Palouse River Temperature Total Maximum Daily Load

Water Quality Improvement Report and Implementation Plan

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For more information contact:

Washington State Department of Ecology
Eastern Regional Office
Water Quality Program
4601 N. Monroe St.
Spokane, WA 99205

Phone: 509-329-3436

Washington State Department of Ecology - www.ecy.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Cover photo: Palouse Falls (photo credit: Ecology)

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

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Water Resource Inventory Areas for this study: 34

Palouse River Temperature Total Maximum Daily Load

Water Quality Improvement Report and Implementation Plan

by

Elaine Snouwaert
Water Quality Program

and

Tighe Stuart
Environmental Assessment Program

Eastern Regional Office
Washington State Department of Ecology
Spokane, Washington 99205

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Abstract

The Palouse River has high water temperatures that do not protect fish and other native species that depend on cool, clean water. This report documents this problem and outlines the solutions needed to improve stream temperatures.

The study area for the Palouse River Temperature Total Maximum Daily Load (TMDL) includes the mainstem of the Palouse River from the Washington/Idaho state line near Palouse, Washington to its mouth at the Snake River, as well as the lower two miles of all Palouse River tributaries except for the South Fork Palouse River. The South Fork Palouse River will be addressed in a separate TMDL.

As part of the Palouse TMDL study for temperature, the Washington State Department of Ecology (Ecology) conducted field work during 2007.

This report presents the analysis performed by Ecology and establishes shade load allocations for the Palouse River study area. Effective shade is used as a surrogate measure of heat flux to fulfill the requirements of Clean Water Act Section 303(d) for a TMDL for temperature. Effective shade is defined as the fraction of solar shortwave radiation that is blocked by vegetation and topography from reaching the stream surface. The effective shade produced by full potential riparian vegetation is needed to meet water quality standards in the Palouse River.

To reduce instream temperatures, the implementation plan requires the restoration of riparian areas, wetlands, and natural stream hydrology. In addition, benefits can be gained from agricultural best management practices. Dischargers of waste and storm water must also assure treatment or other activities are implemented so the effluent does not contribute to impairment of the instream temperature goals of this TMDL.

Acknowledgements

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Executive Summary

Introduction

Ecology conducted a total maximum daily load (TMDL) study for the Palouse River because it has high water temperatures that do not protect fish and other native species that depend on cool, clean water. Data gathered by Ecology and the U.S. Geological Survey were the basis for listing segments of the Palouse River as impaired for temperature on Washington's 2008 303(d) list of polluted water bodies and on prior 303(d) lists beginning in 1996. In 2007, Ecology initiated the study in this watershed to address these 303(d) listings. This report contains the study findings and an implementation plan to reduce stream temperatures.

What is a total maximum daily load (TMDL)?

The federal Clean Water Act (CWA) requires that a TMDL be developed for each water body on the 303(d) list. The 303(d) list, which the CWA requires states to prepare, contains water bodies that do not meet state water quality standards. The TMDL study identifies pollution problems in the watershed, and then the plan specifies pollution reductions and actions to achieve water quality standards for the river. With the assistance of local governments, agencies, and the community, Ecology developed the implementation plan to describe the actions necessary to reduce temperatures and a monitoring plan to assess the effectiveness of the water quality improvement activities.

Watershed description

The Palouse River basin is located primarily in Whitman County, Washington, with its headwaters located in the Hoodoo Mountains in the St. Joe National Forest in Latah County, Idaho. The Palouse River is approximately 144 miles (232 km) long, 124 miles (193 km) of which is within Washington State. From the Idaho border, the reach of the Palouse River, locally referred to as the North Fork Palouse River, flows roughly 33 river miles to the South Fork Palouse River confluence at Colfax, Washington. From there, the river flows about 85 miles to Palouse Falls. Palouse Falls drops over a 198 foot cliff about six river miles upstream of the Palouse River's mouth. The borders of Whitman, Adams, and Franklin counties follow the Palouse River above and below Palouse Falls to its confluence with the Snake River.

The study area for this temperature TMDL is limited to the Palouse River and the lower two miles of all tributaries. However, the water quality of the entire length of the tributaries can benefit from the information provided by the study and activities required by the implementation plan.

