.63
WR-4	Trout (nr mouth, UCD)	UCD	6/19/00	10/2/00	20.5	7/31/00	8/6/00	21.0	7/31/00	0.96
WR-5	Wind (Stabler, UCD)	UCD	6/15/99	10/5/99	15.8	7/29/99	8/4/99	16.4	8/4/99	0.98
WR-5	Wind (Stabler, UCD)	UCD	6/15/99	10/5/99						
WR-5	Wind (Stabler, UCD)	UCD	6/19/00	10/2/00	17.0	7/29/00	8/4/00	17.5	7/31/00	1.28
WR-5	Wind (Stabler, UCD)	UCD	6/19/00	10/2/00	17.0	7/30/00	8/5/00			
WR-5	Wind (Stabler, UCD)	UCD	6/19/00	10/2/00	17.0	7/31/00	8/6/00			
WR-6	Trapper (UCD)	UCD	6/14/99	10/5/99	14.1	8/18/99	8/24/99	14.5	8/28/99	0.64
WR-6	Trapper (UCD)	UCD	6/14/99	10/5/99	14.1	8/19/99	8/25/99			
WR-6	Trapper (UCD)	UCD	6/14/99	10/5/99	14.1	8/20/99	8/26/99			
WR-6	Trapper (UCD)	UCD	6/14/99	10/5/99	14.1	8/21/99	8/27/99			
WR-6	Trapper (UCD)	UCD	6/14/99	10/5/99	14.1	8/22/99	8/28/99			
WR-6	Trapper (UCD)	UCD	6/14/99	10/5/99	14.1	8/23/99	8/29/99			
WR-6	Trapper (UCD)	UCD	6/19/00	10/2/00	15.5	7/31/00	8/6/00	15.6	7/31/00	0.64
WR-6	Trapper (UCD)	UCD	6/19/00	10/2/00	15.5	8/3/00	8/9/00	15.6	8/1/00	0.64
WR-6	Trapper (UCD)	UCD	6/19/00	10/2/00				15.6	8/5/00	0.64
WR-6	Trapper (UCD)	UCD	6/19/00	10/2/00				15.6	8/6/00	0.64
WR-6	Trapper (UCD)	UCD	6/19/00	10/2/00				15.6	8/8/00	0.64
WR-6	Trapper (UCD)	UCD	6/19/00	10/2/00				15.6	8/9/00	0.64
WR-8	Wind (bel Falls, UCD)	UCD	6/14/99	10/5/99	13.2	7/30/99	8/5/99	14.1	8/4/99	0.65
WR-8	Wind (bel Falls, UCD)	UCD	6/14/99	10/5/99	13.2	7/31/99	8/6/99	14.1	8/18/99	0.64
WR-8	Wind (bel Falls, UCD)	UCD	6/14/99	10/5/99	13.2	8/18/99	8/24/99			
WR-8	Wind (bel Falls, UCD)	UCD	6/19/00	10/2/00	14.7	7/29/00	8/4/00	15.6	7/31/00	0.64
WR-8	Wind (bel Falls, UCD)	UCD	6/19/00	10/2/00	14.7	7/30/00	8/5/00			
USFS01	Bear (abv dam, USFS)	USFS	6/12/98	10/2/98	16.3	7/24/98	7/30/98	17.1	7/28/98	0.49
USFS01	Bear (abv dam, USFS)	USFS	7/9/99	9/23/99	15.1	8/22/99	8/28/99	15.6	8/28/99	0.24
USFS01	Bear (abv dam, USFS)	USFS	7/9/99	9/23/99	15.1	8/23/99	8/29/99			

Appendix A. Summary of maximum daily maximum temperatures in the Wind River basin for 1998, 1999, and 2000.

					Maximum 7-day-average daily maximum			Maximum daily maximum		
Station Id	Name	Data Source	Station Start Date	Station End Date	Water Temp. (degC)	7-day Start Date	7-day End Date	Water Temp. (degC)	Date	Peak Hourly Change on that day (degC/hr)
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00	15.5	7/30/00	8/5/00	15.8	7/31/00	0.48
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00	15.5	7/31/00	8/6/00			
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00						
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00						
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00						
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00						
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00						
USFS01	Bear (abv dam, USFS)	USFS	6/28/00	9/27/00						
USFS02	Panther (bel 65 br, USFS)	USFS	6/10/98	9/30/98	12.0	7/22/98	7/28/98	12.4	7/28/98	0.85
USFS02	Panther (bel 65 br, USFS)	USFS	6/10/98	9/30/98						
USFS02	Panther (bel 65 br, USFS)	USFS	7/9/99	9/23/99	10.1	7/26/99	8/1/99	10.4	7/11/99	0.79
USFS02	Panther (bel 65 br, USFS)	USFS	7/9/99	9/23/99	10.1	7/27/99	8/2/99	10.4	7/12/99	0.80
USFS02	Panther (bel 65 br, USFS)	USFS	7/9/99	9/23/99	10.1	7/28/99	8/3/99	10.4	7/13/99	0.80
USFS02	Panther (bel 65 br, USFS)	USFS	7/9/99	9/23/99	10.1	7/29/99	8/4/99	10.4	7/28/99	0.79
USFS02	Panther (bel 65 br, USFS)	USFS	7/11/00	9/27/00	11.4	7/29/00	8/4/00	11.7	7/31/00	0.93
USFS02	Panther (bel 65 br, USFS)	USFS	7/11/00	9/27/00	11.4	7/30/00	8/5/00			
USFS02	Panther (bel 65 br, USFS)	USFS	7/11/00	9/27/00						
USFS02	Panther (bel 65 br, USFS)	USFS	7/11/00	9/27/00						
USFS02	Panther (bel 65 br, USFS)	USFS	7/11/00	9/27/00						
USFS04	Trout (abv Hemlock, USFS)	USFS	6/11/98	10/2/98	22.1	7/23/98	7/29/98	23.2	7/28/98	1.15
USFS04	Trout (abv Hemlock, USFS)	USFS	6/11/98	10/2/98	22.1	7/24/98	7/30/98			
USFS04	Trout (abv Hemlock, USFS)	USFS	7/9/99	9/27/99	18.4	8/18/99	8/24/99	19.1	8/19/99	
USFS04	Trout (abv Hemlock, USFS)	USFS	6/28/00	9/27/00	20.0	7/30/00	8/5/00	20.8	7/31/00	0.83
USFS04 (5?)	Trout Creek (43 bridge, USFS)	USFS	6/28/00	9/27/00	20.0	7/31/00	8/6/00			
USFS06	Wind (bel Trapper, USFS)	USFS	6/10/98	10/1/98	17.0	7/23/98	7/29/98	17.8	7/28/98	0.75
USFS06	Wind (bel Trapper, USFS)	USFS	6/10/98	10/1/98	17.0	7/24/98	7/30/98			
USFS06	Wind (bel Trapper, USFS)	USFS	7/9/99	9/21/99	15.2	8/18/99	8/24/99	15.8	8/28/99	0.72
USFS06	Wind (bel Trapper, USFS)	USFS	7/9/99	9/21/99	15.2	8/19/99	8/25/99			
USFS06	Wind (bel Trapper, USFS)	USFS	7/9/99	9/21/99	15.2	8/23/99	8/29/99			
USFS06	Wind (bel Trapper, USFS)	USFS	8/23/00	9/26/00	15.4	8/19/00	8/25/00	15.8	8/24/00	1.15
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/9/99	9/27/99	13.3	8/22/99	8/28/99	13.7	8/28/99	0.45
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/9/99	9/27/99	13.3	8/23/99	8/29/99			
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/9/99	9/27/99	13.3	8/24/99	8/30/99			
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/11/00	9/26/00	14.5	8/3/00	8/9/00	14.6	7/31/00	0.46
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/11/00	9/26/00	14.5	8/4/00	8/10/00	14.6	8/5/00	0.46
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/11/00	9/26/00				14.6	8/6/00	0.46
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/11/00	9/26/00				14.6	8/8/00	0.46
USFS07	Trapper (abv foot bridge, USFS)	USFS	7/11/00	9/26/00				14.6	8/9/00	0.46
USFS08	Ninemile (USFS)	USFS	6/12/98	9/4/98	17.0	7/26/98	8/1/98	19.7	8/31/98	1.52
USFS08	Ninemile (USFS)	USFS	6/12/98	9/4/98	17.0	7/27/98	8/2/98			
USFS08	Ninemile (USFS)	USFS	7/27/99	9/23/99	14.5	8/24/99	8/30/99	15.3	8/28/99	0.24
USFS08	Ninemile (USFS)	USFS	7/12/00	9/26/00	11.5	7/29/00	8/4/00	11.7	7/31/00	0.77
USFS08	Ninemile (USFS)	USFS	7/12/00	9/26/00	11.5	7/30/00	8/5/00			
USFS08	Ninemile (USFS)	USFS	7/12/00	9/26/00	11.5	7/31/00	8/6/00			
USFS08	Ninemile (USFS)	USFS	7/12/00	9/26/00	11.5	8/1/00	8/7/00			
USFS08	Ninemile (USFS)	USFS	7/12/00	9/26/00	11.5	8/2/00	8/8/00			
USFS08	Ninemile (USFS)	USFS	7/12/00	9/26/00	11.5	8/3/00	8/9/00			
USFS08	Ninemile (USFS)	USFS	7/12/00	9/26/00	11.5	8/4/00	8/10/00			
USFS09	Falls (USFS)	USFS	6/12/98	10/1/98	15.5	7/24/98	7/30/98	16.1	7/27/98	0.48
USFS09	Falls (USFS)	USFS	7/15/99	9/23/99	13.0	8/23/99	8/29/99	13.5	8/4/99	0.44
USFS09	Falls (USFS)	USFS	7/15/99	9/23/99				13.5	8/18/99	0.45
USFS09	Falls (USFS)	USFS	7/12/00	9/26/00	14.3	7/29/00	8/4/00	15.1	7/30/00	0.62
USFS09	Falls (USFS)	USFS	7/12/00	9/26/00	14.3	7/30/00	8/5/00	15.1	7/31/00	0.32
USFS10	Wind (abv Falls, USFS)	USFS	7/15/99	9/23/99	16.4	8/17/99	8/23/99	16.6	8/4/99	0.95
USFS10	Wind (abv Falls, USFS)	USFS	7/15/99	9/23/99	16.4	8/18/99	8/24/99	16.6	8/10/99	0.96
USFS10	Wind (abv Falls, USFS)	USFS	7/15/99	9/23/99				16.6	8/18/99	0.93
USFS10	Wind (abv Falls, USFS)	USFS	7/15/99	9/23/99				16.6	8/19/99	0.72
USFS10	Wind (abv Falls, USFS)	USFS	7/15/99	9/23/99				16.6	8/20/99	0.93
USFS10	Wind (abv Falls, USFS)	USFS	7/15/99	9/23/99				16.6	8/23/99	0.95
USFS10	Wind (abv Falls, USFS)	USFS	7/15/99	9/23/99				16.6	8/24/99	0.94
USFS10	Wind (abv Falls, USFS)	USFS	7/12/00	9/26/00	16.2	8/3/00	8/9/00	16.3	7/30/00	0.92
USFS10	Wind (abv Falls, USFS)	USFS	7/12/00	9/26/00				16.3	7/31/00	0.96
USFS10	Wind (abv Falls, USFS)	USFS	7/12/00	9/26/00				16.3	8/5/00	0.96
USFS10	Wind (abv Falls, USFS)	USFS	7/12/00	9/26/00				16.3	8/8/00	0.96
USFS10	Wind (abv Falls, USFS)	USFS	7/12/00	9/26/00				16.3	8/9/00	0.94

