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Walla Walla River Tributaries Temperature Total Maximum Daily Load Study

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Walla Walla River Tributaries Temperature Total Maximum Daily Load Study

by

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Washington State Department of Ecology

April 2007

Waterbody Numbers: See Table 1

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Abstract

The study area for the *Walla Walla Tributaries Temperature Total Maximum Daily Load* (TMDL) includes all major tributaries to the Walla Walla River in Washington State. The Walla Walla River basin contains anadromous fish habitat that supports spring chinook, rainbow/steelhead trout, bull trout, and mountain whitefish.

The federal Clean Water Act Section 303(d) listings for temperature in the study area include the Touchet River, Mill Creek, and 25 additional streams.

The Washington State Department of Ecology (Ecology) conducted field work for this study during 2002-2004. This report presents an analysis of the spatial and temporal stream temperature patterns of selected streams in the Walla Walla River basin based on instream data and thermal infrared radiation (TIR) surveys. A stream temperature model (QUAL2Kw) is used to investigate possible thermal behaviors of the streams for different meteorological, shade, and flow conditions.

Reductions in water temperature are predicted for hypothetical conditions with mature riparian vegetation and improvements in riparian microclimate. Model simulations performed using low-flow conditions – representing the 7-day average low flow having a 10-year reoccurrence interval (7Q10) – show that stream temperature reductions ranging from 2.5 – 6.0ºC are expected compared with the current conditions. Potential reduced temperatures are predicted to be less than the threshold for fish lethality of 23ºC, but greater than 18ºC in Class A waters in most of the segments in all streams evaluated.

Potential reduced temperatures in two Class AA streams, the North Fork Touchet River and Wolf Fork Touchet River, are predicted to be less than 18°C but greater than the numeric standard of 16°C for those waters. Although currently supporting salmonids, these high-quality bull trout habitat streams will be very vulnerable to the effects of near-stream development. Future reduction to streamflow, reduction of riparian vegetation, alteration of natural channel, or increase in sediment could increase stream temperatures.

Stream temperatures in the upper reaches of Mill Creek above the drinking water diversion remained under 13.5°C all year round.

In addition to increasing stream shading, other management activities are recommended for compliance with the water quality standards for water temperature. These include measures to increase channel stability and complexity.

Acknowledgements

We would like to thank the following for their contributions to this study:

- Glen Mendel and other Washington Department of Fish and Wildlife staff for collecting temperature, flow, and habitat data.

- Bob Bower, Walla Walla Basin Watershed Council, for coordinating technical work in the watershed.

- Don Butcher, Oregon Department of Environmental Quality, for stream temperature modeling work on the mainstem Walla Walla River.

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Executive Summary

Introduction

The Walla Walla River basin lies in Walla Walla and Columbia Counties in Washington State. The Washington State Department of Ecology (Ecology) identified the Walla Walla watershed (WRIA 32) as a high priority for development of a Total Maximum Daily Load (TMDL) for temperature. The purpose of this *Walla Walla River Tributaries Temperature TMDL Study* is to (1) characterize water temperature in the basin, and (2) establish load and wasteload allocations for heat sources to meet water quality standards for water temperature.

Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. This study was initiated because of 303(d) listings in the Touchet River and Mill Creek tributaries to the Walla Walla River for exceeding Washington State water quality standards for temperature. The original exceedances were found during routine monitoring at three Ecology ambient monitoring stations during 1991-1996. Work by others in the watershed (Mendel, 2000, 2001, 2002) showed that exceedances were common throughout the watershed. Many of these stream segments are on the 2002/04 303(d) list.

In addition to the three segments on the 1998 303(d) list – Mill Creek and two segments of the Touchet River – the present TMDL also includes load allocations to address 93 segments (27 uniquely named streams) that are documented as not meeting the water quality standard for temperature in the 2002/2004 303(d) list.

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, as well as numeric threshold criteria and narrative directives designed to achieve those uses.

Section 303(d) of the Clean Water Act mandates that the state establish TMDLs for surface waters that do not meet the water quality standards. The U.S. Environmental Protection Agency (EPA) has issued regulations (40 CFR 130) and developed guidance (EPA, 1991) for establishing TMDLs.

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

The TMDL must also consider seasonal variations and include a margin of safety that takes into account 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.

Study Area

The study area includes all major tributaries to the Walla Walla River in Washington State. The Walla Walla mainstem is excluded from this study because the water temperature TMDL analysis is covered by the Oregon Department of Environmental Quality (ODEQ) as part of a larger project to address the entire Walla Walla mainstem, which lies in both Oregon and Washington (ODEQ, 2005).

The Walla Walla basin (WRIA 32) is a 1,758-square-mile area with about 70% of the basin located in Washington State. The major tributaries of concern for this temperature TMDL are the Touchet River, Mill Creek, and Dry Creek drainages.

The four primary forks of the Touchet River (South, North, Wolf, and Robinson) originate deep in the Blue Mountains at an elevation of 6,074 feet. The four forks are mainly forested with only small farms in the valleys. The forks converge just above the city of Dayton to form the mainstem Touchet River. The Touchet River flows through the cities of Dayton, Waitsburg, and Prescott, reaching its confluence with the Walla Walla River by the town of Touchet at an elevation of 420 feet. Land use in the Touchet basin from Dayton to the confluence of the Walla Walla River is predominantly agricultural with both irrigated and non-irrigated crops.

Mill Creek headwaters are located in the Blue Mountains where 22,000 acres are preserved as a drinking water source for the city of Walla Walla. The 100-square-mile drainage flows through Oregon, where a portion of the streamflow is diverted for the city of Walla Walla water supply, and then continues to the Washington border and downstream through the city of Walla Walla. The city of Walla Walla and the U.S. Army Corps of Engineers built a control structure in the 1940s to stop catastrophic flooding during the spring months. Currently, a portion of Mill Creek's spring flow is diverted at RM 10.5 into Garrison Creek, Yellowhawk Creek, and Bennington Lake. Mill Creek's remaining flow passes through the city of Walla Walla in an engineered concrete channel. Mill Creek enters the Walla Walla River downstream of the city, near the historical Whitman Mission. During May through October, the majority of Mill Creek flow is diverted at RM 10.5 to Yellowhawk and Garrison Creeks which enter the Walla Walla River just upstream of the Mill Creek confluence.

Dry Creek is in a 239-square-mile basin with elevations from 460 feet at the confluence with the Walla Walla River near Lowden to 4,600 feet in the Blue Mountains. Dry Creek's watershed is mainly used for dry wheat agriculture with only sparse forests in the headwaters.

This region has a continental type climate with hot, arid summers and cold, wet winters. Temperatures in the basin can easily reach 37.8 °C (100 °F) in the summer and below freezing in the winter. The lower portions of the basin receive less than 10 inches of annual precipitation. The upper sections, in the Blue Mountains, can receive up to 60 inches of annual precipitation. Most of the precipitation falls as snow in the winter causing a significant accumulation of snowpack in the mountains. Spring thaw, compounded with rain showers, is the source of flooding for the basin. Significant flood events occurred in 1933, 1964, and 1996.

The Walla Walla basin contains federally designated critical habitat for bull trout and steelhead trout, both of which are listed as threatened species protected under the Endangered Species Act (USFW, 2005). Mendel et al. (2004) surveyed the fish populations within the Walla Walla basin, finding the highest abundances of salmonid species in Mill Creek and the North and Wolf Forks of the Touchet River. Native salmonid species identified were mountain whitefish (*Prosopium williamsoni*), bull trout (*Salvelinus confluentus*), and rainbow/steelhead trout (*Oncorhynchus mykiss*). Most spawning habitat was found in the upper reaches, while the lower reaches of the Touchet and Walla Walla Rivers are mainly used for fish migration with little rearing capability.

Bull trout redds counted in 2002 by the Washington Department of Fish and Wildlife (WDFW), U.S. Forest Service (USFS), and Oregon Department of Fish and Wildlife (ODFW) staff totaled: 161 in Mill Creek, 29 in the North Fork Touchet River, and 92 in the Wolf Fork Touchet River (Mendel et al., 2004).

Load Allocations Summary

The load allocation for all streams in the Walla Walla tributaries study area located below the USFS boundary and the City of Walla Walla diversion dam is the effective shade that would occur from system potential mature riparian vegetation. *System potential mature riparian vegetation* is defined as that vegetation which can grow and reproduce on a site, given: climate, elevation, soil properties, plant biology, and hydrologic processes. Figure ES-1 shows system potential vegetation zones of shrubs, deciduous, mixed deciduous and conifer, and conifer riparian vegetation.

Water temperatures in the basin do not meet numeric water quality standards during the hottest period of the year and thus drive the need for maximum protection from direct solar radiation (Figures ES-2 and ES-3). An exception to this is the portion of Mill Creek located in the preserved watershed above the City of Walla Walla diversion dam in Oregon. This section of Mill Creek currently meets the numeric water quality standard of 16°C year round. The highest seven-day-average maximum (*7-DADMax*) temperature measured at the site immediately upstream of the dam was 13.8°C during the summer of 2002. However, due to bull trout using this portion of the watershed for spawning, the water quality criteria for upper Mill Creek is expected to be changed to 12°C during the next revision of Washington State's water quality standards.

Significant reductions in temperature are expected for all waters studied; however, it would be prudent for local watershed scientists and citizens to prioritize locations for riparian improvements. In portions of the watershed, fulfillment of load allocations could reduce temperatures enough to maintain and increase stream miles of salmonid-friendly habitat. Other portions of the watershed are expected to remain a migration corridor, but are not likely to support extensive salmonid rearing even with the implementation of system potential conditions.

The Dayton Wastewater Treatment Plant (WWTP) is currently operating within the limits of this temperature TMDL. When the National Pollution Discharge Elimination System (NPDES) permit is due for renewal in 2010, the discharge temperature limit may need to be adjusted if the volume of the summer discharge has increased. Growth in discharge or an increase in upstream water withdrawals could require the Dayton WWTP to release cooler wastewater.

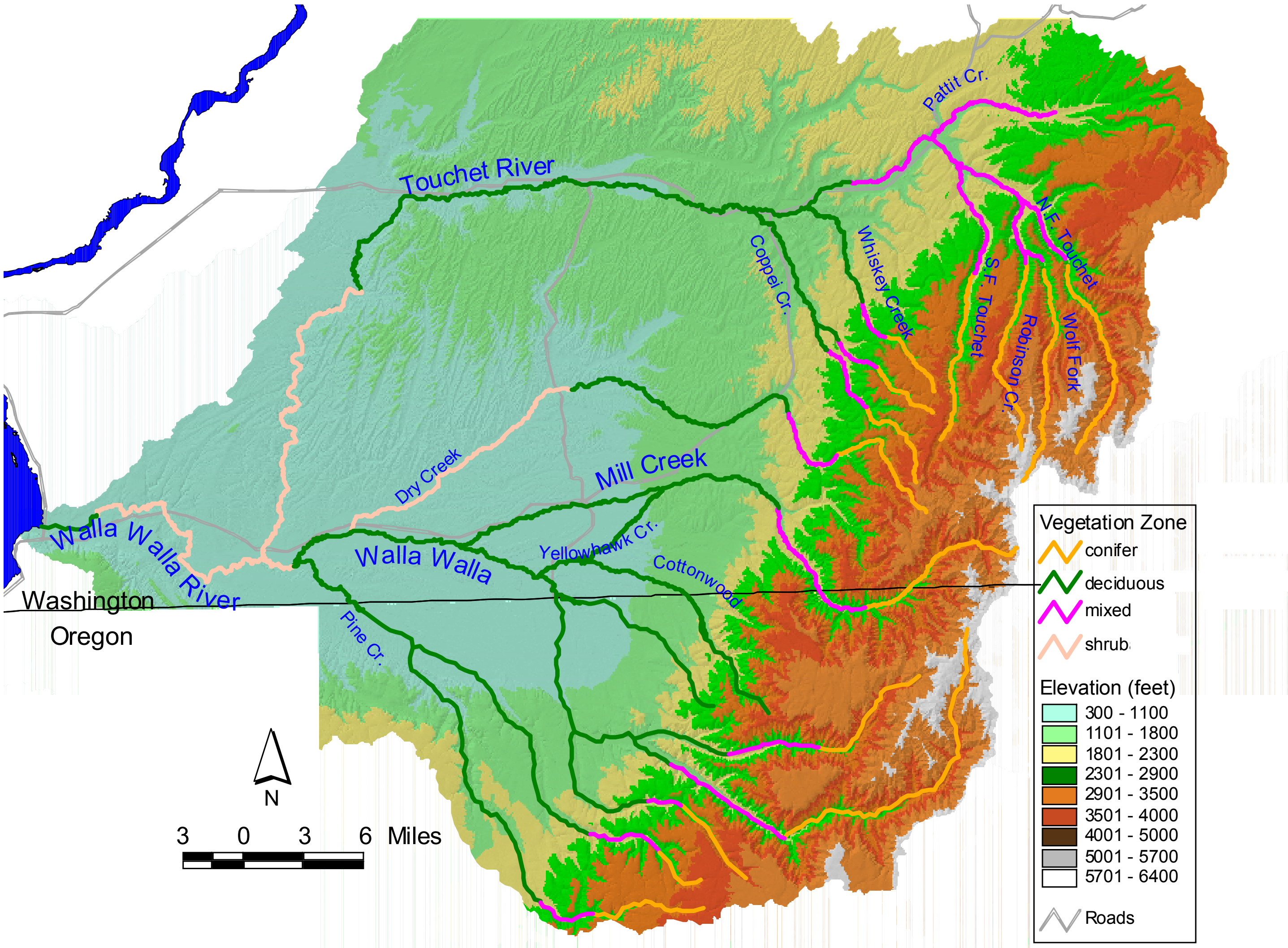

Figure ES-1. Map of potential vegetation zones in the Walla Walla watershed study area.

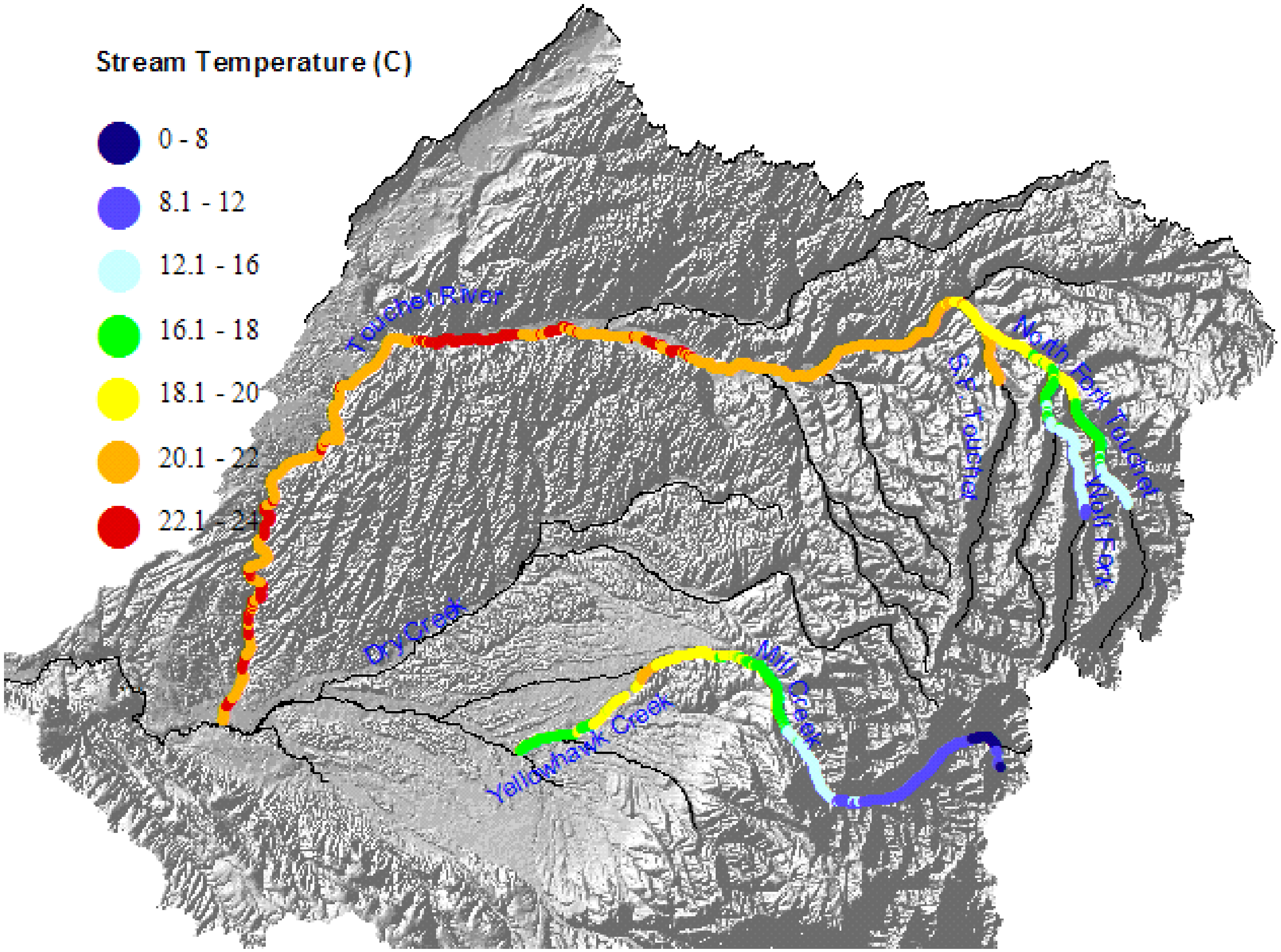

Figure ES-2. Water temperature measured by Thermal Infrared Survey during a cooler than typical summer period, August 7-9, 2002.

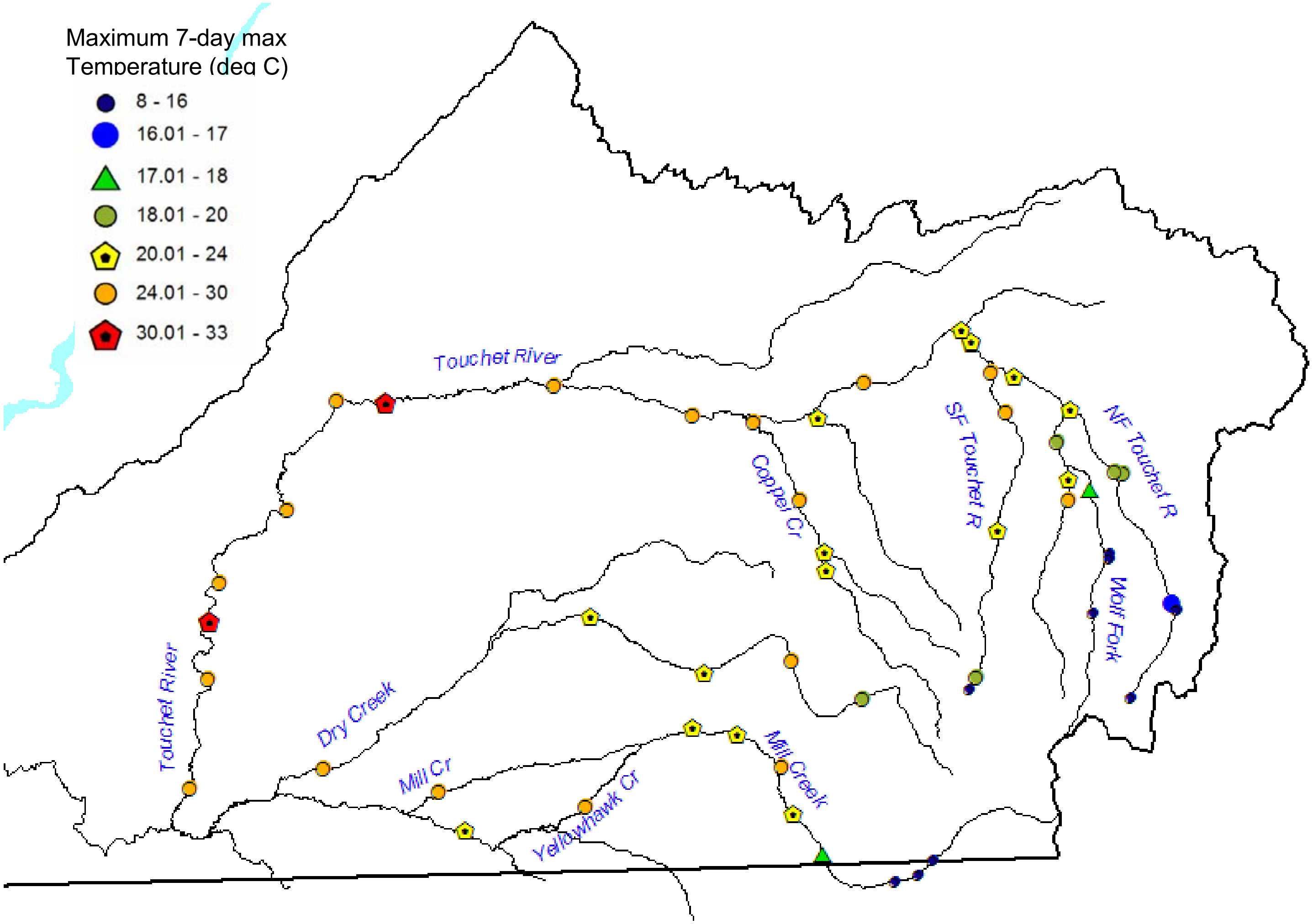

Figure ES-3. The highest 7-day averages of daily maximum water temperatures in the Walla Walla River tributaries during 2002.

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Conclusions and Recommendations

Conclusions related to loading capacity results

The QUAL2Kw model simulations indicated that:

1. A buffer of mature riparian vegetation along the river banks is expected to decrease the average daily maximum water temperatures. At 7Q10 flow conditions, a 4.6ºC reduction is expected for the Touchet River. Significant reductions of 1.7ºC and 2.9ºC are expected for upper Mill Creek and Yellowhawk Creek, respectively.

2. The changes in microclimate conditions associated with mature riparian vegetation could further lower the daily average maximum water temperature by about 1.0ºC.

3. Improvements in riparian vegetation above kilometer 60 (Figure 28) in the Touchet River system can reduce temperatures below the lethal limit to salmonids, although daily highs will not be optimal for salmonids. Below the 60-kilometer marker between Luckenbill and Lamar roads, water temperatures during July and August are expected to be very high except in localized areas of groundwater input.

4. A reduction of the widest areas in the channel to a maximum of 41 meters (120 feet) in the Touchet River results in little reduction of temperature, because the channel at those locations is still difficult to shade.

5. The addition of streamflow to recommended New Appropriation Flow (NAF) levels led to a further decrease in the maximum (across all reaches) simulated water temperature ranging from 0.7ºC in the Touchet River to 2.2ºC in the Mill Creek/Yellowhawk Creek system.

6. With all management scenarios in place (1 through 5 above), the overall decrease in the average maximum temperature for the simulated critical condition ranged from 4.6ºC to 6.6ºC, with average of 5.9ºC.

7. The North Fork Touchet River is expected to realize a 3.4ºC reduction in temperature with the addition of system potential shade. A further reduction of 1ºC is possible if cooler upstream waters enter the segment at 16ºC and if the air temperature under the riparian canopy (microclimate) is 2ºC cooler.

8. The Wolf Fork Touchet River is expected to realize a 2.0ºC reduction in temperature with the addition of system potential shade. A further reduction of 0.6ºC is possible if cooler upstream waters enter the segment at 16ºC and if the air temperature under the riparian canopy (microclimate) is 2ºC cooler.

Other conclusions and recommendations

1. The South Fork Touchet River has much higher stream temperatures (Table 16) than the North and Wolf Forks. System potential shade is required to reduce stream temperatures. The stream substrate in the South Fork site sampled by Ecology was primarily bedrock. Because of the lack of cobble and gravels to encourage subsurface streamflow and exchange, the South Fork likely will not be able to reach temperatures as low as those found in the North and Wolf Forks.

2. The Upper Touchet River subbasin is a vulnerable system. Current conditions are supporting communities of bull trout and steelhead trout. Improvements in shading should increase the area usable by salmonids. This system will be very vulnerable to development that impacts/ removes riparian shading, reduces streamflow, or results in channel alterations, such as diking, that would reduce channel complexity. Currently the Wolf Fork and North Fork Touchet streams are staying cooler than some systems with similar levels of shading because the large size cobble substrate allows for a high level of intergravel mixing and contact with cooler springs and groundwater.

   Reduction in summer flows, reduction in spring input, or increase of fine sediment in the gravel and cobbles could cause this Upper Touchet River system to heat instead of maintain or improve temperature. Further development should favor off-stream setbacks to sustain as natural a riparian corridor as possible, and maintenance of summer streamflows at the current level.

3. Mill Creek channel widths were not reduced in a model simulation (as they were for the Touchet, #4) because of difficulty in predicting a restored channel width. Numerous flood-control measures are in place, and water diversions at both the drinking water intake and at Bennington Dam normalize flows during portions of the year. Additional simulations could be performed to estimate further temperature reductions associated with a narrower channel. However, recommended restoration measures for system potential conditions will be the same under either scenario because temperatures under critical conditions exceed the numeric water quality standard. If restoration results in healthy channels with proper sinuosity that are narrower or deeper, the cooling effects may be larger than those shown with the temperature model.

4. Local groups and the Washington Department of Fish and Wildlife (WDFW) should continue to work together through adaptive management on improving practices to gain the best water quality possible in Yellowhawk, Garrison, and lower Mill Creeks. Because the three creeks diverge and then each flow independently into the Walla Walla River, it is thought that splitting the limited summer streamflow among all three will result in none having good water quality for salmonids. Currently, most of the summer flow is routed through Yellowhawk Creek.

   Mendel et al. (2002), with cooperation of other groups, researched the water temperature effects of increasing streamflow levels in lower Mill Creek below the Yellowhawk/Garrison diversion. Mendel reported that increasing the flows by 3-12 cfs through the engineered flood-control channel downstream of the Yellowhawk Creek diversion resulted in a large increase in Mill Creek water temperature (10-12°F, *5.6-6.7°C*) from the Yellowhawk diversion to Roosevelt Street. Lethal temperatures over 90°F (32°C) were measured. Having just the cold spring-fed water under the city of Walla Walla was found to be more beneficial to steelhead rearing than increasing the flows by 3-12 cfs through the flood-control structure which added hot water to Mill Creek.

Next Steps

The Department of Ecology is seeking input from local groups and the public to help develop a plan for improving stream temperatures in the Walla Walla River basin. Information gathered will be used to develop a strategy on how, when, and where restoration activities will be implemented to improve stream temperatures. A workgroup will be formed and your participation will be welcome. The workgroup will:

- Evaluate technical studies and potential implementation measures.
- Prioritize any additional studies and implementation measures.
- Coordinate implementation of selected measures.
- Develop a monitoring plan to measure improvement.

These technical studies, identified implementation measures, and monitoring plan will serve as our "TMDL" submittal to the U.S. Environmental Protection Agency.

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Introduction

The Walla Walla River basin lies in Walla Walla and Columbia Counties in Washington State (Figure 1). The Washington State Department of Ecology (Ecology) identified the Walla Walla watershed as a high priority for development of a Total Maximum Daily Load (TMDL) for temperature.

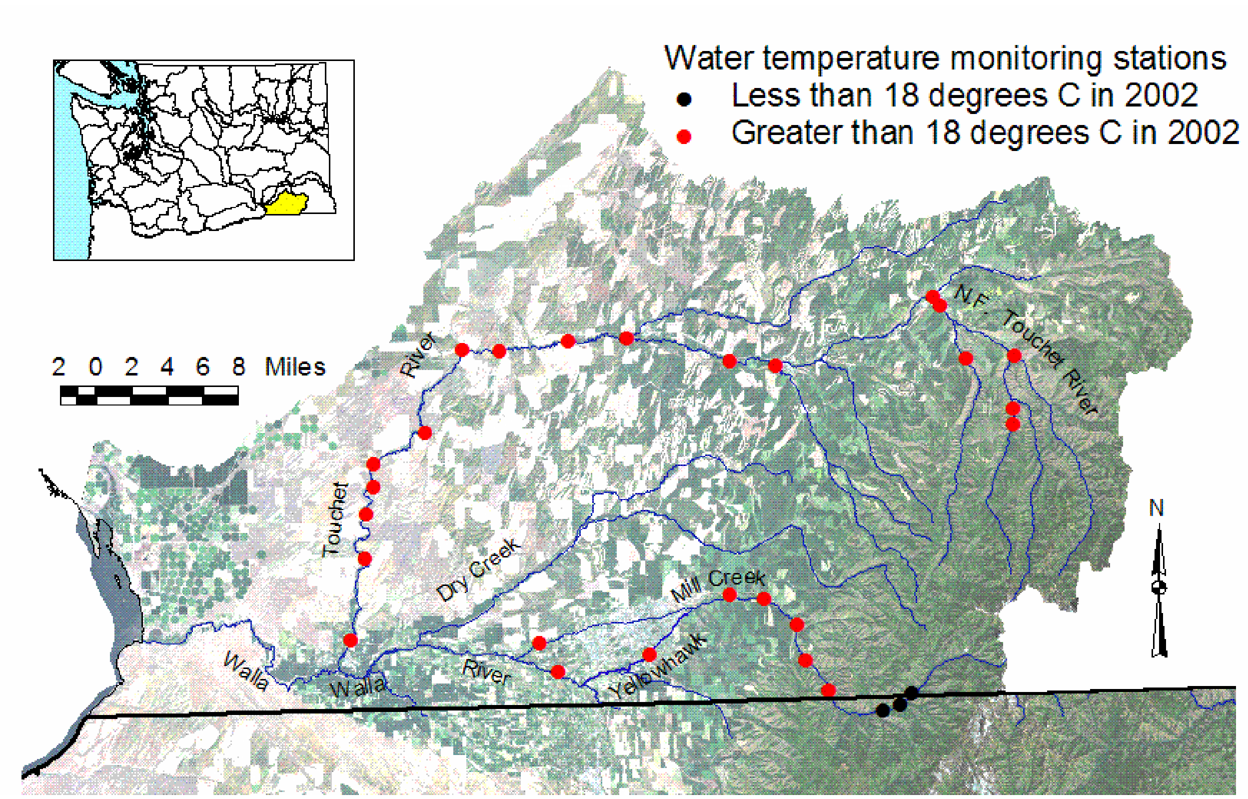

Figure 1. Land cover from a satellite image (2000) in the study area of the *Walla Walla River Tributaries Temperature TMDL.*

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The purpose of the *Walla Walla River Tributaries Temperature TMDL Study* is to characterize water temperature in the basin and to establish load and wasteload allocations for heat sources to meet water quality standards for water temperature.

Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. This study was initiated because of 303(d) listings of the Touchet River and Mill Creek tributaries to the Walla Walla River for exceeding the water quality standards for temperature (Table 1).

Table 1. Summary of waterbodies included in this TMDL that are on the 1996 or 1998 303(d) list, on the 2002/04 list as impaired (category 5), or on the 2002/04 list as a water of concern (category 2).

Waterbody	New ID	Old WBID	303(d) list		
			1996	1998	2002/2004
Mill Creek	SS77BG	WA-32-1070	Y	Y	Y(5)
Touchet River*	LV94PX	WA-32-1020	Y	Y	Y(5)
Touchet River*	LV94PX	WA-32-1020	Y	N	Y(5)
Blue Creek	BN32DU		N	N	Y(5)
Garrison Creek	DH35GB	WA-32-2000	N	N	Y(5)
North Fork Touchet River	EQ96XO		N	N	Y(5)
Russell Creek	GU90FL		N	N	Y(5)
North Fork Coppei Creek	GW49AT		N	N	Y(5)
Robinson Creek	HP78FD		N	N	Y(5)
Cottonwood Creek	HU10XJ		N	N	Y(5)
Cold Creek	HV66NE		N	N	Y(5)
Doan Creek	IW37TE		N	N	Y(5)
South Fork Touchet River	MS30PY		N	N	Y(5)
South Fork Dry Creek	OH98HK		N	N	Y(5)
Whiskey Creek	OP00ZN		N	N	Y(5)
Dry Creek	OT03FJ	WA-32-1040	N	N	Y(5)
Yellowhawk Creek	RK92TG		N	N	Y(5)
Coppei Creek	RT07DK	WA-32-1022	N	N	Y(5)
Jim Creek	SP57BG		N	N	Y(5)
South Fork Coppei Creek	SR81ZC		N	N	Y(5)
Wolf Creek (Fork)	XM92BG		N	N	Y(5)
East Little Walla Walla River	XO26DW		N	N	Y(5)
West Little Walla Walla River	YA44BO		N	N	Y(5)
Coldwell Creek	YY09VX		N	N	Y(5)
Lewis Creek	ZH05OC		N	N	Y(5)
Pine Creek	ZX47PC		N	N	Y(5)
Patit Creek			N	N	Y(2)
Mud Creek			N	N	Y(2)

*These two Touchet River listings are approximately 50 miles apart.

Note: Impaired waterbodies may be identified on the 2002/2004 list with more than one listing ID if impairments were measured at more than one location along the stream. Listing IDs for all category 5 and category 2 waterbodies covered by this report can be found in Table D-5 in the Appendices.

The original water temperature exceedances were found during routine monitoring at three Ecology ambient monitoring stations during 1991-1996. Work by others (Mendel et al., 2000, 2001, 2002) showed that exceedances were common throughout the watershed, and many of these stream segments are on the 2002/04 303(d) list.

In addition to the three segments listed in 1998, the present TMDL also includes load allocations to address segments that are documented as not meeting the water quality standard for temperature in the 2002/2004 list (Table 1).

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, as well as numeric threshold criteria and narrative directives designed to achieve those uses.

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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 waterbody and still meet standards, and allocates that load among the various sources. If the pollutant comes from a discrete (point) source such as an industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload* allocation. If a pollutant enters a stream from a diffuse (nonpoint) source, then that share is called a *load* allocation.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account 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.

Overview of Stream Heating Processes

The temperature of a stream reflects the amount of heat energy in the water. Changes in water temperature within a particular segment of a stream are induced by the balance of the heat exchange between the water and the surrounding environment during transport through the segment. If there is more heat energy entering the water in a stream segment than there is leaving, the temperature will increase. If there is less heat energy entering the water in a stream segment than there is leaving, then the temperature will decrease. The general relationships between stream parameters, thermodynamic processes (heat and mass transfer), and stream temperature change is outlined in Figure 2.

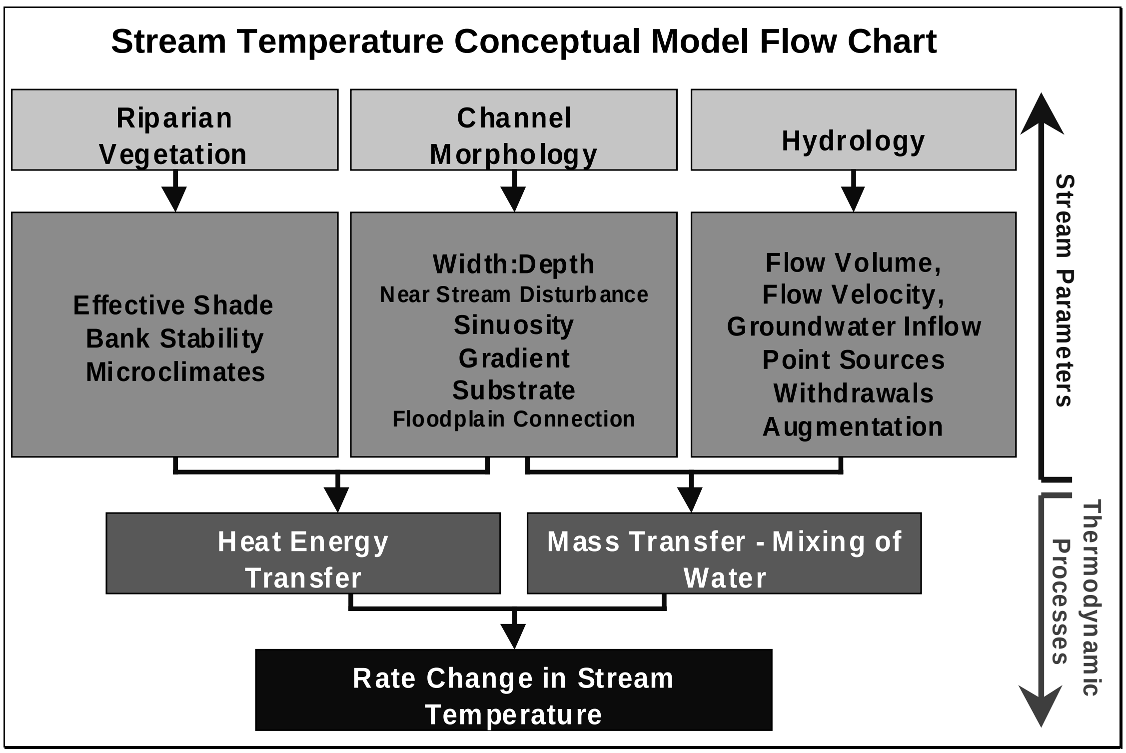

Figure 2. Conceptual model of factors that affect stream temperature.

Adams and Sullivan (1989) reported that the following environmental variables were the most important drivers of water temperature in forested streams:

- **Stream depth.** Stream depth affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental conditions.
- **Air temperature.** Daily average stream temperatures and daily average air temperatures are both highly influenced by incoming solar radiation (Johnson, 2004). When the sun is not shining, the temperature in a volume of water tends toward the dew-point temperature (Edinger et al., 1974).
- **Solar radiation and riparian vegetation.** The daily maximum temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar heat flux. Daily average temperatures are less affected by removal of riparian vegetation.
- **Groundwater.** Inflows of groundwater can have an important cooling effect on stream temperature. This effect will depend on the rate of groundwater inflow relative to the flow in the stream and the difference in temperatures between the groundwater and the stream.

Heat budgets and temperature prediction

Heat exchange processes occur between the waterbody and the surrounding environment, and these processes control stream temperature. Edinger et al. (1974) and Chapra (1997) provide thorough descriptions of the physical processes involved. Figure 3 shows the major heat energy processes or fluxes across the water surface or streambed.

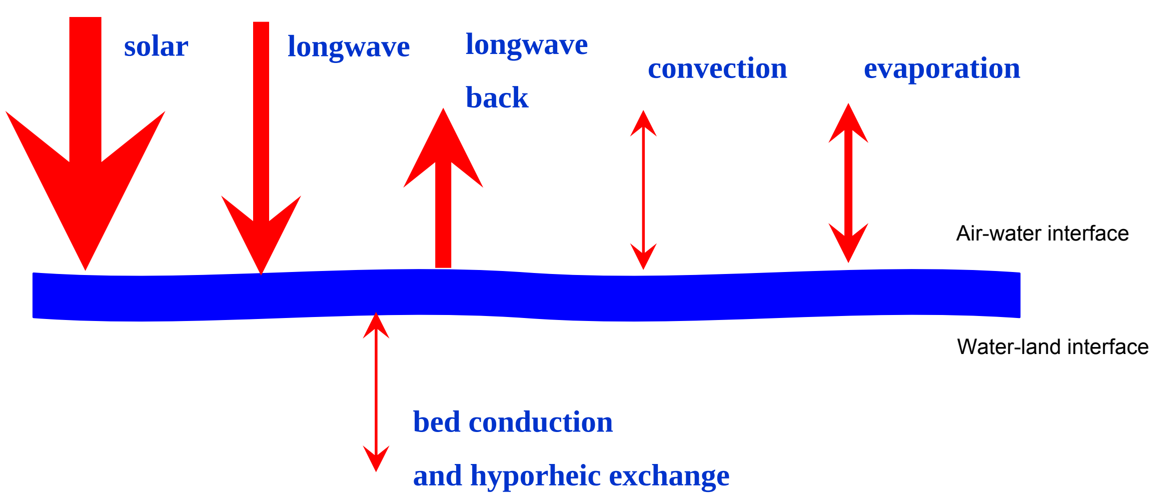

Figure 3. Surface heat exchange processes that affect water temperature (net heat flux = solar + longwave atmosphere + longwave back + convection + evaporation + bed). Heat flux between the water and streambed occurs through conduction and hyporheic exchange.

The heat exchange processes with the greatest magnitude are as follows (Edinger et al., 1974):

- **Short-wave solar radiation**. Short-wave solar radiation is the radiant energy which passes directly from the sun to the earth. Short-wave solar radiation is contained in a wavelength range between 0.14 μm and about 4 μm. At Washington State University's (WSU) Tree Forest Research and Extension Center (TFREC) station in Wenatchee, the daily average global shortwave solar radiation for August 2002 was 259 W/m2. The peak values during daylight hours are typically about 3 times higher than the daily average. Short-wave solar radiation constitutes the major thermal input to an unshaded body of water during the day when the sky is clear.
- **Long-wave atmospheric radiation.** The long-wave radiation from the atmosphere ranges in wavelength from about 4 μm to 120 μm. Long-wave atmospheric radiation depends primarily on air temperature and humidity, and increases as both of those increase. It constitutes the major thermal input to a body of water at night and on warm cloudy days. The daily average heat flux from long-wave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes (Edinger et al., 1974).
- **Long-wave back radiation from the water to the atmosphere.** Water sends heat energy back to the atmosphere in the form of long-wave radiation in the wavelength range from about 4 μm to 120 μm. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases. The daily average heat flux out of the water from long-wave back radiation typically ranges from about 300 to 500 W/m^2 (Edinger et al., 1974).

The remaining heat exchange processes generally have less magnitude and are as follows:

- **Evaporation flux at the air-water interface** is influenced mostly by wind speed and the vapor pressure gradient between the water surface and the air. When the air is saturated, the evaporation stops. When the gradient is negative (vapor pressure at the water surface is less than the vapor pressure of the air), condensation, the reversal of evaporation takes place; this term then becomes a gain component in the heat balance.
- **Convection flux at the air-water interface** is driven by the temperature difference between water and air and by wind speed. Heat is transferred in the direction of decreasing temperature.
- **Streambed conduction flux and hyporheic exchange** component of the heat budget represents the heat exchange through conduction between the bed and the waterbody and the influence of hyporheic exchange. The magnitude of streambed conduction is driven by the size and conductance properties of the substrate. The heat transfer through conduction is more pronounced when thermal differences between the substrate and water column are higher. This heat transfer usually affects the temperature diel profile, rather than the magnitude of the maximum daily water temperature.

  Hyporheic exchange recently received increased attention as a possible important mechanism for stream cooling (Johnson and Jones, 2000, Poole and Berman, 2000, Johnson, 2004). The hyporheic zone is defined as the region located beneath the channel characterized by complex hydrodynamic processes that combine stream water and groundwater. The resulting fluxes can have significant implications for stream temperature at different spatial and temporal scales.

Figures 4 and 5 show surface heat flux in a relatively unshaded stream reach and in a more heavily shaded stream reach, respectively.

Figure 4 shows an example of the estimated diurnal pattern of the surface heat fluxes in one of Washington's coastal rivers for the week of August 8-14, 2001. The daily maximum temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar shortwave heat flux (Adams and Sullivan, 1989). The solar shortwave flux can be controlled by managing vegetation in the riparian areas adjacent to the stream.

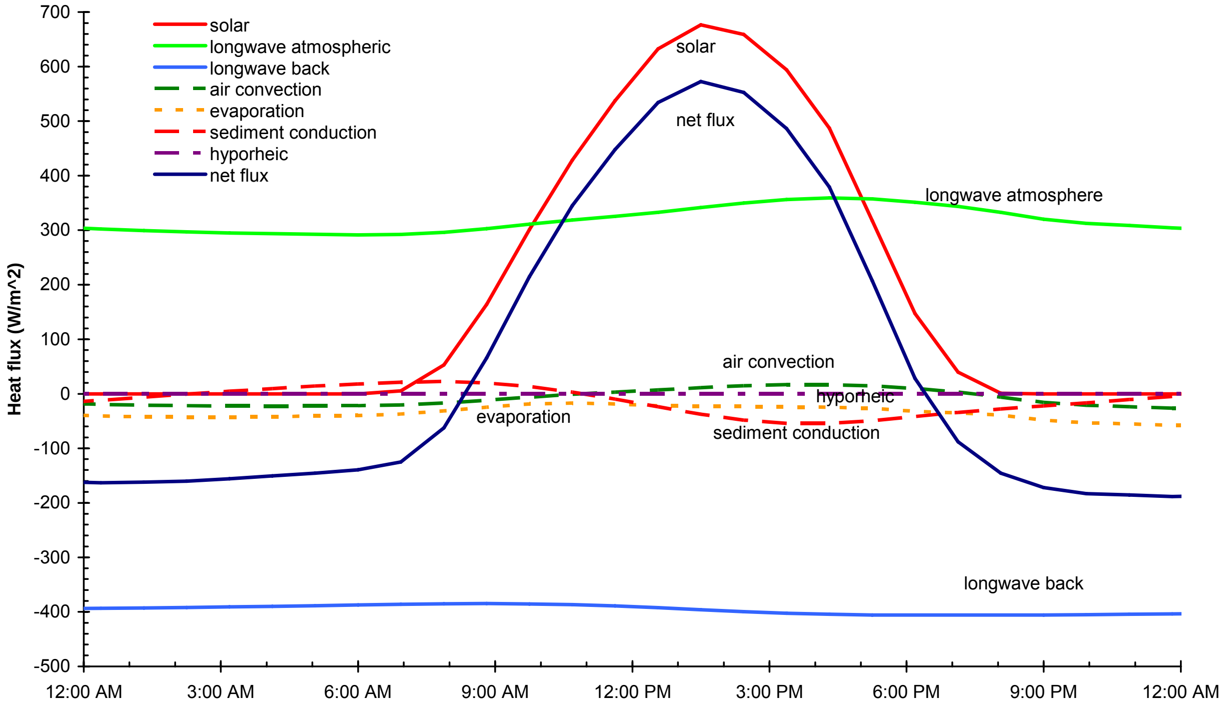

Figure 4. Estimated heat fluxes in a river during August 8-14, 2001.

(net heat flux = solar + longwave atmosphere + longwave back + air convection + evaporation + sediment conduction + hyporheic).

Figure 5 shows an example of the estimated diurnal pattern of the surface heat fluxes in a more heavily shaded location in the same river. Shade that is produced by riparian vegetation or topography can reduce the solar shortwave flux. Other processes – such as long-wave radiation, convection, evaporation, bed conduction, or hyporheic exchange – also influence the net heat flux into or out of a stream.

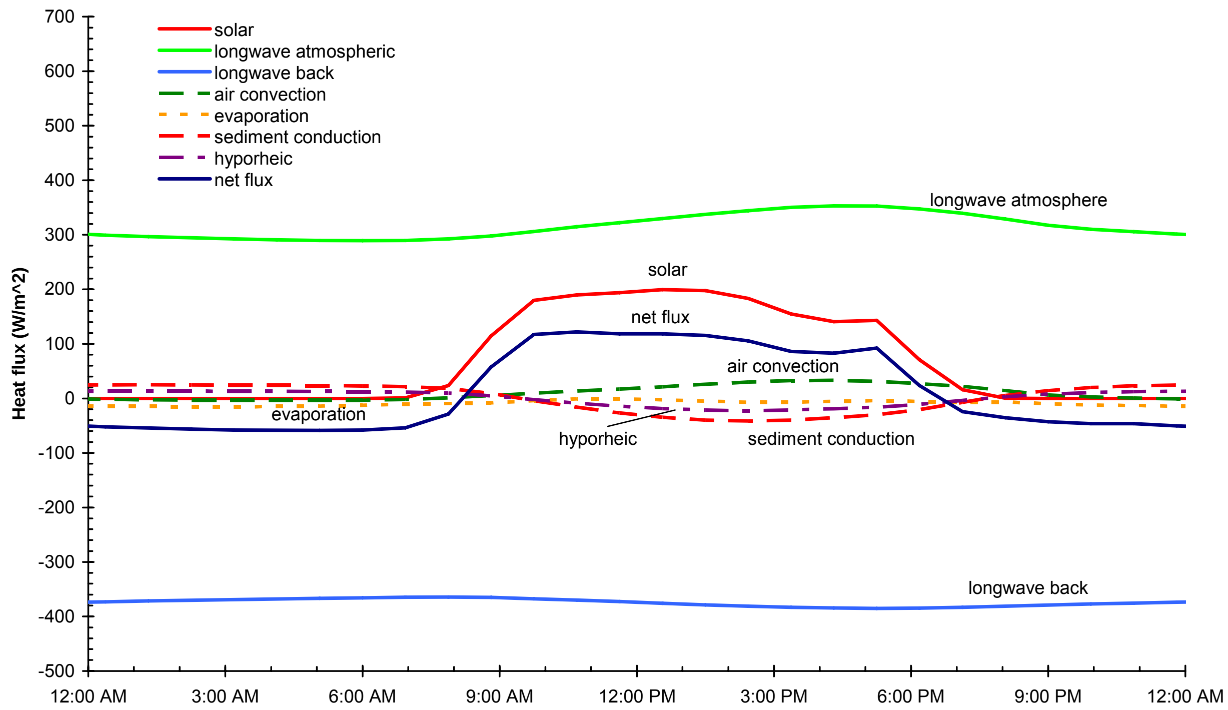

Figure 5. Estimated heat fluxes in a more shaded section of a river during August 8-14, 2001.

(net heat flux = solar + longwave atmosphere + longwave back + air convection + evaporation + sediment conduction + hyporheic).

Heat exchange between the stream and the streambed has an important influence on water temperature. The temperature of the streambed is typically warmer than the overlying water at night and cooler than the water during the daylight (Figure 6). Heat is typically transferred from the water into the streambed during the day, then back into the stream during the night (Adams and Sullivan, 1989). This has the effect of dampening the diurnal range of stream temperature variations without affecting the daily average stream temperature.

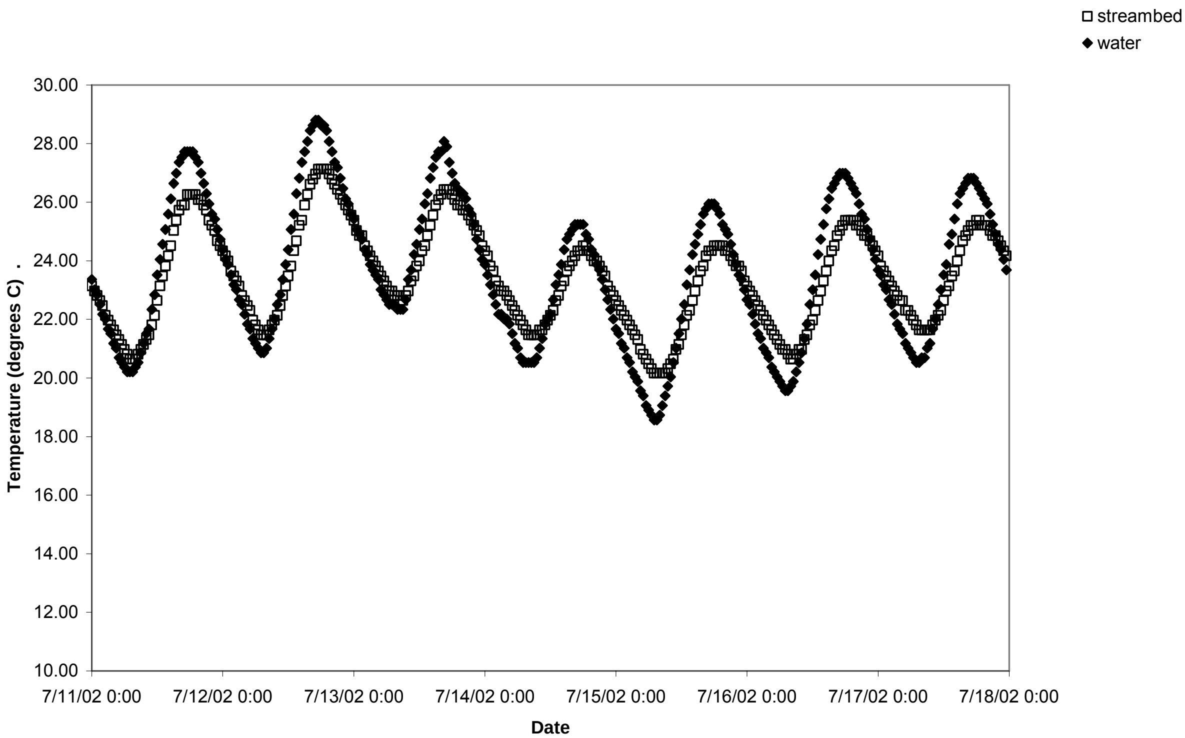

Figure 6. Water and streambed temperatures in mid-July 2002 in the Touchet River at Highway 124 near Bolles Road (station TOU-40.5).

