Tucannon River and Pataha Creek Temperature Total Maximum Daily Load

Water Quality Improvement Report and Implementation Plan

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Cover photo: *Cover photo of Tucannon River taken by HDR, 2005*

Project Codes and 1996 303(d) Water body ID Numbers

Data for this project are available at Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, TUWS35TM.

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Numbers: WA-35-2010

Tucannon River & Pataha Creek Temperature Total Maximum Daily Load

Water Quality Improvement Report and Implementation Plan

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Abstract

Cool stream temperatures are vital to threatened and endangered salmon that need cold, clean water to survive. The Washington State Department of Ecology prepared this total maximum daily load report, or TMDL for stream temperature on the Tucannon River and its tributaries. The Tucannon watershed is in the lower southeast corner of the state and has a mix of forest and agricultural land uses, as well as natural fire disturbance regimes. The watershed planning committee contracted a temperature water quality study report in 2005. This TMDL includes that report and other existing credible data to calculate load and wasteload allocations for effective shade for the Tucannon River and Pataha Creek, as well as other recommendations to reduce temperatures and meet state water quality standards.

Acknowledgements

The authors of this report would like to thank especially the following people for their contribution of data to this study:

- Brad Johnson and the members of the WRIA 35 Watershed Planning Group
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- WDFW Snake River Lab office and Wooten Fish Hatchery
- City of Pomeroy Sewage Treatment Plant staff
- Landowners in the Tucannon River watershed

The authors would also like to thank Helen Bresler, Tony Whiley, Anita Stohr, Paul Pickett, and Stephanie Brock for their review, advice, and encouragement.

Executive Summary

Introduction

The Tucannon River and Pataha Creek are on Washington State's 303(d) list of impaired water bodies for temperature, fecal coliform, and pH exceedances. The Tucannon River is also listed for turbidity.

Once placed on the 303(d) list, a water quality improvement project (also known as a total maximum daily load, or TMDL) is normally completed. However, traditional TMDLs are costly and time consuming, and Ecology's resources for conducting TMDLs are limited. In many rural watersheds nonpoint sources are typically dominant, with few point source dischargers. In such situations the pollution problems are often less complex and therefore do not need complex TMDL work. With this in mind, Ecology developed a "streamlined" approach to TMDL development. The Tucannon/Pataha watershed was chosen as a pilot project because of its small size and largely rural character. Also, we chose this project because many local jurisdictions and landowners have already begun to implement the restoration projects and management practices necessary to address the pollution sources.

What is a total maximum daily load (TMDL)?

The federal Clean Water Act (CWA) requires that a total maximum daily load (TMDL) be developed for each of the water bodies on the 303(d) list. The 303(d) list is a list of water bodies, which the CWA requires states to prepare, that do not meet state water quality standards. The TMDL study identifies pollution problems in the watershed, and then specifies how much pollution needs to be reduced or eliminated to achieve clean water. Then Ecology, with the assistance of local governments, agencies, and the community develops a plan that describes actions to control the pollution and a monitoring plan to assess the effectiveness of the water quality improvement activities. The water quality improvement report (WQIR) consists of the TMDL study and implementation plan.

Watershed description

The Tucannon/Pataha watershed is located in southeastern Washington State in Garfield and Columbia counties. The Tucannon River drains a watershed area of approximately 318 square miles. It flows into the Snake River 4 miles upstream of Lyons Ferry State Park. Pataha Creek enters the Tucannon River about 11 miles above the Tucannon's confluence with the Snake River. The Pataha drains a watershed of 185 square miles.

The Tucannon basin ranges from 540 feet (165 meters) above sea level at the confluence of the Tucannon and the Snake River, to 6,400 feet (1,950 meters) above sea level in the Blue Mountains. The climate is semi-arid. Average annual precipitation ranges from 5-10 inches in the lowlands of the Snake River up to 45 inches in the Blue Mountains.

Historically, the lower elevation areas were covered with canyon grasslands and shrub-steppe vegetation. Much of this land has now been converted to livestock and crop (mainly non-irrigated crops such as wheat) production. Coniferous forests still dominate the higher elevations of the Blue Mountains. Much of this area is under state or federal ownership. Land use in the watershed is primarily rural with few urban areas. The city of Pomeroy is the most populated area in the watershed, with a population in the year 2000 of 1,517.

This study area is part of the Lower Snake River Water Resource Inventory Area (WRIA) 35 in the southeast corner of Washington State. This TMDL's footprint encompasses the Tucannon River watershed and its perennial tributaries, including Pataha Creek. The watershed is contained within the boundaries of Columbia and Garfield counties, and includes the towns of Pomeroy and Starbuck (Figure ES-1). No tribal lands are designated in this subbasin. U.S. National Forest lands were evaluated for this study, but are not included in the TMDL compliance area. They are subject to their own forest management plan.

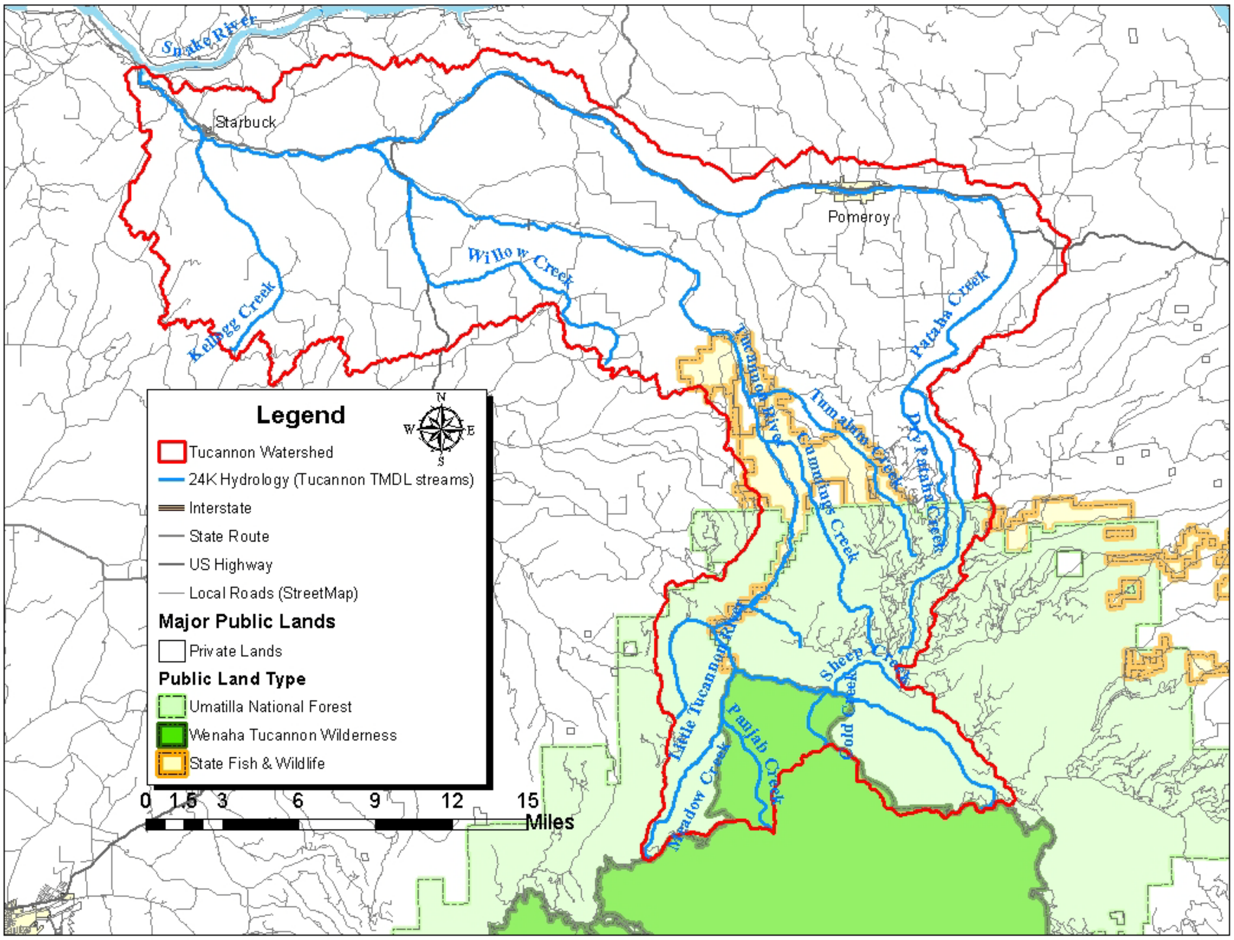

Figure ES-1. Tucannon River Watershed

What needs to be done in this watershed?

This temperature TMDL develops load allocations for effective shade on the Tucannon River and its tributaries that would occur from system potential mature riparian vegetation (Figure ES-2).

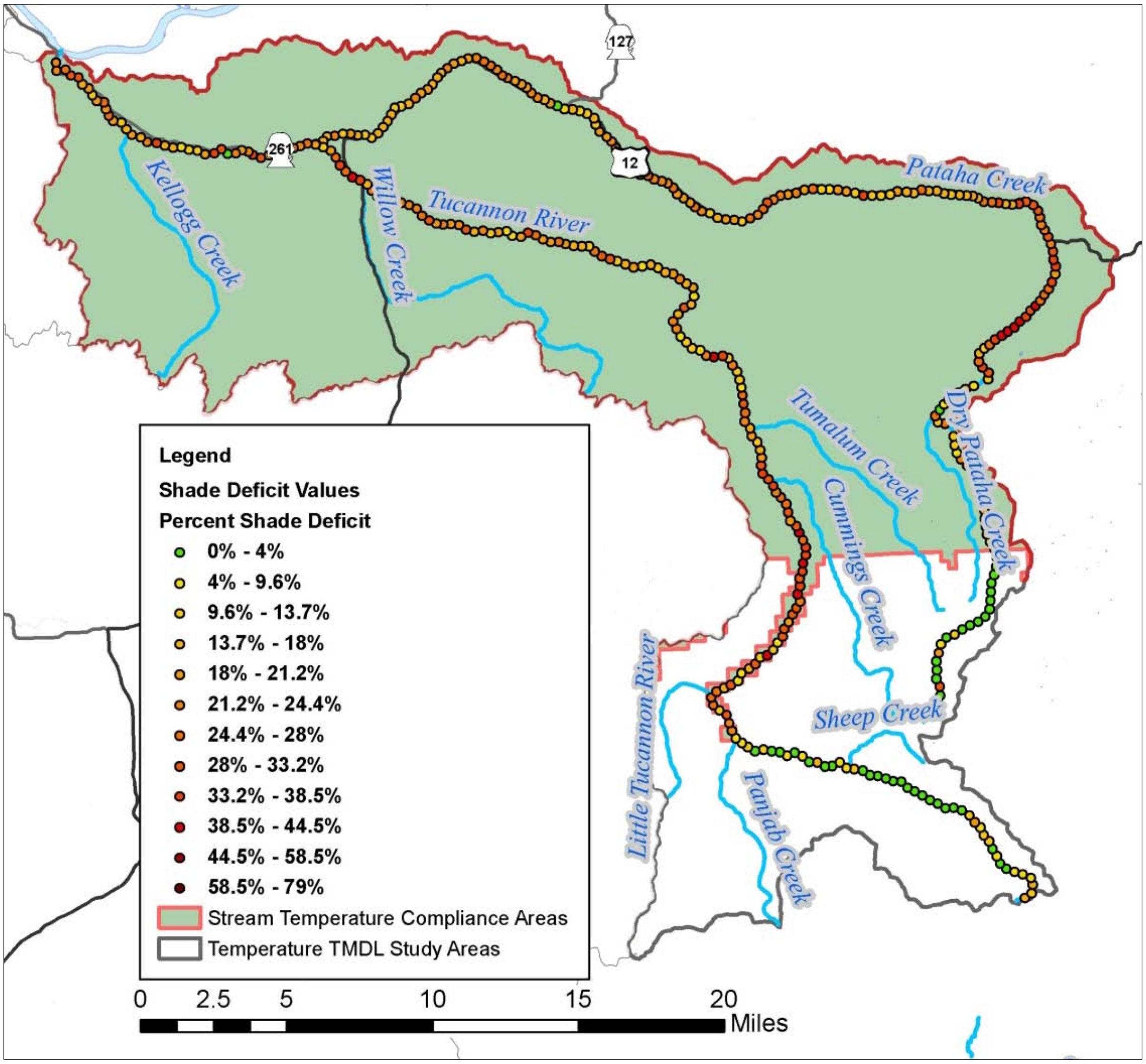

Figure ES-2. Tucannon temperature TMDL compliance area and modeled shade deficit values for Tucannon River and Pataha Creek.

Figure ES-3 prioritizes reaches for the implementation of nonpoint source pollution control and restoration activities. This map was developed by combining the results of the TMDL shade deficit analysis with existing hydrologic data.

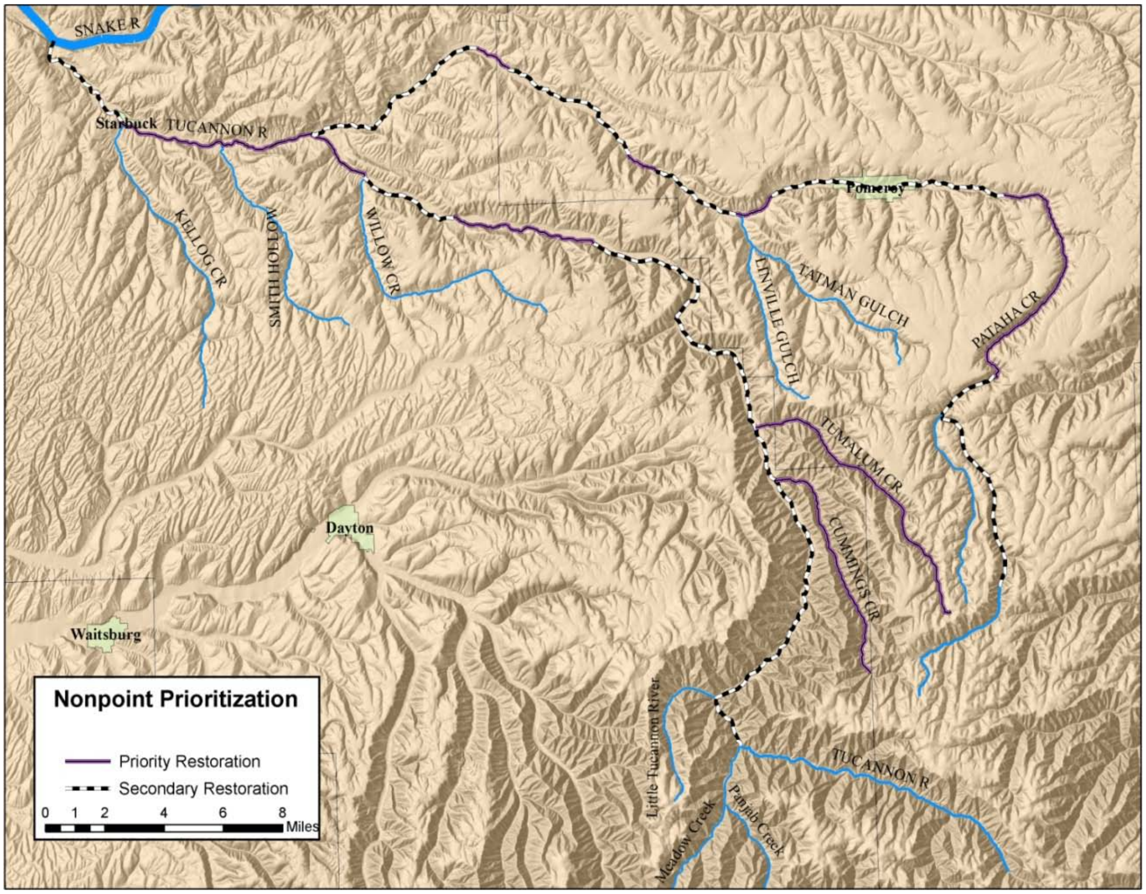

Figure ES-3. Implementation Prioritization for the Tucannon/Pataha Watershed.

Table ES-1 shows the wasteload allocations that apply during the critical period, from July to August, for the two point source dischargers in the watershed. Continuous temperature monitoring of the facilities' effluent is recommended. Violations of the numeric standard may occur outside of the critical period due to natural conditions. The state narrative standard allows sources a cumulative allowance for additional warming of 0.3ºC above the natural conditions.

Table ES- 1. Wasteload allocations for permitted discharges to Pataha Creek and Tucannon River.

Water-Body Name	Parameter of Concern	Time Period Restrictions	Permittee Name and ID	Permit Type	Wasteload Allocation
Pataha Creek	Temperature	July-August	Town of Pomeroy STP WA0021164D.	NPDES	95th percentile 7DADMax not to exceed 21.2ºC during the critical period
Tucannon River	Temperature	July-August	Tucannon Fish Hatchery	NPDES	No discharge during critical period

Why this matters

Stream temperature is vital to threatened and endangered salmon that need cold, clean water to survive. It can also affect other water quality problems.

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What is a Total Maximum Daily Load (TMDL)

Federal Clean Water Act requirements

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

The Water Quality Assessment and the 303(d) List

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

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

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

Category 2 – Waters of concern.

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

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

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

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

Further information is available at Ecology’s Water Quality Assessment website.

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

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. The TMDL study identifies pollution problems in the watershed, and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology, with the assistance of local governments, tribes, agencies, and the community then develops a strategy to control and reduce pollution sources and a monitoring plan to assess effectiveness of the water quality improvement activities. Together, the study and implementation strategy comprise the *water quality improvement report* (WQIR).

Elements the Clean Water Act requires in a TMDL

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

A water body's *loading capacity* is the amount of a given pollutant that a water body can receive and still meet water quality standards. The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with the standards.

The portion of the receiving water's loading capacity assigned to a particular source is a *wasteload* or *load* allocation. If the pollutant comes from a discrete (point) source subject to a National Pollutant Discharge Elimination System (NPDES) permit, such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from diffuse (non-point) sources not subject to an NPDES permit, such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation*.

The TMDL must also consider *seasonal variations*, and include a *margin of safety* that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A *reserve capacity* for future pollutant sources is sometimes included as well.

Therefore, a TMDL is the sum of the wasteload and load allocations, any margin of safety, and any reserve capacity. The TMDL must be equal to or less than the loading capacity.

Streamlined approach to TMDL development

Once placed on the 303(d) list, a water quality improvement project (also known as a Total Maximum Daily Load, or TMDL) is normally completed. Traditional TMDLs are costly and time consuming, and Ecology's resources for conducting TMDLs are limited. However, in many rural watersheds nonpoint sources are typically dominant with few point source dischargers. We believe that in such situations the pollution problems are often less complex and therefore do not need complex TMDL work. With this in mind, we developed a "streamlined" approach to TMDL development. This strives to reduce monitoring complexity and to develop a simpler and shorter TMDL report that is more management-focused. We decided to pilot this approach in the Tucannon/Pataha watershed because of its small size and largely rural character. Also, we chose this project because many local jurisdictions and landowners have already begun to implement the restoration projects and management practices necessary to address the pollution sources. There are invariably “teething problems” when developing any new process. Therefore, we decided to simplify our task by limiting our scope to the parameter we believed best fit the “streamlined” concept - temperature. We hope to apply the lessons learned from this project to develop similar TMDLs for the remaining pollution problems in the watershed.

Who should participate in this TMDL?

Non-point source pollutant load targets have been set in this TMDL and described in Figure 4. Because non-point pollution comes from diffuse sources, all upstream watershed areas have the potential to affect downstream water quality. Therefore, all potential nonpoint sources in the watershed must use the appropriate best management practices to reduce impacts to water quality. Similarly, all point source dischargers (the city of Pomeroy’s wastewater treatment plant and the Tucannon Fish Hatchery) in the watershed must also comply with the TMDL.

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Why Ecology is Conducting a TMDL Project in this Watershed

Ecology is conducting a TMDL project in this watershed because the Tucannon River and Pataha Creek are on Washington State's 303(d) list of impaired water bodies for temperature, fecal coliform, and pH exceedances. The Tucannon River is also listed for turbidity.

Impairments addressed by this TMDL

This TMDL addresses heat as a pollutant. Table 1 shows the 2008 category 5, or 303(d) listings for temperature that are addressed in this study. In addition to the listed segments, this report addresses all surface waters within the Tucannon basin and establishes allocations for shade on all waters. This watershed has other water quality issues that will not be addressed in this TMDL, because the implementation actions called for in this TMDL will improve those issues as well.

Potential pollution sources

NPDES permitted point sources

There are two point source dischargers operating under NPDES permits in the basin. These include the Pomeroy sewage treatment plant (STP; WA0021164D) and the Tucannon Fish Hatchery (WAG 137017). The town of Starbuck does not discharge wastewater to surface waters, so this TMDL does not assign the Starbuck treatment plant a wasteload allocation. Starbuck has a State Waste Discharge permit (#ST0008070 and addendum).

Non-point sources

Degraded riparian areas that do not provide adequate shade are the largest nonpoint source of thermal loading in this watershed. Riparian areas in the Tucannon/Pataha watershed are impacted by both natural disturbances, such as flooding and fire, and man-made disturbances, the most significant being:

- Livestock grazing.
- Crop agriculture.
- Road construction.
- Timber harvesting.
- Hydrologic modifications.

These disturbances can over-stress or completely remove natural vegetation. This can impact temperature directly by reducing potential shade, but also indirectly by speeding up erosion. In addition, the elimination of the soil-binding root mass often compounds the problems associated with hydrologic modifications.

Table 1. 303(d) listed water bodies for temperature addressed in this TMDL

Water body and LLID	Parameter	2008 Listing ID	T-R-S	Lower Route Address (Rkm)	On the 1996 list?
Tucannon River 1181740465575	Temperature	3725	12N-37E-11	3.051	Y
		13848	12N-37E-03	0	N
		13849	12N-38E-21	11.71	N
		13850	12N-39E-29	21.465	N
		13853	12N-39E-02	27.451	N
		13855	11N-40E-09	34.548	N
Tucannon River 1181740465575	Temperature	13856	11N-40E-13	40.089	N
		13857	11N-41E-19	43.37	N
		13859	11N-41E-32	48.466	N
		13861	11N-41E-04	29.873	N
		13864	10N-41E-21	56.583	N
		13982	09N-41E-02	62.353	Y
		13983	09N-41E-15	66.165	N
		13984	09N-41E-21	68.213	N
Tucannon River Hatchery Intake 1176638463218	Temperature	13865	10N 41E 27	1.330	N
Pataha Creek 1179867465091	Temperature	13847	12N-38E-24	0	N
		22437	12N-41E-36	35.381	N
		40528	12N-39E-19	0.619	N
		40529	12N-40E-17	15.227	N
		40530	11N-41E-05	28.095	N
		40531	11N-43E-07	51.209	N
Cummings Creek 1176742463327	Temperature	22432	10N-41E-22	1.842	N

Hydrologic modifications such as damming, stream straightening, and diking can have serious impacts on stream temperature by altering natural groundwater-surface water interactions, and creating bank instability, causing increased erosion. The Tucannon and Pataha systems have both experienced hydrologic modifications in the past. There are flood control structures along Pataha Creek through Pomeroy, but these should not increase further thermal loading to Pataha Creek. However, they may contribute to other pollution problems (pH, fecal coliform, turbidity, and dissolved oxygen). Perhaps more significant is the reduction of natural flow through surface water withdrawal.

There are water-rights holders within the Tucannon watershed who withdraw water for agricultural purposes. Pataha Creek has a much lower flow than the Tucannon and is at a greater risk from irrigation withdrawals. To the credit of the local landowners and watershed planning group, they have already taken steps to address the effects of irrigation withdrawals on the Tucannon River. The Columbia Conservation District, in conjunction with private landowners, placed roughly 11 cubic feet/second (cfs) of water at 951 acre feet to date in the Tucannon watershed through various irrigation efficiency projects (B. Johnson, personal communication, October 19, 2009). This TMDL does not attempt to reverse existing water rights, but rather attempts to implement water conservation measures through the application of appropriate best management practices (BMPs) listed in the Implementation Plan section of this report. However, this TMDL discourages any new withdrawals, particularly on Pataha Creek.

Riparian restoration efforts have been ongoing in this watershed. As a result, many reaches have healthy riparian buffers. However, much restoration work still needs to be done. These areas are identified in the TMDL Analysis section of this report. Further discussion of the role of riparian shade, channel morphology, and microclimates are included in Appendix C.

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Water Quality Standards and Beneficial Uses

In the state water quality standards, aquatic life-use categories are described using key species (salmon versus warm water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2003 edition]. Temperature standards that apply to this watershed are shown in Table 2. Temperature increases, resulting from the combined effect of all nonpoint source activities in the water body must not, at any time, exceed 2.8°C (5.04°F) when the background condition of the water is cooler than the criteria. Nonpoint sources may warm the water only until the numeric criteria are reached. If a water body's temperature is warmer than the criteria (or within 0.3°C (0.54°F) of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DADMax temperature of that water body to increase more than 0.3°C (0.54°F).

Table 2. Aquatic life uses in the Tucannon River subbasin

Water body description	Aquatic Life Uses	7-DADMax criteria
Cummings Creek and all tributaries	Char Spawning/Rearing	**12°C (53.6°F)**
Hixon Canyon and all tributaries	Char Spawning/Rearing	**12°C (53.6°F)**
Little Tucannon River and all tributaries	Char Spawning/Rearing	**12°C (53.6°F)**
Pataha Creek from mouth to confluence with Dry Creek	Spawning/Rearing	**17.5°C (63.5°F)**
Pataha Creek and Dry Pataha Creek: All water (including tributaries) above the junction.	Char Spawning/Rearing	**12°C (53.6°F)**
Tucannon River from mouth to RKm 33.2	Spawning/Rearing	**17.5°C (63.5°F)**
Tucannon River and tributaries from latitude 46.4592 longitude -117.8461 (Section 6, T11N R40E or RKm 33.2) to Panjab Creek (except where designated Char).	Core Summer Habitat	**16°C (60.8°F)**
Tucannon River mainstem from between Little Tucannon River and Panjab Creek	Char Spawning/Rearing	**12°C (53.6°F)**
Tucannon River and Panjab Creek: All waters (including tributaries) above the junction	Char Spawning/Rearing	**12°C (53.6°F)**
Tucannon River's unnamed tributaries in Sect. 1 T10N R40E and in Sect. 35 T11N R40E (South of Marengo): all waters above their forks.	Char Spawning/Rearing	**12°C (53.6°F)**
Tumalum Creek and the unnamed tributary at latitude 46.3594 longitude -117.6488: All waters (including tributaries) above the junction.	Char Spawning/Rearing	**12°C (53.6°F)**
Willow Creek and the unnamed tributary at latitude 46.4182 longitude -117.8314: All waters (including tributaries) above the junction.	Char Spawning/Rearing	**12°C (53.6°F)**
Tucannon River and Cummings Creek (outside of USFS lands)	Supplemental Salmon Criteria (Sep 1- Jun 15)	**13ºC (55.4ºF)**
Tucannon River upstream of confluence with Panjab Creek and Panjab Creek	Supplemental Char Criteria (Sep 1 – May 15)	**9ºC (48.2ºF)**

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Watershed Description

The Tucannon/Pataha watershed is located in southeastern Washington State in Garfield and Columbia counties. This watershed is part of the Lower Snake River Water Resource Inventory Area (WRIA) 35, and includes the towns of Pomeroy and Starbuck (Figure 1). The Tucannon River drains a watershed area of approximately 318 square miles. It flows into the Snake River four miles upstream of Lyons Ferry state Park. Pataha Creek enters the Tucannon River about 11 miles above the Tucannon's confluence with the Snake River. The Pataha drains a watershed of 185 square miles.

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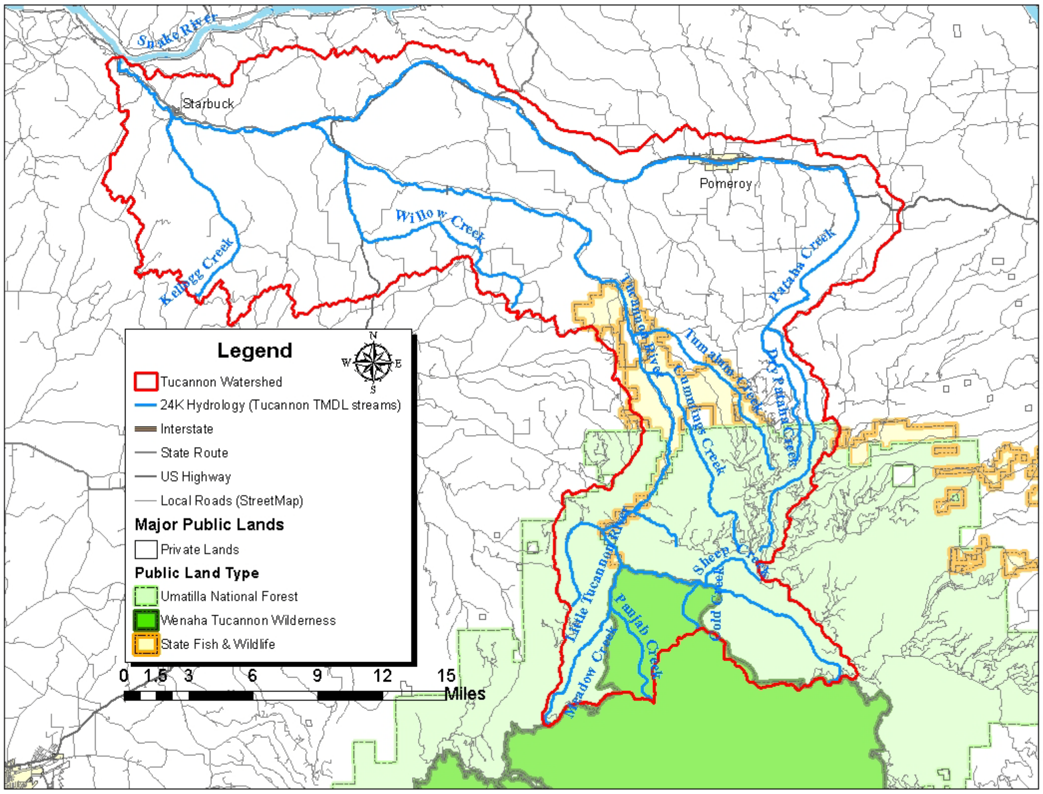

Figure 1. Map of the Tucannon/Pataha watershed.

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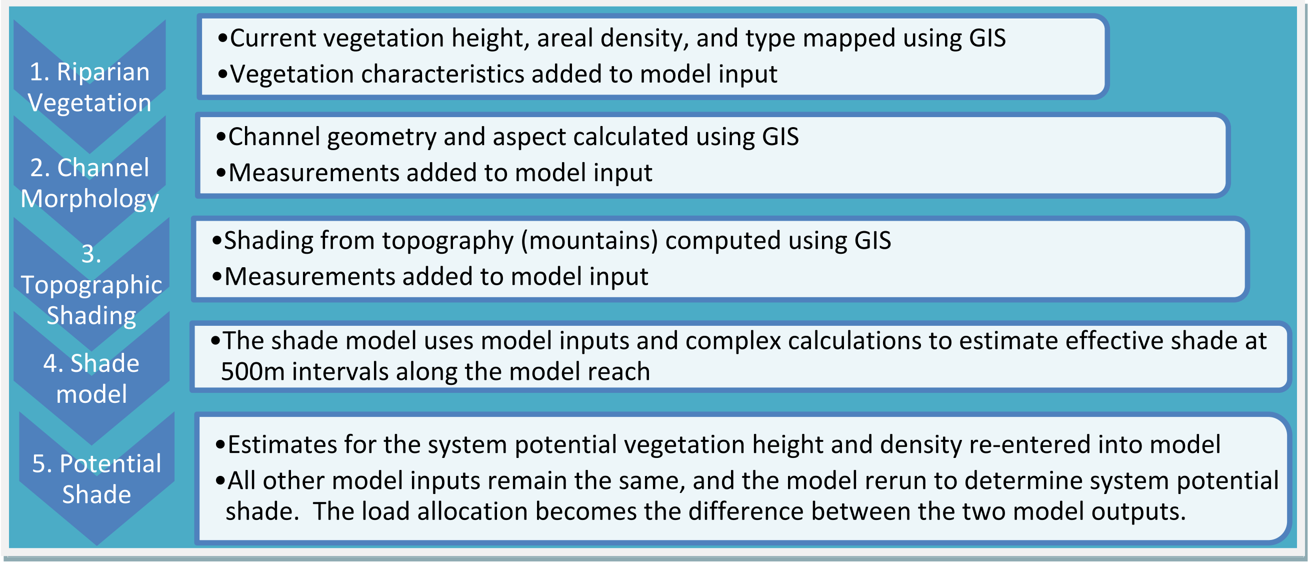
TMDL Analysis

An overview of stream heating processes can be found in Appendix C. Appendices D through G provide a more in-depth discussion of the TMDL study including data summaries, modeling approaches, and results.

Loading capacity

The *loading capacity* is the maximum pollutant that can be discharged to the water body and still meet standards. This provides a reference for calculating the amount of pollutant reduction needed to bring a water body into compliance with standards. If the pollutant comes from a discrete (point) source subject to an NPDES permit, such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from diffuse (nonpoint) sources not subject to an NPDES permit, such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation*.

The loading capacities for the Tucannon/Pataha are calculated as solar radiation heat loads based on system potential shade from riparian vegetation. Ecology guidance for implementing temperature standards (Hicks, 2007) is online: http://www.ecy.wa.gov/biblio/0610100.html. The steps for modeling system potential shade in this TMDL are shown in Figure 2. This project uses an innovative approach to develop a temperature TMDL for the Tucannon basin that incorporates data collected by HDR (HDR, 2006, and HDR/EES, Inc. 2005), the Washington State Department of Fish and Wildlife (WDFW), United States Forest Service (USFS), and Ecology (Appendix D). This differs from typical TMDL development in that Ecology's Environmental Assessment Program (EAP) collected only a limited amount of data (Ecology collected some data to calculate wasteload allocations and to fill data gaps for Pataha Creek).