What needs to be done in this watershed?

Based on the TMDL study and modeling results, Ecology predicts that much of the Palouse River will at times be naturally warm during the critical summer months due to climate, native vegetation, and hydrology. However, a buffer of mature riparian vegetation along the banks of the Palouse River can decrease average daily maximum temperatures by up to 2.2°C. For the

Palouse River to meet water quality standards, the 7-Day-Average-Daily Maximum temperature (7-DADMax) must meet the numeric criteria assigned in the water quality standards (WAC 173-201A) or attain temperatures that would occur under natural conditions. Because Ecology's modeling predicts that some portions of the Palouse River will at times be naturally warm during the summer critical period, it is especially important that system-potential mature riparian vegetation is established along all of the Palouse River and its tributaries to ensure that system-potential temperatures are achieved. This will ensure that the river meets either the numeric water quality criteria or its natural condition.

In addition to system-potential mature riparian vegetation, other measures, such as restoring wetlands and natural stream hydrology, and use of best management practices to increase infiltration and decrease erosion, are needed help restore a natural temperature regime in the river. Finally, the Palouse wastewater treatment plant will need to reduce the temperature of their effluent to avoid contributing to an impairment of this TMDL's temperature goals.

Why this matters

Elevated water temperature is a common problem in many streams in Washington State. When temperatures are too high, it can make the streams uninhabitable for fish and other aquatic animals. Fish can suffer a variety of ill effects, ranging from decreased spawning success to death when waters are too warm. Temperatures in the range of 23-25˚C (73-77˚ F) can be lethal, depending on the species. The temperature of the water can also affect how much oxygen is dissolved in the water. It is this dissolved oxygen (DO) that the fish need to breathe. The warmer the water, the less DO it can hold. The warmer temperatures also tend to speed up the metabolism of the fish so they require more oxygen for biological functions.

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 they were collected using appropriate scientific methods before they are used to develop the assessment. The WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list].

Category 1 – 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 they:

- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, or 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 a numerical value representing the highest pollutant load a surface water body can receive and still meet water quality standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. The TMDL study identifies pollution problems in the watershed and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology, with the assistance of local governments, tribes, agencies, and the community, then develops an implementation plan to control and reduce pollution sources as well as a monitoring plan to assess effectiveness of the water quality improvement activities. This combined report is sent to the U.S. Environmental Protection Agency (EPA) for review and approval to ensure it meets the requirements of the Clean Water Act.

Who should participate in this TMDL?

Nonpoint-source pollutant load targets have been set in this TMDL and are described in Appendix C. Because nonpoint 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 (BMPs) to reduce impacts to water quality. The area subject to the TMDL is shown in Figure 1.

Similarly, all point-source dischargers in the watershed must also comply with the TMDL. Point source discharges include wastewater treatment plants in Palouse and Colfax as well as stormwater from one industrial operation covered by the industrial stormwater general permit.