The bulk temperature of a vertically mixed volume of water in a stream segment under natural conditions tends to increase or decrease with time during the day according to whether the net heat flux is either positive or negative. When the sun is not shining, the water tends toward the dew-point temperature (Edinger et al., 1974; Brady et al., 1969). The equilibrium temperature of a natural body of water is defined as the temperature at which the water is in equilibrium with its surrounding environment and the net rate of surface heat exchange would be zero (Edinger et al., 1968; 1974).

The dominant contribution to the seasonal variations in the equilibrium temperature of water is from seasonal variations in the dew-point temperature (Edinger et al., 1974). The main source of hourly fluctuations in water temperature during the day is solar radiation. Solar radiation generally reaches a maximum during the day when the sun is highest in the sky unless cloud cover or shade from vegetation interferes.

The complete heat budget for a stream also accounts for the mass transfer processes which depend on the amount of flow and the temperature of water flowing into and out of a particular volume of water in a segment of a stream. Mass transfer processes in open channel systems can occur through advection, dispersion, and mixing with tributaries and groundwater inflows and outflows. Mass transfer relates to transport of flow volume downstream, instream mixing, and the introduction or removal of water from a stream. For instance, flow from a tributary will cause a temperature change if the temperature is different from the receiving water.

Thermal role of riparian vegetation

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature. Summer stream temperature increases due to the removal of riparian vegetation is well documented (*e.g.*, Holtby, 1988; Lynch et al., 1984; Rishel et al., 1982; Patric, 1980; Swift and Messer, 1971; Brown et al., 1971; and Levno and Rothacher, 1967). These studies generally support the findings of Brown and Krygier (1970) that loss of riparian vegetation results in larger daily temperature variations and elevated monthly and annual temperatures. Adams and Sullivan (1989) also concluded that daily maximum temperatures are strongly influenced by the removal of riparian vegetation because of the effect of diurnal fluctuations in solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al., 1992; Beschta et al., 1987; Bolton and Monahan, 2001; Castelle and Johnson, 2000; CH2M Hill, 2000; GEI, 2002; Ice, 2001; and Wenger, 1999. All of these summaries recognize that the scientific literature indicates that riparian vegetation plays an important role in controlling stream temperature. The list of important benefits that riparian vegetation has upon the stream temperature includes:

- Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.
- Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.
- Bank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land-cover type and condition by affecting flood plain and instream roughness, contributing coarse woody debris, and influencing sedimentation, stream substrate compositions, and streambank stability.

The warming of water temperatures as a stream flows downstream is a natural process. However, the rates of heating can be dramatically reduced when high levels of shade exist and heat flux from solar radiation is minimized. The overriding justification for increases in shade from riparian vegetation is to minimize the contribution of solar heat flux in stream heating. There is a natural maximum level of shade that a given stream is capable of attaining, and the importance of shade decreases as the width of a stream increases.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in the stream.

Effective shade

Shade is an important parameter that controls the stream heating derived from solar radiation. Solar radiation has the potential to be one of the largest heat-transfer mechanisms in a stream system. Human activities can degrade near-stream vegetation and/or channel morphology, and in turn, decrease shade. Reductions in stream surface shade have the potential to cause significant increases in heat delivery to a stream system. Stream shade is an important factor in describing the heat budget for the present analysis. Stream shade may be measured or calculated using a variety of methods (Chen, 1996; Chen et al., 1998; Ice, 2001; OWEB, 1999; Teti, 2001; Teti and Pike, 2005).

Shade is the amount of solar energy that is obscured or reflected by vegetation or topography above a stream. Effective shade is defined as the fraction or percentage of the total possible solar radiation heat energy that is prevented from reaching the surface of the water:

$$\text{effective shade} = (J_1 - J_2)/J_1$$

where J_1 is the potential solar heat flux above the influence of riparian vegetation and topography, and J_2 is the solar heat flux at the stream surface.

In the Northern Hemisphere, the earth tilts on its axis toward the sun during the summer, 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) (Figure 7). Geographic position (i.e., latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation (direction of streamflow). Near-stream vegetation 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) (Table 2). The solar position has a vertical component (i.e., solar altitude) and a horizontal component (i.e., solar azimuth) that are both functions of time/date (i.e., solar declination) and the earth's rotation.

While the interaction of these shade variables may seem complex, the mathematics that describes them is relatively straightforward geometry. Using solar tables or mathematical simulations, the potential daily solar load can be quantified. The shade from riparian vegetation can be measured with a variety of methods, including (Ice, 2001; OWEB, 1999; Boyd, 1996; Teti, 2001; Teti and Pike, 2005):

- Hemispherical photography
- Angular canopy densiometer
- Solar pathfinder

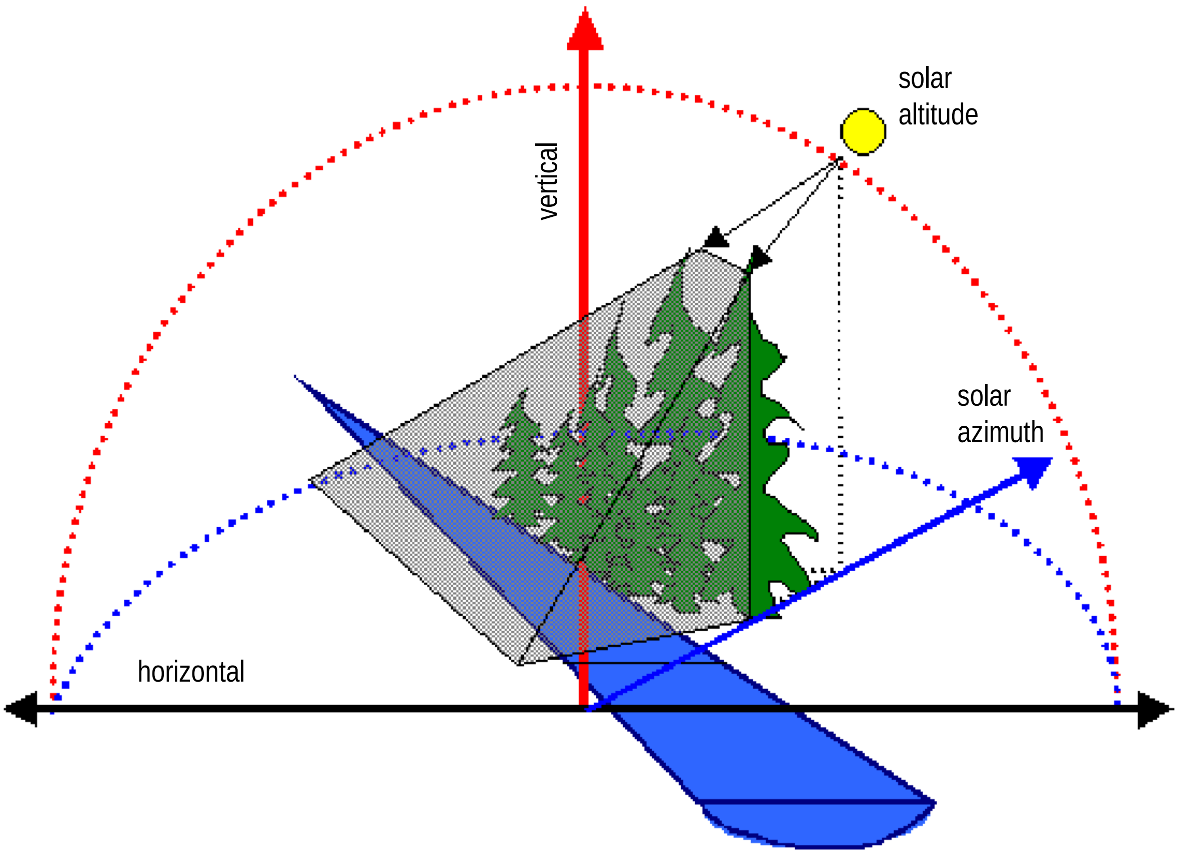

Figure 7. Parameters that affect shade and geometric relationships.

Solar altitude is a measure of the vertical angle of the sun's position relative to the horizon. *Solar azimuth* is a measure of the horizontal angle of the sun's position relative to north. (Boyd and Kasper, 2003.)

Hemispherical photography is generally regarded as the most accurate method for measuring shade, although the equipment that is required is significantly more expensive compared with other methods. Angular canopy densiometers (ACD) and solar pathfinders provide a good balance of cost and accuracy for measuring the importance of riparian vegetation for preventing increases in stream temperature (Beschta et al., 1987; Teti, 2001, 2005). Whereas canopy density is usually expressed as a vertical projection of the canopy onto a horizontal surface, the ACD is a projection of the canopy measured at an angle above the horizon at which direct beam solar radiation passes through the canopy. This angle is typically determined by the position of the sun above the horizon during that portion of the day (usually between 10 A.M. and 2 P.M. in mid to late summer) when the potential solar heat flux is most significant. Typical values of the ACD for old-growth stands in western Oregon have been reported to range from 80% to 90%.

Computer programs for the mathematical simulation of shade may also be used to estimate shade from measurements or estimates of the key parameters listed in Table 2 (Ecology 2003a; Chen, 1996; Chen et al., 1998; Boyd, 1996; Boyd and Park, 1998).

Table 2. Factors that influence stream shade (bold indicates influenced by human activities).

Description	Parameter
Season/time	Date/time
Stream characteristics	Aspect, **channel width**
Geographic position	Latitude, longitude
Vegetative characteristics	**Riparian vegetation height, width, and density**
Solar position	Solar altitude, solar azimuth

Riparian buffers and effective shade

Trees in riparian areas provide shade to streams and minimize undesirable water temperature changes (Brazier and Brown 1973; Steinblums et al., 1984). The shading effectiveness of riparian vegetation is correlated to riparian area width (Figure 8). The shade as represented by angular canopy density (ACD) for a given riparian buffer width varies over space and time because of differences among site potential vegetation, forest development stages (e.g., height and density), and stream width. For example, a 50-foot-wide riparian area with fully developed trees could provide from 45% to 72% of the potential shade in the two studies shown in Figure 8.

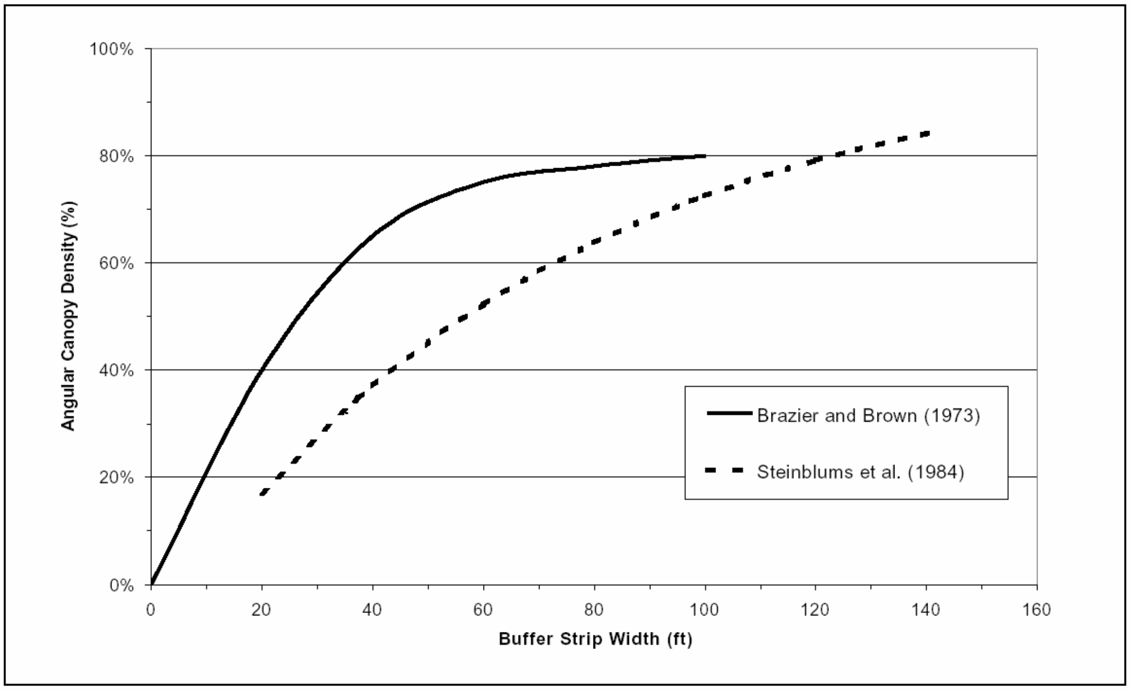

Figure 8. Relationship between angular canopy density and riparian buffer width for small streams in old-growth riparian stands (after Beschta et al., 1987; and CH2M Hill, 2000).

The Brazier and Brown (1973) shade data show a stronger relationship between ACD and buffer strip width than the Steinblums et al. (1984) data: the r^2 correlation for ACD and buffer width was 0.87 and 0.61 in Brazier and Brown (1973) and Steinblums et al. (1984), respectively. This difference supports the use of the Brazier and Brown curve as a base for measuring shade effectiveness under various riparian buffer proposals. These results reflect the natural variation among old-growth sites studied, and show a possible range of potential shade.

Several studies of stream shading report that most of the potential shade comes from the riparian area within about 75 feet (23 m) of the channel (CH2M Hill, 2000; Castelle and Johnson, 2000):

- Beschta et al. (1987) report that a 98-foot-wide (30-m) buffer provides the same level of shading as that of an old-growth stand.
- Brazier and Brown (1973) found that a 79-foot (24-m) buffer provides maximum shade to streams.
- Steinblums et al. (1984) concluded that a 56-foot (17-m) buffer provides 90% of the maximum ACD.
- Corbett and Lynch (1985) concluded that a 39-foot (12-m) buffer should adequately protect small streams from large temperature changes following logging.
- Broderson (1973) reported that a 49-foot-wide (15-m) buffer provides 85% of the maximum shade for small streams.
- Lynch et al. (1984) found that a 98-foot-wide (30-m) buffer maintains water temperatures within 2°F (1°C) of their former average temperature in small streams (channel width less than 3 m).

GEI (2002) reviewed the scientific literature related to the effectiveness of buffers for shade protection in agricultural areas in Washington and concluded that buffer widths of 10 m (33 feet) provide nearly 80% of the maximum potential shade in agricultural areas. Wenger (1999) concluded that a minimum continuous buffer width of 10-30 m should be preserved or restored along each side of all streams on a municipal or county-wide scale to provide stream temperature control and maintain aquatic habitat. GEI (2002) considered the recommendations of Wenger (1999) to be relevant for agricultural areas in Washington.

Steinblums et al. (1984) concluded that shade could be delivered to forest streams from beyond 75 feet (22 m) and potentially out to 140 feet (43 m). In some site-specific cases, forest practices between 75 and 140 feet from the channel have the potential to reduce shade delivery by up to 25% of maximum. However, any reduction in shade beyond 75 feet would probably be relatively low on the horizon, and the impact on stream heating would be relatively low because the potential solar radiation decreases significantly as solar elevation decreases.

Microclimate - surrounding thermal environment

A secondary consequence of near-stream vegetation is its effect on the riparian microclimate. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity, and lower wind speeds are characteristic. Riparian microclimates tend to moderate daily air temperatures. Relative humidity increases result from the evapotranspiration that is occurring by riparian plant communities. Wind speed is reduced by the physical blockage produced by riparian vegetation.

Riparian buffers commonly occur on both sides of the stream, compounding the edge influence on the microclimate. Brosofske et al. (1997) reported that a buffer width of at least 150 feet (45 m) on each side of the stream was required to maintain a natural riparian microclimate environment in small forest streams (channel width less than 4 m) in the foothills of the western slope of the Cascade Mountains in western Washington with predominantly Douglas-fir and western hemlock.

Bartholow (2000) provided a thorough summary of literature of documented changes to the environment of streams and watersheds associated with extensive forest clearing. Changes summarized by Bartholow (2000) are representative of hot summer days and indicate the mean daily effect unless otherwise indicated:

- **Air temperature**. Edgerton and McConnell (1976) showed that removing all or a portion of the tree canopy resulted in cooler terrestrial air temperatures at night and warmer temperatures during the day, enough to influence thermal cover sought by elk (*Cervus canadensis)* on their eastern Oregon summer range. Increases in maximum air temperature varied from 5 to 7ºC for the hottest days (estimate). However, the mean daily air temperature did not appear to have changed substantially since the maximum temperatures were offset by almost equal changes to the minima. Similar temperatures have been commonly reported (Childs and Flint, 1987; Fowler et al., 1987), even with extensive clearcuts (Holtby, 1988).

  In an evaluation of buffer strip width, Brosofske et al. (1997) found that air temperatures immediately adjacent to the ground increased 4.5ºC during the day and about 0.5ºC at night (estimate). Fowler and Anderson (1987) measured a 0.9ºC air temperature increase in clearcut areas, but temperatures were also 3ºC higher in the adjacent forest. Chen et al. (1993) found similar (2.1ºC) increases.

  All measurements reported here were made over land instead of water, but, in aggregate, support about a 2ºC increase in ambient mean daily air temperature resulting from extensive clearcutting.

- **Relative humidity**. Brosofske et al. (1997) examined changes in relative humidity within 17 to 72 m buffer strips. The focus of their study was to document changes along the gradient from forested to clearcut areas, so they did not explicitly report pre- to post-harvest changes at the stream. However, there appeared to be a reduction in relative humidity at the stream of 7% during the day and 6% at night (estimate). Relative humidity at stream sites increased exponentially with buffer width. Similarly, a study by Chen et al. (1993) showed a decrease of about 11% in mean daily relative humidity on clear days at the edges of clearcuts.

- **Wind speed**. Brosofske et al. (1997) reported almost no change in wind speed at stream locations within buffer strips adjacent to clearcuts. Speeds quickly approached upland conditions toward the edges of the buffers, with an indication that wind actually increased substantially at distances of about 15 m from the edge of the strip, and then declined farther upslope to pre-harvest conditions. Chen et al. (1993) documented increases in both peak and steady winds in clearcut areas; increments ranged from 0.7 to 1.2 m/s (estimated).

Thermal role of channel morphology

Changes in channel morphology impact stream temperatures. As a stream widens, the surface area exposed to heat flux increases, resulting in increased energy exchange between a stream and its environment (Chapra, 1997). Further, wide channels are likely to have decreased levels of shade due to the increased distance created between vegetation and the wetted channel and the decreased fraction of the stream width that could potentially be covered by shadows from riparian vegetation. Conversely, narrow channels are more likely to experience higher levels of shade.

Channel widening is often related to degraded riparian conditions that allow increased streambank erosion and sedimentation of the streambed, both of which correlate strongly with riparian vegetation type and condition (Rosgen, 1996). Channel morphology is not solely dependent on riparian conditions. Sedimentation can deposit material in the channel, fill pools, and aggrade the streambed, reducing channel depth and increasing channel width. Channel straightening can increase flow velocities and lead to deeply incised streambanks and washout of gravel and cobble substrate.

Channel modification usually occurs during high-flow events. Land uses that affect the magnitude and timing of high-flow events may negatively impact channel width and depth. Riparian vegetation conditions will affect the resilience of the streambanks/flood plain during periods of sediment introduction and high flow. Disturbance processes may have differing results depending on the ability of riparian vegetation to shape and protect channels.

Channel morphology is related to riparian vegetation composition and condition by:

- **Building streambanks**. Traps suspended sediments, encourages deposition of sediment in the flood plain, and reduces incoming sources of sediment.
- **Maintaining stable streambanks**. High rooting strength and high streambank and flood plain roughness prevent streambank erosion.
- **Reducing flow velocity** (erosive kinetic energy). Supplies large woody debris to the active channel, provides a high pool to riffle ratio, and adds channel complexity that reduces shear stress exposure to streambank soil particles.

Pollutants and Surrogate Measures

Heat loads to the stream are calculated in this TMDL study in units of calories per square centimeter per day (cal/cm²/day) or watts per square meter (W/m^2). However, heat loads are of limited value in guiding management activities needed to solve identified water quality problems.

This *Walla Walla River Tributaries Temperature TMDL Study* incorporates measures other than "daily loads" to fulfill the requirements of Section 303(d). This TMDL allocates other appropriate measures, or "surrogate measures," as provided under EPA regulations [40 CFR 130.2(i)]. The Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

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

This technical assessment for the *Walla Walla River Tributaries Temperature TMDL* uses riparian effective 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. Other factors influencing heat flux and water temperature were also considered, including microclimate, channel geometry, groundwater recharge, and instream flow.

Background

Study Area

The study area includes all major tributaries to the Walla Walla River (WRIA 32) in Washington State. The Walla Walla mainstem will be excluded from this study because the water temperature TMDL analysis is covered by the Oregon Department of Environmental Quality (ODEQ) as part of a larger project. This larger project addressed the entire Walla Walla mainstem, which lies in both states (ODEQ, 2005).

The Walla Walla basin is a 1,758-square-mile area with about 70% located in Washington State. The major tributaries of concern for this temperature TMDL are the Touchet River, Mill Creek, and Dry Creek drainages.

The four primary forks of the Touchet River (South, North, Wolf, and Robinson) originate deep in the Blue Mountains at an elevation of 6,074 feet. The four forks are mainly forested with only small farms in the valleys. The forks converge just above the city of Dayton to form the mainstem Touchet River. The Touchet River flows through the cities of Dayton, Waitsburg, and Prescott reaching its confluence with the Walla Walla River by the town of Touchet at an elevation of 420 feet. Land use in the Touchet basin from Dayton to the confluence of the Walla Walla River is predominantly agricultural with both irrigated and non-irrigated crops.

Mill Creek headwaters are located in the Blue Mountains where 22,000 acres are preserved as a drinking water source for the City of Walla Walla. The 100-square-mile drainage flows through Oregon, where a portion of the streamflow is diverted for the City of Walla Walla water supply, and then continues to the Washington border and downstream through the City of Walla Walla. The City of Walla Walla and the U.S. Army Corps of Engineers built a control structure in the 1940s to stop catastrophic flooding during the spring months. Currently, a portion of Mill Creek's spring flow is diverted at river mile (RM) 10.5 into Garrison Creek, Yellowhawk Creek, and to Bennington Lake. Mill Creek's remaining flow passes through the city of Walla Walla in an engineered concrete channel. Mill Creek enters the Walla Walla River downstream of the city, near the historical Whitman Mission. During May through October, the majority of Mill Creek flow is diverted at RM 10.5 to Yellowhawk and Garrison Creeks which enter the Walla Walla River just upstream of the Mill Creek confluence.

Dry Creek is a 239-square-mile basin with elevations from 460 feet at the confluence with the Walla Walla River near Lowden to 4,600 feet in the Blue Mountains. Dry Creek's watershed is mainly used for dry wheat agriculture with only sparse forests in the headwaters.

This region has a continental type climate with hot arid summers and cold wetter winters. Temperatures in the basin can easily reach 37.8 °C (100 °F) in the summer and below freezing in the winter. The lower portions of the basin receive less than 10 inches of annual precipitation, and the upper sections, in the Blue Mountains, can receive up to 60 inches of annual precipitation. Most of the precipitation falls as snow in the winter months causing a significant accumulation of snowpack in the mountains. Spring thaw, compounded with rain showers, is the source of flooding for the basin. Significant flood events occurred in 1933, 1964, and 1996.

The Walla Walla basin contains federally designated critical habitat for bull trout and steelhead trout, both of which are listed as threatened species protected under the Endangered Species Act (USFW, 2005). Mendel et al. (2004) surveyed the fish populations within the Walla Walla basin, finding the highest abundances of salmonid species in Mill Creek and the North and Wolf Forks of the Touchet River. Native salmonid species identified were mountain whitefish (*Prosopium williamsoni*), bull trout (*Salvelinus confluentus*), and rainbow/steelhead trout (*Oncorhynchus mykiss*). Most spawning habitat was found in the upper reaches, while the lower reaches of the Touchet and Walla Walla Rivers are mainly used for fish migration with little rearing capability.

Bull trout redds counted in 2002 by Washington Department of Fish and Wildlife (WDFW), U.S. Forest Service (USFS), and Oregon Department of Fish and Wildlife (ODFW) staff were 161 in Mill Creek, 29 in the North Fork Touchet River, and 92 in the Wolf Fork Touchet River (Mendel et al., 2004).

Chinook salmon were originally native to this basin, with some reintroduction work being done in recent years by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR).

Forest Land Cover

Much of the land area in the upper Touchet River and upper Mill Creek watersheds is covered with forest (Figure 9). Federally owned forest land is managed by the U.S. Forest Service.

Forest land in the watersheds that is not owned and managed by the USFS is subject to the state forest practices rules.

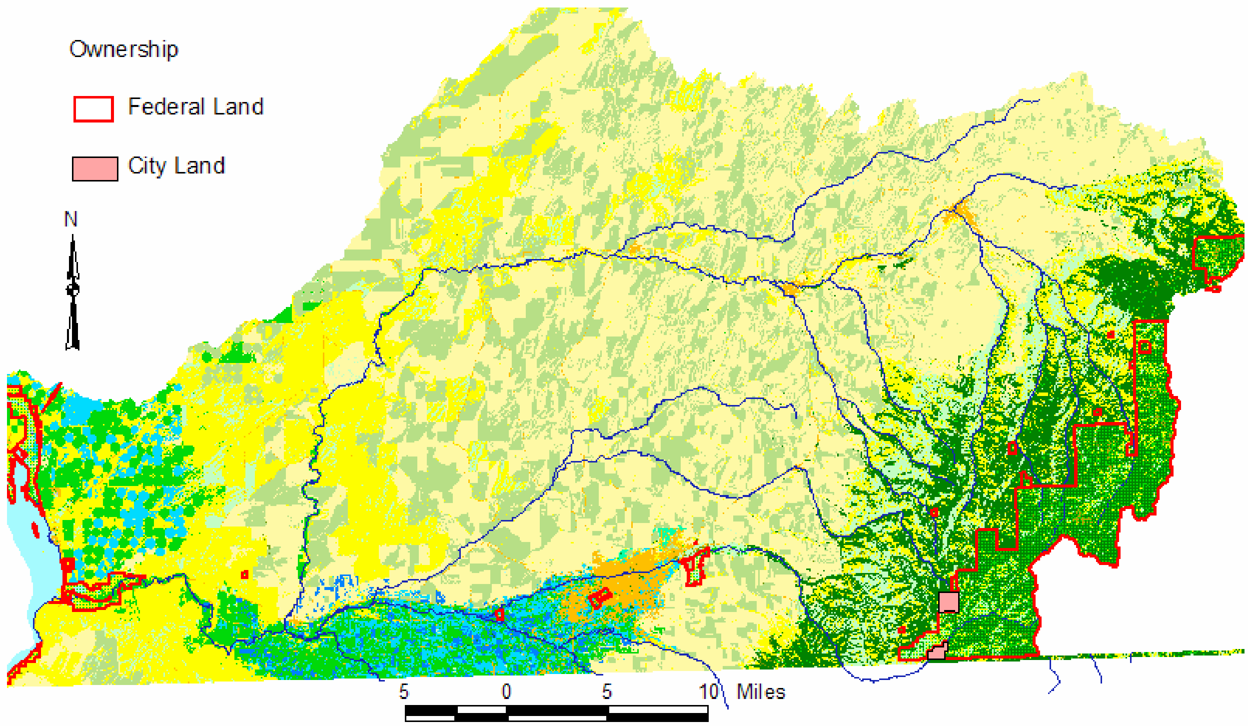

Figure 9. Land cover (from satellite image) and federal ownership in the Walla Walla River watershed.

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Forest Practices

Load allocations are included in this TMDL study for non-federal forest lands in accordance with Section M-2 of the *Forests and Fish Report*. This report can be found online at: www.dnr.wa.gov/forestpractices/rules/forestsandfish.pdf .

The Washington State Department of Natural Resources **(**DNR) has primary administrative and enforcement responsibilities for the Forest Practices Act (Ch. 76.09 RCW), which includes implementation of the 1999 *Forests and Fish Report.* The *Forests and Fish Report* (ESHB 2091) was adopted by the state Legislature to protect salmon listed under the federal Endangered Species Act, other aquatic species, and clean water, while keeping the timber industry economically viable. The resulting rules address forest roads, unstable slopes, riparian shading, and effectiveness monitoring.

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 practices 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.

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.

New forest practices 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, better streambank stability protection, and meet current best management practices. DNR is also responsible for oversight of these activities.

U.S. Forest Service

The headwaters of Mill Creek and the Touchet River system are managed by the U.S. Forest Service.

Forest plans are required by the National Forest Management Act for each national forest. These plans establish land allocations, goals and objectives, and standards and guidelines that direct how National Forest System lands are managed.

The Aquatic Conservation Strategy, a component of the amended forest plan, is designed to protect and restore the ecological health of the aquatic system and its dependent species. Restoration priorities are based on watershed analysis and planning which will help to determine areas where the greatest benefits can be achieved along with the likelihood of success. In general, watersheds that currently have the best habitat, or those with the greatest potential for recovery, are priority areas for increased protection and for restoration treatments. The conservation strategy aims to maintain the natural disturbance regime.

Components of the Aquatic Conservation Strategy include:

- *Riparian Reserves:* Lands along streams, wetlands, ponds, lakes, and unstable and potentially unstable areas where special standards and guidelines direct land use. Riparian reserves are designed to maintain and restore the ecological health of watersheds and aquatic ecosystems. Interim widths for riparian reserves are established based on ecological, hydrologic, and geomorphic factors. Interim riparian reserves for federal lands are delineated as part of the watershed analysis process based on identification and evaluation of critical hillslope, riparian, and channel processes. Final riparian reserve boundaries are determined at the site-specific level during the appropriate National Environmental Policy Act analysis.

- *Key Watersheds:* A system of refugia comprising watersheds crucial to at-risk fish species and stocks while also providing high quality habitat. Key watersheds are generally those identified as having the best habitat or those with the greatest potential for recovery. Key watersheds are priority areas for increased protection and for restoration treatments. Activities to protect and restore aquatic habitat in key watersheds are a higher priority than similar activities in other watersheds.

- *Watershed Analysis:* An on-going, iterative analysis procedure for characterizing watershed and ecological processes to meet specific management objectives within the subject watershed. This analysis should enable watershed planning that achieves Aquatic Conservation Strategy objectives. Watershed analysis provides the basis for monitoring and restoration programs and the foundation from which the riparian reserves can be delineated.

- *Watershed Restoration:* A comprehensive, long-term program of watershed restoration to restore watershed health and aquatic ecosystems, including habitats supporting fish and other aquatic and riparian-dependent organisms.

Riparian reserves are specified for categories of streams or waterbodies 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 non-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 one site-potential tree, or 150 feet slope distance (300 feet total, including both sides of the stream channel), whichever is greatest.

Specific riparian reserves ranging from 100 to 300 feet of slope distance are also specified for the following categories of riparian areas: constructed ponds and reservoirs; wetlands (greater than one acre), lakes, and natural ponds; seasonally flowing or intermittent streams; wetlands less than or equal to one acre; and unstable and potentially unstable areas.

Confederated Tribes of the Umatilla Indian Reservation

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) have co-management responsibilities in the Walla Walla River basin. Some CTUIR lands are located in the Rainwater Wildlife area in the upper South Fork Touchet watershed. The CTUIR have expressed interest in this project and are concerned with salmon and steelhead production in the Walla Walla River basin.

Other Regulations Affecting Riparian Land Use

For private land that is not covered by the *Forests and Fish Report,* some regulations affect land use and management along rivers and streams:

- Shorelines of streams with mean annual flows greater than 20 cubic feet per second (cfs) are protected under the Shoreline Management Act. Larger rivers (greater than 200 cfs east of the Cascade crest or greater than 1,000 cfs for Western Washington) are defined as shorelines of statewide significance.
- Within municipal boundaries, land management practices next to streams may be limited if there is a local critical areas ordinance.
- Outside municipalities, county sensitive areas ordinances may affect such practices as grading or clearing next to a stream, if the activity comes under county review as part of a permit application.

Instream Flows and Water Withdrawals

Instream flows and water withdrawals are managed through regulatory avenues separate from TMDLs. However, stream temperature is related to the amount of instream flow, and increases in flow generally result in decreases in maximum temperatures. The complete heat budget for a stream segment accounts for the amount of flow and the temperature of water flowing into and out of the stream.

Actual water withdrawals at any given time from streams in the Walla Walla River watershed are not known, but information from the Water Rights Application Tracking database system (WRATS) can be used as an indicator of the amounts of water that may be legally withdrawn. In many cases, actual consumptive withdrawals are significantly less than the listed water rights.

This project used actual field-measured streamflows in analysis as well as estimates of likely water diversions from Ecology’s Walla Walla basin water master, Bill Neve. The project also used data from WRATS to verify likely stream segments where water is diverted.

Walla Walla Basin Temperature Related Studies

Temperature monitoring in the Walla Walla watershed has been quite extensive. Key research has been conducted by the WDFW, ODEQ, Conservation Districts, USDA/USFS, and WCC (see following descriptions). Monitoring has also been done by the U.S. Army Corps of Engineers, Confederated Tribes of the Umatilla Indian Reservation, the Washington State Department of Natural Resources, and Irrigation Districts.

Washington State Department of Fish and Wildlife (WDFW)

Mendel et al. (2004) of the WDFW has extensively collected temperature, water quantity, and biological information within the Walla Walla River and its tributaries. This is an ongoing effort by WDFW with funding from the Bonneville Power Administration (BPA) to continue monitoring salmonid fish species and their habitat within this basin. Mendel publishes annual reports of his findings on stream temperature, streamflow, and fish habitat. (Mendel et al., 1999, 2000, 2001, 2002, 2003, 2004, 2005.

Mendel et al. (2004) surveyed the fish populations within the Washington State portion of the Walla Walla basin. Mill Creek and the North and Wolf Forks of the Touchet River supported the highest abundances of salmonid species. Native salmon species identified were mountain whitefish (*Prosopium williamsoni*), bull trout (*Salvelinus confluentus*), and rainbow/steelhead trout (*Oncorhynchus mykiss*). Brown trout (*Salmo trutta*) was the only non-native salmonid species discovered. Most spawning habitat was found in the upper reaches, while the lower reaches of the Touchet and Walla Walla Rivers are mainly used for fish migration with little rearing capability. Bull trout redds counted by WDFW staff in 2002 were 161 in Mill Creek, 29 in the North Fork Touchet River, and 92 in the Wolf Fork Touchet River (Mendel et al., 2004).

In response to discussions about low summer streamflow levels in lower Mill Creek, Mendel et al. (2002), with cooperation of numerous other groups, researched water temperature effects of increasing flow levels in lower Mill Creek below the Yellowhawk/Garrison diversion. The current practice is to divert most summer Mill Creek flow to Yellowhawk Creek and leave essentially none to flow down lower Mill Creek. Water for irrigation needs is diverted through Garrison Creek.

Mendel et al. (2002) reported that increasing the flows in lower Mill Creek resulted in a large increase in Mill Creek water temperature. The purpose of the test, titled the Mill Creek test, was to determine the effects on salmonids of diverting 3-12 cfs into the Mill Creek engineered flood control channel downstream of the Yellowhawk Creek diversion. The test flow in Mill Creek produced substantial increases in water temperature (10-20°F, *5.6-6.7°C*)) from the Yellowhawk diversion to Roosevelt Street, reaching lethal maximum temperatures over 90°F (*32°C*). Some fish mortalities were likely caused by the high temperatures (85-91°F, *29.4-32.8°C*) created by the increased flow. Fish were found throughout Mill Creek in June, but after the test flow from mid June through early July, few rainbow/steelhead existed from the Yellowhawk diversion to 9th Ave, and from Gose Street downstream.

Because portions of lower Mill Creek are very wide, unshaded, and concrete-lined, water can be heated rapidly. Natural springs under the city of Walla Walla currently provide small amounts of cold water to the concrete channel in Mill Creek. Having just the cold spring-fed water is more beneficial to steelhead rearing than increasing the flows by 3-12 cfs through the flood control structure which adds hot water to Mill Creek.

Local groups continue to work through adaptive management on improving best management practices (BMPs) to gain the best water quality possible in these creeks. Because the three creeks diverge and then each flows independently into the Walla Walla, it is thought that trying to split the limited summer flow between all three will result in none having good water quality for salmonids.

Oregon State Department of Environmental Quality (ODEQ)

ODEQ published the *Walla Walla Subbasin Stream Temperature Total Maximum Daily Load and Water Quality Management Plan* in August 2005 (Butcher and Bower, 2005). This temperature project covers the entire mainstem of the Walla Walla River to its confluence with the Columbia River as well as all tributaries to the Walla Walla River that lie within the state of Oregon. ODEQ's extensive data gathering and analysis in both Oregon and Washington was very valuable to our effort in the tributaries in Washington State. Major conclusions were that increasing riparian shade, increasing streamflow, and decreasing channel width would all result in reduction of stream heating. Channel straightening has led to a 50% increase in channel width in parts of the basin.

Columbia Conservation District

Krause et al. (2001) participated in a two-year water quality study of the upper section of the Touchet watershed located in Columbia County. The focus of the study was to address the water quality concerns within the area during 1999 and 2000. Temperature, total suspended solids (TSS), fecal coliform (FC), ammonia, nitrate, total Kjeldahl nitrogen (TKN), total phosphorous (TP), and flow were monitored at nine sites.

Krause et al. stated that temperature was their primary concern, with seven of the nine sampling sites exceeding the 18°C (65 °F) Class A standard. Fecal coliform levels also exceeded Ecology standards for Class A streams in seven of the nine sites sampled. Overall, water quality degradation increases as one moves downstream through the sites.

Krause et al. recommended future water quality monitoring with special focus on temperature, sediment, fecal coliforms, and flow. Sites should be selected to properly assess loading of tributaries in order to pinpoint sources of degradation. Flow, sediment, and fecal coliforms should be measured more extensively to accurately address their sources.

Walla Walla County Conservation District

More than 100 miles of conservation practices have been installed through funding obtained by the Walla Walla County Conservation District through the Natural Resources Conservation Service (NRCS). (www.nacdnet.org/buffers/04Aug/buffer.htm)

When the Conservation Reserve Enhancement Program (CREP) was first introduced in 2000, landowners were anxious to install preventive measures, and more than five streambank miles were repaired along Coppei Creek and the Walla Walla River that spring. Today, project applications have been received for the Touchet River, Dry Creek, Mill Creek, Cottonwood Creek, Mud Creek, Pine Creek, Cold Creek, and others.

By the end of 2003, the popularity of the program had grown, as neighbors joined together to create contiguous miles of riparian habitat. At this time, Walla Walla County had 89 CREP contracts that totaled approximately 109 stream miles, creating about 2175 acres of riparian habitat. Through CREP, the buffer must be at least 75 feet in width and average no more than 180-foot per side of the stream. Average project size is 1.2 miles of stream length, about 22 acres of area, and a buffer width averaging 159 feet.

United States Department of Agriculture (USDA)

USDA (1981a, 1981b, 1981c) studied eight basins in southeast Washington. The scope of the study was to evaluate present and potential agricultural productivity in regards to the region's natural resources. Each basin was separated into its own study to focus locally on the problems in this region of the state.

USDA found that high stream temperature and low stream discharge were primary water quality problems in the Walla Walla watershed in 1981. Solutions to these problems that will ultimately increase agricultural production and reduce stream degradation are the following: impose better tillage techniques, plant riparian vegetation, and augment streamflows during the summer season. The study is documented in further detail in the Quality Assurance Project Plan (LeMoine and Stohr, 2002)

Washington State Conservation Commission (WCC)

Kuttle et al. (2001) assessed the limiting factors for salmonid habitat within the Walla Walla River basin (WRIA 32). The WCC found that surface water withdrawals, dryland agriculture, and residential development have profound negative impacts on salmonid habitat. Many of the streams exhibit low or non-existent summer streamflows and water temperatures exceeding the tolerance level of salmonids. According to WCC, these conditions are a result of removal of riparian habitat, surface water withdrawals, disruption of surface water-groundwater exchange, channel straightening and bank armoring, and diking of flood plains. Water diversions are improperly screened, and many stream reaches carry extremely high fine-sediment loads from agricultural erosion. The lack of large woody debris, pools, and off-channel habitat compounds the problem and greatly reduces salmonid spawning/rearing habitat.

In contrast, habitat conditions on public lands managed by the United States Forest Service (USFS) are the last remaining refuge for salmonid species. Habitats within these reaches have maintained riparian shading, pool quantities, and large woody debris. This has maintained a slowly dwindling population of salmonid species. WCC noted these conditions are not “ideal”, but are far more favorable than the lower privately-owned reaches.

The WCC made recommendations for restoration efforts to reduce the most major limiting factors for salmonid habitat (List 1). In addition, the Technical Advisory Group (TAG) listed the most important reaches to protect for salmonid habitat (List 2). The TAG is a local interest group made up of scientists and resource managers who worked with the WCC in the development of this report.

List 1: WCC recommendations for reducing limiting factors for salmonid habitat.

1. Restore instream flows on the Walla Walla River from Nursery Bridge downstream to the state line.
2. Conduct a comprehensive inventory of surface water diversions and ensure compliance with juvenile fish screening regulations, particularly on the highly developed Little Walla Walla River System.
3. Protect the remaining quality salmonid habitat located on U.S. Forest Service lands.
4. Restore flood plain connectivity and natural channel migration on the Walla Walla River from the North/South Fork confluence downstream to the state line.
5. Implement instream projects on the Walla Walla River from Milton-Freewater, Oregon, downstream to the state line to reduce surface water loss to the gravel aquifer and create a low-flow channel.
6. Restore riparian zones throughout the subbasin.
7. Ensure coordination of flow management on the Little Walla Walla River System near the state line to prevent stranding or mortality of salmonids in the Washington portion of the system.
8. Reduce fine sediment inputs to streams by replacing conventional tillage with no till farming practices.

List 2: Vital areas for improving or maintaining salmonid habitat, selected by the Technical Advisory Group (TAG).

1. North Fork Touchet River from Lewis Creek upstream
2. Wolf Fork from Whitney Creek upstream
3. Mill Creek from Blue Creek upstream
4. Yellowhawk Creek
5. South Fork Coppei Creek from the North/South Fork confluence upstream
6. South Fork Walla Walla River from the confluence to the headwaters
7. North Fork Walla Walla River on U.S. Forest Service lands

Walla Walla Basin Watershed Council

The mission of the Walla Walla Basin Watershed Council is to protect the resources of the Walla Walla watershed, deal with issues in advance of resource degradation, and enhance the overall health of the watershed, while also protecting, as far as possible, the welfare, customs, and cultures of all citizens residing in the basin.

The Watershed Council is a major player in coordinating watershed groups and research in the Walla Walla basin (especially within Oregon). They regularly post research documents and monitoring maps to their web site and also distributed Ecology's Quality Assurance Project Plan (LeMoine and Stohr, 2002) to their extensive mailing list. The 2002 monitoring maps for stream temperature and streamflow were used to see where groups were collecting data. This helped to avoid duplication of effort and increase data sharing.

Snake River Salmon Recovery Plan for Southeast Washington

The Snake River Salmon Recovery Plan identifies actions that will assist in the overall effort to restore salmon populations that are "biologically, culturally and economically viable" (Snake River Salmon Recovery Board, 2006). As a subbasin of the Snake River, the plan includes several recommended actions for the Walla Walla watershed. Plan text and recommendations can be found at www.snakeriverboard.org/resources/library.htm#drpsummary

Applicable Water Quality Criteria

Current

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 Walla Walla River basin tributary streams are as follows (Chapter 173-201A WAC):

The tributaries of the Walla Walla River are classified as Class AA (extraordinary), Class A (excellent), and Class B (good), as defined by Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC) (Table 3).

Table 3. Stream classifications of the Walla Walla tributaries as defined by Water Quality Standards for Surface Waters of the State of Washington.

Tributary Name and Location	Classification
Mill Creek from mouth to 13th St. bridge in Walla Walla (RM 6.4).	Class B
Mill Creek from 13th St. bridge in Walla Walla (RM 6.4) to the Corps' Mill Creek diversion dam (RM 11.5).	Class A
Mill Creek and tributaries from city of Walla Walla waterworks dam (RM 21.6) to headwaters.	Class AA
North Fork Touchet River from Dayton water intake structure (RM 3.0) to headwaters.	Class AA

All streams that are not specifically named in Table 3 that are tributaries to Class AA waters are classified Class AA. All surface waters lying within national parks, national forests, or wilderness areas are classified Class AA. All other non-specified surface waters are classified Class A.

The water quality standards establish beneficial uses of waters and incorporate specific numeric and narrative criteria for parameters such as water temperature. The criteria are intended to define the level of protection necessary to support the beneficial uses. The beneficial uses of the waters in the Walla Walla River basin include:

- *Recreation*: Primary contact recreation, sport fishing, boating, and aesthetic enjoyment.
- *Fish and Shellfish*: Salmonid migration, rearing, spawning, and harvesting; and other fish migration, rearing, spawning, and harvesting: spring chinook salmon (*Oncorhynchus tshawytscha*), rainbow/steelhead trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and mountain whitefish (*Prosopium williamsoni*) are the salmonid species in the Walla Walla basin. The lower reaches of the basin are mainly used by these species for migration and some rearing, while the headwaters provide a majority of the spawning habitat.

- *Water Supply (domestic, industrial, and agricultural) and Stock Watering*: Agriculture extracts water for irrigation and stock watering, and the City of Walla Walla uses Mill Creek as a drinking water source.
- *Wildlife Habitat*: Riparian areas are used by a variety of wildlife species, which are dependent on the habitat.
- *Commerce and Navigation*

WAC 172-201A states that: "Temperature shall not exceed [the numeric criteria] due to human activities. When natural conditions exceed [the numeric criteria], no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°."
(WAC 173-201A-030(1)(c)(iv), (2)(c)(iv), (3)(c)(iv), (4)(c)(iii))

Numeric freshwater water quality criteria for Class AA, Class A, and Class B state that temperature shall not exceed the following:

- AA (extraordinary) 16.0°C
- A (excellent) 18.0°C
- B (good) 21.0°C

These numeric criteria are designed to ensure specific communities of aquatic life will be fully protected whenever and wherever the numeric criteria are met. The state standards recognize, however, that some waterbodies may not be able to meet the numeric criteria at all places and all times.

Thus at times and locations where the assigned numeric criteria cannot be attained even under estimated natural conditions, the state standards hold human warming to a cumulative allowance for additional warming of 0.3°C above the natural conditions estimated for those locations and times.

In addition to placing a limit on the amount of human warming allowed when temperatures exceed the numeric criteria, the state standards restrict the amount of warming point and nonpoint sources can cause when temperatures are cooler than the numeric criteria.

If natural conditions are below the temperature standard, incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C or bring the stream temperature above the specified standard of the class at any time (Chapter 173-201A-030 WAC). Where natural conditions are below the temperature standard, incremental temperature increases from point sources are restricted using equation 23/(T+5) in Class AA waters, where T is the upstream water temperature. The equation of 28/(T+7) is used for Class A waters and t=34/(T+9) is used in Class B waters.

Temperature is a water quality concern because most aquatic organisms, including salmonids, are cold-blooded and are strongly influenced by water temperature (Schuett-Hames et al., 1999). Temperature affects the physiology and behavior of fish and other aquatic life.

Temperature is a major concern in the Walla Walla River and its tributaries because of the use of its waters by steelhead and bull trout, and their listing as threatened species under the Endangered Species Act. Elevated temperature and altered channel morphology resulting from various land-use activities – such as timber harvest, flood control, and agriculture – in the area limit available spawning and rearing habitat for salmonids. In the Walla Walla basin, temperature has been noted as being the most critical physiological barrier to salmonids, particularly for passage or rearing (Mendel et al., 2000).

2003 Revised

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

The revised water quality standards regulation was submitted to the U.S. Environmental Protection Agency (EPA) for federal approval. EPA was not satisfied that Ecology's 2003 standards met the requirements of the federal Clean Water Act and the federal Endangered Species Act. Their main concerns were over the temperature criteria applied to waters that support endangered fish species (e.g., bull trout, salmon, steelhead). As a consequence, EPA has formally disapproved portions of the revised standards.

Ecology agreed to initiate state rule revision proceedings that consider making the changes EPA has highlighted as necessary. This revision was completed in November 2006. The result of the corrective state rulemaking will be that a number of streams and stream segments will receive more stringent temperature and dissolved oxygen criteria.

EPA expects to conclude its review of Washington's rulemaking proceedings by October 2007. This current TMDL must be based on the 1997 version of the state water quality standards, rather than the 2003/2006 version that has not been approved by EPA.

Table 4 provides a general structure for understanding how the 1997 standards for temperature were translated into the 2003 and draft 2006 standards:

Table 4. Expected changes in temperature standards based on the EPA corrective rule.

1997 Standards Classification	Water Quality Parameter	1997 Criteria[3]	2003/2006 Use Revision	2003/2006 Criteria[3]
Class AA [1]	Temperature	16°C 1-Dmax[5]	Char Spawning and Rearing	12°C 7-DADMax[4, 6]
			Core Summer Salmonid Habitat	16°C 7-DADMax[4, 6]
Class A[2]	Temperature	18°C 1-Dmax[5]	Char Spawning and Rearing	12°C 7-DADMax[4, 6]
			Salmonid, Spawning Rearing, and Migration	17.5°C 7-DADMax[4, 6]
Class B	Temperature	21°C 1-Dmax[5]	Salmonid Rearing and Migration Only	17.5°C 7-DADMax[6]

1. Class AA waters were subcategorized into “Char Spawning and Rearing” and “Core Summer Salmonid Habitat” designated use types during the 2006 revision to the water quality standards regulation.
2. Class A waters were subcategorized into “Char Spawning and Rearing” and “Salmonid, Spawning Rearing, and Migration” designated use types during the 2006 revision to the water quality standards regulation.
3. Criteria have been established in the existing water quality standards for specific waterbodies that differ from the general criteria shown in the above table. These special conditions can be found in WAC 173-201A-130 of the 1997 version, and WAC 173-201A-602 of the 2006 version of the standards.
4. The 2006 water quality standards rule contains supplemental spawning and incubation temperature criteria (13°C for salmon and trout, and 9°C for native char) that will be applied to specific portions of many of these waters.
5. 1-DMax means the highest annual daily maximum temperature occurring in the waterbody.
6. 7-DADMax means the highest annual running 7-day average of daily maximum temperatures.

TMDLs will be designed during this uncertain transition period with formal allocations that meet the existing (1997) EPA approved standards. In all TMDL technical studies completed during this transition period, the analysis must include a scenario evaluating what would be needed to meet the EPA required standards in the corrective rule.

Sources of further information include:

- Proposed revisions to the existing standards can be found online at Ecology’s water quality standards website www.ecy.wa.gov/programs/wq/swqs.
- Appendix G shows Ecology’s 2006 proposed use designations for streams in the Walla Walla basin.
- Information on EPA’s findings on the fisheries uses of the Walla Walla basin can be found in map form on EPAs website: http://yosemite.epa.gov/R10/WATER.NSF/Water+Quality+Standards/WA+WQS+EPA+Disapproval
- The most current information about how the state’s 2003 temperature criteria were developed can be found in a draft discussion paper by Hicks (2002).

Water Quality and Resource Impairments

The 1998 303(d) listings for temperature in the Walla Walla River watershed (Table 1) are confirmed by the data collected by Ecology during 2002 (Table 5). Temperatures in excess of the water quality standard were observed in 2002 throughout the watershed at numerous locations. Additional locations monitored by the Washington Department of Fish and Wildlife (WDFW) support this (Mendel et al., 2003).

Table 5. Highest daily maximum temperatures in the Walla Walla basin and its tributaries during 2002, sorted in decreasing order of temperature. (Data above the line show values greater than the Class A water quality numeric criteria of 18°C).