1. Riparian Vegetation
- Current vegetation height, areal density, and type mapped using GIS
- Vegetation characteristics added to model input

2. Channel Morphology
- Channel geometry and aspect calculated using GIS
- Measurements added to model input

3. Topographic Shading
- Shading from topography (mountains) computed using GIS
- Measurements added to model input

4. Shade model
- The shade model uses model inputs and complex calculations to estimate effective shade at 500m intervals along the model reach

5. Potential Shade
- Estimates for the system potential vegetation height and density re-entered into model
- All other model inputs remain the same, and the model rerun to determine system potential shade. The load allocation becomes the difference between the two model outputs.

Figure 2. Shade modeling process steps.

This analysis does not predict a system potential temperature resulting from system potential vegetation to determine if stream temperatures would comply with state water quality standards. Temperature TMDLs developed in adjacent watersheds (within the same ecoregion and with similar stream characteristics) predict that system potential temperatures may not be cooler than the 17.5ºC numeric standard during the critical period with full system potential shade. Rather, full system potential shade could reduce stream temperatures below the 23ºC lethal limit for salmonids (Stohr et al, 2007, and ODEQ, 2000).

For this TMDL, shade deficits were calculated based on the current riparian vegetation and the effective shade possible by restoring system potential riparian vegetation. Effective shade is the fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area. Effective shade was calculated using GIS data and Ecology's Shade computer model (available at: http://www.ecy.wa.gov/programs/eap/models.html). Model calibration and assumptions are discussed further in Appendix F. Table 3 lists the model input and methods used for deriving those parameters.

Table 3. Shade model input parameters.

Input parameter	Data collection method
Stream bankfull and wetted widths	Combination of channel survey measurements from site visits and GIS digitization from 18" pixel resolution full-color aerial imagery flown in 2006.
Channel Incision	Channel survey measurements from site visits.
Riparian code {Riparian vegetation type, height, and areal density**}**	GIS digitization from 2006 aerial imagery and ground-truthed with vegetation surveys from site visits. Riparian codes are provided in Appendix D.
Topographic shade	Calculated using GIS with Ttools and a 10-meter resolution digital elevation model
Stream elevation	Calculated using GIS and a 10-meter resolution digital elevation model
Stream aspect	Calculated using GIS and Ttools.

Load and Wasteload Allocations

Wasteload allocations

Table 4 shows the wasteload allocations that apply during the critical period, from July to August, for dischargers within this watershed who are covered under individual or statewide National Pollutant Discharge Elimination System (NPDES).

Table 4. Wasteload allocations for permitted discharges to Pataha Creek and Tucannon River.

Receiving Water body Name	Parameter of Concern	Critical Period	Name and Permit Number	Waste Load Allocation for Permit Holders
Pataha Creek	Temperature	July-August	Town of Pomeroy STP WA0021164D	95th percentile 7DADMax not to exceed 21.2ºC during the critical period
Tucannon River	Temperature	July-August	Tucannon Fish Hatchery WAG137017D	No discharge during critical period

Pataha Creek violates the stream temperature standards mostly during July and August. However, there may be short-term weather variations that raise background temperatures above the criteria at other times of the year (for example the 5/28/07 to 6/4/07 period in Figure 3).

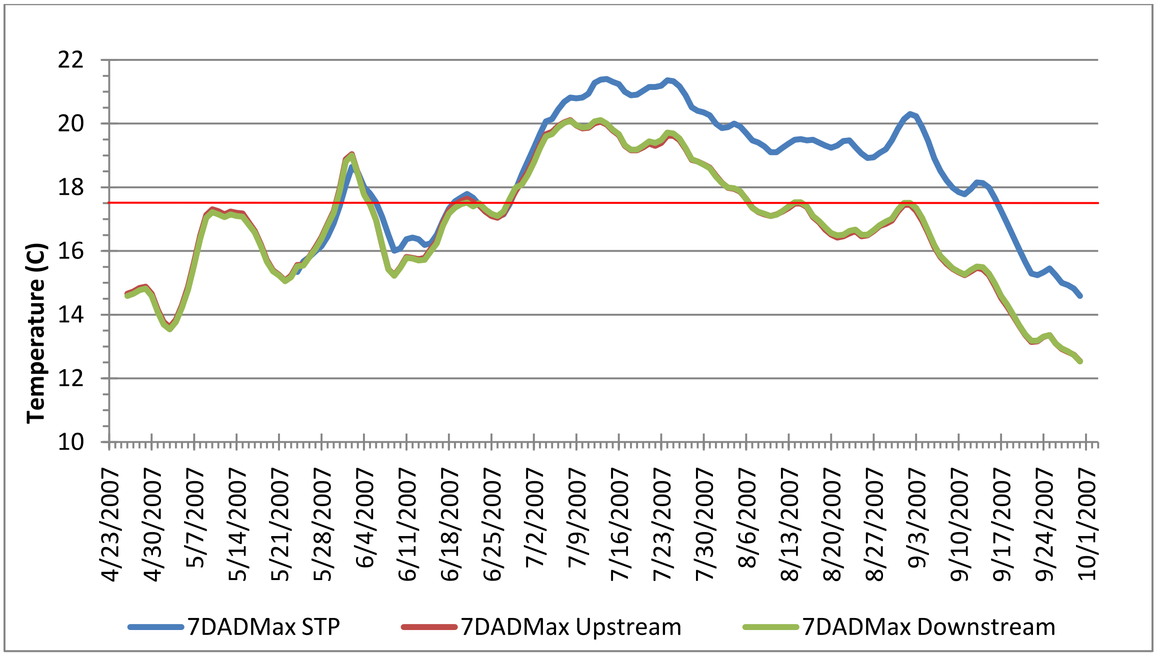


Figure 3. 7-day average daily maximum stream temperature for Pataha Creek and Pomeroy STP effluent.

The critical period is the period of sustained heating above the criteria. Data collected at the Pomeroy STP (Figure 3) show that the 2007 seven-day average daily maximum (7DADMax) temperatures upstream and downstream of the outfall do not differ from each other by greater than 0.3ºC, even though the STP discharge temperature is on average 2.63ºC warmer than the creek from July through September. The discharge was increasingly warmer than Pataha Creek at the beginning of July, at which point both the receiving water and discharge were consistently warmer than the water quality standard of 17.5º C (7DADMax).

Ecology's guidance for implementing the state's temperature standards (Hicks, 2007) for effluent chronic criteria recommends using a dilution analysis timed to match the critical condition for meeting the standard. The dilution factors in the existing permit do not reflect the mixing volumes observed during the critical period. So a dilution factor for the July through August critical period was calculated using both the:

- 2007 discharge monitoring report data from the Pomeroy treatment plant.
- 25 percent of the estimated lowest seven-day average flow that can be expected to occur once every ten years on average (the 7Q10 flow) in Pataha Creek for July through August at Ecology stream gage number 35F100. (Water quality standards allow only 25 percent of the receiving water flow to be used for mixing.)

The Pataha gage number 35F100 is approximately 5.5 river kilometers upstream of the treatment plant discharge. Stream flow regressions between the staff gage on Pataha and the long-term flow record from the USGS continuous gage for the Tucannon River near Starbuck were used to estimate a July through August 7Q10 for Pataha near Pomeroy. The July through August 7Q10 for the Tucannon River was calculated and the result used to regress a 7Q10 for Pataha (statistically, an r^2 value of .14 was the best relationship possible with the available data).

Table 5 shows the values used to develop the wasteload allocation. Using the equation from the guidance to determine the reasonable potential to exceed the temperature standards resulted in a downstream mixed temperature of 17.8ºC. Thus, the current facility 95th percentile 7DADMax discharge temperature of 21.2ºC does not show any effect on ambient temperature in Pataha Creek above the 0.3ºC allowance. More temperature and flow data should be collected to verify the values used for these calculations and then re-evaluated with a longer period of record.

Table 5. Values used to develop the Pomeroy treatment plant wasteload allocation.

Estimated 7Q10 low flow for July-August (Pataha near Pomeroy)	4.4 cfs*
DMR reported average effluent flow for July-August period (2005-2008)	0.12 cfs*
Chronic Dilution Factor at Mixing Zone Boundary	10.1
7DADMax Ambient Temperature (Upstream Background 90th percentile)	19.4ºC
7DADMax Effluent Temperature (95th percentile)	21.2º
Temperature at Chronic Mixing Zone Boundary	19.6ºC
Incremental Temperature Increase or decrease	0.2ºC
Maximum Allowable Temperature at Mixing Zone Boundary:	19.7ºC

*cfs = cubic feet per second

Hatchery operations are at a minimum during the critical period, and typically, no water is discharged during the July through August critical period, according to their discharge monitoring reports (DMRs) and conversations with the hatchery. Therefore, a wasteload allocation is not required for the hatchery during the critical period. The Tucannon River does have supplemental salmon spawning criteria from September 1 – June 15 where the numeric standard is a 7DADMax of 13ºC. Continuous temperature monitoring of their discharge and the receiving water from September through June should be added to their permit requirements to better understand the thermal patterns during the supplemental criteria period.

Load allocations

Using Equation 1 below, the load allocation (LA) is calculated as the amount of shade that could be produced if existing vegetation is protected from degradation and denuded riparian areas are restored to their potential.

Equation 1. Calculation to determine the shade load allocation

$$\{system\ potential\ shade\} - \{current\ shade\} = \ Effective\ Shade\ LA$$

Load allocations for nonpoint 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 the criteria. According to the water quality standards:

- When a water body's temperature is *warmer* than the numeric criteria due to natural conditions, then the human actions considered cumulatively may not cause the temperature of the water body to increase more than 0.3°C (0.54°F).

- When the background condition of the water is *cooler* than the numeric criteria, the incremental temperature increases resulting from the combined effect of all nonpoint sources must not exceed 2.8°C (5.04°F).

Load allocations in this TMDL are based on "growing" the current vegetation and extrapolating into successive riparian vegetation categories (riparian codes) shown in Table D-(1) 9 in Appendix D. The load allocations should be met by 2060, assuming a 50-year time frame for riparian plantings to reach maturity. System potential shade and load allocation calculations are discussed in detail under Appendix G. Figure 4 shows a map of shade load allocations at 500-meter intervals along the river. Each colored dot represents the effective shade improvement needed within that 500-meter reach upstream from each point; the higher the shade deficit percentage the more riparian improvement will be needed. Groundwater and surface water interaction study (seepage survey) results (HDR, 2006, and HDR/EES, Inc., 2005) are shown in Figure 5.

U.S. National Forest lands were evaluated for this study, but are not included in the TMDL allocations because they are subject to their own forest management plan. Therefore, the compliance area for this TMDL excludes the Umatilla National Forest lands in the watershed.

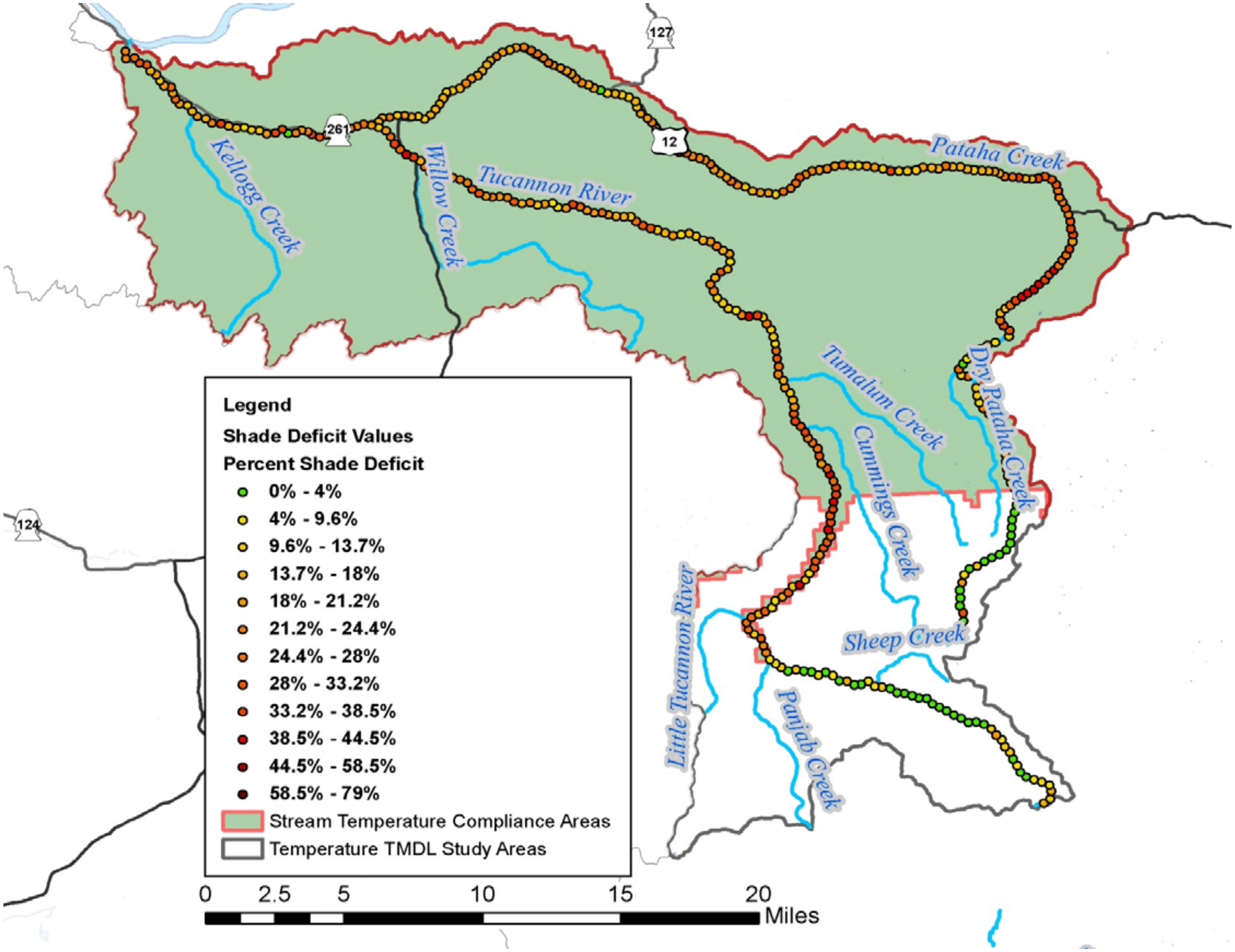


Figure 4. Percent shade deficit load allocations for Tucannon River and Pataha Creek and the TMDL compliance area.

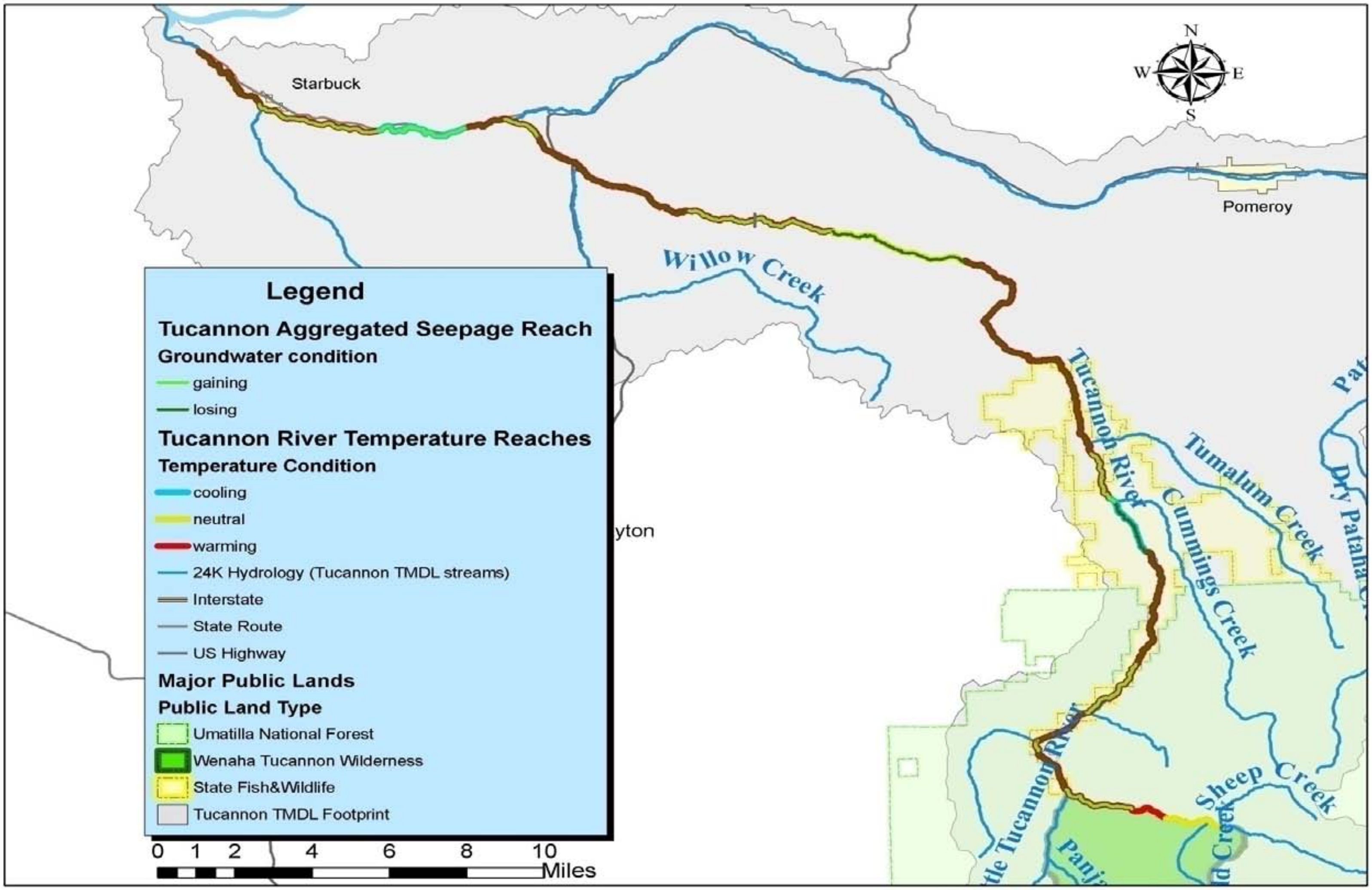


Figure 5. Areas of groundwater/surface water interactions and daily maximum stream temperatures during July 13, 2005.

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Seasonal Variation

The load allocations in this TMDL are prescribed using system potential shade. Heat loading to surface water will vary with seasonal and annual climatic variations. But, given the assumption that system potential shade is fully implemented and riparian function restored, there may still be some time during the year where parts of the river will not meet numeric criteria. Thus, at times and locations where the assigned numeric criteria cannot be attained even under estimated natural conditions, the narrative standard holds human warming to a cumulative allowance for additional warming of 0.3ºC above the natural conditions estimated for those locations and times.

Reserve capacity for future growth

The Tucannon/Pataha is a small, rural watershed unlikely to see much, if any growth in the future. Currently there is no reserve capacity for growth or development activities that reduces riparian shade. If future activities within the riparian area meet the TMDL objectives of improving or not adversely affecting riparian function of shade, then there should not be a conflict with the TMDL.

Margin of Safety

The margin of safety accounts for uncertainty about pollutant loading and water body response. In this TMDL, the margin of safety is addressed, in part, by conservative analytical assumptions and the assumption that system potential vegetation will provide maximum shade to achieve the coolest surface water in the absence of further improvements to channel morphology. A restored riparian area would also create a microclimate effect that reduces air temperatures near the stream and moderates daily stream temperature patterns. General protective measures to reduce stream heating include maintaining adequate stream width-to-depth ratios as described in Appendix C. Attempts to reduce stream bank erosion and prevent further stream degradation will have to occur on a reach-by-reach or project-by-project basis.

Recommendations

Following are recommendations for future data collection efforts:

- NPDES permitted dischargers should install continuous temperature data loggers in their effluent waters and at a point on the receiving water body that is upstream of any influence of the effluent. Data logging at 30-minute intervals is recommended. Standard operating procedures for temperature data collection should follow prescriptions in Bilhimer and Stohr (2007).
- Temperature monitoring at the mouth of Willow Creek should be added to the existing monitoring network.
- Future stream temperature monitoring efforts by Washington State Department of Fish and Wildlife (WDFW) should include a check of each instrument’s accuracy both pre and post deployment to ensure that data quality is quantified.

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Implementation Plan

Introduction

Ecology believes that in nonpoint source-dominated watersheds like the Tucannon/Pataha, the pollution problems of multiple parameters are often interrelated. In this watershed, water quality violations are primarily a result of the same poor land management practices. Thus, implementing best management practices and restoring degraded riparian areas is the best way to achieve improvements for multiple parameters. This TMDL addresses temperature only, but we believe that the actions described below will address the remaining pollution problems in the watershed (fecal coliform, turbidity, pH, and dissolved oxygen). This is our strategy: Following EPA's approval of this TMDL, we will delay work on the remaining TMDLs and focus our energies on working with local landowners and organizations to implement the recommendations in this TMDL plan. After effectiveness monitoring typically scheduled five years after TMDL approval, Ecology will reassess the state of the pollution problem and decide whether to continue this course or develop TMDLs for the remaining parameters. The table in Appendix I will be used to track implementation progress. The implementation plan, contained in Tables 7, 8 and 9, is meant as a framework to guide future action. This is a "living document", subject to modification through adaptive management.

Recommended actions

Point sources

In the Tucannon/Pataha watershed, the only point sources are the Pomeroy wastewater treatment plant and the Tucannon Fish Hatchery. Point sources are addressed through the National Pollutant Discharge Elimination System (NPDES) permitting process. This TMDL assigned the city of Pomeroy a wasteload allocation that will be the basis for permit limits when their NPDES permit is reissued. The Tucannon Fish Hatchery was not assigned a wasteload allocation because they do not discharge during the critical period (June through September).

Nonpoint sources

The Tucannon/Pataha watershed is dominated by nonpoint pollution sources. Although large portions of the watershed are under state and federal ownership, much of the lower watershed is under private ownership.

The towns of Starbuck and Pomeroy are the largest urban areas, but are relatively small. In April 2009, the Washington State Office of Financial Management estimated the population of Starbuck and Pomeroy at 130 and 1,525 respectively. It is unlikely that either will see much growth in the near future, so traditional urban non-point sources, such as stormwater and failing septic systems, are thought to be insignificant compared to agriculture.

Most privately-owned land in the watershed is used for livestock or crop agriculture. When an agricultural operation causes a water quality problem, it is usually because of its proximity to surface water, lack of best management practices (BMPs), and/or lack of appropriate maintenance. Table 6 provides general estimates of the size of existing operations and associated environmental problems in the watershed (based on the personal knowledge of TMDL technical workgroup members). It is important to note that although agriculture continues to be a source of pollution in the watershed, many landowners have voluntarily made considerable efforts to improve their management practices and restore riparian areas. This work will provide a valuable springboard for future TMDL implementation activities.

Table 6. Estimated sizes of agricultural operations and BMPs needed.

Agricultural Operations and BMPs	Tucannon River	Pataha Creek
Est. no. livestock operations	22	10
Est. no. head per operation	100	15
Est. total miles of livestock exclusion fencing needed	15	10
Est. no. off-stream watering facilities needed	8	10
Est. miles eroded stream bank needing restoration	50	25
Est. miles of cropland riparian buffer needed	15	5

Nonpoint sources are assigned load allocations that are addressed using a combination of BMPs and restoration or protection activities. Maximum potential shade is Ecology’s primary management focus in the Tucannon/Pataha watershed, but several other actions will further assist in achieving compliance with temperature standards. We believe these actions will also address the remaining pollution problems in the watershed. A list of these recommended actions is provided in Table 7.

The state water quality standards contain an antidegradation policy (Chapter 173-201A-300 WAC) to maintain and protect surface water from all sources of pollution. This policy applies to all human activities that are likely to have an impact on the quality of the surface waters of the state. Future urban and rural growth and development, as well as agricultural land use changes not covered directly in this TMDL, must apply all known, available, and reasonable methods of prevention, control, and treatment (AKART) for any actions that may directly or indirectly affect water quality in the Tucannon River watershed.

Any land-use actions that will negatively affect proper riparian function should be redesigned or mitigated so there is a net zero impact. While Ecology is authorized under Chapter 90.48 RCW to impose requirements or issue enforcement actions to achieve compliance with state water quality standards, it is the goal of all participants in the Tucannon/Pataha TMDL process to achieve clean water through best management practices to reduce or remove pollutant loading.

Table 7. Implementation activities needed to meet load allocations and the water quality parameters they affect.

Priority Ranking	Factors Related to Impairment	Implementation Category	General Action (BMP) to Improve Water Quality	Water Quality Outcomes	Stream Temperature	Turbidity	Nutrients and DO	Fecal Coliform	Point Source Flow	Metals	Toxics	Instream Flows
4	Agriculture	Behavior Change	Shallow aquifer recharge	Protects or enhance ground water flows in gaining reaches	☑	☐	☐	☐	☐	☐	☐	☑
			Education to promote strip cropping/divided slope	Prevents runoff into streams	☑	☑	☑	☐	☐	☐	☐	☐
			Education to promote direct seeding practices	Less sediment delivered to stream	☑	☑	☑	☐	☐	☐	☐	☐
			Education to promote Livestock BMPs	Landowners restore and maintain healthy riparian areas	☑	☑	☑	☑	☐	☐	☐	☐
		Infrastructure Development	Pipe or line canals	Protects or enhances surface water flows	☑	☑	☑	☐	☐	☐	☐	☑
			Install buffer strips, field borders, filter strips	Filters and minimizes stormwater runoff	☑	☑	☑	☐	☐	☐	☐	☐
		Resource Management Improvement	Enroll in seasonal, annual or permanent trust water program	Protects or enhance surface & ground water flows	☑	☐	☐	☐	☐	☐	☐	☑
			Conversion of high water demand crops to low water demand crops	Protects or enhance surface & ground water flows	☑	☐	☐	☐	☐	☐	☐	☑
			Apply water scheduling program	Protects or enhance surface & ground water flows	☑	☐	☐	☐	☐	☐	☐	☑
			Increase efficiency of irrigation systems	Protects or enhance surface & ground water flows	☑	☐	☐	☐	☐	☐	☐	☑

Priority Ranking	Factors Related to Impairment	Implementation Category	General Action (BMP) to Improve Water Quality	Water Quality Outcomes	Stream Temperature	Turbidity	Nutrients and DO	Fecal Coliform	Point Source Flow	Metals	Toxics	Instream Flows
2	Animal Husbandry	Infrastructure Development	Fence riparian areas	Reduces impact on water quality and damage to riparian vegetation	☑	☑	☑	☑	☐	☐	☐	☐
			Install off-stream watering troughs away from the riparian area	Alternative to watering in streams, used in conjunction with fencing	☐	☑	☑	☑	☐	☐	☐	☐
		Resource Management Improvement	Develop and follow a riparian grazing management plan.	Protects riparian vegetation from grazing damage.	☑	☑	☑	☑	☐	☐	☐	☐
			Place salt licks in the upland areas	Controls access to surface water	☐	☐	☐	☐	☐	☐	☐	☐
3	Channel Instability	Restore Natural Function	Channel Stability/Habitat Improvement Structures	Restores floodplain connectivity and reduces channel entrenchment	☑	☑	☐	☐	☐	☐	☐	☑
				Re-established stream channel meanders increases effective shade	☑	☑	☐	☐	☐	☐	☐	☑
				Increases channel complexity, Increases inter-gravel flow, Improves fish habitat and survival	☑	☐	☐	☐	☐	☐	☐	☑
			Add riparian vegetation, build and maintain stable streambanks	Decrease stream width-to-depth ratios results in a decrease in the rate of stream heating	☑	☑	☑	☑	☐	☑	☑	☑
1	Shade Deficit & Microclimate Cooling	Restore Natural Function	Restore and Conserve riparian appropriate buffer widths	Increases success of new plantings, restores native ecology	☑	☑	☑	☑	☐	☑	☑	☑
			Riparian width sufficient to provide for microclimate cooling	Reduces air temp, and convective heat transfer, increases humidity	☑	☑	☑	☑	☐	☑	☑	☑

Priority Ranking	Factors Related to Impairment	Implementation Category	General Action (BMP) to Improve Water Quality	Water Quality Outcomes	Stream Temperature	Turbidity	Nutrients and DO	Fecal Coliform	Point Source Flow	Metals	Toxics	Instream Flows
5	Roads	Infrastructure Development	Decommission or relocate roads near surface water where possible	Reduce impacts from roads, especially near surface water	☑	☑	☑	☑	☐	☑	☑	☑
			Vegetated buffers to roads adjacent to streams	Reduce impacts from roads, especially near surface water	☑	☑	☐	☐	☐	☐	☐	☐
7	Stormwater	Infrastructure Development	Install swales, catch/filtration basins	Prevent run-off	☑	☑	☑	☑	☐	☑	☑	☐
			Permeable parking lots, roads & sidewalks	Allow stormwater to infiltrate	☑	☑	☑	☑	☐	☑	☑	☑
6	Water Conservation	Behavior Change	Low flow shower heads & toilets	Reduce residential water use thereby reducing influent to STPs	☑	☐	☐	☐	☑	☐	☐	☑
			Efficient irrigation systems; use low flow systems	Reduced need for withdrawals for irrigation	☑	☐	☐	☐	☐	☐	☐	☑

State environmental policy act (SEPA) lead agencies and reviewers are required to look at potentially significant environmental impacts and alternatives and to document that the necessary environmental analyses have been made. Land use planners and project managers should consider findings and actions in this TMDL to help prevent new land uses from violating water quality standards. Ecology published a focus sheet on how TMDLs play a role in SEPA impact analysis, threshold determinations, and mitigation (http://www.ecy.wa.gov/biblio/0806008.html). Additionally, the TMDL should be considered in the issuance of land-use permits by local authorities.

Nonpoint prioritization

It is important to prioritize reaches for implementation to ensure limited resources are maximized, and clean-up efforts achieve compliance as quickly as possible. The Tucannon/Pataha watershed is fortunate in having several organizations that have planned and/or are implementing actions that will help decrease temperature and improve general water quality. Of these, perhaps the most active are the WRIA 35 watershed planning (WP) group and the Snake River Salmon Recovery Board (SRSRB). Their focus is primarily on addressing water quantity problems and the protection of Endangered Species Act (ESA)-listed fish species, but many of their proposals will also benefit water quality. Close communication and cooperation between TMDL staff and those involved with these other processes is essential to ensure they are not working at cross-purposes and that proposed actions are not duplicative. To this end, this prioritization process was a collaborative effort between Ecology staff and members of the WP and SRSRB groups. A TMDL technical workgroup was formed to work on the prioritization processes. It consists of Ecology staff and volunteers with implementation expertise from both groups.

The prioritization process was developed specifically with the needs of implementers in mind and strived to answer what we believe to be the three most important questions of land management: *what* needs to happen?; *where* does it need to happen?; and *when* does it need to happen?

1) What needs to happen?

The first step was to develop a prioritized list of general actions to reduce stream temperature, with the goal that this would then serve as the framework for developing a detailed list of projects to be implemented after TMDL development. We found the simplest solution was to rank the BMPs listed in Table 7 based on their importance in reducing temperature in the watershed:

1. Shade Deficit and Microclimate Cooling
2. Animal Husbandry
3. Channel Instability
4. Agriculture
5. Roads
6. Water Conservation
7. Stormwater

However, we recognized that Table 7 was not detailed enough to be able to guide project development. Fortunately, many of the actions described in both the WRIA 35 Watershed Detailed Implementation Plan and SRSRB Plan are quite detailed and protective of water quality. So, to save time and avoid duplication, we reviewed the action tables of both plans and extracted those most closely associated with the ranked BMPs in Table 7. These actions were then subjected to further ranking under each BMP category. The result is a prioritized list of detailed actions to be implemented in the watershed, which is included as Table 8. This list will form the framework for the development of future TMDL implementation projects.

2) Where does it need to happen?

The second step in the prioritization process was to map TMDL priority implementation zones. As in the previous step, map development was a collaborative process within the TMDL technical workgroup. Stream temperature and seepage survey data derived from the HDR study (Figure 5) were used in conjunction with the riparian shade allocations (Figure 4) to prioritize zones for implementation (Figure 6). Riparian areas with the least amount of existing shade, but that also gain ground water, are likely to have the most cooling effect, so we classified these reaches as *priority restoration zones***.** Reaches with existing shade or less influence from cooling ground water we classified as *secondary restoration zones*. The restoration zone delineation was subject to an additional fine-tuning based on the personal observations and knowledge of TMDL technical workgroup members. Ephemeral tributaries and the headwaters outside the TMDL compliance area were not categorized and will not be the focus of TMDL implementation work.

3) When does it need to happen?

In order to develop a timeline for implementation, it was necessary to do two things: first, link the actions in Table 7 and 8 with the various restoration zones, then rank the restoration zones in the order work should begin. We decided the easiest way to begin the linkage was to start with the ranked headings from Table 7. The workgroup looked at each restoration zone and selected three or four items from Table 7 that were the most serious problems there. Because “1. Shade Deficit and Microclimate Cooling” is the primary focus of implementation in this TMDL and the basis for the restoration zone delineation, it was assumed that this would be the priority action in each zone regardless of any other management concern. Therefore, the group only considered the remaining rankings (number 2 through 7) in this linkage process. Once the top implementation concerns were defined for each zone, the group selected detailed action items from Table 8 that were most relevant to the specific problems faced in each zone. The workgroup then ranked each zone based on their personal knowledge of shade deficit severity and implementation logistical concerns. The results were a ranked list of detailed implementation actions shown in Table 9 and a corresponding priority restoration and protection map (Figure 6). The final task was to assign work start dates to project development under each action. We decided, for the sake of consistency, to time TMDL project development so that it matched that of the WP and SRSRB, which is a three-year planning cycle.