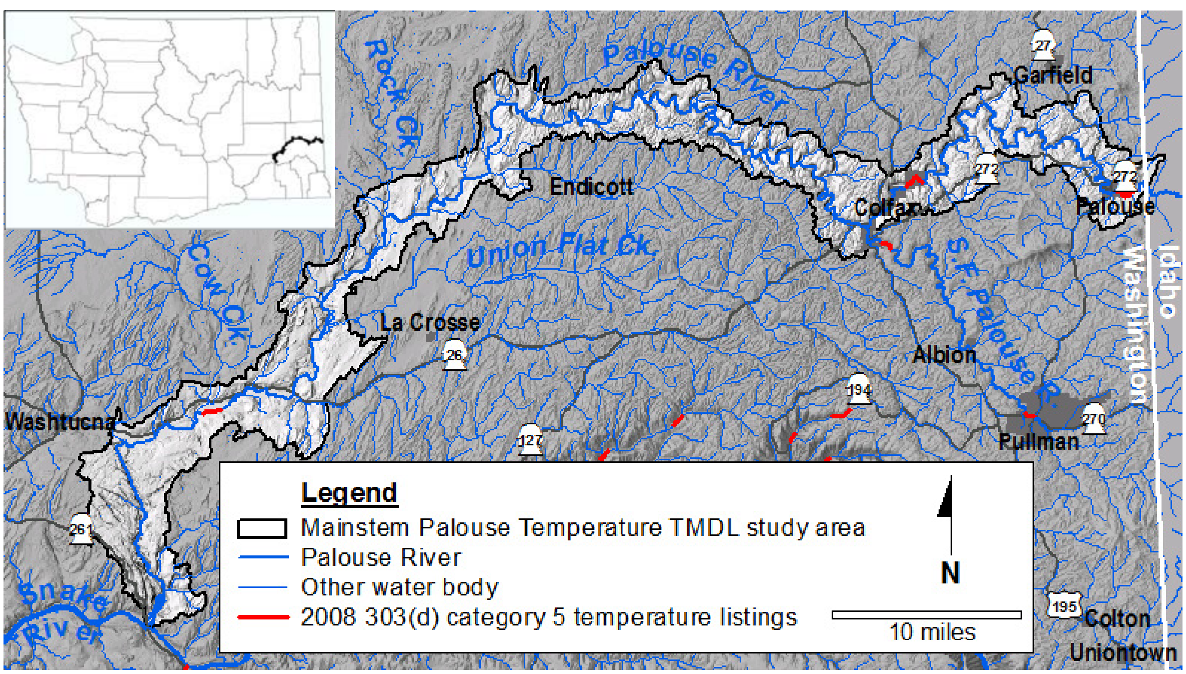

Figure 1. Palouse River Temperature TMDL study area.

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 (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 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.

Surrogate measures

To provide more meaningful and measurable pollutant-loading targets, a TMDL may also incorporate *surrogate measures*. EPA regulations [40 CFR 130.2(i)] allow other appropriate measures in a TMDL.

Heat loads to the stream are calculated in units of Kilocalories per day (Kcal/day) or watts per square meter (W/m^2). However, heat loads are of limited value in guiding management activities needed to solve identified water quality problems. It is more useful to describe what is necessary to prevent the heat load causing the problem rather than simply describing the amount of heat load that needs to be removed. The Palouse River Temperature TMDL uses effective shade as a surrogate measure for heat flux. Effective shade is defined as the fraction of shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface.

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Why Ecology Conducted a TMDL Study in this Watershed

Background

Ecology conducted a TMDL study in this watershed because the Palouse River has high water temperatures that do not protect fish and other native species that depend on cool, clean water. Data gathered by Ecology and the U.S. Geological Survey were the basis for placing segments of the Palouse River on the 2008 303(d) list for temperature and on prior 303(d) lists beginning in 1996. In 2007, Ecology initiated a TMDL study in this watershed to address these 303(d) listings (Kardouni et al., 2007). This report presents the findings of that study and the steps needed to reduce stream temperatures to meet water quality standards.

Study area

The Palouse River flows through Water Resource Inventory Area (WRIA) 34 in southeastern Washington. The upper part of the watershed extends into western Idaho beyond Potlatch. The Idaho Department of Environmental Quality (IDEQ) developed a TMDL for the upper tributaries in the Idaho portion of the Palouse River watershed (Henderson, 2005), but the Idaho TMDL did not include the mainstem Palouse River.

This TMDL effort includes the portion of the watershed within Washington State, from the Idaho state border to the Snake River confluence. The study focuses on the mainstem Palouse River and associated tributaries near their confluence with the mainstem (Figure 1). The South Fork Palouse River was the subject of data collection during 2006 and 2007 for a related TMDL study (Bilhimer et al., 2006), which will be presented in a separate report. The South Fork Palouse River meets the mainstem Palouse River immediately downstream of Colfax at river mile 89.6. For all other Palouse River tributaries, the study area includes only the two miles nearest the confluence with the Palouse River.

Impairments addressed by this TMDL

This TMDL addresses the Category 5 2008 303(d) listings for temperature in the Palouse River (Table 1, Figure 1). Within the study area, an additional five sites are listed as waters of concern, or Category 2 for temperature on Washington's 2008 Water Quality Assessment (Table 2). Locations that are listed as impaired are limited to where there is available water quality data. It should not be assumed that unlisted reaches meet standards, but rather that when the 2008 assessment was conducted there was no available data. This TMDL study found that additional reaches of the Palouse River violate the temperature criteria. Additional listings for dissolved oxygen and pH will be addressed by a separate TMDL currently under development (Carroll, 2007).