EIM_ID	Station Description	Township	Range	Section	Latitude (decimal degrees)	Longitude (decimal degrees)	1-DAD Max (C)	7-DAD Max (C)	Class
32TOU-26.1	Touchet @ Harvey Shaw Rd	09N	35E	06	46.287410	-118.487350	32.35	30.05	A
32TOU-10.8	Touchet @ Sims Rd	08N	33E	23	46.157930	-118.646600	32.27	30.25	A
32TOU-07.0	Touchet above Hofer diversion @ Touchet	07N	33E	02	46.122570	-118.649240	31.69	29.17	A
32TOU-25.0	Touchet west in between Harvey Shaw and…	09N	34E	02	46.288750	-118.531070	31.69	29.39	A
32TOU-12.8	Touchet north of Plucker Rd @ Touchet N…	08N	33E	12	46.180330	-118.637720	31.11	29.16	A
32TOU-17.8	Touchet @ Luckenbill Rd	09N	34E	32	46.223150	-118.576260	31.06	29.18	A
32TOU-02.0	Touchet @ Cummins Rd	07N	33E	27	46.057240	-118.667800	30.87	29.17	A
32TOU-34.2	Touchet @ Hwy 125	09N	36E	05	46.294620	-118.339470	30.39	28.35	A
32TOU-40.5	Touchet @ Hwy 124 Near Bolles Rd	09N	37E	08	46.274300	-118.220310	28.80	27.08	A
32BLU-00.2	Blue Cr @ Mill Creek Rd	07N	37E	26	46.060020	-118.151110	28.24	26.77	A
32YEL-05.0	Yellowhawk Cr @ Cottonwood Rd	07N	36E	33	46.039650	-118.322830	27.56	25.58	A
32SFT-02.5	S F Touchet @ Pettyjohn Grade Rd	09N	39E	09	46.270400	-117.946070	26.88	25.58	A
32COP-00.5	Coppei Cr @ Hwy 124 west of Waitsburg	09N	37E	10	46.269370	-118.166410	25.91	24.24	A
32ROB-02.3	Robinson Fork @ 2nd Bridge south of Mount..	09N	39E	35	46.216060	-117.893710	25.86	24.84	AA
32GAR-00.5	Garrison Cr @ Mojonnier Rd	06N	35E	03	46.027780	-118.428460	25.82	23.97	A
32MIL-01.7	Mill Cr @ Last Chance Rd	07N	35E	28	46.051300	-118.449660	25.51	24.62	B
32MIL-12.8	Mill Cr @ Five Mile Rd	07N	37E	18	46.085860	-118.227930	24.68	23.73	A
32TOU-53.9	Touchet @ Dayton City Park	10N	39E	30	46.313600	-117.973710	24.58	23.47	A
32MIL-14.8	Mill Cr @ Seven Mile Rd	07N	37E	16	46.081490	-118.188610	23.80	23.09	A
32ROB-00.7	Robinson Fork @ 1st Bridge south of Mount..	09N	39E	26	46.229110	-117.892100	23.56	22.91	AA
32NFT-04.9	N F Touchet @ Wolf Fork Rd	09N	39E	11	46.271130	-117.889270	23.46	22.50	AA
32PAT-00.1	Patit at Front St Bridge	10N	39E	30	46.320820	-117.982370	22.60	20.80	A
32MIL-19.1	Mill Cr @ Mill Creek Rd between Blue Cr…	06N	37E	02	46.031660	-118.142780	21.38	20.56	A
32MIL-21.3	Mill Cr South of Kooskooskie @ old gaging…	06N	38E	07	46.006210	-118.117310	18.66	17.97	A
32MIL-26.5	Mill Cr @ the City of Walla Walla intake…	06N	38E	ore	45.989420	-118.054420	14.31	13.80	AA
32MIL-27.5	Mill Cr 1/4 mile above the City of Walla…	06N	38E	ore	45.993220	-118.034560	13.72	13.34	AA
32MIL-28.4	Mill Cr @ border where Mill flow from W…	06N	38E	14	46.001660	-118.020700	12.91	12.51	AA

1-DADMax = highest daily maximum temperature during 2002 (C)
7-DADMax = highest 7-day average of daily maximum temperatures during 2002 (C)

Because the locations where temperature exceeds the water quality standard are spread throughout the watershed, this TMDL was developed to address water temperature in perennial streams in the entire watershed.

Seasonal Variation

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

Existing conditions for stream temperatures in the Walla Walla River watershed reflect seasonal variation. Cooler temperatures occur in the winter, while warmer temperatures are observed in the summer. Figures 10 and 11 summarize the highest daily maximum and the highest seven-day average maximum water temperatures for 2002. These figures include all data gathered by Ecology and selected data gathered by WDFW (Mendel et al., 2003), not including lowland tributaries sampled by WDFW. The highest temperatures typically occur from mid-July through mid-August. This timeframe is used as the critical period for development of the TMDL.

Seasonal estimates for streamflow, 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 streamflows 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 July and August. The 7Q2 streamflow was assumed to represent conditions that would occur during a typical climatic year, and the 7Q10 streamflow was assumed to represent a reasonable worst-case climatic year.

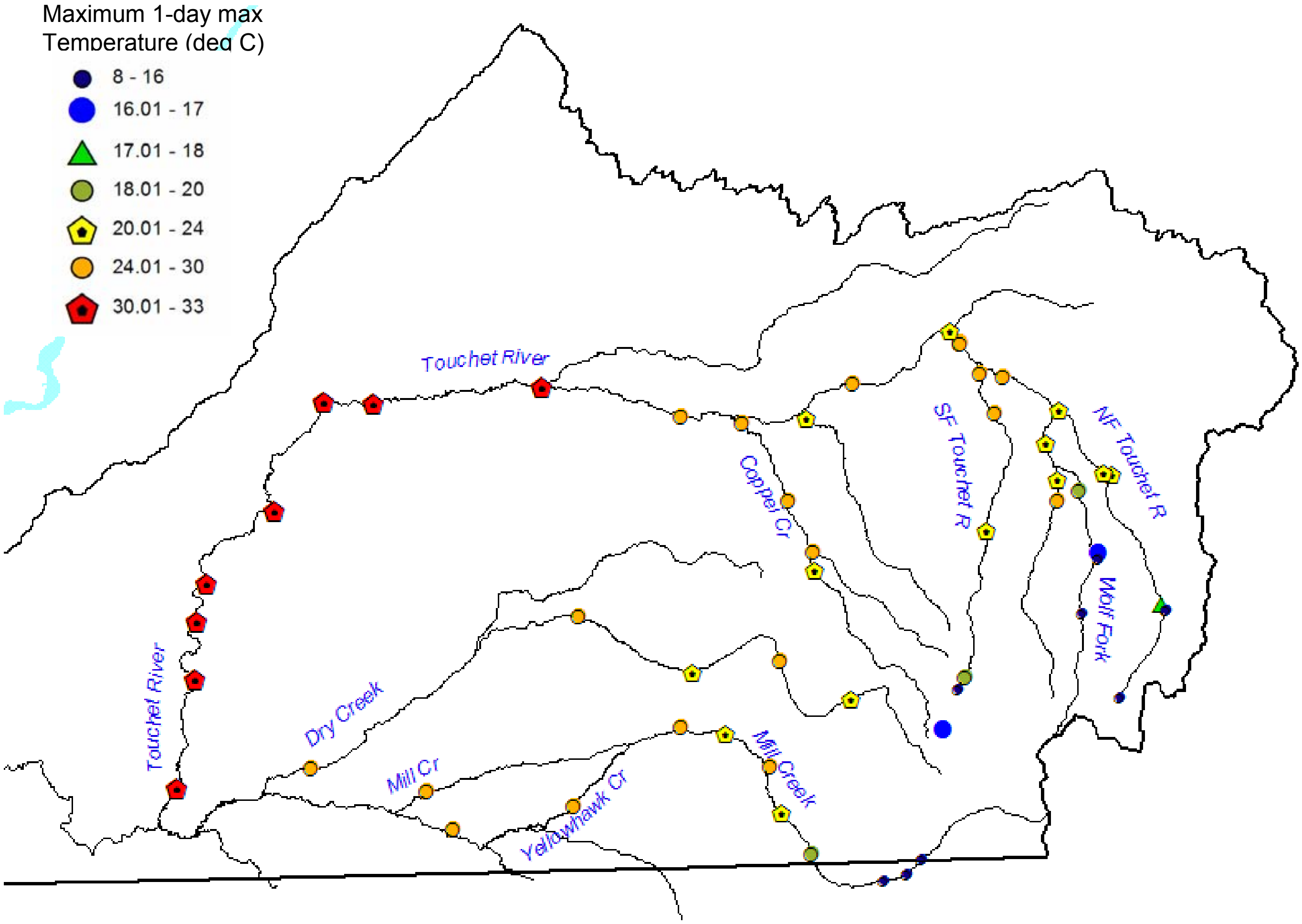

Figure 10. The highest daily maximum water temperatures in the Walla Walla River tributaries during 2002.

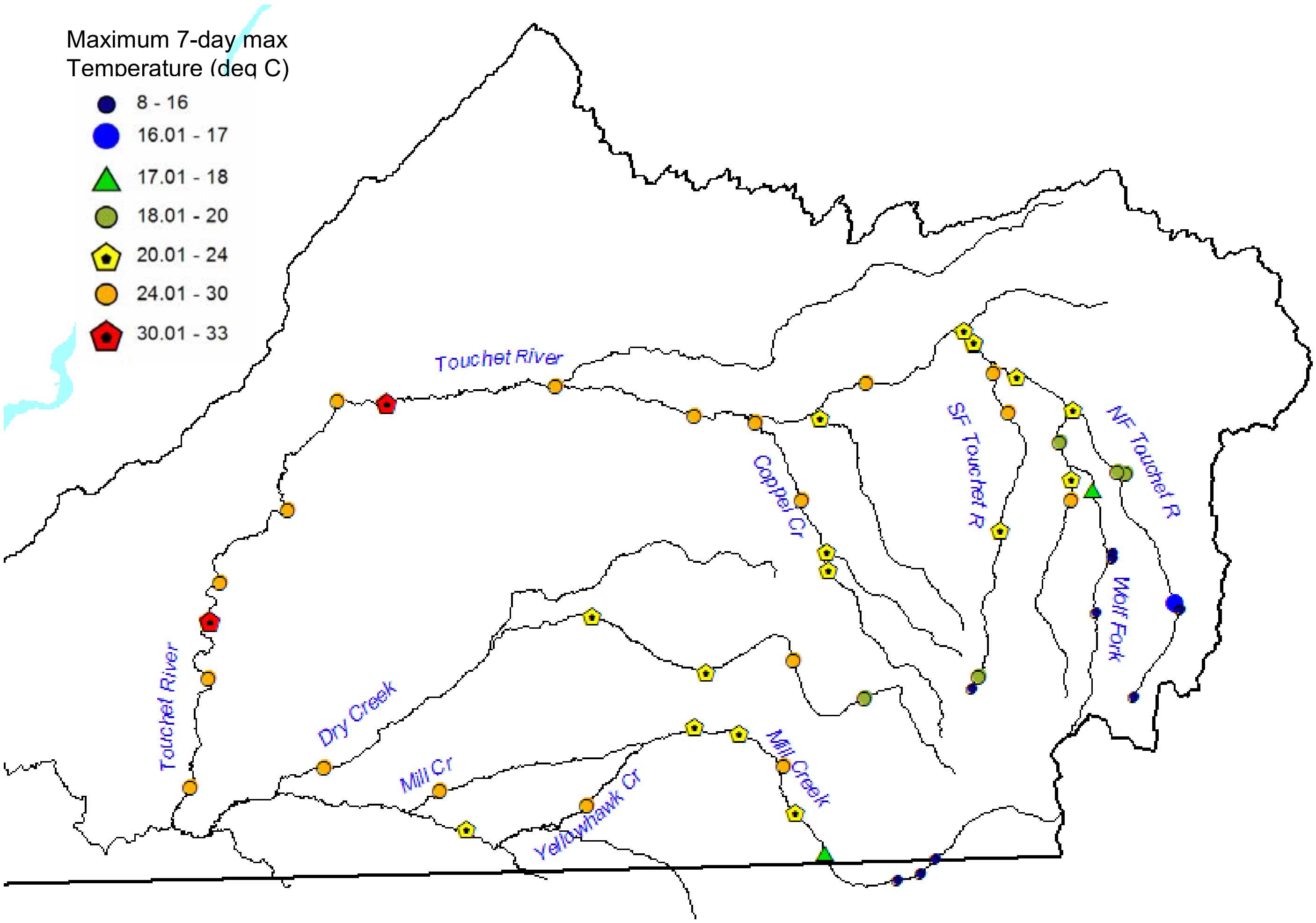

Figure 11. The highest 7-day averages of daily maximum water temperatures in the Walla Walla River tributaries during 2002.

Technical Analysis

Current Conditions

Water temperature data – continuous dataloggers

A network of continuous temperature dataloggers was installed in the Walla Walla River watershed by Ecology as described by LeMoine and Stohr (2002) (Figure 12). Data from 2002 show that water temperatures in excess of the Class A standard of 18°C are common throughout the watershed (Table 5 and Appendix A). Water temperatures in excess of 28°C were observed in the lower half of the mainstem Touchet River, while the upper portion exceeded 24°C during the hottest time periods. Cooler maximum temperatures of less than 16°C were found all summer long upstream of the drinking water diversion in upper Mill Creek. Summer maximums in the remainder of Mill and Yellowhawk Creeks ranged from 18 – 26°C. The hottest 7-day period of 2002 occurred from July 11-17. WDFW (Mendel et al., 2003) sampled numerous additional sites throughout the watershed, finding the lowest temperatures in the upstream reaches of the North Fork and Wolf Fork Touchet River. Relatively low temperatures were also found in the lowland streams of Russell and Cottonwood Creeks near the mouth of Yellowhawk Creek.

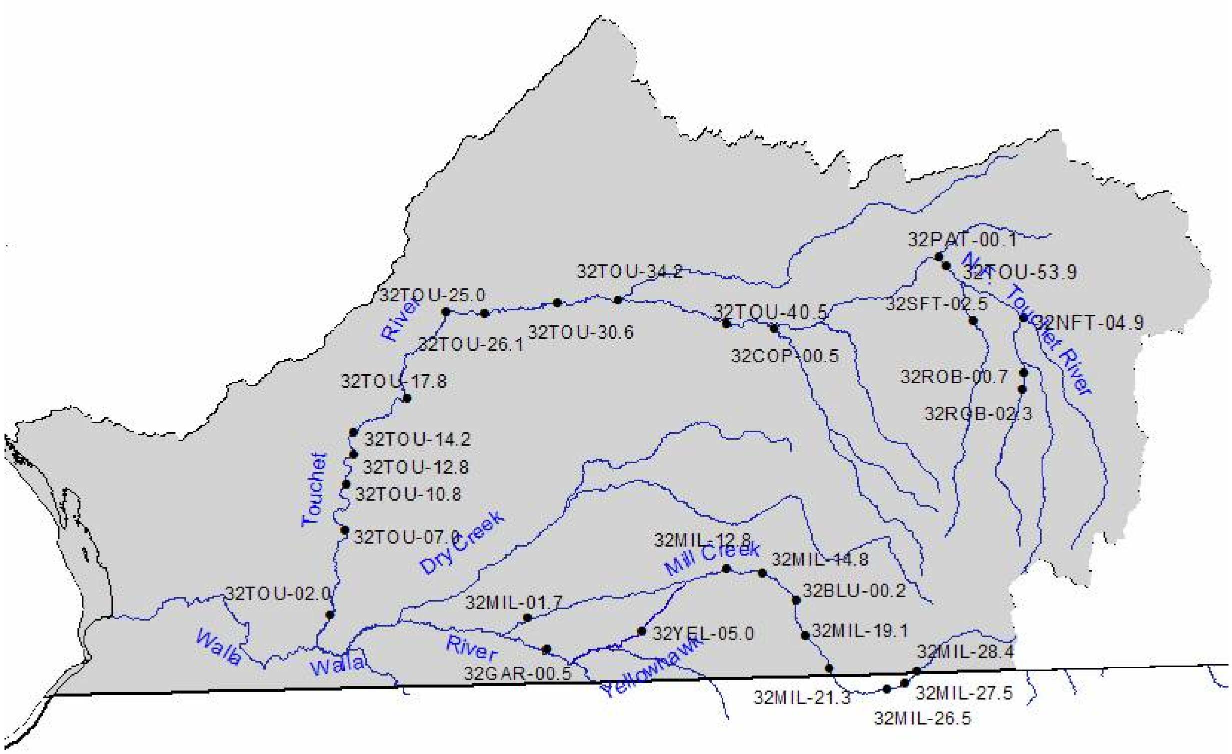

Figure 12. Locations and station IDs of Ecology's temperature monitoring stations in the Walla Walla River watershed.

Water temperature data – aerial surveys

In addition to the network of continuously recording temperature dataloggers, a helicopter-mounted thermal infrared radiation (TIR) sensor and color video camera was used to take TIR and visible color images of selected segments of the streams and rivers in the watershed to provide a spatially-continuous image of surface temperature. Surveys were conducted on August 7, 8, and 9, 2002 of Yellowhawk Creek, Mill Creek upstream of the Yellowhawk diversion to and including sections in Oregon, the mainstem Touchet River, and portions of the upper Touchet River forks (North, Wolf, and South). The TIR images and report can be viewed at: www.ecy.wa.gov/apps/watersheds/temperature/index.html

Water temperatures during this August 7-9 flight were much cooler than were measured earlier in the summer. Although the flight was on a warm day, the weather during the previous week was cold and stream temperatures had not fully responded by flight time. Figure 13 from Mill Creek (site 32MIL-19.1) shows that water temperature during the TIR flight was at least 4°C cooler than the summer maximum. Although the TIR flight was on a cooler day, Figure 14 can be used to show which areas of the watershed are cooler, which are hotter, and how some of these waters mix.

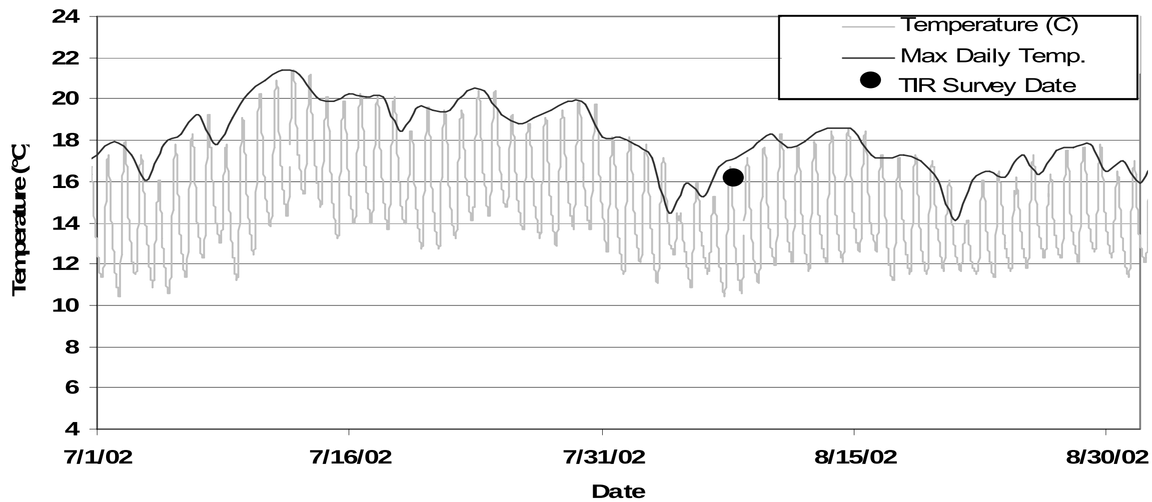

Figure 13. Water temperature at Mill Creek 32MIL-19.1 Site, July 1- September 1, 2002.

Figure 14 shows that the waters above the drinking water diversion in upper Mill Creek stay very cold throughout the summer (< 14°C). Below the water withdrawal, the water continuously warms to peak near the confluence with Yellowhawk Creek. Near the mouth of Yellowhawk a combination of groundwater recharge and contribution of cooler small tributaries reduce Yellowhawk Creek temperatures before combining with the mainstem Walla Walla River. The mainstem of the Touchet River is very warm compared to its cooler upper tributaries at the base of the Blue Mountains. The North Fork and Wolf Fork Touchet River provide relatively cool water that heats as elevation is lost approaching the town of Dayton. Water slowly heats from Dayton to the Lewis and Clark State Park. The remaining portion of the Touchet from the Park to the mouth is very warm, often in excess of 23ºC during the summer.

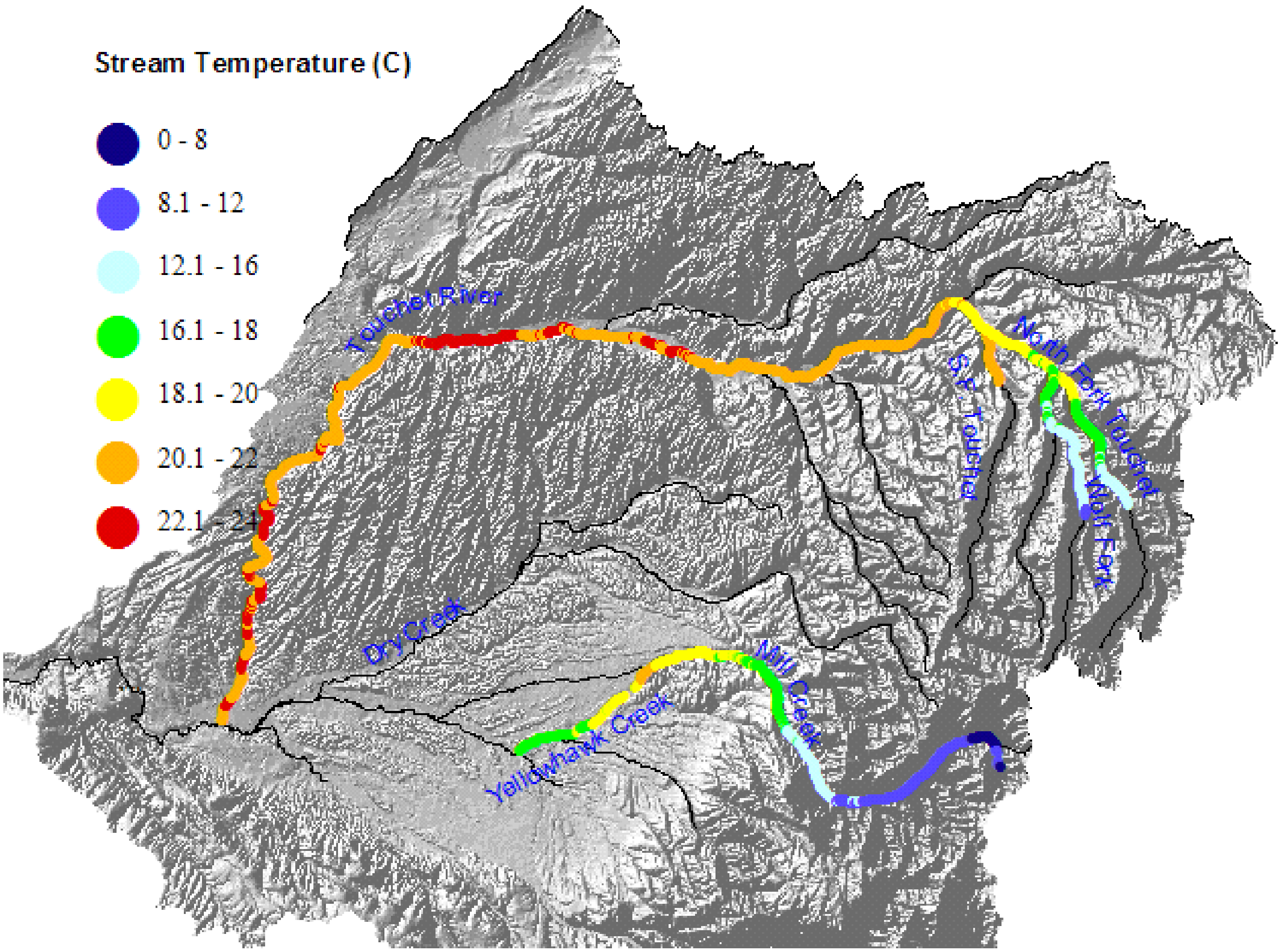

Figure 14. Water temperature measured by Thermal Infrared Survey (TIR) on August 7-9, 2002.

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Streamflow data

The Department of Ecology's Stream Hydrology Unit installed four continuous flow measurement stations in the study area during 2002 as described in LeMoine and Stohr (2002) and Springer (2005) (Figure 15). Additionally, a permanent telemetered continuous flow station on the Touchet River near Cummings Road was installed in June 2002. The Ecology stations recorded stage height continuously from June to October, 2002. Instantaneous flow measurements at temperature monitoring stations and at continuous flow-monitoring stations were taken approximately monthly during this period (Appendix B). Instantaneous flow measurements were also taken at all locations on August 6 and 7 (see seepage run described in the *Groundwater* section below). The standard protocols for the on-site continuous dataloggers followed those currently established by the Stream Hydrology Unit (Ecology, 2000). Other permanent telemetered flow stations were installed in the watershed by Ecology during 2002, but were not active soon enough to be used for the July to August low-flow period. See the following web site for details:
https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?sta=32D050

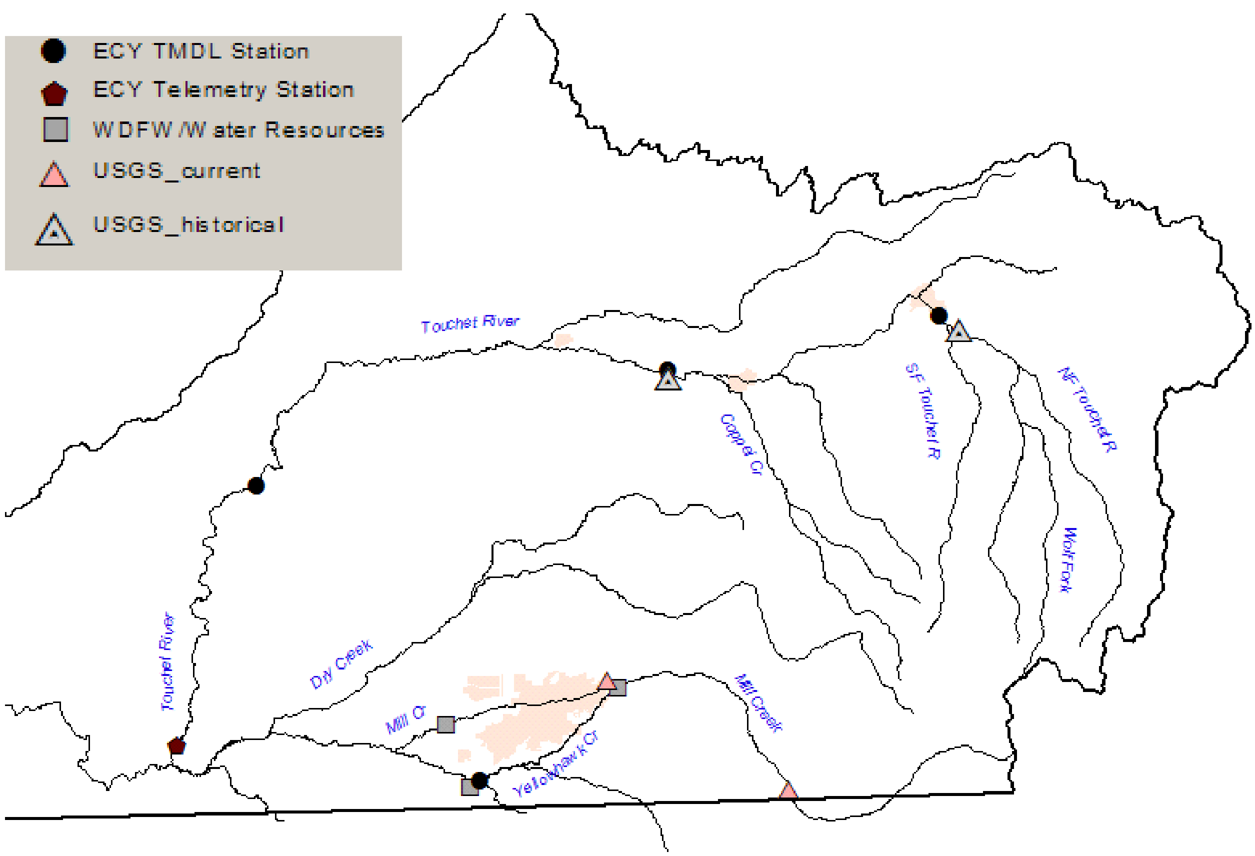

Figure 15. Continuous flow gaging stations operating in the Walla Walla River tributaries during summer 2002.

The USGS measured summer flows at two long-term tributary gages in 2002, Mill Creek at Kooskooskie (ID 14013000) and Mill Creek at Walla Walla (14015000). USGS has historically gaged two additional long-term locations, Touchet at Bolles (14017000) and EF (NF) Touchet River at Dayton (14016500). Flow monitoring sites established by the basin water master in cooperation with the Washington Department of Fish and Wildlife were also used during this project (Mendel et al., 2003).

Flow statistics for selected long-term USGS streamflow gages in the Walla Walla River basin are reported in Table 6. Typically in a TMDL analysis, the lowest 7-day average flow with a 2-year recurrence interval (7Q2) is selected to represent an average condition year, and the lowest 7-day average flow with a 10-year recurrence interval (7Q10) is selected to represent a reasonable worst-case condition for the July-August period. The 7Q10 streamflow is typically considered the critical condition for steady-state discharges in riverine systems (WAC 173-201A-200). Flow statistics for some Walla Walla mainstem sites are reported to maintain consistency with the Walla Walla TMDL for pH and dissolved oxygen that is currently underway (Joy et al., 2007).

Table 6. Low-flow statistics for July-August at selected USGS streamflow gages in the Walla Walla River basin.

Location	USGS station number	WRIA 32 planning unit Management Point number	Period of record	7-day-10-year low flow during July-Aug (7Q10, cfs)	7-day-2-year low flow during July-Aug (7Q2, cfs)	WRIA 32 minimum monthly NAF (cfs)
Mill Creek near Walla Walla	14013000	1	1914-17, 1938-2002	21.7	28.4	41
Mill Creek at Walla Walla	14015000	--	1941-2002	0	0.85	--
Touchet River at Bolles	14017000	11	1951-1989	21.9	31.3	48
Touchet River near Touchet	14017500	--	1941-1955	11.4	20.3	--
Walla Walla R near Touchet	14018500	--	1952-2002	2.8	8.1	--
Walla Walla R at Detour Rd bridge	--	5a	--	--	--	closed
North Fork Touchet River	--	6a	1941-68	31.6	39.9	51

Note: the North Fork Touchet River value of 51 cfs is for the Dayton site. It accounts for a 2 cfs loss in streamflow from the NAF value of 53 cfs at the historical USGS gage location upstream.

The evaluation of critical streamflows also considered the New Appropriation Flow (NAF) recommendations for four management points (Appendix F; HDR/EES, 2005). These flow recommendations were made by the Walla Walla Watershed Planning Unit (for WRIA 32) and submitted to Ecology for rule-making consideration in May 2005.

- Management Point 1 – Mill Creek just downstream of the OR/WA state line (at Kooskooskie)
- Management Point 6a – North Fork Touchet just upstream of the South Fork confluence
- Management Point 11 – Touchet River near the county line (at Bolles)
- Management Point 5a – Walla Walla River at the Detour Road Bridge

The July-August 7Q10 and 7Q2 low flows at USGS gaging stations and the proposed NAFs for the WRIA 32 management points are presented in Table 6. In general the 7Q10 and 7Q2 flows are lower than the NAF values. The NAF values reflect the minimum flow for allowing new consumptive, out-of-stream uses and groundwater withdrawals. The NAF values are not intended to represent the lowest flows that are likely to occur in the basin.

Groundwater data

A synoptic flow survey (seepage run) was performed on August 6 and 7, 2002 to assist in determining the influence of groundwater in the basin and developing a water balance for the low-flow season (Figure 16). The survey consisted of measuring instantaneous flow along the length of the Touchet River and its major tributaries on August 6 and along Mill Creek, Yellowhawk Creek, and the mainstem Walla Walla River on August 7. These flow data (Appendix B) – along with continuous flow gage data, an estimate of water withdrawals in the basin, flow data from 2001 (Mendel et al., 2002), and piezometer data (Figure 17) – determined reaches that gain and lose groundwater. These findings were consistent with the findings of Marti (2005) from hydrogeologic data available in the basin.

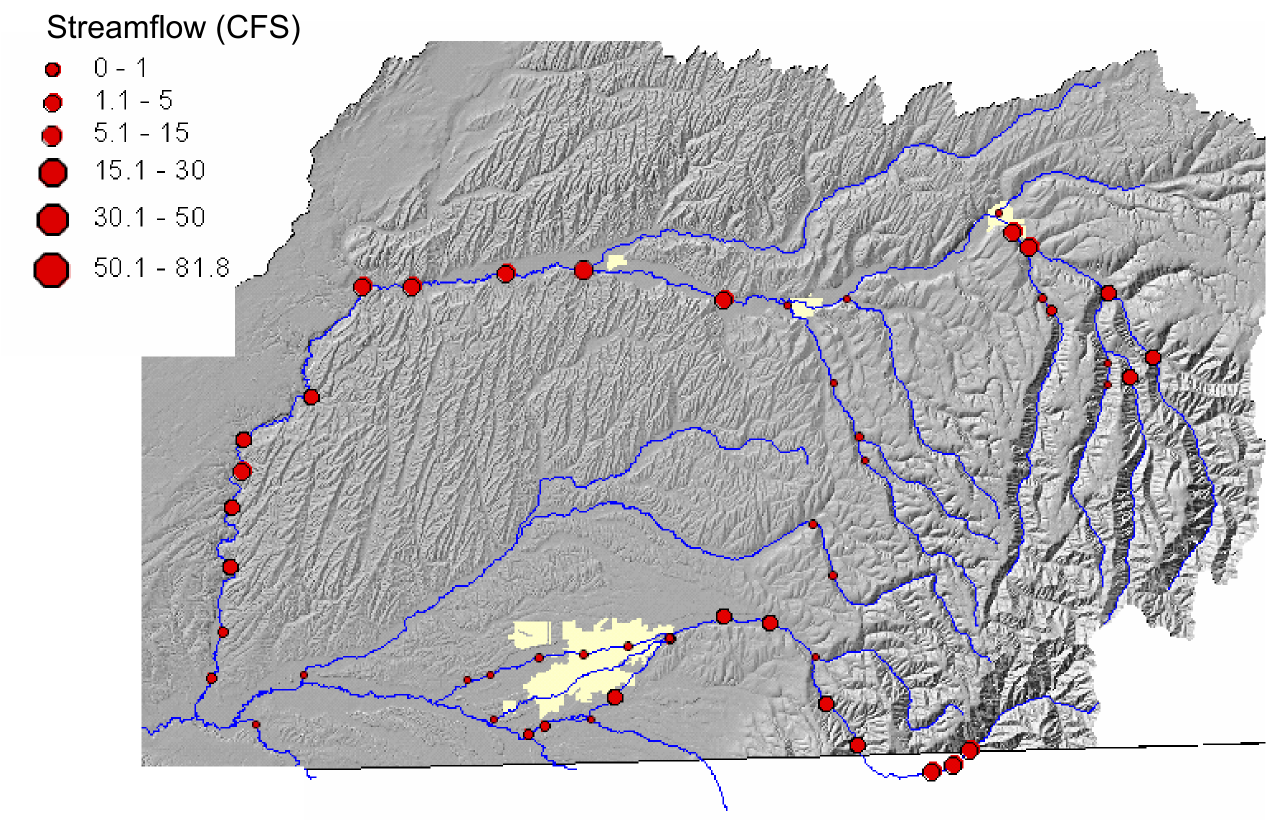

Figure 16. Synoptic streamflow measurements on August 6-7, 2002 (WDFW, Ecology).

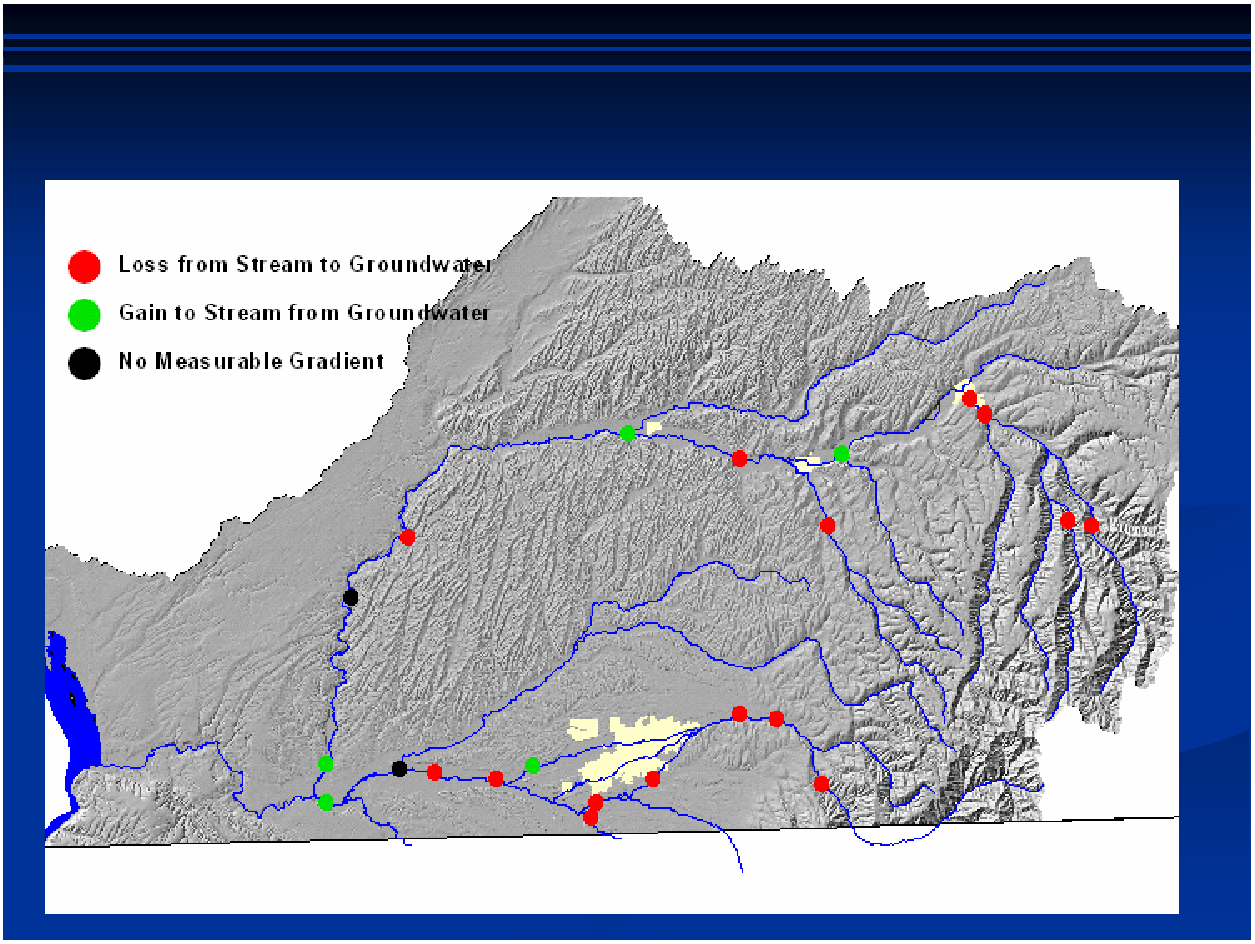

Figure 17. Direction of water movement (into/out of stream) as indicated by gradient measurements from instream piezometers during July 2002.

Hydraulic geometry

The channel width, depth, and velocity have an important influence on the sensitivity of water temperature to the flux of heat. Stream surveys were completed on 1000-foot reaches above most temperature monitoring locations during the low-flow period as described in LeMoine and Stohr, 2002. Six cross-sections were established, beginning at the monitoring station and then moving upstream at 200-foot intervals. At each cross-section, the wetted width, bankfull width, width of the near-stream disturbance zone, channel incision, and bankfull depth were recorded. Channel data collected during these surveys are reported in Appendix C.

At different discharges, the observed mean velocity, mean depth, and width of flowing water reflect the hydraulic characteristics of the channel cross-section. Graphs of these three parameters as functions of discharge at the cross-section constitute a part of what Leopold (1994) called the hydraulic geometry of stream channels. Width, depth, and velocity can be related to discharge (Q) by power functions:

$$W=aQ^b \; ; \; d=cQ^f \; ; u=kQ^m$$

Where w is width, Q is discharge, d is mean depth, and u is mean velocity. The letters b, f, and m are exponents, and a, c, and k are coefficients.

Coefficients were determined for individual flow measurement sites by fitting power curves to data collected for instantaneous discharge measurements. The curves are used to estimate width and depth for flow regimes not specifically measured (e.g., 7Q2 or 7Q10). Tables 7 and 8 summarize these equations.

Coefficients for stream segments that were not located at a flow site were calculated using linear interpolation between the upstream and downstream flow measurement sites and adjusted with results from the travel time study.

Table 7. Summary of hydraulic geometry relationships with flow (Q) in the Touchet River watershed, June 2001 through June 2003.

Station	Station name	Velocity (m/sec) = $c\,Q^d$ (Q in m^3/sec)		Depth (m) = $e\,Q^f$ (Q in m^3/sec)	
		Velocity "c"	Velocity "d"	Depth "e"	Depth "f"
Touchet at RM 1.5 (WDFW) and RM 2.0 (Ecology)	Touchet R. near Cummins (WDFW)	0.55	0.64	0.19	0.27
Touchet at RM 7.0 to RM 3.9	Touchet R. above Hofer diversion	0.20	0.61	0.28	0.26
Touchet at RM 7.0	Above Hofer at north of Touchet Rd	0.15	0.74	0.48	0.12
Touchet at RM 10.8	Touchet R. at Sims Rd	0.15	0.74	0.66	0.15
Touchet at RM 12.8	Touchet R. north of Plucker	0.33	0.70	0.30	0.02
Touchet at RM 14.2	Touchet R. south of Luckenbill	0.20	0.79	0.37	0.18
32B090 (and RM 17.8)	Touchet R. at Luckenbill Rd	0.21	0.67	0.35	0.31
Touchet at RM 25	Touchet R. at Lamar Rd (Tunnel)	0.30	0.83	0.33	0.06
Touchet at RM 34.2	Touchet R. at Hwy 125	0.37	0.26	0.22	0.52
Touchet at RM 40.5	Touchet R. at Hwy 124 (nr Bolles Rd)	0.35	0.43	0.15	0.54
32B110 (and RM 46.2)	Touchet R. at County Line (Hogeye)	0.35	0.43	0.21	0.57
Touchet at RM 53.5 (WDFW)	Touchet R. above Dayton at Flagpole	0.35	0.43	0.20	0.33

Table 8. Summary of hydraulic geometry relationships with flow at flow measurement stations in Mill, Yellowhawk, and Garrison Creeks (from Table 6 in Joy and Pelletier, 2006).

Station name	Width (m) = a Q^b (Q in m^3/sec)		Velocity (m/sec) = c Q^d (Q in m^3/sec)		Depth (m) = e Q^f (Q in m^3/sec)	
	Width "a"	Width "b"	Velocity "d"	Depth "e"	Depth "f"	Depth "f"
Mill Creek at Swegle Rd. (32C070)	12.65	0.0179	0.4474	0.5579	0.1691	0.4731
Yellowhawk Cr at mouth (32D050)	6.345	0.0092	0.5572	0.6730	0.2824	0.3147
Mill Creek at RM 0.4	8.01943	0.08943	1.0328	0.7421	0.1207	0.1685
Mill Creek at RM 0.5	5.1668	0.1512	0.8744	0.54	0.2213	0.3088
Mill Creek at RM 0.7	5.9713	0.2798				
Mill Creek at RM 1.7	7.8001	0.3045	0.5109	0.3839	0.2509	0.3116
Mill Creek at RM 2.7	6.3027	0.114	0.9391	0.6619	0.169	0.1941
Mill Creek at RM 2.8	6.2753	0.1683	1.1345	0.7046	0.1405	0.127
Mill Creek at RM 4.8	2.9376	0.137	1.199	0.3743	0.2839	0.4887
Mill Creek at RM 6.6	2.9918	0.0397	1.1733	0.4072	0.2849	0.5531
Mill Creek at RM 8.1	2.7184	-0.01776	1.5231	0.435	0.2415	0.5828
Mill Creek at RM 12.8	9.4567	0.2045	0.6616	0.5563	0.1572	0.2473
Mill Creek at RM 14.8	14.475	0.1728	0.3813	0.5509	0.1812	0.2763
Mill Creek at RM 19.1	12.596	0.1161	0.3326	0.6393	0.2387	0.2446
Mill Creek at RM 21.1	10.185	0.1546	0.4844	0.7111	0.2027	0.1342
Mill Creek at RM 21.3	9.2855	0.1019	0.3303	0.5998	0.326	0.2983
Mill Creek at RM 26.5	19.07	-0.1106	0.3811	0.9088	0.1376	0.2018
Mill Creek at RM 27.5	9.4984	0.1598	0.4161	0.4566	0.253	0.3835
Mill Creek at RM 28.4	9.0168	0.03802	0.4423	0.4882	0.2507	0.4738
				0.61		
Yellowhawk Creek at RM 0.2	6.6715	0.0508	0.6496	0.6376	0.2308	0.3116
Yellowhawk Creek at RM 1.0	6.4899	0.146	1.044	0.7023	0.1476	0.1516
Yellowhawk Creek at RM 1.1	6.3849	0.2764				
Yellowhawk Creek at RM 5.0	5.2947	0.07154	0.8144	0.3548	0.2319	0.5737
Yellowhawk Creek at RM 8.0	6.3759	0.2731	0.6927	0.1666	0.2264	0.5603
				0.58		
Garrison Creek at RM 0.3	3.0133	0.198	1.1167	0.338	0.2999	0.4686
Garrison Creek at RM 0.5	1.9432	0.1223	1.1853	0.3763	0.523	0.5147
Garrison Creek at RM 9.1	2.9939	0.007271	1.8139	0.9172	0.181	0.07224
Average of all Mill Creek stations	8.578	0.1178	0.7214	0.5716	0.2135	0.3216
Average of all Yellowhawk Cr stations	6.260	0.1378	0.7516	0.5069	0.2238	0.3824
Average of Mill Creek RM 0.4-0.7	7.5255	0.1891	0.9953	0.6625	0.1355	0.1939
Average of Mill Creek RM 2.7-2.8	6.3491	0.1438	0.945	0.6584	0.1667	0.1978
Average of Mill Creek RM 21.1-21.3	9.6865	0.07194	0.3967	0.4646	0.2603	0.4634
Average of Yellowhawk Cr RM 1.0-1.1	6.5338	0.1802	1.0512	0.7386	0.146	0.09622
Average of Garrison Cr RM 0.3-0.5	2.5701	0.1719	1.1808	0.3641	0.3364	0.4554

Climate data

Hourly air temperature, humidity, wind speed, and either solar radiation or cloud cover are collected at the locations identified in Table 9. In addition to these stations, Ecology installed a network of dataloggers to continuously monitor near-stream air temperature at 13 locations and relative humidity at five locations throughout the study area in accordance with LeMoine and Stohr, 2002. Because of an unusually high failure rate with the relative humidity sensors, data from only one of the five Ecology sites were used in this study.

Table 9. Sources of meteorological data in the Walla Walla basin.

Site	Data Source	Type
LeGrow	AgriMet	Temperature, humidity, wind, solar radiation
Walla Walla	PAWS	Temperature, humidity, wind, solar radiation
Walla Walla Airport	National Weather Service	Temperature, humidity, wind, cloud cover
Welland	PAWS	Temperature, humidity, wind, solar radiation
Touchet	PAWS	Temperature, humidity, wind, solar radiation
K2H	PAWS	Temperature, humidity, wind, solar radiation
College Place	PAWS	Temperature, humidity, wind, solar radiation

PAWS - Public Agricultural Weather System (Washington State University)
AgriMet – U.S. Bureau of Reclamation

The National Weather Service site at the Walla Walla Airport provides a long term (54-year) record of climate data. The PAWS and AgriMet stations usually do not have data prior to 1989. Comparison of data collected at the airport with data collected near-stream by Ecology and at PAWS and AgriMet stations show that all stations measure similar air temperature and relative humidity, except for the airport station. Mid-day (high) air temperatures and relative humidities (low) are similar at all stations. Early-morning (low) air temperatures and relative humidities (high) are much different at the airport. Near-stream temperatures for years not measured by Ecology will be derived from the PAWS stations. The airport will be used to determine which are hot and cold years and to derive the typical (50% percentile) and the extreme (90% percentile) years for climate conditions. Then actual data from the PAWS/AgriMet will be used for near-stream temperature.

The highest 7-day-average of daily maximum air temperatures for each year of record at the Walla Walla Airport were ranked to determine the 50th and 90th percentile conditions (Table 10). The corresponding median and 90th percentile air temperature conditions for the near-stream conditions along the mainstem Touchet River were calculated from measurements taken at the Touchet PAWS weather station located near the mouth of the Touchet River. The Touchet PAWS station was in place during 1997 and 1998 which were the years that represent the 50% and 90% condition. Air temperatures from the PAWS station were used for the mouth of the Touchet River in the model.

Table 10. Air temperature statistics for Walla Walla, Washington.

Condition	Walla Walla (grayskies-average from hourly data)		Near-stream Mouth Touchet PAWS Temperature (15-minute data)		LeGrow AgriMet Temperature (15-minute data)		Near-stream Dayton Temperature	
	(°F)	(°C)	(°F)	(°C)	(F)	(°C)	(°F)	(°C)
7/11-7/17/2002 7-day average of daily maximum (2002)	99.9	37.7	98.8	37.1	97.7	36.5	89.9	32.1
Typical weather condition (exceeded 50% of time) (1997)	98.3	36.8	95.7	35.4	95.2	35.1	**85.9**	**29.9**
Extreme weather condition (exceeded 10% of time) (1998)	102.6	39.2	100.5	38.1	100.3	37.9	**90.1**	**32.3**

Air temperatures determined from Figure 18 regression are shown in bold.

In most watersheds, as elevation increases air temperature decreases. Daily air temperature data gathered near the mouth of the Touchet River and in Dayton during the summer of 2002 were used to establish air temperature relationships between the two sites (Figure 18). Air temperatures for the headwater of the model at Dayton were calculated from the PAWS data by applying the regression equation from Figure 18. Air temperatures for intermediate locations between the Touchet River mouth and Dayton were calculated by using an interpolation with stream elevation. The complete diurnal air temperature profile for the Touchet River mouth at critical, average, and 2002 conditions are shown in Figure 19. The air temperature profile at the Walla Walla Airport for the 2002 conditions is included for information.

Wind speeds measured at the PAWS stations were assumed to better represent near-stream wind speed than those measured at the airport. A comparison of July wind speeds showed that those measured at the Welland PAWS site were approximately one-half of those measured at the Walla Walla Airport. A cloud cover of 0% is used for the 90% condition.