Table 8. Prioritized TMDL implementation actions for the Tucannon/Pataha watershed.
(Cost estimates: Low = <$100,000; Medium = $100,000-$150,000; High = >$500,000)

Priority	Project	Cost	Funding Sources	Implementing Organizations	Start
1a.	Implement aquatic habitat protection plans for streams with ESA listed species for instream restoration/protection: 1. Enhancement Restoration and Protection Projects; 2. Riparian buffers; 3. Large Woody Debris Replenishment; and Replacement/Enhancement; 4. Enhancement of habitat for Fall Chinook/steelhead; 5. Control noxious weeds; 6. Plant native vegetation.	High	BPA, WCC, SRFB	WDFW, CCD, Nez Perce Tribe, CTUIR, County Weed Boards	2009-2011
1b.	Implement passive restoration projects, including Conservation Reserve Enhancement Program, riparian buffers, pilot conservation easements, and public education on use of easements.	Med/High	CREP, WCC, BPA, SRFB	WDFW, CDs, Nez Perce Tribe, CTUIR	2009-2011
2a.	Implement the following strategies to reduce fecal coliform levels: 1. Identify failing septic systems; repair and/or upgrade or connect to sewer if available	Med/High	Ecology, DOH, County Health, SRFB, BPA, WCC	CDs	2009-2011
2b.	Intensive Managed Grazing Practices – work with landowners to reduce the effects of grazing in the riparian areas. This project would focus on indentifying projects (i.e. Fencing riparian, cross fencing, and other management practices) that could be competed throughout the Tucannon/Pataha watershed.	Med/High	USFS, DOE	CDs, Ecology	2009-2011
3a.	Restore and enhance natural floodplain, riparian and wetland capacities, where feasible, to increase aquifer recharge, improve water quality, provide aquatic and riparian habitat, and reduce the duration and severity of flood events.	High	DOE, WCC, BPA, SRFB	CDs, Counties, Nez Perce, CTUIR	2009-2011
3b.	Reduce Channel Incision – Pataha has experienced extensive scouring as a result of past land practices. This project would look to identify landowners interested in ceasing and reducing the effects of incision.	High	DOE	PCD	2009-2011

Priority	Project	Cost	Funding Sources	Implementing Organizations	Start
3c.	Identify wetland restoration, protection and enhancement projects	High	DOE	DOE/CDs	2009-2011
3d.	Implement pilot project to encourage beaver activity for multi-purpose storage through dams, wetlands and water retention.	Low	WDFW, DOE	WDFW, CDs, Ecology	2009-2011
4a.	Implement the following strategies to reduce TSS levels and erosion control for pasture, crop and forested land: 1. Direct seed; s. CRP; 3. Grassed waterways; 4. Sediment basins; 5. Weed control; 6. Grazing management; 7. Cross fencing; 8. Alternative water sources; 9. Manure management.	Med/High	WCC, DOE, BPA, SRFB	CDs, DOE, WDFW, USFS	2012-2014
4b.	Work with individual landowners to review pesticide and fertilizer use, and to implement the following best management practices to limit water quality impacts: 1. Restore riparian areas; 2. Urban/rural education program; 3. Conservation tillage.	Med	WCC, DOE, BPA, SRFB	NRCS, CDs, WSU Coop. Ext.	2012-2014
5a.	Road Maintenance Project – this project would work within the state, and counties to identify sediment sources and routing on road right of ways throughout WRIA 35. The uses of BMPs would be employed to reduce the impacts of road maintenance.	Med/High	WSDOT, Counties	WDOT, WWC, Counties	2012-2014
6a.	Promote conservation and efficiency of water use, including but not limited to municipal, residential, commercial, industrial, agricultural, recreational, and instream water uses.	Medium	DOE	DOE, CDs	2015-2017
6b.	Improve irrigation efficiencies, including conveyance and application methods, as well as updated screens and meters.	Medium	DOE, WCC, BPA, SRFB	CDs	2015-2017
6c.	Identify and develop opportunities to enhance available water supply, emphasizing aquifer storage and recovery, source substitution, reclamation and reuse, and stormwater.	High	DOE	DOE, CDs	2015-2017
6d.	Explore opportunities for water right leases and/or acquisitions through the DOEW Trust Water Program and/or water banking.	Low	DOE, SRFB	WDFW, CDs	2015-2017

Priority	Project	Cost	Funding Sources	Implementing Organizations	Start
7a.	Adopt Eastern Washington Stormwater manual and implement the following strategies to improve stormwater management and treatment and increase groundwater infiltration: 1. Sediment basins; 2. Infiltration trenches; 3. Swales/wetlands; 4. Rural/urban drainage ditch upgrades and treatment; 5. Shaping/grading; 6. Reclamation/reuse; 7. Mowing vs. spraying.	High	DOE	Counties	2015-2017
7b.	Encourage stormwater and/or wastewater reclamation and reuse to satisfy other water resource needs.	High	DOE	Counties, CDs	2015-2017

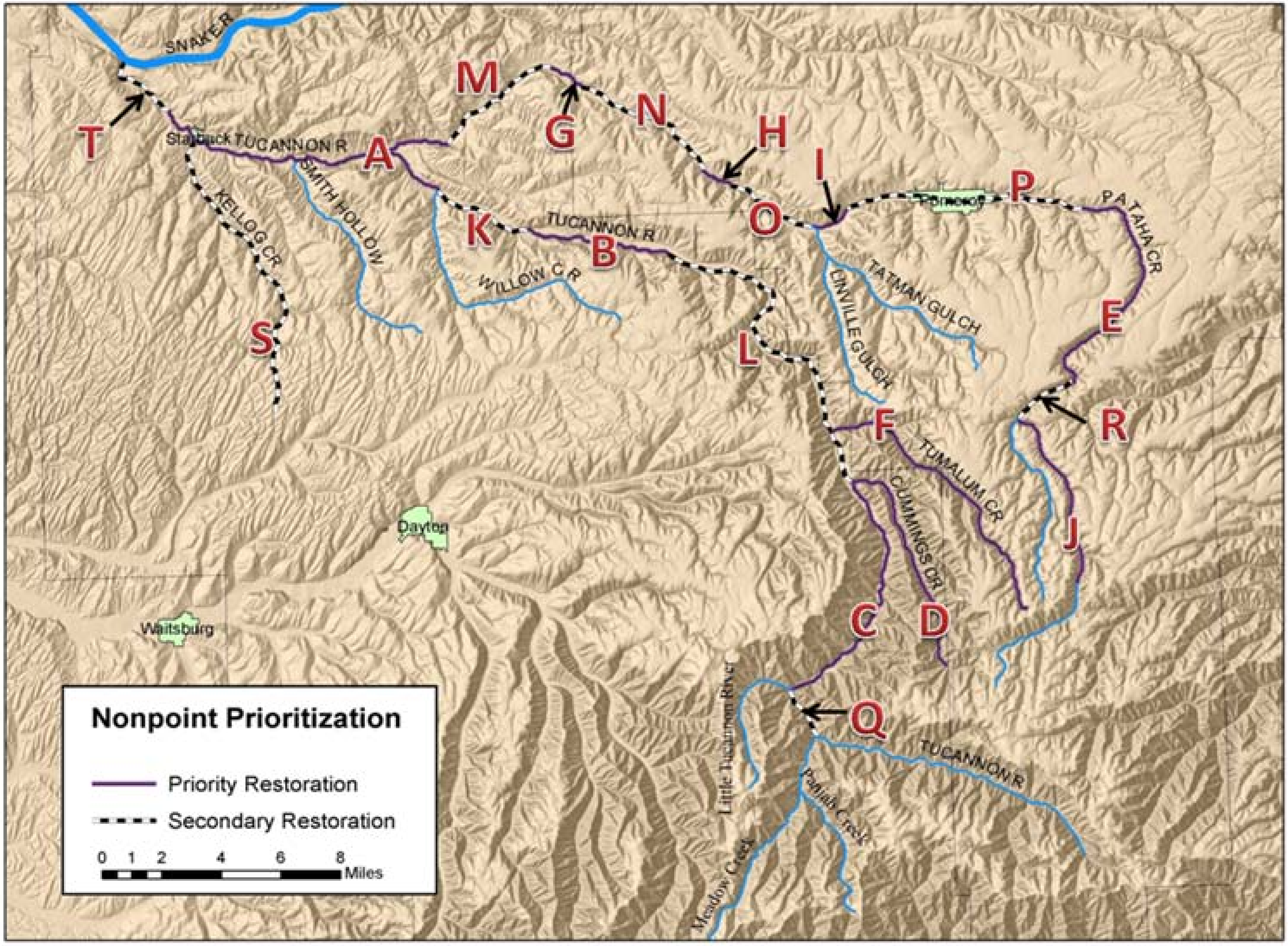

Figure 6. Priority restoration and protection zones for the Tucannon/Pataha watershed.

Table 9. Prioritized List of detailed implementation actions for the Tucannon/Pataha Watershed

Priority	Action	Zone Coordinates
A	1a	From 118° 8´26˝ W, 46° 31´ 43˝ N to 117° 56´ 47˝W, 46° 30´ 41˝ N (Pataha) & to 117° 57´ 18˝W, 46° 29´ 16˝N (Tucannon)
	1b	
	2a	
	2b	
	3a	
	3b	
	3d	
	4a	
	4b	
B	1a	From 117° 53´ 31˝ W, 46° 28´ 0˝N to 117° 47´ 44˝ W, 46° 27´ 10˝ N
	1b	
	3a	
	4a	
C	1a	From 117° 40´ 18˝W, 46° 20´ 2˝ N to 117° 43´ 9˝ W, 46° 13´ 45˝ N
	1b	
	3a	
	3c	
	5a	
D	1a	From 117° 40´ 18˝ W, 46° 20´ 2˝ N to 117° 36´ 29˝ W, 46° 14´ 14˝ N
	1b	
	3a	
	3c	
	5a	
E	1a	From 117° 30´ 8˝ W, 46° 28´ 4˝ N to 117° 30´ 56˝ W, 46° 22´ 48˝ N
	1b	
	2b	
H	4b	
I	1a	From 117°41´33˝W, 46°27´48˝N to 117°39´56˝W, 46°28´20˝N
	1b	
	2b	
	4a	
	4b	
J	1a	From 117°33´9˝W, 46°21´45˝ N to 117° 30´57˝W, 46°16´46˝N
	1b	
	2a	
	2b	
	5a	
K	1a	From 117°57´18˝W, 46°29´16˝N to 117°53´31˝W, 46°28´0˝N
	1b	
	3c	
	4a	
	4b	
L	1a	From 117°47´44˝W, 46°27´10˝N to 117°40´18˝W, 46°20´2˝N
	1b	
	3a	
	3c	
	4a	
	4b	
M	1a	From 117°56´47˝W, 46°30´41˝N to 117°52´22˝W, 46°32´54˝N
	1b	
	4a	
	4b	
O	3b*	
P	1a	From 117°39´56˝W, 46°28´20˝N to 117°30´8˝W, 46°28´4˝N
	1b	
	2a	
	2b	
	4a	
	4b	
	6a	
	6b	
	6c	
	6d	
	7a	
	7b	
	3b*	
Q	1a	From 117°43´9˝W, 46°13´45˝N to 117°42´10˝W, 46°12´20˝N
	1b	
	3a	
	3c	
	5a	
R	1a	From 117°30´56˝W, 46°22´48˝N to 117°33´9˝W, 46°21´45˝N
	1b	
	2a	
	2b	
	4a	
	4b	
	5a	

Priority	**Action**	**Zone Coordinates**
	4a	
	4b	
F	1a	From 117° 41´ 4˝ W, 46° 21´ 36˝ N to 117° 33´ 5˝ W, 46° 16´ 0˝ N
	1b	
G	1a	From 117° 52´ 22˝W, 46° 32´ 54˝ N to 117° 51´ 1˝ W, 46° 32´ 17˝ N
	1b	
	4a	
	4b	
H	1a	From 117° 46´ 2˝W, 46° 29´ 37˝ N to 117° 44´ 40˝ W, 46° 29´ 5˝ N
	1b	
	2b	
	4a	
	3b*	
N	1a	From 117°51´1˝ W, 46°32´17˝N to 117°46´2˝W, 46°29´37˝N
	1b	
	2b	
	4a	
	4b	
	3b*	
O	1a	From 117°44´40˝ W, 46°29´5˝N to 117°41´33˝W, 46°27´48˝N
	1b	
	2b	
	4a	
	4b	
S	1a	From 118° 7´ 34˝ W, 46° 31´5˝N to 118° 4´26˝ W, 46° 22´ 42˝ N
	1b	
	2b	
	4a	
	4b	
T	1a	From the mouth to 118° 8´ 26˝ W, 46° 31´ 43˝N
	1b	
Starbuck	7a	N/A
	7b	N/A
Pomeroy	7a	N/A
	7b	N/A

** indicates actions that are a low priority because of current insufficient management resources to implement them.*

Forest management

Forest management activities, particularly road construction and timber harvesting, have the potential to impair water quality. Cutting trees removes shade from streams. Soil erosion and vegetation removal caused by logging, road construction, and maintenance can change stream geometry, which also contributes to increased stream temperature. This TMDL requires that riparian areas throughout the watershed be returned to system potential riparian conditions to meet state temperature standards. Most forested ground in the Tucannon/Pataha watershed is managed by state and federal authorities.

The state's forest practices regulations will be relied upon to bring waters into compliance with the load allocations established in this TMDL on private and state forest lands. This strategy, referred to as the Clean Water Act Assurances, was established as a formal agreement to the 1999 Forests and Fish Report:

> http://www.dnr.wa.gov/Publications/fp_rules_forestsandfish.pdf

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

To ensure the rules are as effective as assumed, a formal adaptive management program was established to assess and revise the forest practices rules as needed. The agreement to rely on the forest practices rules in lieu of developing separate TMDL load allocations or implementation requirements for forestry is conditioned on maintaining an effective adaptive management program.

Consistent with the directives of the 1999 Forests and Fish agreement, Ecology conducted a formal 10-year review of the forest practices and adaptive management programs in 2009:

> http://www.ecy.wa.gov/programs/wq/nonpoint/ForestPractices/CWAassurances-FinalRevPaper071509-W97.pdf

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

The success of this TMDL will be assessed using monitoring data from streams in the watershed.

The TMDL technical analysis showed that the stretch of the Tucannon mainstem that burned during the 2005 School Fire was one of the areas in the watershed most in need of shading. This area stretches from just south of the confluence with Tumalum Creek to the mouth of Little Tucannon River. Wildfire is a natural occurrence in forestlands, and this area should recover naturally over time. However, managers of this portion of the watershed are encouraged to monitor recovery in 2010 (5 years after the fire) and replant the riparian area if necessary. This area sees heavy recreational use, which could slow recovery. We recommend managers monitor and control these activities to protect recovery/restoration efforts.

Ecology's original intent was to include U. S. Forest Service (USFS) land located in the headwaters of the watershed in this TMDL. Data were collected and analyzed to calculate shade deficit allocations for those portions of the Tucannon and Pataha watersheds in the Umatilla Forest. However, at the time of this writing, Ecology is considering options to develop a statewide or regional approach for remaining TMDLs on USFS land. So, for the sake of consistency, Ecology chose to exclude the Umatilla Forest from this TMDL and address it later through that process. Ecology chose to keep the shade deficit data for the Umatilla Forest in this TMDL to ensure it would not be lost, but these data will not be used for compliance purposes in this TMDL.

In the interim, Ecology regional staff will continue to work with Umatilla Forest staff to ensure that existing policies, guidelines, and regulations are implemented appropriately and water quality is protected. Ecology recommends the following management actions:

- A primary objective of the USFS's riparian management activities should be to achieve a system potential riparian condition as soon as possible, either through protection of existing riparian vegetation or restoration of degraded sites.
- Apply Ecology-approved BMPs on allotment areas to reduce livestock impacts where necessary. Approved practices include livestock exclusion fencing, riparian buffers, and off-stream watering facilities. Contact the Department of Ecology's Eastern Regional Office's water quality program to obtain details on the site-specific Ecology approved practices. The USFS should continue to monitor Cummings and Tumalum Creeks and protect these areas from damage caused by stray cattle. In addition, the USFS should monitor grazing allotments on areas recovering from the School Fire to ensure recovery is adequate prior to initiating long-term grazing practices.
- Manage recreation to protect riparian vegetation and water quality. Move campsites away from streams, particularly on the upper Tucannon River. Construct vaulted outhouses and develop designated trails to minimize impacts from hikers, especially in riparian areas recovering from the School Fire.
- Provide educational materials and/or place information boards in high-use areas to educate users on the need to protect recovering vegetation within the riparian corridor burned by the School Fire.
- Monitor vegetation recovery within the School Fire burn zone in 2010 and plant additional trees if necessary. Emphasis should be on the riparian area 150 feet on each side of the stream. When necessary, supplemental planting of shrubs and trees is recommended.

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Reasonable Assurance

Ecology believes that the prescribed activities supported in this TMDL and implementation plan provide reasonable assurance that instream temperatures in the Tucannon River and its perennial tributaries will meet conditions provided by Washington State water quality standards. This assumes that the activities recommended here are implemented and maintained. Ecology staff are chiefly responsible for ensuring this TMDL is implemented, but other agencies and local jurisdictions have responsibilities under existing statutes and programs that will help implement the TMDL. Ecology will work collaboratively with these groups and use traditional methods to meet the TMDL goals including:

- Education and outreach.
- Technical and financial assistance.
- Permit administration.
- Enforcement.

There is a lot of local support for water quality improvement. Many local stakeholders are already actively participating in restoration projects, particularly along the Tucannon River. To date, the Columbia Conservation District (CCD) has worked with local landowners to protect 51.4 miles of stream within the Tucannon/Pataha watershed and install seven irrigation efficiency projects (T. Bruegman, personal communication, February 16, 2009). The Pomeroy Conservation District (PCD) has worked to protect 88 miles of stream (D. Bartels, personal communication, February 24, 2009). Both conservation districts have worked hard to promote conservation tillage practices in upland areas. An example of work done so far is found in Ecology's Transforming Watersheds publication (Atkins, 2008) which describes work along the middle Tucannon.

There are several other planning processes in place that will help address the temperature problem. The following plans cite upcoming projects that provide additional reasonable assurance that the TMDL goals will be met:

- WRIA 35 Watershed Plan (WP)
- WRIA 35 Watershed Detailed Implementation Plan (WDIP)
- Snake River Salmon Recovery Plan (SRSRP)
- Tucannon Subbasin Plan (TSP)

Ecology believes the work completed and the plans above provide reasonable assurance that the Tucannon watershed nonpoint source TMDL goals for stream temperature will be met by 2060 (assuming a 50-year growth period for vegetation to reach maturity).

Monitoring

Monitoring is crucial to assessing the success of implementation. Monitoring includes both project tracking and water quality assessment. After this water quality improvement report is finished, Ecology staff will track whether organizations' commitments in the plan are being achieved. Water quality assessments will be done at both the project level post installation (implementation monitoring) and at the watershed scale (effectiveness monitoring). Implementation monitoring is typically the responsibility of the group doing the restoration work, while effectiveness monitoring is Ecology's responsibility. Ecology typically conducts effectiveness monitoring across the watershed about five years after a TMDL is finished. If project goals, interim targets or water quality standards are not met, adaptive management strategies will be used until success is achieved.

Funding Opportunities

Financial assistance programs managed by Ecology and the U.S. Department of Agriculture (USDA), through the Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA), will likely fund many of the TMDL implementation programs in this watershed.

1. Ecology funding sources:
    - Centennial Clean Water Fund grants
    - Section 319 grants under the federal Clean Water Act
    - State Revolving Fund loans
    - Terry Husseman (Coastal Protection Funds)

2. USDA (NRCS & FSA)funding sources:
    - Conservation Reserve Program (CRP)
    - Conservation Reserve Enhancement Program (CREP)
    - Continuous Conservation Reserve Program (CCRP)
    - Environmental Quality Incentives Program (EQIP)
    - Wildlife Habitat Incentives Program (WHIP)
    - Grassland Reserve Program (GRP)
    - Wetlands Reserve Program (WRP)
    - Conservation Security Program (CSP)

3. Other funding sources include:
    - Watershed Planning Implementation
    - Snake River Salmon Recovery Board
    - Bonneville Power Administration
    - Bonneville Power Foundation
    - Landowners' personal contributions

Summary of Public Involvement Methods

As mentioned, there are currently several overlapping planning processes in the watershed that work on water resource issues. The WRIA 35 Watershed Planning group acts as somewhat of a nexus for these various processes. One of the principles of this streamlined TMDL pilot project is the elimination of duplicative processes. With this in mind, Ecology decided to use the existing Watershed Planning group for all TMDL work in lieu of a formal advisory group.

Ecology staff met with the group several times prior to the start of the project to make sure they understood the pilot process and were comfortable with it. The streamlined TMDL process relies heavily on the synthesis of previous work and existing data. This made it unnecessary to meet with stakeholders on a frequent basis after the project was initiated, as they were already largely familiar with the material. However, Ecology staff did meet with the group once every 3 to 6 months from January 2007, watershed-planning work permitting, to update them on developments and present new data and results. Ecology staff also remained in close and frequent contact with the Watershed Planning Coordinator regarding the TMDL. During development of the TMDL implementation plan, Ecology staff and some members of the watershed planning group and Snake River Salmon Recovery Board joined to form a technical work group to prioritize nonpoint implementation.

Ecology maintains a website on the TMDL at: www.ecy.wa.gov/programs/wq/tmdl/TucannonPatahaTMDL.html. Ecology held a 30-day public comment period for this report from April X to X, 2010. A news release was sent to all the local media in the watershed and advertisements were placed in the following publications:

X

X

X

Responses to the public comments received during the public comment period will be placed in Appendix B.

Next steps

After EPA approves this TMDL, the implementation specialist should review the existing SRSRB 2009-2011 three-year work plan and, using the strategy developed in this TMDL, develop a list of additional projects that address water quality issues not already covered. The TMDL implementation specialist should also work with the WP and SRSRB groups during their future three planning processes to promote those habitat and flow improvement projects that have the greatest likelihood of improving water quality. At that time, the implementation lead should also develop and prioritize projects to address any outstanding water quality issues. This should be done using the framework described in the Implementation Plan section, similar to the current 2009-2011 planning cycle. The implementation lead should also evaluate the success of previous projects and determine whether any of these need follow up work. The implementation specialist should develop a tracking table for all implementation projects with which to record progress (see Appendix I).

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Appendix A. Glossary, Acronyms, and Abbreviations

Glossary

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

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

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

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

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

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

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

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

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 water body can receive and still meet water quality standards.

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

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

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program.

Generally defined, 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.

PACFISH: Interim strategies for managing anadromous fish-producing watersheds in Oregon, Washington, Idaho, and Northern California

Phase I stormwater permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

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

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

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

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

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

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

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

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

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

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).

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.

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

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

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

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

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.

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 water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

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

AKART	all known, available, and reasonable technology
BMP	best management practices
BPA	Bonneville Power Administration
cfs	cubic feet per second
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
DMR	Discharge Monitoring Report
DNR	Washington State Department of Natural Resources
DOH	Washington State Department of Health
EAP	Washington State Department of Ecology's Environmental Assessment Program
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FSA	Farm Service Agency
GIS	Geographic Information System software
NAF	New Approximation Flow
NCDC	National Climate Data Center
NPDES	National Pollution Discharge Elimination System
NRCS	National Resource Conservation Service
NSDZ	near-stream disturbance zones
RM	river mile
RKm	river kilometer
SEPA	State Environmental Policy Act
SRSRB	Snake River Salmon Recovery Board
SRFB	Salmon Recovery Funding Board
STP	Sewage treatment plant
TIR	thermal infrared radiation
TMDL	Total maximum daily load (water cleanup plan)
USFS	United States Forest Service
USGS	United States Geological Survey

WAC	Washington Administrative Code
WCC	Washington Conservation Commission
WDFW	Washington State Department of Fish and Wildlife
WP	Watershed Planning
WRIA	Water Resources Inventory Area
WSDOT	Washington State Department of Transportation

Appendix B. Response to Public Comments

This appendix will be completed after the public comment period.

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Appendix C: Overview of Stream Heating Processes

List of Figures and Tables

Overview of stream heating process

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 C-1.

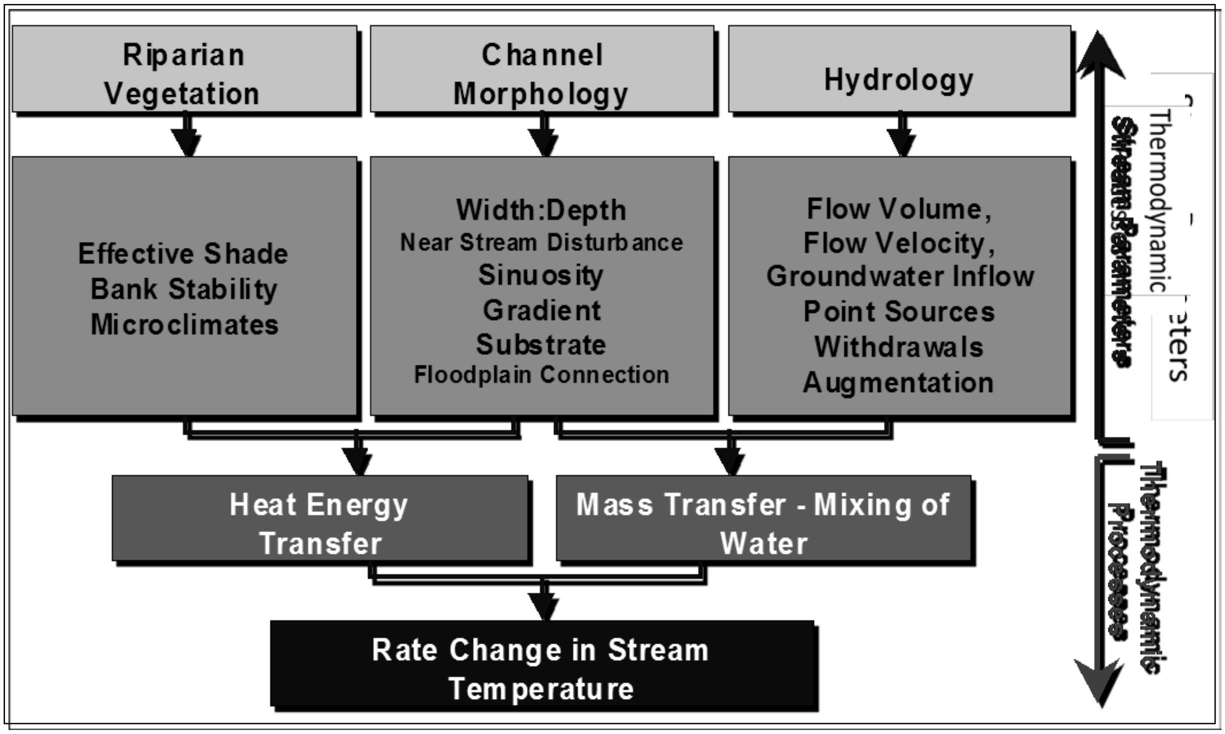

Figure C-(1) 9: Conceptual model of factors that affect stream temperature.

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 water 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.

- ***Ground water.*** 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 as well as the difference in temperatures between the groundwater and the stream.

Heat budgets and temperature prediction

Heat exchange processes occur between the water body and the surrounding environment; these processes control stream temperature. Edinger et al., (1974) and Chapra (1997) provide thorough descriptions of the physical processes involved. Figure C-2 shows the major heat energy processes or fluxes across the water surface or streambed.

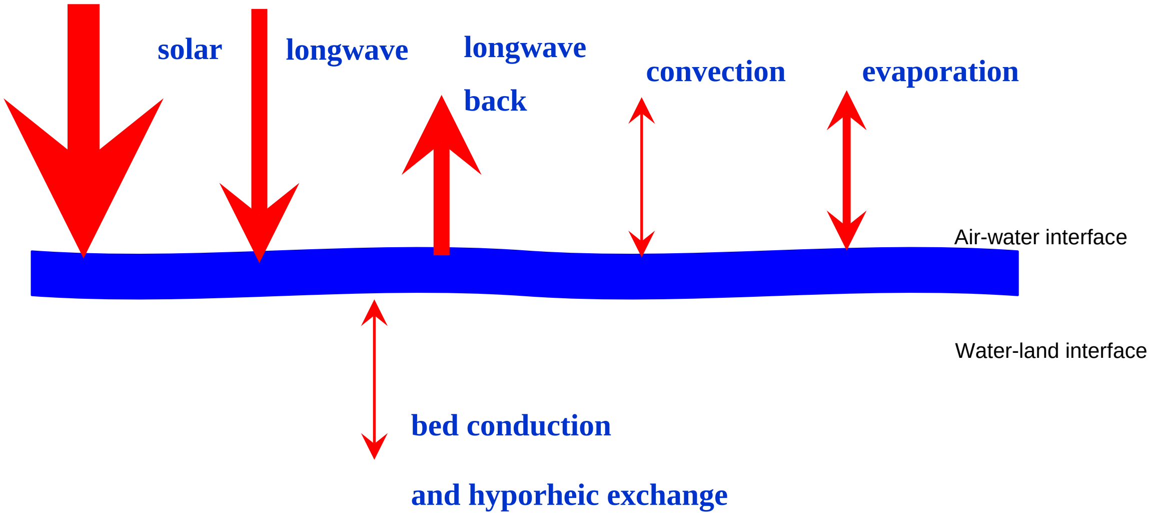

Figure C-(2) 10: Surface heat exchange processes that affect water temperature (*net heat flux = solar + longwave atmosphere + longwave back + convection + evaporation + bed). Heat flux between the water and streambed occurs through conduction and hyporheic exchange.*

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

- ***Shortwave solar radiation***. Shortwave solar radiation is the radiant energy which passes directly from the sun to the earth. The shortwave radiation entering a stream will be the difference between the energy that comes directly from the sun and that reflected by the water. Shortwave solar radiation is contained in a wavelength range from 0.14 µm and about 4 µm.

  The peak values during daylight hours are typically about 3 times higher than the daily average. Shortwave solar radiation constitutes the major thermal input to an un-shaded body of water during the day when the sky is clear. Solar exposure was identified as the most influential factor in stream heating processes (Sinokrot and Stefan, 1993; Johnson and Jones; 2000, Danehy, 2005).

- ***Longwave atmospheric radiation.*** Longwave radiation from the atmosphere ranges in wavelength from about 4 µm to 120 µm. Longwave 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 longwave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes (Edinger et al., 1974).

- ***Longwave back radiation from the water to the atmosphere.*** Water sends heat energy back to the atmosphere in the form of longwave 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 longwave back radiation typically ranges from about 300 to 500 W/^{m2} (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 the 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 the 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 water body and the influence of hyporheic exchange. The magnitude of bed 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 usually affects the temperature diel profile, rather than affecting 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.

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 hours. 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.

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 positive or negative. When the sun is not shining, the water temperature 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; Edinger et al., 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; Patrick, 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; 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. Important benefits that riparian vegetation has on the stream temperature include:

- 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.
- Streambank 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, and contributing coarse woody debris as well as 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. Riparian vegetation restoration was identified as one of the most important management steps that may improve stream temperatures (Johnson and Jones, 2000, Blann et al, 2002). 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 is one of the largest heat-transfer mechanisms in a stream system. Human activities can degrade near-stream vegetation and/or channel morphology (widening), and in turn, decrease shade. Reductions in stream surface shade 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:

$$Effective\ Shade = \frac{(J_1 - J_2)}{J_1}$$

Where:

J1 = the potential solar heat flux above the influence of riparian vegetation and topography, and

J2 = the solar heat flux at the stream surface.

Canopy cover is the percent of sky covered by vegetation and topography at a given point. Shade is influenced by cover, but changes throughout each day, as the position of the sun changes spatially and temporally with respect to the canopy cover (Kelley and Krueger, 2005).

In the Northern Hemisphere, the earth tilts on its axis toward the sun during summer months, allowing longer day length and higher solar altitude, both of which are functions of solar declination (i.e., a measure of the earth's tilt toward the sun) (Figure C-3). 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 C-1). The solar position has a vertical component (solar altitude) and a horizontal component (solar azimuth) that are both functions of time/date (solar declination) and the earth's rotation.

While the interaction of these shade variables may seem complex, the mathematics that describes them is 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 hemispherical photography and solar pathfinder. (Ice, 2001; OWEB, 1999; Boyd, 1996; Teti, 2001; Teti and Pike, 2005):

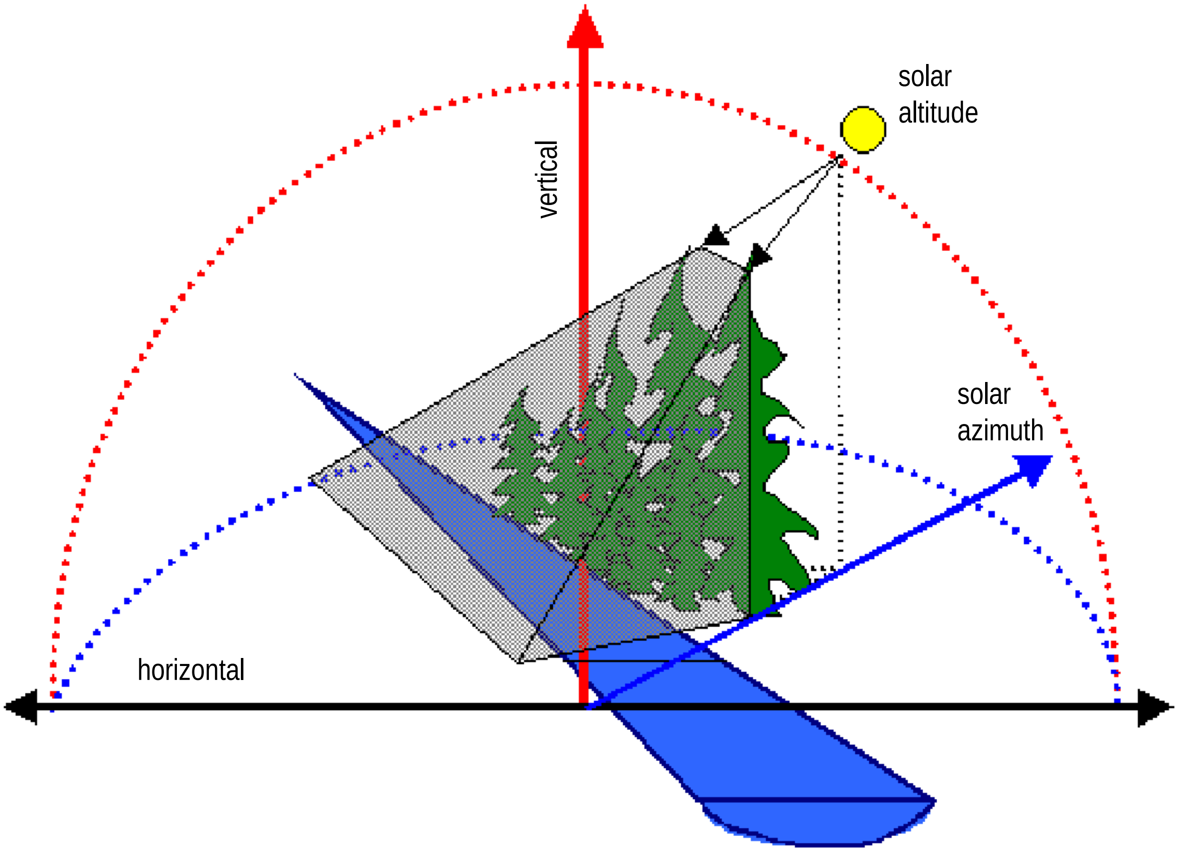

Figure C-(3) 11: Parameters that affect shade and geometric relationships. Solar altitude is a measure of the vertical angle of the sun's position relative to the horizon. Solar azimuth is a measure of the horizontal angle of the sun's position relative to north. (Boyd and Kasper, 2003.)