Table 1. Study area water bodies on the 2008 303(d) list for Temperature.

Water Body	Listing ID	Listing Category	Water Body ID	Township	Range	Section
Palouse River	11130	5	1182144465889	15N	37E	26
Palouse River	8115	5	1182144465889	17N	44E	31
Palouse River	3723	5	1182144465889	16N	46E	6

Table 2. Study area Waters of Concern for Temperature on the 2008 Water Quality Assessment.

Water Body	Listing ID	Listing Category	Water Body ID	Township	Range	Section
Palouse River	8114	2	1182144465889	13N	37E	30
Palouse River	16923	2	1182144465889	14N	37E	31
Rebel Flat Creek (mouth)	8152	2	1178031469443	17N	40E	29
Palouse River	8123	2	1182144465889	17N	41E	02
Palouse River	8117	2	1182144465889	17N	44E	11

Water Quality Standards and Beneficial Uses

Designated beneficial uses

The 2006 Water Quality Standards for Surface Waters of the State of Washington Chapter 173-201A WAC (Ecology, 2006) designate the following uses within the Palouse River watershed:

- *Salmonid Spawning, Rearing, and Migration* – This use protects salmon and trout spawning that only occurs outside of the summer season (September 16 – June 14). Other characteristic aquatic life uses include rearing and migration by salmonids.
- *Salmonid Rearing and Migration Only* – This use protects rearing and migration by salmonids, but not spawning.

Temperature criteria

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

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

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200].

To protect the designated aquatic life uses of both "Salmonid Spawning, Rearing, and Migration", and "Salmonid Rearing and Migration Only," the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average. This criterion applies from the South Fork confluence downstream to the river's mouth at the Snake River.

A special condition was designated in the water quality standards for the portion of the Palouse River (locally known as the North Fork Palouse River) upstream of the South Fork Palouse River confluence to the Idaho border. This condition states that temperature shall not exceed a 1-DMax of 20.0°C in this reach due to human activities.

Washington State uses the criteria described previously to ensure that when a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a water body is naturally warmer than the previously-described criteria, the state provides a small allowance for additional warming due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition. Whether or not the water body is naturally high in temperature is predicted using a model. The model roughly approximates natural conditions and is appropriate for determining the implementation of the temperature criteria. This model results in what is called the *system thermal potential* or *system potential* of the water body.

Table 3 lists the use designations and numeric temperature criteria by water body.

Table 3. Use designations and numeric temperature criteria for water bodies in the study area within the Palouse River watershed (WRIA 34).

Water Body	Aquatic Life Uses		Numeric Criteria
	Salmonid Spawning, Rearing, and Migration	Salmonid Rearing and Migration Only	
Palouse River mainstem from mouth to Palouse Falls	X		17.5°C
Palouse River from Palouse Falls to South Fork (Colfax, river mile 89.6)		X	17.5°C
Palouse River from South Fork (Colfax, river mile 39.6) to Idaho border (river mile 123.4)[1]	X		20.0°C[1]
All other waters[2]	X		17.5°C

[1]Temperature shall not exceed a 1-DMax of 20.0°C due to human activities. When natural conditions exceed a 1-DMax of 20.0°C, no temperature increase will be allowed which will raise the receiving water by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9).

[2]The water quality standards include a provision that any waters not given an explicit use designation default to "Salmonid spawning, rearing, and migration." (173-201A-600 WAC)

Watershed Description

The Palouse River basin is located primarily in Whitman County, Washington, with its headwaters located in the Hoodoo Mountains in the St. Joe National Forest in Latah County, Idaho (Henderson, 2005; Figure 1). From the Idaho border, the reach of the Palouse River locally referred to as the North Fork Palouse River flows roughly 33 river miles to the South Fork Palouse River confluence. There the river flows about 85 miles to Palouse Falls. Palouse Falls drops over a 198 foot high basalt shelf about six river miles upstream of the Palouse River's mouth. The borders of Whitman, Adams, and Franklin Counties follow the Palouse River above and below Palouse Falls to its confluence with the Snake River. The Snake River flows into the Columbia River, which ultimately flows along the Washington/Oregon state border and into the Pacific Ocean.