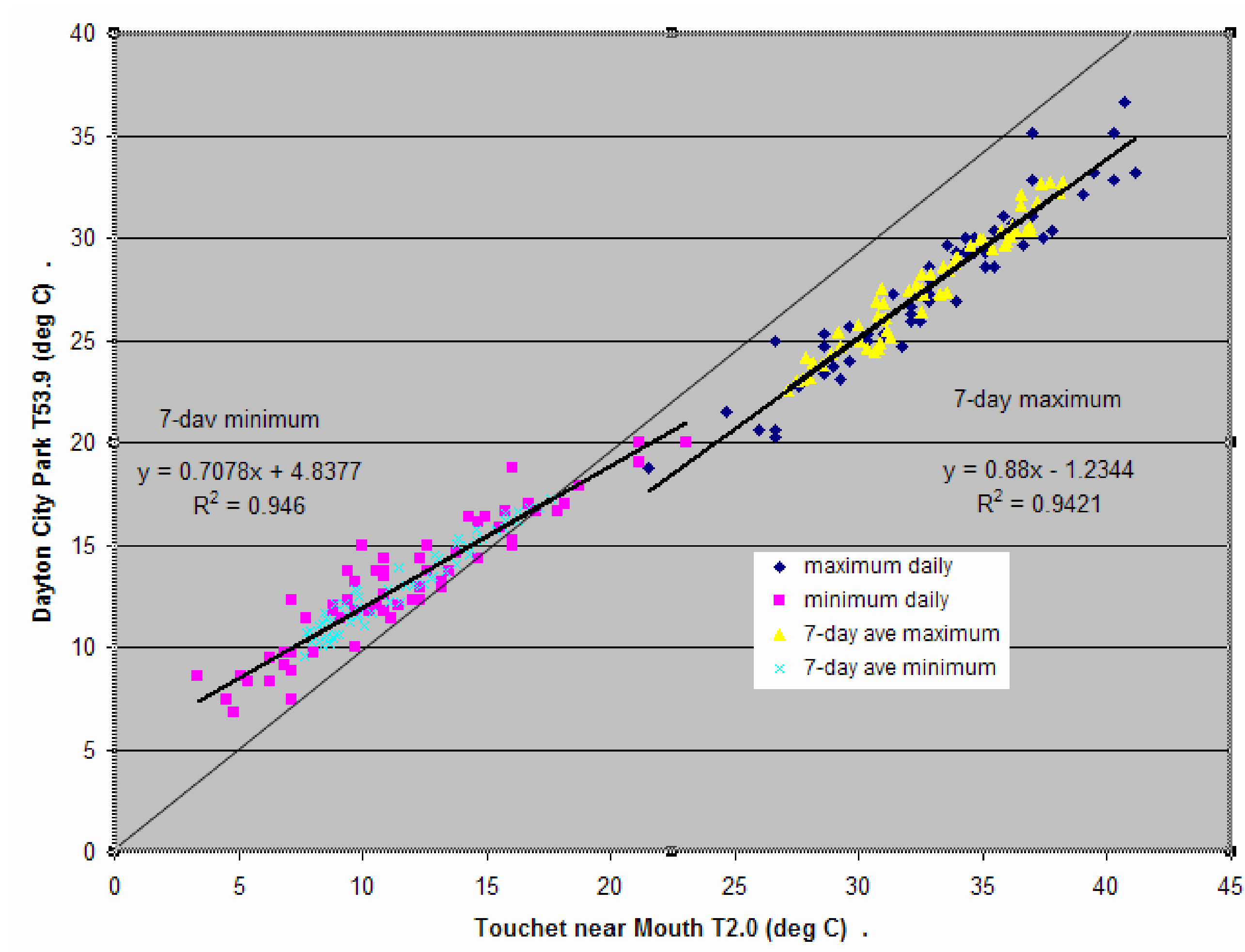

Figure 18. Regression of 7-day average daily maximum and minimum air temperatures during July and August, 2002 at the Touchet River station near its mouth (RM 2.0) versus the Touchet River station near Dayton (RM 53.9).

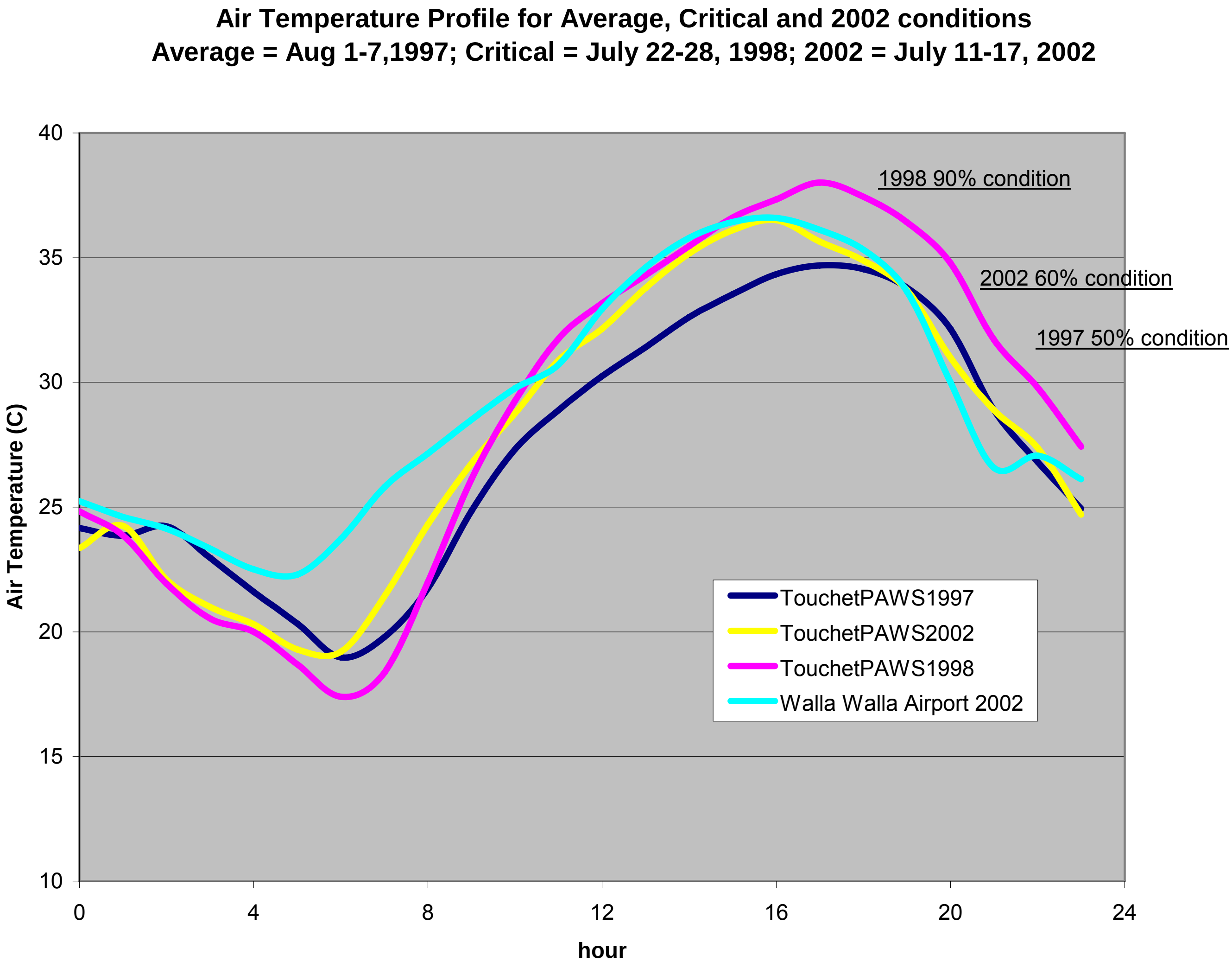

Figure 19. Average hourly air temperatures measured during average, critical, and sample year conditions at the Touchet PAWS station near the mouth of the Touchet River.

Riparian vegetation and effective shade

Near-stream vegetation cover, along with channel morphology and stream hydrology, represent the most important factors that influence stream temperature. To obtain a detailed description of the existing riparian conditions in the Walla Walla River basin, a combination of field-collected riparian vegetation data, GIS analysis, and aerial photography interpretation was used.

Riparian vegetation data were collected during stream surveys of approximately 30 thermal reaches during 2002. An adapted form of the Timber-Fish-Wildlife Stream Temperature Survey methodology was followed to collect these data (Schuett-Hames et al., 1999). Surveys to collect both channel morphology and riparian vegetation information took place above each of the temperature sites established by Ecology (Figure 12). Additionally, WDFW collected some of these data above their temperature monitors.

Stream surveys began at the location of each temperature monitor and continued upstream for 1000 feet. Measurements were taken at 0, 200, 400, 600, 800, and 1000 feet above the temperature monitor. Data collected consisted of bankfull width and depth, wetted width and depth, effective shade (using a Solar Pathfinder), canopy cover, active channel width, vegetation height, vegetation density, general vegetation type, distance that vegetation covers the stream channel, and bank incision. Hemispherical photography was used to measure effective shade and canopy density at all water temperature stations to ground-truth the range of vegetation classes digitized from inspection of digital orthophotos. A summary of effective shade and canopy cover is reported in Appendix F.

Geographic Information System (GIS) coverages of riparian vegetation in the study area (Figure 20) were created from field information collected during the 2002 temperature study, analysis of the color digital orthophotos taken during the spring of 2002 by Walla Walla County, analysis of the most current black-and-white digital orthophotos for Columbia County (1994-1996), and analysis of the aerial photos taken by Watershed Sciences (Faux, 2002) during the summer of 2002. Riparian coverages were created by qualifying three attributes: tree height, species (conifer, deciduous, shrub), and average canopy density.

The near-stream disturbance zones (NSDZs) were digitized from digital rectified orthophotos. The NSDZ is the active stream channel area without riparian vegetation that includes features such as gravel bars. A mapping area, 400 feet from each bank of the river (Figure 20), was defined along both sides of the river in a GIS environment. Vegetation polygons were mapped at a 1:3000 scale within this area. A vegetation type code that combines information about the average tree height and canopy density was assigned to each delineated polygon using the full-color digital orthophotos.

To increase the accuracy of the image vegetation interpretation, the digital aerial photographs gathered by helicopter during the TIR survey were used. These photos were taken from low altitude (approximately 300 meters) and provided a high level of detail. The TIR images are helpful in assisting with species composition and height, and were necessary in the areas of Columbia County where only older black-and-white orthophotos were available.

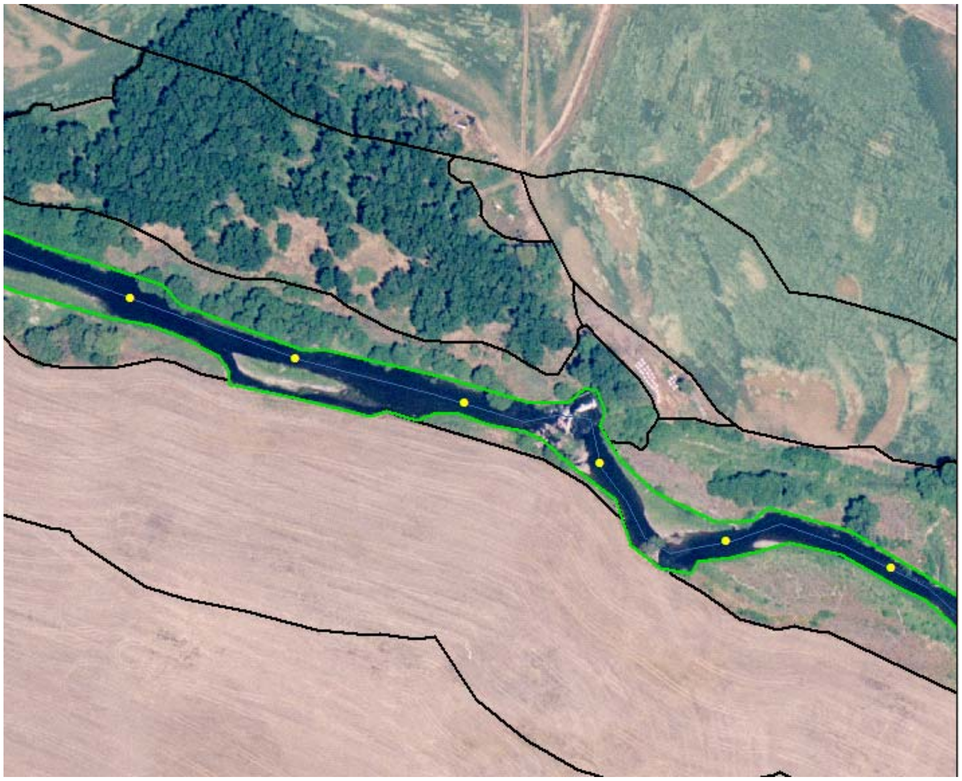

Figure 20. Example of the color digital orthophoto quad (DOQ) for the mainstem of the Touchet River between Prescott and Waitsburg and digitized near-stream disturbance zone edges.

Field observations of vegetation type, height, and density were also compared against the digitized GIS data.

After the GIS vegetation coverages were completed as described above, the vegetation size and density in the riparian zone on the right and left bank was sampled from the coverages along the stream at 100-meter intervals using the Ttools extension for ArcView that was developed by ODEQ (2001). Stream aspect, elevation, and topographic shade angles to the west, south, and east were also calculated at each transect location.

Effective shade produced by current riparian vegetation was estimated using Ecology’s Shade model (Ecology, 2003a). The Shade model was adapted from a program originally developed by the Oregon Department of Environmental Quality (ODEQ) as part of the HeatSource model. Effective shade can be calculated using ODEQ's original method from the HeatSource model version 6 (ODEQ, 2003) or using Chen’s method based on the Fortran program HSPF SHADE (Chen, 1996). 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.

Effective shade calculations were made for current and maximum potential riparian vegetation on Mill/Yellowhawk Creek, mainstem Touchet River, and the North and Wolf Forks of the Touchet River.

1. **Current vegetation.** Effective shade estimates for current vegetation were based on spatial data for height and canopy density (Figure 21).

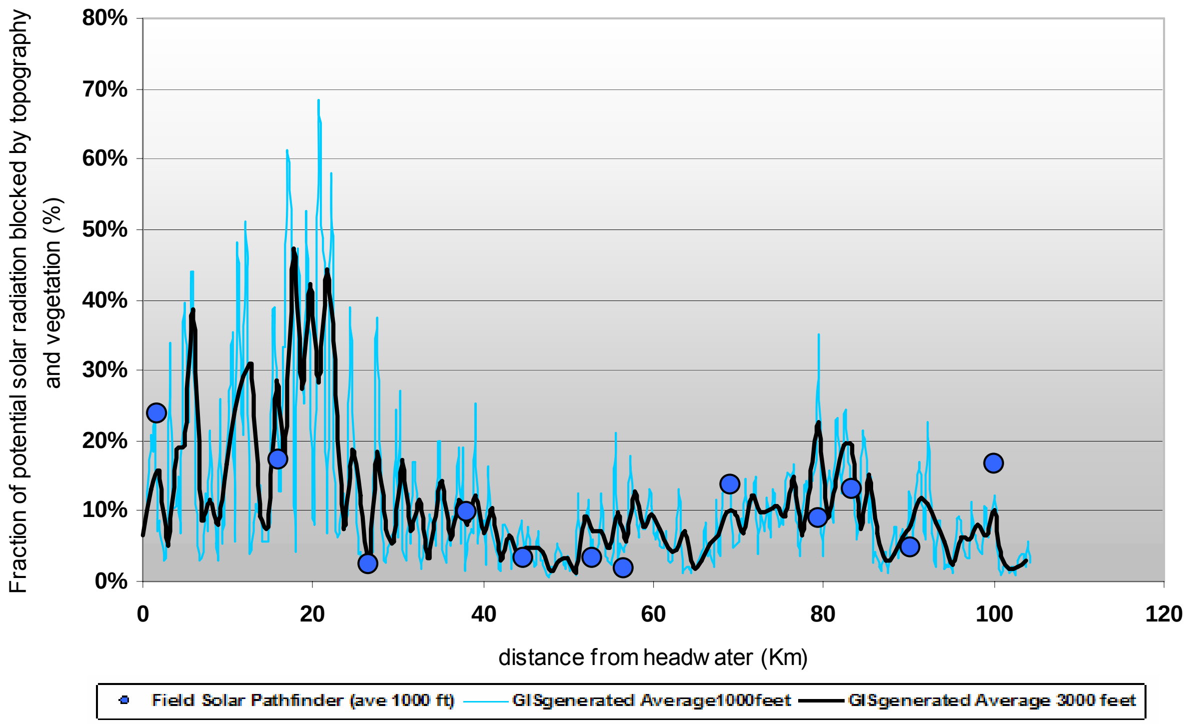

Figure 21. Effective shade from current riparian vegetation along the mainstem Touchet River in the Walla Walla River basin.

2. **Maximum effective shade from system potential riparian vegetation that would naturally occur in riparian areas within the study area** (see Figures 22, 23, 24, and 25 and Tables 11 and 12.) Ecology relied heavily on work reported by Oregon DEQ (ODEQ, 2005) in their Walla Walla basin temperature TMDL. Extensive research into historical maps including Mullan (1858) (Figure 26), diaries of Lewis and Clark, interviews with local citizens, and Washington State University (WSU) resulted in a map of potential near-stream land cover in the Walla Walla basin (Figure 27). Data on existing vegetation (height, density, vegetation type) collected during Ecology's stream surveys in 2002 and aerial photos from the TIR flight were also consulted. Additional documentation is found in Appendix H.

Two options for maximum potential vegetation were used in the lower portion of the mainstem Touchet River:

- The high-range estimate of vegetation in the Touchet River Luckenbill Road to mouth segment.
- The low-range estimate of vegetation in the Touchet River Luckenbill Road to mouth segment.

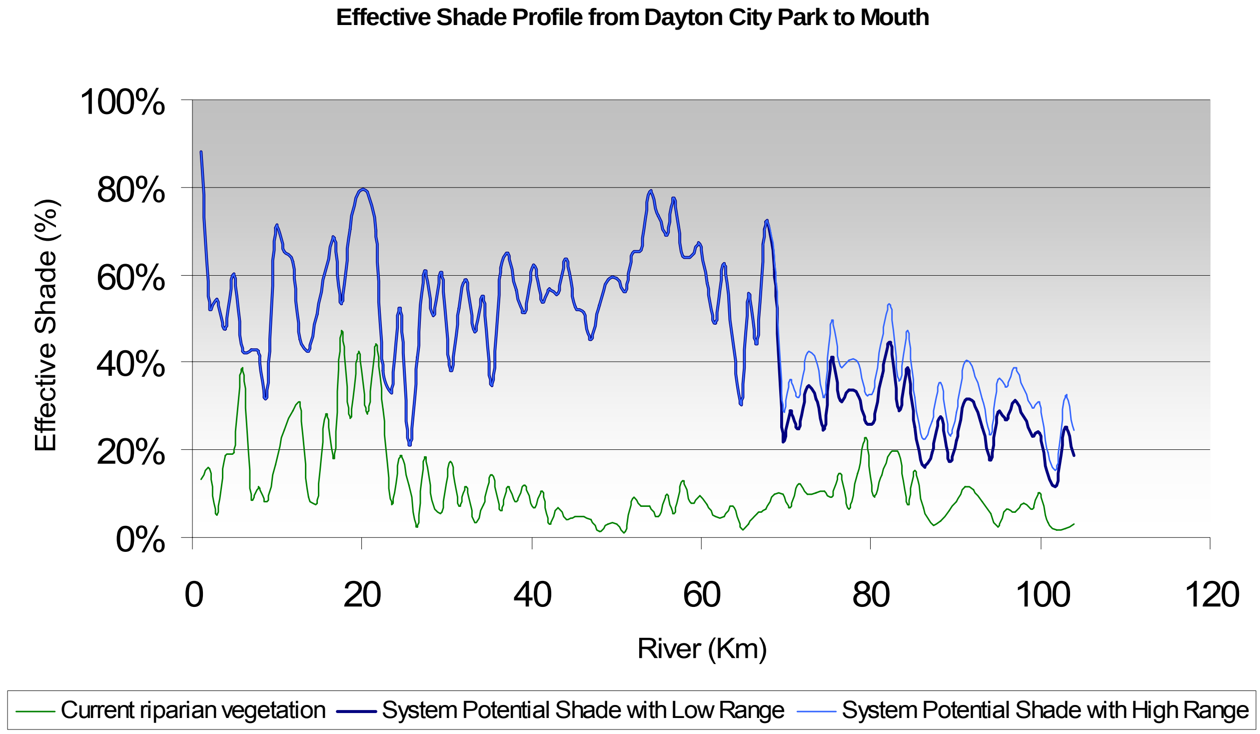

Figure 22. Effective shade from current and potential mature vegetation along the Touchet River.

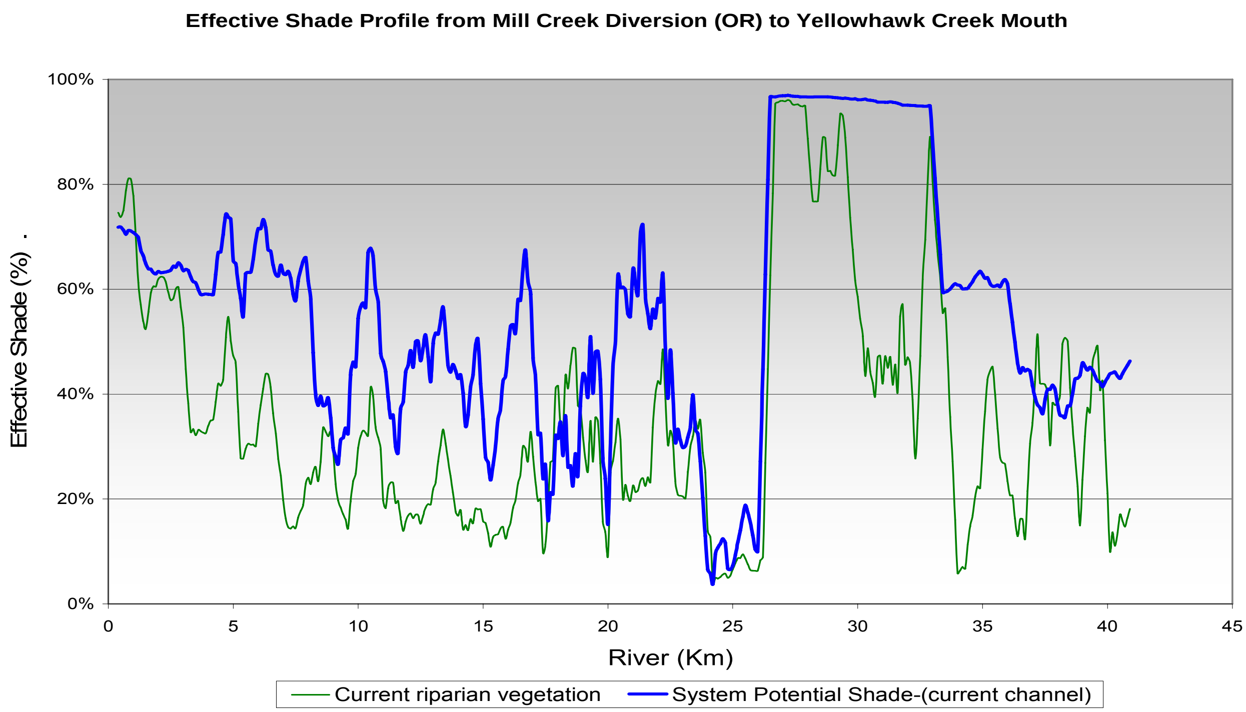

Figure 23. Effective shade from current and potential mature vegetation along the Mill Creek and Yellowhawk Creek tributaries of the Walla Walla River.

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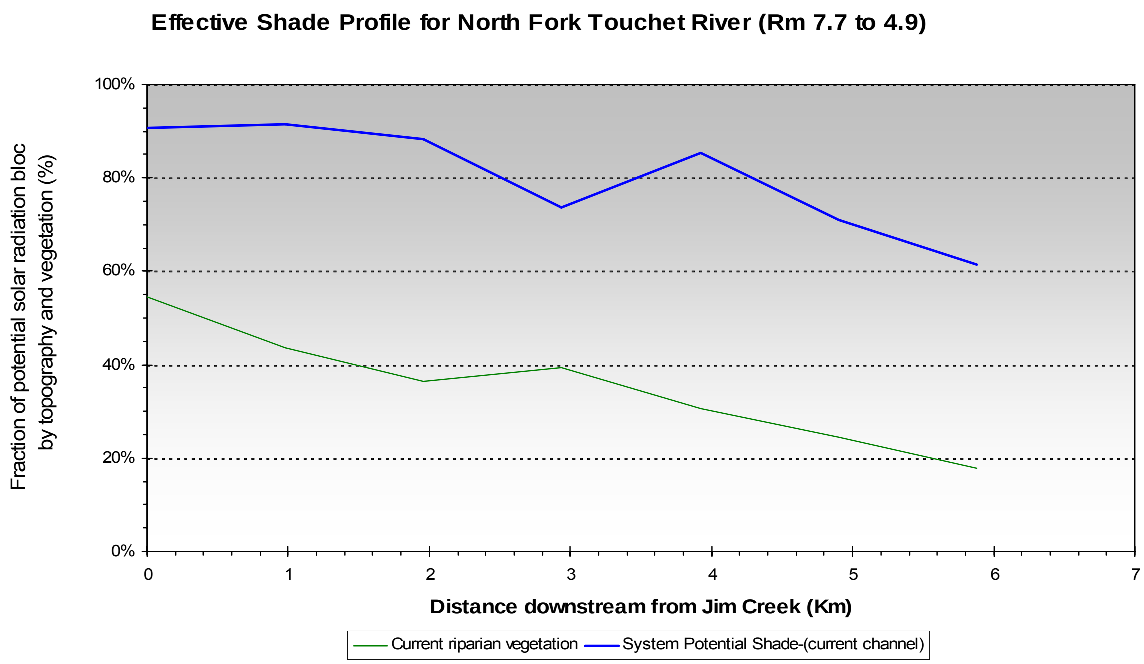

Figure 24. Effective shade from current and potential mature vegetation along the North Fork Touchet River from RM 7.7 (near Jim Creek) to 4.9 (near confluence with Wolf Fork).

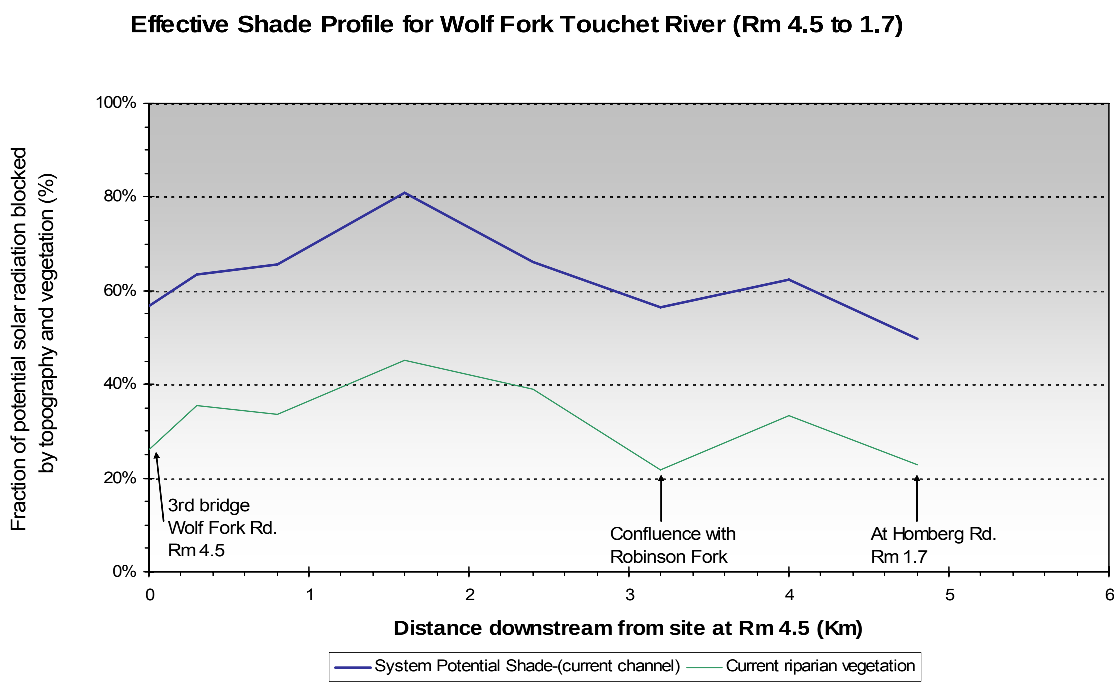

Figure 25. Effective shade from current and potential mature vegetation along the Wolf Fork Touchet River from RM 4.5 (3rd Bridge Wolf Fk Rd) to RM 1.7 (Homberg Rd).

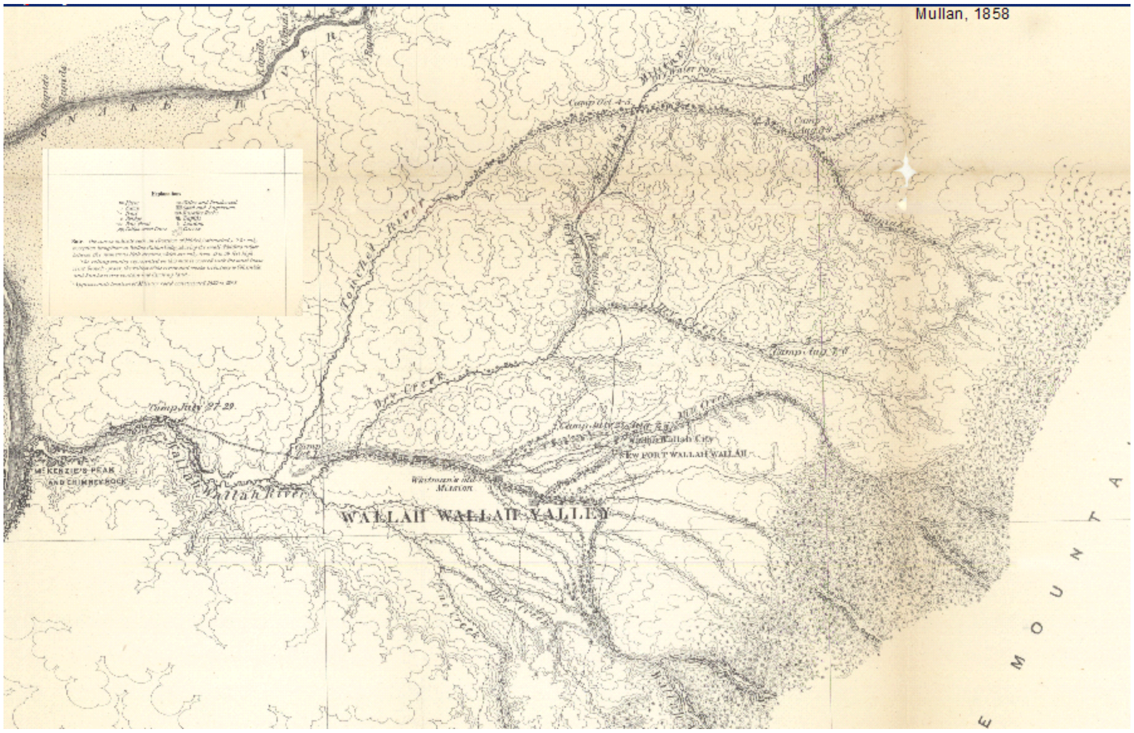

Figure 26. Lieutenant Mullan's 1858 map for military road reconnaissance includes a key roughly addressing riparian vegetation types.

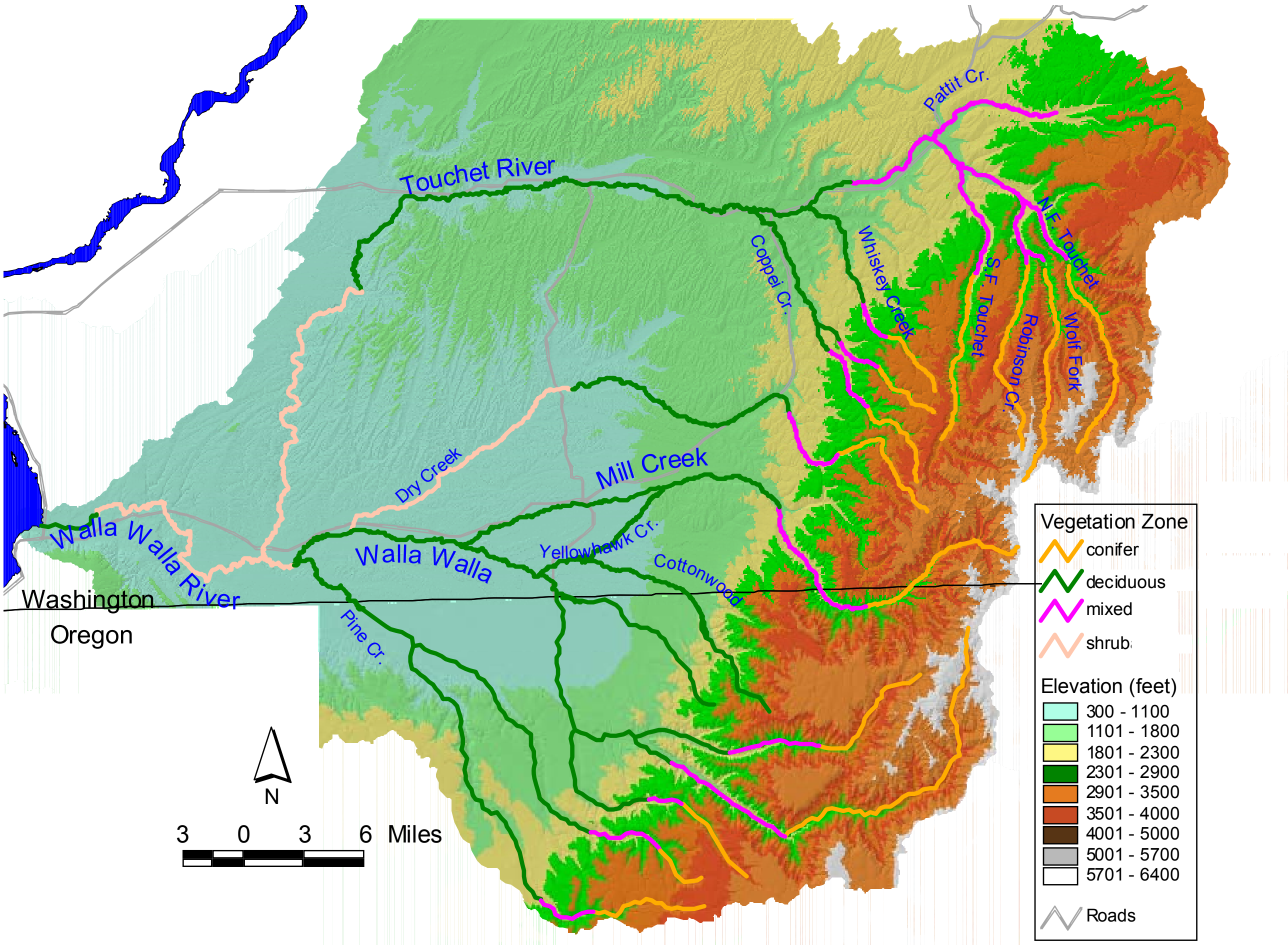

Figure 27. Map of potential vegetation zones in the Walla Walla watershed study area. Refer to Tables 11 and 12 for color coding and description of zones.

Table 11. Potential vegetation composition, height, and density (ODEQ, 2005).

See ODEQ Walla Walla report Table 3-3. The description columns below are color-coded in relation to the map (Figure 27) of potential vegetation zones.

River mile (km)	Riparian zone name	Height dominant plants	Percent stream length with trees	Percent stream length with shrubs	Average tree canopy height (m)	Average willow-shrub height (m)	Canopy density (%)	Longitudinal distance-weighted average height (m)
Walla Walla mouth to 7.8 (Zangar Junction)	Lower Deciduous Zone	Black Cottonwood, Large Willows, Red Osier Dogwood, Mixed Shrubs	100%	N/A	N/A	N/A	80	approximately 22 (or Cottonwood Gallery-28)
7.8 to 11.8 (Nine Mile Bridge)	Indefinite Lower Shrub-Deciduous Zone	Black Cottonwood, Large Willows, Red Osier Dogwood, Mixed Shrubs	25%	75%	14.6	4.3	80	6.9
			50%	50%	14.6	4.3	80	9.4
11.8 to 19.8 (~2.5 miles downstream from Touchet confluence)	Indefinite Shrub-Deciduous Zone	Black Cottonwood, Large Willows, Red Osier Dogwood, Mixed Shrubs	5%	95%	14.6	4.3	80	4.8
			25%	75%	14.6	4.3	80	6.9
19.8 to 23.0 (Confluence with Pine Creek)	Indefinite Upper Shrub-Deciduous Zone	Black Cottonwood, Large Willows, Red Osier Dogwood, Mixed Shrubs	25%	75%	14.6	4.3	80	6.9
			50%	50%	14.6	4.3	80	9.4
Walla Walla 23.0 to 52.2 (South Fork in Oregon 2.8 miles upstream of North fork Confluence)	Deciduous Zone	Mixed Willow, Mixed Alder, interspersed Black Cottonwood	100%	0%	22.0 m	N/A	80	approximately 22 (or Cottonwood Gallery-28)
Walla Walla 52.2 to 59.0 (Oregon BLM trailhead)	Deciduous-Conifer Zone	**Deciduous**- Quaking Aspen, Mixed Willow, Mixed Alder, Black Cottonwood, Red Osier Dogwood **Conifer**- Mixed Firs, Ponderosa Pine, Engelmann Spruce	100%	0%	dominant classes are 22.0, 25.0 and 28.0 meter	N/A	80	approximately 25
59.0 to Model Upper Boundary	Conifer Zone	Mixed Firs, Ponderosa Pine, Engelmann Spruce	100%	0%	dominant classes are 22.0, 25.0 and 25.0 meter	N/A	80	approximately 24

Grey area - low range

Blue area - high range

Table 12. Potential vegetation composition, height, and density for Walla Walla tributaries located in Washington State.

The description columns below are color-coded in relation to the map (Figure 27) of potential vegetation zones. This table should be used in conjunction with Table 11.

River mile (km)	Riparian zone name	Height dominant plants	Percent stream length with trees	Percent stream length with shrubs	Average tree canopy height (m)	Average willow-shrub height (m)	Canopy density (%)	Longitudinal distance-weighted average height (m)
Touchet River mouth to Luckenbill bridge	Indefinite Upper Shrub-Deciduous Zone	Black Cottonwood, Large Willows, Red Osier Dogwood, Mixed Shrubs	25%	75%	14.6	4.3	80	6.9
			50%	50%	14.6	4.3	80	9.4
Touchet River at Luckenbill Road to Lewis and Clark State Park upstream of Waitsburg	Deciduous Zone	Mixed Willow, Mixed Alder, interspersed Black Cottonwood	100%	0%	22.0 m	N/A	80	approximately 22 (or Cottonwood Gallery-28)
Touchet River at Lewis and Clark State Park upstream to and above Wolf Fork	Deciduous-Conifer Zone	**Deciduous**- Quaking Aspen, Mixed Willow, Mixed Alder, Black Cottonwood, Red Osier Dogwood **Conifer** - Mixed Firs, Ponderosa Pine, Engelmann Spruce	100%	0%	dominant classes are 22.0, 25 and 28 meter	N/A	80	approximately 25
Yellowhawk mouth to upstream confluence with Mill Creek	Deciduous Zone	Mixed Willow, Mixed Alder, interspersed Black Cottonwood	100%	0%	22.0 m	N/A	80	approximately 22 (or Cottonwood Gallery-28)
Mill Creek confluence with Yellowhawk Creek to confluence with Blue Creek	Deciduous Zone	Mixed Willow, Mixed Alder, interspersed Black Cottonwood	100%	0%	22.0 m	N/A	80	approximately 22 (or Cottonwood Gallery-28)
Mill Creek at Blue Creek to near the drinking water diversion in Oregon	Deciduous-Conifer Zone	**Deciduous**- Quaking Aspen, Mixed Willow, Mixed Alder, Black Cottonwood, Red Osier Dogwood **Conifer**- Mixed Firs, Ponderosa Pine, Engelmann Spruce	100%	0%	dominant classes are 22.0, 25.0 and 28.0 meter	N/A	80	approximately 25
Mill Creek near drinking water diversion to headwaters and Touchet River upper forks headwaters	Conifer Zone	Mixed Firs, Ponderosa Pine, Engelmann Spruce	100%	0%	dominant classes are 22.0, 25.0 and 25.0 meter	N/A	80	approximately 24

Grey area - low range

Blue area - high range

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Analytical Framework

Data collected during this TMDL effort has been used to simulate temperatures continuously along streams using a methodology that is both spatially continuous and spans full-day timeframes. The GIS and modeling analysis was conducted using three specialized software tools:

1. ODEQ's Ttools extension for ArcView (ODEQ, 2001) was used to sample and process GIS data for input to the QUAL2Kw model.

2. Ecology's Shade model (Ecology, 2003a) was used to estimate effective shade along the mainstems of the Touchet River (Figure 22), Mill Creek, and Yellowhawk Creek (Figure 23), and along selected segments of the North and Wolf Forks of the Touchet River (Figure 24 and Figure 25). Effective shade was calculated at 100-meter intervals along the streams and then averaged over 1000-meter intervals for input to the QUAL2Kw model.

3. The QUAL2Kw model (Chapra, 2001; Chapra and Pelletier, 2003; and Pelletier and Chapra, 2003) was used to calculate the components of the heat budget and simulate water temperatures. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw was applied by assuming that flow remains constant for a given condition such as a 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.

   QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget that are shown in Figure 3 and described in Chapra (1997). Complete model documentation and software can be found at www.ecy.wa.gov/programs/eap/models/index.html. Diurnally varying water temperatures at 1000-meter intervals along the streams in the Walla Walla River basin were simulated using a finite difference numerical method. The water temperature model was calibrated and confirmed to instream data.

All input data for the Shade and QUAL2Kw 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 or other data sources. Detailed spatial data sets were developed for the following parameters for model calibration and confirmation:

- Rivers and tributaries were mapped at 1:3,000 scale from one-foot-resolution color digital orthophoto quads (DOQs) flown in April 2002 for the portions of the watershed within Walla Walla County. The portion of the upper Touchet River that lies in Columbia County was mapped at 1:3,000 scale from 1-meter-resolution black-and-white DOQs.

- Riparian vegetation size and density were mapped at 1:3,000 scale from the DOQs and sampled from the GIS coverage along the stream at 100-meter intervals along the streams in the study area. Effective shade was calculated from vegetation height and density with

Ecology's Shade model. The effective shade values calculated from the Shade model were found to be highly correlated with solar pathfinder field measurements taken during the summer 2002 stream surveys (Figure 21).

- Near-stream disturbance zone (NSDZ) widths were digitized at 1:3000 scale.

- West, east, and south topographic shade angle calculations were made from the 10-meter digital elevation model (DEM) grid using ODEQ's Ttools extension for ArcView.

- Stream elevation was sampled from the 10-meter DEM grid with the Milagrid ArcView extension. Gradient was calculated from USGS 1:24,000 quad maps.

- Aspect (streamflow direction in decimal degrees from north) was calculated by the Ttools extension for ArcView.

- The hourly observed temperatures for the boundary conditions at the headwaters, and the daily minimum and maximum observed temperatures for the tributaries, were used as input to the QUAL2Kw model for the calibration and confirmation periods. The QUAL2Kw model of the mainstem Touchet River was calibrated using data collected during July 11-17 and August 9-15, 2002 and confirmed using data from July 22-28, 1998. The QUAL2Kw model of Mill and Yellowhawk Creeks was calibrated using data collected during July 11-17, 2002, and August 9-15 and August 31, 2004. The QUAL2Kw models of the North and Wolf Forks Touchet River were calibrated using data collected during July 11-17, 2002 and confirmed with data collected during the TIR flight on August 9, 2002.

- Flow balances for the calibration periods were estimated from field measurements and gage data of flows made by Ecology and the Washington Department of Fish and Wildlife (WDFW). The lowest 7-day-average flows during the July-August period with recurrence intervals of 2 years (7Q2) and 10 years (7Q10) were calculated for three long-term USGS gaging stations in the Walla Walla River basin (Table 6). Water balance for the remainder of the Touchet and Mill systems was calculated using continuous flow data from 2002 and from seepage run (synoptic flow) data collected in the watershed by WDFW in 1998, 2000, and 2001, and by Ecology in 2002 and 2004.

  Typical gains and losses between stations for the low-flow period in July and August, estimates of actual water withdrawal from the basin water master, and estimates of groundwater input from August 2002 were used to construct the complete water balance for the Touchet River. The procedure for estimating the water balance for the Mill Creek system is documented in Ecology's conventional pollutant TMDL (Pelletier and Joy, 2006).

- Hydraulic geometry (wetted width, depth, and velocity as a function of flow) for the mainstem Touchet River, and for Mill and Yellowhawk Creeks, was estimated using relationships between wetted width, wetted depth, average velocity, and flow. Travel time from the 2004 dye study data and from the channel survey was used to augment these relationships to represent entire reaches instead of static flow points. Hydraulic geometry for the Wolf and North Fork Touchet was based on field measurements taken during the two time periods modeled.

- The temperature of groundwater in the Touchet River mainstem was set to 11.2°C based on data collected in nearby wells and by the recommendation of Kirk Sinclair, the Ecology hydrogeologist assigned to this Walla Walla project.

- Air temperature, relative humidity, and cloud cover were estimated from meteorological data. The observed minimum and maximum air temperatures and relative humidity at the stations occupied by Ecology during the 2002 study year were used to represent the conditions for the calibration periods. Cloud cover data came from the Walla Walla National Weather Service station located near the middle of the watershed at the Walla Walla Airport. Wind speed measured at the Welland PAWS station was used for Touchet River temperature modeling. Wind speed for the Yellowhawk and Mill Creek systems was measured at the Walla Walla PAWS station located near the Yellowhawk diversion from Mill Creek.

- Heat exchange between the water and the streambed is simulated in QUAL2Kw by two processes: (1) conduction according to Fick's law is estimated as a function of the temperature gradient between the water and surface sediment, thickness of the surface sediment layer, and the thermal conductivity, and (2) hyporheic exchange is estimated as a function of the temperature gradient between the water and surface sediment and the bulk diffusive flow exchange between the water and the streambed, the thickness of the surface sediment layer, the density and heat capacity of water.

  Calibration of the QUAL2Kw model involved specification of the thickness of the surface sediment layer in the range of 50 cm to 100 cm, and specification of the bulk diffuse flow exchange between the water and the streambed between 0 and 100% of the surface flow in a stream reach.

  A typical constant value for the thermal conductivity of the surface sediment of 1.57 W/(m°C) (0.0035 cal/sec/cm/°C) was assumed (Chapra, 2001), which is in the typical range of 1 to 2 W/(m°C) in the literature values summarized by Sinokrot and Stefan (1993) for typical streambed materials.

Calibration of the QUAL2Kw Model

The hottest 7-day period of 2002 occurred from July 11-17 and was used for calibration of the Touchet River QUAL2Kw model (Figure 28). An aerial survey of Thermal Infrared Radiation (TIR, often referred to as FLIR) was conducted during a cooler period during August 7, 8, and 9, 2002. The TIR survey covered Mill Creek on August 7, the mainstem Touchet River on August 8, and the upper Touchet forks on August 9. The next warm week following the TIR flight was August 9-15 and was used to assist in model calibration. The Touchet model was confirmed with data from July 22-28, 1998. The 1998 week was a warm low-flow period when numerous streamflow and field measurements were taken by WDFW.

The goodness-of-fit for the QUAL2Kw model was summarized using the root mean squared error (RMSE) as a measure of the deviation of model-predicted stream temperature from the measured values. The RMSE represents an estimation of the overall model performance and was calculated as:

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

For the calibration and confirmation periods, the RMSE of the predicted versus observed daily maximum temperatures in the Touchet River averaged around 0.65°C (Table 13). The RMSE of the combined maximum and minimum predicted daily temperatures was similar.

Table 13. Summary root mean square error (RMSE) of differences between the predicted and observed daily maximum temperatures and combined maximum and minimum temperatures in the Touchet River.

Watercourse	Statistic	RMSE for July 11-17, 2002 (ºC)	RMSE for August 9-15, 2002 (ºC)	RMSE for July 22-28, 1998 (ºC)
Touchet mainstem	Maximum	0.62	0.72	0.73
Touchet mainstem	Total (max + min)	0.55	0.69	0.67

Although locations in the upper Touchet River forks were not 303(d) listed as temperature impaired at the time of original project design, monitoring by WDFW had indicated that this high quality salmonid habitat was impaired and that those streams would be included on the 2004 303(d) list. Data collection was planned in 2002 to allow modeling of representative channel reaches on the North Fork and Wolf Fork Touchet River. A three-mile section of the North Fork and a three- mile section of the Wolf Fork were modeled.

The hottest 7-day period of 2002, July 11-17, was used for calibration of the North Fork and Wolf Fork segments. Since field collected temperature data were available for only the start and end points of each model segment, the August 9 TIR flight (which provides continuous temperatures along the three-mile segments) was used for confirmation of the North Fork at Wolf Fork model segments (Figures 29 and 30).

For the calibration and confirmation periods, the RMSE of the predicted versus observed daily maximum temperatures in the upper Touchet River forks showed a very good fit (Table 14).

Table 14. Summary root mean square error (RMSE) of differences between the predicted and observed daily maximum temperatures for the upper Touchet River forks.

Watercourse	Statistic	RMSE for July 11-17, 2002 (ºC)	RMSE for the TIR period tidbits August 7-9, 2002 (ºC)	RMSE for all TIR segments August 7-9, 2002 (ºC)
North Fork Touchet RM 7.7 to 4.9	Maximum	0.16	0.02	0.55
Wolf Fork Touchet RM 4.5 to 1.7	Maximum	0.00	0.06	0.19

A slightly different approach to calibration was used for the Mill/Yellowhawk QUAL2Kw model. The Mill/Yellowhawk Creek model was set up with data from July 11-17 and August 9-15, 2002 resulting in very good fits of predicted and observed temperatures. The model inputs were then entered into a larger QUAL2Kw model for August 31, 2004. In addition to temperature, this expanded model was used to solve for dissolved oxygen, pH, nutrients, and other water quality parameters. Final calibration of the August 31, 2004 model for all water quality parameters resulted in a RMSE of 0.65°C for temperature (Figure 31).

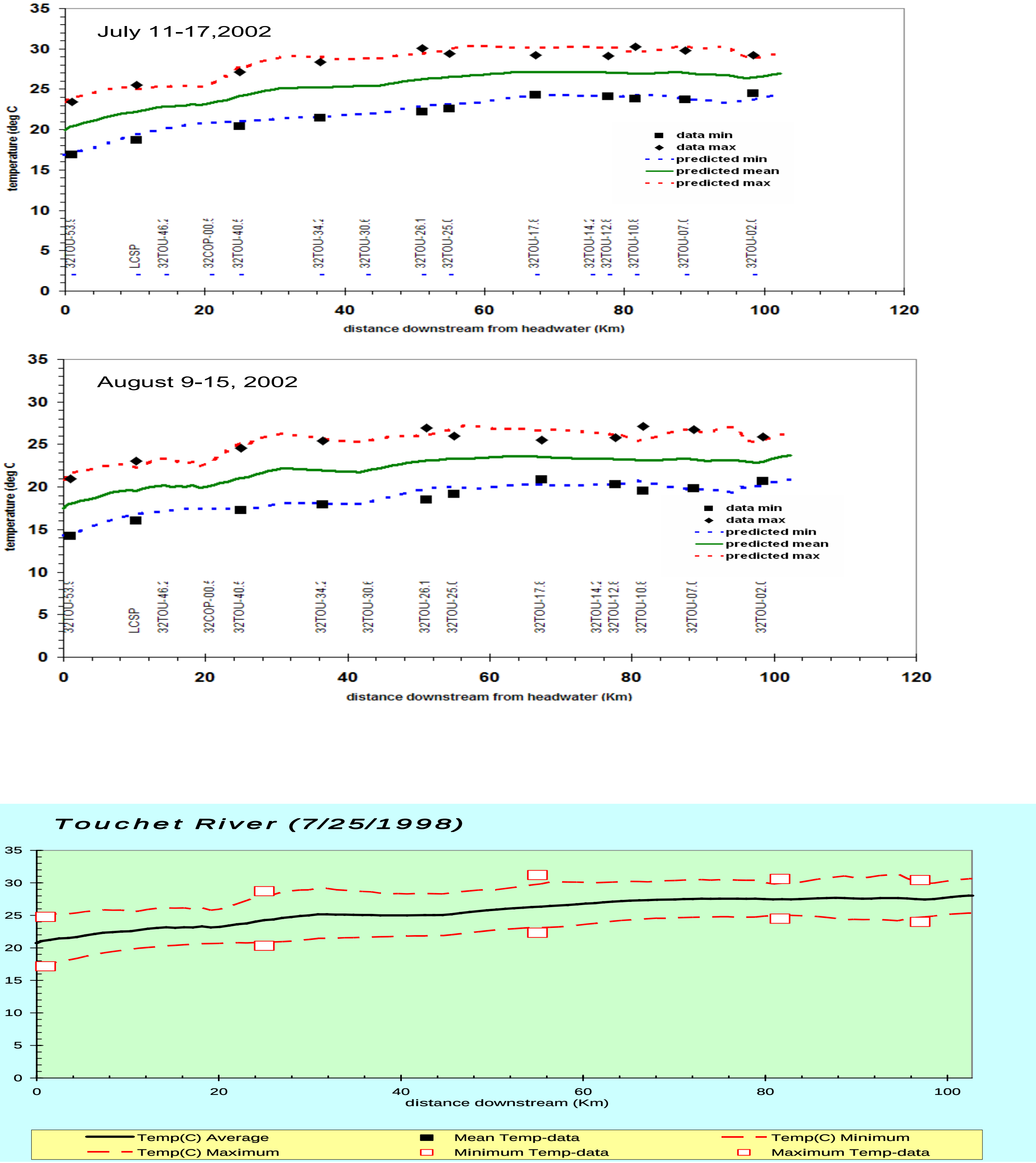
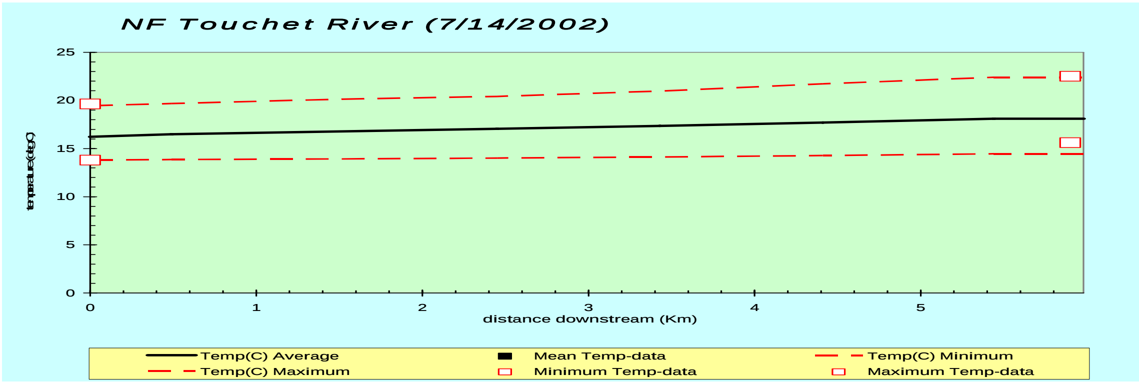


Figure 28. Predicted and observed water temperatures in the Touchet River for calibration (July 11-17 and August 9-16, 2002) and confirmation (July 22-28, 1998) periods.