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 C-1 (Ecology 2003a; Chen, 1996; Chen et al., 1998; Boyd, 1996; Boyd and Park, 1998).

Table C-(1) 8: Factors that influence stream shade
(italics indicate 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; Teti, 2003). The shading effectiveness of riparian vegetation is correlated to riparian area width (Figure C-4).

The shade, as represented by angular canopy density (ACD) for a given riparian buffer width, varies over space and time. This is 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 C-4.

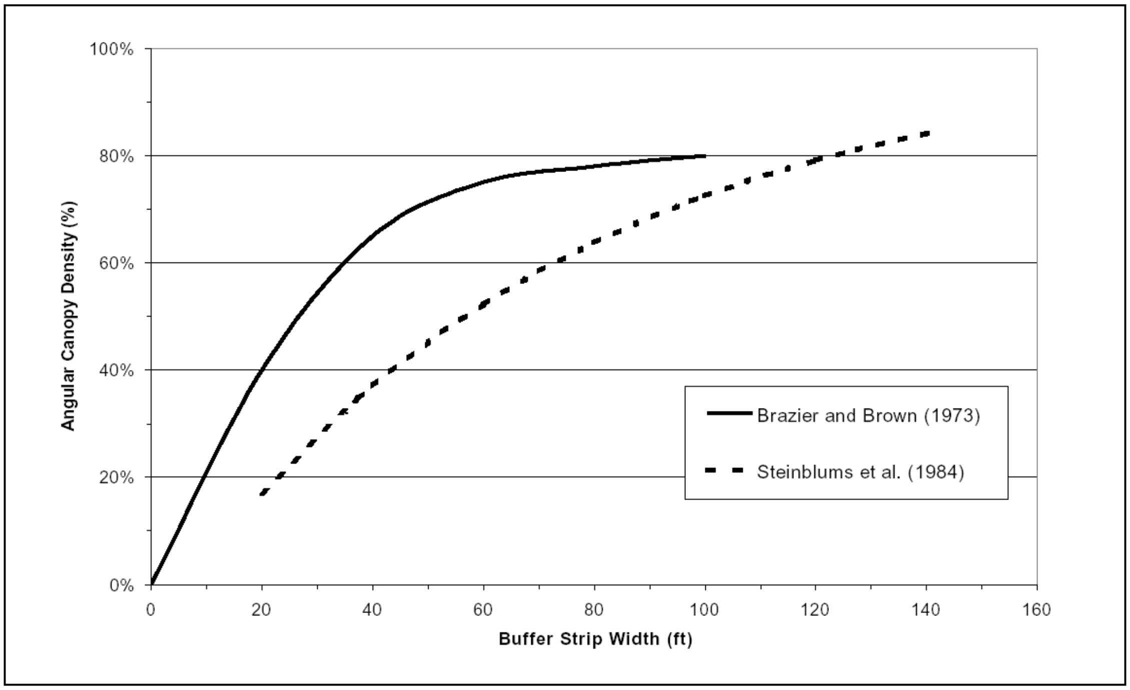

Figure C-(4)12: Relationship between angular canopy density (ACD) and riparian buffer width for small streams in old-growth riparian stands (after Beschta et al., 1987 and CH2M Hill, 2000).

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 meters) 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 would provide 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).

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. 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. Therefore, 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 7°C 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 4.5°C during the day and about 0.5°C at night (estimate). Fowler and Anderson

(1987) measured a 0.9°C air temperature increase in clearcut areas, but temperatures were also 3°C higher in the adjacent forest. Chen et al., (1993) found similar (2.1°C) increases.

All measurements reported here were made over land instead of water, but in aggregate support about a 2°C 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 meters 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 (widening) 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 erosion and sedimentation 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**. Riparian vegetation traps suspended sediments, encouraging deposition of sediment in the flood plain (instead of the streambed) and reducing incoming sources of sediment.
- **Maintaining stable streambanks**. High rooting strength and high streambank and flood plain roughness prevents streambank erosion.

Reducing flow velocity (erosive kinetic energy). Riparian vegetation supplies large woody debris to the active channel, increases the pool-to-riffle ratio, and adds channel complexity that reduces shear stress exposure to streambank soil particles.

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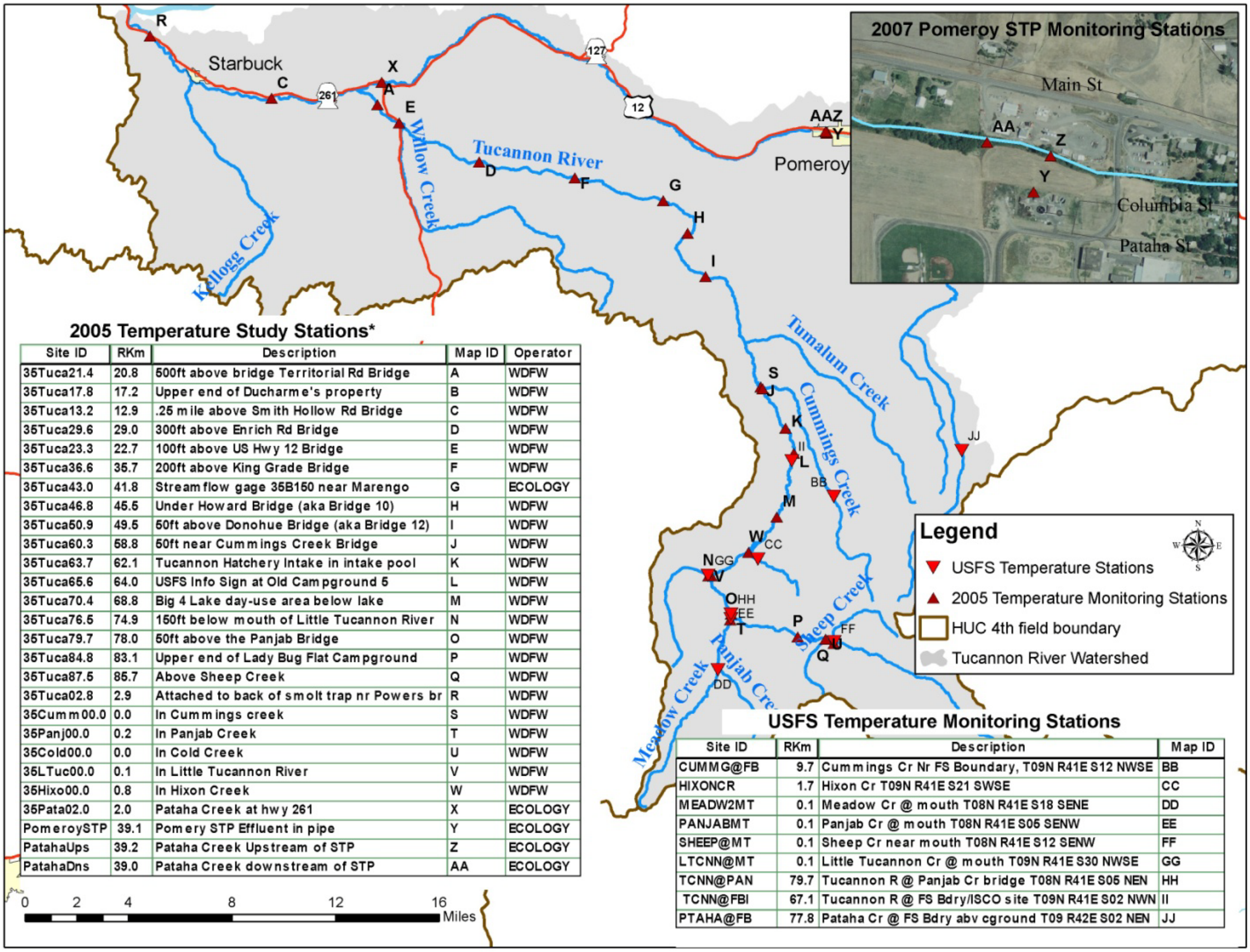
Appendix D: Data Summaries

This appendix contains maps and data referenced in the report that are too large to put in the text of the report. The following items are included:

List of Figures and Tables



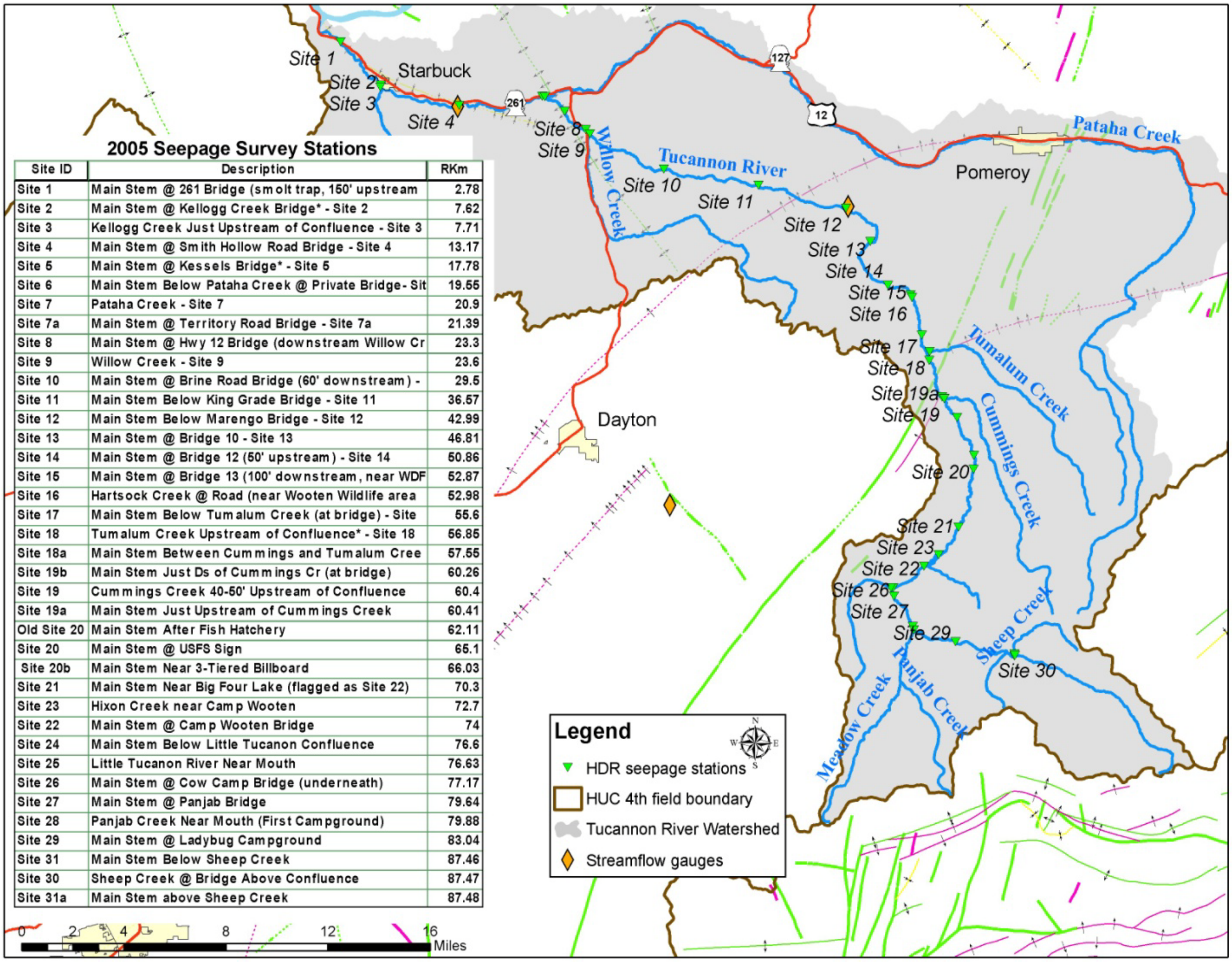
2005 Temperature Study Stations*

Site ID	RKm	Description	Map ID	Operator
35Tuca21.4	20.8	500ft above bridge Territorial Rd Bridge	A	WDFW
35Tuca17.8	17.2	Upper end of Ducharme's property	B	WDFW
35Tuca13.2	12.9	.25 mile above Smith Hollow Rd Bridge	C	WDFW
35Tuca29.6	29.0	300ft above Enrich Rd Bridge	D	WDFW
35Tuca23.3	22.7	100ft above US Hwy 12 Bridge	E	WDFW
35Tuca36.6	35.7	200ft above King Grade Bridge	F	WDFW
35Tuca43.0	41.8	Streamflow gage 35B150 near Marengo	G	ECOLOGY
35Tuca46.8	45.5	Under Howard Bridge (aka Bridge 10)	H	WDFW
35Tuca50.9	49.5	50ft above Donohue Bridge (aka Bridge 12)	I	WDFW
35Tuca60.3	58.8	50ft near Cummings Creek Bridge	J	WDFW
35Tuca63.7	62.1	Tucannon Hatchery Intake in intake pool	K	WDFW
35Tuca65.6	64.0	USFS Info Sign at Old Campground 5	L	WDFW
35Tuca70.4	68.8	Big 4 Lake day-use area below lake	M	WDFW
35Tuca76.5	74.9	150ft below mouth of Little Tucannon River	N	WDFW
35Tuca79.7	78.0	50ft above the Panjab Bridge	O	WDFW
35Tuca84.8	83.1	Upper end of Lady Bug Flat Campground	P	WDFW
35Tuca87.5	85.7	Above Sheep Creek	Q	WDFW
35Tuca02.8	2.9	Attached to back of smolt trap nr Powers br	R	WDFW
35Cumm00.0	0.0	In Cummings creek	S	WDFW
35Panj00.0	0.2	In Panjab Creek	T	WDFW
35Cold00.0	0.0	In Cold Creek	U	WDFW
35LTuc00.0	0.1	In Little Tucannon River	V	WDFW
35Hixo00.0	0.8	In Hixon Creek	W	WDFW
35Pata02.0	2.0	Pataha Creek at hwy 261	X	ECOLOGY
PomeroySTP	39.1	Pomery STP Effluent in pipe	Y	ECOLOGY
PatahaUps	39.2	Pataha Creek Upstream of STP	Z	ECOLOGY
PatahaDns	39.0	Pataha Creek downstream of STP	AA	ECOLOGY

USFS Temperature Monitoring Stations

Site ID	RKm	Description	Map ID
CUMMG@FB	9.7	Cummings Cr Nr FS Boundary, T09N R41E S12 NWSE	BB
HIXONCR	1.7	Hixon Cr T09N R41E S21 SWSE	CC
MEADW2MT	0.1	Meadow Cr @ mouth T08N R41E S18 SENE	DD
PANJABMT	0.1	Panjab Cr @ mouth T08N R41E S05 SENW	EE
SHEEP@MT	0.1	Sheep Cr near mouth T08N R41E S12 SENW	FF
LTCNN@MT	0.1	Little Tucannon Cr @ mouth T09N R41E S30 NWSE	GG
TCNN@PAN	79.7	Tucannon R @ Panjab Cr bridge T08N R41E S05 NEN	HH
TCNN@FBI	67.1	Tucannon R @ FS Bdry/ISCO site T09N R41E S02 NWN	II
PTAHA@FB	77.8	Pataha Cr @ FS Bdry abv cground T09 R42E S02 NEN	JJ

Figure D-(1) 13: Stream temperature monitoring stations.



2005 Seepage Survey Stations

Site ID	Description	RKm
Site 1	Main Stem @ 261 Bridge (smolt trap, 150' upstream	2.78
Site 2	Main Stem @ Kellogg Creek Bridge* - Site 2	7.62
Site 3	Kellogg Creek Just Upstream of Confluence - Site 3	7.71
Site 4	Main Stem @ Smith Hollow Road Bridge - Site 4	13.17
Site 5	Main Stem @ Kessels Bridge* - Site 5	17.78
Site 6	Main Stem Below Pataha Creek @ Private Bridge- Sit	19.55
Site 7	Pataha Creek - Site 7	20.9
Site 7a	Main Stem @ Territory Road Bridge - Site 7a	21.39
Site 8	Main Stem @ Hwy 12 Bridge (downstream Willow Cr	23.3
Site 9	Willow Creek - Site 9	23.6
Site 10	Main Stem @ Brine Road Bridge (60' downstream) -	29.5
Site 11	Main Stem Below King Grade Bridge - Site 11	36.57
Site 12	Main Stem Below Marengo Bridge - Site 12	42.99
Site 13	Main Stem @ Bridge 10 - Site 13	46.81
Site 14	Main Stem @ Bridge 12 (50' upstream) - Site 14	50.86
Site 15	Main Stem @ Bridge 13 (100' downstream, near WDF	52.87
Site 16	Hartsock Creek @ Road (near Wooten Wildlife area	52.98
Site 17	Main Stem Below Tumalum Creek (at bridge) - Site	55.6
Site 18	Tumalum Creek Upstream of Confluence* - Site 18	56.85
Site 18a	Main Stem Between Cummings and Tumalum Cree	57.55
Site 19b	Main Stem Just Ds of Cummings Cr (at bridge)	60.26
Site 19	Cummings Creek 40-50' Upstream of Confluence	60.4
Site 19a	Main Stem Just Upstream of Cummings Creek	60.41
Old Site 20	Main Stem After Fish Hatchery	62.11
Site 20	Main Stem @ USFS Sign	65.1
Site 20b	Main Stem Near 3-Tiered Billboard	66.03
Site 21	Main Stem Near Big Four Lake (flagged as Site 22)	70.3
Site 23	Hixon Creek near Camp Wooten	72.7
Site 22	Main Stem @ Camp Wooten Bridge	74
Site 24	Main Stem Below Little Tucanon Confluence	76.6
Site 25	Little Tucanon River Near Mouth	76.63
Site 26	Main Stem @ Cow Camp Bridge (underneath)	77.17
Site 27	Main Stem @ Panjab Bridge	79.64
Site 28	Panjab Creek Near Mouth (First Campground)	79.88
Site 29	Main Stem @ Ladybug Campground	83.04
Site 31	Main Stem Below Sheep Creek	87.46
Site 30	Sheep Creek @ Bridge Above Confluence	87.47
Site 31a	Main Stem above Sheep Creek	87.48

Figure D-(2) 14: Streamflow measurement stations.

Table D-(1) 9: Riparian codes for Shade model.

Rip Code	Source	Description	Current Vegetation Codes			System Potential Vegetation		
			Height (m)	Density (%)	Overhang (m)	Height (m)	Density (%)	Overhang (m)
111	ECY	Conifer, small, sparse	12.8	25%	1.5	35.5	75%	3.0
112	ECY	Conifer, small, moderate	12.8	50%	1.5	35.5	75%	3.0
113	ECY	Conifer, small, dense	12.8	75%	1.5	35.5	75%	3.0
114	ECY	Conifer, small, very dense	12.8	90%	1.5	35.5	90%	3.0
121	ECY	Conifer, medium, sparse	25.8	25%	2.1	35.5	75%	3.0
122	ECY	Conifer, medium, moderate	25.8	50%	2.1	35.5	75%	3.0
123	ECY	Conifer, medium, dense	25.8	75%	2.1	35.5	75%	3.0
124	ECY	Conifer, medium, very dense	25.8	90%	2.1	35.5	90%	3.0
131	ECY	Conifer, large, sparse	30.9	25%	3.0	35.5	75%	3.0
132	ECY	Conifer, large, moderate	30.9	50%	3.0	35.5	75%	3.0
133	ECY	Conifer, large, dense	30.9	75%	3.0	35.5	75%	3.0
134	ECY	Conifer, large, very dense	30.9	90%	3.0	35.5	90%	3.0
211	ECY	Deciduous, small, sparse	10.7	25%	0.8	22.3	75%	2.7
212	ECY	Deciduous, small, moderate	10.7	50%	0.8	22.3	75%	2.7
213	ECY	Deciduous, small, dense	10.7	75%	0.8	22.3	75%	2.7
214	ECY	Deciduous, small, very dense	10.7	90%	0.8	22.3	90%	2.7
221	ECY	Deciduous, medium, sparse	18.3	25%	1.5	22.3	75%	2.7
222	ECY	Deciduous, medium, moderate	18.3	50%	1.5	22.3	75%	2.7
223	ECY	Deciduous, medium, dense	18.3	75%	1.5	22.3	75%	2.7
224	ECY	Deciduous, medium, very dense	18.3	90%	1.5	22.3	90%	2.7
231	ECY	Deciduous, large, sparse	22.3	25%	2.7	22.3	75%	2.7
232	ECY	Deciduous, large, moderate	22.3	50%	2.7	22.3	75%	2.7
233	ECY	Deciduous, large, dense	22.3	75%	2.7	22.3	75%	2.7

Rip Code	Source	Description	Current Vegetation Codes			System Potential Vegetation		
			Height (m)	Density (%)	Overhang (m)	Height (m)	Density (%)	Overhang (m)
234	ECY	Deciduous, large, very dense	22.3	90%	2.7	22.3	90%	2.7
311	ECY	Mixed, small, sparse	10.7	25%	1.1	24.0	75%	1.8
312	ECY	Mixed, small, moderate	10.7	50%	1.1	24.0	75%	1.8
313	ECY	Mixed, small, dense	10.7	75%	1.1	24.0	75%	1.8
314	ECY	mixed, small, very dense	10.7	90%	1.1	24.0	90%	1.8
321	ECY	Mixed, medium, sparse	18.3	25%	1.8	24.0	75%	1.8
322	ECY	Mixed, medium, moderate	18.3	50%	1.8	24.0	75%	1.8
323	ECY	Mixed, medium, dense	18.3	75%	1.8	24.0	75%	1.8
324	ECY	Mixed, medium, very dense	18.3	90%	1.8	24.0	90%	1.8
332	ECY	Mixed, large, moderate	24.0	50%	2.9	24.0	75%	2.9
333	ECY	Mixed, large, dense	24.0	75%	2.9	24.0	75%	2.9
411	ECY	Herbaceous, sparse	1.5	25%	0.6	10.7	75%	0.8
433	ECY	Herbaceous, dense	1.5	75%	0.6	10.7	75%	0.8
555	ECY	Barren, grass/lawn	0.0	100%	0.0	0.0	100%	0.0
600	ECY	Water	0.0	100%	0.0	0.0	100%	0.0
434	ECY	Agricultural field in production	3.0	100%	0.0	22.3	75%	2.7
500	ECY	Residential	3.0	100%	0.0	3.0	100%	0.0
711	ECY	Burned w/ sparse trees remaining	0.0	5%	0.0	35.5	75%	0.0
712	ECY	Burned w/ med density trees remaining	0.0	25%	0.0	35.5	75%	0.0
550	ECY	Roads	0.0	100%	0.0	0.0	100%	0.0

Table D-(2) 10: Tucannon tributary shade curve values for deciduous vegetation

	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar short-wave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
Bankfull width (m)	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%	97.4%	98.1%	9	8	6
2	96.5%	97.1%	97.8%	11	9	7
3	96.1%	96.6%	97.4%	12	10	8
4	95.6%	96.2%	97.1%	13	12	9
5	93.8%	94.5%	96.1%	19	17	12
6	92.0%	92.6%	94.8%	24	22	16
7	89.8%	90.4%	93.4%	31	29	20
8	86.4%	87.0%	91.6%	41	39	26
9	82.6%	83.2%	85.2%	53	51	45
10	77.6%	78.9%	74.7%	68	64	77
12	69.1%	70.7%	63.0%	94	89	113
14	62.2%	63.6%	55.0%	115	111	137
16	56.6%	57.5%	48.9%	132	129	156
18	52.0%	52.4%	44.1%	146	145	170
20	47.9%	48.0%	40.1%	158	158	182
25	40.0%	39.4%	32.9%	183	184	204
30	34.2%	33.2%	28.0%	200	203	219
35	29.8%	28.7%	24.3%	214	217	230
40	26.4%	25.3%	21.5%	224	227	239
45	23.6%	22.6%	19.3%	232	235	245
50	21.4%	20.4%	17.5%	239	242	251
55	19.5%	18.6%	16.0%	245	248	255
60	17.9%	17.1%	14.8%	250	252	259
65	16.6%	15.8%	13.7%	254	256	263
70	15.4%	14.7%	12.8%	257	259	265
75	14.4%	13.8%	11.9%	260	262	268
80	13.5%	12.9%	11.2%	263	265	270
85	12.7%	12.2%	10.6%	266	267	272
90	12.0%	11.5%	10.0%	268	269	274

	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar short-wave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
Bankfull width (m)	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
95	11.4%	10.9%	9.5%	270	271	275
100	10.8%	10.4%	9.0%	271	273	277
110	9.8%	9.4%	8.2%	274	275	279
120	9.0%	8.7%	7.6%	277	278	281
130	8.3%	8.0%	7.0%	279	280	283
140	7.7%	7.4%	6.5%	281	282	284
150	7.2%	6.9%	6.1%	282	283	286
160	6.7%	6.5%	5.7%	284	284	287
170	6.3%	6.1%	5.4%	285	286	288
180	6.0%	5.8%	5.1%	286	287	289
190	5.7%	5.5%	4.8%	287	287	290
200	5.4%	5.2%	4.6%	288	288	290
210	5.1%	5.0%	4.3%	289	289	291
220	4.9%	4.7%	4.2%	289	290	292
230	4.7%	4.5%	4.0%	290	290	292
240	4.5%	4.4%	3.8%	290	291	293
250	4.3%	4.2%	3.7%	291	291	293
260	4.2%	4.0%	3.5%	292	292	293
270	4.0%	3.9%	3.4%	292	292	294
280	3.9%	3.7%	3.3%	292	293	294
300	3.6%	3.5%	3.0%	293	294	295

Table D-(3) 11: Tucannon tributary shade curve values for conifer vegetation

	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar short-wave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
Bankfull width (m)	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	95.5%	95.8%	96.9%	14	13	9
2	95.1%	95.5%	96.7%	15	14	10
3	94.8%	95.4%	96.5%	16	14	11
4	92.5%	94.1%	95.9%	23	18	13
5	87.9%	91.6%	95.1%	37	26	15
6	82.4%	86.4%	92.2%	54	41	24
7	76.4%	80.7%	88.1%	72	59	36
8	71.2%	75.8%	83.8%	88	74	49
9	66.6%	71.1%	79.2%	101	88	63
10	62.9%	67.3%	74.9%	113	100	76
12	56.9%	60.7%	67.0%	131	120	100
14	52.0%	55.6%	59.5%	146	135	123
16	48.0%	51.1%	51.4%	158	149	148
18	44.6%	47.2%	43.0%	169	160	173
20	41.6%	44.0%	38.7%	178	170	186
25	35.6%	37.2%	31.9%	196	191	207
30	31.1%	32.0%	27.2%	209	207	221
35	27.6%	27.9%	23.8%	220	219	232
40	24.6%	24.7%	21.1%	229	229	240
45	22.3%	22.1%	19.0%	236	237	246
50	20.3%	20.0%	17.3%	242	243	252
55	18.7%	18.2%	15.8%	247	249	256
60	17.2%	16.8%	14.6%	252	253	260
65	15.9%	15.5%	13.6%	256	257	263
70	14.9%	14.4%	12.7%	259	260	266
75	13.9%	13.5%	11.9%	262	263	268
80	13.1%	12.7%	11.2%	264	266	270
85	12.3%	12.0%	10.6%	267	268	272
90	11.7%	11.3%	10.0%	269	270	274

	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar short-wave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
Bankfull width (m)	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
95	11.0%	10.7%	9.5%	271	272	275
100	10.5%	10.2%	9.1%	272	273	277
110	9.6%	9.3%	8.3%	275	276	279
120	8.8%	8.5%	7.6%	277	278	281
130	8.1%	7.9%	7.0%	280	280	283
140	7.5%	7.3%	6.6%	281	282	284
150	7.0%	6.9%	6.1%	283	283	286
160	6.6%	6.4%	5.8%	284	285	287
170	6.2%	6.0%	5.4%	285	286	288
180	5.8%	5.7%	5.1%	286	287	289
190	5.5%	5.4%	4.9%	287	288	289
200	5.3%	5.1%	4.6%	288	289	290
210	5.0%	4.9%	4.4%	289	289	291
220	4.8%	4.7%	4.2%	290	290	291
230	4.6%	4.5%	4.0%	290	291	292
240	4.4%	4.3%	3.9%	291	291	292
250	4.2%	4.1%	3.7%	291	292	293
260	4.0%	4.0%	3.6%	292	292	293
270	3.9%	3.8%	3.4%	292	293	294
280	3.8%	3.7%	3.3%	293	293	294
300	3.5%	3.4%	3.1%	294	294	295

Table D-(4) 12: Tucannon tributary shade curve values for mixed vegetation

	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar short-wave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
Bankfull width (m)	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	96.3%	96.8%	97.6%	11	10	7
2	95.9%	96.4%	97.3%	12	11	8
3	95.4%	95.9%	96.9%	14	12	9
4	93.6%	94.0%	95.9%	19	18	13
5	91.2%	92.2%	94.7%	27	24	16
6	86.7%	88.8%	93.1%	40	34	21
7	80.5%	83.3%	88.8%	59	51	34
8	74.6%	77.9%	82.2%	77	67	54
9	69.7%	73.1%	75.4%	92	82	75
10	65.6%	68.7%	67.9%	105	95	98
12	58.7%	61.1%	54.7%	126	118	138
14	53.1%	55.1%	47.4%	143	136	160
16	48.4%	49.9%	42.1%	157	152	176
18	44.6%	45.5%	38.0%	168	166	188
20	41.2%	41.7%	34.7%	179	177	199
25	34.7%	34.4%	28.5%	199	200	217
30	29.7%	29.1%	24.3%	214	216	230
35	25.9%	25.1%	21.1%	225	228	240
40	23.0%	22.1%	18.7%	234	237	247
45	20.6%	19.7%	16.8%	242	244	253
50	18.7%	17.9%	15.3%	247	250	258
55	17.0%	16.3%	14.0%	252	255	262
60	15.6%	14.9%	12.9%	257	259	265
65	14.5%	13.8%	11.9%	260	262	268
70	13.5%	12.9%	11.1%	263	265	270
75	12.6%	12.0%	10.4%	266	268	272
80	11.8%	11.3%	9.8%	268	270	274
85	11.1%	10.6%	9.2%	270	272	276
90	10.5%	10.0%	8.7%	272	274	278

	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar short-wave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
Bankfull width (m)	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
95	9.9%	9.5%	8.3%	274	275	279
100	9.4%	9.1%	7.9%	275	277	280
110	8.6%	8.2%	7.2%	278	279	282
120	7.9%	7.6%	6.6%	280	281	284
130	7.3%	7.0%	6.1%	282	283	286
140	6.7%	6.5%	5.7%	284	284	287
150	6.3%	6.1%	5.3%	285	286	288
160	5.9%	5.7%	5.0%	286	287	289
170	5.5%	5.4%	4.7%	287	288	290
180	5.2%	5.1%	4.4%	288	289	291
190	5.0%	4.8%	4.2%	289	290	291
200	4.7%	4.6%	4.0%	290	290	292
210	4.5%	4.3%	3.8%	290	291	293
220	4.3%	4.1%	3.6%	291	292	293
230	4.1%	4.0%	3.5%	292	292	294
240	3.9%	3.8%	3.3%	292	293	294
250	3.8%	3.6%	3.2%	293	293	294
260	3.6%	3.5%	3.1%	293	294	295
270	3.5%	3.4%	3.0%	294	294	295
280	3.4%	3.3%	2.9%	294	294	295
300	3.1%	3.0%	2.7%	295	295	296

Table D-(5) 13: Tucannon River Shade Deficits and Solar Radiation Load Allocations. *US Forest Service Lands are not included in the TMDL compliance area but are expected to comply with their forest management plan to attain water quality that meets standards.*

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.12092	117.50426	99.772	Outside of compliance area	2%	82%	98%	16%	7.44
46.12318	117.49929	99.344		6%	87%	97%	10%	9.87
46.12749	117.49817	98.872		13%	80%	97%	17%	9.77
46.13089	117.49936	98.457		9%	92%	97%	5%	10.28
46.13278	117.50486	97.954	Near upstream extent of perennial water	4%	89%	97%	8%	10.07
46.13404	117.51081	97.446		3%	94%	99%	5%	5.04
46.13582	117.51647	96.955		4%	97%	98%	2%	5.61
46.13862	117.52075	96.472		7%	96%	96%	0%	13.77
46.14235	117.52322	96.022		10%	92%	96%	5%	13.77
46.14610	117.52571	95.547		11%	95%	98%	3%	8.62
46.14986	117.52807	95.053		11%	85%	97%	12%	11.00
46.15304	117.53156	94.591		7%	85%	96%	11%	13.20
46.15685	117.53414	94.103		8%	87%	96%	9%	13.12
46.15965	117.53797	93.620		10%	78%	97%	19%	12.90
46.16305	117.54156	93.164		10%	85%	98%	13%	7.38
46.16565	117.54671	92.646		4%	98%	99%	1%	4.52
46.16699	117.55242	92.162		3%	99%	99%	0%	3.77
46.16710	117.55861	91.666		4%	99%	99%	0%	2.99
46.16948	117.56376	91.153		4%	98%	98%	0%	6.31
46.17134	117.56935	90.662		4%	99%	99%	0%	4.08
46.17372	117.57464	90.172		5%	98%	99%	0%	5.66
46.17602	117.58002	89.676		4%	98%	98%	0%	7.48
46.17791	117.58499	89.203		4%	98%	98%	0%	6.39
46.18100	117.58907	88.724		5%	96%	97%	1%	9.08