Appendix A. Summary of maximum daily maximum temperatures in the Wind River basin for 1998, 1999, and 2000.

					Maximum 7-day-average daily maximum			Maximum daily maximum		
Station Id	Name	Data Source	Station Start Date	Station End Date	Water Temp. (degC)	7-day Start Date	7-day End Date	Water Temp. (degC)	Date	Peak Hourly Change on that day (degC/hr)
USFS11	Wind (bel Paradise, USFS)	USFS	7/14/99	9/27/99	15.1	8/18/99	8/24/99	15.6	8/19/99	0.70
USFS11	Wind (bel Paradise, USFS)	USFS	7/14/99	9/27/99	15.1	8/19/99	8/25/99			
USFS11 (12?)	Paradise (abv 30 bridge, USFS)	USFS	7/12/00	9/26/00	16.6	7/30/00	8/5/00	17.1	7/31/00	0.80
USFS11 (12?)	Paradise (abv 30 bridge, USFS)	USFS	7/12/00	9/26/00	16.6	7/31/00	8/6/00			
USFS13	Wind (abv Paradise, USFS)	USFS	7/14/99	9/27/99	15.1	8/18/99	8/24/99	15.6	8/19/99	0.70
USFS13	Wind (abv Paradise, USFS)	USFS	7/14/99	9/27/99	15.1	8/19/99	8/25/99			
USFS13	Wind (abv Paradise, USFS)	USFS	7/12/00	8/3/00	16.4	7/30/00	8/5/00	17.1	7/31/00	0.73
USFS13	Wind (abv Paradise, USFS)	USFS	7/12/00	8/3/00	16.4	7/31/00	8/6/00			
USFS14	Pete's Gulch (USFS)	USFS	7/14/99	9/27/99	13.7	8/23/99	8/29/99	14.1	8/18/99	0.46
USFS14	Pete's Gulch (USFS)	USFS	7/14/99	9/27/99				14.1	8/28/99	0.31
USFS15	Wind (abv Pete's, USFS)	USFS	6/12/98	10/2/98	15.6	7/22/98	7/28/98	16.5	7/27/98	0.63
USFS15	Wind (abv Pete's, USFS)	USFS	6/12/98	10/2/98	15.6	7/23/98	7/29/98			
USFS15	Wind (abv Pete's, USFS)	USFS	6/12/98	10/2/98	15.6	7/24/98	7/30/98			
USFS15	Wind (abv Pete's, USFS)	USFS	6/12/98	10/2/98	15.6	7/25/98	7/31/98			
USFS15	Wind (abv Pete's, USFS)	USFS	7/14/99	9/27/99	14.5	7/31/99	8/6/99	15.2	8/4/99	0.60
USFS15	Wind (abv Pete's, USFS)	USFS	7/14/99	9/27/99	14.5	8/1/99	8/7/99	15.2	8/5/99	0.31
USFS15	Wind (abv Pete's, USFS)	USFS	7/14/99	9/27/99	14.5	8/2/99	8/8/99			
USFS15	Wind (abv Pete's, USFS)	USFS	7/14/99	9/27/99	14.5	8/3/99	8/9/99			
USFS15	Wind (abv Pete's, USFS)	USFS	7/14/99	9/27/99	14.5	8/4/99	8/10/99			
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00	13.9	7/29/00	8/4/00	14.9	7/30/00	0.47
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00	13.9	7/30/00	8/5/00			
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS15	Wind (abv Pete's, USFS)	USFS	7/13/00	9/26/00						
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99	9.8	8/17/99	8/23/99	10.0	8/3/99	1.00
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99	9.8	8/18/99	8/24/99	10.0	8/4/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99	9.8	8/22/99	8/28/99	10.0	8/10/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99				10.0	8/17/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99				10.0	8/18/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99				10.0	8/19/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99				10.0	8/23/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99				10.0	8/24/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99				10.0	8/27/99	0.50
USFS17	NF Falls (USFS)	USFS	7/15/99	9/27/99				10.0	8/28/99	0.50
USFS17	NF Falls (USFS)	USFS	7/14/00	9/28/00	10.8	7/29/00	8/4/00	11.3	7/31/00	0.78
USFS17	NF Falls (USFS)	USFS	7/14/00	9/28/00	10.8	7/30/00	8/5/00			
USFS17	NF Falls (USFS)	USFS	7/14/00	9/28/00	10.8	7/31/00	8/6/00			
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99	16.4	7/26/99	8/1/99	17.0	7/26/99	1.00
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99	16.4	7/27/99	8/2/99	17.0	7/28/99	1.00
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99				17.0	8/4/99	1.00
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						

Appendix A. Summary of maximum daily maximum temperatures in the Wind River basin for 1998, 1999, and 2000.