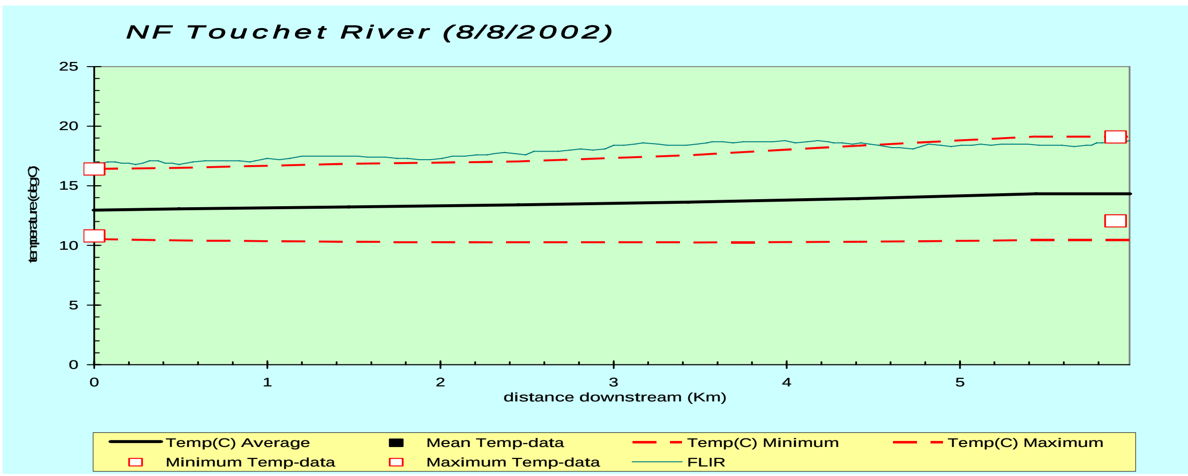
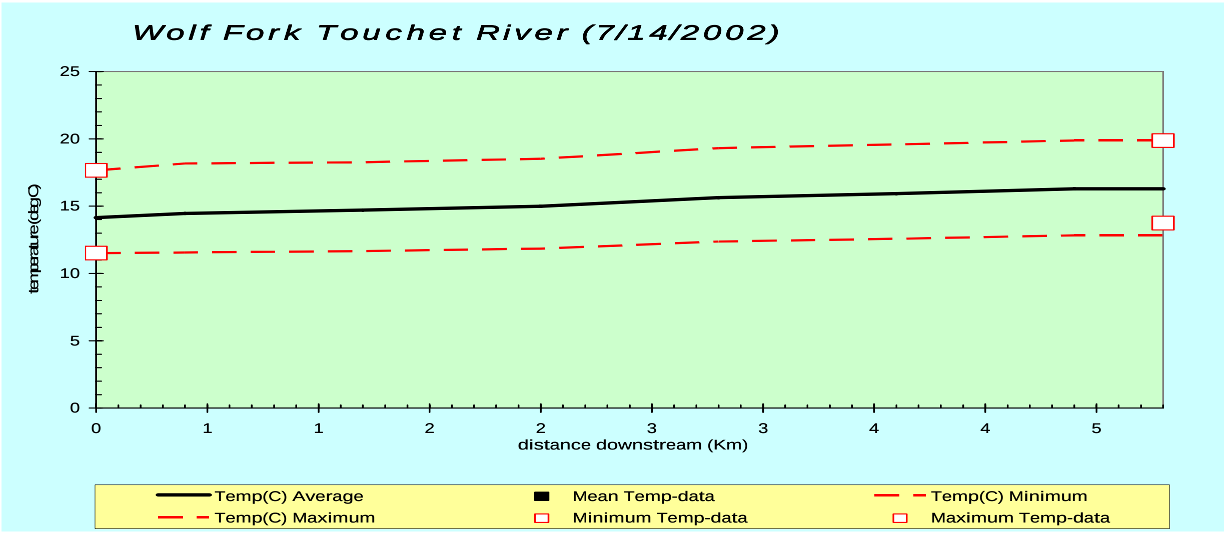


Figure 29. Predicted and observed water temperatures in the North Fork Touchet River for calibration (July 11-17) and confirmation (August 7-9) periods.



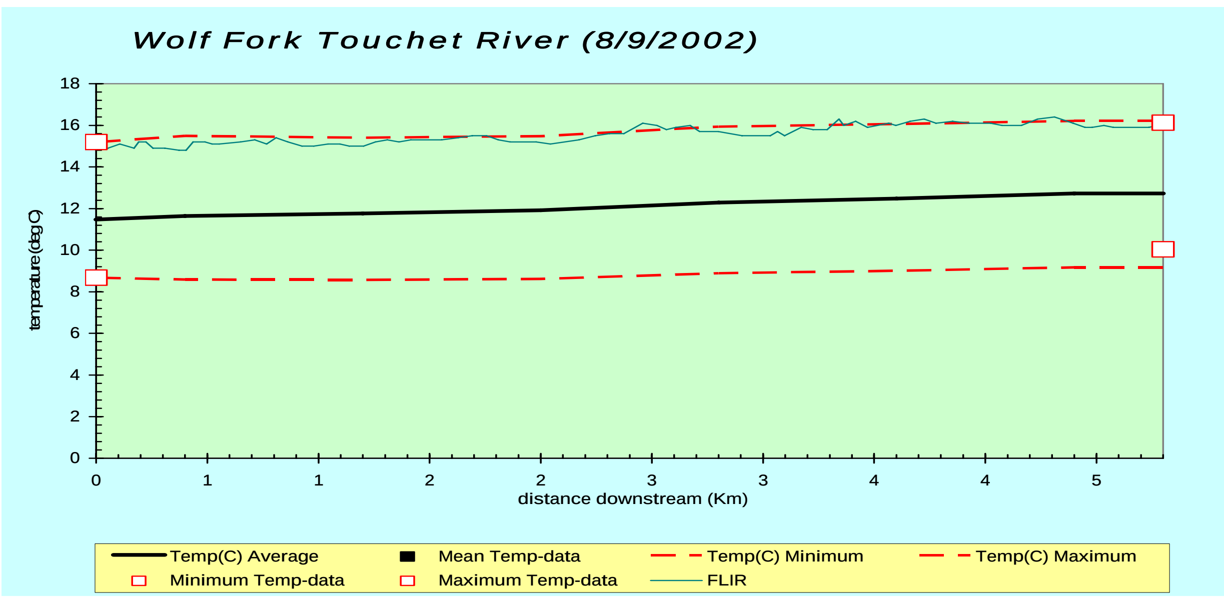


Figure 30. Predicted and observed water temperatures in the Wolf Fork Touchet River for calibration (July 11-17) and confirmation (August 7-9) periods.

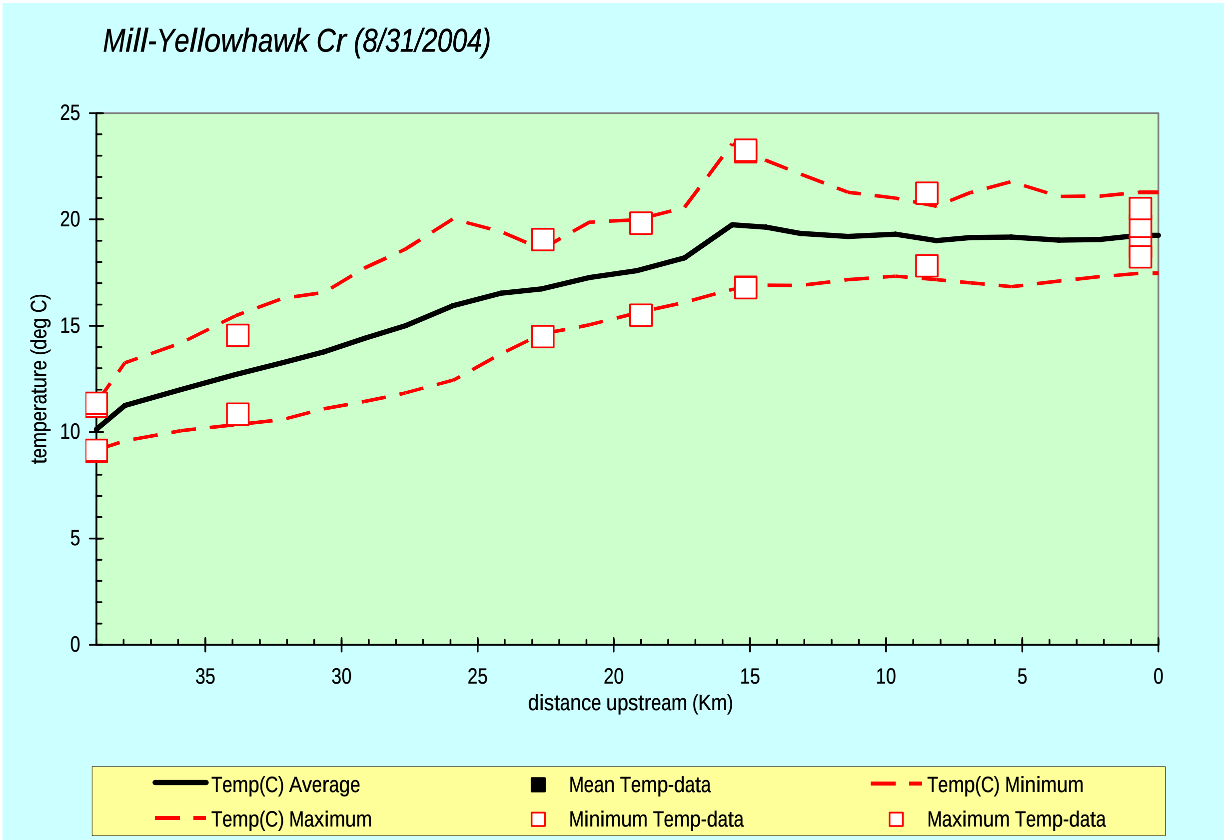


Figure 31. Predicted and observed water temperatures in Mill and Yellowhawk Creeks for the August 31, 2004 calibration period.

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Loading Capacity

Analysis

Mill/Yellowhawk Creeks and the mainstem Touchet River

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with standards. EPA's current regulation defines loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (40 CFR § 130.2(f)). Loading capacities in the Walla Walla River tributaries are solar radiation heat loads based on potential land cover (primarily vegetation) and channel width.

The *system potential temperature* is an approximation of the temperature that would occur under natural conditions during specified conditions of air temperature and streamflow. The system potential temperature is estimated using analytical methods and computer simulations proven effective in modeling and predicting stream temperatures in Washington. The system potential temperature is based on our best estimates of the *mature riparian vegetation, natural channel shape, and riparian microclimate* that did not include human modifications.

A system potential temperature is estimated for both an average year (50th percentiles of climate and low streamflows) and a *critical condition* year (upper 90th percentile air temperature and low flows that occur only once every ten years). The system potential temperature does not, however, replace the numeric criteria, nor invalidate the need to meet the numeric criteria at other times of the year and at other less extreme low flows and warm climatic conditions.

At locations and times where the system potential temperature is greater than the numeric criterion assigned to the waterbody (e.g., 18ºC in Class A or 16ºC in Class AA waters), the loading capacity and load allocations in this TMDL are to be based on not allowing human sources to warm the water by more than an additional 0.3°C. In all waters where the system potential temperature is higher than the assigned criterion, maximum riparian shade and the best channel and flow conditions possible are needed.

The calibrated QUAL2Kw model was used to determine the loading capacity for effective shade for tributary streams in the Walla Walla 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 lowest 7-day average flow with a 2-year recurrence interval (7Q2) was selected to represent a typical climatic year, and the lowest 7-day average flow with a 10-year recurrence interval (7Q10) was selected to represent a reasonable worst-case condition for the July-August period.

Air temperature values for the 7Q2 condition were assumed to be represented by the average of the hottest week of 1997, which was the median condition from the historical record at Walla Walla (Table 10). The air temperature values for the 7Q10 condition were the average of the hottest week of 1998, which was the 90^{th} percentile condition from Walla Walla. The corresponding median and 90^{th} percentile air temperature conditions for the near-stream conditions near the mouth of the Touchet River were calculated from measurements taken at the Touchet PAWS weather station during 1997 and 1998.

Critical and average air temperatures for the remainder of the Touchet system were calculated by applying the regression equation from Figure 18 to the Touchet PAWS temperature data. The Mill Creek/Yellowhawk Creek model used air temperatures measured at the Walla Walla PAWS station during 1997 and 1998. The Walla Walla PAWS station is located in the middle of the watershed near the confluence of Mill and Yellowhawk Creeks.

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

- The effective shade that is produced by the current condition of riparian vegetation.
- Maximum effective shade from mature riparian vegetation that would naturally occur in the Walla Walla River watershed using the *high range estimate of vegetation in the Touchet River mouth to Luckenbill Road segment*. Mature vegetation was represented by height and densities reported earlier (in Table 11) and by a riparian vegetation width of 180 feet on each side of the stream. This is the zone width set by the Natural Resources Conservation Service (NRCS) as the maximum for its Conservation Reserve Enhancement Program (CREP) riparian planting program.
- Maximum effective shade from system potential riparian vegetation that would naturally occur in riparian areas within the study area (using the *low range estimate of vegetation in the Touchet River mouth to Luckenbill Road segment*).

Additional critical scenarios were evaluated to test the sensitivity of predicted water temperatures to changes in riparian microclimate, decreases in channel width, and reduction of tributary temperatures:

- **Microclimate.** Increases in vegetation height, density, and riparian zone width are expected to result in decreases in air temperature. To evaluate the effect of this potential change in microclimate on water temperature, the daily maximum air temperature was reduced by 2°C for reaches modeled with deciduous or conifer trees based on the summary of literature presented by Bartholow (2000). Reaches in shrub zones received no reduction in air temperature.
- **Channel width.** Channel banks are expected to stabilize and become more resistant to erosion as the riparian vegetation increases along the stream matures. Some areas of the Touchet River have experienced large amounts of erosion, and streambanks are very wide as seen from the aerial orthophotos. The sensitivity of predicted stream temperatures to reduction of channel width was tested by predicting stream temperatures that would occur if channel width could be no wider than 41.1 meters (the 95% value for channel widths in the

Touchet River) (Figure 32). This simulation keeps most of the channel widths the same as the current channel, but reduces the wide areas where erosion of the banks has taken place to 41.1 meters.

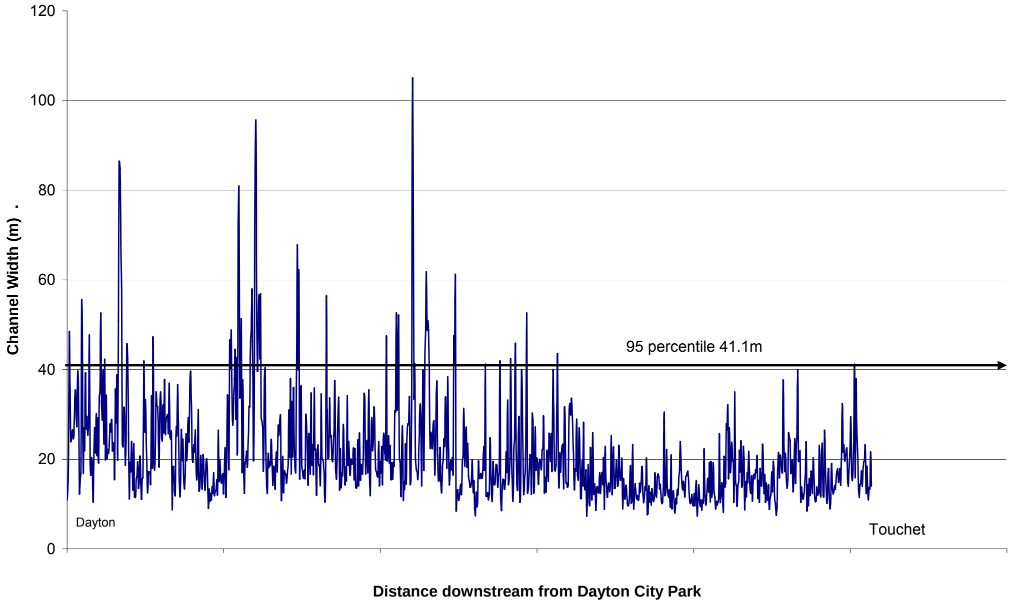


Figure 32. Channel width (NSDZ) for Touchet River from aerial photography (measured from orthophotos using GIS)

- **Reduced tributary temperatures.** A scenario was evaluated with the assumption that the inflowing Touchet River upstream of Dayton did not exceed 18°C. Other tributaries that supply far less water (Coppei and Whiskey Creeks) were not reduced to 18°C, but water temperatures may be reduced in the future if riparian vegetation is increased and other implementation activities occur.

The results of the model runs for the critical 7Q2 and 7Q10 conditions are presented in Figures 33 and 34. The current condition in the Walla Walla watershed is expected to result in daily maximum water temperatures that are greater than 18°C in most of the evaluated reaches. Portions of the evaluated streams could be greater than the approximate threshold for lethality of 23°C under current riparian conditions. The “lethality” limit or “threshold for lethality” in Figures 33 and 34 is referring to the following excerpt from an Ecology study (Hicks, 2002) that evaluates lethal temperatures for coldwater fish:

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

Substantial reductions in water temperature are predicted for hypothetical conditions with mature riparian vegetation, improvements in riparian microclimate, and reduction of channel width. Current temperatures in the Touchet River are above the 23°C lethal limit for salmonids during the summer months. Potential reduced maximum temperatures under critical conditions are predicted to be greater than the 18°C numeric standard in the mainstem Touchet River. However large portions of the river from Dayton downstream to Lamar Road can be reduced to below the lethal limit of 23°C for salmonids. Sections above the Lewis and Clark State Park are cool enough to have the ability to become summer rearing habitat. The Touchet River from Luckenbill Road to the mouth can continue to provide a migration corridor during the spring and winter, but system potential temperatures during the summer are too high to provide healthy summer habitat for salmonids (Table 15). Further reductions are likely if all tributaries and channel complexity are restored.

Table 15. Summary of daily water temperatures (°C) at critical conditions in the Touchet River, Mill Creek, and Yellowhawk Creek.

Scenario	Touchet River		Mill Creek		Yellowhawk Creek	
	Tave (average daily average of all reaches)	Tmax (average daily maximum of all reaches)	Tave (average daily average of all reaches)	Tmax (average daily maximum of all reaches)	Tave (average daily average of all reaches)	Tmax (average daily maximum of all reaches)
7Q2						
current condition	24.5	27.5	16.9	19.5	22.6	24.9
mature riparian vegetation- low shrub	21.4	23.6	na	na	na	na
mature riparian vegetation- high shrub	21.2	23.3	16.0	18.2	20.6	22.5
plus upper tributary inputs at WQS	21.0	23.0	na [1]	na [1]	na [1]	na [1]
plus reduced channel widths	20.9	23.0	[2]	[2]	[2]	[2]
plus microclimate improvement	20.0	22.0	15.3	17.4	19.3	21.2
plus NAF flows	19.7	21.6	14.4	16.3	18.3	20.0
7Q10						
current condition	25.7	29.2	17.9	21.0	23.9	26.7
mature riparian vegetation- low shrub	22.4	24.9	na	na	na	na
mature riparian vegetation- high shrub	22.1	24.6	16.7	19.3	21.4	23.8
plus upper tributary inputs at WQS	21.9	24.3	na [1]	na [1]	na [1]	na [1]
plus reduced channel widths	21.8	24.3	[2]	[2]	[2]	[2]
plus microclimate improvement	20.9	23.3	16.0	18.5	20.0	22.4
plus NAF flow	20.4	22.6	14.3	16.4	18.4	20.2

[1] Upper boundary already at water quality standards (WQS): maximum headwater temperature is 13.1°C July 11-12, 2002
[2] Did not calculate (could do if necessary)

Best estimates of potential summertime stream temperature reductions for Mill and Yellowhawk Creeks are 3.0°C and 4.3°C respectively. Although portions of the system, especially in the wide area of Mill Creek just above the confluence with Yellowhawk, are predicted to still have temperatures higher than 23°C during critical conditions. Most of the system has the ability to achieve temperatures in the range of 18-22°C during the hottest portions of the summer. Currently the uppermost reaches of the Mill Creek system are below 16°C year round.

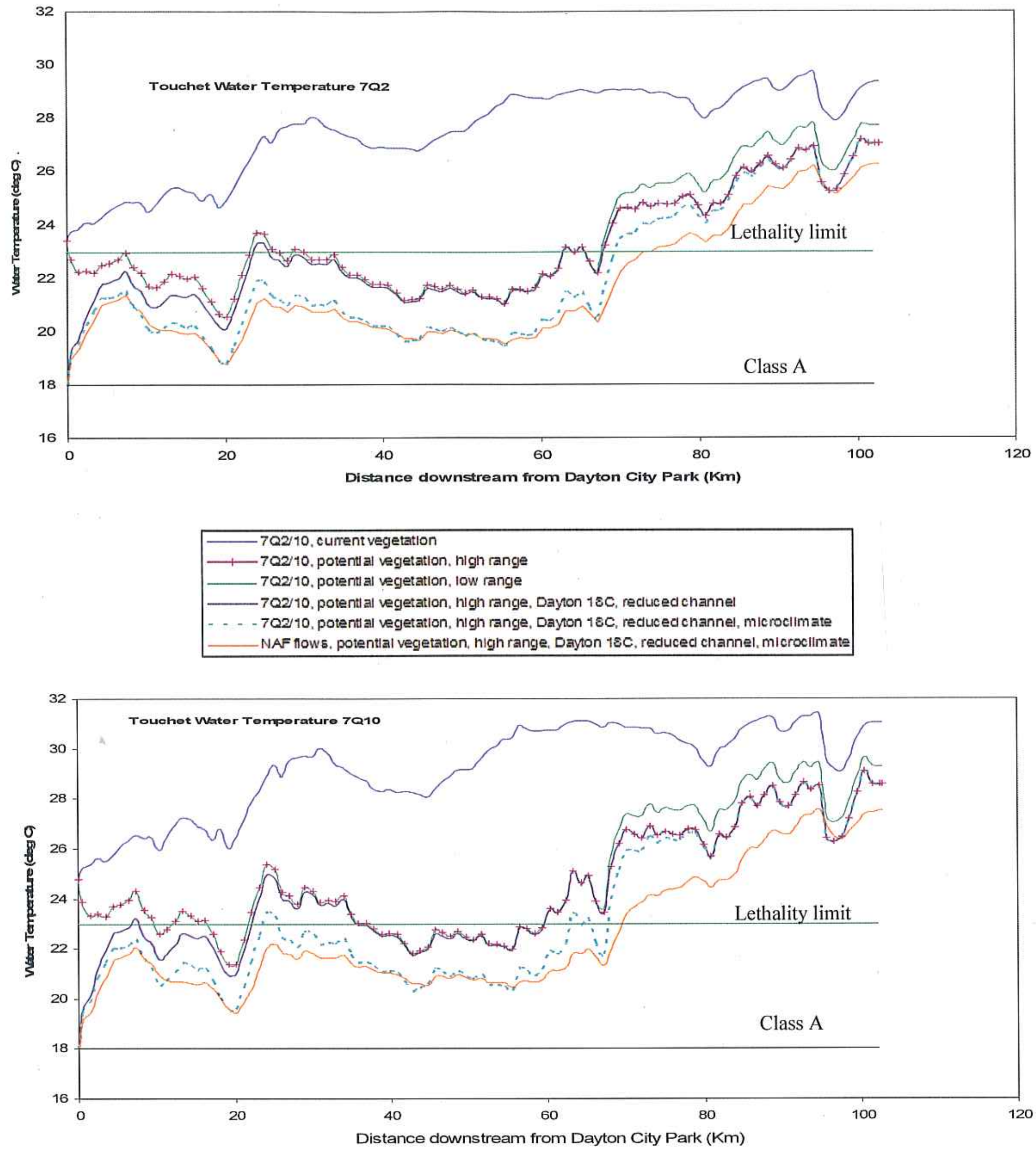
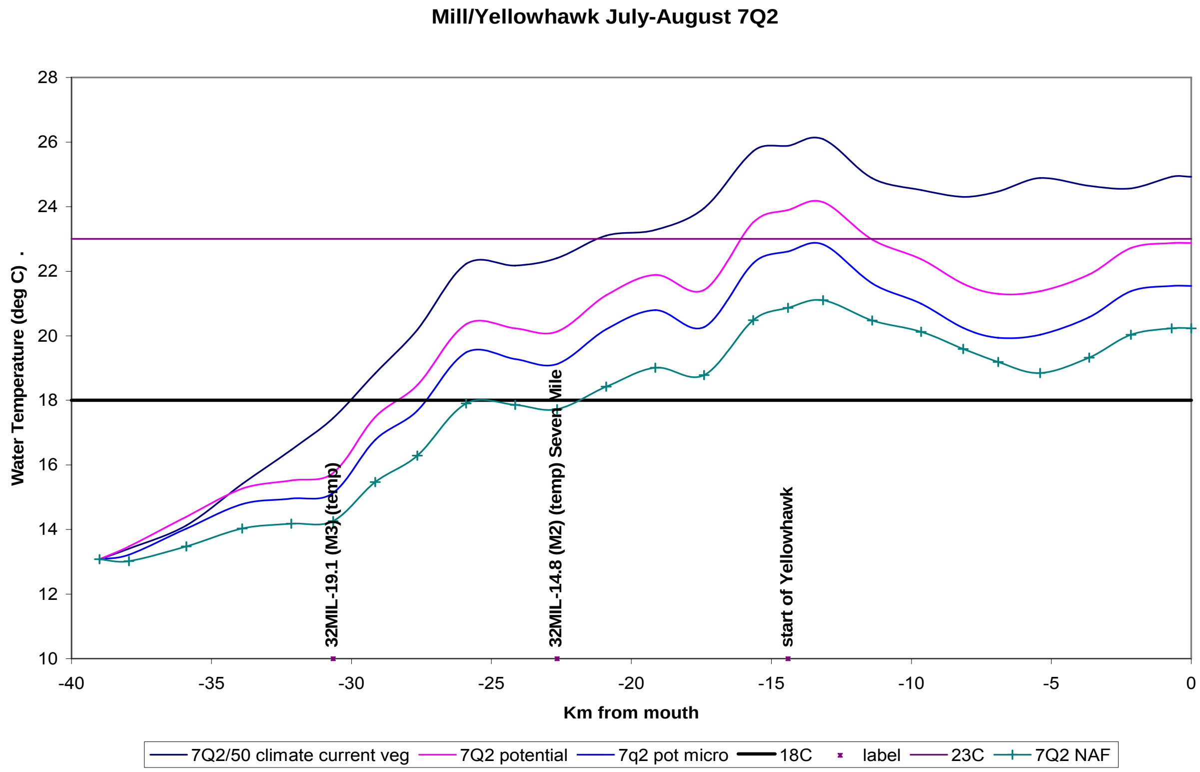


Figure 33. Predicted daily maximum water temperatures in the Touchet River for critical conditions during July-August 7Q2 and 7Q10.



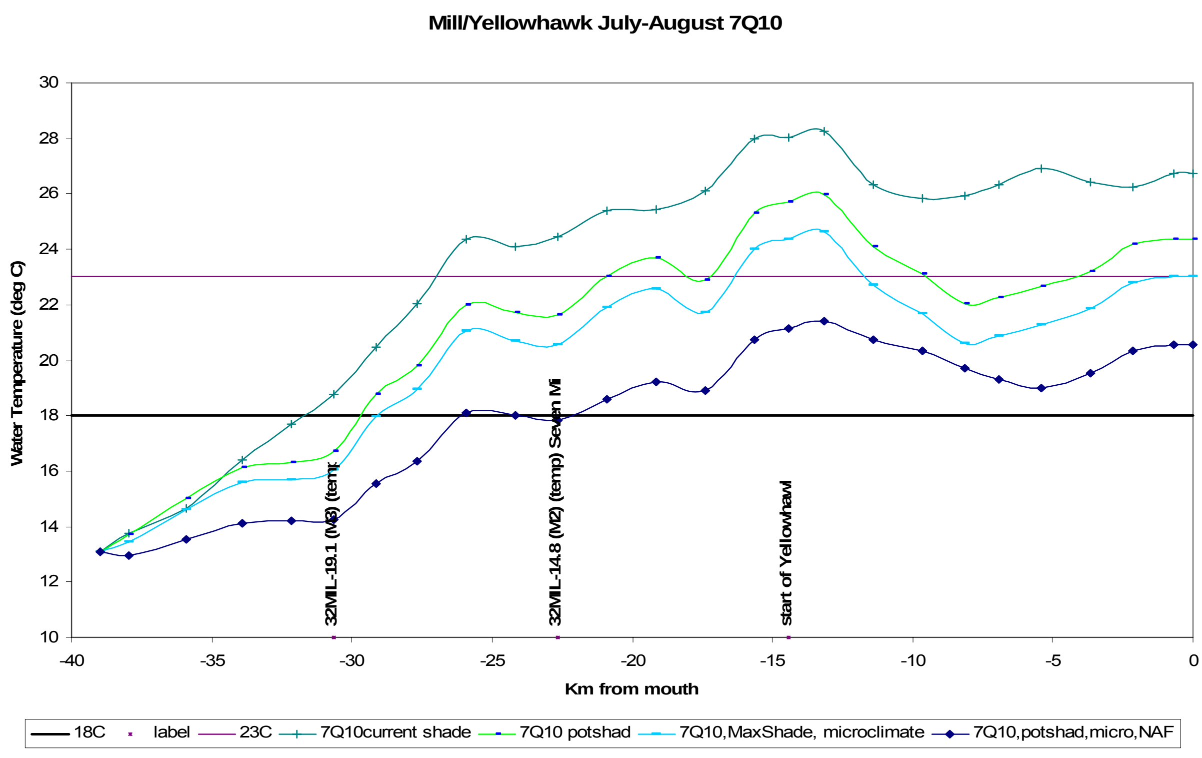


Figure 34. Predicted daily maximum water temperatures in Mill and Yellowhawk Creeks for critical conditions during July-August 7Q2 and 7Q10.

Upper Touchet River forks

Model simulations for the Wolf and North Forks of the Touchet River showed that on the hottest week of 2002, with mature riparian vegetation in place, the water temperature would be less than 18°C but greater than the numerical temperature criteria of 16°C for those type AA waters. Since the water quality standard is expected to be exceeded under the 2002 conditions and because there are no point source permits needing further analysis in this upper portion of the watershed, model simulations were not performed for the 90th percentile climate and low-flow conditions. It is clear that under the 90th percentile condition, water temperature would be higher than in July 2002, and that under both conditions, the maximum riparian shade and best channel and flow conditions possible would be needed.

Figure 35 shows that the North Fork Touchet River is expected to realize a 3.4ºC reduction in temperature with the addition of system potential shade. A further reduction of 1ºC is possible if upstream waters enter the segment at 16ºC and if air temperature under the mature riparian canopy is 2ºC cooler (microclimate). The North Fork Touchet, under the flow and climate conditions during the hottest week of July 2002, could be under 18ºC, but not under 16ºC.

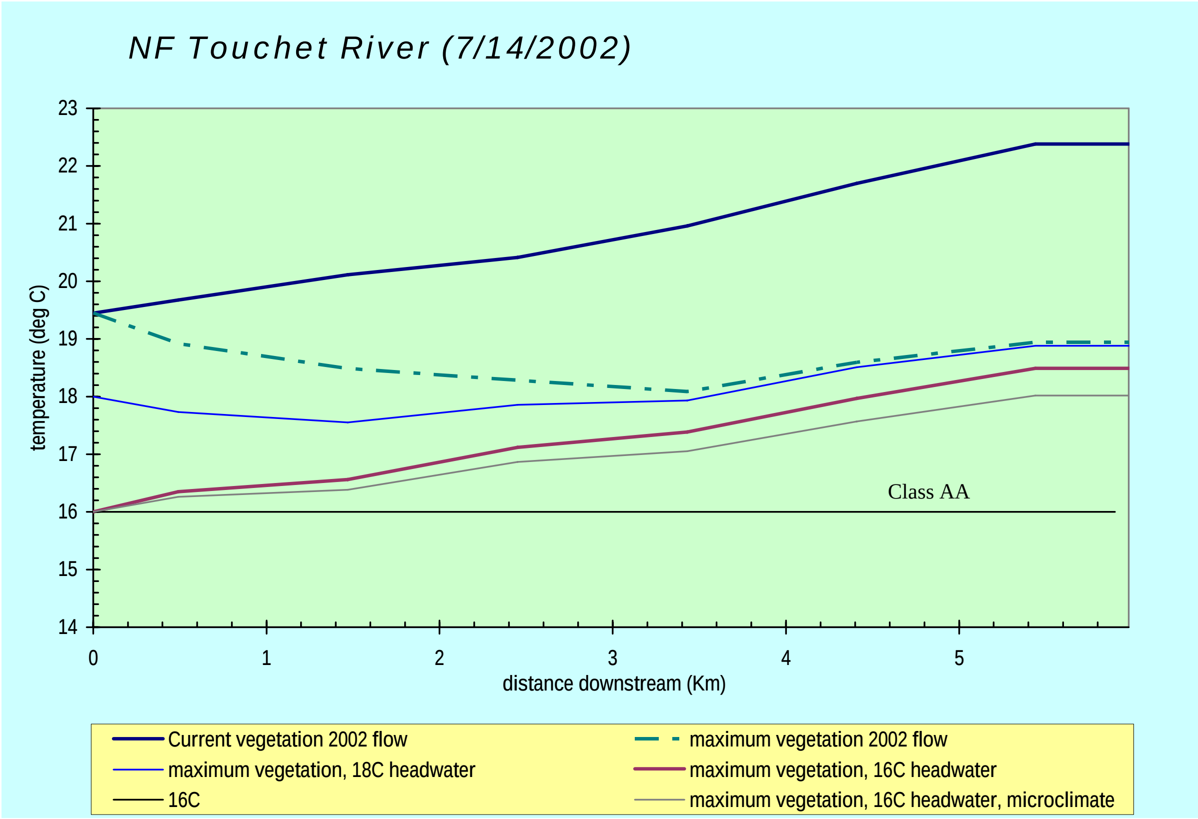


Figure 35. Predicted daily maximum water temperatures in the North Fork Touchet River for critical (July 11-17, 2002) conditions under various vegetation and headwater conditions.

Figure 36 shows that the Wolf Fork Touchet River is expected to realize a 2.0ºC reduction in temperature with the addition of system potential shade. A further reduction of 0.6ºC is possible if upstream waters enter the segment at 16ºC and if air temperature under the mature riparian canopy is 2ºC cooler (microclimate). The Wolf Fork, under the flow and climate conditions during the hottest week of July 2002, could be under 18ºC, but not under 16ºC. Under hotter, 90th percentile climate conditions and lower flows (7Q10), stream temperature would potentially be higher. Therefore, maximum shade and riparian conditions are needed.

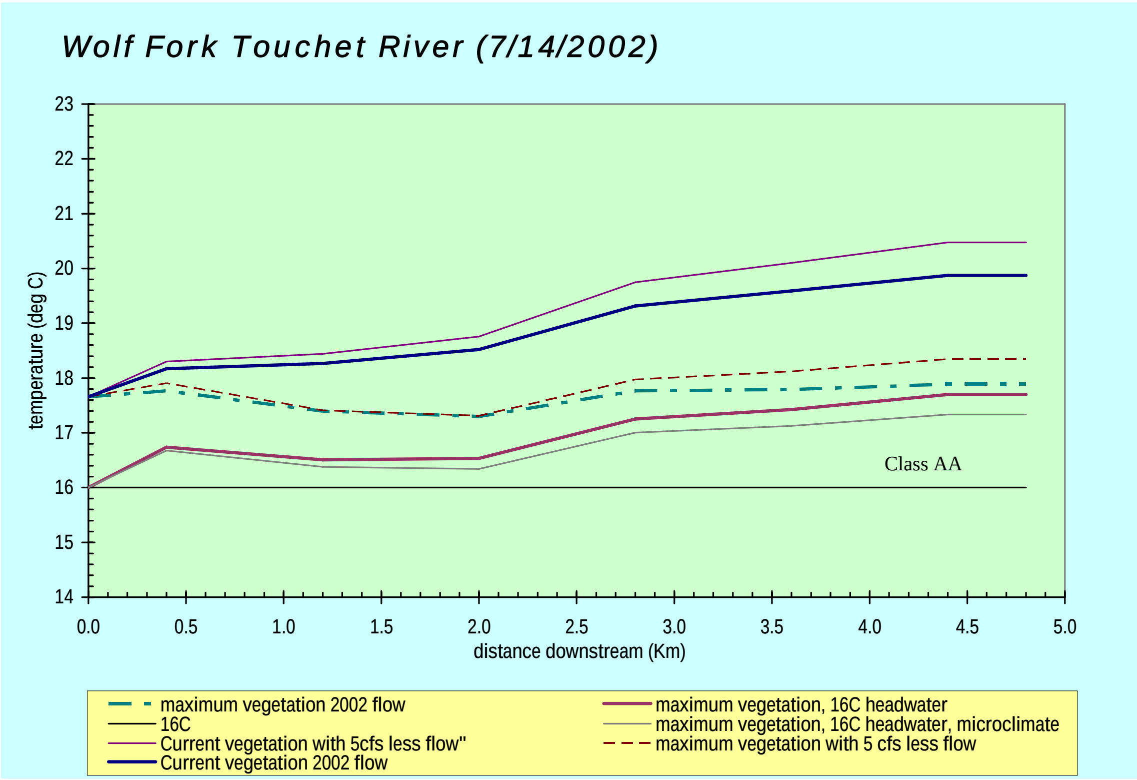


Figure 36. Predicted daily maximum water temperatures in the Wolf Fork Touchet River for critical (July 11-17, 2002) conditions under various vegetation and headwater conditions.

The Wolf Fork currently has the lowest temperatures of the main upper Touchet River forks (Table 16). Maintenance and improvement of the riparian and flow conditions will be important to salmonid species that spawn and rear in these waters. The current stream hydrology, channel conditions, and large cobble substrate is keeping the stream cool enough to support salmonids. The large cobble allows for intergravel (hyporheic) streamflow and free exchange with the numerous interspersed cool springs. A natural stream channel is important to help maintain gravels with little impacted sediment to close pores (spaces between the gravels). Because flood events occur on a fairly regular basis, channel widths are not expected to change significantly over time. Maintenance of mature near-stream riparian vegetation is vital to avoid degradation of this habitat. Decreases in streamflow will increase temperature in this segment.

The North Fork Touchet River has similar structure and capability to reach stream temperatures approaching those of the Wolf Fork.

Table 16. Highest daily maximum temperature (°C) in the upper Touchet River forks, 1998-2003.

Site	1998	1999	2000	2001	2002	2003
Wolf Fork (Nelson) 2nd Bridge	--	17.91	17.79	17.81	18.38	17.50
Wolf Fork (Homberg)	--	20.13	20.38	20.52	20.68	19.44
North Fork near Jim Creek	21.15	19.96	19.97	20.27	20.43	19.72
Mainstem Touchet abv Dayton (at Snake River Lab)	26.00	24.07	--	24.43	24.43	--
South Fork mouth (RM 00.5)	--	27.15	27.17	27.48	27.48	25.00
North Fork (abv SF) Baileysburg	--	24.24	24.17	24.55	24.90	23.89
Date of Annual High	7/27/98	8/4/99	7/31/00	7/9/01	7/12/02	--

Table 16 shows that annual temperatures in the upper Touchet forks sites sampled by WDFW have remained relatively the same over the past few years with temperature changes per climatic condition. The year 1998 is well known as a critical condition for stream temperature and has been used in many TMDLs to establish load allocations. As seen above 1998 has the highest temperatures on record, and temperatures would not be expected to exceed those except on a rare basis.

Also seen is that with the addition of shade and channel maintenance, reduction of the expected 2-3°C can keep these streams in relatively good condition for the summer rearing of salmonids. The Wolf Fork and Upper North Fork currently have relatively cool temperatures. The lower portion of the North Fork near Baileysburg is being impacted by high temperatures for fish, and the area near the mouth of the South Fork has temperatures that are lethal to salmonids.

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Results and Discussion

The QUAL2Kw model simulations indicated that:

1. A buffer of mature riparian vegetation along the banks of the rivers is expected to decrease the average daily maximum stream temperatures. At 7Q10 flow conditions, a 4.6ºC reduction is expected for the Touchet River. Significant reductions of 1.7ºC and 2.9ºC are expected for upper Mill Creek and Yellowhawk Creek, respectively.

2. The changes in microclimate conditions associated with mature riparian vegetation could further lower the daily average maximum water temperature by about 1.0ºC.

3. Improvements in riparian vegetation above kilometer 60 (Figure 33) in the Touchet River system can reduce temperatures below the lethal limit to salmonids, although daily highs will still not be healthy for salmonids. Below the 60 kilometer marker (between Luckenbill and Lamar Roads), water temperatures during July-August are expected to be very high, except in localized areas of groundwater input.

4. A reduction of the widest areas in the channel to a maximum of 41 meters (120 feet) in the Touchet River results in little reduction of temperature, because the channel at those locations is still difficult to shade.

5. The addition of streamflow to recommended NAF levels led to a further decrease in the maximum (across all reaches) simulated water temperatures, ranging from 0.7ºC in the Touchet to 2.2ºC in the Mill Creek/Yellowhawk Creek system.

6. With all management scenarios in place (those listed in 1 through 5 above), the overall decrease in the average maximum temperature for the simulated critical condition ranged from 4.6ºC to 6.6ºC, with an average of 5.9ºC.

7. The North Fork Touchet River is expected to realize a 3.4ºC reduction in temperature with the addition of system potential shade. A further reduction of 1ºC is possible if cooler upstream waters enter the segment at 16ºC and if the air temperature under the riparian canopy (microclimate) is 2ºC cooler.

8. The Wolf Fork Touchet River is expected to realize a 2.0ºC reduction in temperature with the addition of system potential shade. A further reduction of 0.6ºC is possible if cooler upstream waters enter the segment at 16ºC and if the air temperature under the riparian canopy (microclimate) is 2ºC cooler.

Other discussion and recommendations

- The South Fork Touchet River has much higher stream temperatures (Table 16) than the North and Wolf Forks. System potential shade is required to reduce stream temperatures. The stream substrate in the South Fork site sampled by Ecology was primarily bedrock. Because of the lack of cobble and gravels to encourage subsurface streamflow and exchange, the South Fork likely will not be able to reach temperatures as low as those found in the other upper forks.

- Mill Creek channel widths were not reduced (as they were for the Touchet, #4 above) because of difficulty in predicting a restored channel width. Numerous flood control measures are in place, and water diversions at both the drinking water intake and at Bennington Dam normalize flows during portions of the year. Additional simulations could be performed to estimate further temperature reductions associated with a narrower channel. However, recommended restoration measures for system potential conditions will be the same under either scenario because temperatures under critical conditions exceed the numeric water quality standard.

- The Upper Touchet River subbasin is a vulnerable system. Current conditions are supporting communities of bull trout. Improvements in shading should increase the area usable by salmonids. This system will be very vulnerable to development that impacts/removes riparian shading, reduces streamflow, or results in channel alterations such as diking that would reduce channel complexity.

  Currently the Wolf Fork and North Fork Touchet streams are staying cooler than some systems with similar levels of shading because the large-size cobble substrate allows for a high level of intergravel mixing and contact with cooler springs and groundwater. Reduction in summer flows, reduction in spring input, or increase of fine sediment in the gravel and cobbles could cause this system to heat instead of maintaining or improving temperature. Further development should favor off-stream setbacks to sustain as natural a riparian corridor as possible, and maintenance of summer streamflows at the current level.

- Channel widths were not reduced in the upper forks. Because flood events are fairly common, reduction of channel widths may or may not be a byproduct of adding riparian vegetation that would stabilize the banks. If restoration results in healthy channels with proper sinuosity that are narrower or deeper, the cooling effects may be larger than those shown with the temperature model. Research generally shows that it is not the large floods that control channel shape. Stream channels are built and maintained by bankfull stage flows that occur roughly each 1.5 years (ODEQ, 2005)

  Within the Walla Walla basin, research has identified the bankfull discharge recurrence interval for the Walla Walla River, based on the Touchet gage-site on the Walla Walla River (1.03 year) and the Touchet River (1.15 year) gage-site (Castro and Jackson, 2001). A 100-year flood occurred during 1996. Research conducted following the 1996 flood (Clifton et al., 1999) stated that channel adjustments in cross-section area, volume of stored sediment, and particle size distributions appear to be more related to reach-level controls such as large wood jams and local mass-wasting sources than to overall flood magnitude. Locally, channels may be modified by a 25-100-year flood, but overall it is not the large floods that control channel shape. Stream channels are built and maintained by bankfull stage flows that occur roughly each 1.5 years (ODEQ, 2005)

  Bankfull stage is formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels" (Dunne and Leopold, 1978).

Load Allocations

Numeric threshold temperature criteria are established in the Washington State water quality standards (WAC 173-201A-030). These numeric criteria are designed to ensure specific communities of aquatic life will be fully protected whenever and wherever the numeric criteria are met. The state standards recognize, however, that some waterbodies may not be able to meet the numeric criteria at all places and all times.

WAC 172-201A states that: *"Temperature shall not exceed [the numeric criteria] due to human activities. When natural conditions exceed [the numeric criteria], no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°."*
(WAC 173-201A-030(1)(c)(iv), (2)(c)(iv), (3)(c)(iv), (4)(c)(iii))

Thus at times and locations where the assigned numeric criteria cannot be attained even under estimated natural conditions, the state standards hold human warming to a cumulative allowance for additional warming of 0.3°C above the natural conditions estimated for those locations and times.

In addition to placing a limit on the amount of human warming allowed when temperatures exceed the numeric criteria, the state standards restrict the amount of warming point and nonpoint sources can cause when temperatures are cooler than the numeric criteria.

For Class AA fresh waters, WAC 173-201A-030(c)(iv) states that: *"Incremental temperature increases resulting from point source activities shall not, at any time, exceed 23/(T+5) (freshwater) . . . Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C. For purposes hereof, "t" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge." [The equation of t=28/(T+7) is used for Class A waters, and t=34/(T+9) used in Class B waters.]*

Load allocations (for nonpoint sources) and wasteload allocations (for point sources) are established in this TMDL to meet both the numeric threshold criteria and the allowances for human warming under conditions that are naturally warmer than those criteria.

The *system potential temperature* is an approximation of the temperature that would occur under natural conditions during specified conditions of air temperature and streamflow. The system potential temperature is estimated using analytical methods and computer simulations proven effective in modeling and predicting temperatures stream temperatures in Washington. The system potential temperature is based on our best estimates of the *mature riparian vegetation, natural channel shape, and riparian microclimate* that did not include human modifications.

A system potential temperature is estimated for both an average year (50^{th} percentiles of climate and low streamflows) and a *critical condition* year (upper 90^{th} percentile air temperature and low flows that occur only once every ten years). The system potential temperature does not, however, replace the numeric criteria, nor invalidate the need to meet the numeric criteria at other times of the year and at other less extreme low flows and warm climatic conditions.

At locations and times where the system potential temperature is greater than the numeric criterion assigned to the waterbody (e.g., 18ºC in Class A or 16ºC in Class AA waters), the loading capacity and load allocations in this TMDL are to be based on not allowing human sources to warm the water by more than an additional 0.3°C. In all waters where the system potential temperature is higher than the assigned criterion, maximum riparian shade and best channel and flow conditions possible are needed.

Since system potential water temperatures would not meet numeric water quality standards during the hottest period of the year throughout most of the Walla Walla basin, there is a widespread need to achieve maximum protection from direct solar radiation. An exception to this may be the portion of Mill Creek located in the preserved watershed above the City of Walla Walla diversion dam in Oregon. This section of Mill Creek currently meets the numeric water quality standard of 16°C year round. The highest 7-day-average maximum (7-DADMax**)** temperature measured at the site immediately upstream of the dam was 13.8°C during the summer of 2002. However, due to bull trout using this portion of the watershed for spawning, the water quality criteria for upper Mill Creek is expected to be changed to 12°C during the next revision of the state's water quality standards.

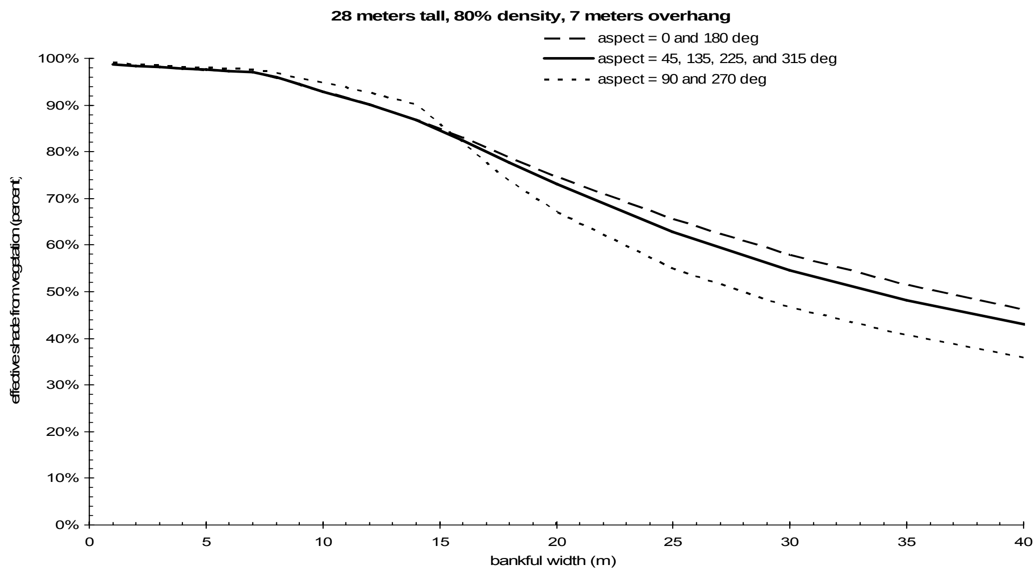
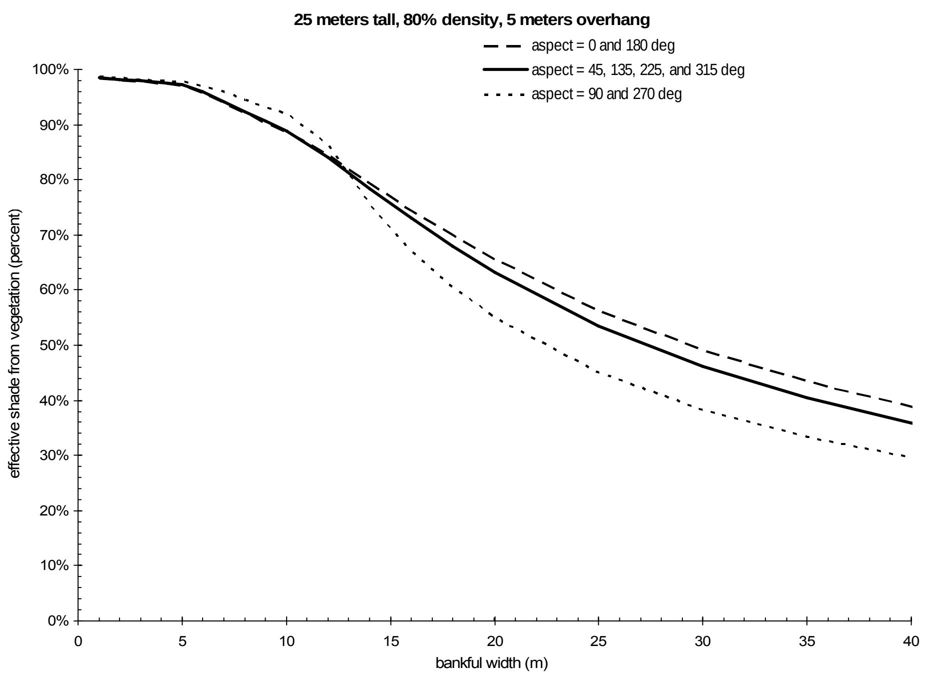
The load allocation for all streams in the Walla Walla tributaries study area located below the USFS boundary and the City of Walla Walla diversion dam is the effective shade that would occur from system potential mature riparian vegetation. *System potential mature riparian vegetation* is defined as that vegetation which can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.