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.18138	117.59515	88.284		2%	97%	99%	2%	3.43
46.18281	117.60016	87.790		4%	95%	98%	3%	7.44
46.18438	117.60582	87.280		2%	95%	97%	3%	9.44
46.18499	117.61135	86.818		2%	96%	97%	1%	11.47
46.18728	117.61658	86.334	Near end of Tucannon Road	3%	96%	96%	0%	13.04
46.18826	117.62267	85.842	~530ft upstream of Sheep Creek confluence	2%	80%	93%	13%	25.67
46.18881	117.62821	85.350		2%	89%	95%	6%	20.01
46.19175	117.63264	84.854	~500ft downstream of Cold Creek confluence	4%	85%	95%	10%	18.73
46.19029	117.63814	84.411		2%	98%	98%	0%	8.02
46.19009	117.64342	83.964		3%	97%	97%	0%	9.55
46.19223	117.64865	83.475		2%	73%	87%	14%	46.99
46.19275	117.65470	82.998		3%	94%	95%	1%	15.82
46.19553	117.65941	82.517		2%	69%	78%	8%	81.54
46.19738	117.66454	82.062		3%	93%	94%	1%	19.75
46.19601	117.67012	81.579		3%	79%	84%	6%	56.65
46.19794	117.67525	81.059		3%	91%	94%	4%	19.48
46.19851	117.68118	80.566		2%	93%	95%	2%	16.96
46.19953	117.68706	80.056		2%	75%	88%	13%	43.89
46.19905	117.69321	79.569		3%	89%	91%	2%	32.03
46.20120	117.69839	79.077		4%	67%	79%	11%	77.99
46.20323	117.70210	78.615		5%	73%	80%	8%	70.52
46.20575	117.70630	78.135	~420ft downstream of Panjab Creek xing	6%	56%	64%	8%	121.61
46.20924	117.70904	77.645		7%	25%	48%	24%	171.54
46.21325	117.71097	77.119		9%	41%	64%	22%	126.98
46.21724	117.71242	76.632		7%	25%	57%	32%	143.63

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.21973	117.71731	76.152		4%	31%	45%	14%	182.32
46.22228	117.72165	75.686	~510ft upstream of Cow Camp Bridge xing	7%	32%	60%	27%	137.25
46.22628	117.72292	75.203		7%	32%	57%	25%	145.42
46.22910	117.71930	74.696	~850ft downstream of Little Tucannon River confluence	5%	35%	60%	25%	145.41
46.23070	117.71367	74.222		3%	43%	58%	15%	154.99
46.23216	117.70868	73.792		3%	30%	59%	29%	125.46
46.23419	117.70354	73.327		6%	57%	63%	6%	125.25
46.23786	117.70061	72.817		3%	51%	57%	5%	139.64
46.23995	117.69527	72.332		4%	43%	58%	15%	139.24
46.24220	117.69070	71.875	~580ft upstream of road xing to Camp Wooten	4%	33%	65%	32%	115.60
46.24534	117.68726	71.347		4%	52%	65%	13%	118.97
46.24627	117.68183	70.925	~540ft downstream of Hixon Creek confluence	4%	25%	64%	39%	120.18
46.24869	117.67740	70.472		6%	62%	75%	13%	88.79
46.25213	117.67438	69.991		5%	57%	65%	8%	118.89
46.25528	117.67053	69.489		8%	25%	59%	33%	149.36
46.25888	117.66902	69.063	~680ft upstream of WDFW temperature station near Big 4 Lake	6%	36%	67%	31%	114.64
46.26231	117.66567	68.586		3%	24%	42%	18%	188.23
46.26588	117.66301	68.058		6%	32%	65%	33%	119.61
46.26915	117.65974	67.571		5%	23%	52%	29%	161.22
46.27246	117.65725	67.091		9%	25%	48%	22%	175.17
46.27615	117.65875	66.626		5%	14%	54%	40%	153.24
46.28005	117.65666	65.970		5%	12%	48%	35%	173.78

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.28383	117.65684	65.519		5%	6%	35%	30%	210.98
46.28722	117.65462	65.030		7%	7%	45%	37%	186.20
46.29108	117.65374	64.558		5%	5%	44%	39%	192.65
46.29519	117.65179	64.072	Near WDFW temperature station near USFS Info sign	6%	12%	48%	36%	181.60
46.29912	117.65182	63.572		5%	6%	43%	36%	189.43
46.30275	117.65329	63.104		5%	5%	33%	28%	218.85
46.30649	117.65605	62.523		5%	11%	50%	39%	163.92
46.30981	117.65781	62.061	Near Fish Hatchery intake pool	5%	34%	63%	29%	124.54
46.31246	117.66184	61.592		7%	33%	53%	20%	157.00
46.31678	117.66323	61.108		6%	21%	54%	33%	151.35
46.32093	117.66443	60.615	Near Fish Hatchery point of discharge	4%	21%	46%	26%	177.81
46.32439	117.66808	60.136		4%	18%	44%	26%	183.01
46.32695	117.67153	59.651		6%	20%	42%	22%	187.27
46.33005	117.67338	59.234		6%	13%	48%	35%	173.64
46.33359	117.67657	58.746	~500ft downstream of Cummings Creek confluence	6%	33%	64%	31%	122.14
46.33644	117.68053	58.201		6%	22%	55%	34%	153.54
46.34045	117.68165	57.695		8%	21%	54%	33%	153.67
46.34432	117.68090	57.237		5%	31%	53%	21%	152.90
46.34830	117.68200	56.736		3%	38%	53%	16%	157.59
46.35227	117.68345	56.249		6%	36%	47%	11%	176.64
46.35552	117.68730	55.745		5%	41%	59%	18%	131.21
46.35938	117.68833	55.306	~160ft downstream of Tumalum Creek confluence	4%	37%	55%	18%	146.11
46.36275	117.69214	54.816		5%	10%	33%	23%	217.57

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.36708	117.69147	54.300	~460ft upstream of Tucannon Road xing near Mcgovern Lane	5%	17%	44%	27%	178.89
46.37130	117.69240	53.808		7%	16%	47%	31%	169.65
46.37559	117.69312	53.316		6%	23%	49%	26%	165.23
46.37957	117.69331	52.852		7%	43%	50%	7%	163.21
46.38351	117.69469	52.393		7%	48%	60%	13%	131.84
46.38749	117.69654	51.878		8%	48%	60%	12%	131.22
46.39096	117.69955	51.431	~130ft downstream of Tucannon Road Bridge 13 xing and WDFW boundary	9%	41%	64%	23%	115.87
46.39460	117.70183	50.943		9%	52%	63%	11%	123.32
46.39573	117.70642	50.556		3%	23%	61%	38%	127.35
46.39524	117.71254	50.034		2%	23%	66%	43%	99.92
46.39632	117.71796	49.581	~100ft upstream of Donohue Bridge (#12) xing	3%	39%	62%	23%	123.15
46.39873	117.72222	49.094		3%	67%	72%	6%	86.71
46.40014	117.72810	48.603		3%	39%	52%	13%	146.79
46.40312	117.73210	48.113		4%	30%	43%	13%	180.24
46.40599	117.73585	47.666		5%	43%	49%	6%	160.94
46.40993	117.73860	47.170		8%	32%	54%	21%	148.45
46.41370	117.74125	46.687		4%	28%	52%	24%	158.07
46.41704	117.73709	46.195		6%	42%	57%	15%	136.45
46.42035	117.73279	45.691	~600ft upstream of Howard Bridge (#10) xing	6%	26%	56%	30%	138.93
46.42166	117.72741	45.200		6%	30%	46%	16%	166.17
46.42580	117.72548	44.691		5%	46%	54%	8%	143.83
46.42993	117.72601	44.189		8%	28%	47%	20%	157.58
46.43207	117.73049	43.698		3%	35%	53%	18%	149.14

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.43449	117.73512	43.216		2%	38%	61%	23%	125.25
46.43716	117.74006	42.701		2%	36%	55%	19%	140.47
46.43813	117.74521	42.236		2%	40%	55%	14%	143.07
46.44046	117.75045	41.750	~180ft downstream of Turner Road xing at Marengo	3%	44%	58%	13%	134.27
46.44209	117.75559	41.280		5%	64%	80%	16%	63.76
46.44149	117.76186	40.786		2%	63%	72%	9%	85.98
46.44131	117.76821	40.299		1%	23%	44%	21%	173.36
46.44280	117.77378	39.826		1%	31%	48%	16%	161.41
46.44458	117.77955	39.329		1%	48%	58%	10%	131.40
46.44573	117.78483	38.879		2%	24%	53%	29%	144.78
46.44747	117.79051	38.372		3%	45%	76%	31%	77.72
46.44979	117.79549	37.902		3%	38%	66%	28%	107.27
46.45254	117.79960	37.437		1%	52%	64%	11%	117.46
46.45266	117.80464	37.006		1%	31%	47%	16%	161.54
46.45293	117.81057	36.551		1%	47%	65%	17%	108.27
46.45375	117.81653	36.053		1%	35%	56%	21%	132.82
46.45500	117.82132	35.586	At King Grade bridge xing	1%	48%	73%	25%	82.42
46.45512	117.82705	35.117		1%	51%	70%	20%	91.81
46.45641	117.83242	34.648		1%	45%	63%	19%	112.76
46.45855	117.83765	34.148		1%	29%	53%	25%	145.55
46.46016	117.84313	33.697		1%	16%	54%	38%	140.75
46.45824	117.84844	33.265		1%	33%	52%	19%	152.08
46.45869	117.85450	32.727		1%	53%	62%	9%	112.23
46.46122	117.85853	32.287		1%	53%	58%	5%	128.45
46.46084	117.86444	31.809		1%	27%	48%	20%	160.45
46.46041	117.86990	31.362		1%	15%	27%	12%	222.60

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.46192	117.87555	30.836		1%	31%	53%	22%	144.68
46.46151	117.88181	30.358		1%	30%	48%	18%	161.13
46.46256	117.88767	29.867		1%	19%	49%	30%	152.41
46.46495	117.89263	29.376		1%	15%	39%	24%	188.58
46.46575	117.89854	28.881	At Enrich Road bridge xing	1%	15%	35%	21%	202.34
46.46544	117.90398	28.467		1%	23%	44%	22%	175.13
46.46619	117.90884	28.007		1%	12%	32%	20%	213.56
46.46789	117.91377	27.491		1%	9%	37%	28%	192.44
46.47016	117.91879	27.059		4%	28%	52%	25%	149.68
46.47375	117.92230	26.555		2%	25%	46%	21%	171.30
46.47572	117.92790	26.056		1%	26%	48%	22%	161.95
46.47705	117.93364	25.511		1%	13%	34%	21%	202.71
46.47730	117.93954	25.056		1%	14%	26%	13%	224.32
46.47878	117.94486	24.590		2%	22%	55%	34%	138.64
46.48081	117.95028	24.107		1%	14%	18%	4%	224.58
46.48377	117.95439	23.600		2%	31%	56%	25%	144.86
46.48690	117.95740	23.080		1%	29%	45%	16%	176.09
46.48900	117.96243	22.620	~240ft downstream of Hwy 12 xing	1%	20%	57%	37%	134.47
46.49079	117.96812	22.128		1%	9%	48%	39%	160.15
46.49354	117.97267	21.663		2%	18%	44%	26%	174.68
46.49663	117.97661	21.152		4%	25%	59%	34%	134.29
46.50050	117.97928	20.667	~420ft downstream of Territorial Road xing	4%	14%	41%	27%	185.93
46.50408	117.98278	20.185		6%	24%	44%	20%	176.90
46.50587	117.98820	19.655		2%	26%	40%	14%	169.73
46.50737	117.99386	19.157		1%	14%	33%	19%	206.35

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.50792	117.99964	18.637		1%	11%	37%	26%	194.73
46.50682	118.00507	18.174		2%	17%	39%	22%	186.81
46.50597	118.00972	17.766		0%	13%	34%	21%	201.93
46.50547	118.01571	17.296	~350ft upstream of River Ranch Lane xing	2%	11%	45%	34%	159.53
46.50392	118.02161	16.790		1%	41%	56%	15%	134.70
46.50263	118.02767	16.292		1%	43%	65%	22%	116.55
46.50164	118.03332	15.798		1%	23%	55%	32%	140.19
46.50325	118.03883	15.314		1%	17%	52%	36%	148.89
46.50481	118.04222	14.930		1%	26%	50%	24%	149.90
46.50566	118.04718	14.517		1%	31%	50%	19%	144.18
46.50425	118.05119	14.121		1%	29%	50%	21%	159.36
46.50415	118.05697	13.649		1%	63%	63%	0%	112.50
46.50641	118.06125	13.194		1%	20%	48%	28%	162.08
46.50442	118.06672	12.689	~430ft downstream of Smith Hollow Road xing	1%	15%	53%	38%	133.17
46.50422	118.07314	12.190		1%	28%	47%	19%	161.09
46.50594	118.07890	11.691		1%	34%	46%	12%	168.29
46.50675	118.08490	11.177		1%	20%	34%	14%	204.56
46.50804	118.09036	10.708		2%	28%	37%	9%	202.10
46.50785	118.09626	10.214		1%	36%	52%	16%	130.49
46.50921	118.10235	9.699	~740ft upstream of HA Fletcher Road xing	1%	6%	20%	14%	246.18
46.51059	118.10812	9.205		1%	12%	46%	34%	169.49
46.51104	118.11449	8.713		1%	44%	67%	23%	99.43
46.51366	118.11949	8.210	~820ft upstream of Starbuck Town boundary	1%	35%	53%	18%	146.12
46.51489	118.12545	7.687		1%	25%	44%	19%	171.56

Latitude	Longitude	Distance from River mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade deficit (%) load allocation	DAve Solar Rad. below veg (W/m^2)
46.51782	118.12930	7.205	~190ft downstream of Kellog Hollow Road xing	1%	27%	43%	16%	178.29
46.52110	118.13299	6.675	Near downstream boundary of Starbuck	3%	38%	49%	11%	158.84
46.52225	118.13905	6.105		1%	17%	37%	20%	190.87
46.52501	118.14182	5.724		2%	35%	60%	25%	122.99
46.52831	118.14384	5.294		1%	33%	51%	19%	131.44
46.53158	118.14513	4.828		2%	24%	51%	26%	159.02
46.53252	118.15008	4.398		2%	26%	47%	20%	164.11
46.53538	118.15301	3.922		1%	37%	49%	12%	162.25
46.53862	118.15603	3.514	~330ft downstream of Tucker Road xing	1%	24%	44%	20%	175.80
46.54076	118.16009	3.073	~860ft upstream of Hwy 261 (Powers Bridge)	2%	27%	43%	16%	179.11
46.54415	118.16281	2.601		2%	22%	53%	31%	147.82
46.54543	118.16817	2.148		1%	11%	43%	32%	170.69
46.54832	118.17198	1.701		1%	12%	38%	26%	194.57
46.54778	118.17825	1.210		3%	6%	29%	23%	218.75
46.55206	118.17871	.731	Near mouth of Tucannon River	6%	13%	35%	22%	202.45

Table D-(6) 14: Pataha Creek Shade Deficits and Solar Radiation Load Allocations. *US Forest Service Lands are not included in the TMDL compliance area but are expected to comply with their forest management plan to attain water quality that meets standards.*

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.21321	117.56796	89.19		4%	97%	97%	0%	8.9
46.21465	117.56256	88.69		4%	98%	98%	0%	7.5
46.21882	117.56046	88.19		7%	96%	96%	0%	11.1
46.22317	117.55924	87.69		7%	96%	96%	0%	11.2
46.22755	117.55933	87.18	End of perennial water	8%	63%	94%	31%	17.8
46.23145	117.56161	86.69		8%	96%	96%	0%	11.6
46.23582	117.56094	86.18		9%	95%	95%	0%	14.0
46.24014	117.56118	85.69		10%	95%	95%	0%	16.1
46.24429	117.55891	85.19		10%	71%	90%	19%	30.8
46.24852	117.55741	65.00		10%	82%	92%	9%	25.5
46.25163	117.55301	84.19		4%	94%	94%	0%	19.5
46.25295	117.54702	83.68		5%	81%	92%	11%	23.6
46.25536	117.54164	83.19		7%	93%	93%	0%	19.9
46.25735	117.53591	82.69		5%	93%	93%	0%	19.9
46.25888	117.53000	82.19		3%	93%	93%	0%	21.5
46.26148	117.52481	81.68		6%	90%	90%	0%	30.3
46.26508	117.52146	81.18		9%	82%	82%	0%	55.6
46.26943	117.52064	80.69		13%	84%	84%	0%	49.5
46.27367	117.52009	80.20		12%	82%	82%	0%	54.3
46.27794	117.51941	79.70		14%	83%	83%	0%	52.0
46.28202	117.51720	79.21		10%	86%	86%	0%	41.4
46.28595	117.51549	78.71		14%	90%	90%	0%	30.2
46.29033	117.51511	78.23		12%	82%	88%	6%	35.6
46.29451	117.51636	77.75	~115ft downstream of USFS boundary	9%	77%	86%	9%	42.1

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.29832	117.51925	77.25		8%	86%	93%	7%	21.4
46.30211	117.52123	76.78		9%	68%	79%	11%	64.8
46.30626	117.52174	76.30		9%	21%	45%	24%	166.0
46.31023	117.52246	75.84		10%	30%	51%	21%	150.5
46.31433	117.52240	75.38		10%	34%	55%	20%	138.3
46.31851	117.52133	74.89		12%	59%	78%	19%	67.1
46.32267	117.52151	74.42		12%	60%	78%	18%	68.2
46.32673	117.52382	73.93		12%	58%	74%	16%	78.9
46.33069	117.52566	73.47		13%	39%	55%	17%	136.0
46.33362	117.52967	72.99		6%	54%	77%	23%	70.9
46.33684	117.53391	72.51		5%	54%	78%	24%	67.4
46.33996	117.53811	72.03		6%	54%	76%	22%	73.1
46.34316	117.54069	71.61		6%	59%	65%	7%	106.0
46.34719	117.54216	71.14		8%	51%	64%	14%	108.1
46.35147	117.54264	70.65		10%	61%	73%	12%	83.4
46.35533	117.54404	70.20		10%	64%	64%	0%	111.0
46.35805	117.54834	69.74		5%	46%	73%	27%	83.1
46.35885	117.55357	69.32		3%	69%	81%	12%	58.0
46.36198	117.55546	68.85	~270ft downstream of road xing at Columbia Center	4%	43%	69%	27%	94.0
46.36489	117.55176	68.38		5%	75%	78%	3%	66.9
46.36756	117.54888	67.97		4%	69%	76%	7%	72.6
46.36962	117.54517	67.56		4%	51%	71%	21%	87.3
46.37166	117.54165	67.21		4%	51%	62%	12%	114.6
46.37314	117.53769	66.84		4%	49%	67%	18%	101.5
46.37472	117.53278	66.42		3%	57%	77%	20%	69.5
46.37607	117.52685	65.91		2%	83%	87%	4%	38.8

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.37774	117.52100	65.43		4%	83%	83%	0%	51.6
46.37925	117.51646	64.92		5%	65%	75%	11%	74.7
46.38242	117.51583	64.46		7%	33%	64%	32%	108.2
46.38509	117.52011	63.96		5%	24%	59%	35%	125.3
46.38826	117.52273	63.50		7%	38%	63%	25%	113.8
46.39228	117.52191	63.03		6%	42%	57%	15%	130.8
46.39465	117.51833	62.60		5%	44%	57%	13%	130.7
46.39635	117.51434	62.14		3%	25%	50%	25%	152.1
46.39884	117.51026	61.67		4%	18%	53%	35%	144.2
46.40064	117.50544	61.19		3%	14%	56%	42%	132.8
46.40277	117.50077	60.73		3%	13%	57%	43%	132.0
46.40464	117.49596	60.26		3%	22%	66%	44%	104.3
46.40740	117.49217	59.79		5%	11%	51%	40%	148.8
46.40957	117.48757	59.32		5%	10%	48%	38%	156.7
46.41238	117.48407	58.85		6%	19%	49%	30%	154.5
46.41461	117.48026	58.38		5%	21%	63%	43%	111.3
46.41717	117.47669	57.94		6%	28%	54%	25%	141.2
46.42006	117.47367	57.46		6%	29%	56%	28%	133.0
46.42287	117.47056	57.02		5%	29%	56%	27%	134.8
46.42625	117.46777	56.55		4%	21%	55%	35%	135.4
46.43023	117.46555	56.05	~80ft downstream of Pataha Canyon Lane xing	4%	23%	43%	20%	174.0
46.43399	117.46475	55.59		5%	26%	63%	37%	113.8
46.43748	117.46610	55.09		5%	32%	70%	38%	92.4
46.44137	117.46615	54.62		7%	36%	65%	29%	107.1
46.44509	117.46750	54.14	~600ft upstream of start of Pataha Canyon Lane	7%	63%	85%	22%	44.8

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.44866	117.46967	53.65		3%	37%	67%	30%	101.5
46.45219	117.47142	53.17		3%	45%	68%	23%	97.6
46.45472	117.47384	52.75		3%	32%	56%	24%	132.6
46.45842	117.47476	52.28		2%	33%	58%	26%	126.5
46.46190	117.47594	51.76		2%	14%	46%	32%	165.5
46.46484	117.47919	51.27		2%	21%	53%	32%	143.9
46.46659	117.48446	50.78		1%	10%	40%	30%	183.0
46.46586	117.48968	50.33		1%	13%	51%	38%	147.7
46.46531	117.49437	49.91		1%	41%	59%	18%	126.1
46.46577	117.49893	49.45		1%	38%	55%	17%	136.3
46.46657	117.50377	49.02		1%	21%	56%	34%	134.6
46.46696	117.50865	48.60		1%	19%	44%	25%	170.7
46.46749	117.51438	48.13		1%	16%	42%	26%	176.1
46.46945	117.51857	47.64		1%	39%	57%	17%	132.2
46.47055	117.52259	47.21	~650ft downstream of Rickman Gulch Road xing	1%	30%	50%	20%	153.2
46.47086	117.52699	46.77		1%	34%	49%	16%	154.0
46.47128	117.53154	46.30		1%	36%	54%	18%	139.6
46.47154	117.53775	45.80		1%	53%	66%	13%	104.6
46.47226	117.54299	45.25	~470ft downstream of Hutchens Hill Road xing	1%	47%	63%	16%	112.6
46.47363	117.54809	44.75		1%	46%	60%	14%	122.0
46.47392	117.55398	44.26		1%	28%	45%	17%	167.7
46.47458	117.55922	43.79	~810ft downstream of Fairgrounds Road xing	1%	14%	41%	27%	178.1
46.47320	117.56478	43.30		1%	34%	51%	17%	149.7
46.47385	117.57007	42.84	~230ft downstream of Pomeroy Town boundary	1%	50%	65%	15%	105.4

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.47428	117.57645	42.34		1%	56%	74%	19%	78.8
46.47269	117.58193	41.84	~110ft upstream of 20th Street xing	1%	50%	61%	12%	118.0
46.47235	117.58824	41.33	Near Pomeroy Town Park	1%	58%	70%	12%	91.6
46.47253	117.59451	40.84	At 12th Street xing	1%	56%	66%	10%	102.0
46.47274	117.60086	40.34	~100ft downstream of 8th Street xing	1%	28%	64%	36%	110.1
46.47416	117.60687	39.84	~150ft upstream of 3rd Street xing	1%	52%	64%	11%	111.0
46.47516	117.61313	39.34	Upstream of Pomeroy STP discharge	1%	51%	72%	21%	84.7
46.47610	117.61933	38.85	Downstream of Pomeroy STP discharge	1%	42%	63%	21%	111.9
46.47637	117.62551	38.35		1%	64%	73%	9%	82.6
46.47650	117.63086	37.88	~760ft downstream of Pomeroy Town boundary	2%	67%	77%	10%	70.1
46.47702	117.63710	37.38		2%	42%	68%	26%	97.7
46.47655	117.64321	36.88		2%	50%	68%	19%	96.4
46.47534	117.64909	36.38		1%	42%	67%	24%	101.1
46.47453	117.65489	35.89		1%	41%	60%	19%	121.7
46.47424	117.66069	35.38		1%	37%	61%	24%	119.0
46.47238	117.66536	34.95		1%	29%	52%	23%	146.1
46.47096	117.67024	34.50		2%	16%	46%	30%	165.0
46.46775	117.67358	34.02		2%	15%	40%	24%	183.9
46.46493	117.67727	33.58		3%	14%	39%	24%	187.0
46.46348	117.68293	33.11		1%	11%	39%	27%	186.2
46.46207	117.68878	32.61	~300ft upstream of Tatman Mountain Road xing	1%	44%	53%	10%	141.9
46.46276	117.69448	32.12		0%	22%	43%	21%	174.4

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.46333	117.70044	31.62		1%	33%	52%	19%	144.7
46.46428	117.70653	31.13	~100ft downstream of Marengo Road xing	2%	23%	38%	15%	189.0
46.46667	117.71167	30.63		1%	30%	42%	12%	176.9
46.46790	117.71760	30.15		1%	9%	31%	22%	208.5
46.46981	117.72238	39.70		1%	7%	32%	25%	208.1
46.47239	117.72569	29.26		1%	17%	37%	20%	192.6
46.47472	117.73006	28.77		1%	13%	33%	19%	205.1
46.47676	117.73487	28.30		1%	5%	26%	21%	226.4
46.47987	117.73738	27.85		1%	6%	33%	26%	205.3
46.48239	117.74131	27.37		1%	7%	31%	24%	211.4
46.48342	117.74570	26.92		1%	6%	28%	22%	217.8
46.48458	117.75126	26.45		1%	5%	27%	22%	220.8
46.48664	117.75544	26.01		1%	8%	32%	25%	206.0
46.48708	117.76093	25.55		1%	6%	32%	26%	208.1
46.48942	117.76446	25.11		1%	6%	22%	16%	236.2
46.49127	117.76911	24.63		1%	6%	28%	22%	218.2
46.49424	117.77058	24.15		1%	5%	26%	21%	224.4
46.49772	117.77354	23.66		2%	16%	37%	22%	190.8
46.50044	117.77751	23.17		1%	5%	26%	22%	224.2
46.50398	117.78062	22.69		5%	20%	42%	23%	175.6
46.50643	117.78414	22.27		1%	13%	33%	20%	204.2
46.50908	117.78887	21.76		1%	25%	46%	21%	163.5
46.51248	117.79164	21.29		1%	23%	35%	12%	196.4
46.51599	117.79265	20.81		1%	16%	34%	18%	202.2
46.51823	117.79768	20.33		1%	37%	47%	10%	160.5
46.51962	117.80272	19.83		1%	35%	48%	14%	157.9

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.52076	117.80815	19.36		1%	19%	36%	17%	195.2
46.52109	117.81373	18.86		1%	30%	39%	9%	185.5
46.52264	117.81898	18.40		1%	42%	43%	1%	172.1
46.52397	117.82419	17.92	~600ft downstream of Owens Road xing	1%	11%	30%	20%	212.1
46.52584	117.82792	17.48		1%	10%	27%	17%	222.5
46.52709	117.83289	17.01		1%	14%	36%	22%	194.7
46.52937	117.83696	16.56		1%	12%	34%	22%	200.2
46.53247	117.84044	16.07		1%	14%	33%	18%	205.2
46.53394	117.84438	15.62		1%	20%	41%	21%	178.7
46.53566	117.84852	15.17		1%	20%	40%	20%	183.7
46.53731	117.85394	14.70	~530ft upstream of Chard Road xing	1%	18%	42%	24%	176.1
46.53858	117.85751	14.25		1%	21%	48%	27%	158.6
46.54156	117.86146	13.78		1%	15%	38%	23%	188.7
46.54376	117.86593	13.27		1%	6%	32%	27%	205.6
46.54572	117.87056	12.80		1%	13%	38%	25%	189.2
46.54759	117.87620	12.33		1%	6%	28%	22%	218.4
46.54749	117.88211	11.84		1%	4%	24%	21%	230.3
46.54635	117.88688	11.38		1%	5%	22%	17%	238.3
46.54524	117.89238	10.90	~90ft upstream of Archer Road xing	1%	6%	25%	19%	227.4
46.54296	117.89686	10.47		2%	8%	30%	22%	212.1
46.54100	117.90162	10.02		1%	5%	22%	17%	236.3
46.53859	117.90469	9.58		2%	5%	20%	16%	242.5
46.53550	117.90786	9.11		1%	5%	22%	18%	236.3
46.53286	117.91199	8.63	~250ft downstream of Pataha Lane xing	0%	6%	26%	20%	225.3

Latitude	Longitude	Distance from Creek mouth (Km)	Landmark	Topographic Shade only (%)	Current Shade condition (%)	System Potential Shade (%)	Shade Deficit (%)	DAve Solar Rad. below veg (W/m^2)
46.53133	117.91658	8.18		1%	8%	27%	20%	221.4
46.52873	117.92094	7.72		1%	7%	31%	24%	210.0
46.52626	117.92593	7.24		1%	8%	24%	17%	229.9
46.52512	117.93135	6.78		1%	3%	15%	13%	257.3
46.52428	117.93596	6.35		1%	3%	14%	11%	260.9
46.52107	117.93854	5.88		1%	4%	20%	17%	242.7
46.51779	117.94125	5.42		1%	4%	21%	18%	239.6
46.51494	117.94472	4.95		1%	3%	19%	16%	246.6
46.51178	117.94874	4.46		1%	4%	21%	18%	238.8
46.50975	117.95298	3.98		1%	4%	18%	14%	249.6
46.51121	117.95785	3.50		1%	12%	24%	12%	231.5
46.51110	117.96318	3.05		1%	8%	24%	16%	232.1
46.51201	117.96814	2.58		1%	9%	29%	20%	215.9
46.51225	117.97358	2.09	~170ft downstream of Hwy 261 xing and stream gage 35F050	1%	3%	14%	11%	262.6
46.51131	117.97962	1.61		1%	7%	31%	23%	210.6
46.51115	117.98528	1.13		1%	8%	24%	16%	230.3
46.50887	117.98817	0.74		2%	9%	25%	16%	227.9
46.50752	117.99333	0.30	Near mouth of Pataha Creek	1%	12%	29%	17%	216.4

Table D-(7) 15: Tucannon River 2005 Seepage Survey Results *Using sprinkler observations*

RKm	Site ID	Site Description	Watershed Area (mi^2)*	Measured Discharge (cfs)	BFW (ft)	Sum of tributary inflows to reach (cfs)	Sum of water right claims by reach (cfs)	HDR irrigation diversions from observations during survey (cfs)	Calculated Net Seepage gain/loss with observed irrigation(cfs)	10% Meas. Error Range	Calculated Net Seepage gain/loss for aggregated reach (cfs)[‡]	Aggregated reach designation	Calculated Net Seepage gain or loss for reach (cfs/RKm)	Seepage gain or loss for reach (%)[†]	Reach Length (Km)
87.48	31a	**Main Stem above Sheep Creek**	23.80	18.3	12.6					0.9					
87.47	30	Sheep Creek @ Bridge Above Confluence	3.04	8.0	*	8.0				0.4					
87.46	31	**Main Stem Below Sheep Creek**	27.50	25.5	47				-0.7	1.3	-0.7	P	-0.7	-3%	0.02
		Cold Creek (LLID #1176302461912)	2.33			0.0									
83.04	29	**Main Stem @ Ladybug Campground**	34.70	25.5	72.0				0.0	1.3	0.0	O	0.0	0%	4.42
79.88	28	Panjab Creek Near Mouth (First Campground)	25.40	6.7	37.8	6.7				0.3					
79.64	27	**Main Stem @ Panjab Bridge**	63.70	47.6	66.0				15.4	2.4	15.4	N	4.5	32%	3.40
		Unnamed Cr 1177085462099													
		Unnamed Cr 1177104462154				0.0									
77.17	26	**Main Stem @ Cow Camp Bridge (underneath)**	65.90	43.6	49.0				-4.0	2.2	-4.0	M	-1.6	-9%	2.47
		Unnamed Cr 1177213462252													
76.63	25	Little Tucanon River Near Mouth	7.25	1.0	9.5	1.0									
76.60	24	**Main Stem Below Little Tucannon Confluence**	74.90	53.5	49.0				8.9	2.7	8.9	L	15.6	17%	0.57
		Unnamed Cr 1177092462319													
74.40	22	**Main Stem @ Camp Wooten Bridge**	81.00	52.0	42.0				-1.4	2.6	-1.4	K	-0.6	-3%	2.20
72.70	23	Hixon Creek near Camp Wooten (LLID #1176828462460)	2.79	0.6	13.5										
		Unnamed Cr 1176784462474													
		Unnamed Cr 1176779462478													
70.30	21	**Main Stem Near Big Four Lake**	86.00	61.3	64.0			0.1	8.7	3.1	8.7	J	2.1	14%	4.10
		Unnamed Cr 1176649462621													
		Unnamed Cr 1176639462632													
		Unnamed Cr 1176582462697													
		Unnamed Cr 1176572462754													
		Unnamed Cr 1176577462763													
		Unnamed Cr 1176558462814				0.0									
66.03	20b	**Main Stem Near 3-Tiered Billboard**	94.30	56.4	75.0				-4.9	2.8					4.27
		Unnamed Cr 1176503462993				0.0				0.0					
62.11	old site 20	**Main Stem After Fish Hatchery**	96.60	53.0	75.0		16.0		-3.3	2.7					3.92
		Unnamed Cr 1176622463171													
		Unnamed Cr 1176703463271				0.0									

60.41	19a	**Main Stem Just Upstream of Cummings Creek**	98.30	51.4	70.0				-1.6	2.6	-9.8	I	-1.0	-19%	1.70
60.40	19	Cummings Creek 40-50' Upstream of Confluence		2.5	16.5	2.5				0.1					
60.26	19b	**Main Stem Just Downstream of Cummings Creek (at bridge)**	118.18	55.4	*				1.5	2.8					0.15
58.30		Unnamed Cr 1176800463439	0.47												
57.90		Unnamed Cr 1176820463512	1.53			0.0									
57.55	18a	**Main Stem Between Cummings and Tumalum Creeks**	121.52	70.8	>300		0.5	0.1	15.5	3.5	17.0	H	5.9	24%	2.71
56.85	18	Tumalum Creek Upstream of Confluence	16.04	0.3	28.0	0.3									
55.60	17	**Main Stem Below Tumalum Creek (at bridge)**	138.66	70.6	--		8.5		-0.5	3.5					1.95
52.98	16	Hartsock Creek @ Road (near Wooten Wildlife area sign)	2.08	0.0	21	0									
52.87	15	**Main Stem @ Bridge 13 (100' downstream, near WDFW land)**	142.53	67.9	250.0		1.5		-2.7	3.4					2.73
50.86	14	**Main Stem @ Bridge 12 (50' upstream)**	144.43	60.7	>300				-7.2	3.0					2.01
49.70		Unnamed Cr 1177297464010	3.54												
48.30		Unnamed Cr 1177381464110	4.81			0.0									
46.81	13	**Main Stem @ Bridge 10**		60.0	61.0		4.7		-0.8	3.0					4.05
45.40		Unnamed Cr 1177253464308	2.01			0.0									
42.99	12	**Main Stem Below Marengo Bridge**	159.75	56.2	63		2.0	1.7	-2.1	2.8					3.82
40.80		Unnamed Cr 1177748464436	3.62												
36.70		Unnamed Cr 1178195464539	2.90			0.0									
36.57	11	**Main Stem Below King Grade Bridge**	172.75	51.0	42		19.1	0.5	-4.7	2.5	-17.9	G	-0.9	-35%	6.42
29.50	10	**Main Stem @ Brine Road Bridge (60' downstream)**	180.79	59.0	80		14.2		8.0	3.0	8.0	F	1.1	14%	7.07
23.60	9	Willow Creek	29.92	0.0	--	0									
23.30	8	**Main Stem @ Hwy 12 Bridge (downstream Willow Cr)**	216.64	49.8	38.0		7.1	2.9	-6.3	2.5					6.20
21.39	7a	**Main Stem @ Territory Road Bridge**	219.47	40.3	39.0		1.7		-9.5	2.0	-15.8	E	-2.0	-39%	1.91
20.90	7	Pataha Creek	184.52	8.2	--	1.1				0.4					
19.55	6	**Main Stem Below Pataha Creek @ Private Bridge**	405.33	54.0	90.0		1.1		5.6	2.7	5.6	D	3.0	10%	1.84
17.78	5	**Main Stem @ Kessels Bridge**	405.77	47.2	50.0		9.9	1.2	-5.7	2.4	-5.7	C	-3.2	-12%	1.77
13.90		Smith Hollow Cr (LLID #1180572465051)	20.92			0.0									
13.17	4	**Main Stem @ Smith Hollow Road Bridge**	431.32	60.0	60.0		10.5		12.8	3.0					4.61
12.10		Unnamed Cr 1180764465059	3.67												
12.00		Unnamed Cr 1180773465059	8.51												
9.90		Unnamed Cr 1181032465099	8.16												
7.71	3	Kellogg Creek	34.70	5.7	60.0	5.7				0.3					
7.62	2	**Tucannon @ Kellogg Creek Bridge**	491.02	65.7	100.0		19.8	4.2	4.2	3.3	17.0	B	3.1	26%	5.55
		Unnamed Cr 1181419465278	4.87			0.0									

2.78	1	**Tucannon @ 261 Bridge (smolt trap, 150' upstream of bridge)**	501.59	58.2	70.0	2.4	2.0	-5.5	2.9	-5.5	A	-1.1	-10%	4.84

*Watershed areas were calculated using StreamStats and are based on the area upstream of the measurement point.