The Palouse River is approximately 144 miles (232 km) long, 124 miles (193 km) of which is within Washington State. Its total watershed area is 3,303 mi^2 (8,555 km^2; 2,114,000 acres) of which approximately 83% lies in Washington and 17% in Idaho (Gilmore, 2004). The basin area of the Palouse River upstream of the South Fork Palouse River is approximately 495 mi^2 (1,282km^2; 316,799 acres) and contributes around 83% of the mean annual flow of the Palouse River at Colfax (Ahmed, 2004). The South Fork Palouse River basin area is approximately 344 square miles (890 km^2; 219,943 acres) and joins the Palouse River at Colfax (Bilhimer et al., 2006).

Climate

The Palouse River watershed in Washington has a semi-arid climate. Annual precipitation throughout the full range of this watershed can range from 10 inches in the western region to 50 inches in the eastern headwater mountains of Idaho, where the mean annual precipitation increases roughly seven inches with every 1,000 foot increase in elevation. Precipitation peaks during winter and falls primarily as snow, especially in the mountains (Resource Planning Unlimited, Inc., 2004). Summer precipitation is typically less than an inch per month, with July being the driest month. Summer precipitation typically falls during intermittent thunderstorms. A drought was declared in 2001 and again in 2005. Summer daily maximum air temperatures can range from the mid-70s (ºF) to the mid-90s (around 21ºC to 35ºC) and occasionally over 100ºF (37.8ºC).

Geology

Around 110 million years ago, geologic activity forced giant granite slabs upward, creating certain landscape features in southeast Washington. Eventually, regional volcanic activity began. Fissures opened as the Palouse River basin received intermittent lava flows 10-30 million years ago, which filled the valleys with Columbia River basin basalts. Receding ice age glaciers, coupled with an arid climate, produced fine-grained sediment that was carried by prevailing winds. This wind-blown sediment, called loess, deposited on the basalt, forming large dunes known as the Palouse formation. Immense Missoula floods occurred several times, washing away areas of loess, altering the landscape, and creating channeled scablands. These scablands comprise an area of approximately 15,000 square miles including segments of the Spokane, Snake, and Columbia rivers as well as the lower Palouse River (Resource Planning Unlimited, Inc., 2004; Kuttel, 2002). The cliffs at Palouse Falls were formed by a massive waterfall during the Missoula floods.

Vegetation

Historically, the Palouse River watershed supported a variety of vegetation types which varied between sub-regional climates. For example, the eastern region of the watershed predominantly grew two types of perennial grass, Idaho fescue (*Festuca idahoensis*) and blue bunch wheatgrass (*Pseudoregneria spicata*). Shrubs included snowberry (*Symphoricarpos* spp.), black hawthorn (*Crataegus douglasii*), and rose (*Rosa* spp.) that grew often on the north aspect of the loess hills. Riparian areas in the eastern region commonly supported quaking aspen (*Populus tremuloides*) and cow parsnip (*Heracleum lanatum*) (an herb) among other mentioned species herein.

Forest communities grew in the higher elevations of the eastern region. Such species included ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), grand fir (*Abies grandis*), and western larch (*Larix occidentalis*), depending on aspect and available water. The forest understory included ocean spray (*Holodiscus discolor*), ninebark (*Physocarpus malvaceus*), serviceberry (*Amelanchier alnifolia*), snowberry, and wild rose.

The western region of the watershed was dominated by bluebunch wheatgrass. The western region riparian corridor also supported trees such as cottonwood (*Populus deltoids*), quaking aspen, mountain maple (*Acer glabrum*), and red alder (*Alnus rubra*). Currently, most of the Palouse Prairie has been converted to cropland (Resource Planning Unlimited, Inc., 2004). Riparian corridors are now dominated by reed canary grass (*Phalaris arundinacea*), a widespread exotic invasive species.