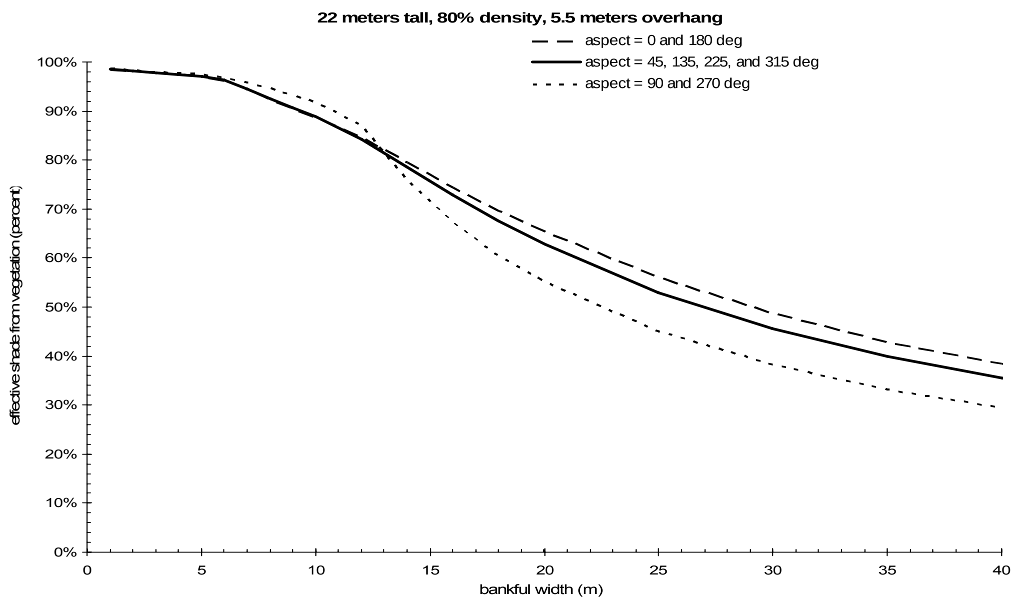
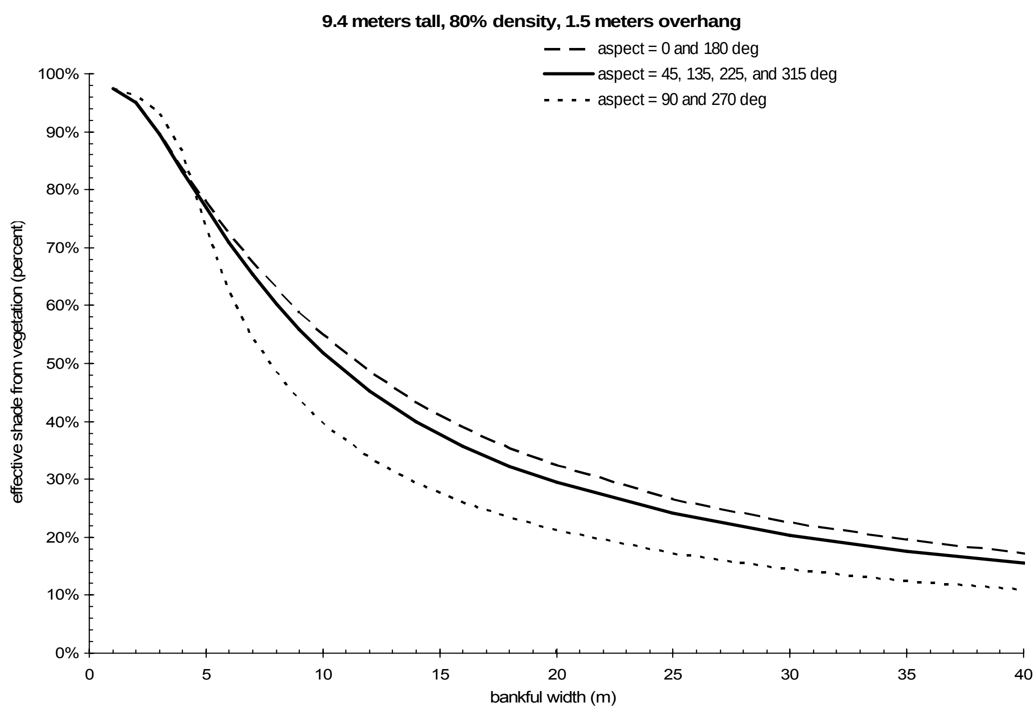
Load allocations for effective shade are quantified in Appendix D for the Touchet River, Mill Creek, and Yellowhawk Creek.

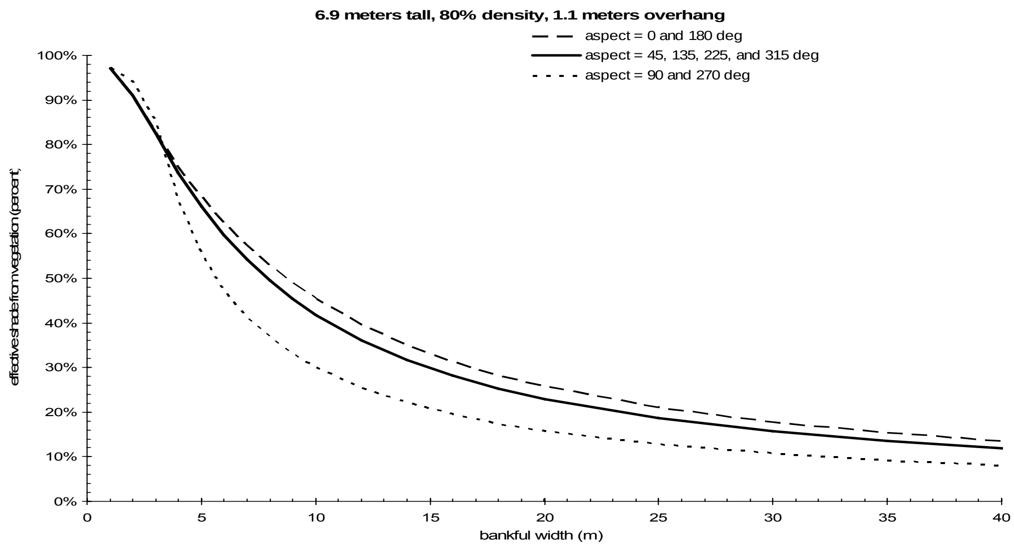
For lowland perennial streams in the watershed, the load allocations for shade are represented in Figure 37 (following three pages) and Appendix D based on the estimated relationship between shade, channel width, and stream aspect at the assumed maximum riparian vegetation condition from Figure 27 and Tables 11 and 12. Figure 37 shows that the importance of shade decreases as the width of the channel increases. Perennial streams include those that would naturally have flow year round but are currently dry part of the year due to withdrawals.

The load allocations are expected to result in water temperatures that are equivalent to the temperatures that would occur under natural conditions. Therefore, the load allocations are expected to result in water temperatures that meet the water quality standard.

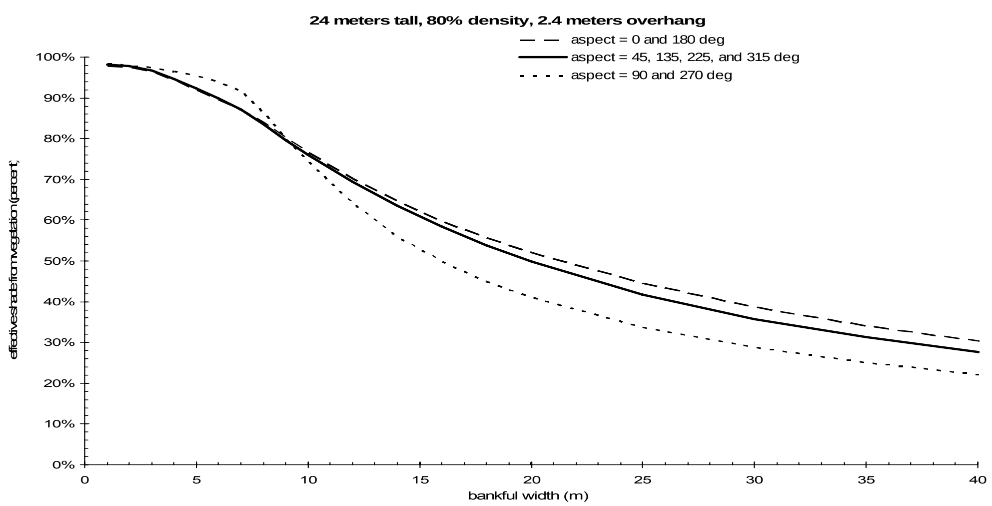
Establishment of mature riparian vegetation is expected to also have a secondary benefit of reducing channel widths and improving microclimate conditions to address those influences on the loading capacity. An adaptive management strategy is recommended to address other influences on stream temperature such as sediment loading, groundwater inflows, and hyporheic exchange.

	Cottonwood Gallery (location unspecified)
	Mixed Deciduous/ Conifer Zone (see map, Figure 27)

	Deciduous Zone
	Shrub/ Willow Zone High Estimate



Shrub/ Willow Zone Low Estimate



Conifer Zone – Blue Mountains

Figure 37. Load allocations for effective shade for various bankfull width and aspect of un-simulated perennial streams in the Walla Walla River watershed.

In addition to the load allocations for effective shade in the study area, the following management activities are recommended for compliance with the water quality standards throughout the watershed:

- Load allocations are included in this TMDL for non-federal forest lands in accordance with Section M-2 of the *Forests and Fish Report.* The report can be found at: www.dnr.wa.gov/forestpractices/rules/forestsandfish.pdf. 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 practices regulations.

- For areas that are not managed by the U.S. Forest Service or in accordance with the state forest practices rules, such as private non-forest areas, voluntary programs to increase riparian vegetation should be developed (for example, riparian buffers or conservation easements sponsored under the U.S. Department of Agriculture Natural Resources Conservation Service's Conservation Reserve Enhancement Program).

- Instream flows and water withdrawals are managed through regulatory avenues separate from TMDLs. However, stream temperature is related to the amount of instream flow, and increases in flow generally result in decreases in maximum temperatures. Future projects that have the potential to increase groundwater or surface water inflows to streams in the watershed should be encouraged and have the potential to decrease stream temperatures.

- Management activities that would reduce the loading of sediment to the surface waters from upland and channel erosion are also recommended.

- Hyporheic exchange flows and groundwater discharges are important to maintain the current temperature regime and reduce maximum daily instream temperatures. Factors that influence hyporheic exchange flow include the vertical hydraulic gradient between surface and subsurface waters as well as the hydraulic conductivity of the streambed sediments. Activities that reduce the hydraulic conductivity of streambed sediments could increase stream temperatures. Management activities should reduce upland and channel erosion and avoid sedimentation of fine materials in the stream substrate.

- Management activities that increase the amount of large woody debris in the Walla Walla River system will assist in pool forming processes and will assist in reducing flow velocities that wash out spawning gravels and contribute to channel downcutting.

Wasteload Allocations

The wasteload allocation for the National Pollution Discharge Elimination System (NPDES) discharge from the Dayton Wastewater Treatment Plant (WWTP) was evaluated. The Dayton WWTP discharges water to the Touchet River downstream of the confluence with Patit Creek.

The Washington State water quality standards (WAC 173-201A) restrict the amount of warming that point sources can cause when temperatures are cooler than the 18°C criteria in Class A waters:

Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=28/(T+7). For purposes hereof "t" represents the maximum permissible temperature increase measured at a mixing zone boundary; and T represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

At times and locations where the assigned numeric criteria cannot be attained even under estimated natural conditions, the state standards hold human warming to a cumulative allowance for additional warming of 0.3°C above the natural conditions estimated for those locations and times.

Maximum effluent temperatures should also be no greater than 33ºC to avoid creating areas in the mixing zone that would cause instantaneous lethality to fish and other aquatic life.

The load allocations for the nonpoint (diffuse) sources are considered to be sufficient to attain the water quality standards by resulting in water temperatures that are equivalent to natural conditions. Therefore, the water quality standards allow an increase over natural conditions for the point (discrete) sources for establishment of the wasteload allocations. However, point sources must still be regulated to meet the incremental warming restrictions established in the standards to protect cool water periods.

Maximum temperature for the Dayton WWTP NPDES-regulated effluent discharge to the Touchet River (T_{NPDES}) was calculated from the following mass balance equation (Ecology, 2007), in recognition that the system potential upstream temperature is greater than 18ºC.

Class A: T_{NPDES} = [18 ºC-0.3ºC] + [chronic dilution factor] * 0.3 ºC

Table 17 presents the maximum effluent temperature allowable for the reported dilution factor for the Dayton WWTP Permit No WA-002072-9 (Ecology, 2005). The system potential temperature upstream from the NPDES discharger may be greater than 18ºC for Class A waters and will vary depending on the river flow and weather conditions, but the wasteload allocation expressed in the permit limit must ensure the discharge does not exceed the water quality standards under all but the most critical conditions (7Q10 flows).

Table 17. Wasteload allocation for effluent temperature from the Dayton Wastewater Treatment Plant discharge to the Touchet River.

NPDES Facility	Chronic dilution factor	Water quality standard for temperature (degrees C)	Allowable increase in temperature at the mixing zone boundary (degrees C)	Tnpdes = Maximum allowable effluent temperature WLA (degrees C)
Dayton WWTP	13.6	18	0.3	21.8

WLA – wasteload allocation

Discharge Monitoring Report (DMR) data from the Dayton WWTP for June-Sept 2002 shows a maximum discharge temperature of 21.7ºC (71°F) (Ecology, 2003b). This current discharge temperature is within the limits of this TMDL. Therefore, the Dayton WWTP is currently operating within the limits of this temperature TMDL. When the NPDES permit is due for renewal in 2010, the discharge temperature limit may need to be adjusted if the volume of the summer discharge has increased. Growth in discharge or increase in upstream water withdrawals could cause Dayton to need to release at a cooler temperature.

EPA guidance suggests considering anticipated *future growth* when allocating loadings for point sources. Table 18 can be used to estimate the effect of increase in discharge volume on outfall temperature limits. It can also be used to compare discharge temperature limits under different numeric water quality temperature standards.

Effluent temperatures in Table 18 were calculated using the same equation as for Table 17 but with new chronic dilution factors. Dilution factors incorporate flow characteristics and volume of both the discharge and the receiving water. Instructions for conducting the mixing zone analysis to establish dilution factors and size of mixing zone are found in the NPDES permit guidance manual (Bailey, 2006).

In the absence of a mixing zone analysis to determine dilution factors, 25% of the 7Q10 flow is being used as dilution for the chronic condition. The estimated 7Q10 streamflow for July and August in this section of river is 29.6 cfs. The portion of the receiving water that is available for dilution would be 25% of 29.6, or 7.4 cfs.

Allowable effluent temperatures are calculated for three levels of discharge: the average June-Sept 2002 discharge, the plant design flow, and 85% of the design flow. Allowable effluent temperatures are also calculated using the equation above and three numeric water quality standards. Dilution factors for this analysis are calculated using the following equation from mixing zone guidance (Bailey, 2006; Appendix 6)

$$DF = \frac{(Qa + Qe)}{Qe}$$

Where:
DF=volumetric dilution factor
Qa = receiving water design flow (e.g., 25% of 7Q10)
Qe = effluent design flow

Table 18. Dayton Wastewater Treatment Plant effluent temperature limits under various scenarios of future growth and change in numeric temperature standard.

<table>
<tr><th>Condition</th><th>7Q10 flow for receiving water July-August (Touchet R.)</th><th>25% of flow available for dilution</th><th>Effluent flow from WWTP</th><th>Chronic dilution factor. Current permit is 13.6°C</th><th>Water quality standard for temp. (°C)</th><th>Allowable increase in temp. at the mixing zone boundary (°C)</th><th>Tnpdes = Maximum allowable effluent temp. WLA (°C)</th></tr>
<tr><td rowspan="3">Current condition: Average discharge June-Sept. 2002</td><td rowspan="9">29.6 cfs
=19.13mgd,
=0.838cms</td><td rowspan="9">7.4cfs
=4.78mgd,
=0.21cms</td><td rowspan="3">0.51cfs
=.328mgd,
=0.014cms</td><td rowspan="3">15.58</td><td>18</td><td rowspan="3">0.3</td><td>22.37</td></tr>
<tr><td>17.5</td><td>21.87</td></tr>
<tr><td>16</td><td>20.37</td></tr>
<tr><td rowspan="3">WWTP design flow condition</td><td rowspan="3">1.16 cfs
=0.75mgd,
=0.033cms</td><td rowspan="3">7.38</td><td>18</td><td rowspan="3">0.3</td><td>19.91</td></tr>
<tr><td>17.5</td><td>19.41</td></tr>
<tr><td>16</td><td>17.91</td></tr>
<tr><td rowspan="3">85% design flow condition</td><td rowspan="3">0.99cfs
=0.64mgd,
=.028cms</td><td rowspan="3">8.47</td><td>18</td><td rowspan="3">0.3</td><td>20.24</td></tr>
<tr><td>17.5</td><td>19.74</td></tr>
<tr><td>16</td><td>18.24</td></tr>
</table>

WLA – wasteload allocation
cfs – cubic feet per second
mgd – million gallons per day
cms – cubic meters per second

Other NPDES dischargers in the basin that are not given temperature wasteload allocations in this TMDL are the Walla Walla WWTP which discharges into lower Mill Creek, and the smaller College Place WWTP which discharges through wetlands prior to discharge into Garrison Creek. The Walla Walla WWTP (permit WA-002462-7) discharges to Mill Creek at RM 5.4 from December 1 – April 30 of each year which is not the critical time period for this TMDL.

The College Place WWTP discharges from May through October through wetlands prior to discharge into Garrison Creek. Effluent is discharged November through April directly to Garrison Creek. Average Ecology measured streamflows at the mouth of Garrison Creek during August-September 2002 were less than 0.4 cfs.

Modeling of Garrison Creek to determine the temperature of the system potential condition was not in the scope of the project plan (LeMoine and Stohr, 2002). The current NPDES permit WA-002065-6 (1) allows a maximum daily discharge temperature of 20°C during April through November and (2) has an interim measure stating that whenever effluent temperatures exceed 18.7ºC, the effluent may be re-directed to the constructed wetland through the West Wetland to Garrison Creek downstream of the Travaille irrigation diversion.

Margin of Safety

The margin of safety accounts for uncertainty about pollutant loading and waterbody response. In this TMDL, the margin of safety is addressed by using critical climatic conditions in the modeling analysis. The margin of safety in this TMDL is implicit because of the following:

- The 90th percentile of the highest 7-day averages of daily maximum air temperatures for each year of record at the Walla Walla Airport represents a reasonable worst-case condition for prediction of water temperatures in the Walla Walla watershed. Typical conditions were represented by the median of the highest 7-day averages of daily maximum air temperatures for each year of record.

- The lowest 7-day average flows during July-August with recurrence intervals of 10 years (7Q10) were used to evaluate reasonable worst-case conditions. Typical conditions were evaluated using the lowest 7-day average flows during July-August with recurrence intervals of 2 years (7Q2).

- Model uncertainty for prediction of maximum daily water temperatures was assessed by estimating the root-mean-square error (RMSE) of model predictions compared with observed temperatures during model validation. The average RMSE for model calibration and confirmation was 0.6°C.

- The load allocations are set to the effective shade provided by full mature riparian shade, which are the maximum values achievable in the Walla Walla River basin.

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Glossary, Acronyms, and Abbreviations

Glossary

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

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels (Dunne and Leopold, 1978).

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

Chronic critical effluent concentration: The maximum concentration of effluent during critical conditions at the boundary of the mixing zone assigned in accordance with WAC 173-201A-100. The boundary may be based on distance or a percentage of flow. Where no mixing zone is allowed, the chronic critical effluent concentration shall be 100% effluent.

Clean Water Act: Federal Act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

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

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

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100.
http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020

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

Effective shade: Effective **s**hade is the fraction or percentage of incoming solar radiation heat energy above the vegetation and topography that is blocked from reaching the surface of the water. Effective shade for this project is a daily value. Solar radiation above and below the vegetation and topography is calculated for each hour of the day from sunrise to sunset.

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

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

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

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

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

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

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

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

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

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of Washington State.

System potential: The design condition used for TMDL analysis.

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

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

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

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) load allocations for nonpoint sources, (3) contribution of natural sources, and (4) margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

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

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

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

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

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

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

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

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

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

Appendices

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Appendix A. Continuous water temperature monitoring data for May-October 2002

This appendix shows graphs of the daily maximum water temperatures measured by the Department of Ecology during this study. Temperatures were recorded every 30 minutes by Onset Stowaway Tidbit monitors (Stohr, 2002). Complete digital files of all continuous air and water temperature data measured by Ecology are available at
www.ecy.wa.gov/programs/wq/tmdl/watershed/wallawalla/prelim_results.html#Temperature

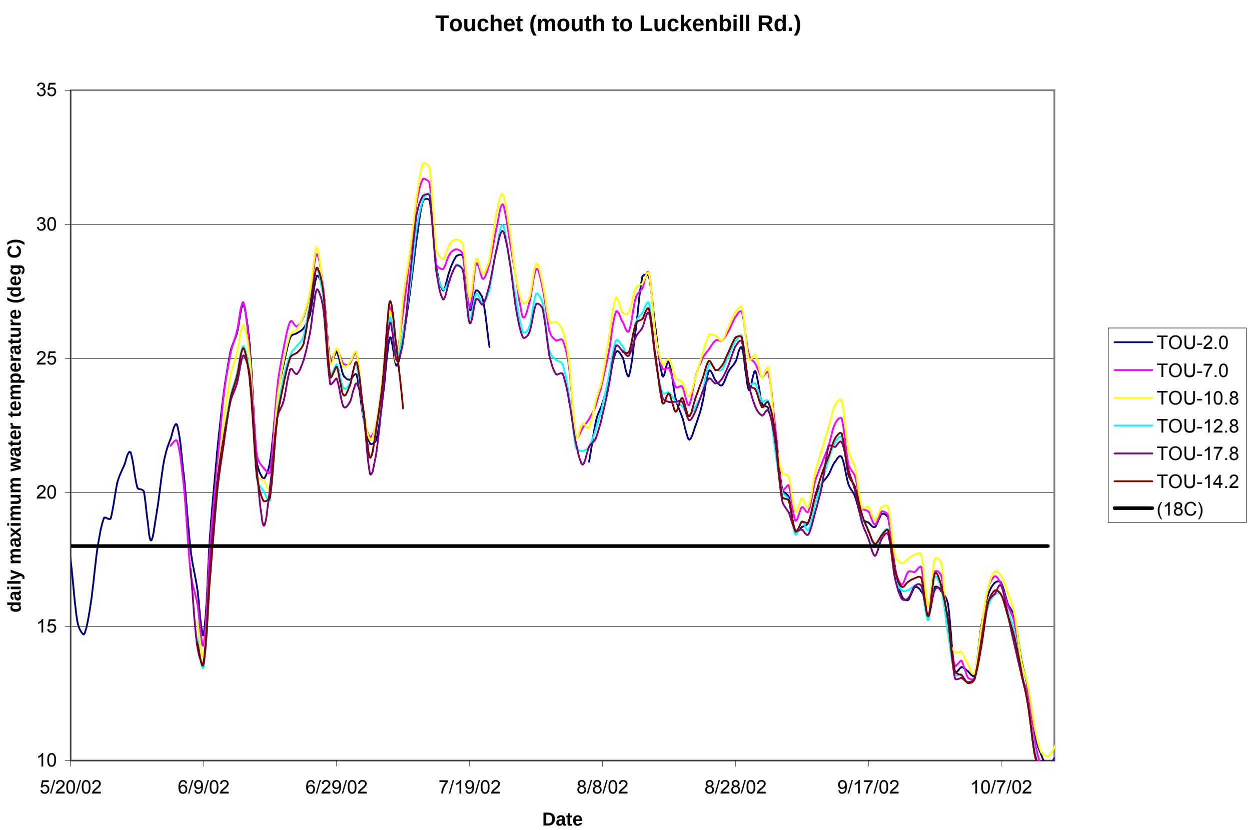

Figure A-1. Daily maximum water temperatures in the mainstem Touchet River from the mouth to Luckenbill Road (RM 17.8).

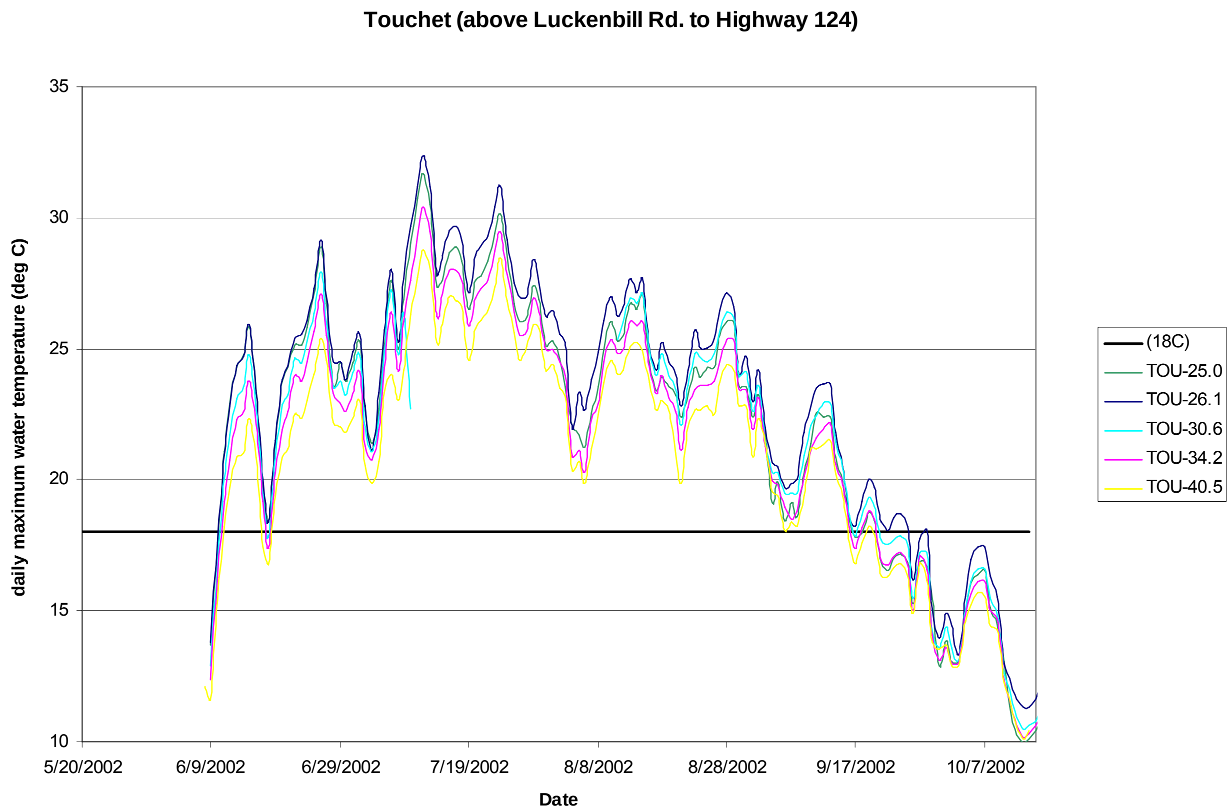

Figure A-2. Daily maximum water temperatures in the mainstem Touchet River from above Luckenbill Road (RM 25.0) to Bolles Road (Highway 124, RM 40.5).

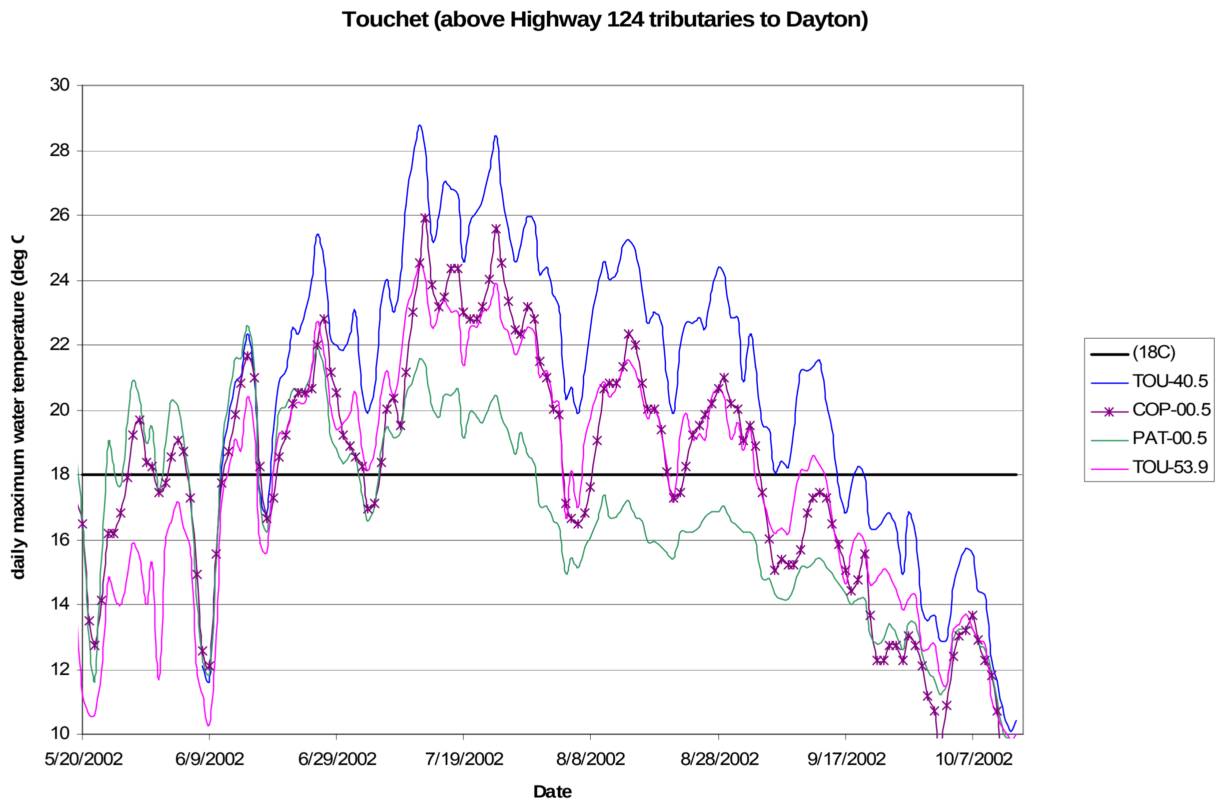

Figure A-3. Daily maximum water temperatures in the mainstem Touchet River and tributaries from Bolles Road (Highway 124, RM 40.5) to Dayton City Park (RM 53.9).

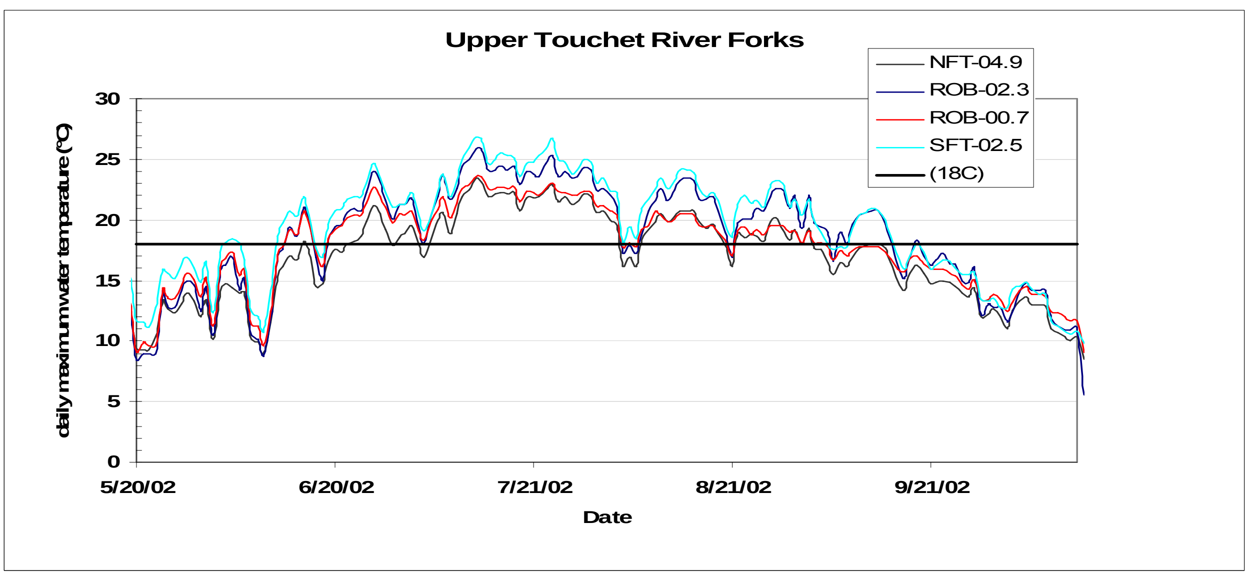

Figure A-4. Daily maximum water temperatures in the upper Touchet River forks (above Dayton).

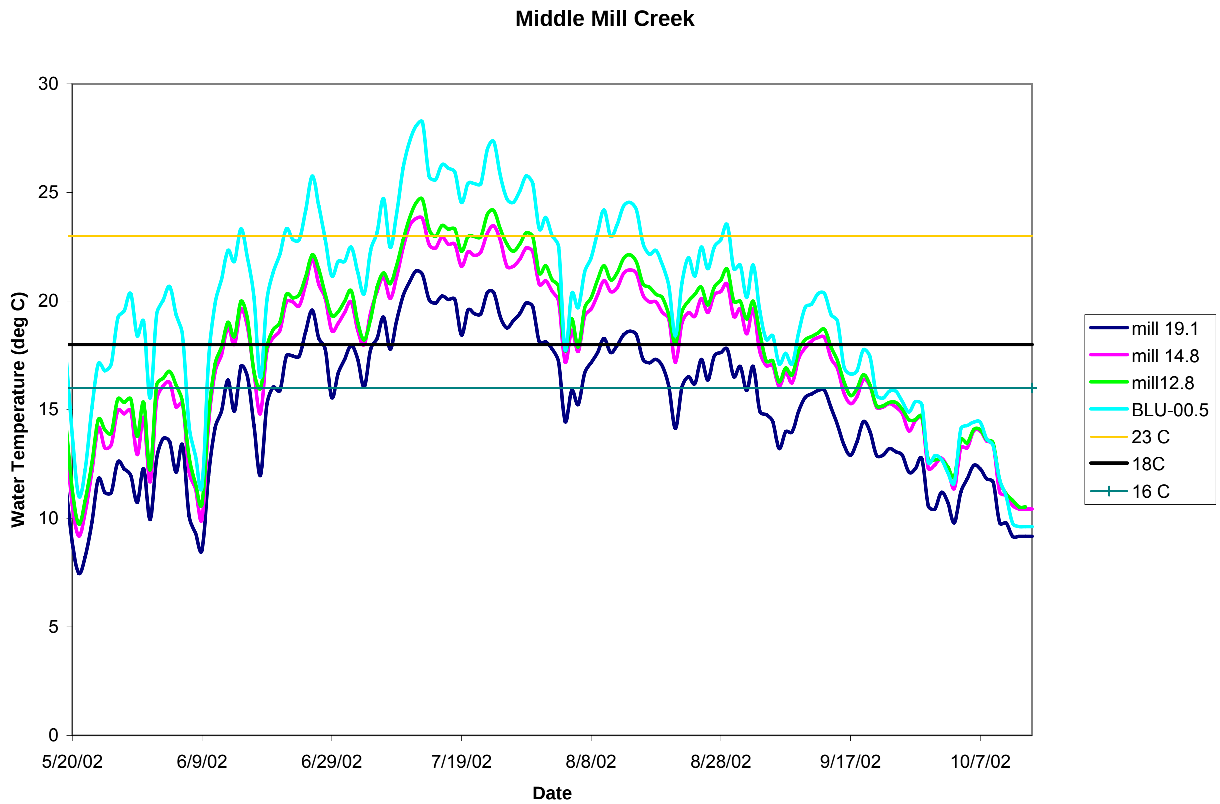

Figure A-5. Daily maximum water temperatures in Mill Creek from RM 12.8 (5-mile bridge) to RM 19.1 (below Kooskooskie).

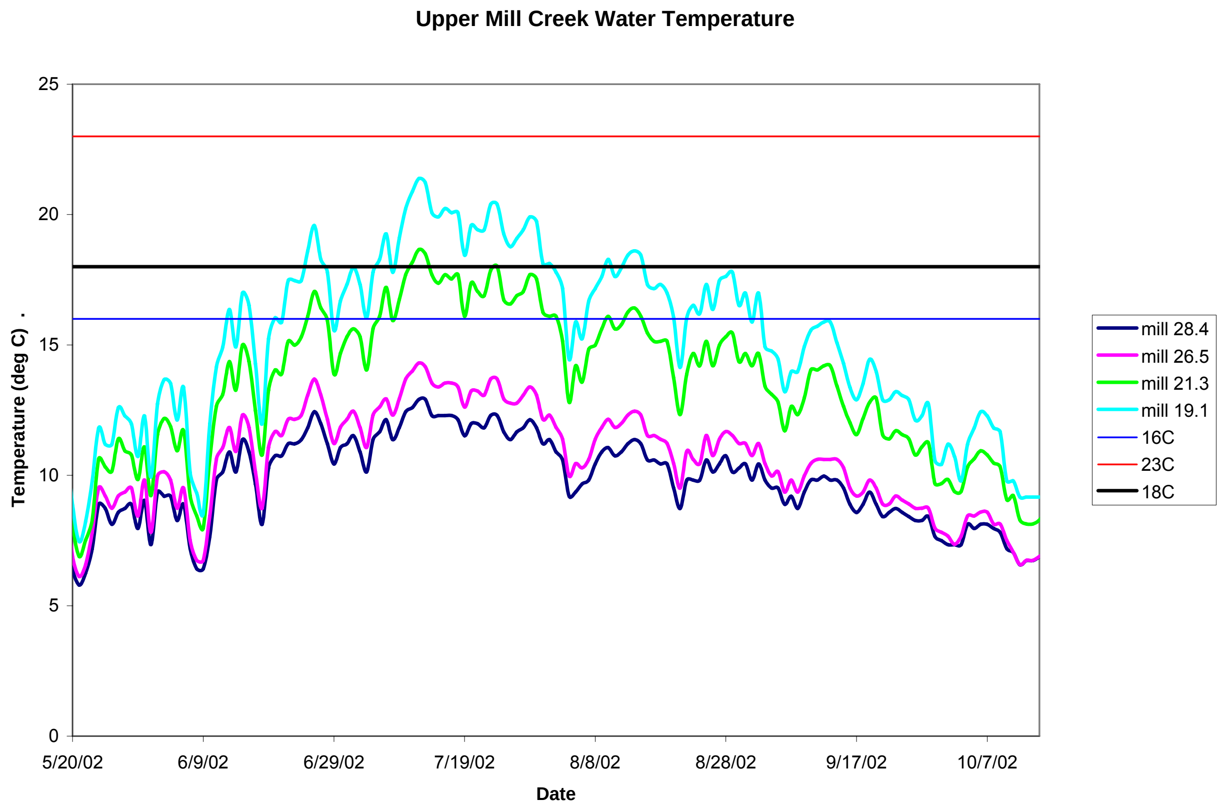

Figure A-6. Daily maximum water temperatures in upper Mill Creek from RM 19.1 (just downstream of WA/OR border), to RM 21.3 (below drinking water diversion), to RM 28.4 (above diversion near the upstream crossing of the WA/OR border).

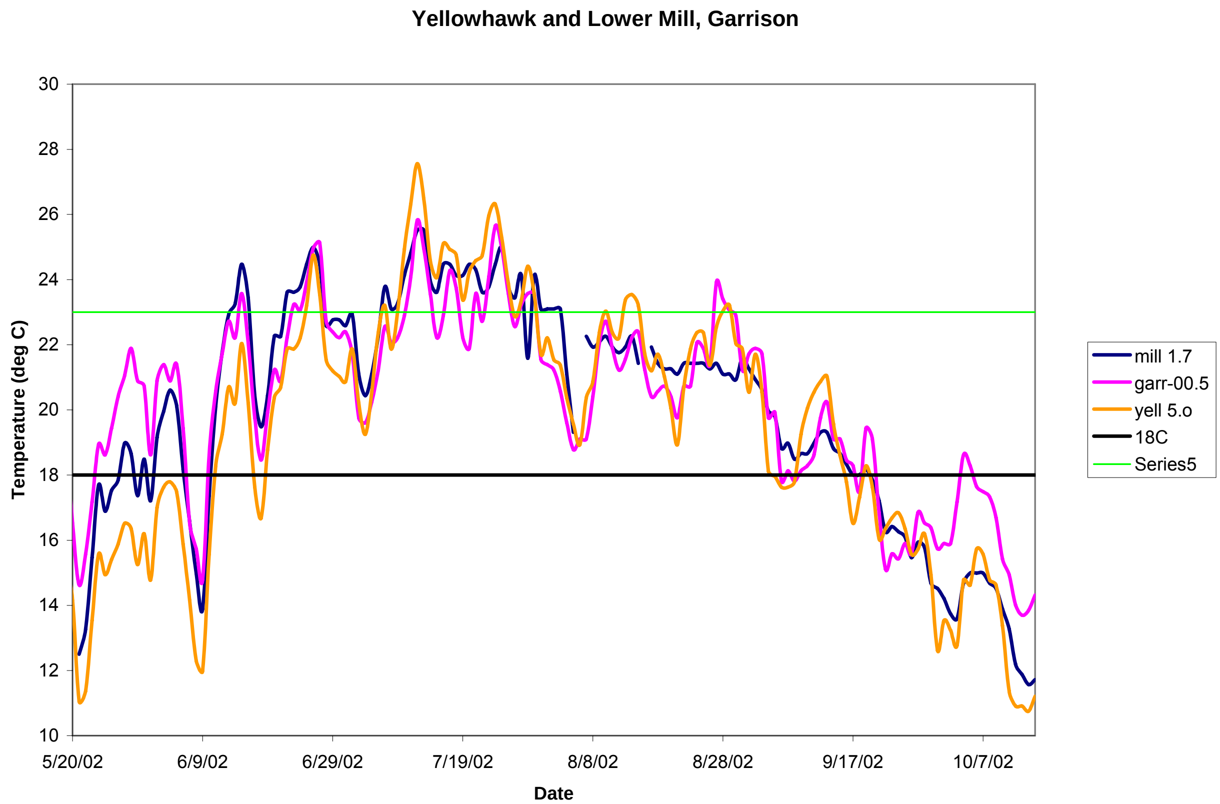

Figure A-7. Daily maximum water temperatures in Yellowhawk Creek and lower Mill and Garrison Creeks.

Appendix B. Flow data from Ecology's field surveys

Table B-1. Individual flow measurements from Department of Ecology field surveys, 2002.