Station Id	Name	Data Source	Station Start Date	Station End Date	Maximum 7-day-average daily maximum Water Temp. (degC)	7-day Start Date	7-day End Date	Maximum daily maximum Water Temp. (degC)	Date	Peak Hourly Change on that day (degC/hr)
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/15/99	8/10/99						
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/14/00	9/28/00	16.8	7/27/00	8/2/00	17.9	7/31/00	0.79
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/14/00	9/28/00	16.8	7/28/00	8/3/00			
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/14/00	9/28/00	16.8	7/29/00	8/4/00			
USFS18	SF Falls (bel Black Cr, USFS)	USFS	7/14/00	9/28/00	16.8	7/30/00	8/5/00			
USFS19	SF Falls (abv Black Cr, USFS)	USFS	8/19/99	10/6/99	17.5	8/25/99	8/31/99			
USFS19	SF Falls (abv Black Cr, USFS)	USFS	8/19/99	10/6/99						
USFS19	SF Falls (abv Black Cr, USFS)	USFS	8/19/99	10/6/99						
USFS19	SF Falls (abv Black Cr, USFS)	USFS	8/19/99	10/6/99						
CEDA	Cedar (USGS)	USGS	4/1/98	10/8/98	16.1	7/22/98	7/28/98	16.9	7/28/98	0.72
CEDA	Cedar (USGS)	USGS	4/1/98	10/8/98	16.1	7/23/98	7/29/98			
CEDA	Cedar (USGS)	USGS	4/1/98	10/8/98	16.1	7/24/98	7/30/98			
CEDA	Cedar (USGS)	USGS	5/20/99	10/18/99	15.3	7/27/99	8/2/99	15.6	7/28/99	0.70
CEDA	Cedar (USGS)	USGS	5/20/99	10/18/99	15.3	7/28/99	8/3/99	15.6	8/4/99	0.62
CEDA	Cedar (USGS)	USGS	5/20/99	10/18/99	15.3	7/29/99	8/4/99			
COMP	Compass (USGS)	USGS	4/22/98	10/7/98	15.7	7/24/98	7/30/98	16.3	7/28/98	0.40
COMP	Compass (USGS)	USGS	4/22/98	10/7/98	15.7	7/25/98	7/31/98			
COMP	Compass (USGS)	USGS	4/22/98	10/7/98	15.7	7/26/98	8/1/98			
COMP	Compass (USGS)	USGS	4/22/98	10/7/98	15.7	7/27/98	8/2/98			
COMP	Compass (USGS)	USGS	5/11/99	10/4/99	13.8	8/22/99	8/28/99	14.0	8/28/99	0.31
COMP	Compass (USGS)	USGS	5/11/99	10/4/99						
COMP	Compass (USGS)	USGS	5/11/99	10/4/99						
COMP	Compass (USGS)	USGS	5/23/00	10/13/00	14.8	8/2/00	8/8/00	14.9	8/5/00	0.31
COMP	Compass (USGS)	USGS	5/23/00	10/13/00	14.8	8/3/00	8/9/00	14.9	8/8/00	0.31
CRAT	Crater (USGS)	USGS	4/22/98	10/7/98	19.0	7/23/98	7/29/98	20.0	7/28/98	0.80
CRAT	Crater (USGS)	USGS	4/22/98	10/7/98	19.0	7/24/98	7/30/98			
CRAT	Crater (USGS)	USGS	5/11/99	10/4/99	16.9	8/18/99	8/24/99	17.4	8/19/00	0.71
CRAT	Crater (USGS)	USGS	6/15/00	10/13/00	17.9	7/30/00	8/5/00	18.4	7/31/00	0.64
CRAT	Crater (USGS)	USGS	6/15/00	10/13/00	17.9	7/31/00	8/6/00			
DRYC00	Dry (upper, USGS)	USGS	6/21/00	10/19/00	15.0	8/3/00	8/9/00	15.2	7/31/00	1.01
DRYC00	Dry (upper, USGS)	USGS	6/21/00	10/19/00				15.2	8/5/00	1.08
DRYC00	Dry (upper, USGS)	USGS	6/21/00	10/19/00				15.2	8/8/00	1.08
DRYC00	Dry (upper, USGS)	USGS	6/21/00	10/19/00				15.2	8/9/00	1.01
EFTR	EF Trout (USGS)	USGS	5/25/99	10/14/99	18.1	7/28/99	8/3/99	19.0	8/4/99	0.95
EFTR	EF Trout (USGS)	USGS	5/25/99	10/14/99	18.1	7/29/99	8/4/99			
EFTR	EF Trout (USGS)	USGS	6/15/00	10/13/00	18.4	7/29/00	8/4/00	19.2	7/31/00	1.20
EFTR	EF Trout (USGS)	USGS	6/15/00	10/13/00	18.4	7/30/00	8/5/00			
FALL	Falls (USGS)	USGS	7/28/00	10/19/00	13.5	7/28/00	8/3/00	14.3	7/30/00	0.46
FALL	Falls (USGS)	USGS	7/28/00	10/19/00	13.5	7/29/00	8/4/00	14.3	7/31/00	0.31
FALL	Falls (USGS)	USGS	7/28/00	10/19/00	13.5	7/30/00	8/5/00			
HEML	Trout (blw Hemlock, USGS)	USGS	5/10/99	10/21/99	19.4	7/28/99	8/3/99	20.3	8/4/99	0.49
HEML	Trout (blw Hemlock, USGS)	USGS	5/10/99	10/21/99	19.4	7/29/99	8/4/99			
HEML	Trout (blw Hemlock, USGS)	USGS	5/10/99	10/21/99	19.4	7/30/99	8/5/99			
HEML	Trout (blw Hemlock, USGS)	USGS	5/10/99	10/21/99	19.4	7/31/99	8/6/99			
HEML	Trout (blw Hemlock, USGS)	USGS	5/10/99	10/21/99	19.4	8/18/99	8/24/99			
HEML	Trout (blw Hemlock, USGS)	USGS	5/10/99	10/21/99	19.4	8/19/99	8/25/99			
HEML	Trout (blw Hemlock, USGS)	USGS	6/1/00	10/19/00	21.8	7/31/00	8/6/00	22.6	7/31/00	0.57
LAYO	Layout (USGS)	USGS	4/22/98	10/19/98	19.0	8/8/98	8/14/98	19.6	8/13/98	0.88
LAYO	Layout (USGS)	USGS	5/14/99	10/4/99	16.8	8/18/99	8/24/99	17.4	8/4/99	0.80
LAYO	Layout (USGS)	USGS	5/14/99	10/4/99						
LAYO	Layout (USGS)	USGS	7/28/00	10/11/00	14.4	7/28/00	8/3/00	14.6	7/31/00	0.70
LAYO	Layout (USGS)	USGS	7/28/00	10/11/00	14.4	7/29/00	8/4/00			
LAYO	Layout (USGS)	USGS	7/28/00	10/11/00	14.4	7/30/00	8/5/00			
LAYO	Layout (USGS)	USGS	7/28/00	10/11/00	14.4	7/31/00	8/6/00			
LAYO	Layout (USGS)	USGS	7/28/00	10/11/00	14.4	8/1/00	8/7/00			
LEIG	Eightmile (lwr, within debris flow, USGS)	USGS	4/1/98	10/8/98	17.8	7/22/98	7/28/98	18.6	7/27/98	1.12
LEIG	Eightmile (lwr, within debris flow, USGS)	USGS	4/1/98	10/8/98	17.8	7/23/98	7/29/98			
LEIG	Eightmile (lwr, within debris flow, USGS)	USGS	6/8/00	10/25/00	18.1	7/30/00	8/5/00	18.4	7/31/00	1.27
LEIG	Eightmile (lwr, within debris flow, USGS)	USGS	6/8/00	10/25/00	18.1	7/31/00	8/6/00	18.4	8/5/00	1.51
LEIG	Eightmile (lwr, within debris flow, USGS)	USGS	6/8/00	10/25/00	18.1	8/1/00	8/7/00			

Appendix A. Summary of maximum daily maximum temperatures in the Wind River basin for 1998, 1999, and 2000.