Hydrology

The Palouse River system includes over 398 miles of streams. Major tributaries and their relative percent contribution of drainage area are as follows (Golder Associates Inc., 2004):

- Cow Creek 22.4%
- Palouse River mainstem (including small tributaries) 17.2%
- Palouse River upstream of South Fork Palouse River 14.9%
- Rock Creek 12.1%
- Pine Creek 10.8%
- Union Flat Creek 9.6%
- South Fork Palouse River 8.9%
- Cottonwood Creek 4.2%

The United States Geological Survey (USGS) currently operates two streamflow gages on the Palouse River.

- USGS streamflow gage station #13351000 is located near Hooper, Washington at river mile 19.6 downstream of the State Highway 26 Bridge and 0.3 miles upstream of Cow Creek confluence. This gage station captures 2,500 square miles of the Palouse River watershed. It has recorded from 1897 to 1916, and 1951 to present.
- USGS streamflow gage #13345000 is located near Potlatch, ID at river mile 132.2 downstream of US Highway 95. This gage station near Potlatch captures 317 square miles of the Palouse watershed. It has recorded from 1914 to 1919, and 1966 to present.

Figures 2 and 3 depict the box-plots of monthly flows for the Palouse River recorded at Hooper and Potlatch, respectively. Peak flows typically occur from January through March, and baseflows from August through September. Streamflows in the Palouse River vary dramatically between seasons, with average March flows about 70 times higher than average September flows at Potlatch.

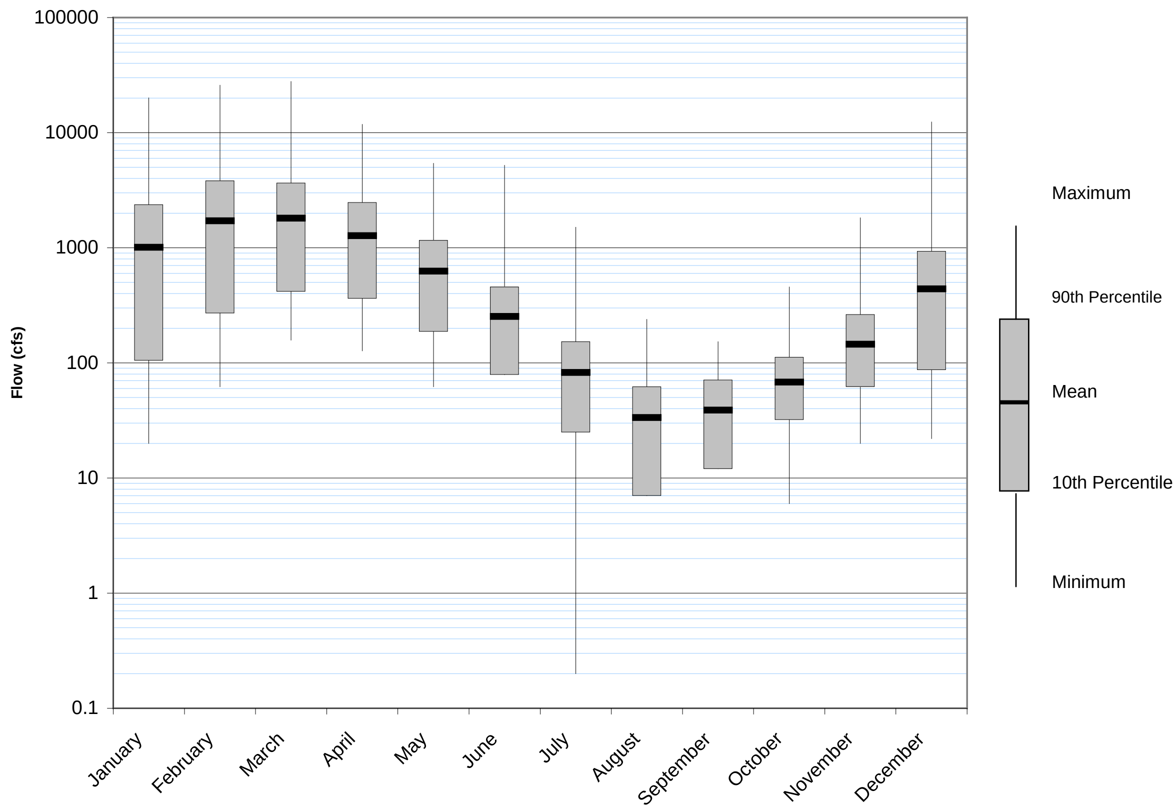

Figure 2. USGS stream-gage mean monthly flows between 1897 and 2005 for the Palouse River near Hooper, Washington.