† The percent gain or loss for each reach is the absolute difference between the discharge measurement and the Net Seepage gain or loss for each reach to determine if the Net Seepage value is within the measurement error of 10%

‡ Seepage values were calculated as follows: Qd - Qu - T + D *where:*

Qd is the mainstem Tucannon R. discharge measured at the lower boundary of the seepage reach

Qu is the mainstem Tucannon R. discharge measured at the upper boundary of the seepage reach

T is the sum of all tributary inputs for the seepage reach

D is the sum of all water diversions for the seepage reach

Appendix E: Ecology Study Results and Discussion

List of Figures and Tables

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Ecology Study Methods

Data Collection

Ecology's Environmental Assessment Program (EAP) conducted field studies in August 2008 to supplement data needed for the SHADE model. Channel geometry surveys were conducted at 17 locations on Pataha Creek. During the surveys, wetted width, bankfull width, and incision width and height were measured at 3-5 transects at approximately 50-meter intervals to correspond with shade model nodes. Measurements were made using a laser range/height finder under similar protocols used by Ecology for other temperature TMDLs.

Riparian vegetation heights were measured and vegetation types classified during the Pataha Creek channel surveys. Field crews had maps with the 2006 NAIP aerial imagery in the field so that measured vegetation could be directly correlated with the digitized current vegetation map for Pataha Creek. Vegetation heights were measured using a laser range/height finder. A Quality Assurance Project Plan (QAPP) was not prepared for this data collection effort because of its small scope, time and staff limitations.

Continuous stream temperature data for Pataha Creek and the Pomeroy STP discharge was collected using standard operating procedure EAP044 (Bilhimer & Stohr, 2007). This data was used to calculate wasteload allocations for the facility. Streamflow measurements and data from Ecology operated stream gages follow the protocols defined in Butkus (2005).

Information and Data from Sources outside Ecology

Many sources of data were directly and indirectly used in the analysis of this study. Data directly used in the temperature, seepage, and shade modeling efforts include the sources listed in Table E-1. Other studies also helped guide this study and interpretation of the results and have been cited throughout this report.

Each agency had its own standard operating procedures for their data collection. These protocols were reviewed to ensure compatibility with Ecology's data quality assurance requirements. Results of this review are presented in the Quality Assurance Results section.

Stream temperature and streamflow measurement stations, including stations operated by WDFW, USFS, and Ecology, are shown in Figures D-1 and D-2 (Appendix D).

Table E-(1) 16: List of non-Ecology data originators

Organization	*Data Used in this TMDL*	*Comments*
USFS	Stream Temperature Vegetation Height/Type	Umatilla Ranger District
WDFW	Stream Temperature	60-minute interval time-series for 2003-2006
HDR	Channel Surveys for Tucannon River Seepage Survey for Tucannon River Solar Pathfinder survey Digital photos from site visits	This data was presented in the HDR report (2006).
USGS	Streamflow for station #13344500, Tucannon River near Starbuck, WA 10m Digital Elevation Model	http://waterdata.usgs.gov/nwis/uv?13344500
NRCS	Soil data for Columbia and Garfield counties	http://www.or.nrcs.usda.gov/pnw_soil/wa_reports.html
NCDC	Silcott Island Weather Station (SILW) Alder Ridge Weather Station (ALDER)	http://www,usbr.gov/pn/agrimet/webarcread.html http://www.wrcc.dri.edu/cgi-bin/rawMAIN.pl?waWALD

Quality Assurance Results

Ecology

Field staff met the study objectives of 5 transect surveys per reach and completed 17 reaches. The measurement error using the laser survey equipment is typically ±0.2 feet. This is a much finer resolution than is possible with existing aerial imagery with a 1.5 foot pixel resolution.

Water temperature dataloggers for the Pomeroy STP and Pataha Creek were deployed and retrieved successfully without any loss of data. Temperature dataloggers for the Tucannon River upstream and downstream of the Tucannon Fish Hatchery discharge were lost during the spring high flows, but the data from the hatchery discharge channel was recovered.

Table E-(2) 17: Accuracy check data for Pataha Creek STP temperature monitoring

Instrument Serial Number	Deployment Location	Expected Accuracy	Measured Accuracy
457367	Pataha Creek upstream of STP	±0.2ºC	±0.05ºC
457368	Pataha Creek downstream of STP	±0.2ºC	±0.11ºC
466952	Pomeroy STP effluent	±0.2ºC	±0.01ºC

Ecology temperature monitoring for ambient stations and the Pomeroy STP stations follow agency protocols for temperature data collection (Ward, 2003). All instruments deployed in the field by Ecology met both their pre- and post-season accuracy checks and were within ±0.2ºC (Table F-2). The only exception is for the data loggers deployed in 2008 at the Tucannon Fish Hatchery. These data loggers were not checked for accuracy post-season because all devices were lost in the field.

Sources outside Ecology

Field data collection by HDR for the 2005 Tucannon River temperature study was conducted with consultation from the Department of Ecology. Stream temperature data from the 2005 report was collected by several sources. There are two temperature monitoring stations operated by WDFW's Snake River Lab office and USFS that were located near each other. A comparison of both the accuracy and spatial variability of the data follows.

Stream temperature data loggers deployed by WDFW were not calibrated to any standard during the 2005 monitoring years. However, the instruments they used, Onset Optic StowAway™ tidbits and Hobo™ data loggers, are similar to models used by the Ecology for TMDL studies and a review of Ecology's calibration data shows that those instruments are generally reliable and operate within design specifications. When the instruments do go bad, due to low batteries or unknown errors, the data is usually irretrievable. Compared to a NIST standard thermometer, Ecology's Onset instruments resolve temperatures either within the manufacturer's stated accuracy or no more than twice the stated accuracy range.

The USFS Umatilla National Forest Ranger District does conduct calibration checks for their Hobo™ temperature dataloggers. They use an adaptation of the protocol described in the publication "Water Quality Monitoring; Technical Guide Book; The Oregon Plan for Salmon and Watersheds" (OPSW, 1999). If instruments do not perform within their specified accuracy range during pre-deployment checks, then the instruments are not deployed in the field. The USFS data is classified as Level B on a scale from A-C where A is the highest level of data quality. Level B data is described as "used as an early warning of potential problems or for screening information." Their reported measurement accuracy is ±0.7ºC.

Figures E-1 and E-2 show comparisons between two locations where there was both a WDFW and USFS operated temperature monitoring station within about 100ft of each other. The average difference between the Little Tucannon River locations (near the confluence with the Tucannon River) was 0.54ºC that occurred on 9/16/2005.

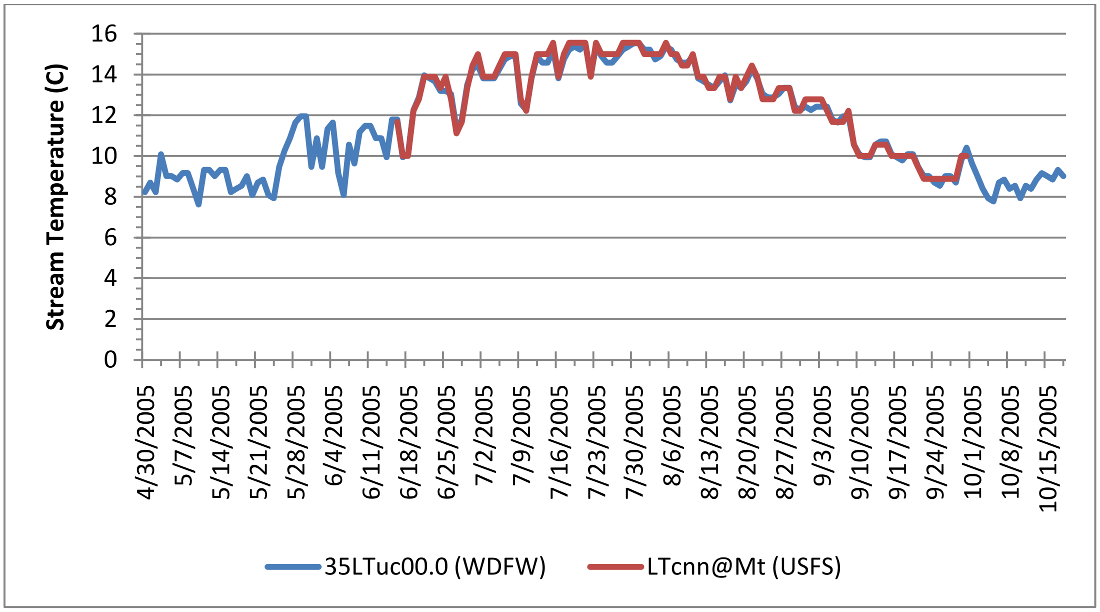

Figure E-(1) 15: Comparison of daily maximum temperatures measured by WDFW and USFS on Little Tucannon River near mouth.

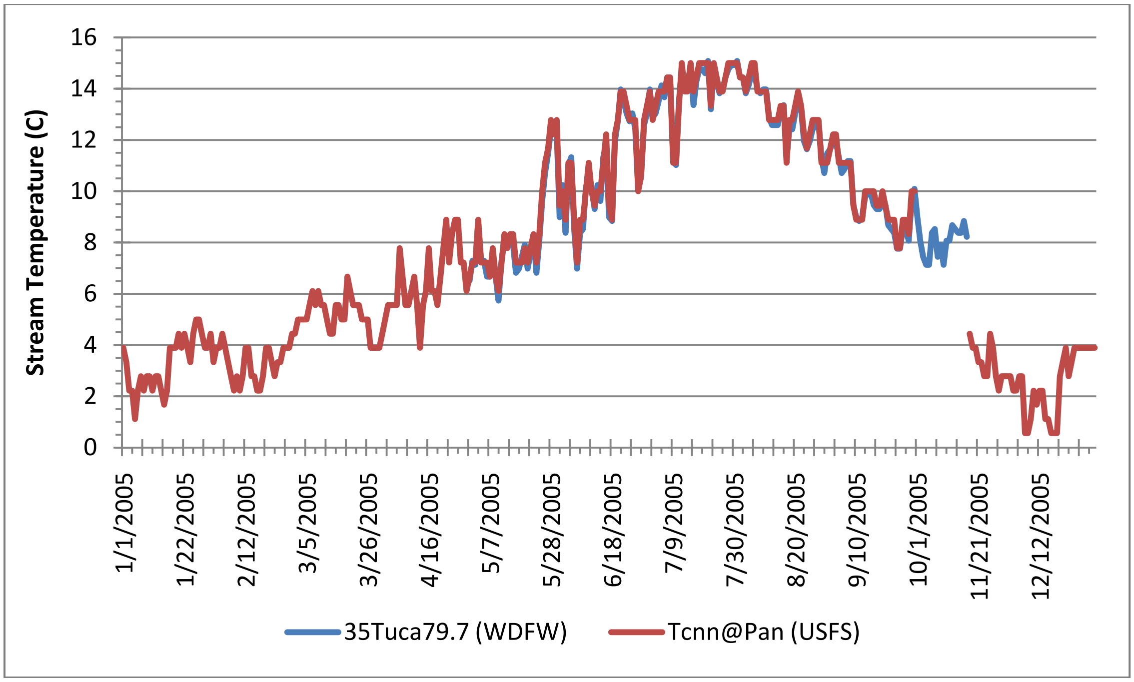

Figure E-(2) 16: Comparison of daily maximum temperatures measured by WDFW and USFS on Tucannon River downstream of Panjab Creek.

The average difference of the daily maximum temperature measured at the Tucannon River location downstream of Panjab Creek was 0.7ºC that occurred on 6/25/2005. This difference is within the usual instrument accuracy range of ±0.2-0.4ºC depending on the instrument used. It is a reasonable and safe assumption that WDFW instruments had measurement accuracy no greater than the USFS measurement accuracy of ±0.7ºC.

Streamflow

In 2005, HDR conducted a seepage survey of the Tucannon River that resulted in a water mass balance. Water right claims and available metering data were considered in lieu of using the sprinkler observation estimates (Table D-7 in Appendix D shows the comparison) but using water right claim amounts do not fit the data as well as actual withdrawals during the survey as the observation estimates.

Figure E-3 shows the comparison between the HDR seepage results and Ecology's analysis of the same data. Daily average (DAve) stream temperatures are graphed for the day of the seepage run (7/13/05) and the warmest day of this time period (7/31/05). When comparing the big gains and losses in surface water with the location of known geologic features, such as the Hite Fault and numerous geologic folds and faults in the lower watershed, it appears that geology is controlling streamflow in the Tucannon River.

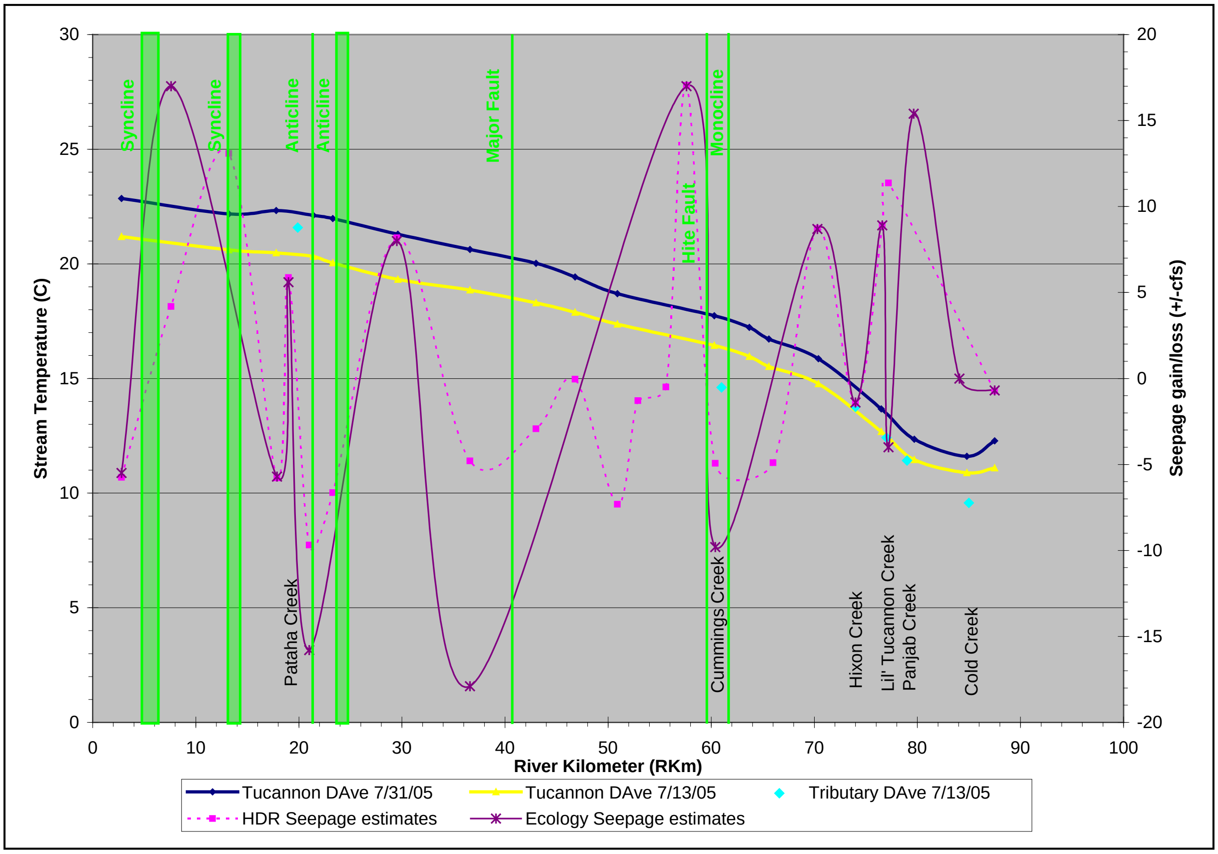

Figure E-(3) 17: Comparison of daily average (DAve) stream temperature for the Tucannon River and tributaries as well as groundwater gain and loss volumes using HDR and Ecology seepage analysis values.

Figure 14 also shows that when the river loses significant amounts of water, through surface water withdrawals or groundwater recharge, the slope of the daily average stream temperature

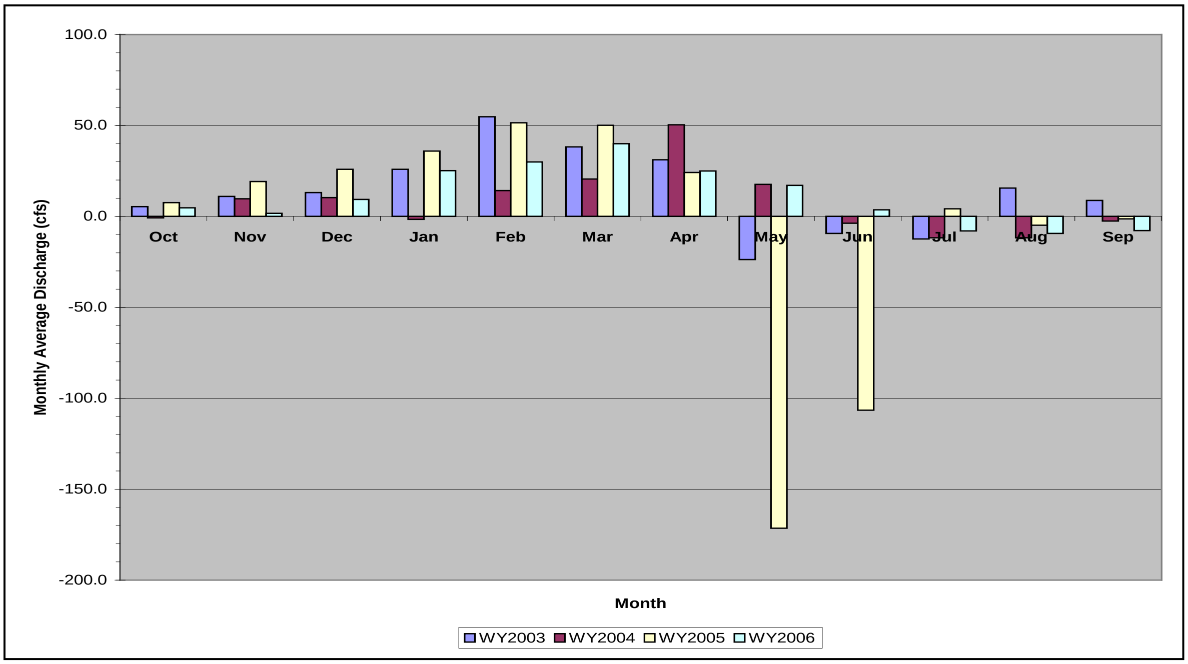

Figure E-(4) 18: Difference in Monthly Average streamflow between the gage near Marengo and the gage near Starbuck for WY2003-2006.

trend increases. The sharp increase in temperature between RKm 79.6 and 76.6 (RM_49.5 to 47.6) is due in part to the heat load input from the Little Tucannon River. The average temperature of the Little Tucannon River on July 13, 2005 was 1ºC warmer than Panjab Creek (the only other input to this reach of the Tucannon).

A comparison of four years of monthly average streamflows (Figure E-4) collected at Ecology's gage near Marengo (35B150) and the USGS gage near Starbuck (#13344500) shows the Figure E-(4)18: Figure E-(4) 18: Difference in Monthly Average streamflow between the gage near Marengo and the gage near Starbuck for WY2003-2006.

Tucannon River loses water in this reach during June through September of most years. Because the river looses water in this lower reach, it will be important to implement maximum system potential shade and minimum channel width to depth ratios to offset the heat gain potential of this reach.

Stream Temperature

Tucannon River

The general trend for the Tucannon River shows stream temperature continually increasing as surface water moves downstream (Figure E-5). The river begins exceeding the 7DADMax 17.5ºC standard during the 2005 summer critical period (June – August) and also warmer than the supplemental salmon spawning and incubation criteria of 13ºC during May, September, and October where data is available. Pataha Creek was warmer than Tucannon during the spring freshet and then several degrees cooler beginning in July and continuing thru October.

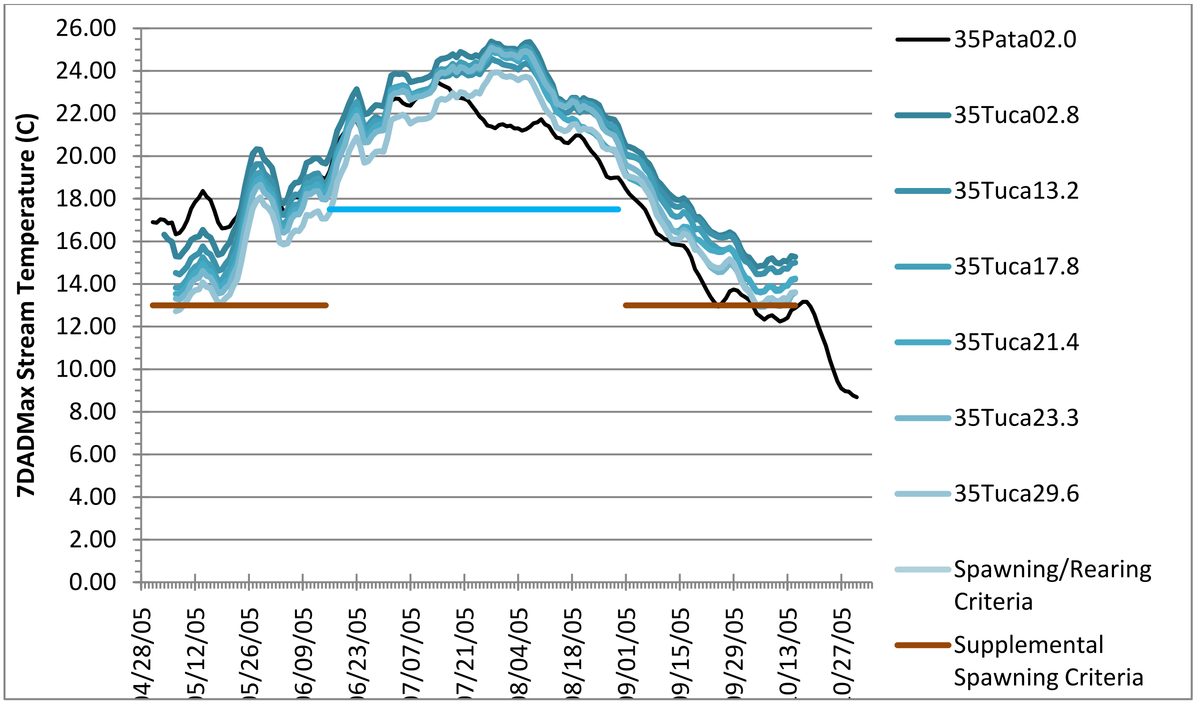

Figure E-(5) 19: 7DADMax stream temperatures from the Tucannon River where salmon spawning/rearing and supplemental spawning temperature criteria applies.

The monitoring stations where core summer habitat aquatic criteria applies, show a similar pattern of temperature exceedences. Figure E-6 shows stations where stream temperatures increase rapidly between Rkm 60.3 and 50.9 (RM 37.5 – 31.6) as well as Rkm 76.5 and 70.4 (RM 47.5 – 43.7) where there is a nearly 2ºC increase in the 7DADMAx along a 6.1 kilometer long reach despite cooler water entering from the Little Tucannon River. It is important to note that this reach shows alternating groundwater discharge (gaining) and groundwater recharge (losing) conditions between Cold Creek and Hixon Creek. The influence of groundwater and surface water interactions and the deficit of riparian shade are probably causing the rapid increase in stream temperature in this reach.

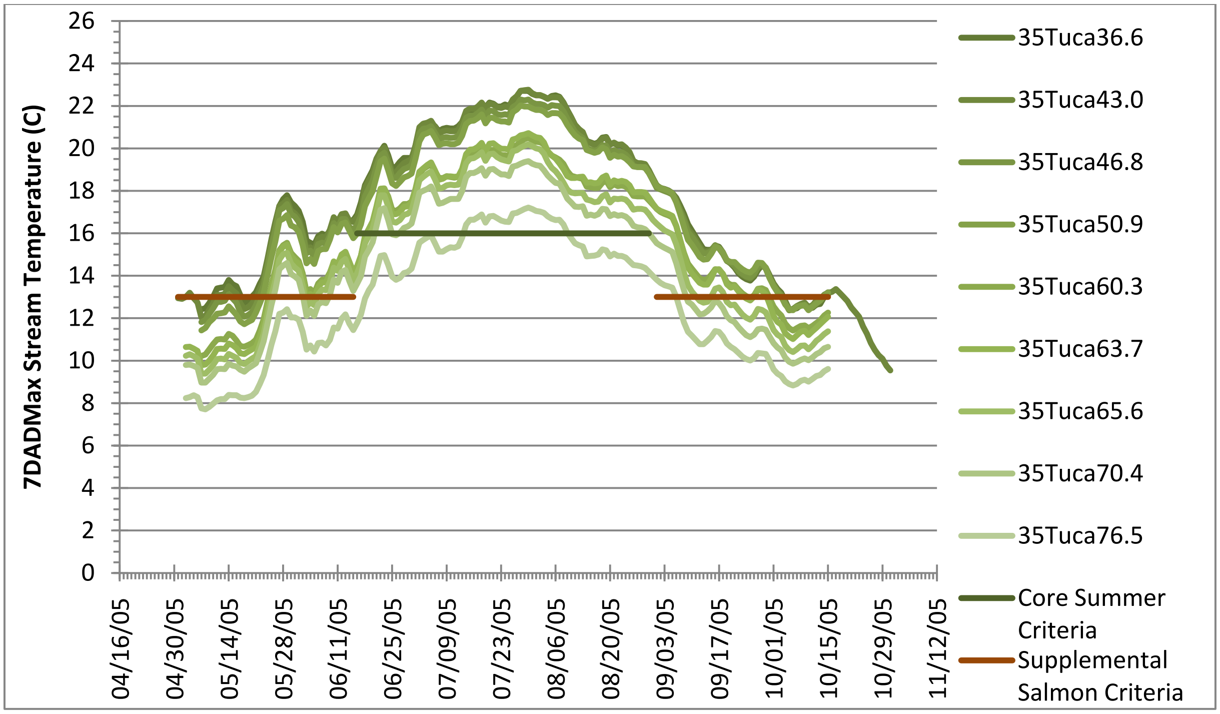

Figure E-(6) 20: 7DADMax temperatures where core summer rearing criteria apply.

The Tucannon River and tributaries designated with char spawning/rearing temperature criteria of 12ºC 7DADMax exceeds the standard (Figure E-7), even though daily maximum summer temperatures didn't exceed 16ºC. Of particular interest in this reach is how much warmer Cummings Creek and Hixon Creek are compared to the Tucannon River (2-4ºC during the summer. Both of these tributaries contribute significant heat loading to the river.

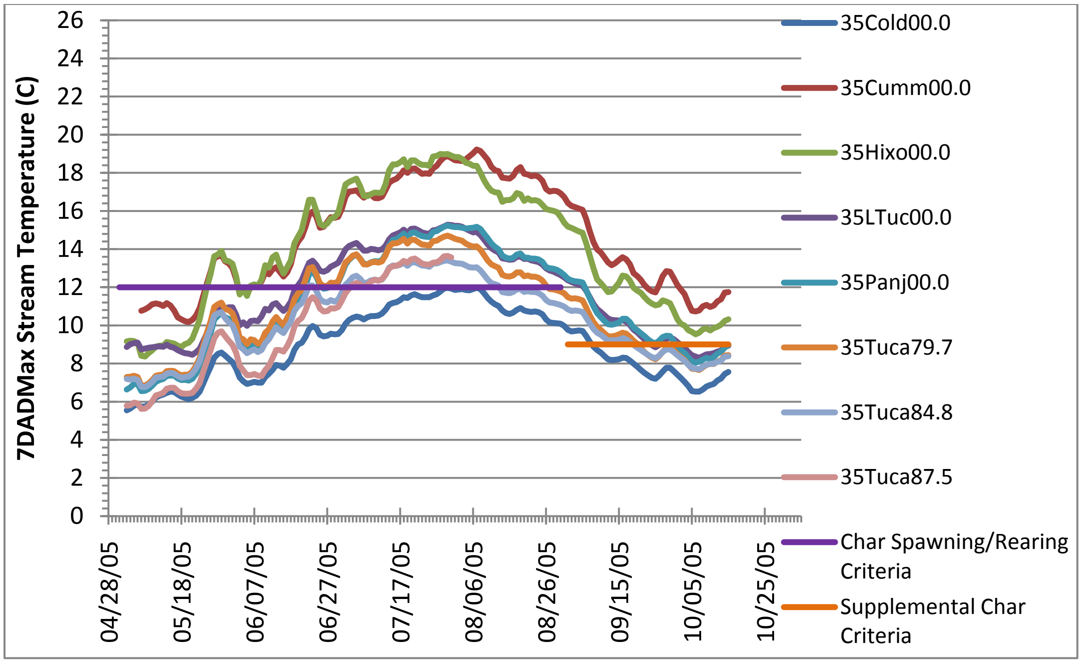

Figure E-(7) 21: 7DADMax stream temperatures where the Char spawning/ rearing criteria apply.

The daily maximum temperatures (DMax) decrease slightly on the Tucannon River between Rkm 63.7and 60.3 (RM 39.6 – 37.5) on 13 July 2005. The Tucannon Fish Hatchery is located on this reach. Although the decrease in DMax temperature is small, it is consistent during the summer period and is occurring despite a losing stream condition (surface water lost to the ground).

Cummings Creek has very poor riparian cover. However, Cummings Creek appears to help moderate the daily maximum temperature of the Tucannon between the fish hatchery intake and the Cummings Creek bridge during the summer critical period (Figure E-8). Therefore, a reduction of temperature in Cummings Creek would help further reduce the temperature of the Tucannon River.