					Maximum 7-day-average daily maximum			Maximum daily maximum		
Station Id	Name	Data Source	Station Start Date	Station End Date	Water Temp. (degC)	7-day Start Date	7-day End Date	Water Temp. (degC)	Date	Peak Hourly Change on that day (degC/hr)
LEIG	Eightmile (lwr, within debris flow, USGS)	USGS	6/8/00	10/25/00	18.1	8/2/00	8/8/00			
LEIG	Eightmile (lwr, within debris flow, USGS)	USGS	6/8/00	10/25/00	18.1	8/3/00	8/9/00			
LMIN	Wind (abv Falls, USGS)	USGS	7/28/00	10/19/00	12.5	7/29/00	8/4/00	12.7	8/1/00	0.47
LMIN	Wind (abv Falls, USGS)	USGS	7/28/00	10/19/00	12.5	7/30/00	8/5/00	12.7	8/3/00	0.63
LMIN	Wind (abv Falls, USGS)	USGS	7/28/00	10/19/00	12.5	7/31/00	8/6/00			
LOOG	Trout (lwr old growth, USGS)	USGS	5/14/99	10/14/99	14.3	8/18/99	8/24/99	16.1	7/22/99	1.01
LOOG	Trout (lwr old growth, USGS)	USGS	6/15/00	10/13/00	15.3	7/29/00	8/4/00	15.8	7/31/00	1.24
LOOG	Trout (lwr old growth, USGS)	USGS	6/15/00	10/13/00	15.3	7/30/00	8/5/00			
LOOG	Trout (lwr old growth, USGS)	USGS	6/15/00	10/13/00	15.3	7/31/00	8/6/00			
LPAN	Panther (lower, USGS)	USGS	6/8/00	10/25/00	13.8	7/29/00	8/4/00	14.3	7/31/00	0.93
LPAN	Panther (lower, USGS)	USGS	6/8/00	10/25/00	13.8	7/30/00	8/5/00			
LPAN99	Panther (lower, USGS)	USGS	5/20/99	10/21/99	13.1	7/26/99	8/1/99	13.5	7/12/99	0.93
LPAN99	Panther (lower, USGS)	USGS	5/20/99	10/21/99	13.1	7/27/99	8/2/99	13.5	7/28/99	0.85
LPAN99	Panther (lower, USGS)	USGS	5/20/99	10/21/99	13.1	7/28/99	8/3/99			
LPAN99	Panther (lower, USGS)	USGS	5/20/99	10/21/99	13.1	7/29/99	8/4/99			
LTRO	Trout (abv Hemlock, USGS)	USGS	4/22/98	10/8/98	22.1	7/23/98	7/29/98	23.2	7/28/98	0.99
LTRO	Trout (abv Hemlock, USGS)	USGS	4/22/98	10/8/98	22.1	7/24/98	7/30/98			
LTRO	Trout (abv Hemlock, USGS)	USGS	5/10/99	10/18/99	18.3	8/18/99	8/24/99	13.5	7/12/99	0.70
LTRO	Trout (abv Hemlock, USGS)	USGS	5/10/99	10/18/99				17.2	7/28/99	0.71
LTRO	Trout (abv Hemlock, USGS)	USGS	6/16/00	10/19/00	20.6	7/30/00	8/5/00	21.3	7/31/00	0.89
LTRO	Trout (abv Hemlock, USGS)	USGS	6/16/00	10/19/00	20.6	7/31/00	8/6/00			
MART	Martha (USGS)	USGS	3/30/98	10/8/98	20.1	7/22/98	7/28/98	21.2	7/28/99	0.97
MART	Martha (USGS)	USGS	3/30/98	10/8/98	20.1	7/23/98	7/29/98			
MART	Martha (USGS)	USGS	3/30/98	10/8/98	20.1	7/24/98	7/30/98			
MART	Martha (USGS)	USGS	6/17/99	10/21/99	18.3	7/27/99	8/2/99	18.7	7/28/99	0.80
MART	Martha (USGS)	USGS	5/10/00	10/16/00	19.2	7/29/00	8/4/00	19.8	7/31/00	0.81
MART	Martha (USGS)	USGS	5/10/00	10/16/00	19.2	7/30/00	8/5/00			
MART	Martha (USGS)	USGS	5/10/00	10/16/00	19.2	7/31/00	8/6/00			
MS33	Trout (33 bridge, USGS)	USGS	4/22/98	10/7/98	10.2	7/22/98	7/28/98	10.4	7/28/98	0.55
MS33	Trout (33 bridge, USGS)	USGS	6/17/99	10/4/99	8.8	7/26/99	8/1/99	9.0	7/12/99	0.55
MS33	Trout (33 bridge, USGS)	USGS	6/17/99	10/4/99	8.8	7/27/99	8/2/99	9.0	7/28/99	0.47
MS33	Trout (33 bridge, USGS)	USGS	6/17/99	10/4/99	8.8	7/28/99	8/3/99	9.0	8/3/99	0.39
MS33	Trout (33 bridge, USGS)	USGS	6/17/99	10/4/99	8.8	7/29/99	8/4/99	9.0	8/4/99	0.47
MS33	Trout (33 bridge, USGS)	USGS	6/17/99	10/4/99	8.8	7/30/99	8/5/99			
MS33	Trout (33 bridge, USGS)	USGS	5/23/00	10/13/00	8.9	7/27/00	8/2/00	9.2	7/31/00	0.47
MS33	Trout (33 bridge, USGS)	USGS	5/23/00	10/13/00	8.9	7/28/00	8/3/00			
MS33	Trout (33 bridge, USGS)	USGS	5/23/00	10/13/00	8.9	7/29/00	8/4/00			
MS33	Trout (33 bridge, USGS)	USGS	5/23/00	10/13/00	8.9	7/30/00	8/5/00			
MS33	Trout (33 bridge, USGS)	USGS	5/23/00	10/13/00	8.9	7/31/00	8/6/00			
MS43	Trout (43 bridge, USGS)	USGS	4/1/98	10/19/98	17.9	7/22/98	7/28/98	18.6	7/28/98	1.19
MS43	Trout (43 bridge, USGS)	USGS	5/14/99	10/14/99	15.2	7/29/99	8/4/99	15.7	8/4/99	1.01
MS43	Trout (43 bridge, USGS)	USGS	5/14/99	10/14/99						
MS43	Trout (43 bridge, USGS)	USGS	5/14/99	10/14/99						
MS43	Trout (43 bridge, USGS)	USGS	5/18/00	10/13/00	16.3	7/30/00	8/5/00	16.7	7/31/00	0.86
MS43	Trout (43 bridge, USGS)	USGS	5/18/00	10/13/00						
NINE	Ninemile (USGS)	USGS	6/16/00	10/19/00	13.5	7/30/00	8/5/00	13.7	7/31/00	0.31
NINE	Ninemile (USGS)	USGS	6/16/00	10/19/00	13.5	7/31/00	8/6/00	13.7	8/5/00	0.31
NINE	Ninemile (USGS)	USGS	6/16/00	10/19/00	13.5	8/1/00	8/7/00	13.7	8/6/00	0.24
NINE	Ninemile (USGS)	USGS	6/16/00	10/19/00	13.5	8/2/00	8/8/00	13.7	8/8/00	0.31
NINE	Ninemile (USGS)	USGS	6/16/00	10/19/00	13.5	8/3/00	8/9/00	13.7	8/9/00	0.31
NINE	Ninemile (USGS)	USGS	6/16/00	10/19/00	13.5	8/4/00	8/10/00			
PARA	Paradise (USGS)	USGS	6/1/00	10/18/00	15.3	7/30/00	8/5/00	15.7	7/31/00	0.63
PARA	Paradise (USGS)	USGS	6/1/00	10/18/00	15.3	7/31/00	8/6/00			
PARA	Paradise (USGS)	USGS	6/1/00	10/18/00	15.3	8/1/00	8/7/00			
PARA	Paradise (USGS)	USGS	6/1/00	10/18/00	15.3	8/3/00	8/9/00			
PLAN	Planting (USGS)	USGS	4/1/98	10/19/98	18.0	7/24/98	7/30/98	19.2	7/28/98	0.73
TRAP	Trapper (abv Cabins, USGS)	USGS	5/18/99	10/14/99	13.4	8/23/99	8/29/99	13.8	8/28/99	0.23
TRAP	Trapper (abv Cabins, USGS)	USGS	5/18/99	10/14/99						
TRAP	Trapper (abv Cabins, USGS)	USGS	5/18/99	10/14/99						
TRAP	Trapper (abv Cabins, USGS)	USGS	6/19/00	10/19/00	14.4	7/31/00	8/6/00	14.5	7/31/00	0.31
TRAP	Trapper (abv Cabins, USGS)	USGS	6/19/00	10/19/00	14.4	8/1/00	8/7/00	14.5	8/1/00	0.31