Flows are plotted on a log-scale

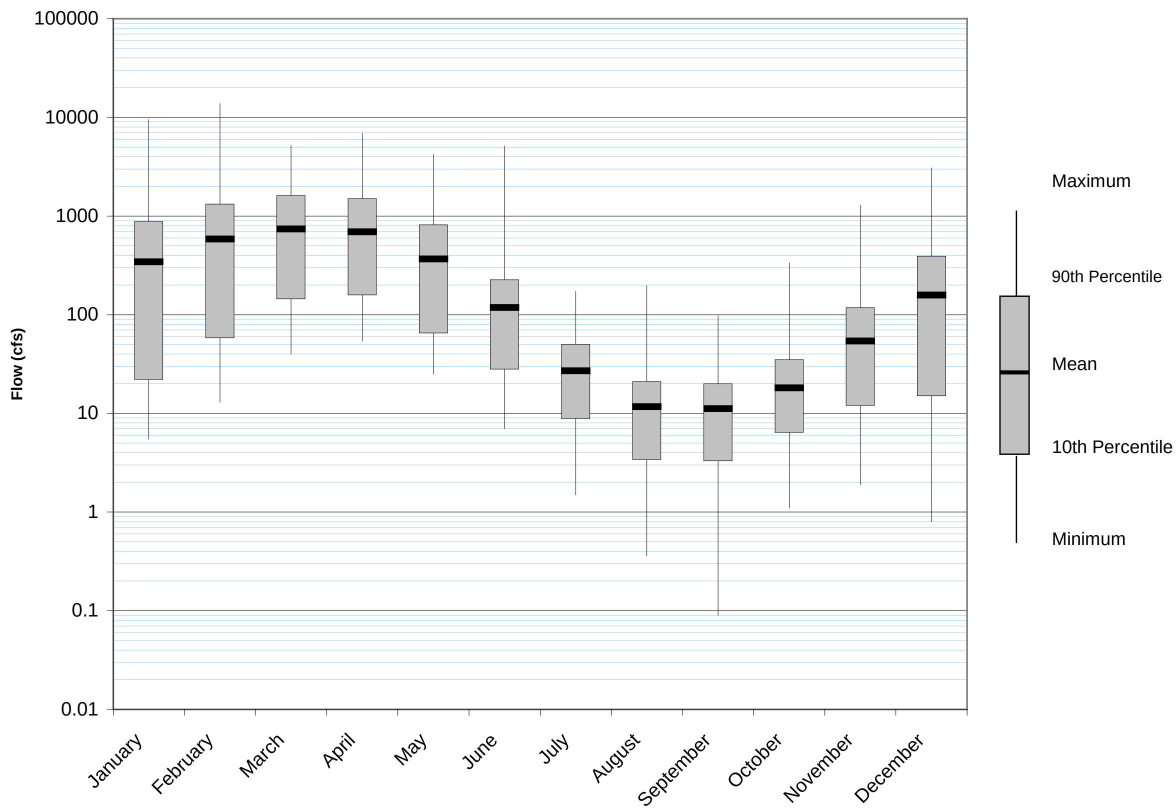

Figure 3. USGS stream-gage mean monthly flows between 1914 and 2005 for the Palouse River near Potlatch, ID.

Flows are plotted on a log-scale

The hydrology of the Palouse River is influenced by a number of groundwater inputs and springs. For example, piezometer data show a significant groundwater input near the mouth of Willow Creek (Sinclair and Kardouni, 2009). These groundwater inputs provide localized cooling and add to streamflow. Additionally, there are also reaches of the Palouse River that do not have significant groundwater inflows.

Land-use patterns

Land use within the study area is dominated by agriculture and rangeland with small rural city populations. Colfax (population about 3,000) is the largest town within the Palouse watershed, not including the South Fork Palouse subbasin. The next largest town is Palouse (population about 1,000). Smaller towns, with populations not exceeding 650, are located within the watershed as well, but generally outside the study area for this project (WA OFM, 2005). Agricultural use of water from the Palouse River is limited to adjacent land. To date, slightly over 100 water rights exist that draw from the Palouse River. These surface water withdrawals are typically used for irrigation and stock. Rangeland mostly occurs in the scablands or the western region of the Palouse River watershed (Resource Planning Unlimited, Inc., 2004).