Q = streamflow, A = area of wetted cross-section, WP = wetted perimeter

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft^2)	WP (ft)	Wet Width (ft)
Blue Creek	0.2	32BLU-00.2	5/15/02	15:30	8.26	7.85	12.52	12.1
Blue Creek	0.2	32BLU-00.2	6/7/02	9:02	2.69	5.09	11.57	11.3
Blue Creek	0.2	32BLU-00.2	7/12/02	9:20	0.96	3.54	10.56	10.3
Blue Creek	0.2	32BLU-00.2	8/7/02	9:38	0.68	2.36	8.81	8.6
Blue Creek	0.2	32BLU-00.2	9/10/02	14:19	0.46	1.46	6.87	6.0
Blue Creek	0.2	32BLU-00.2	10/16/02	9:08	1.07	4.50	11.84	11.1
Coppei Creek	0.5	32COP-00.5	5/16/02	15:00	7.02	6.65	13.00	12.5
Coppei Creek	0.5	32COP-00.5	6/5/02	15:40	3.37	4.67	11.78	11.2
Coppei Creek	0.5	32COP-00.5	7/10/02	9:45	0.91	11.81	16.66	14.9
Coppei Creek	0.5	32COP-00.5	7/30/02	10:00	0.19	0.39	3.19	2.9
Coppei Creek	0.5	32COP-00.5	8/6/02	12:00	0.76	5.50	11.01	10.5
Coppei Creek	0.5	32COP-00.5	9/3/02	13:30	0.21	0.95	4.29	4.1
Coppei Creek	0.5	32COP-00.5	9/10/02	17:00	0.62	6.75	12.74	12.3
Coppei Creek	0.5	32COP-00.5	10/18/02	14:47	1.82	9.66	13.67	13.7
Cottonwood Creek	1	32COT-01.0	8/1/02	9:00	0.31	2.02	11.53	11.5
Dry Creek	0.5	32DRY-00.5	6/12/02	11:15	7.21	na	na	8.9
Dry Creek	0.5	32DRY-00.5	5/14/02	14:30	14.87	na	na	9.5
Dry Creek	0.5	32DRY-00.5	9/16/02	15:20	0.98	na	na	9.6
Dry Creek	0.5	32DRY-00.5	8/21/02	16:15	0.29	na	na	9.1
Dry Creek	0.5	32DRY-00.5	9/3/02	17:15	0.26	na	na	9.8
Dry Creek	0.5	32DRY-00.5	5/29/02	19:15	11.62	na	na	9.4
Dry Creek	0.5	32DRY-00.5	7/31/02	12:55	0.14	0.29	3.64	3.6
Dry Creek	0.5	32DRY-00.5	9/5/02	10:25	0.58	0.62	4.60	4.5
Dry Creek	3	32DRY-03.0	8/7/02	10:15	2.73	2.88	6.67	6.2
Dry Creek	27.4	32DRY-27.4	8/7/02	14:52	0.00	3.13	5.19	4.8
Garrison Creek	0.5	32GAR-00.5	9/17/02	9:20	0.06	na	na	4.5
Garrison Creek	0.5	32GAR-00.5	8/22/02	11:25	0.11	na	na	2.8
Garrison Creek	0.5	32GAR-00.5	9/4/02	12:20	0.27	na	na	4.9
Garrison Creek	0.5	32GAR-00.5	5/14/02	12:45	3.39	na	na	6.3
Garrison Creek	0.5	32GAR-00.5	5/29/02	16:15	3.9	na	na	6.0
Garrison Creek	0.5	32GAR-00.5	6/11/02	16:45	2.78	na	na	5.6
Garrison Creek	0.5	32GAR-00.5	5/16/02	17:10	2.52	1.66	4.47	4.1
Garrison Creek	0.5	32GAR-00.5	6/4/02	12:18	2.15	1.67	4.61	4.0
Garrison Creek	0.5	32GAR-00.5	6/27/02	14:55	1.06	0.63	3.39	3.5
Garrison Creek	0.5	32GAR-00.5	7/10/02	7:20	0.31	0.32	2.97	2.9
Garrison Creek	0.5	32GAR-00.5	8/1/02	11:30	0.22	0.46	3.07	2.8
Garrison Creek	0.5	32GAR-00.5	8/7/02	16:00	0.04	0.14	2.94	2.9
Garrison Creek	0.5	32GAR-00.5	9/4/02	13:50	0.43	0.60	3.09	3.0
Garrison Creek	0.5	32GAR-00.5	9/19/02	13:55	0.39	0.71	3.16	3.0
Garrison Creek	0.5	32GAR-00.5	10/16/02	9:00	0.62	0.61	3.50	3.7

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft²)	WP (ft)	Wet Width (ft)
Garrison Creek	0.5	32GAR-00.5	11/20/02	14:30	1.68	2.28	4.35	4.2
Garrison Creek	10.2	32GAR-10.2	8/7/02	15:15	2.41	5.84	9.74	9.1
Mill Creek	0.5	32MIL-00.5	6/27/02	16:15	8.17	9.15	12.40	12.1
Mill Creek	0.5	32MIL-00.5	7/11/02	9:35	4.48	3.70	12.30	12.9
Mill Creek	0.5	32MIL-00.5	8/1/02	10:15	0.13	0.76	3.53	4.4
Mill Creek	0.5	32MIL-00.5	9/4/02	15:40	0.26	1.62	10.77	11.1
Mill Creek	0.5	32MIL-00.5	9/19/02	15:55	0.32	1.54	10.59	10.9
Mill Creek	0.5	32MIL-00.5	10/16/02	15:45	2.01	2.93	10.90	11.4
Mill Creek	0.5	32MIL-00.5	11/20/02	15:05	14.46	7.21	13.54	14.1
Mill Creek	0.7	32MIL-00.7	8/22/02	13:15	0.11	na	na	3.4
Mill Creek	0.7	32MIL-00.7	9/16/02	16:35	0.82	na	na	7.4
Mill Creek	0.7	32MIL-00.7	5/13/02	17:30	99.62	na	na	25.0
Mill Creek	0.7	32MIL-00.7	9/3/02	18:30	0.50	na	na	6.6
Mill Creek	1.7	32MIL-01.7	5/16/02	17:35	95.74	30.52	25.08	24.5
Mill Creek	1.7	32MIL-01.7	6/3/02	17:20	76.11	26.54	25.10	23.8
Mill Creek	1.7	32MIL-01.7	7/12/02	7:45	7.00	21.92	50.29	49.8
Mill Creek	1.7	32MIL-01.7	8/7/02	14:09	0.04	0.32	2.78	2.7
Mill Creek	1.7	32MIL-01.7	9/10/02	7:40	1.21	1.52	6.71	6.5
Mill Creek	1.7	32MIL-01.7	10/16/02	13:55	2.52	4.42	12.36	12.1
Mill Creek	2.8	32MIL-02.8	6/27/02	9:00	8.50	5.19	23.62	23.5
Mill Creek	2.8	32MIL-02.8	7/11/02	10:55	5.22	5.72	13.19	13.0
Mill Creek	2.8	32MIL-02.8	8/1/02	10:34	3.80	4.92	13.44	13.3
Mill Creek	2.8	32MIL-02.8	8/7/02	9:55	2.96	8.19	29.59	25.5
Mill Creek	2.8	32MIL-02.8	8/14/02	15:30	3.54	4.47	10.41	10.6
Mill Creek	2.8	32MIL-02.8	9/4/02	14:15	4.10	3.22	11.82	11.7
Mill Creek	2.8	32MIL-02.8	9/19/02	15:00	3.81	3.63	12.72	12.5
Mill Creek	2.8	32MIL-02.8	10/16/02	15:20	5.66	6.50	13.23	12.7
Mill Creek	2.8	32MIL-02.8	11/20/02	15:30	13.18	8.59	17.63	17.0
Mill Creek	4.8	32MIL-04.8	6/27/02	9:00	3.32	14.04	21.68	22.2
Mill Creek	4.8	32MIL-04.8	8/1/02	15:35	0.15	0.22	2.52	2.5
Mill Creek	4.8	32MIL-04.8	8/7/02	13:30	0.37	2.52	9.13	8.3
Mill Creek	4.8	32MIL-04.8	8/14/02	14:15	0.17	0.23	2.48	2.5
Mill Creek	4.8	32MIL-04.8	9/4/02	14:20	0.15	0.25	2.54	2.5
Mill Creek	4.8	32MIL-04.8	9/19/02	14:25	0.36	0.48	4.13	2.7
Mill Creek	4.8	32MIL-04.8	10/16/02	12:45	0.43	0.35	2.58	2.5
Mill Creek	4.8	32MIL-04.8	11/20/02	13:30	5.13	12.99	15.21	14.7
Mill Creek	6.7	32MIL-06.7	9/19/02	12:45	2.75	1.64	3.95	3.1
Mill Creek	6.7	32MIL-06.7	10/16/02	11:50	2.22	1.02	3.48	3.1
Mill Creek	6.7	32MIL-06.7	11/20/02	12:10	6.46	1.90	4.00	3.0
Mill Creek	12.8	32MIL-12.8	5/15/02	17:10	134.20	50.22	43.90	43.6
Mill Creek	12.8	32MIL-12.8	6/7/02	7:50	89.00	40.90	42.98	42.7
Mill Creek	12.8	32MIL-12.8	6/27/02	10:30	40.88	24.58	41.65	41.5
Mill Creek	12.8	32MIL-12.8	7/12/02	7:43	26.98	26.32	34.26	34.1
Mill Creek	12.8	32MIL-12.8	7/12/02	7:43	29.92	28.91	34.26	34.1
Mill Creek	12.8	32MIL-12.8	8/1/02	9:00	20.08	14.20	38.98	38.9
Mill Creek	12.8	32MIL-12.8	8/7/02	12:45	25.86	17.57	36.49	36.4
Mill Creek	12.8	32MIL-12.8	9/4/02	10:00	23.75	16.20	35.30	35.2
Mill Creek	12.8	32MIL-12.8	9/10/02	8:57	22.33	16.44	39.08	39.0

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft²)	WP (ft)	Wet Width (ft)
Mill Creek	12.8	32MIL-12.8	9/19/02	10:55	24.69	16.76	37.81	37.7
Mill Creek	12.8	32MIL-12.8	10/15/02	18:21	27.97	25.61	35.57	35.4
Mill Creek	14.8	32MIL-14.8	5/15/02	16:15	142.78	54.53	61.18	60.7
Mill Creek	14.8	32MIL-14.8	6/7/02	8:40	84.26	40.19	55.23	55.0
Mill Creek	14.8	32MIL-14.8	7/12/02	8:30	31.21	27.17	46.77	46.6
Mill Creek	14.8	32MIL-14.8	8/7/02	8:05	27.04	23.84	47.07	46.9
Mill Creek	14.8	32MIL-14.8	9/10/02	9:30	25.94	26.79	44.83	44.4
Mill Creek	14.8	32MIL-14.8	10/16/02	9:41	31.82	25.69	45.77	45.6
Mill Creek	19.1	32MIL-19.1	5/15/02	14:30	126.05	51.57	48.82	48.3
Mill Creek	19.1	32MIL-19.1	6/7/02	9:40	84.32	43.54	45.64	45.1
Mill Creek	19.1	32MIL-19.1	7/12/02	10:43	31.01	31.71	41.97	41.5
Mill Creek	19.1	32MIL-19.1	8/7/02	8:52	28.80	30.52	39.96	39.6
Mill Creek	19.1	32MIL-19.1	9/10/02	10:07	26.00	27.69	40.03	39.8
Mill Creek	19.1	32MIL-19.1	10/16/02	8:25	32.32	31.81	41.83	41.2
Mill Creek	21.1	32MIL-21.1	7/12/02	11:35	27.98	29.98	31.28	30.8
Mill Creek	21.1	32MIL-21.1	8/1/02	9:00	28.70	18.12	32.97	32.5
Mill Creek	21.1	32MIL-21.1	8/14/02	11:25	25.12	17.79	32.70	32.3
Mill Creek	21.1	32MIL-21.1	9/19/02	10:15	31.67	22.11	33.05	32.3
Mill Creek	21.1	32MIL-21.1	10/16/02	9:00	31.59	18.79	35.59	34.3
Mill Creek	21.1	32MIL-21.1	11/20/02	9:50	38.94	23.10	34.71	33.8
Mill Creek	21.3	32MIL-21.3	5/15/02	13:35	115.18	52.42	34.57	33.6
Mill Creek	21.3	32MIL-21.3	6/7/02	10:20	70.60	42.94	34.70	33.8
Mill Creek	21.3	32MIL-21.3	7/12/02	11:35	27.98	29.98	31.28	30.8
Mill Creek	21.3	32MIL-21.3	8/7/02	13:44	27.53	29.38	29.80	29.3
Mill Creek	21.3	32MIL-21.3	9/10/02	10:45	27.12	30.70	29.85	28.9
Mill Creek	21.3	32MIL-21.3	10/18/02	8:40	28.28	28.30	30.33	29.6
Mill Creek	26.5	32MIL-26.5	5/15/02	12:30	82.66	29.21	52.95	51.1
Mill Creek	26.5	32MIL-26.5	6/7/02	11:25	71.83	33.12	69.54	68.6
Mill Creek	26.5	32MIL-26.5	7/12/02	16:09	40.94	26.22	48.57	47.7
Mill Creek	26.5	32MIL-26.5	8/7/02	12:35	38.23	27.31	67.38	66.2
Mill Creek	26.5	32MIL-26.5	9/10/02	13:15	37.96	25.85	67.36	66.9
Mill Creek	26.5	32MIL-26.5	10/18/02	12:18	34.03	33.50	67.04	66.2
Mill Creek	27.5	32MIL-27.5	5/15/02	10:00	106.18	46.92	37.19	36.5
Mill Creek	27.5	32MIL-27.5	6/7/02	14:30	68.09	37.27	36.95	35.8
Mill Creek	27.5	32MIL-27.5	8/7/02	11:03	39.93	27.51	31.70	31.0
Mill Creek	27.5	32MIL-27.5	9/10/02	12:05	35.14	27.55	31.51	30.7
Mill Creek	27.5	32MIL-27.5	10/18/02	11:15	36.07	24.50	32.50	32.0
Mill Creek	28.4	32MIL-28.4	6/7/02	13:05	56.15	31.64	31.04	30.5
Mill Creek	28.4	32MIL-28.4	7/12/02	13:56	28.43	20.26	27.69	26.8
Mill Creek	28.4	32MIL-28.4	8/7/02	10:05	30.61	22.25	31.16	30.4
Mill Creek	28.4	32MIL-28.4	10/18/02	10:05	22.17	20.44	31.21	30.4
Mud Creek	0.5	32MUD-00.5	7/31/02	11:00	3.57	4.84	7.26	6.1
Mud Creek	0.5	32MUD-00.5	9/5/02	11:20	1.54	2.79	7.57	7.3
Mud Creek	0.5	32MUD-00.5	9/18/02	12:55	2.43	4.31	8.75	8.5
North Fork Touchet	0	32NFT-00.0	6/25/02	10:05	55.27	24.82	38.65	40.0
North Fork Touchet	0	32NFT-00.0	7/9/02	11:25	61.22	29.71	37.92	38.7
North Fork Touchet	0	32NFT-00.0	7/30/02	15:05	43.00	30.59	34.74	37.9

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft²)	WP (ft)	Wet Width (ft)
North Fork Touchet	0	32NFT-00.0	8/6/02	12:20	46.09	16.62	30.70	30.3
North Fork Touchet	0	32NFT-00.0	8/13/02	8:45	42.90	17.71	26.05	25.9
North Fork Touchet	0	32NFT-00.0	9/3/02	10:25	37.30	21.69	37.91	38.4
North Fork Touchet	0	32NFT-00.0	9/17/02	9:20	39.92	23.10	36.98	37.8
North Fork Touchet	0	32NFT-00.0	10/15/02	10:00	44.93	26.92	37.61	38.2
North Fork Touchet	0	32NFT-00.0	11/19/02	9:30	51.25	33.02	38.48	38.5
North Fork Touchet	4.9	32NFT-04.9	5/16/02	11:30	98.04	27.29	30.95	30.4
North Fork Touchet	4.9	32NFT-04.9	6/5/02	12:20	91.48	24.18	31.45	30.6
North Fork Touchet	4.9	32NFT-04.9	7/11/02	15:13	28.48	18.05	23.92	23.6
North Fork Touchet	4.9	32NFT-04.9	8/6/02	10:10	18.04	18.69	21.36	20.6
North Fork Touchet	4.9	32NFT-04.9	9/12/02	12:35	13.71	16.73	20.18	19.5
North Fork Touchet	4.9	32NFT-04.9	10/15/02	12:10	20.83	16.45	29.53	29.2
Patit Creek	0.1	32PAT-00.1	5/17/02	10:25	17.49	11.45	17.96	17.6
Patit Creek	0.1	32PAT-00.1	6/5/02	14:47	11.28	8.97	17.37	16.8
Patit Creek	0.1	32PAT-00.1	7/10/02	14:30	1.43	3.26	14.19	12.1
Patit Creek	0.1	32PAT-00.1	7/31/02	13:00	0.00	1.13	4.34	4.2
Patit Creek	0.1	32PAT-00.1	8/6/02	15:30	0.79	1.80	14.90	14.5
Pine Creek	1.4	32PIN-01.4	5/30/02	10:00	5.02	na	na	12.0
Pine Creek	1.4	32PIN-01.4	6/12/02	11:45	15.5	na	na	13.5
Pine Creek	1.4	32PIN-01.4	5/13/02	14:00	15.09	na	na	13.5
Pine Creek	1.4	32PIN-01.4	8/21/02	15:00	0.08	na	na	1.9
Pine Creek	1.4	32PIN-01.4	9/3/02	16:15	0.02	na	na	0.3
Pine Creek	1.4	32PIN-01.4	8/7/02	8:20	0.00	2.63	7.24	7.1
Robinson Creek	0.7	32ROB-00.7	5/16/02	10:40	17.49	11.45	35.71	35.5
Robinson Creek	0.7	32ROB-00.7	6/5/02	11:40	11.28	8.97	32.59	32.3
Robinson Creek	0.7	32ROB-00.7	7/11/02	14:07	1.43	3.26	32.74	32.5
Robinson Creek	0.7	32ROB-00.7	8/6/02	11:25	0.79	1.80	28.38	28.0
Robinson Creek	0.7	32ROB-00.7	9/12/02	12:52	0.33	2.41	22.31	22.2
Robinson Creek	2.3	32ROB-02.3	5/16/02	10:15	25.08	10.61	35.71	35.5
Robinson Creek	2.3	32ROB-02.3	6/5/02	11:05	12.99	7.29	32.59	32.3
Robinson Creek	2.3	32ROB-02.3	7/11/02	12:21	1.76	10.87	32.74	32.5
Robinson Creek	2.3	32ROB-02.3	8/6/02	9:25	0.66	1.87	28.38	28.0
Robinson Creek	2.3	32ROB-02.3	9/12/02	11:30	0.15	9.68	22.31	22.2
Robinson Creek	2.3	32ROB-02.3	10/15/02	10:10	0.66	4.68	9.16	8.6
Russell Creek	0.1	32RUS-00.1	8/1/02	12:00	0.53	0.95	6.25	6.2
Russell Creek	0.1	32RUS-00.1	9/4/02	12:45	1.00	0.76	4.26	4.1
South Fork Touchet	0	32SFT-00.0	6/25/02	11:00	20.51	9.23	19.82	19.7
South Fork Touchet	0	32SFT-00.0	7/9/02	12:21	8.82	6.92	17.49	17.3
South Fork Touchet	0	32SFT-00.0	7/30/02	14:40	3.92	5.52	14.06	13.9
South Fork Touchet	0	32SFT-00.0	8/6/02	12:45	3.53	4.41	13.12	12.9
South Fork Touchet	0	32SFT-00.0	8/13/02	9:10	2.24	3.49	12.53	12.5
South Fork Touchet	0	32SFT-00.0	9/3/02	10:00	1.49	2.93	11.97	11.8
South Fork Touchet	0	32SFT-00.0	9/17/02	9:30	1.39	3.48	12.68	12.6
South Fork Touchet	0	32SFT-00.0	10/15/02	10:20	2.64	3.27	15.85	15.6
South Fork Touchet	0	32SFT-00.0	11/19/02	10:00	5.50	6.18	16.44	16.3
South Fork Touchet	2.5	32SFT-02.5	5/16/02	12:15	63.21	28.02	39.07	38.8
South Fork Touchet	2.5	32SFT-02.5	6/5/02	13:00	48.67	24.84	38.75	38.3
South Fork Touchet	2.5	32SFT-02.5	7/10/02	10:35	11.86	12.10	26.82	26.6

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft²)	WP (ft)	Wet Width (ft)
South Fork Touchet	2.5	32SFT-02.5	8/6/02	13:30	5.03	4.33	11.96	11.6
South Fork Touchet	2.5	32SFT-02.5	9/12/02	13:14	2.47	9.03	21.77	21.5
South Fork Touchet	2.5	32SFT-02.5	10/15/02	12:50	4.04	9.30	23.56	23.4
Touchet River	2	32TOU-02.0	5/17/02	12:00	231.80	85.74	59.85	57.6
Touchet River	2	32TOU-02.0	6/4/02	15:25	192.50	83.21	60.95	58.8
Touchet River	2	32TOU-02.0	7/8/02	9:30	44.09	25.96	37.84	37.7
Touchet River	2	32TOU-02.0	8/6/02	8:20	11.15	46.33	50.89	50.5
Touchet River	2	32TOU-02.0	9/11/02	8:40	10.51	18.51	58.71	58.1
Touchet River	2	32TOU-02.0	10/16/02	6:43	20.79	22.80	44.14	43.7
Touchet River	2	32TOU-02.0	11/19/02	15:15		0.00	0.00	
Touchet River	3.9	32TOU-03.9	8/9/02	9:30	15.26	91.68	47.30	45.8
Touchet River	3.9	32TOU-03.9	10/17/02	12:40	33.71	66.86	45.31	66.9
Touchet River	7	32TOU-07.0	6/4/02	9:48	209.88	159.73	59.50	57.0
Touchet River	7	32TOU-07.0	7/8/02	8:59	62.54	29.19	36.96	36.7
Touchet River	7	32TOU-07.0	7/9/02	9:42	57.70	102.63	56.66	55.5
Touchet River	7	32TOU-07.0	7/29/02	14:55	32.70	47.98	65.16	64.7
Touchet River	7	32TOU-07.0	8/6/02	11:48	27.08	107.48	49.20	47.9
Touchet River	7	32TOU-07.0	9/11/02	12:15	18.15	98.73	49.51	47.7
Touchet River	7	32TOU-07.0	9/17/02	17:00		0.00	0.00	
Touchet River	7	32TOU-07.0	10/15/02	14:55		0.00	0.00	
Touchet River	7	32TOU-07.0	10/17/02	13:45	36.03	106.07	49.19	47.9
Touchet River	10.8	32TOU-10.8	6/6/02	10:28	171.56	153.05	57.84	55.9
Touchet River	10.8	32TOU-10.8	8/6/02	14:10	21.64	109.83	53.15	52.3
Touchet River	10.8	32TOU-10.8	9/11/02	13:05	19.16	102.31	53.80	52.4
Touchet River	10.8	32TOU-10.8	10/17/02	14:32	35.50	111.13	54.65	53.5
Touchet River	12.8	32TOU-12.8	6/7/02	12:00	191.38	57.81	50.38	49.5
Touchet River	12.8	32TOU-12.8	7/9/02	10:55	64.08	32.97	47.12	46.7
Touchet River	12.8	32TOU-12.8	8/6/02	14:07	34.10	33.17	31.80	31.3
Touchet River	12.8	32TOU-12.8	9/11/02	15:30	26.04	32.13	30.53	30.0
Touchet River	12.8	32TOU-12.8	10/16/02	16:19	38.01	31.47	31.25	30.7
Touchet River	14.2	32TOU-14.2	7/9/02	12:47	60.19	63.01	48.10	46.5
Touchet River	14.2	32TOU-14.2	8/6/02	15:06	27.66	52.90	46.52	45.3
Touchet River	14.2	32TOU-14.2	10/17/02	16:00	44.24	54.37	46.65	45.2
Touchet River	17.8	32TOU-17.8	6/6/02	14:15	160.05	114.61	59.18	58.0
Touchet River	17.8	32TOU-17.8	7/9/02	20:36	61.11	48.17	32.40	30.0
Touchet River	17.8	32TOU-17.8	7/9/02	20:36	61.11	48.17	32.40	30.0
Touchet River	17.8	32TOU-17.8	8/6/02	16:00	28.24	58.86	47.17	46.5
Touchet River	17.8	32TOU-17.8	9/11/02	15:02	22.19	39.95	44.68	44.5
Touchet River	17.8	32TOU-17.8	10/17/02	17:19	39.56	51.72	50.43	50.2
Touchet River	25	32TOU-25.0	7/9/02	15:00	63.76	48.38	41.36	40.8
Touchet River	25	32TOU-25.0	7/29/02	12:48	35.49	24.45	31.30	30.2
Touchet River	25	32TOU-25.0	8/6/02	17:00	34.64	38.37	26.43	26.7
Touchet River	25	32TOU-25.0	9/11/02	15:51	25.35	51.54	42.04	41.3
Touchet River	25	32TOU-25.0	9/17/02	14:00	31.25	26.02	31.19	30.6
Touchet River	25	32TOU-25.0	10/17/02	16:20	44.54	34.66	32.72	32.2
Touchet River	26.1	32TOU-26.1	6/8/02	9:30	176.00	81.38	84.95	84.4
Touchet River	26.1	32TOU-26.1	7/9/02	16:30	53.79	112.34	57.42	56.2

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft²)	WP (ft)	Wet Width (ft)
Touchet River	26.1	32TOU-26.1	8/6/02	8:30	35.13	58.52	49.43	48.6
Touchet River	26.1	32TOU-26.1	9/11/02	16:35	27.33	66.16	64.44	63.7
Touchet River	26.1	32TOU-26.1	10/17/02	17:10	42.25	49.73	51.64	50.9
Touchet River	30.6	32TOU-30.6	6/8/02	9:00	200.22	72.69	67.92	67.2
Touchet River	30.6	32TOU-30.6	7/10/02	8:30	61.31	28.35	34.23	32.8
Touchet River	30.6	32TOU-30.6	7/29/02	11:15	33.37	29.72	30.47	29.4
Touchet River	30.6	32TOU-30.6	8/6/02	10:00	32.30	28.79	29.98	29.3
Touchet River	30.6	32TOU-30.6	9/12/02	9:28	27.93	34.94	31.47	30.9
Touchet River	30.6	32TOU-30.6	9/17/02	13:15	37.39	27.24	30.16	29.4
Touchet River	30.6	32TOU-30.6	10/17/02	17:38	43.95	29.22	31.51	31.0
Touchet River	34.2	32TOU-34.2	6/8/02	8:05	182.84	83.22	57.37	56.3
Touchet River	34.2	32TOU-34.2	6/25/02	14:25	97.82	74.72	50.23	49.1
Touchet River	34.2	32TOU-34.2	7/9/02	15:13	62.82	64.10	47.27	46.1
Touchet River	34.2	32TOU-34.2	7/9/02	15:13	62.82	64.10	47.27	46.1
Touchet River	34.2	32TOU-34.2	7/29/02	11:45	35.82	31.71	46.33	46.2
Touchet River	34.2	32TOU-34.2	8/6/02	9:20	81.76	33.53	45.96	45.8
Touchet River	34.2	32TOU-34.2	9/2/02	9:40	34.23	15.92	25.31	25.2
Touchet River	34.2	32TOU-34.2	9/10/02	16:00	32.51	31.46	44.66	44.5
Touchet River	34.2	32TOU-34.2	9/17/02	12:20	40.78	32.06	45.87	45.7
Touchet River	34.2	32TOU-34.2	10/18/02	15:30	47.02	36.26	47.06	46.9
Touchet River	34.2	32TOU-34.2	11/19/02	13:05	58.07	40.10	49.08	48.9
Touchet River	36.6	32TOU-36.6	7/29/02	9:50	39.00	31.58	40.39	40.2
Touchet River	40.5	32TOU-40.5	6/7/02	17:21	187.96	73.15	54.45	53.7
Touchet River	40.5	32TOU-40.5	6/25/02	13:35	110.91	51.02	52.95	51.9
Touchet River	40.5	32TOU-40.5	7/9/02	12:00	73.11	43.55	46.95	46.2
Touchet River	40.5	32TOU-40.5	7/13/02	8:30	55.45	31.49	39.39	38.1
Touchet River	40.5	32TOU-40.5	7/29/02	9:03	42.75	27.02	36.21	35.4
Touchet River	40.5	32TOU-40.5	8/6/02	11:15	47.54	28.79	34.65	34.2
Touchet River	40.5	32TOU-40.5	9/10/02	16:30	33.40	24.02	31.39	31.0
Touchet River	40.5	32TOU-40.5	10/15/02	16:45	51.70	28.62	32.54	32.0
Touchet River	44.2	32TOU-44.2	7/30/02	10:35	41.51	41.51	29.10	27.2
Touchet River	46.2	32TOU-46.2	6/25/02	13:00	98.65	28.61	27.73	27.3
Touchet River	46.2	32TOU-46.2	7/9/02	12:00	81.03	26.35	26.28	25.9
Touchet River	46.2	32TOU-46.2	7/30/02	11:00	39.76	26.78	36.70	36.3
Touchet River	46.2	32TOU-46.2	9/3/02	12:55	37.45	18.69	23.69	23.4
Touchet River	48.4	32TOU-48.4	7/30/02	11:15	44.27	33.93	31.72	31.1
Touchet River	51.2	32TOU-51.2	6/25/02	12:00	113.84	51.19	54.52	55.9
Touchet River	51.2	32TOU-51.2	7/9/02	13:00	70.90	50.67	46.17	48.1
Touchet River	51.2	32TOU-51.2	7/30/02	11:45	33.98	49.50	31.11	34.1
Touchet River	51.2	32TOU-51.2	9/17/02	10:40	40.82	31.23	43.86	44.0
Touchet River	51.2	32TOU-51.2	11/19/02	11:20	59.74	37.40	51.99	53.3
Touchet River	53.9	32TOU-53.9	5/16/02	13:50	245.38	83.92	47.72	46.5
Touchet River	53.9	32TOU-53.9	6/5/02	9:00	199.67	82.54	47.81	46.1
Touchet River	53.9	32TOU-53.9	7/9/02	12:45	69.61	62.94	45.17	44.3
Touchet River	53.9	32TOU-53.9	7/30/02	14:00	46.81	101.81	44.30	45.1
Touchet River	53.9	32TOU-53.9	8/6/02	1:45	44.78	100.37	45.52	43.5
Touchet River	53.9	32TOU-53.9	9/12/02	14:05	41.44	19.49	41.38	41.2
Touchet River	53.9	32TOU-53.9	10/15/02	13:40	48.62	33.81	33.30	32.8

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft²)	WP (ft)	Wet Width (ft)
Walla Walla River	9.3	32WAL-09.3	6/26/02	15:00	98.98	87.32	66.34	65.7
Walla Walla River	9.3	32WAL-09.3	7/31/02	7:40	21.65	55.06	46.41	45.9
Walla Walla River	9.3	32WAL-09.3	8/15/02	11:25	9.15	10.26	26.64	26.4
Walla Walla River	9.3	32WAL-09.3	11/21/02	13:35	90.01	108.24	61.25	60.3
Walla Walla River	15.6	32WAL-15.6	6/26/02	14:00	102.18	53.01	34.78	34.2
Walla Walla River	15.6	32WAL-15.6	7/10/02	15:45	58.54	33.72	35.13	34.9
Walla Walla River	15.6	32WAL-15.6	7/31/02	9:00	26.98	23.85	31.93	31.7
Walla Walla River	15.6	32WAL-15.6	9/18/02	14:40	29.54	18.12	29.22	29.1
Walla Walla River	15.6	32WAL-15.6	10/17/02	12:25	21.93	17.61	29.62	29.4
Walla Walla River	22.7	32WAL-22.7	7/10/02	20:46	6.95	20.01	28.98	28.8
Walla Walla River	22.7	32WAL-22.7	7/31/02	9:30	5.02	37.63	27.09	26.4
Walla Walla River	22.7	32WAL-22.7	9/18/02	13:35	33.10	63.93	31.16	28.2
Walla Walla River	27.4	32WAL-27.4	6/26/02	12:20	8.96	31.41	28.90	28.6
Walla Walla River	27.4	32WAL-27.4	7/31/02	12:00	4.38	22.60	29.79	28.7
Walla Walla River	27.4	32WAL-27.4	9/5/02	10:55	10.92	23.80	30.78	30.6
Walla Walla River	27.4	32WAL-27.4	9/18/02	12:20	30.39	43.51	31.66	31.2
Walla Walla River	27.4	32WAL-27.4	10/17/02	10:40	8.65	19.72	30.53	30.4
Walla Walla River	27.4	32WAL-27.4	11/21/02	11:30	31.56	37.87	34.73	34.4
Walla Walla River	29.3	32WAL-29.3	6/26/02	11:40	15.28	6.42	20.52	20.4
Walla Walla River	29.3	32WAL-29.3	7/10/02	13:45	11.00	14.65	21.78	21.5
Walla Walla River	29.3	32WAL-29.3	7/31/02	13:45	17.87	28.74	31.08	30.8
Walla Walla River	29.3	32WAL-29.3	8/15/02	12:55	6.30	8.75	19.72	19.6
Walla Walla River	29.3	32WAL-29.3	9/5/02	9:55	16.66	18.48	33.78	33.7
Walla Walla River	29.3	32WAL-29.3	10/17/02	10:10	16.02	30.13	33.98	33.5
Walla Walla River	29.3	32WAL-29.3	11/21/02	10:50	33.53	27.73	36.42	36.3
Walla Walla River	32.8	32WAL-32.8	9/4/02	13:15	34.52			30.6
Walla Walla River	32.8	32WAL-32.8	6/26/02	11:00	34.90	49.64	62.58	62.1
Walla Walla River	32.8	32WAL-32.8	7/10/02	20:00	32.67	42.28	63.72	63.4
Walla Walla River	32.8	32WAL-32.8	7/31/02	14:10	41.43	46.95	65.35	65.1
Walla Walla River	32.8	32WAL-32.8	9/18/02	11:20	38.87	25.07	36.05	35.9
Walla Walla River	32.8	32WAL-32.8	11/21/02	10:15	41.84	55.75	56.41	55.9
Walla Walla River	35.2	32WAL-35.2	7/31/02	15:00	33.31	22.89	45.91	45.6
Walla Walla River	35.2	32WAL-35.2	8/15/02	13:35	29.56	26.90	43.35	43.0
Walla Walla River	35.2	32WAL-35.2	9/4/02	12:00	40.25	21.47	43.65	43.4
Walla Walla River	35.2	32WAL-35.2	9/18/02	9:50	63.30	27.81	47.77	47.6
Walla Walla River	38.7	32WAL-38.7	6/26/02	9:30	20.53	37.00	27.56	27.0
Walla Walla River	38.7	32WAL-38.7	7/10/02	19:30	10.86	15.07	18.14	17.7
Walla Walla River	38.7	32WAL-38.7	7/31/02	15:45	12.24	21.19	25.34	25.1
Walla Walla River	38.7	32WAL-38.7	8/15/02	15:20	12.54	19.08	24.70	24.5
Walla Walla River	38.7	32WAL-38.7	9/4/02	12:00	12.65	11.17	20.12	20.0
Walla Walla River	38.7	32WAL-38.7	9/18/02	8:35	26.27	13.82	22.66	22.4
Walla Walla River	38.7	32WAL-38.7	10/17/02	9:15	19.54	25.00	26.37	33.5
Walla Walla River	38.7	32WAL-38.7	11/21/02	9:00	23.58	16.13	20.58	20.1
Yellowhawk Creek	0.2	32YEL-00.2	6/26/02	10:00	27.12	13.18	22.33	22.1
Yellowhawk Creek	0.2	32YEL-00.2	7/8/02	12:10	22.69	15.14	22.78	22.0
Yellowhawk Creek	0.2	32YEL-00.2	8/1/02	12:00	14.27	8.43	21.04	20.9
Yellowhawk Creek	0.2	32YEL-00.2	8/7/02	17:00	10.12	8.85	20.17	20.0
Yellowhawk Creek	0.2	32YEL-00.2	9/4/02	13:25	14.46	9.95	21.26	21.1

Stream	River Mile	Site Code	Date	Time	Q (cfs)	A (ft²)	WP (ft)	Wet Width (ft)
Yellowhawk Creek	0.2	32YEL-00.2	9/19/02	13:15	20.01	12.74	21.91	21.7
Yellowhawk Creek	0.2	32YEL-00.2	10/16/02	14:00	15.03	11.01	21.61	21.5
Yellowhawk Creek	0.2	32YEL-00.2	11/20/02	14:00	32.33	14.85	22.72	22.5
Yellowhawk Creek	1.1	32YEL-01.1	8/22/02	10:10	18.49	na	na	17.0
Yellowhawk Creek	1.1	32YEL-01.1	9/4/02	11:00	17.03	na	na	18.2
Yellowhawk Creek	1.1	32YEL-01.1	5/14/02	11:30	54.43	na	na	24.1
Yellowhawk Creek	1.1	32YEL-01.1	5/29/02	13:15	50.68	na	na	22.6
Yellowhawk Creek	1.1	32YEL-01.1	8/7/02	16:15	14.39	10.71	16.79	15.9
Yellowhawk Creek	5	32YEL-05.0	5/16/02	16:15	35.38	12.61	17.98	17.2
Yellowhawk Creek	5	32YEL-05.0	6/4/02	13:15	33.97	13.09	18.59	17.3
Yellowhawk Creek	5	32YEL-05.0	7/8/02	18:30	22.93	10.54	17.55	16.8
Yellowhawk Creek	5	32YEL-05.0	8/7/02	11:55	16.30	7.47	16.86	16.3
Yellowhawk Creek	5	32YEL-05.0	9/9/02	16:43	13.37	6.88	15.99	15.6
Yellowhawk Creek	5	32YEL-05.0	10/16/02	10:40	16.87	8.88	18.46	17.5
Yellowhawk Creek	8.5	32YEL-08.5	8/7/02	14:30	14.37	12.23	33.27	32.8

Appendix C. Channel geometry and substrate summary from stream surveys in the Walla Walla River basin

Table C-1. Channel geometry summary.

Data from shaded rows below may not be representative of a typical reach because of a low number of transects measured or because of issues described in the field notes. Stream surveys generally took width and depth measurements every 200 feet and covered a 1000-foot reach above each temperature monitor. Numbers reported below are usually the average of 6 measurements taken at 0, 200, 400, 600, 800, and 1000 feet.

Site	Wetted Width (ft)	Bankfull Width (ft)	NSDZ [1] (ft)	Wetted Depth (ft)	Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	Bankfull Width/Depth Ratio	Channel[2] gradient 5000-ft map
32TOU-02.0	36.4	51.8	52.3	1.1	3.7	5.3	13.9	0.00194
32TOU-07.0	46.2	57.8	53.3	1.2	2.1	5.7	27.4	0.00195
32TOU-10.8	36.2	53.7	56.1	1.4	2.7	6.0	19.6	0.00195
32TOU-12.8	40.4	50.0	53.0	0.9	2.1	4.3	23.6	0.00195
32TOU-14.2	33.6	51.3	59.2	1.0	2.4	3.7	21.3	0.00447
32TOU-17.8	38.9	55.2	57.8	1.2	2.3	6.5	24.3	0.00078
32TOU-25.0	50.6	60.9	69.2	0.9	2.0	3.7	30.6	0.00175
32TOU-26.1	49.9	58.0	72.5	1.1	2.2	4.1	26.4	0.00136
32TOU-30.6	37.7	61.8	77.8	0.7	1.7	3.3	36.0	0.00078
32TOU-34.2	53.4	70.3	73.9	1.0	1.6	4.1	42.8	0.00388
32TOU-40.5	50.7	89.1	77.8	0.9	1.2	3.5	76.4	0.00388
32TOU-53.9	41.6	56.8	64.6	0.7	1.5	3.0	38.7	0.00777
32ROB-02.3	3.3	21.8	88.3	0.1	0.7	1.9	31.7	
32NFT-04.9	25.8	58.5	70.5	0.6	1.5	2.7	39.3	0.01535
32SFT-02.5	17.6	36.4	43.7	0.5	1.9	3.8	19.2	
32NFT-07.7	25.8	36.3	71.1	0.5	1.9	3.9	19.0	0.02100
32DRY-27.4	10.9	24.8	35.9	0.3	1.4	2.5	18.1	
32MIL-01.7	4.7	69.4	99.3	0.3	1.6	5.3	42.9	
32MIL-12.8	43.8	79.0	88.6	1.3	2.0	6.7	40.3	0.01144
32MIL-14.8	35.7	81.2	129.0	0.5	1.3	3.2	60.4	0.01519
32MIL-19.1	40.4	49.5	100.0	0.7	1.3	2.2	37.5	0.01713
32MIL-21.3	36.8	51.4	106.0	0.8	1.6	3.6	32.2	0.01625
32MIL-26.5	37.5	54.6	75.4	0.8	1.7	3.5	31.5	0.02019
32MIL-27.5	31.3	39.9	41.7	0.7	1.8	4.5	21.6	0.01944
32WLF-01.8	25.3	44.0	54.9	0.7	1.5	3.5	28.7	
32WLF-05.2	20.5	24.3	46.3	0.6	1.4	2.5	17.7	

[1] NSDZ (Near Stream Disturbance Zone) is defined as the active channel area without riparian vegetation that includes features such as gravel bars.
[2] Channel gradient was measured from map-based data. Stream gradient was calculated using a 1600-meter stream segment starting at the downstream location of the stream survey. Elevations at each end of the segment came from the USGS 10-meter DEM (Digital Elevation Model).

Channel surveys, along with map-derived data (slope, sinuosity), indicate that the expected stable channel type for most of the Touchet River below Dayton and Mill Creek from the WA/Ore border to the Yellowhawk diversion dam should be Rosgen C-type channels. Mill Creek reaches above the WA/Ore border and reaches in the upper Touchet forks are more commonly B-type.

Field notes recorded during surveys show that some of the reaches of the Touchet River, primarily in the lower half, are entrenched and would be classified currently as F-type channels. F-type channels are usually associated with “disturbance”. Rosgen (1996) states that degraded or disturbed type F streams generally return to their more stable type C form as the disturbance is minimized. Channels that have lost sinuosity (straightened) over time are more prone to become downcut and entrenched. Rosgen reports bankfull width-depth targets as follows

Table C-2. Median bankfull width-depth target ratios by stream type (Rosgen, 1996).

Rosgen Stream Type	A	B	C	F
Bankfull width/depth	7	17	24	29

The measured bankfull width/depth values recorded during field surveys (Table C-1) can be compared against Rosgen’s typical values for type B and C channels (Table C-2). Many of the survey segments are close to or less than the expected range. However, other stream segments that have higher than expected width/depth ratios could show improvement over time as disturbance is reduced.

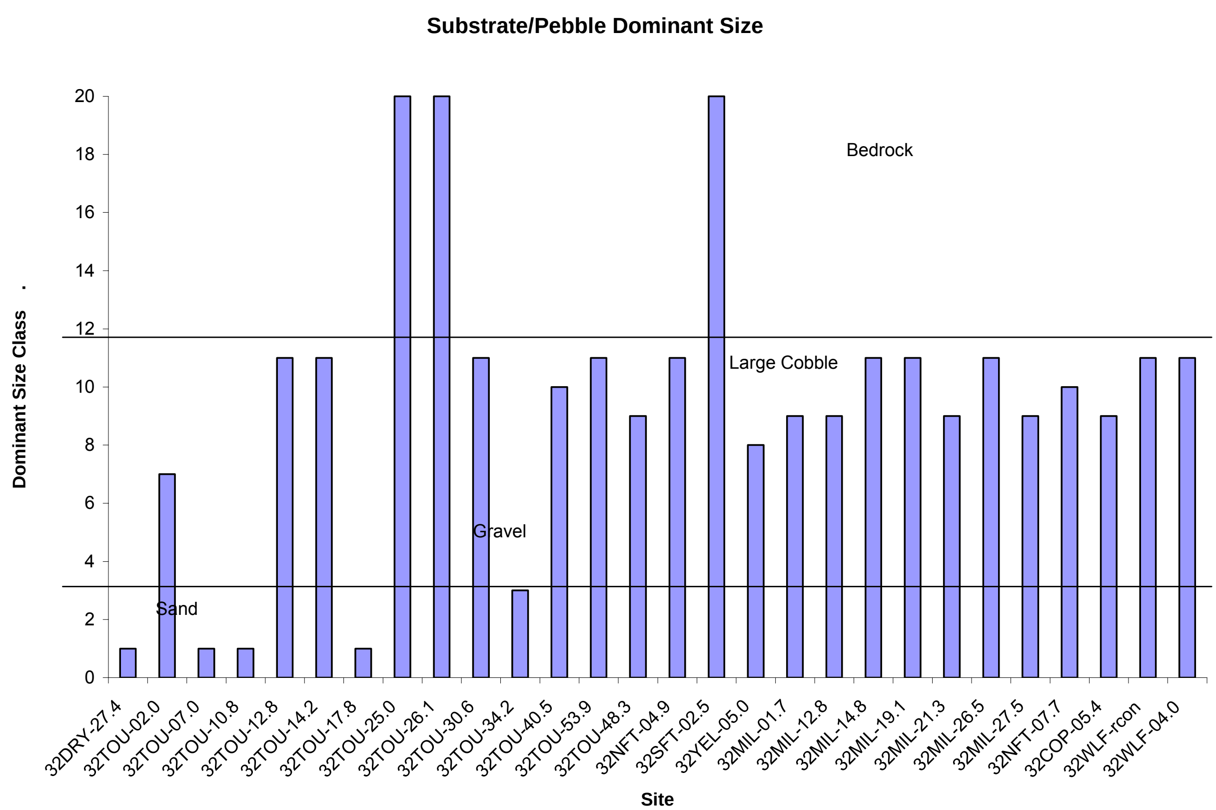

Figure C-1. Wolman pebble dominant size class data

Table C-3. Large woody debris count summary, summer 2002.

Station ID	Date	Reach Length (ft)	Zone	Root Wads (Diameter >/= 7.87 in.)	Medium Log (Diameter 0.66 to 1.64 ft. or 7.87 to 19.69 in.)	Large Log (Diameter >1.64 ft. or > 19.69 in.)	Log Jam
32COP-05.4	8/29/2002	900	1	2	2	0	0
32COP-05.4	8/29/2002	900	2	0	4	0	0
32DRY-27.4	8/29/2002	900	1	0	1	0	0
32DRY-27.4	8/29/2002	900	2	0	4	1	0
32TOU-07.0	8/12/2002	1000	1	0	1	0	0
32TOU-07.0	8/12/2002	1000	2	0	0	0	0
32TOU-10.8	8/12/2002	1000	1	0	1	0	0
32TOU-10.8	8/12/2002	1000	2	0	0	0	0
32TOU-12.8	8/15/2002	1000	1	0	0	0	0
32TOU-12.8	8/15/2002	1000	2	0	0	0	0
32TOU-14.2	8/26/2002	350	1	0	0	0	1
32TOU-14.2	8/26/2002	350	2	0	0	0	0
32TOU-17.8	8/12/2002	1000	1	0	0	0	0
32TOU-17.8	8/12/2002	1000	2	0	0	0	0
32TOU-25.0	8/26/2002	1000	1	0	0	0	0
32TOU-25.0	8/26/2002	1000	2	0	0	0	0
32TOU-26.1	8/27/2002	1000	1	0	1	0	2
32TOU-26.1	8/27/2002	1000	2	0	1	0	0
32TOU-30.6	8/27/2002	1000	1	0	5	0	1
32TOU-30.6	8/27/2002	1000	2	0	0	0	0
32TOU-34.2	8/12/2002	1000	1	0	0	0	0
32TOU-34.2	8/12/2002	1000	2	0	0	0	0
32TOU-40.5	8/13/2002	1000	1	0	0	0	0
32TOU-40.5	8/13/2002	1000	2	0	2	0	0
32TOU-48.3	8/13/2002	600	1	2	3	1	0
32TOU-48.3	8/13/2002	600	2	0	0	0	0
32ROB-02.3	8/29/2002	600	1	0	3	0	0
32ROB-02.3	8/29/2002	600	2	0	4	0	0
32NFT-04.9	8/14/2002	840	1	0	4	0	0
32NFT-04.9	8/14/2002	840	2	0	7	1	0
32SFT-02.5	8/27/2002	550	1	0	0	0	0
32SFT-02.5	8/27/2002	550	2	5	1	0	1
32WLF-04.0	8/14/2002	950	1	2	8	5	1
32WLF-04.0	8/14/2002	950	2	1	8	2	0
32MIL-01.7	7/30/2002	1000	1	1	1	0	0
32MIL-01.7	7/30/2002	1000	2	0	0	0	0
32MIL-14.8	8/15/2002	1050	1	1	15	1	0
32MIL-14.8	8/15/2002	1050	2	1	7	3	0
32MIL-19.1	8/15/2002	200	1	0	0	0	0
32MIL-19.1	8/15/2002	200	2	0	0	0	0
32MIL-21.3	8/15/2002	900	1	1	2	0	0

Station ID	Date	Reach Length (ft)	Zone	Root Wads (Diameter >/= 7.87 in.)	Medium Log (Diameter 0.66 to 1.64 ft. or 7.87 to 19.69 in.)	Large Log (Diameter >1.64 ft. or > 19.69 in.)	Log Jam
32MIL-21.3	8/15/2002	900	2	0	2	2	0
3 MIL-26.25	8/28/2002	900	1	1	5	2	4
32MIL-26.5	8/28/2002	900	2	0	4	3	1
32MIL-27.5	8/28/2002	900	1	4	3	0	1
32MIL-27.5	8/28/2002	900	2	0	6	2	1
32NFT-07.7	8/27/2002	900	1	0	2	0	2
32NFT-07.7	8/27/2002	900	2	0	5	1	1

Figure C-2. Large Woody Debris Survey Field Form

(See next page)

LWD SURVEY

Station ID: M6
Reach Length: 400
Date/Time: 8/28/02
Crew: ML/LP/TS
Units: (ft) m

Zone	Rtwd Dia ≥ 7.874 in	Key Pieces	Medium - LOG ≥ 7.874 to < 19.69 in ≥ .6562 to < 1.64 ft	Key Pieces	Large - LOG ≥ 19.69 in ≥ 1.64 ft	Key Pieces	Log Jam	# of Pieces	Rough Dimension
ZONE 1	IIII		III	I		II	I	5	3Hx12Wx10L
Total	4	0	3	1	0	2	1	5	
ZONE 2			~~IIII~~ I	I	II	II	I	4	3Hx15Wx20L
Total	0	0	6	1	2	2	1	4	

COMMENTS

LWD Key Piece Volume Criteria

BFW		0 - 16.4	19.69 - 32.81	36.09 - 49.21	52.49 - 65.62
Min Diameter		Min Length			
Inches	Feet				
7.874	0.6562	104.99			
9.843	0.8202	68.9			
11.81	0.9843	49.21	118.11		
13.78	1.148	36.09	85.3		
15.75	1.312	26.25	65.62		
17.72	1.476	22.97	52.49	124.67	
19.69	1.64	19.69	42.65	101.71	
21.65	1.804	16.4	36.09	85.3	
23.62	1.969	13.12	29.53	72.18	104.99
25.59	2.133	9.843	26.25	62.34	91.86
27.56	2.297	9.843	22.97	62.34	78.74
29.53	2.461	9.843	19.69	45.93	68.9
31.5	2.625	6.562	16.4	39.37	59.06
33.46	2.789	6.562	16.4	36.09	52.49
35.43	2.953	6.562	13.12	32.81	49.21
37.4	3.117	6.562	13.12	29.53	42.65
39.37	3.281	6.562	13.12	26.25	39.37
41.34	3.445	6.562	9.843	22.97	36.09
43.31	3.609	6.562	9.843	22.97	32.81
45.28	3.773	3.281	9.843	19.69	29.53
47.24	3.937		9.843	19.69	26.25
49.21	4.101		9.843	16.4	26.25
51.18	4.265		6.562	16.4	22.97
55.12	4.593		6.562	13.12	19.69
61.02	5.085		6.562	13.12	16.4
62.99	5.249		6.562	9.843	16.4
66.93	5.577		6.562	9.843	13.12
70.87	5.906		3.281	9.843	13.12
78.74	6.562			6.562	9.843
94.49	7.874			6.562	6.562
110.24	9.186			3.281	6.562
133.86	11.15				3.281

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Appendix D. Load allocations for effective shade for the Walla Walla River tributaries

This appendix contains numerical load allocations for effective shade to address 303(d) listings in the Walla Walla River basin. Contents of this appendix:

- Table D-1. Load allocations for effective shade in the mainstem Touchet River.
- Table D-2. Load allocations for effective shade in the Mill Creek and Yellowhawk Creek tributary to the Walla Walla River.
- Table D-3a through Table D-3f. Load allocations for effective shade for miscellaneous perennial streams in the Walla Walla River watershed, based on bankfull width and stream aspect and potential vegetation zone.
- Table D-4. 2004 303(d) listing IDs and load allocation information.

Table D-1. Load allocations for effective shade in the mainstem Touchet River on August 1 (percent).

Distance from Dayton City Park to upstream segment boundary (Km)	Distance from Dayton City Park to downstream segment boundary (Km)	Current shade condition (%)	System potential shade with low-range shrub land below Luckenbill Rd (code101)	System potential shade with high-range shrub land below Luckenbill Rd (code201)	Increase in % shade needed	Landmark	Load allocation for daily average shortwave solar radiation on August 1 (watts/m²)
0	0.98	15.6%	52.4%	52.4%	36.8%	Dayton City Park	144.6
0.98	1.96	5.1%	54.5%	54.5%	49.4%	Patit Creek Tributary	137.9
1.96	2.94	18.7%	47.6%	47.6%	28.9%		158.9
2.94	3.92	19.4%	60.2%	60.2%	40.8%		120.7
3.92	4.90	38.8%	42.7%	42.7%	3.9%		174.0
4.90	5.88	8.9%	42.9%	42.9%	34.0%		173.2
5.88	6.86	11.7%	42.5%	42.5%	30.8%		174.4
6.86	7.84	8.1%	32.7%	32.7%	24.6%		204.2
7.84	8.82	16.8%	70.7%	70.7%	53.9%		89.0
8.82	9.80	24.5%	65.4%	65.4%	40.9%		104.9
9.80	10.78	29.1%	63.0%	63.0%	34.0%	Lewis/Clark State Park	112.2
10.78	11.76	30.7%	45.4%	45.4%	14.7%		165.8
11.76	12.74	9.3%	42.5%	42.5%	33.2%		174.4
12.74	13.72	7.8%	51.0%	51.0%	43.2%		148.7
13.72	14.70	28.2%	61.3%	61.3%	33.1%	TOU46.2	117.5
14.70	15.68	18.5%	68.3%	68.3%	49.8%		96.3
15.68	16.66	47.4%	53.4%	53.4%	6.0%		141.3
16.66	17.64	27.3%	70.4%	70.4%	43.1%		89.8
17.64	18.62	42.4%	78.8%	78.8%	36.4%		64.4

Distance from Dayton City Park to upstream segment boundary (Km)	Distance from Dayton City Park to downstream segment boundary (Km)	Current shade condition (%)	System potential shade with low-range shrub land below Luckenbill Rd (code101)	System potential shade with high-range shrub land below Luckenbill Rd (code201)	Increase in % shade needed	Landmark	Load allocation for daily average shortwave solar radiation on August 1 (watts/m²)
18.62	19.60	28.4%	78.8%	78.8%	50.4%		64.4
19.60	20.58	44.3%	70.0%	70.0%	25.7%		91.0
20.58	21.56	29.2%	38.1%	38.1%	8.8%		188.0
21.56	22.54	7.8%	33.3%	33.3%	25.5%		202.3
22.54	23.52	18.8%	52.4%	52.4%	33.6%		144.4
23.52	24.50	12.1%	21.2%	21.2%	9.2%	Coppei Creek Tributary	239.0
24.50	25.48	2.2%	41.2%	41.2%	38.9%		178.5
25.48	26.46	18.3%	60.9%	60.9%	42.5%		118.7
26.46	27.44	7.3%	50.8%	50.8%	43.5%		149.2
27.44	28.42	5.7%	60.3%	60.3%	54.6%		120.5
28.42	29.40	17.4%	38.3%	38.3%	20.9%		187.4
29.40	30.38	7.3%	52.5%	52.5%	45.2%		144.2
30.38	31.36	11.6%	59.0%	59.0%	47.4%		124.5
31.36	32.34	3.4%	47.1%	47.1%	43.7%		160.5
32.34	33.32	7.5%	54.7%	54.7%	47.2%		137.4
33.32	34.30	14.2%	34.7%	34.7%	20.6%		198.1
34.30	35.28	6.0%	61.5%	61.5%	55.6%		116.8
35.28	36.26	11.7%	64.8%	64.8%	53.1%	TOU-34.2	106.8
36.26	37.24	8.0%	56.4%	56.4%	48.4%		132.3
37.24	38.22	12.1%	51.2%	51.2%	39.1%		148.1
38.22	39.20	6.7%	62.1%	62.1%	55.4%		115.0
39.20	40.18	10.4%	53.9%	53.9%	43.5%		139.9
40.18	41.16	2.9%	56.9%	56.9%	54.0%		130.6
41.16	42.14	6.6%	55.9%	55.9%	49.3%		133.8
42.14	43.12	4.0%	63.6%	63.6%	59.6%	TOU-30.6	110.4
43.12	44.10	4.7%	52.6%	52.6%	47.9%		143.8
44.10	45.08	4.8%	51.4%	51.4%	46.5%		147.5
45.08	46.06	4.1%	45.2%	45.2%	41.1%		166.3
46.06	47.04	1.5%	53.1%	53.1%	51.6%		142.3
47.04	48.02	3.0%	58.9%	58.9%	55.9%		124.7
48.02	49.00	3.2%	59.3%	59.3%	56.1%		123.5
49.00	49.98	1.5%	56.2%	56.2%	54.7%		133.0
49.98	50.96	8.9%	65.1%	65.1%	56.2%	TOU-26.1	105.9
50.96	51.94	7.2%	65.5%	65.5%	58.3%		104.7
51.94	52.92	7.1%	79.1%	79.1%	72.0%		63.5
52.92	53.90	4.7%	73.6%	73.6%	68.9%		80.0
53.90	54.88	9.7%	69.0%	69.0%	59.3%	TOU-25.0	94.1
54.88	55.86	5.6%	77.6%	77.6%	72.0%		68.0
55.86	56.84	12.8%	64.2%	64.2%	51.4%		108.7
56.84	57.82	7.7%	64.2%	64.2%	56.6%		108.5

Distance from Dayton City Park to upstream segment boundary (Km)	Distance from Dayton City Park to downstream segment boundary (Km)	Current shade condition (%)	System potential shade with low-range shrub land below Luckenbill Rd (code101)	System potential shade with high-range shrub land below Luckenbill Rd (code201)	Increase in % shade needed	Landmark	Load allocation for daily average shortwave solar radiation on August 1 (watts/m²)
57.82	58.80	9.6%	67.0%	67.0%	57.4%		100.0
58.80	59.78	7.5%	58.2%	58.2%	50.7%		126.8
59.78	60.76	4.9%	49.0%	49.0%	44.1%		154.7
60.76	61.74	4.6%	62.5%	62.5%	57.9%		113.7
61.74	62.72	7.1%	45.0%	45.0%	37.9%		166.9
62.72	63.70	2.0%	30.8%	30.8%	28.8%		210.1
63.70	64.68	3.1%	55.5%	55.5%	52.4%		134.9
64.68	65.66	5.3%	44.6%	44.6%	39.3%		168.1
65.66	66.64	6.6%	72.0%	72.0%	65.4%		85.1
66.64	67.62	9.7%	61.2%	64.0%	54.3%	TOU-17.8 Luckenbill	109.2
67.62	68.60	9.9%	22.5%	29.4%	19.5%		214.2
68.60	69.58	6.8%	28.7%	36.2%	29.4%		193.7
69.58	70.56	12.1%	24.9%	32.0%	19.9%		206.4
70.56	71.54	9.9%	34.2%	42.1%	32.2%		175.7
71.54	72.52	10.2%	31.5%	40.5%	30.3%		180.7
72.52	73.50	10.6%	24.7%	32.0%	21.3%		206.4
73.50	74.48	9.1%	41.0%	49.6%	40.5%		153.0
74.48	75.46	14.8%	31.2%	39.2%	24.4%	TOU-14.2	184.6
75.46	76.44	6.6%	33.6%	40.4%	33.8%		180.8
76.44	77.42	14.6%	32.6%	40.1%	25.5%	TOU-12.8	181.9
77.42	78.40	22.6%	26.1%	32.8%	10.2%		203.9
78.40	79.38	9.4%	26.2%	33.4%	24.1%		202.0
79.38	80.36	14.2%	36.8%	45.2%	31.0%		166.2
80.36	81.34	19.4%	44.4%	53.0%	33.6%	TOU-10.8	142.7
81.34	82.32	19.2%	28.8%	35.8%	16.6%		194.9
82.32	83.30	7.5%	38.6%	47.1%	39.6%		160.5
83.30	84.28	15.3%	25.2%	32.0%	16.7%		206.4
84.28	85.26	6.8%	16.2%	22.6%	15.8%		234.9
85.26	86.24	3.0%	19.5%	26.6%	23.5%		222.8
86.24	87.22	3.8%	27.7%	35.2%	31.4%		196.5
87.22	88.20	6.2%	17.4%	23.4%	17.2%		232.6
88.20	89.18	8.1%	22.1%	28.6%	20.5%	TOU-7.0	216.6
89.18	90.16	11.7%	31.3%	40.3%	28.6%		181.2
90.16	91.14	11.0%	31.1%	38.3%	27.2%		187.3
91.14	92.12	8.3%	25.2%	31.7%	23.5%		207.1
92.12	93.10	5.6%	17.7%	23.6%	18.0%		231.8
93.10	94.08	2.5%	28.6%	36.0%	33.6%		194.1
94.08	95.06	6.3%	27.0%	34.4%	28.1%	Hofer Diversion	199.0
95.06	96.04	5.9%	31.5%	38.7%	32.8%		186.0

Distance from Dayton City Park to upstream segment boundary (Km)	Distance from Dayton City Park to downstream segment boundary (Km)	Current shade condition (%)	System potential shade with low-range shrub land below Luckenbill Rd (code101)	System potential shade with high-range shrub land below Luckenbill Rd (code201)	Increase in % shade needed	Landmark	Load allocation for daily average shortwave solar radiation on August 1 (watts/m²)
96.04	97.02	7.9%	27.7%	33.9%	26.0%		200.6
97.02	98.00	6.6%	23.0%	29.4%	22.9%		214.1
98.00	98.98	10.2%	23.7%	30.5%	20.3%	TOU-2.0	211.0
98.98	99.96	3.5%	14.2%	19.3%	15.8%		244.9
99.96	100.94	1.8%	11.9%	15.5%	13.7%		256.5
100.94	101.92	2.0%	25.2%	32.3%	30.2%		205.6
101.92	102.90	3.0%	18.8%	24.6%	21.6%		228.7

Segments below the heavy line (previous page) are in the shrub zone.