Appendix A. Summary of maximum daily maximum temperatures in the Wind River basin for 1998, 1999, and 2000.

					Maximum 7-day-average daily maximum			Maximum daily maximum		
Station Id	Name	Data Source	Station Start Date	Station End Date	Water Temp. (degC)	7-day Start Date	7-day End Date	Water Temp. (degC)	Date	Peak Hourly Change on that day (degC/hr)
TRAP	Trapper (abv Cabins, USGS)	USGS	6/19/00	10/19/00	14.4	8/3/00	8/9/00	14.5	8/5/00	0.39
TRAP	Trapper (abv Cabins, USGS)	USGS	6/19/00	10/19/00				14.5	8/6/00	0.31
TRAP	Trapper (abv Cabins, USGS)	USGS	6/19/00	10/19/00				14.5	8/9/00	0.31
UEIG	Eightmile (upper, USGS)	USGS	4/1/98	10/8/98	15.8	7/24/98	7/30/98	16.1	7/28/98	0.24
UEIG	Eightmile (upper, USGS)	USGS	4/1/98	10/8/98				16.1	8/5/98	0.24
UEIG	Eightmile (upper, USGS)	USGS	5/21/99	10/18/99	14.5	7/29/99	8/4/99	14.9	8/10/99	0.24
UEIG	Eightmile (upper, USGS)	USGS	5/21/99	10/18/99	14.5	7/30/99	8/5/99			
UEIG	Eightmile (upper, USGS)	USGS	5/21/99	10/18/99	14.5	8/4/99	8/10/99			
UEIG	Eightmile (upper, USGS)	USGS	6/8/00	10/25/00	15.1	7/30/00	8/5/00	15.3	7/31/00	0.39
UEIG	Eightmile (upper, USGS)	USGS	6/8/00	10/25/00	15.1	7/31/00	8/6/00	15.3	8/8/00	0.39
UEIG	Eightmile (upper, USGS)	USGS	6/8/00	10/25/00	15.1	8/2/00	8/8/00	15.3	8/9/00	0.40
UEIG	Eightmile (upper, USGS)	USGS	6/8/00	10/25/00	15.1	8/3/00	8/9/00			
UEIG	Eightmile (upper, USGS)	USGS	6/8/00	10/25/00	15.1	8/4/00	8/10/00			
ULAY	Layout (upper, USGS)	USGS	5/21/99	10/4/99	13.6	8/18/99	8/24/99	14.0	8/24/99	0.78
ULAY	Layout (upper, USGS)	USGS	5/21/99	10/4/99						
ULAY	Layout (upper, USGS)	USGS	5/21/99	10/4/99						
ULAY	Layout (upper, USGS)	USGS	5/21/99	10/4/99						
ULAY	Layout (upper, USGS)	USGS	5/18/00	10/19/00	14.4	8/2/00	8/8/00	14.6	8/5/00	0.93
ULAY	Layout (upper, USGS)	USGS	5/18/00	10/19/00	14.4	8/3/00	8/9/00	14.6	8/8/00	0.93
UMAR	Martha (upper, USGS)	USGS	5/25/99	10/21/99	16.6	8/18/99	8/24/99	17.0	8/24/99	0.79
UMAR	Martha (upper, USGS)	USGS	5/25/99	10/21/99	16.6	8/19/99	8/25/99			
UMAR	Martha (upper, USGS)	USGS	5/25/99	10/21/99	16.6	8/20/99	8/26/99			
UMAR	Martha (upper, USGS)	USGS	5/25/99	10/21/99	16.6	8/21/99	8/27/99			
UMAR	Martha (upper, USGS)	USGS	5/25/99	10/21/99	16.6	8/22/99	8/28/99			
UMAR	Martha (upper, USGS)	USGS	5/10/00	10/16/00	16.5	8/3/00	8/9/00	16.7	7/31/00	0.88
UMAR	Martha (upper, USGS)	USGS	5/10/00	10/16/00				16.7	8/6/00	0.88
UMAR	Martha (upper, USGS)	USGS	5/10/00	10/16/00				16.7	8/9/00	0.88
UPAN	Panther (upper, USGS)	USGS	5/20/99	10/21/99	8.9	7/26/99	8/1/99	9.1	7/11/99	0.46
UPAN	Panther (upper, USGS)	USGS	5/20/99	10/21/99	8.9	7/27/99	8/2/99	9.1	7/12/99	0.54
UPAN	Panther (upper, USGS)	USGS	5/20/99	10/21/99	8.9	7/28/99	8/3/99	9.1	7/13/99	0.54
UPAN	Panther (upper, USGS)	USGS	5/20/99	10/21/99	8.9	7/29/99	8/4/99	9.1	7/28/99	0.46
UPAN	Panther (upper, USGS)	USGS	6/8/00	10/25/00	9.0	7/29/00	8/4/00	9.3	7/31/00	0.54
UPAN	Panther (upper, USGS)	USGS	6/8/00	10/25/00	9.0	7/30/00	8/5/00			
UPAN	Panther (upper, USGS)	USGS	6/8/00	10/25/00	9.0	7/31/00	8/6/00			
UPAN	Panther (upper, USGS)	USGS	6/8/00	10/25/00						
UPOG	Trout (upr old growth, USGS)	USGS	4/22/98	10/19/98	15.4	7/22/98	7/28/98	15.9	7/28/98	1.40
UPOG	Trout (upr old growth, USGS)	USGS	4/22/98	10/19/98						
UPOG	Trout (upr old growth, USGS)	USGS	5/14/99	10/18/99	13.1	8/18/99	8/24/99	13.5	7/22/99	1.09
UPOG	Trout (upr old growth, USGS)	USGS	5/14/99	10/18/99						
UPOG	Trout (upr old growth, USGS)	USGS	5/14/99	10/18/99						
UPOG	Trout (upr old growth, USGS)	USGS	5/14/99	10/18/99						
UPOG	Trout (upr old growth, USGS)	USGS	5/14/99	10/18/99						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98	8.2	8/8/98	8/14/98	8.5	8/14/98	0.54
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98				8.5	8/31/98	0.55
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UTRO	Trout (headwater, USGS)	USGS	4/22/98	10/7/98						
UMIN	Wind (abv Paradise, USGS)	USGS	7/28/00	10/18/00	16.1	7/29/00	8/4/00	16.8	7/31/00	0.64
UMIN	Wind (abv Paradise, USGS)	USGS	7/28/00	10/18/00	16.1	7/30/00	8/5/00			
UMIN	Wind (abv Paradise, USGS)	USGS	7/28/00	10/18/00	16.1	7/31/00	8/6/00			

Appendix B1. Locations of Ecology flow stations.