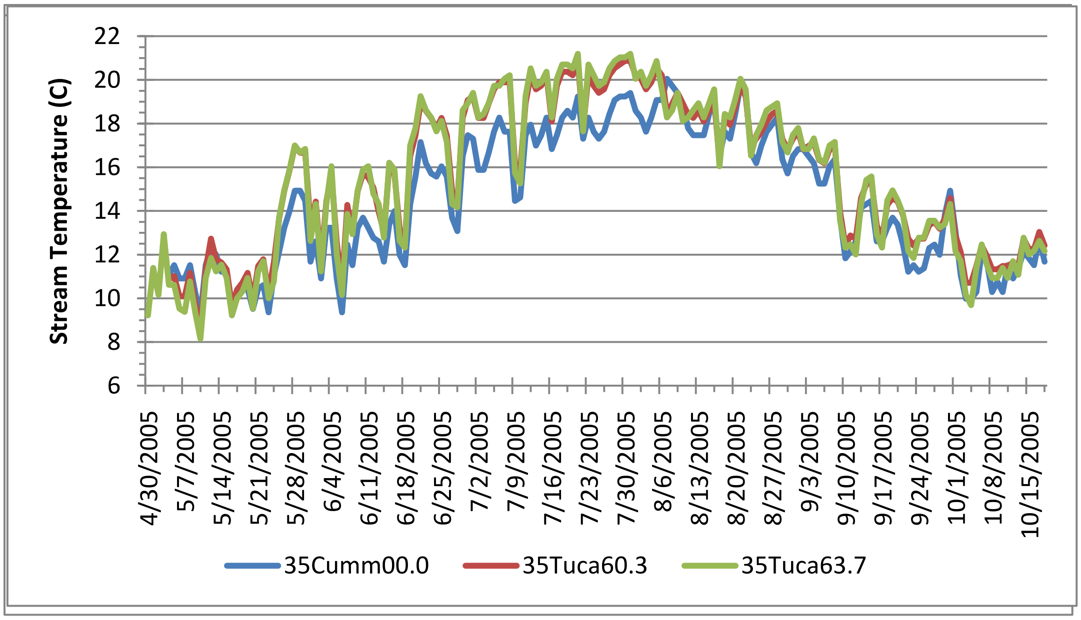

Figure E-(8) 22: Tucannon River and Cummings Creek stream temperatures.

Figure E-9 shows 2005 stream temperatures for the lower part of the Tucannon River. The rate of heating is less here than in the upper watershed reaches. There are interesting thermal patterns, including a cooling reach between station 35Tuca17.8 (downstream of the Pataha Creek confluence) and 35Tuca13.2 (above Smith Hollow Bridge). Stream temperature increases by several degrees celsius between Einrich Road bridge (35Tuca29.6) and 35Tuca17.8. This is a long losing reach. The cooler stream temperatures measured near Smith Hollow Bridge are likely influenced by cooler groundwater inflow in this gaining reach as well as riparian and stream channel improvements already in place.Figure E-(9) 23: Comparison of 7DADMax temperatures for Tucannon River monitoring.

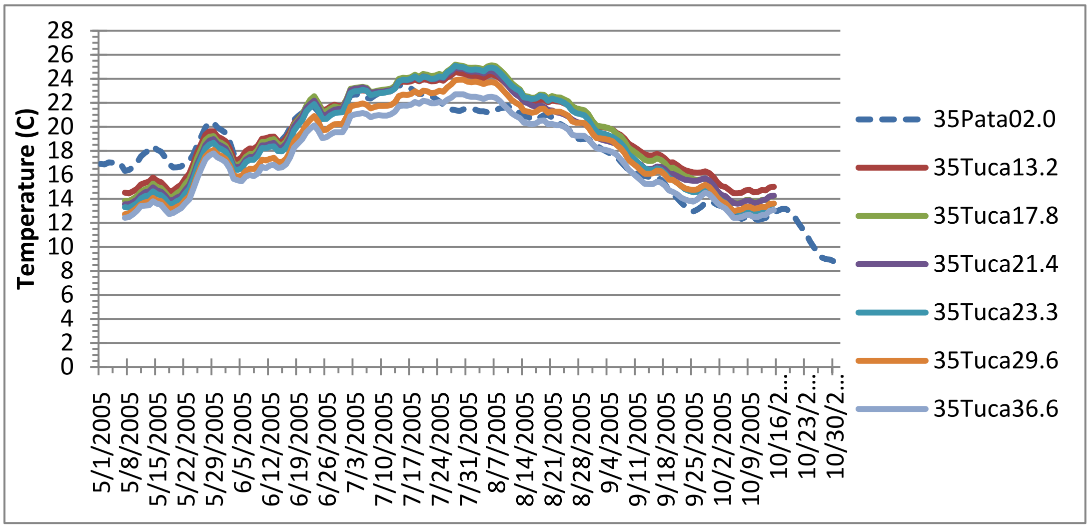

Figure E-(9) 23: Comparison of 7DADMax temperatures for Tucannon River monitoring stations from the lower part of the watershed (HDR, 2006).

Tucannon River Tributaries

Tributary 7DADMax temperatures, shown in Figure E-10, which include data for 2005 through 2007. Cummings Creek, Hixon Creek, and Pataha Creek were the warmest tributaries measured. The coldest tributaries measured were in the upper watershed and include: Cold Creek, Little Tucannon River, Panjab Creek, Meadow Creek, and Sheep Creek. These creeks are all at higher elevations in the Umatilla Forest and have significantly higher densities of riparian vegetation than the nearer, warmer neighboring catchments of Hixon, Cummings, and Tumalum Creeks.

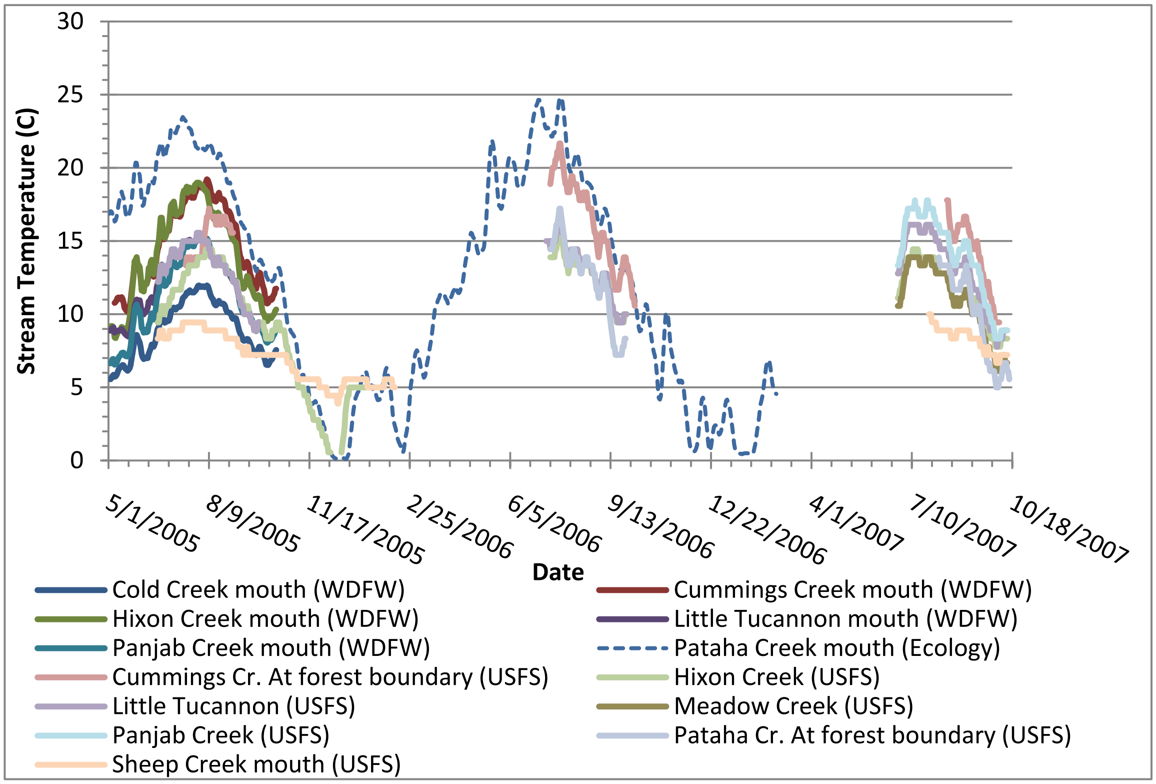

Figure E-(10) 24: Tributary 7DADMax stream temperatures for the time period beginning May 2005 through mid-October 2007.

Pataha Creek

There is very little stream temperature data available for Pataha Creek. There is a telemetry streamflow gage near the mouth, operated by Ecology (35F050, aka 35Pata02.0 for this study), that collects continuous stream temperature data. Stream temperature data loggers were deployed on Pataha Creek upstream and downstream of the Pomeroy STP as well as in the discharge water during the summer of 2007. The Umatilla Ranger District stream temperature monitoring network also includes a station on Pataha Creek at the forest boundary.

The Garfield County Riparian Restoration study (EIM User Study ID# G0300114) data collection included instantaneous temperature measurements for Pataha Creek. Temperatures at station Pataha Cr 4, in the upper subbasin, are much warmer than other stations downstream and may be as warm as stream temperatures recorded at the Ecology stream gage near the creek mouth (Figure E-11). Pataha Cr 4 measurements were made later in the day when daily maximum temperatures are expected to occur. Temperature measurements taken at downstream stations were taken earlier in the day and may not represent the daily maximum for the station.

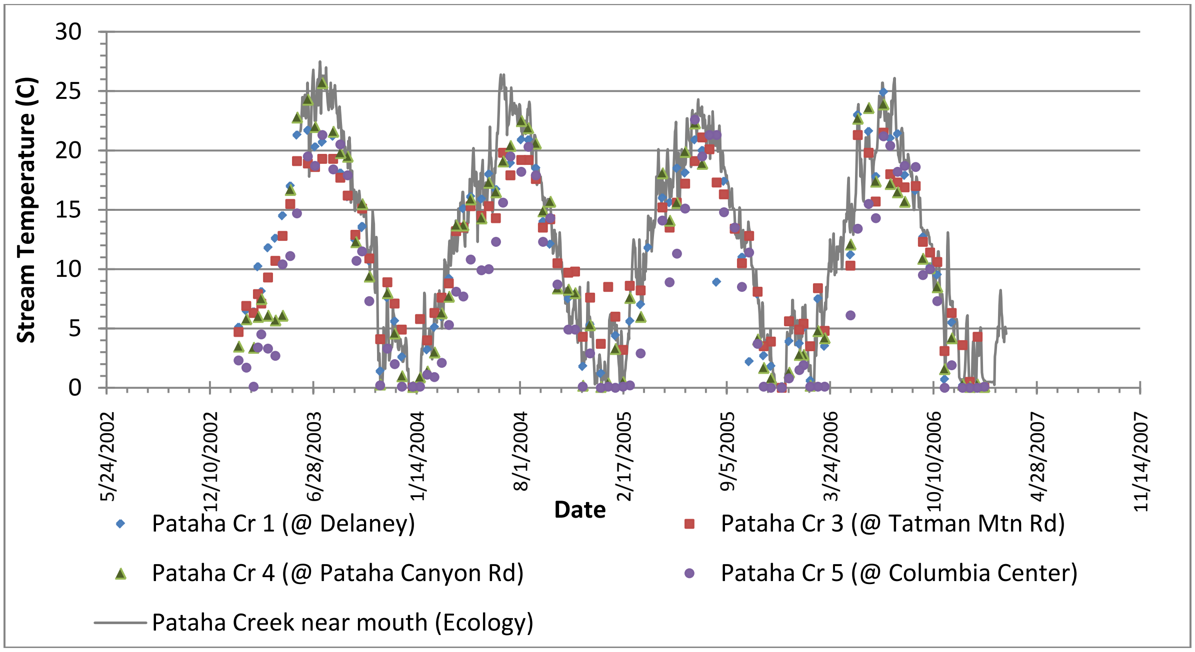

Figure E-(11) 25: Pataha Creek stream temperature data from Garfield County Riparian Restoration Study.

2005 School Fire

The 2005 School Fire reduced the riparian shade significantly on state owned land between RKm 70-63 (RM43.5-39.1) as illustrated by riparian vegetation mapping from full-color aerial images taken in 2006 (Figure E-12). The lack of riparian vegetation in the burned areas increased solar radiation reaching the stream and thus amplified stream heating in the burned reaches. Additional impacts of reduced riparian vegetation include decreased width to depth ratios from a lack of vegetation to reduce channel erosion potential.

Temperature data was not collected in the area of the School Fire prior to 2005. Therefore, it is unclear from the available stream temperature data (Figure E-13) how the 2005 School Fire affected the critical period temperatures of the Tucannon River. July stream temperatures collected in 2005 before the fire were cooler than July temperatures measured in 2006 and 2007. July stream temperatures in 2007 were much warmer than in 2006 but may be within the range of annual variability. Increased stream heating along the burned reaches are most apparent in July and early August.

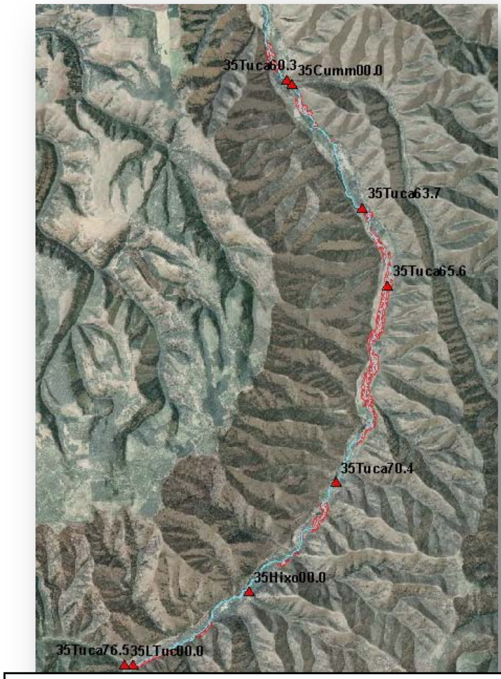

Figure E-(12) 26: Burned Tucannon River riparian areas from the 2005 School Fire

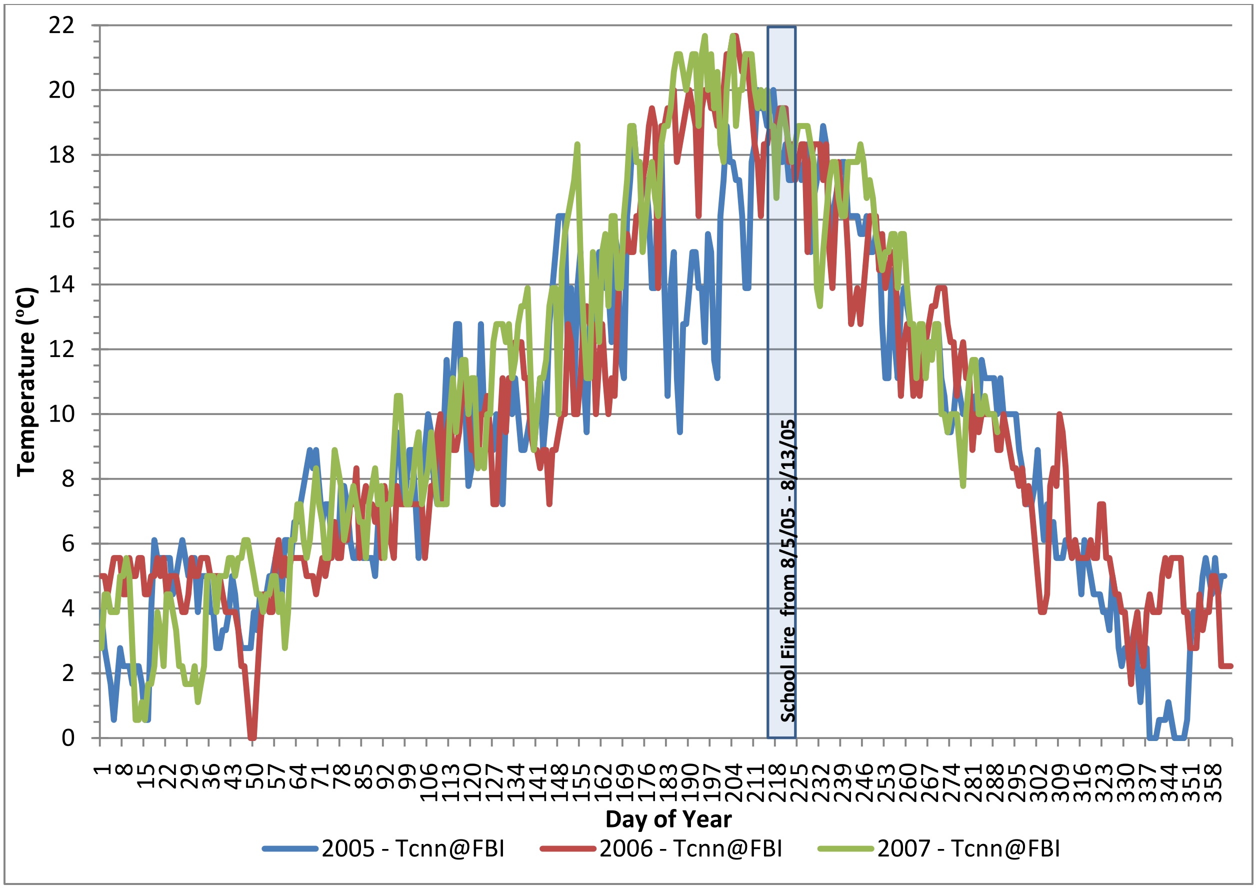

Figure E-(13) 27: Tucannon River temperature at the Umatilla National Forest Boundary for 2005-2007.

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Appendix F: Model Calibration and Assumptions

List of Figures

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Model Calibration

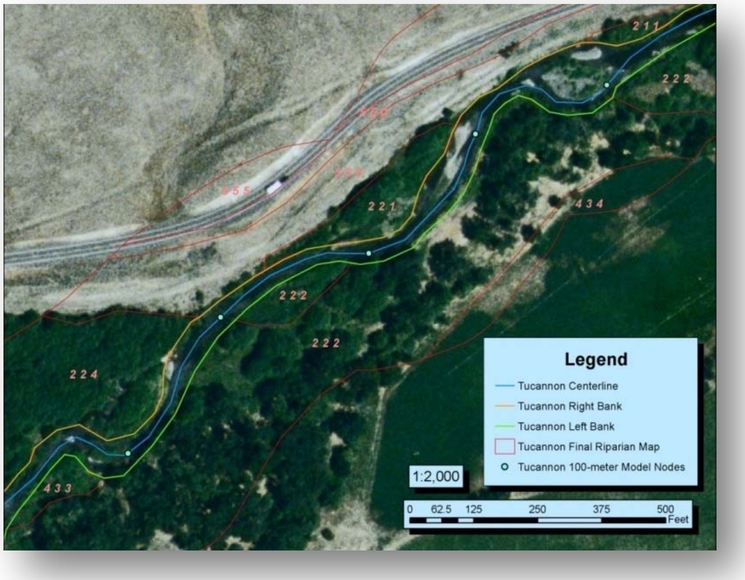
It's important to check the computer model is calibrated correctly by comparing results with field measurements. Because this is a computer simulation some mathematical assumptions must be made to represent (or model) the physical aspects of each stream as close to reality as possible within our measurement accuracy objectives. These assumptions are discussed below.

Stream channel morphology is one key input to produce an accurate shade model. GIS was used to digitize the entire length of the near stream disturbance zone (NSDZ) edges and the centerline of the Tucannon River and Pataha Creek from high-resolution (18-inch pixel), full-color aerial imagery as shown in Figure F-1). For the purposes of this analysis the bankfull width and NSDZ width are the same. Ttools (available at http://www.ecy.wa.gov/programs/eap/models.html) was used to derive channel widths for the Tucannon River from the digitized data at 100-meter intervals. Other channel characteristics such as stream aspect and elevation were calculated by Ttools with the use of a 10-meter digital elevation model (DEM).

Digitization of Tucannon River was fairly easy at a 1:2,000 ft scale or less, however digitization of Pataha Creek NSDZ edges was very difficult due to the fact the stream is only a few pixels across in this imagery as well as being over-grown thick with grasses in many places. Digitization of both streams was difficult in the heavily forested riparian areas in the Umatilla National Forest and is an approximation based on best professional judgment where data is not available.

The other key model input is riparian vegetation data, including vegetation type, height and density. This information is input into the model in the form of a unique riparian code for each vegetation type. Vegetation is defined at user defined intervals throughout the riparian zone at each model zone. The riparian codes are sampled from a map of riparian vegetation that extends 200 feet from the left and right bank line. Riparian vegetation polygons, each assigned a unique riparian code, are digitized on GIS maps and verified using field vegetation surveys (riparian code attributes can be found in Appendix D Table D-(1) 9). Figure F-1 illustrates vegetation mapping for the Tucannon.

Figure F-(1) 28: Stream channel and riparian vegetation map example at 1:2,000 map scale



Tucannon River calibration & shade model assumptions

Figure F-2 compares the average bankfull width measured during the HDR channel surveys to the measurements derived with Ttools. The digitized data fits the field data best using the digitized width plus 1.5 meters if averaged over 500-meters (red line on Figure F-2). Large jumps in the NSDZ width and in the wetted widths graphed on Figure G-3 are due to braided channels where the widths of both channels are combined.

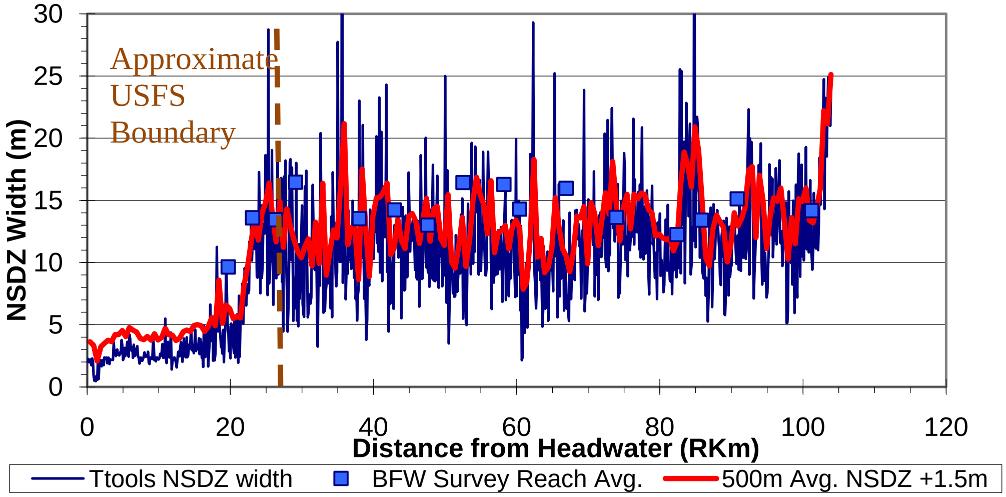


Figure F-(2) 29: Calibration of Tucannon River channel geometry for NSDZ model input.

Wetted width values used in the model are derived from the field measurements and GIS analysis. The ratio of the field measured averaged wetted width to average NSDZ width ranged between 65% and 85%. On Figure F-3, the gray line shows the surveyed wetted width range limits and the orange line represents the wet width at 75% of the NSDZ value (WW75). The WW75 value was chosen for the model input modifier because it is the midpoint between the two range limits.

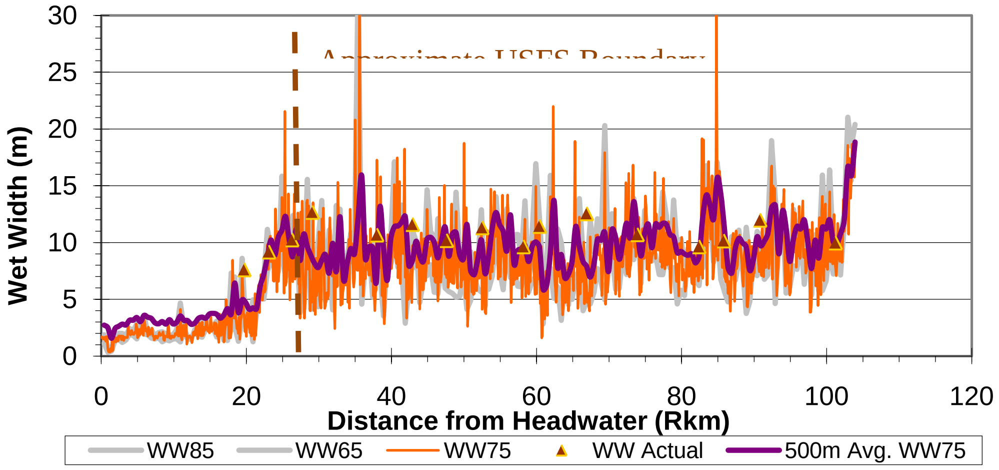


Figure F-(3) 30: Calibration of Tucannon River channel geometry for wetted width model input.

The model channel geometry was completed by applying the modifiers to the digitized NSDZ and wet width values. Channel incision was calculated as the reach average for each survey location and then linearly interpolating incision values between reaches.

Pataha Creek calibration and shade model assumptions

Digitizing the NSDZ width for Pataha Creek was not feasible given the small size of the channel relative to the image resolution of the available aerial photographs. Therefore, reach averages from the Ecology channel surveys were used as the wetted width and bankfull values at each corresponding model node and the width values of nodes in between field measurements nodes were linearly interpolated. Figure F-4 shows one example of the Pataha Creek channel geometry for each transect measured along one survey reach.

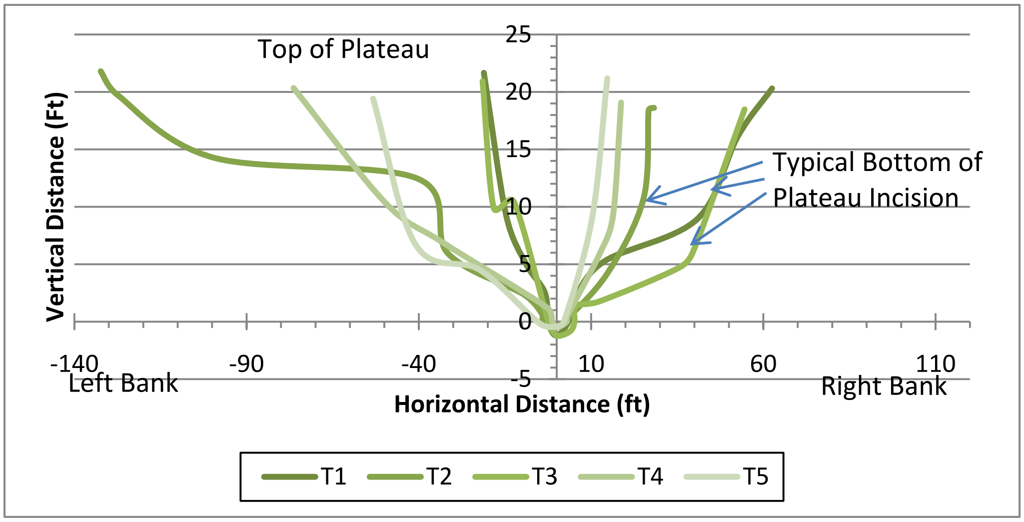


Figure F-(4) 31: Channel survey results for one reach on Pataha Creek. The graph is normalized so that all lines below y=0 is the wetted stream portion and x=0 is the location of the thalweg.

In the SHADE model, incision is defined as the height above bankfull width where the major vegetation starts. The model value is different than simply the height of the down-cut creek channel pervasive throughout the lower Pataha valley. The channel incision values used in the SHADE model, where the channel is down-cut, are calculated as the reach average of the midpoints between the measured bankfull edge elevations and the elevations of the bottom of the incision. The assumption is that the ground elevation where the major vegetation (a combination of large trees and shrubby trees) starts is not the elevation of the bottom of the plateau incision or the bankfull edge, but is halfway in-between.

Figure F-5 shows a comparison between average channel survey measurements and the digitized widths using GIS. Channel wetted width and bankfull width was digitized at 50-meter intervals (light red and orange lines) and then averaged over 500-meter reaches (dark red and orange lines). The final values for wetted width (WW) and bankfull width (BFW) are linearly interpolated from the channel survey measurements and plotted on Figure G-5 to compare against the digitized values.

The digitized values tended to overestimate the bankfull width in the lower Pataha subbasin, and underestimate bankfull in the upper watershed. This difference between the field measurements and the digitized values is the digitization error. The reach average survey data and linearly interpolated width values (lines marked as final in Figure F-5) were used for the channel geometry input to the SHADE model for Pataha Creek.

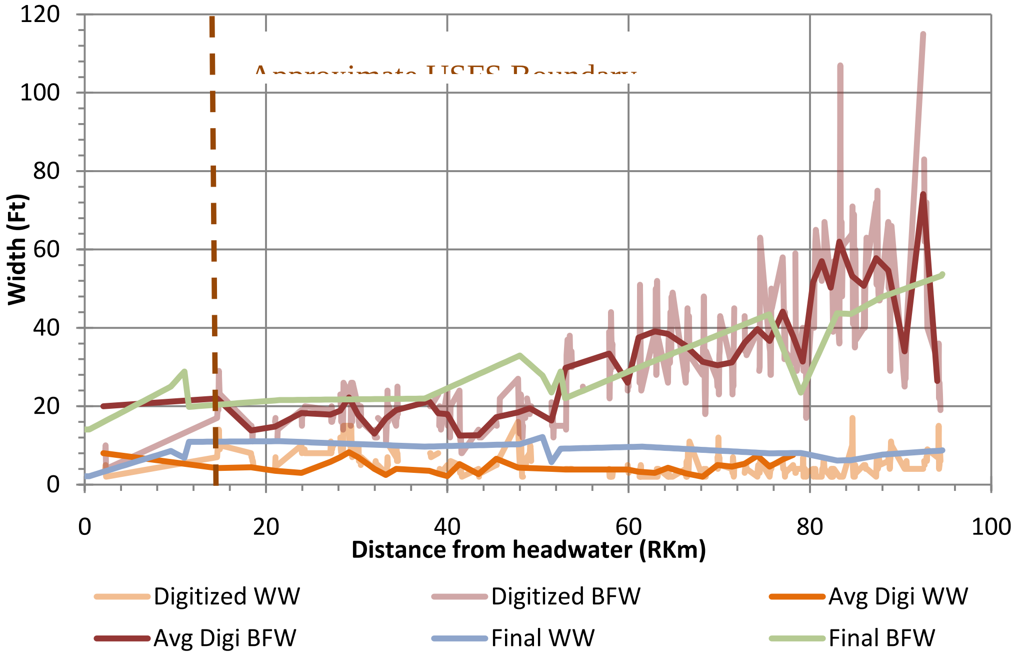


Figure F-(5) 32: Calibration of Pataha Creek channel geometry for model input.
The final WW and BFW were derived from field survey data.

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Appendix G: System Potential Shade and Load Allocations

List of Figures

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System potential riparian vegetation and shade

The system potential riparian vegetation is determined by what vegetation can be supported by the soils and climate of the watershed. In the Tucannon, Ecology estimated the characteristics of the system potential vegetation, including type, height and density, using county soils data and information on existing vegetation along the Tucannon River. County soil maps describe upland soils and vegetation better than along streamside riparian areas. When the soil types underlying the riparian map were compared with the existing vegetation, associations between the two were revealed (Figures G-1 and G-2).

The majority of Ttools sample points categorized soils as general alluvium soils of the Patit Creek series (PkA, PlA, PoA), well-drained silt loams of the Onyx series (OnA), or riverwash (Rn). Tree heights and type associations with soils for windbreaks and environmental plantings are shown in Appendix D. The NRCS data only gives the 20-year average height with the maximum category defined as “greater than 10.7 meters (35 feet) tall.” These tables are a good starting point to match potential vegetation types with soil types, but individual site conditions for riparian restoration projects must be considered.

The current riparian vegetation height codes are derived from the average heights of trees surveyed along the Tucannon River and Pataha Creek. Maximum conifer heights is the average maximum height of trees based on USFS data from their GIS data for potential vegetation and equations to convert diameter at breast height (DBH) to species heights based on tree height regressions presented in Powell (2005 and 2008). The maximum potential density of trees along the stream corridor will vary depending primarily on the presence of roads and tributaries. The potential vegetation density was assumed to be 75% except in areas where greater densities already exist.

The current riparian zone width used in the Pataha Creek shade model was 50 feet from either side of the center of the stream. This was an approximation of a reasonable riparian corridor width for Pataha given its wetted width during summer baseflow conditions and the confinement of the channel incision in the lower subbasin.

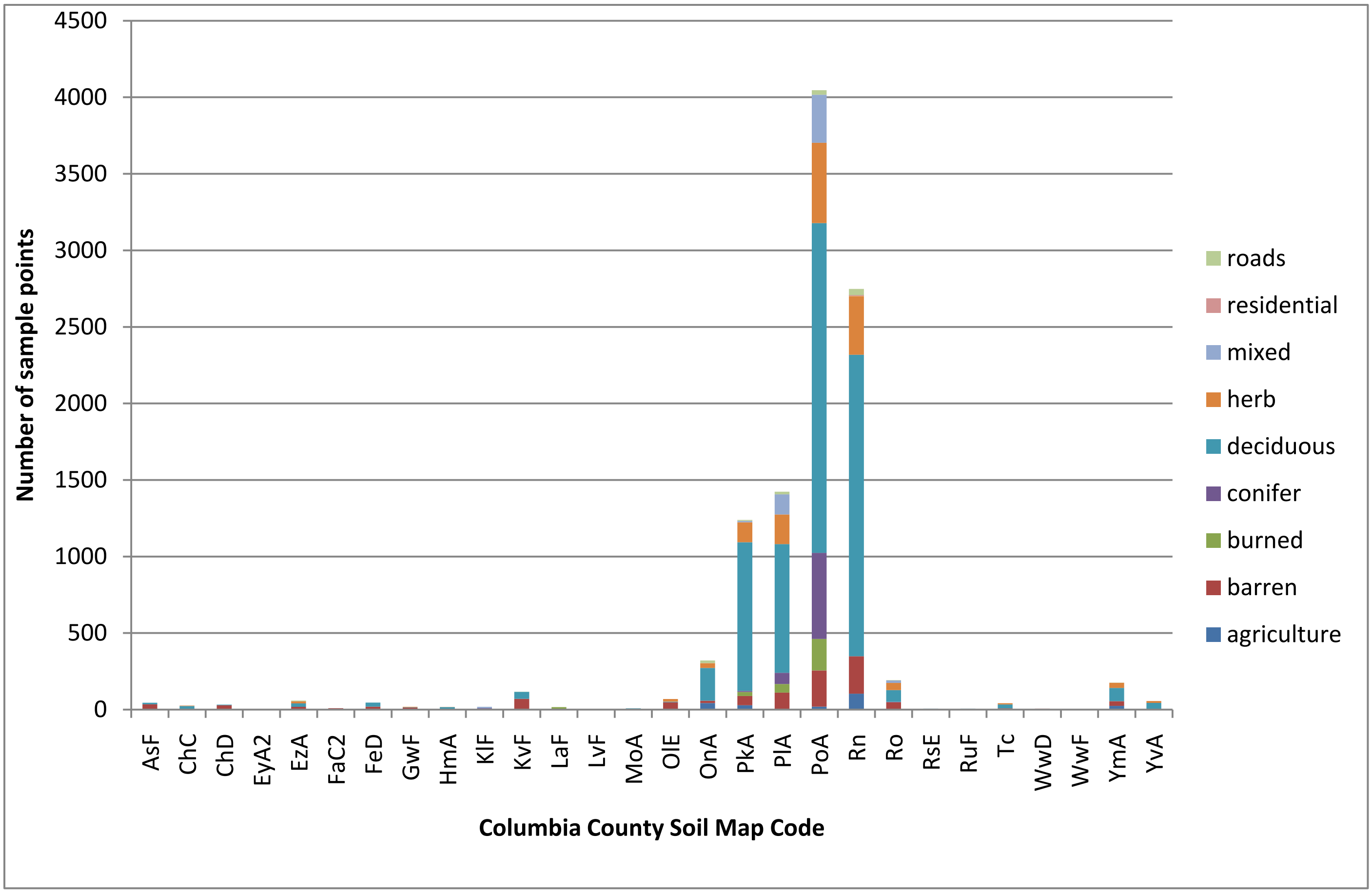

Figure G-(1) 33: Columbia County soil types represented at riparian vegetation Ttools sample points.