Table D-2. Load allocations for effective shade in the Mill Creek and Yellowhawk Creek tributaries to the Walla Walla River on August 1 (percent).

Distance from water withdrawal (Oregon) to upstream segment boundary (Km)	Distance from water withdrawal (Oregon) to downstream segment boundary (Km)	Current shade condition (%)	System potential shade with current channel in Mill/ Yellowhawk Creeks	Increase in percent shade needed	Landmark river mile (RM) station	Load allocation for daily average shortwave solar radiation on August 1 (watts/m2)	GIS ID
0	1.0	75.8%	71.3%	0.0%	32MIL-26.5	87.1	78
1.0	2.0	57.2%	64.1%	7.0%		108.9	88
2.0	3.0	55.3%	63.6%	8.3%		110.7	98
3.0	4.0	33.1%	60.1%	27.1%		121.1	108
4.0	5.0	44.4%	66.3%	21.8%		102.5	118
5.0	6.0	32.0%	67.3%	35.3%		99.5	128
6.0	7.0	30.5%	65.2%	34.6%	32MIL-21.3	105.8	138
7.0	8.0	19.2%	59.7%	40.4%		122.5	148
8.0	9.0	28.1%	34.7%	6.6%		198.4	158
9.0	10.0	22.9%	44.0%	21.1%		170.2	168
10.0	11.0	30.5%	57.0%	26.5%	32MIL-19.1	130.6	178
11.0	12.0	18.0%	37.8%	19.7%		189.1	188
12.0	13.0	18.6%	48.0%	29.5%		157.9	198
13.0	14.0	23.7%	47.3%	23.6%		160.0	208
14.0	15.0	15.9%	38.3%	22.3%	Blue Creek	187.6	218
15.0	16.0	13.7%	39.3%	25.6%		184.5	228
16.0	17.0	26.4%	52.4%	26.0%		144.7	238
17.0	18.0	26.5%	29.0%	2.5%		215.8	248
18.0	19.0	38.6%	35.1%	0.0%	32MIL-14.8	197.2	258
19.0	20.0	22.4%	31.6%	9.2%		207.8	268
20.0	21.0	27.0%	62.1%	35.2%		115.1	278
21.0	22.0	32.5%	58.5%	26.0%	32MIL-12.8 Five Mile Rd.	126.1	288
22.0	23.0	26.8%	39.2%	12.4%		184.9	298
23.0	24.0	24.4%	19.9%	0.0%		243.3	308
24.0	25.0	5.8%	9.3%	3.5%		275.5	318
25.0	26.0	7.5%	14.4%	6.9%		260.2	328
26.0	27.0	79.3%	96.8%	17.5%	Yellowhawk Creek	9.7	338
27.0	28.0	92.0%	96.7%	4.7%		10.0	348
28.0	29.0	82.3%	96.6%	14.3%		10.2	358
29.0	30.0	73.8%	96.3%	22.5%	Yellowhawk School	11.2	368
30.0	31.0	43.2%	95.8%	52.7%	Yellowhawk Park	12.6	378
31.0	32.0	46.3%	95.3%	49.0%	Yellowhawk High	14.2	388
32.0	33.0	63.9%	91.5%	27.6%	Yellowhawk Plaza	25.8	398

Distance from water withdrawal (Oregon) to upstream segment boundary (Km)	Distance from water withdrawal (Oregon) to downstream segment boundary (Km)	Current shade condition (%)	System potential shade with current channel in Mill/ Yellowhawk Creeks	Increase in percent shade needed	Landmark river mile (RM) station	Load allocation for daily average shortwave solar radiation on August 1 (watts/m2)	GIS ID
33.0	34.0	31.1%	60.1%	29.1%		121.1	408
34.0	35.0	22.1%	61.8%	39.7%		116.0	418
35.0	36.0	31.6%	60.8%	29.2%		119.2	428
36.0	37.0	25.3%	42.8%	17.5%		173.8	438
37.0	38.0	40.0%	38.6%	0.0%		186.6	448
38.0	39.0	32.4%	41.8%	9.4%		176.7	458
39.0	40.0	34.5%	43.3%	8.8%		172.4	468
39.9	40.9	16.7%	44.9%	28.2%	Yellowhawk Farm Camp	167.3	477

E:\WallaWalla\New_Mill_yell_fromGreg\recent_greg_from_shade_7505zip\shade_ver30_mill-yh_startnode68_1st_aug02_redoShade_maxveg_currveg_chart25.xls

Table D-3a. Load allocations for effective shade for miscellaneous perennial streams in the Deciduous Potential Vegetation Zone of the Walla Walla River watershed, based on bankfull width and stream aspect.

Bankfull width (meters)	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar shortwave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
1	98.4%	98.5%	98.6%	5	5	4
2	98.1%	98.2%	98.3%	6	6	5
3	97.8%	97.8%	98.0%	7	7	6
4	97.4%	97.4%	97.8%	8	8	7
5	97.1%	97.1%	97.5%	9	9	8
6	96.2%	96.3%	96.8%	12	11	10
7	94.4%	94.6%	95.8%	17	16	13
8	92.4%	92.5%	94.6%	23	23	16
9	90.5%	90.6%	93.2%	29	29	20
10	88.7%	88.8%	91.7%	34	34	25
12	84.6%	84.3%	87.0%	47	48	39
14	79.5%	78.6%	75.8%	62	65	74
16	74.4%	72.9%	67.2%	78	82	99
18	69.6%	67.6%	60.5%	92	98	120
20	65.4%	62.8%	55.1%	105	113	136
25	56.0%	52.9%	45.1%	134	143	167
30	48.7%	45.6%	38.2%	156	165	187
35	42.9%	40.0%	33.2%	173	182	203
40	38.4%	35.6%	29.4%	187	196	214

Table D-3b. Load allocations for effective shade for miscellaneous perennial streams in the Mixed Conifer-Deciduous Potential Vegetation Zone of the Walla Walla River watershed, based on bankfull width and stream aspect.

Bankfull width (m)	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar shortwave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
1	98.4%	98.5%	98.8%	5	5	4
2	98.1%	98.2%	98.5%	6	6	5
3	97.8%	97.9%	98.2%	7	6	5
4	97.5%	97.6%	98.0%	8	7	6
5	97.1%	97.2%	97.7%	9	8	7
6	95.8%	95.9%	97.0%	13	12	9
7	94.0%	94.2%	96.0%	18	18	12
8	92.0%	92.3%	94.6%	24	23	16
9	90.4%	90.6%	93.3%	29	29	20
10	88.7%	88.8%	91.9%	34	34	25
12	84.4%	84.1%	86.3%	47	48	42
14	79.3%	78.4%	75.5%	63	65	74
16	74.4%	73.0%	67.1%	78	82	100
18	70.0%	67.9%	60.4%	91	97	120
20	65.6%	63.2%	55.0%	104	112	136
25	56.3%	53.5%	45.1%	133	141	166
30	49.1%	46.1%	38.4%	154	164	187
35	43.4%	40.4%	33.4%	172	181	202
40	38.9%	35.9%	29.6%	185	194	214

Table D-3c. Load allocations for effective shade for miscellaneous perennial streams in the Shrub (High Estimate) Potential Vegetation Zone of the Walla Walla River watershed, based on bankfull width and stream aspect.

Bankfull width (m)	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar shortwave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
1	97.5%	97.5%	97.5%	8	8	8
2	95.1%	95.1%	96.3%	15	15	11
3	89.5%	89.6%	93.1%	32	31	21
4	83.6%	83.2%	86.5%	50	51	41
5	77.9%	76.9%	73.4%	67	70	81
6	72.5%	70.8%	62.4%	83	89	114
7	67.5%	65.3%	54.4%	99	105	138
8	62.8%	60.3%	48.3%	113	120	157
9	58.7%	55.9%	43.5%	125	134	171
10	54.9%	51.9%	39.6%	137	146	183
12	48.5%	45.2%	33.7%	156	166	201
14	43.3%	40.0%	29.3%	172	182	214
16	39.0%	35.8%	26.0%	185	195	225
18	35.4%	32.3%	23.4%	196	205	233
20	32.4%	29.5%	21.2%	205	214	239
25	26.6%	24.1%	17.2%	223	230	251
30	22.6%	20.3%	14.5%	235	242	259
35	19.6%	17.6%	12.5%	244	250	265
40	17.3%	15.5%	11.0%	251	256	270

Table D-3d. Load allocations for effective shade for miscellaneous perennial streams in the Shrub (Low Estimate) Potential Vegetation Zone of the Walla Walla River watershed, based on bankfull width and stream aspect.

Bankfull width (m)	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar shortwave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
1	97.0%	97.0%	97.3%	9	9	8
2	90.9%	91.0%	94.1%	28	27	18
3	82.8%	82.4%	85.2%	52	53	45
4	75.0%	73.6%	67.9%	76	80	98
5	68.3%	66.1%	55.6%	96	103	135
6	62.5%	59.7%	47.3%	114	122	160
7	57.3%	54.2%	41.3%	129	139	178
8	52.8%	49.5%	36.6%	143	153	192
9	48.9%	45.4%	33.0%	155	166	203
10	45.4%	41.8%	30.0%	166	177	212
12	39.6%	36.1%	25.4%	183	194	226
14	35.0%	31.6%	22.1%	197	207	236
16	31.3%	28.1%	19.5%	208	218	244
18	28.3%	25.3%	17.5%	218	227	250
20	25.8%	23.0%	15.8%	225	234	255
25	21.0%	18.7%	12.8%	240	247	265
30	17.8%	15.7%	10.7%	250	256	271
35	15.4%	13.5%	9.2%	257	262	275
40	13.5%	11.9%	8.1%	262	267	279

Table D-3e. Load allocations for effective shade for miscellaneous perennial streams in the Deciduous (Cottonwood gallery) Potential Vegetation Zone of the Walla Walla River watershed, based on bankfull width and stream aspect.

Bankfull width (m)	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar shortwave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
1	98.6%	98.7%	99.1%	4	4	3
2	98.3%	98.4%	98.8%	5	5	4
3	98.1%	98.1%	98.5%	6	6	5
4	97.8%	97.9%	98.2%	7	6	5
5	97.5%	97.6%	98.0%	8	7	6
6	97.3%	97.3%	97.8%	8	8	7
7	97.0%	97.1%	97.6%	9	9	7
8	95.8%	95.9%	96.9%	13	12	9
9	94.3%	94.5%	95.8%	17	17	13
10	92.8%	92.9%	94.8%	22	21	16
12	90.1%	90.2%	92.6%	30	30	22
14	86.9%	86.8%	90.1%	40	40	30
16	83.0%	82.4%	81.8%	52	53	55
18	78.7%	77.6%	73.6%	65	68	80
20	74.5%	73.0%	67.0%	77	82	100
25	65.6%	62.8%	54.9%	104	113	137
30	57.8%	54.6%	46.6%	128	138	162
35	51.4%	48.1%	40.6%	147	157	180
40	46.1%	43.0%	36.0%	164	173	194

Table D-3f. Load allocations for effective shade for miscellaneous perennial streams in the Conifer Potential Vegetation Zone of the Walla Walla River watershed, based on bankfull width and stream aspect.

Bankfull width (m)	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar shortwave Radiation W/m2) at the stream center at various stream aspects (degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
1	97.9%	98.1%	98.4%	6	6	5
2	97.6%	97.7%	98.1%	7	7	6
3	96.5%	96.7%	97.5%	11	10	8
4	94.5%	94.7%	96.5%	17	16	10
5	92.0%	92.4%	95.4%	24	23	14
6	89.6%	89.9%	93.9%	32	31	19
7	87.1%	87.2%	91.7%	39	39	25
8	84.0%	83.6%	86.2%	49	50	42
9	80.1%	79.7%	80.1%	60	61	61
10	76.5%	76.1%	74.4%	71	73	78
12	70.1%	69.4%	64.1%	91	93	109
14	64.6%	63.5%	55.9%	107	111	134
16	59.7%	58.3%	49.7%	122	126	152
18	55.6%	53.8%	44.9%	135	140	167
20	51.9%	49.9%	41.0%	146	152	179
25	44.5%	41.8%	33.7%	169	177	201
30	38.6%	35.8%	28.7%	186	195	216
35	34.1%	31.3%	25.1%	200	209	227
40	30.3%	27.7%	22.2%	211	219	236

Table D-4. 2004 303(d) listing IDs and load allocation information.

Listing ID	Category	WRIA	Waterbody Name	Load Allocation Code
24240	5	32	Blue Creek	Y
24242	5	32	Caldwell Creek	Y
24244	5	32	Cold Creek	Y
24245	5	32	Coppei Creek	Y
24247	5	32	Coppei Creek, N.F.	Y
24246	5	32	Coppei Creek, N.F.	Y
24248	5	32	Coppei Creek, S.F.	Y
23674	5	32	Coppei Creek, S.F.	Y
23676	5	32	Cottonwood Creek	Y
23675	5	32	Cottonwood Creek	Y
23677	5	32	Doan Creek	Y
23679	5	32	Dry Creek, N.F.	Y
23678	5	32	Dry Creek, S.F.	Y
14176	5	32	Garrison Creek	AD
14177	5	32	Garrison Creek	AD
23685	5	32	Jim Creek	Y
23686	5	32	Lewis Creek	Y
23680	5	32	Little Walla Walla River, East	Y
23682	5	32	Little Walla Walla River, East	Y
23789	5	32	Little Walla Walla River, West	Y
23790	5	32	Little Walla Walla River, West	Y
23762	5	32	Mill Creek	Eng Chan AD
23761	5	32	Mill Creek	Y
23768	5	32	Mill Creek	Y
23766	5	32	Mill Creek	Eng Chan AD
23765	5	32	Mill Creek	Eng Chan AD
23690	5	32	Mill Creek	Eng Chan AD
23689	5	32	Mill Creek	Y
23688	5	32	Mill Creek	Eng Chan AD
23764	5	32	Mill Creek	Y
23769	5	32	Pine Creek	Y
23770	5	32	Pine Creek	Y
23772	5	32	Robinson Creek (Fork)	Y
23771	5	32	Robinson Creek (Fork)	Y
23773	5	32	Russell Creek	Y
23777	5	32	Touchet River	Y
23778	5	32	Touchet River	Y
23775	5	32	Touchet River	Y
23776	5	32	Touchet River	Y
11098	5	32	Touchet River	Y
40510	5	32	Touchet River	Y
23779	5	32	Touchet River, N.F. (E.F.)	Y
23780	5	32	Touchet River, N.F. (E.F.)	Y
23781	5	32	Touchet River, N.F. (E.F.)	Y
23782	5	32	Touchet River, S.F.	Y

Listing ID	Category	WRIA	Waterbody Name	Load Allocation Code
23783	5	32	Touchet River, S.F.	Y
23785	5	32	Walla Walla River	ODEQ Rpt
23784	5	32	Walla Walla River	ODEQ Rpt
23786	5	32	Walla Walla River	ODEQ Rpt
23788	5	32	Walla Walla River	ODEQ Rpt
23787	5	32	Walla Walla River	ODEQ Rpt
6589	5	32	Walla Walla River	ODEQ Rpt
23792	5	32	Whiskey Creek	Y
23794	5	32	Wolf Creek (Fork)	Y
23797	5	32	Yellowhawk Creek	Y
23798	5	32	Yellowhawk Creek	Y
Total in Category 5 = 56				
24243	2	32	Coates Creek	Y-Not Verified
41071	2	32	Coppei Creek	Y-impaired
41073	2	32	Dry Creek	Y-impaired
41105	2	32	Little Walla Walla River, West	Y-impaired
23687	2	32	Mill Creek	Y-impaired
41076	2	32	Mill Creek	Eng Chan AD
41126	2	32	Mill Creek	Y-impaired
41157	2	32	Mill Creek	Y-impaired
41158	2	32	Mill Creek	Eng Chan AD
41079	2	32	Mud Creek	Y-impaired
40512	2	32	Patit Creek	Y-impaired
11105	2	32	Touchet River	Y-impaired
40515	2	32	Touchet River	Y-impaired
40511	2	32	Touchet River	Y-impaired
41084	2	32	Touchet River	Y-impaired
41085	2	32	Touchet River	Y-impaired
41086	2	32	Touchet River	Y-impaired
41088	2	32	Touchet River	Y-impaired
41089	2	32	Touchet River	Y-impaired
41090	2	32	Touchet River	Y-impaired
41091	2	32	Touchet River	Y-impaired
41092	2	32	Touchet River	Y-impaired
41093	2	32	Touchet River	Y-impaired
41095	2	32	Touchet River	Y-impaired
7970	2	32	Touchet River, N.F. (E.F.)	Y-Not Verified
40516	2	32	Touchet River, N.F. (E.F.)	Y-impaired
7968	2	32	Touchet River, N.F. (E.F.)	Y-Not Verified
7969	2	32	Touchet River, N.F. (E.F.)	Y-Not Verified
41127	2	32	Touchet River, N.F. (E.F.)	Y-impaired
40514	2	32	Touchet River, S.F.	Y-impaired
40513	2	32	Touchet River, S.F.	Y-impaired
41097	2	32	Walla Walla River	ODEQ Rpt
41098	2	32	Walla Walla River	ODEQ Rpt
41100	2	32	Walla Walla River	ODEQ Rpt

Listing ID	Category	WRIA	Waterbody Name	Load Allocation Code
41102	2	32	Walla Walla River	ODEQ Rpt
41103	2	32	Walla Walla River	ODEQ Rpt
41104	2	32	Walla Walla River	ODEQ Rpt
Total in Category 2 = 37				

Table D-4 Load Allocation Codes are:

- Y = Load allocation for this listing is set in this report
- AD = Adaptive management. Specific numeric load allocations are not set for Garrison Creek because flows are primarily routed to Yellowhawk Creek during the summer. Use adaptive management to increase shading and improve water quality as much as possible.
- Eng Chan AD = Specific numeric load allocations are not set for the engineered flood control portion of Mill Creek below the Yellowhawk diversion. Use adaptive management to improve conditions as much as possible. Adaptive management should be used to evaluate how changes in operation and design may impact water temperature and to make those changes that result in the best overall improvement to the thermal conditions of the aquatic habitat existing in the watershed.
- ODEQ Rpt = Technical analysis for temperature impairments in the mainstem Walla Walla is documented in ODEQ, 2005. Load allocations for these segments will be based on the analysis done by ODEQ and will be submitted to EPA in the Washington State Walla Walla Basin Submittal report.
- Y-impaired = Load allocation for this listing is set in this report. This listing was found to slightly exceed water quality standards at the time of the 2002/4 303(d) list preparation and was coded a level 2 ‘water of concern’. It was verified as a level 5 impairment during this study and is assigned a load allocation.
- Y-not verified = General load allocation calculated. Level 2 status not verified. High elevation site near Umatilla National Forest boundary.

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Appendix E. Temperature model summary and data requirements

Table E-1. Stream temperature modeling, data requirements.

	Parameter	Model Requirement		Data Source		
		Shade	QUAL2K	Ecology	WDFW	GIS
Flow	discharge - tributary		X	X	X	
	discharge (upstream & downstream)		X	X	X	
	flow velocity		X	X	X	
	groundwater inflow rate/discharge		X	X		
	travel time		X	X		
General	calendar day/date	X	X	X		
	duration of simulation	X	X	X		
	elevation - downstream	X	X	All Data Collected Primarily from USGS or GIS Maps		
	elevation - upstream	X	X			
	elevation/altitude	X	X			
	latitude	X	X			
	longitude	X	X			
	time zone	X				
Physical	channel azimuth/stream aspect	X	X			X
	cross-sectional area	X	X	X	X	
	percent bedrock		X	X		
	reach length	X	X			X
	stream bank slope	X		X		X
	streambed slope	X	X	Collect from USGS or GIS Maps		
	width - bankfull	X		X	X	X
	width - stream	X	X	X	X	
Temperature	temperature - groundwater		X	X		
	temperature - tributaries		X	X	X	
	temperature - water downstream		X	X	X	TIR
	temperature - water upstream		X	X	X	
	temperature - air		X	X		
Vegetation	% forest cover on each side	X		X		X
	canopy-shading coefficient/veg density	X		X	X	X
	vegetation overhang	X		X		X
	distance to shading vegetation	X		X		X
	topographic shade angle	X				X
	vegetation height	X		X		GIS and TIR
	vegetation shade angle	X				X
	vegetation width	X				X
Weather	relative humidity		X	X	Weather Stations and /RH meters	
	% possible sun/cloud cover		X			
	solar radiation		X			
	temperature- air		X	X		
	wind speed/direction		X			

All input data for the Shade and QUAL2Kw models will be longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments.

QUAL2K (or Q2K) is a river and stream water quality model that represents a modernized version of QUAL2E (Brown and Barnwell, 1987). QUAL2Kw is adapted from the QUAL2K model originally developed by Chapra (Chapra and Pelletier, 2003). Q2K is similar to Q2E in the following respects:

- *One dimensional*. The channel is well-mixed vertically and laterally. Non-uniform, steady flow is simulated.
- *Diurnal heat budget*. The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale.
- *Heat and mass inputs*. Point and nonpoint loads and abstractions (withdrawals or losses) are simulated.

The QUAL2Kw framework includes the following new elements:

- *Software environment and interface*. Q2Kw is implemented within the Microsoft Windows environment. It is programmed in the Windows macro language: Visual Basic for Applications (VBA). Excel is used as the graphical user interface.
- *Model segmentation*. Q2Kw can use either constant or varying segment lengths. In addition, multiple loadings and abstractions can be input to any reach.
- *Hyporheic exchange and sediment pore water quality*. Q2K also has the ability to simulate the metabolism of heterotrophic bacteria in the hyporheic zone.

TTools

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

Shade Model

Shade.xls was adapted from a program that was originally developed by the ODEQ as part of the HeatSource model. Shade.xls calculates shade using one of two optional methods:

- ODEQ's original method from the HeatSource model version 6 (ODEQ, 2003).
- Chen’s method based on the Fortran program HSPF SHADE (Chen, 1996). The method uses a slightly different approach to modeling the attenuation of solar radiation through the canopy (Chen et al., 1998a and 1998b).

All data will be assembled from Ecology field surveys and monitoring data. The model output from Shade is a model input to QUAL2Kw.

All continuous temperature data will be stored in a temperature database designed by Ecology that includes station location information and data quality assurance information. This database will facilitate summarization of the temperature data and create a data table to upload temperature information to Ecology's Environmental Information Management (EIM) system.

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Appendix F. Riparian field survey data

Table F-1. Effective shade and canopy cover measurements from 1000-foot reach surveys, 2002.

Station ID	Date	Solar Pathfinder % Total Direct Sunlight			% Canopy Cover			Pathfinder % shade
		Average	SD	N	Average	SD	N	Average
32TOU-02.0	8/1/02	83.5	8.0	5	4.0	4.3	5	16.6
32TOU-07.0	8/13/02	95.1	1.8	6	0.3	0.8	6	4.9
32TOU-10.8	8/12/02	86.8	5.5	6	3.0	5.9	6	13.2
32TOU-12.8	8/15/02	91.2	7.6	6	1.0	1.1	6	8.8
32TOU-14.2	8/26/02	99.8	NA	1	2.0	2.8	2	0.3
32TOU-17.8	8/12/02	86.4	12.5	6	13.8	28.0	6	13.6
32TOU-25.0	8/26/02	98.3	2.0	6	0.3	0.8	6	1.7
32TOU-26.1	8/27/02	96.8	4.6	6	0.3	0.5	6	3.3
32TOU-30.6	8/26/02	96.8	4.9	6	0.2	0.4	6	3.2
32TOU-34.2	8/12/02	90.1	19.6	6	12.2	27.9	6	9.9
32TOU-40.5	8/13/02	97.6	2.9	6	10.3	18.8	6	2.4
32TOU-53.9	8/14/02	76.3	24.2	7	12.7	11.1	7	23.7
32NFT-04.9	8/13/02	87.3	14.0	6	17.0	15.8	6	12.7
32SFT-02.5	8/27/02	54.0	6.2	3	63.0	25.1	3	46.0
32MIL-01.7	7/30/02	NA	NA	NA	9.8	12.4	6	
32MIL-12.8	8/10/02	77.7	7.1	5	26.4	12.8	5	22.3
32MIL-14.8	8/15/02	66.0	33.0	7	10.0	7.5	7	34.0
32MIL-19.1	8/15/02	85.0	NA	1	1.0	NA	1	15.0
32MIL-21.3	8/15/02	48.6	20.4	7	22.1	8.7	7	51.4
32MIL-26.5	8/28/02	32.8	31.8	7	54.6	27.3	7	67.3
32MIL-27.5	8/28/02	25.3	21.7	7	70.7	13.9	7	74.7
32ROB-02.3	8/29/02	75.0	12.1	4	19.3	17.2	4	25.0
32WLF-01.8	8/14/02	41.7	13.7	3	31.7	15.0	3	58.3
32NFT-07.7	8/27/02	60.7	22.3	7	18.9	15.9	7	39.3
32DRY-27.4	8/29/02	21.1	10.4	7	80.1	16.6	7	78.9
32COP-05.4	8/28/02	17.8	21.0	7	77.3	21.7	7	82.2
32TOU-38.3	8/13/02	82.7	20.5	3	18.8	11.9	4	17.3

SD – standard deviation
N – number of samples

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Appendix G. Proposed use designations (2003/2006) for the Walla Walla basin

Table G-1. Proposed use designations (2003/2006) for the Walla Walla basin (WRIA 32), amended November 2006. (www.ecy.wa.gov/biblio/wac173201a.html)

Table 602	Aquatic Life Uses						Recreational Uses			Water Supply Uses				Miscellaneous Uses				
Use designations for fresh waters by Water Resource Inventory Area (WRIA)	Char Spawning/Rearing	Core Summer Habitat	Spawning/Rearing	Rearing/Migration Only	Redband Trout	Warm Water Species	Ex Primary Cont	Primary Cont	Secondary Cont	Domestic Water	Industrial Water	Agricultural Water	Stock Water	Wildlife Habitat	Harvesting	Commerce/Navigation	Boating	Aesthetics
Blue Creek and tributaries above latitude 46.0581 and longitude 118.0971	✓							✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Coppei Creek, North and South Forks (including tributaries).		✓						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Dry Creek and tributaries above junction with unnamed creek at latitude 46.1197 longitude 118.1378 (Seaman Rd).		✓						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Mill Creek from mouth to 13th Street Bridge in Walla Walla (river mile 6.4).[1]			✓						✓		✓	✓	✓	✓	✓	✓	✓	✓
Mill Creek from 13th Street Bridge in Walla Walla (river mile 6.4) to latitude 46.0862 longitude 118.2395 in north channel and latitude 46.0800 longitude 118.2541 in south channel.			✓					✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Mill Creek from latitude 46.0862 longitude 118.2395 in north channel and latitude 46.0800 longitude 118.2541 in south channel to headwaters (including tributaries) except where otherwise designated Char.		✓						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Mill Creek and Railroad Canyon: All waters (including tributaries) above the junction up to city of Walla Walla waterworks dam (river mile 21.6).	✓							✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Mill Creek and tributaries from city of Walla Walla waterworks dam (river mile 21.6) to headwaters (including upstream and downstream of where Mill Creek flows into Oregon).[2]	✓						✓			✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 602	Aquatic Life Uses						Recreational Uses			Water Supply Uses				Miscellaneous Uses				
Use designations for fresh waters by Water Resource Inventory Area (WRIA)	Char Spawning/Rearing	Core Summer Habitat	Spawning/Rearing	Rearing/Migration Only	Redband Trout	Warm Water Species	Ex Primary Cont	Primary Cont	Secondary Cont	Domestic Water	Industrial Water	Agricultural Water	Stock Water	Wildlife Habitat	Harvesting	Commerce/Navigation	Boating	Aesthetics
Touchet River above latitude 46.3172 longitude 118.0000 (Sect. 30 T10N R38E) (including tributaries) not otherwise designated Char.		✓						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Touchet River, North Fork, and Wolf Creek: All waters (including tributaries) above the junction.	✓						✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Touchet River, South Fork, and the unnamed tributary at latitude 46.2307 longitude 117.9397: All waters (including tributaries) above the junction, except those waters in or above the Umatilla National Forest.	✓							✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Touchet River, South Fork, and the unnamed tributary at latitude 46.2307 longitude 117.9397: All waters (including tributaries) above the junction that are in or above the Umatilla National Forest.	✓						✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Walla Walla River from mouth to Lowden (Dry Creek at river mile 27.2).				✓					✓		✓	✓	✓	✓	✓	✓	✓	✓
Walla Walla River from Lowden (Dry Creek at river mile 27.2) to Oregon border (river mile 40).[3]			✓					✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Whiskey Creek and unnamed tributary system at latitude 46.2176 longitude 118.0667 (Section 33 T9N R38E), all waters above junction.		✓						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes for WRIA 32:

1. Dissolved oxygen concentration shall exceed 5.0 mg/L.
2. No waste discharge will be permitted for Mill Creek and tributaries from city of Walla Walla waterworks dam (river mile 21.6) to headwaters.
3. Temperature shall not exceed a 1-DMax of 20.0°C due to human activities. When natural conditions exceed a 1-DMax of 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t = 34/(T + 9).

Portions of the above use designations that may be disapproved by EPA can be found in map form on EPA’s website _
http://yosemite.epa.gov/R10/WATER.NSF/Water+Quality+Standards/WA+WQS+EPA+Disapproval

Appendix H. Historical conditions and vegetation

Following are annotated references compiled by Mike LeMoine on March 4, 2004:

Memoirs of My Life by John Charles Fremont
Volume I
Chicago and New York;
Belford, Clarke & Company
1987

October 22
"The trail passed sometimes through very thick young timber, in which there was much cutting to be done; but after traveling a few miles the mountains became more bald…We were here on the western verge of the Blue Mountains, long spurs of which, very precipitous on either side, extended down into the valley, the waters of the mountain roaring down between them.

On our right was a mountain plateau covered with a dense forest; and to the westward, immediately below us, was the great *Nez Perce* (pierced nose) prairie, in which dark lines of timber indicated the course or many affluents to a considerable stream that was seen pursuing its way across the plain toward what appeared to be the Columbia River. This I knew to be the Walahwalah River, and occasional spots along its banks, which resembled clearings…

The rock displayed here in the escarpments is a compact amorphous trap, which appears to constitute the mass of the Blue Mountains in this latitude; and all the region of the country through which we have traveled since leaving the Snake River has been the seat of violent and extensive igneous action." (page 266)

"The stream here has just issued forth from the narrow ravines, which are walled with precipices, in which the rock has a brown and more burnt appearance than above."   (page 267)

"The morning was clear, with a temperature at sunrise of 24°. Crossing the river we traveled over a hilly country with good bunch grass; the river bottom, which generally contains the best soil in other countries, being here a sterile level of rock and pebbles. We had found the soil in the Blue Mountains to be of excellent quality, and it appeared also to be good here among the lower hills. Reaching a little eminence, over which the trail passed, we had an extensive view along the course of the river, which was divided and spread over its bottom in a net-work of water, receiving several other tributaries from the mountains.

…True to its general character, the reverse of other countries, the hills and mountains here were rich in grass, the bottoms barren and sterile." (page 268)

October 25
"…Our road to-day had in it nothing of interest, and the country offered to the eye only a sandy, undulating plain, through which a scantily timbered river takes its course.

We halted about three miles above the mouth, on account of grass; and the next morning arrived at the Nez Perce Fort…a few hundred yards above the junction of the Walahwalah with the Columbia River. Here we had the first view of this river, and found it about one thousand two hundred yards wide, and presenting the appearance of a fine navigable stream.

We made our camp in a little grove of willows on the Walahwalah, which were the only trees to be seen in the neighborhood….scarcely a blade of grass to be found. The post is on the bank of the Columbia, on a plain of bare sands, from which the air was literally filled with clouds of dust and sand…"

Fur and Trade Empire--George Simpson's Journal
Entitled: Remarks Connected with the Fur Trade in the Course of a Voyage from York Factory to Fort George and Back to York Factory 1824-25
The Belknap Press of Harvard University Press
Cambridge, Massachusetts
1968

November 23.
"The Walla Walla River a smaller Stream likewise falls in from the south…the profit it yields is still very moderate…Its returns this season are estimated at 2000 Beaver got principally from a branch of the Nez Perces tribe called the Caiuses and it does not appear to me that there is a prospect of any considerable increase…" (page 54)

Washington State University
Walla Walla County
Botanical Observations of Captains Lewis and Clark in the Walla Walla Country
1805-1806

"They noted that these people subsist on roots of various descriptions which these plains furnish in great abundance. They also noted that these Indians burn the stems of shrubs for fuel since there is no timber in their neighborhood…

On April 29, 1806 they crossed the Columbia to the area around the mouth of the Walla Walla River and noted a fish weir constructed of willows…

"On April 30, while traveling northeast to the Touchet River, they noted sand banks 15 to 20 feet high and that the plain they traveled through was covered with aromatic shrubs, herbatious plants and a short grass. They noted that many of those plants they saw produce root foods for the natives…At the place where this trail hit the Touchet River, there was adequate firewood, the first such amount since they left the Dalles. Trees in this location consisted of cottonwood, birch (likely water birch), crimson haw (likely black hawthorn), red willow, sweet willow, chokecherry, yellow currants (likely golden currant), gooseberries, white-berried honeysuckle, rose bushes, seen bark, and shoemate (likely smooth sumac). They also observed corn grass (likely basin wild rye) and rushes (possibly Scirpus or Equisetum) in some parts of the river bottom.

…they proceeded further along the Touchet River going east. They noted that in going eastward the timber on the creek became more abundant. They noted more timber than usual along the rivers and the presence of a long leafed pine (likely Ponderosa Pine)…They also observed considerable quantities of camas in bloom in the bottom land they now were passing through after leaving the pine grove." (pages 2-3)

Lyman's History of Old Walla Walla County Vol. I
The S.J. Clarke Publishing Company, Chicago
W.D. Lyman

"A few general statistics as to the average records at Walla Walla…Average annual temperature shown by official records during thirty-one years is fifty-three degrees. The average for January is thirty-three degrees; for July and August, seventy-four degrees….The prevailing wind is always from the south…an average of eight thunder showers in a year…extraordinary differences in rainfall according to elevation and proximity to the mountains" (5)

"One of the interesting and important features of Walla Walla is the fine system of spouting artesian wells. There are now over 30 of these wells in the Walla Walla Valley, the largest having a flow of 2,500 gpm, sufficient to irrigate a half section of land" (Lyman 6)

Water Supt. R.R. McLean
December 31, 1916

"In April, 1907, the headworks and intake on Mill Creek were installed. Extracts from the last report of Water Supt. McLean are here inserted and from them can be derived a view of the present condition of the water and sewerage systems." (Lyman 302)

"On the last day of April 1806, the party turned their horses' heads eastward up the Wallawollah (sic) River across sandy expanses, which however, they soon discovered to improve in verdure and in groves of trees. Having followed the main stream fourteen miles, they reached 'a bold, deep stream, about 10 yards wide, which seems navigable for canoes.' They found a profusion of trees along the course of this creek and were delighted to see all the evidences of increasing timber. This stream they now followed for a number of miles was evidently the Touchet…" (Lyman 39)

1866 and 1867, 4 citizens (H.P. Isaacs, J.C. Isaacs, A. Kyger, J.D.Cook) took initial steps in providing a system of water distribution. In 1877 the reservoirs were built on both sides of Mill Creek, one on what is now the property of the Odd Fellows Home and the other in the City Park. The corporate name of Mr. Isaacs' enterprise was the Walla Walla Water Co. Ownership was ultimately acquired by the Baker-Boyer Bank. (Lyman 149 – not a direct quote).

2001 Columbia Basin
Agricultural Research Center
Annual Report
Stalion Report 1026
Oregon State University

"No-Till Influence on hydrology and stream morphology in dryland crop areas"

The AuK: A Quarterly Journal of Ornithology
Vol. XXXV
April 1918 No. 2

"In the winter of 1904-05 Pine Siskins were numerous in small flocks in the trees and brush along the Touchet River near Prescott. They fed extensively on the seeds of the alder." (The AuK 151)

Referring to the British Columbia Evening Grosbeak:
"In winter at Prescott they commonly feed on sumac seeds…" (150)

Referring to the Lazuli Bunting:
"…They are common in the cottonwoods and willows along the Touchet River at Prescott" (153)

A Bird Census at Prescott, Walla Walla Co., WA
Lee Raymond Dice
May 1921
Taken from The Condor Vol. XXIII page 87

"The native trees and shrubs are willow, wild cherry, dogwood, cottonwood, alder, birch, thorn, and elderberry"

The Walla Walla Story, The Valley They Liked So Well They Named It Twice, 1953
"City Water Supply One of Community's Assets"
Claude M. Gray
Page 33

"Unusually soft, cold water is one of the natural resources of Walla Walla."

"Maximum output is 25,000,000 gallons per day of which 14,000,000 gallons is secured from the city water department's intake 18 miles east of Walla Walla up Mill Creek."

"By chemical analysis based on hard particles per million units, the city water has only 28. Besides this advantage of softness, the Walla Walla water is cold the year round and never has to be doctored. From its main source, Mill Creek, the water has a mean temperature between 34 degrees in winter and 55 degrees."

"…pertinent and vital fact that Walla Walla never has had a water shortage since the city was incorporated…Mill Creek—is literally endless"

Bulletin of the United States Fish Commission Vol. XIV for 1894
Marshall McDonald, Commissioner
Washington: Government Printing Office 1895

Walla Walla River

"This is a river of some importance flowing into the Columbia at the town of Wallula, about 30 miles west of Walla Walla. It was examined August 23, at Wallula, below the railroad bridge. It is here a good-sized stream, 3 to 8 feet deep in the channel, and has a velocity of about one-half foot per second. Temperature at noon, 70º; air, 80º. The bed of the stream was of soft mud, with an abundance of *Charu* and other vegetation in places, and the water was rather muddy…obtained the only specimens of *Columbia transmontana* that were secured by any of us." (186)

Mill Creek
"…examined August 14 south of Walla Walla one half mile. Width, 12 feet; depth, 10 inches; current 11 feet. Temperature at 8:30 a.m. 50º, air, 73º. The bottom here is of course gravel. We could not learn that salmon are ever taken in this steam."

The Journals of the Lewis and Clark Expedition
March 23-June 9, 1806
University of Nebraska Press
Lincoln and London

"…the Creek bottoms then became higher and wider; to the extent of from 2 to 3 miles. we Saw Several Deer…the timber on the Creek become more abundant and less burnt…we Saw a great number or Curloos, Some Crains, Ducks, prairie cocks, and Several Species of Sparrows….Very little difference between the apparent face of the Country here and that of the plains of the Missouri. only that those are not enlivened by the vast herds of Bufafalow, Elk&c. which animated those of the Missouri. The Courses & distances of this day are N. 45º E. 9 mls. & N. 75º E. 17 Miles along the North Side of this Creek…" (Clark 198)

"…more timber than usual on the creek, some pine of the long leaf kind appears on the sides of the creek hills, also about 50 acres of well timbered pine land…the bottoms through which we passed were wide. the main creek boar to the S. and heads in the Mountains; it's bottoms are much narrower above where we passed it…
we passed the small creek at 8 ¾ away from the commencement of this course…this creek is about 4 yds. Wide and bears East…considerable quantities of the quâ-mash in the bottoms…now in bloom. there is much appearance of beaver and otter along these creeks…two deer…many sandhill crains Curloos and other fowls…the soil appears to improve as we advance on this road." (Lewis 199)

South Fork Touchet Watershed Analysis

Sinuosity
"A comparison of aerial photographs from 1937 and 1995…In general, they have become shorter (less sinuosity). Steeper, wider, and more braided. This is consistent with a system which is aggrading, apparently from material resulting from stream bank erosion and debris flows in small, steep tributaries…Photo comparisons indicate that the presence or absence of conifer-dominated riparian stands plays a major role in influencing channel morphology. The trend toward greater channel mobility and increased braiding with decreased stream side forest cover suggests that tree roots play a critical role in maintaining bank stability and hence, channel confinement within the alluvial floodplain." (Page 13, Section 3 Executive Summary)

Suspended Sediment

"Average sediment yields during the study period (July 1962-1965) ranged from 420 tons.mi2 (0.66 t/a) in the mountainous area to more than 4,000 tons/mi2 (6.25 t/a) in the extensively cultivated northern and central parts of the basin, which are drained by the Touchet River and Dry Creek. The Touchet River and Dry Creek transported approximately 80% of the total sediment load discharged from the Walla Walla River basin.

Silt predominates in the suspended sediment transported by all streams in the basin. On the average, sediment from streams draining the Blue Mountains was composed of 205 sand, 60% silt, and 20% clay; for streams draining the Blue Mountains slope-Horse Heaven Hills area, the percentages are 9, 65, and 26, respectively; and for those draining the Skyrocket Hills-Touchet slope, the percentages are 5, 75, and 20, respectively. The bedload in the mountain and upland streams was estimated to be about 5-12% as much as the suspended load. For the Walla Walla River and its tributaries in the lower basin area, the bedload was estimated to be only about 2-8% as much as the suspended load." (Appendix B, B-25, Surface Erosion Assessment Module)

Passive Restoration Strategies (7.2) in order of decreasing priority

1. Identification and protection of, and long term knowledge building from reference slopes, landings, or road segments for use as restoration templates. (suggested BMP)
2. Deep assessment of terrestrial sediment transport pathways and channel network structure and function from a geomorphology perspective, providing 'custom, locally derived' input for systematic restoration designs. (suggested BMP)
3. Monitoring effectiveness of anthropogenic and natural inputs affecting slope complexity and soil quality (e.g. vegetation debris) for interception of compacted surface runoff, soil moisture infiltration and percolation, sediment storage, and establishment of plant cover. (suggested BMP)

(Appendix B, B-33, Surface Erosion Assessment Module)

Active Restoration Strategies (7.3) in order of decreasing priority

1. Treatment of actively eroding roads with chronic, high sediment delivery rates to the channel network (implemented BMP)
2. Stream crossing improvements at numerous stream crossings to reduce erosion and find sediment delivery (implemented BMP)
3. Well designed addition of slope, road, and channel roughness where lacking, with regular broadly cast communications evaluating multi-attribute slope, road, and channel performance (implemented BMP)
4. Riparian and wetlands area exclusion to reduce soil, vegetation, and channel damage from cattle grazing…and residential and commercial (non forestry) areas (implemented BMP)
5. Treatment of actively eroding banks through bioengineering techniques (implemented BMP)

(Appendix B, B-34, Surface Erosion Assessment Module)

Vegetation and Channel Morphology

"The presence or absence of conifer-dominated riparian stands plays a major role in influencing channel morphology. For example, in section 16 (T9N, R39E), the channel evolves from a single-thread, meandering morphology in 1937 to a braided channel in 1995, with mid-channel bars as much as 125 ft. wide. The riparian forest in 1937 was dominated by ponderosa pines and extended about 700 ft. from the active channel margin. There is no riparian forest along this

channel reach today. In addition, the main channel has widened since 1937, and the active floodplain has widened by approximately 30 ft. on either side of the channel…
…The trend toward greater channel mobility and increased braiding with decreased streamside-forest cover suggests that tree roots play a critical role in maintaining bank stability and, hence, channel confinement within the alluvial floodplain."
(Appendix E, E-12, Stream Channel Assessment)

Land/Vegetation

Situation
"Timber harvesting, forest road construction, livestock grazing, and natural disturbances (floods) in the riparian zone over the last 100 years have resulted in riparian forest stands that are of insufficient size and/or density to supply adequate volumes of large woody debris in the near term necessary to create and maintain diverse channel and off-channel habitat associated with migration, spawning, rearing…"

Triggering Mechanisms
"Direct removal of riparian trees via timber harvest has eliminated near term inputs of large woody debris. Forest road construction within the riparian zone has eliminated near term as well as long term inputs. Livestock has retarded the regeneration and/or growth of woody vegetation directly via browsing or indirectly via soil compaction and disturbance. In most cases, a combination of the above activities has contributed to the current LWD recruitment situation, rather than any single practice. "
(Casual Mechanism Report and Prescriptions #8)

Fish Habitat, Temperature and Shade

Summer Rearing (3.4.3)

Current Problem Areas
"Land use practices such as forest practices and livestock grazing have resulted in diminished riparian canopy and shade leading to instream temperature problems throughout the basin, particularly along lower elevation channel segments of the South Fork and Robinson Fork."

Uncertainties
"Detailed temperature data is currently not available throughout the watershed, so thermal impacts on fish populations are difficult to determine. However, the riparian assessment did find numerous areas that have potential temperature problems based on lack of shade."

Winter Rearing (3.4.4)

Current Problem Areas)
"There are limited off channel and side channel rearing areas…that provide refuge during high winter flows throughout the basin. Most of this type of habitat has been eliminated by road building, diking, and deposition of coarse sediment which fills side channels and pools and blocks access to smaller tributaries."

Key Vulnerabilities
"…Filling of side channels and pools and blockage of tributaries from coarse sediment deposition was evident during field surveys, particularly in the lower gradient channel segments." (Appendix F, F-9, Fish Habitat Assessment)

Shade

Situation
"Past timber harvesting, forest road construction, livestock grazing, and natural disturbances (floods) in the riparian zone over the last 100 years has resulted in riparian forest stands that lack sufficient canopy closure relative to target canopy closure levels necessary to maintain water temperatures below the designated water quality standards. This may result in degraded summer rearing conditions…"

Triggering Mechanisms
"Direct removal of riparian trees via timber harvest has eliminated or reduced canopy cover below target minimum in the near term. Forest road construction within the riparian zone has eliminated or reduced canopy cover below target minimums in the near term as well as the long term equivalent to the life of the road). Live stock grazing has retarded the regeneration of shade-providing woody vegetation (particularly hardwoods) directly via browsing or indirectly via soil compaction and disturbance. In most cases, a combination of the above activities has contributed to the current canopy closure situation, rather than any single practice."

(Casual Mechanism Reports and Prescriptions #9)

Touchet, As Grandpa Knew It
Zola Burnap Irwin
Burwin Publications
W. 3902 Longfellow Avenue
Spokane, Washington 99205

April 30, 1806
"At a distance of fourteen miles we reached a branch [the Touchet River] of the Wollawolla river rising in the same range of mountains and emptying itself six miles above the mouth of the latter. It is a bold stream about ten yards wide and seems to be navigable for canoes. The hills of this creek are generally abrupt and rocky but the narrow bottom is very fertile and both possess twenty times as much timber as the Columbia itself; indeed we now find, for the first time since leaving Rock fort, an abundance of fire wood. The growth consists of cottonwood, birch, the crimson haw, red and sweet willow, chokecherry, yellow currants, gooseberry, the honeysuckle with a white berry, rose, bushes, seven bark, sumac, together with corn grass and rushes" (page 2)

More floods occurred in 1887 (page 9)

January 30, 1892
"Interest in the irrigation of dry land around Touchet…. 'a regular land fever has prevailed among the Touchet people and all who are able to have taken up lands….Our people believe an irrigation ditch will be put in though on what exact basis is not yet known." (page 20)

April 6, 1893
"The water is taken out of the Touchet River at a point three miles above town. It is turned into the ditch which is eight miles in length and ten feet wide. The Touchet…River rises high in the heart of the Blue Mountains fed by never failing small springs and flows with plenty of water

when needed for irrigation purposes...In years gone by this country contained a generous growth of bunch grass and the old settlers say that for years their cattle were fat enough for market the year round.. Subsequently, however, the fame went abroad, large herds of horses, cattle and sheep were driven in and since have kept the grass down to a tithe of its former growth…the bottom lands being the only farming land…this valley could be made more valuable for farming than it could be as a stock range…”
(page 21)

November 28, The Statesman
“Work on the old Boyer-Burlingame ditch by which it is expected to reclaim several thousand acres of arid lands in the vicinity of the Hudson Bay [sic] country discontinued through lack of funds during the hard times is to be taken up again. There are 15 miles of ditch yet to be dug. A five mile stretch was completed in ’93.” (page 37)

January 8, 1903
“…the wild current of the Walla Walla River” (page 38)

February 24
“News of a new irrigation company…Articles on incorporation of Touchet Land Irrigation and Improvement Company have been filed in the county auditors office…Capital stock is placed at $3,000” (page 51)

May 27
.”…the finish of the big ditch...the water is now turned into canals of the Walla Walla Irrigation Company as the pipe line across Pine Creek is finished and many perspective buyers are flocking in…purchasers are beginning to clear their land preparatory to putting in crops” (page 53)

May 31
“…drastic floods at Touchet…The Walla Walla River has wrought havoc to the alfalfa fields near Touchet…practically all on the river bottom was washed away. The bridge over the Walla Walla River near Touchet is in great danger…The Touchet is not yet as high as the Walla Walla but is rapidly rising. The rainfall exceeded four inches in four hours.” (page 58)

January 20, 1909
“As a result of the Chinook the Walla Walla and Touchet rivers have risen very rapidly in the last two days….The Touchet is now twenty feet deep and the water is within a foot and a half of the O.R. &N. railroad bridge. The wagon bridge over the Touchet is nearly impassable, being now under two feet of water….Touchet is receiving no mail these days because of washouts on the O.R. &N. between Walla Walla and Pendleton. (page 72)

January 27, 1916
“A new well, drilled at Gardena…sunk 75 feet and a flow estimated at 36,000 gallons per hour was struck.”