Station name	longitude (decimal degrees NAD27)	latitude (decimal degrees NAD27)
Bear Creek	-121.8149	45.7752
Panther Creek	-121.8478	45.7716
Wind River at Stabler	-121.9077	45.8086
Trout Creek	-121.9144	45.7999
Trapper Creek	-121.9805	45.8798
Wind River ab Trapper Creek	-121.9661	45.8828
Dry Creek	-121.9766	45.8822
Little Wind River	-121.7926	45.7276
Wind River nr Carson	-121.7931	45.7266

Appendix B2. Estimated stream flows at Ecology flow stations (cubic meters per second).

Date	Wind River near Carson	Trout Cr	Panther Cr	Trapper Cr	Middle Wind	Little Wind	Upper Wind
7-Jul-99	15.36	2.16	3.14	1.32	10.87	0.16	4.97
8-Jul-99	14.95	2.02	3.10	1.21	10.33	0.15	4.65
9-Jul-99	14.66	1.92	3.07	1.14	9.95	0.15	4.44
10-Jul-99	14.85	1.98	3.09	1.19	10.19	0.15	4.58
11-Jul-99	14.72	1.94	3.08	1.16	10.03	0.15	4.48
12-Jul-99	14.58	1.90	3.06	1.12	9.85	0.15	4.38
13-Jul-99	14.36	1.83	3.04	1.07	9.57	0.15	4.23
14-Jul-99	14.18	1.77	3.03	1.03	9.35	0.15	4.10
15-Jul-99	14.02	1.72	3.01	1.00	9.15	0.15	3.99
16-Jul-99	13.19	1.47	2.93	0.83	8.14	0.14	3.45
17-Jul-99	13.15	1.46	2.93	0.82	8.10	0.14	3.42
18-Jul-99	13.16	1.47	2.93	0.82	8.12	0.14	3.43
19-Jul-99	12.75	1.35	2.89	0.75	7.64	0.14	3.18
20-Jul-99	12.71	1.34	2.88	0.74	7.59	0.14	3.15
21-Jul-99	12.66	1.33	2.88	0.73	7.54	0.14	3.12
22-Jul-99	12.50	1.29	2.86	0.70	7.35	0.13	3.03
23-Jul-99	12.30	1.24	2.84	0.67	7.14	0.13	2.92
24-Jul-99	12.19	1.21	2.83	0.65	7.02	0.13	2.85
25-Jul-99	12.04	1.17	2.81	0.63	6.85	0.13	2.77
26-Jul-99	11.75	1.10	2.78	0.58	6.54	0.13	2.61
27-Jul-99	11.75	1.10	2.78	0.58	6.54	0.13	2.61
28-Jul-99	12.30	1.24	2.84	0.67	7.13	0.13	2.91
29-Jul-99	11.57	1.06	2.76	0.56	6.35	0.13	2.52
30-Jul-99	11.20	0.98	2.72	0.50	5.97	0.13	2.33
31-Jul-99	11.02	0.94	2.70	0.48	5.80	0.12	2.24
1-Aug-99	10.81	0.89	2.68	0.45	5.58	0.12	2.14
2-Aug-99	10.31	0.79	2.62	0.39	5.10	0.12	1.91
3-Aug-99	10.43	0.82	2.64	0.40	5.22	0.12	1.96
4-Aug-99	10.54	0.84	2.65	0.42	5.33	0.12	2.01
5-Aug-99	10.77	0.88	2.67	0.45	5.54	0.12	2.12
6-Aug-99	10.49	0.83	2.64	0.41	5.27	0.12	1.99
7-Aug-99	10.74	0.88	2.67	0.44	5.51	0.12	2.10
8-Aug-99	10.49	0.83	2.64	0.41	5.27	0.12	1.99
9-Aug-99	10.04	0.74	2.59	0.36	4.85	0.12	1.79
10-Aug-99	9.79	0.69	2.56	0.33	4.62	0.11	1.68
11-Aug-99	9.58	0.66	2.54	0.31	4.44	0.11	1.60
12-Aug-99	9.48	0.64	2.53	0.30	4.35	0.11	1.56
13-Aug-99	9.45	0.64	2.52	0.30	4.32	0.11	1.55
14-Aug-99	9.59	0.66	2.54	0.31	4.44	0.11	1.60
15-Aug-99	9.41	0.63	2.52	0.30	4.29	0.11	1.53
16-Aug-99	9.17	0.59	2.49	0.27	4.08	0.11	1.44
17-Aug-99	9.00	0.56	2.47	0.26	3.94	0.11	1.38
18-Aug-99	8.86	0.54	2.45	0.25	3.83	0.11	1.33
19-Aug-99	8.73	0.52	2.43	0.24	3.72	0.11	1.28
20-Aug-99	8.70	0.52	2.43	0.23	3.70	0.11	1.27
21-Aug-99	8.50	0.49	2.41	0.22	3.54	0.10	1.20
22-Aug-99	8.38	0.47	2.39	0.21	3.45	0.10	1.16
23-Aug-99	8.28	0.46	2.38	0.20	3.37	0.10	1.13
24-Aug-99	8.18	0.44	2.36	0.19	3.29	0.10	1.09
25-Aug-99	8.12	0.43	2.36	0.19	3.24	0.10	1.08
26-Aug-99	8.06	0.43	2.35	0.18	3.20	0.10	1.06
27-Aug-99	7.98	0.42	2.34	0.18	3.14	0.10	1.03
28-Aug-99	7.85	0.40	2.32	0.17	3.04	0.10	0.99
29-Aug-99	7.83	0.40	2.32	0.17	3.03	0.10	0.99
30-Aug-99	7.82	0.39	2.32	0.17	3.02	0.10	0.98
31-Aug-99	8.27	0.45	2.38	0.20	3.36	0.10	1.12
1-Sep-99	8.81	0.53	2.44	0.24	3.79	0.11	1.31
2-Sep-99	8.19	0.44	2.36	0.19	3.29	0.10	1.10
3-Sep-99	8.27	0.45	2.38	0.20	3.36	0.10	1.12
4-Sep-99	7.85	0.40	2.32	0.17	3.04	0.10	0.99
5-Sep-99	7.65	0.37	2.29	0.16	2.90	0.10	0.93
6-Sep-99	7.38	0.34	2.26	0.14	2.70	0.09	0.85
7-Sep-99	7.38	0.34	2.26	0.14	2.70	0.09	0.85
8-Sep-99	7.39	0.34	2.26	0.14	2.71	0.09	0.86
9-Sep-99	7.35	0.34	2.25	0.14	2.68	0.09	0.85
10-Sep-99	7.85	0.40	2.32	0.17	3.04	0.10	0.99
11-Sep-99	7.35	0.34	2.25	0.14	2.68	0.09	0.85
12-Sep-99	7.22	0.32	2.23	0.13	2.59	0.09	0.81
13-Sep-99	6.89	0.29	2.19	0.11	2.37	0.09	0.72
14-Sep-99	6.92	0.29	2.19	0.12	2.39	0.09	0.73
15-Sep-99	7.08	0.31	2.22	0.12	2.50	0.09	0.77
16-Sep-99	7.07	0.31	2.21	0.12	2.50	0.09	0.77
17-Sep-99	7.17	0.32	2.23	0.13	2.56	0.09	0.80
18-Sep-99	7.32	0.33	2.25	0.14	2.66	0.09	0.84
19-Sep-99	6.64	0.26	2.15	0.10	2.21	0.09	0.66
20-Sep-99	6.59	0.26	2.15	0.10	2.18	0.09	0.65
21-Sep-99	6.62	0.26	2.15	0.10	2.20	0.09	0.66
22-Sep-99	6.47	0.24	2.13	0.09	2.11	0.09	0.62

Appendix C. Effective shade for the Wind River, Trout Creek, Panther Creek, Bear Creek, and Eightmile Creek