The riparian zone width used in the Tucannon River shade model was 150 feet from either bankfull edge. This approximation of the riparian corridor width corresponds with the riparian width used in the HDR study and field measurements of effective shade using the Solar Pathfinder. There are many places along the Tucannon River that currently have greater than 150-feet of riparian vegetation, but for the purposes of this project the SHADE model only evaluates the influence of vegetation in the first 150 feet.

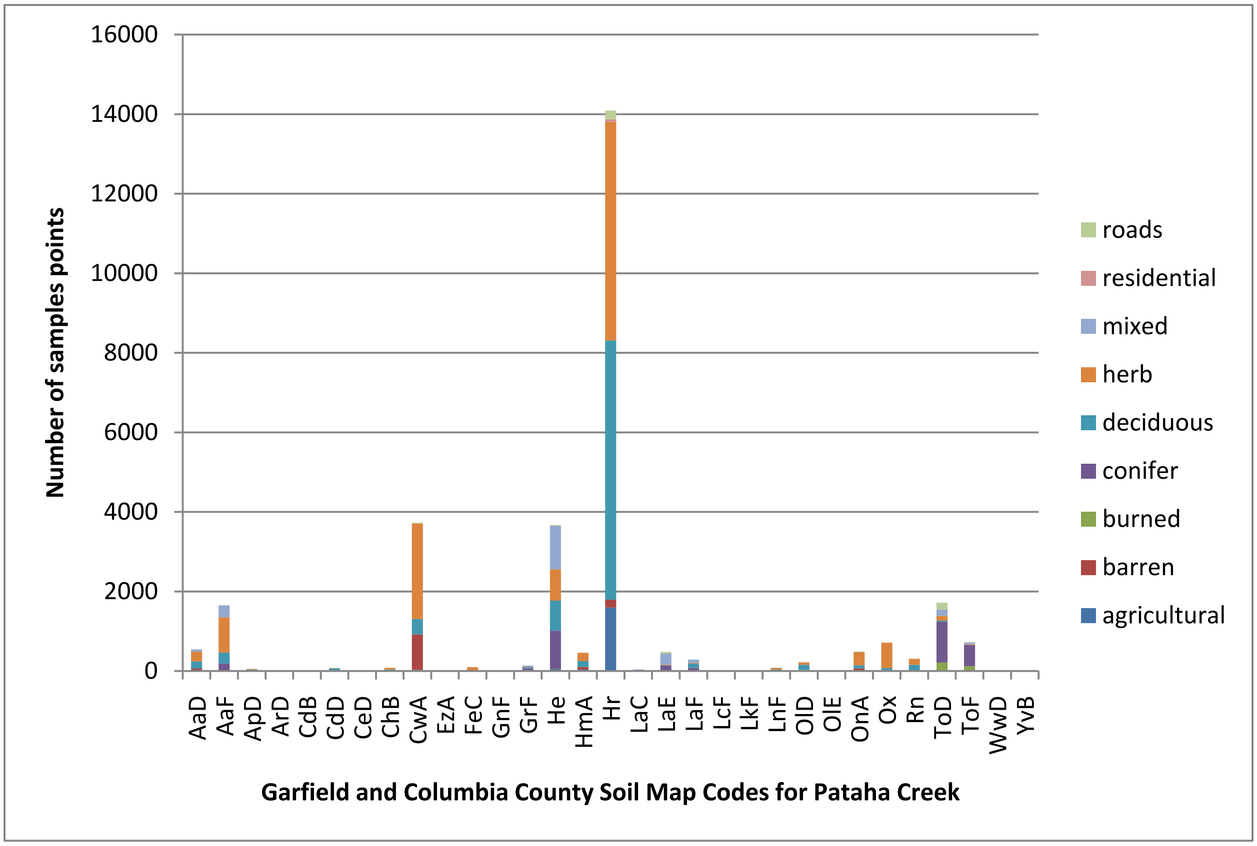

Figure G-(2) 34: Soil types represented at riparian vegetation Ttools sample points.

SHADE model validation

Ecology compared the current vegetation conditions effective shade calculated by HDR's SHADE model with output from the SHADE model developed for the same conditions for this TMDL. This was necessary because HDR mapped current vegetation using black and white aerial photographs taken in the 1990's and did not evaluate the impact of the riparian areas burned during the 2005 School fire. Ecology used newer and higher quality color aerial photographs taken in 2006 after the 2005 School Fire. Figure G-3 shows the comparison between HDR's current condition shade estimates and Ecology's results. There are some noticeable differences in the burned areas of the Tucannon River, but overall the HDR field measurements compared well with Ecology's effective shade model.

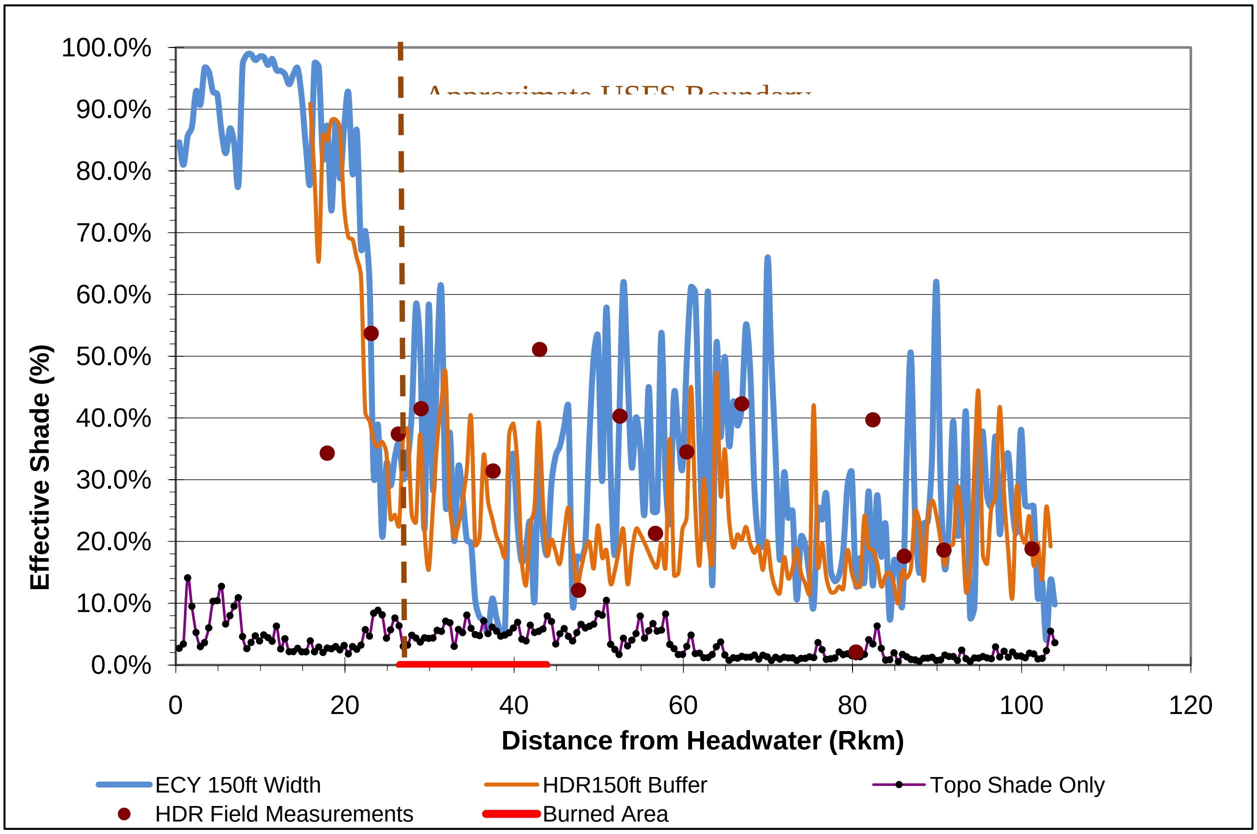

Figure G-(3) 35: HDR field measurements and shade model output compared to Ecology's shade model output.

The reduction of shade from the School fire is very noticeable between RKm 35-40 (RM 21.7-24.8). In general, the HDR estimated shade is lower than Ecology's estimates because it is more difficult to discern trees from grassy herbaceous areas when mapping the current vegetation from black and white aerial imagery. Ecology's modeled effective shade compared well against effective shade measured in the field using a solar pathfinder.

Load Allocations

Tucannon River

Figure G-4 is a graph of the shade modeling results for the current vegetation and system potential shade (the maximum potential height and density), and the topographic shade (contributed by the topography only). Land that is within the Umatilla National Forest is not subject to compliance with this TMDL.

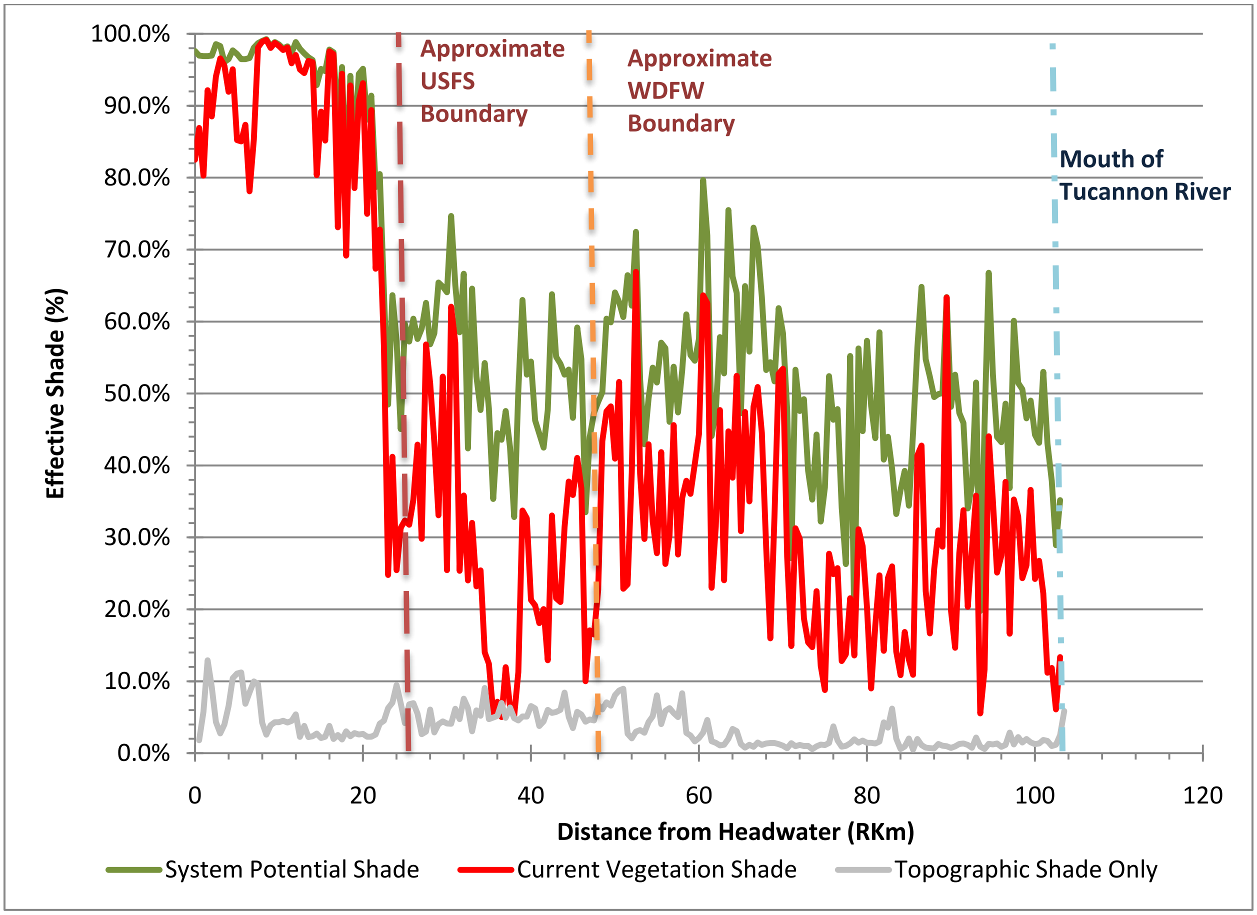

Figure G-(4) 36: Comparison of current riparian shade and system potential shade for Tucannon River.

Pataha Creek

Shade load allocations for Pataha Creek were calculated using the same method and system potential vegetation framework as the Tucannon River. The patchiness of the current vegetation along the creek was better characterized with this approach. Figure G-5 compares the multiple shade model results for current vegetation and system potential shade scenarios as well as the shade contributed by topography only. Land within the Umatilla National Forest is not subject to this TMDL.

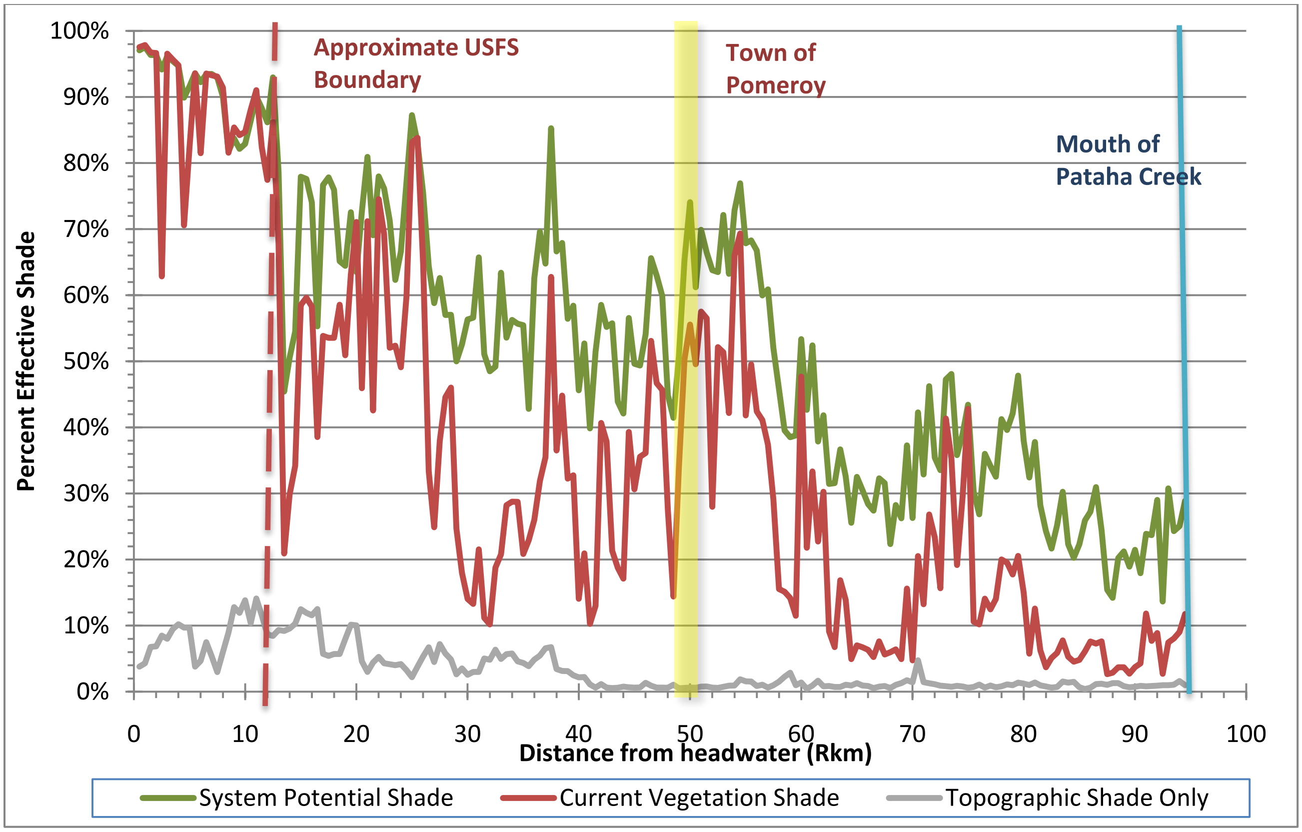

Figure G-(5) 37: Comparison of current riparian shade and system potential shade for Pataha Creek.

Large increases in shade can be achieved in many reaches along the creek, especially in the lower reaches downstream of Pomeroy. Riparian restoration in these areas will be difficult due to the severe entrenchment of Pataha Creek (Figure G-6), which effectively lowers the water table out of reach to replantings on top of the incised banks. This problem could increase management costs and resources for irrigating restoration projects that are not planted down in the incisions along the new floodplain. Riparian restoration efforts should focus replanting within the incised channel in reaches where that is a problem.

Figure G-(6)38: An example of Pataha Creek's incised channel.

Existing riparian shade within the town of Pomeroy was relatively high compared to downstream and upstream stream reaches. Restoration efforts should be focused on the upstream reach between RKm 50-69 (RM 31.1-42.9). The river is not deeply entrenched in this area, like it is downstream of Pomeroy, which will make riparian restoration easier.

Pataha Creek is highly incised in the lower subbasin, downstream of the town of Pomeroy. This is likely due to the lack of riparian vegetation to stabilize the stream banks, the high erosion potential of the soils in the area, and past land-use practices. It is outside the scope of this study and the available data to determine how the natural stream channel can be restored. The stream has cut itself down significantly from the valley terrace and is building a new flood plain. Channel incision heights vary widely from only a few feet to greater than 15 feet along the reaches that were surveyed.

Perennial Tributaries to Tucannon River

Tributaries to the Tucannon River and Pataha Creek were not modeled for shade. However, reduction of stream temperatures of the tributaries is important when trying to reduce heat loading to the mainstem. For all tributaries flowing into the Tucannon River, shade curves were developed so that percent effective shade values for conifers (Figure G-7), deciduous vegetation (Figure G-8), and mixed vegetation stands (Figure G-9) could be applied to these water bodies.

The shade curves define the relationship between shade provided by system potential vegetation, channel width, and stream aspect. Effective shade will differ for each stream reach depending on bankfull width and stream aspect and can be determined using the shade curves. These are the same tree height characteristics for conifer and mixed as the largest category riparian codes used for the other shade models.

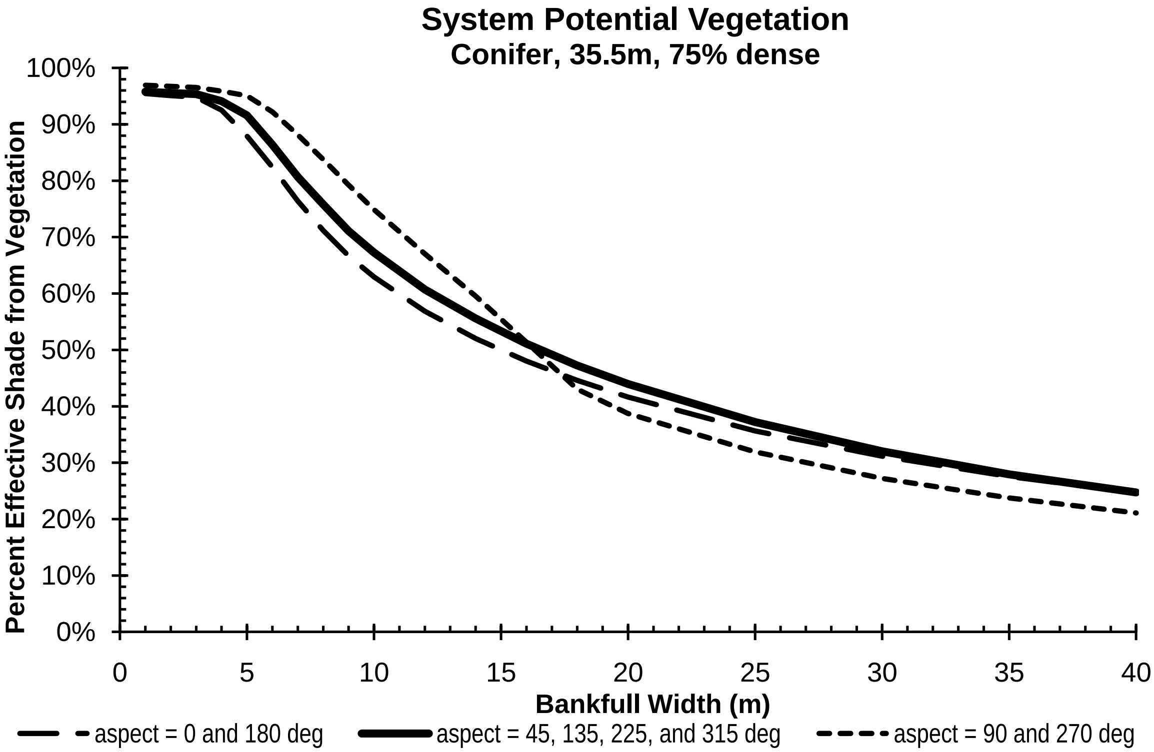

Figure G-(7) 39: Shade Curve for riparian conifer vegetation on tributaries to the Tucannon River and Pataha Creek

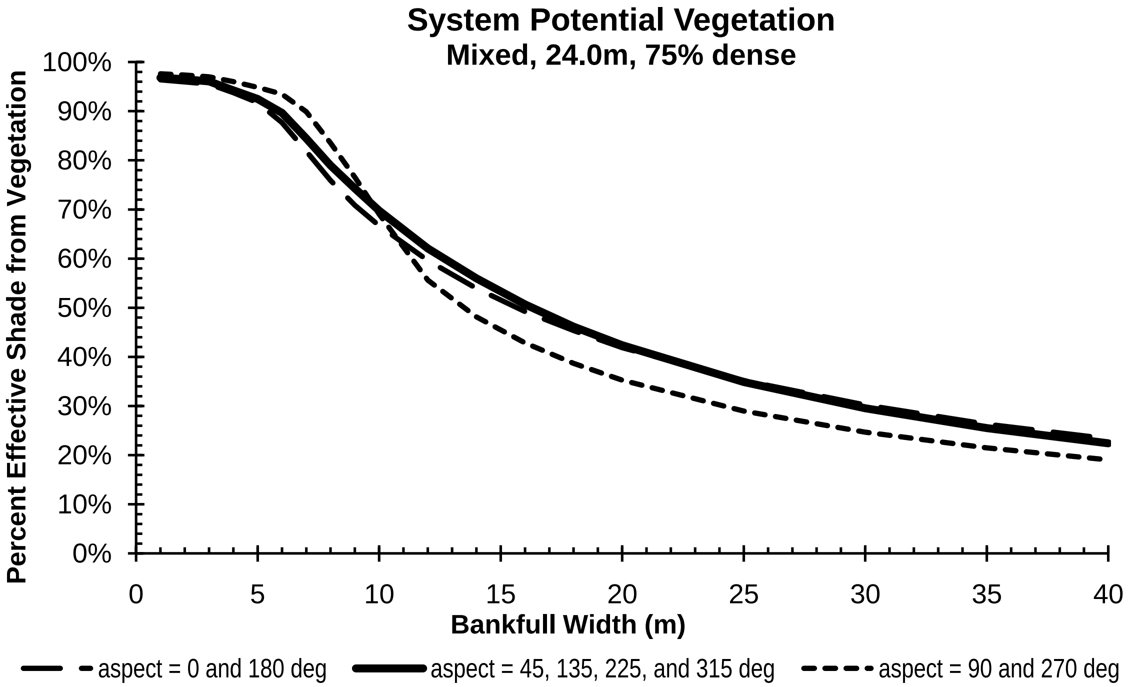

Figure G-(8) 40: Shade Curve for riparian mixed vegetation on tributaries to the Tucannon River and Pataha Creek.

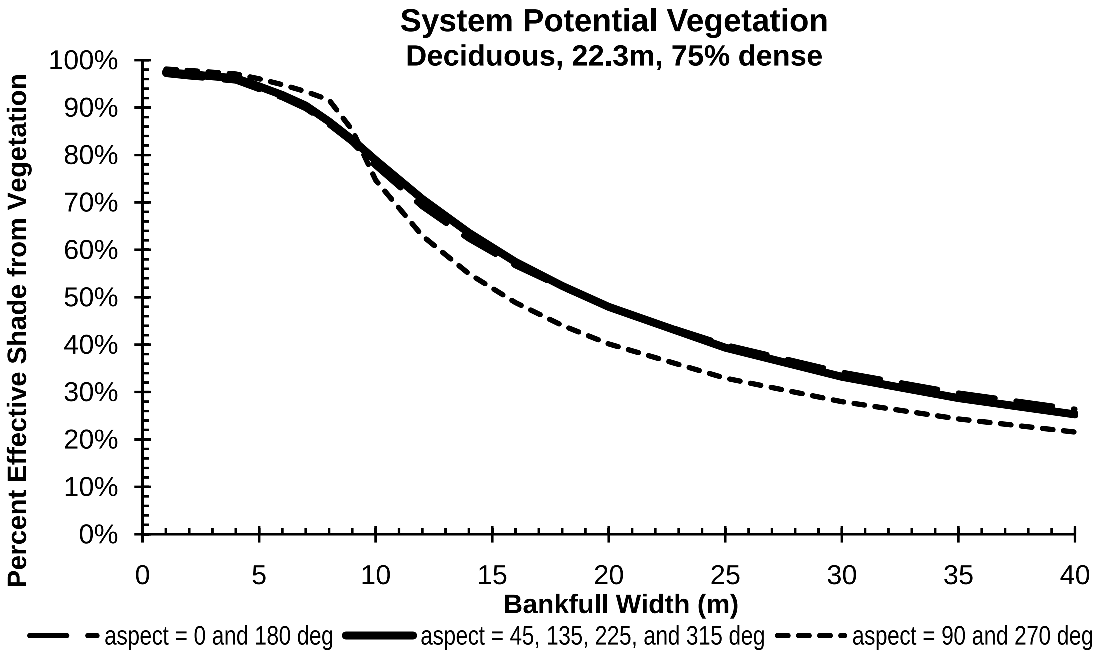

Figure G-(9) 41: Shade Curve for riparian deciduous vegetation on tributaries to the Tucannon River and Pataha Creek.

References

Powell, David C. 2005. “Height-Diameter Equations for Tree Species of the Blue and Wallowa Mountains”. Unpublished manuscript. Umatilla National Forest. Pendleton, OR.

Powell, David C. 2008. “Schmitt Height-Diamter Equations Analysis Update: March 14, 2008” Unpublished manuscript. Umatilla National Forest. Pendleton, OR.

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Appendix H: Planned Implementation Actions

Table I-(1) 17: Summary of Implementation Projects in the Tucannon/Pataha Watershed planned at this time.

Project Description	Schedule	Funding Source/Partners	Proposed Lead
Restore and enhance natural floodplain, riparian areas and wetlands.	On-going	DOE, WCC, BPA, SRFB	CDs, Counties, Nez Perce Tribe
Review and update land use plans and regulations…to support water management goals.	On-going	State Legislature	Counties, Cities, DOE
Support implementation of urban and rural land management BMPs.	On-going	State Legislature, DOE, WCC, BPA, SRFB	Counties, CDs
Establish and maintain water resource management education and outreach.	On-going	DOE	CDs, Counties
Develop and implement noxious weed control programs.	On-going	State Legislature	County Weed Boards
Emphasize CCRP, CSP, CREP, WRP, and WWRP.	On-going	USDA	NRCS, FSA, CDs, WDFW, Nez Perce Tribe
Protect and improve surface water and groundwater sources for public water supplies.	On-going	State Legislature, DOE, WDFW	DOE, WDFW, CDs, PUD
Manage stormwater in urban and rural areas…reduce flooding and enhance aquifer recharge.	On-going	State Legislature, DOE, WCC	Counties, CDs
Characterize surface and ground water availability…to ensure water resources meet existing needs.	On-going	DOE	DOE, PUD
Encourage stormwater reclamation and reuse to satisfy water resource needs.	On-going	DOE	Counties, CDs
Identify and develop opportunities to enhance water supply, emphasizing aquifer storage, source substitution, and reclamation reuse.	On-going	DOE	DOE, CDs

Promote water conservation and efficiency.	On-going	DOE	DOE, CDs
Project Description	**Schedule**	**Funding Source/Partners**	**Proposed Lead**
Implement passive restoration projects, including: CREP; riparian buffers; conservation easements, and public education on easements.	On-going	CREP, WCC, BPA, SRFB	WDFW, CDs, Nez Perce Tribe
Implement aquatic habitat protection plans for streams with ESA listed species.	By 2010	BPA, WCC, SRFB	WDFW, CDs, Nez Perce Tribes, County Weed Boards
Work with landowners to protect and enhance headwaters by encouraging application of riparian and instream BMPs.	On-going	USFS, BPA	WDFW, CDs, Nez Perce Tribe
Implement strategies to reduce fecal coliform including restoring riparian buffers and managing grazing in riparian areas.	By 2010	DOE, DOH, County Health, SRFB, BPA, WCC	CDs, Counties, Ecology
Implement strategies to control erosion including: direct seed; CRP; grassed waterways, weed control, grazing management, other water sources, and manure management.	By 2010	WCC, DOE, BPA, SRFB	CDs, DOE, WDFW, USFS
Indentify and designate aquifer recharge areas and protect known aquifer recharge areas through critical areas ordinances.	On-going	DOE	Counties
Prioritize post ‘School Fire’ projects on public and private lands. (WDIP)	On-going	USFS, CREP, WDFW, BPA, SRFB	WDFW, CCD, USFS
Adopt the Eastern Washington Stormwater Manual and implement appropriate stormwater BMPs sited therein.	Plan by 2009, implement by 2012	DOE	Counties
Identify wetland restoration, protection, and enhancement projects.	By 2015	DOE	DOE, CDs

Improve irrigation efficiencies, including conveyance and application methods.	By 2010	DOE, WCC, BPA, SRFB	CDs
Implement pilot project to encourage beaver activity for multi-purpose storage through dams, wetlands, and water retention.	By 2010	WDFW	WDFW, CDs

Appendix I: Implementation Responsibilities Tracking Sheet

Entity	**Actions**	**Year**									**Comments**
		2011	2012	2013	2014	2015	2016	2017	2018	2019	
WA Dept of Ecology	1, 4, 7, 8, 12, 14										
WDFW	1, 8, 15										
CCD	1										
Nez Perce Tribe	1, 2,5										
CTUIR	1, 2, 5										
County Weed Boards	1										
CDs	2, 3, 4, 7, 8, 10, 12, 13, 14, 15, 17										
NRCS	10										
PCD	5, 6										
WSU Extensio	10										

n											
WDOT	11										
Counties	5, 11, 16, 17										
USFS	9										
WWC	11										

Actions:

1. (1a from Table 8) Implement aquatic habitat protection plans for streams with ESA listed species for instream restoration/protection: 1. Enhancement restoration and protection projects, 2. Riparian buffers, 3. Large woody debris replenishment and replacement/enhancement; 4. Enhancement of habitat for Fall Chinook/steelhead; 5. Control noxious weeds; 6. Plant native vegetation.
2. (1B From Table 8) Implement passive restoration projects, including Conservation Reserve Enhancement Program, riparian buffers, pilot conservation easements and public education on use of easements.
3. (2a from Table 8) Implement the following strategies to reduce fecal coliform levels: 1. Identify failing septic systems; repair and/or upgrade or connect to sewer if available.
4. (2b from Table 8) Intensive Managed Grazing Practices
5. (3a from Table 8) Restore and enhance natural floodplain
6. (3b from Table 8) Reduce channel incision
7. (3c from Table 8) Identify wetland restoration, protection and enhancement projects
8. (3d from Table 8) Implement pilot project to encourage beaver activity
9. (4a from Table 8) Implement strategies to reduce TSS levels
10. (4b from Table 8) Work with individual landowners to review pesticide and fertilizer use, and to implement the following best management practices to limit water quality impacts: 1. Restore riparian areas; 2 Urban/rural education program; 3. Conservation tillage.
11. (5a from Table 8) Road Maintenance Project
12. (6a from Table 8) Promote conservation and efficiency of water use.
13. (6b from Table 8) Improve irrigation efficiencies
14. (6c from Table 8) Identify and develop opportunities to enhance available water supply.
15. Explore opportunities for water right leases and/or acquisitions through the DOEW Trust Water Program and/or water banking.
16. (7a from Table 8) Adopt Eastern Washington Stormwater manual and implement the following strategies: 1. Sediment basins; 2. Infiltration trenches; 3. Swales/wetlands; 4. Rural/urban drainage ditch upgrades and treatment; 5. Shaping/grading; 6. Reclamation/reuse; 7. Mowing vs. spraying.
17. (7b from Table 8) Encourage stormwater and/or wastewater reclamation.