	Distance from mouth to upstream segment boundary (Km)	Distance from mouth to downstream segment boundary (Km)	Current condition effective shade from HeatSource model using current vegetation estimates	Current condition average effective shade from HeatSource model using estimated treeheight and assumed 85% density	Site potential effective shade from HeatSource model using minimum 160-ft treeheight and 85% canopy density
Wind River:	46.8	45.8	77%	86%	89%
Wind River:	45.8	44.8	78%	87%	90%
Wind River:	44.8	43.8	69%	73%	91%
Wind River:	43.8	42.8	69%	87%	87%
Wind River:	42.8	41.8	82%	91%	91%
Wind River:	41.8	40.8	43%	43%	92%
Wind River:	40.8	39.8	15%	19%	89%
Wind River:	39.8	38.8	28%	37%	89%
Wind River:	38.8	37.8	21%	28%	93%
Wind River:	37.8	36.8	71%	87%	89%
Wind River:	36.8	35.8	64%	76%	88%
Wind River:	35.8	34.8	90%	90%	90%
Wind River:	34.8	33.8	81%	81%	82%
Wind River:	33.8	32.8	81%	81%	82%
Wind River:	32.8	31.8	70%	83%	86%
Wind River:	31.8	30.8	36%	39%	85%
Wind River:	30.8	29.8	21%	25%	86%
Wind River:	29.8	28.8	25%	29%	84%
Wind River:	28.8	27.8	19%	23%	84%
Wind River:	27.8	26.8	10%	15%	86%
Wind River:	26.8	25.8	4%	5%	85%
Wind River:	25.8	24.8	5%	6%	85%
Wind River:	24.8	23.8	9%	10%	86%
Wind River:	23.8	22.8	30%	31%	86%
Wind River:	22.8	21.8	22%	27%	88%
Wind River:	21.8	20.8	10%	19%	90%
Wind River:	20.8	19.8	16%	28%	92%
Wind River:	19.8	18.8	32%	46%	89%
Wind River:	18.8	17.8	21%	26%	85%
Wind River:	17.8	16.8	14%	15%	88%
Wind River:	16.8	15.8	41%	38%	91%
Wind River:	15.8	14.8	28%	30%	89%
Wind River:	14.8	13.8	29%	36%	85%
Wind River:	13.8	12.8	27%	41%	84%
Wind River:	12.8	11.8	18%	29%	75%
Wind River:	11.8	10.8	4%	20%	79%
Wind River:	10.8	9.8	11%	16%	78%
Wind River:	9.8	8.8	23%	25%	75%
Wind River:	8.8	7.8	16%	24%	81%
Wind River:	7.8	6.8	36%	56%	86%
Wind River:	6.8	5.8	24%	38%	84%
Wind River:	5.8	4.8	26%	32%	85%
Wind River:	4.8	3.8	55%	55%	78%
Wind River:	3.8	2.8	25%	27%	83%
Wind River:	2.8	1.8	30%	42%	81%
Wind River:	1.8	0.8	6%	6%	54%
Wind River:	0.8	0.0	5%	5%	44%

Appendix C. Effective shade for the Wind River, Trout Creek, Panther Creek, Bear Creek, and Eightmile Creek

	Distance from mouth to upstream segment boundary (Km)	Distance from mouth to downstream segment boundary (Km)	Current condition effective shade from HeatSource model using current vegetation estimates	Current condition average effective shade from HeatSource model using estimated treeheight and assumed 85% density	Site potential effective shade from HeatSource model using minimum 160-ft treeheight and 85% canopy density
Trout Creek:	15.1	14.6	42%	45%	92%
Trout Creek:	14.6	14.1	31%	42%	92%
Trout Creek:	14.1	13.6	48%	49%	90%
Trout Creek:	13.6	13.1	58%	75%	89%
Trout Creek:	13.1	12.6	72%	86%	87%
Trout Creek:	12.6	12.1	29%	32%	89%
Trout Creek:	12.1	11.6	22%	30%	89%
Trout Creek:	11.6	11.1	36%	39%	85%
Trout Creek:	11.1	10.6	57%	63%	88%
Trout Creek:	10.6	10.1	38%	47%	88%
Trout Creek:	10.1	9.6	28%	35%	89%
Trout Creek:	9.6	9.1	70%	70%	87%
Trout Creek:	9.1	8.6	64%	64%	88%
Trout Creek:	8.6	8.1	42%	44%	87%
Trout Creek:	8.1	7.6	23%	27%	88%
Trout Creek:	7.6	7.1	50%	58%	89%
Trout Creek:	7.1	6.6	23%	24%	88%
Trout Creek:	6.6	6.1	6%	7%	90%
Trout Creek:	6.1	5.6	22%	30%	90%
Trout Creek:	5.6	5.1	49%	69%	90%
Trout Creek:	5.1	4.6	34%	42%	79%
Trout Creek:	4.6	4.1	32%	43%	87%
Trout Creek:	4.1	3.6	26%	28%	90%
Trout Creek:	3.6	3.1	44%	44%	89%
Trout Creek:	3.1	2.6	2%	2%	42%
Trout Creek:	2.6	2.1	27%	41%	88%
Trout Creek:	2.1	1.6	28%	41%	89%
Trout Creek:	1.6	1.1	41%	59%	89%
Trout Creek:	1.1	0.6	13%	18%	90%
Trout Creek:	0.6	0.0	38%	44%	95%
Panther Creek:	12.4	11.9	68%	68%	88%
Panther Creek:	11.9	11.4	78%	86%	88%
Panther Creek:	11.4	10.9	20%	23%	88%
Panther Creek:	10.9	10.4	15%	16%	85%
Panther Creek:	10.4	9.9	54%	54%	78%
Panther Creek:	9.9	9.4	58%	59%	75%
Panther Creek:	9.4	8.9	35%	34%	75%
Panther Creek:	8.9	8.4	70%	69%	78%
Panther Creek:	8.4	7.9	7%	9%	82%
Panther Creek:	7.9	7.4	6%	13%	87%
Panther Creek:	7.4	6.9	31%	52%	86%
Panther Creek:	6.9	6.4	51%	77%	87%
Panther Creek:	6.4	5.9	29%	71%	80%
Panther Creek:	5.9	5.4	34%	76%	87%
Panther Creek:	5.4	4.9	24%	76%	89%
Panther Creek:	4.9	4.4	37%	82%	88%
Panther Creek:	4.4	3.9	54%	86%	89%
Panther Creek:	3.9	3.4	65%	85%	88%
Panther Creek:	3.4	2.9	51%	82%	85%
Panther Creek:	2.9	2.4	57%	86%	88%
Panther Creek:	2.4	1.9	56%	89%	91%
Panther Creek:	1.9	1.4	60%	86%	88%
Panther Creek:	1.4	0.9	61%	88%	89%
Panther Creek:	0.9	0.4	55%	89%	90%
Panther Creek:	0.4	0.0	54%	90%	91%

Appendix C. Effective shade for the Wind River, Trout Creek, Panther Creek, Bear Creek, and Eightmile Creek

	Distance from mouth to upstream segment boundary (Km)	Distance from mouth to downstream segment boundary (Km)	Current condition effective shade from HeatSource model using current vegetation estimates	Current condition average effective shade from HeatSource model using estimated treeheight and assumed 85% density	Site potential effective shade from HeatSource model using minimum 160-ft treeheight and 85% canopy density
Bear Creek:	9.7	9.2	56%		88%
Bear Creek:	9.2	8.7	91%		92%
Bear Creek:	8.7	8.2	93%		93%
Bear Creek:	8.2	7.7	89%		89%
Bear Creek:	7.7	7.2	85%		91%
Bear Creek:	7.2	6.7	60%		88%
Bear Creek:	6.7	6.2	83%		87%
Bear Creek:	6.2	5.7	20%		87%
Bear Creek:	5.7	5.2	19%		95%
Bear Creek:	5.2	4.7	64%		91%
Bear Creek:	4.7	4.2	29%		93%
Bear Creek:	4.2	3.7	76%		92%
Bear Creek:	3.7	3.2	82%		90%
Bear Creek:	3.2	2.7	83%		90%
Bear Creek:	2.7	2.2	74%		92%
Bear Creek:	2.2	1.7	73%		91%
Bear Creek:	1.7	1.2	73%		90%
Bear Creek:	1.2	0.7	81%		92%
Bear Creek:	0.7	0.0	58%		92%
Eightmile Creek:	5.1	4.6	98%		99%
Eightmile Creek:	4.6	4.1	78%		93%
Eightmile Creek:	4.1	3.6	83%		93%
Eightmile Creek:	3.6	3.1	83%		94%
Eightmile Creek:	3.1	2.6	86%		94%
Eightmile Creek:	2.6	2.1	93%		95%
Eightmile Creek:	2.1	1.6	89%		94%
Eightmile Creek:	1.6	1.1	67%		94%
Eightmile Creek:	1.1	0.6	95%		95%
Eightmile Creek:	0.6	0.0	95%		95%

Appendix D. Boundary input conditions for headwater, tributary, and groundwater flows and temperatures.

	Qual2K Km downstream from model headwater	Flow estimate for 7/30/99 - 8/5/99 (cms)	Flow estimate for 8/11/99 - 8/17/99 (cms)	Flow estimate for July-Aug low-flow 7Q2 (cms)	Flow estimate for July-Aug low-flow 7Q10 (cms)	Daily minimum temperature for 7/30/99 - 8/5/99 (deg C)	Daily maximum temperature for 7/30/99 - 8/5/99 (deg C)	Daily minimum temperature for 8/11/99 - 8/17/99 (deg C)	Daily maximum temperature for 8/11/99 - 8/17/99 (deg C)	Daily minimum temperature for 7Q2/7Q10 critical condition (deg C)	Daily maximum temperature for 7Q2/7Q10 critical condition (deg C)
Wind River											
Headwater	0.00	0.0822	0.0588	0.0453	0.0362	12.2	14.4	11.0	12.5	12.2	14.4
Tributaries											
Pete's Gulch	0.10	0.1695	0.1212	0.0933	0.0745	9.0	11.8	10.4	11.7	9.0	11.8
Paradise Cr	4.70	0.1203	0.1051	0.0662	0.0529	9.4	12.2	9.8	11.5	9.4	12.2
Falls	10.10	0.8618	0.6166	0.4743	0.3790	9.9	12.5	9.3	11.2	9.9	12.5
Ninemile	12.70	0.2245	0.1606	0.1235	0.0987	10.9	12.7	10.1	11.1	10.9	12.7
Dry	15.00	0.0657	0.0323	0.0362	0.0289	11.3	13.3	10.8	11.9	11.3	13.3
Trapper	15.30	0.3279	0.2648	0.1805	0.1442	11.7	13.8	11.5	12.7	11.7	13.8
Trout	29.10	0.8760	0.6250	0.4821	0.3853	14.7	17.8	13.9	15.7	14.7	17.8
Panther	39.50	2.6700	2.5140	1.4695	1.1742	8.5	12.8	8.2	10.9	8.5	12.8
Bear	39.60	0.7129	0.8557	0.3924	0.3135	13.7	16.4	13.2	15.0	13.7	16.4
Little Wind	44.90	0.1220	0.1110	0.0671	0.0537	14.8	17.9	14.1	16.5	14.8	17.9
Groundwater inflow/outflow											
headwater to Ecy upper Wind gage	0.0 - 14.0	0.6426	0.4597	0.3537	0.2826	12.0	12.0	12.0	12.0	12.0	12.0
Ecy upper to mid Wind gage	14.0 - 27.7	3.0114	2.4480	1.6575	1.3244	12.0	12.0	12.0	12.0	12.0	12.0
Ecy mid to lower Wind gage	27.7 - 45.0	0.8401	1.0083	0.4624	0.3695	12.0	12.0	12.0	12.0	12.0	12.0
Trout Creek											
Headwater	0.00	0.4010	0.3157	0.2207	0.1763	6.7	8.8	6.5	7.8	6.7	8.8
Tribs											
Compass	0.45	0.0809	0.0577	0.0445	0.0356	11.5	13.2	11.4	12.4	11.5	13.2
EF Trout	1.30	0.1005	0.0717	0.0553	0.0442	13.7	17.9	12.8	15.3	13.7	17.9
Layout	2.70	0.0750	0.0620	0.0413	0.0330	12.0	16.6	11.9	14.6	12.0	16.6
Planting	6.10	0.0518	0.0369	0.0285	0.0228	12.9	16.5	12.5	14.5	12.9	16.5
un-named	9.60	0.0346	0.0247	0.0191	0.0152	12.9	16.5	12.5	14.5	12.9	16.5
Martha	14.30	0.0048	0.0011	0.0026	0.0021	14.5	18.1	13.8	16.0	14.5	18.1
Groundwater inflow/outflow											
headwater - abv Compass	0 - 0.45	0.0007	0.0003	0.0004	0.0003	6.5	6.5	6.5	6.5	6.5	6.5
bel Compass - abv EF Trout	0.45 - 1.3	0.0042	0.0018	0.0023	0.0018	6.5	6.5	6.5	6.5	6.5	6.5
bel EF Trout - abv Layout	1.3 - 2.7	0.0097	0.0041	0.0053	0.0042	6.5	6.5	6.5	6.5	6.5	6.5
bel Layout - abv Planting	2.7 - 6.1	0.0431	0.0183	0.0237	0.0189	6.5	6.5	6.5	6.5	6.5	6.5
bel Planting - abv un-named	6.1 - 9.6	0.0340	0.0145	0.0187	0.0150	6.5	6.5	6.5	6.5	6.5	6.5
bel un-named - ecy gage	9.6 - 13.95	0.0405	0.0172	0.0223	0.0178	6.5	6.5	6.5	6.5	6.5	6.5
ecy gage - abv Martha	13.95 - 14.3	0.0005	0.0002	0.0003	0.0002	6.5	6.5	6.5	6.5	6.5	6.5
bel Martha - mouth	14.3 - 15.05	0.0037	0.0026	0.0020	0.0016	6.5	6.5	6.5	6.5	6.5	6.5
Panther Creek											
Headwater	0.00	1.4220	1.3390	0.7827	0.6254	6.8	8.7	6.6	7.7	6.8	8.7
Tribs											
Eightmile Cr	0.90	0.2512	0.2365	0.1383	0.1105	13.5	14.5	13.3	13.9	13.5	14.5
Stub Cr	2.30	0.0410	0.0386	0.0226	0.0180	13.1	14.8	12.7	13.7	13.1	14.8
Cedar Cr	6.80	0.3966	0.3734	0.2183	0.1744	12.7	15.2	12.1	13.6	12.7	15.2
Jimmy Cr	9.20	0.1242	0.1169	0.0683	0.0546	13.1	14.8	12.7	13.7	13.1	14.8
un-named Cr	11.70	0.0441	0.0415	0.0243	0.0194	13.1	14.8	12.7	13.7	13.1	14.8
Distributed inflow/outflow											
headwater - abv 8-mile	0 - 0.9	0.0546	0.0514	0.0300	0.0240	7.2	7.2	7.2	7.2	7.2	7.2
bel 8-mile - abv Stub	0.9 - 2.3	0.0634	0.0597	0.0349	0.0279	7.2	7.2	7.2	7.2	7.2	7.2
bel Stub - abv Cedar	2.3 - 6.8	0.2212	0.2082	0.1217	0.0973	7.2	7.2	7.2	7.2	7.2	7.2
bel Cedar - abv Jimmy	6.8 - 9.2	0.0573	0.0540	0.0316	0.0252	7.2	7.2	7.2	7.2	7.2	7.2
bel Jimmy - ecy flow gage	9.2 - 10.6	0.0385	0.0362	0.0212	0.0169	7.2	7.2	7.2	7.2	7.2	7.2
ecy flow gage - abv un-named	10.6 - 11.7	0.0233	0.0219	0.0128	0.0102	7.2	7.2	7.2	7.2	7.2	7.2
bel un-named - mouth	11.7 - 12.4	0.0101	0.0095	0.0055	0.0044	7.2	7.2	7.2	7.2	7.2	7.2