Sources of pollution

Both nonpoint sources and point sources of thermal pollution are present in the Palouse River. Of the two, nonpoint sources are by far the most important and wide-reaching, with effects felt throughout the study area. Appendix B provides a detailed overview of stream heating processes.

Nonpoint sources

Nonpoint sources are pollutant loads that cannot be attributed to a single point of discharge, but which represent the diffuse accumulation of pollutant loads over a given area. Contributing nonpoint factors to stream heating loads in the study area include:

1. Riparian vegetation disturbance and loss of shade due to:
   - Removal of trees and shrubs for pasture, crops, timber harvest, roads, or buildings.
   - Grazing by livestock and wild animals.
   - Alteration of the local hydrograph or lowering the water table to such an extent that riparian vegetation cannot complete its life history requirements.
   - Competition from aggressive non-native plant species.

2. Channel morphology (depth and width) impacts resulting from:
   - Increased sediment loading from agriculture and roads.
   - Constraining, straightening, retaining, or diking the channel for agriculture, flood control, and roads.
   - Increased bank instability, erosion, and sedimentation from removal of established riparian vegetation and high stream velocities from past channel-straightening projects and other land-use practices in the watershed.
   - Altered sediment/energy regimes that result in channel incision or aggradation.

3. Hydrologic changes influenced by:
   - Extraction and return of groundwater or surface water.
   - Altered streamflow patterns from urban and rural residential development, timber harvest, and agriculture areas resulting in increased spring runoff and decreased summer baseflows.
   - Global climate change and its regional effects on overall water quantity (snow pack), as well as the timing and magnitude of the spring freshet.
   - Altered sediment/energy regimes that result in channel incision or aggradation.

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature (see Appendix B). Summer stream temperature increases due to the removal of riparian vegetation are well documented (for example, Lynch et al., 1984; Swift and Messer, 1971; and Brown et al., 1971). 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 fluctuation in solar heat flux.

Point sources

Included in this TMDL are point sources which discharge directly into the Palouse River. Point sources located upstream from the Palouse River along tributaries are not expected to have an effect on temperatures in the Palouse River. Wastewater treatment plants (WWTPs) in the towns of Palouse and Colfax are the primary point-source contributors to the Palouse River. In addition, there is an industrial stormwater source (Empire Disposal). There are also two sand and gravel general permits; however, these do not have discharges to rivers or streams. Point sources covered by this TMDL are listed in detail in the Wasteload Allocations section of this document.

Goals and Objectives

Project goals

The goal of this water quality improvement report and implementation plan is to address temperature problems in the Palouse River watershed in order to improve water quality and restore beneficial uses. More specifically, the goal is for the Palouse River to meet Washington State temperature water quality standards.

Study objectives

To support these project goals, a TMDL field monitoring and modeling analysis study was undertaken. A Quality Assurance Project Plan was developed for the TMDL study (Kardouni et al., 2007), which defined study objectives:

- Characterize summertime stream temperatures in the Palouse River and at the mouths of its tributaries.
- Characterize vegetation, flow, channel characteristics, and related variables to support modeling.
- Develop a predictive computer temperature model using QUAL2Kw for the Palouse River, focusing on the instream temperature regime at critical conditions.
- Evaluate the ability of various watershed BMPs to reduce water temperature to meet water quality standards.
- Establish a TMDL for temperature in the Palouse River.
- For ease of implementation, report load allocations in terms of surrogates for solar radiation such as: shade, size of tree necessary in the riparian zone to produce adequate shade, channel width, or miles of active eroding streambanks.

Implementation objectives

- Reduce point-source temperature inputs.
- Implement BMPs and other activities to address nonpoint sources of temperature loading.
- Return the Palouse River's temperature regime to one that approximates natural conditions and therefore, meets water quality standards.

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TMDL Analyses

Data collection methods

As part of the TMDL study, a field data collection effort was conducted during summer low-flow and high temperature conditions in 2007. Methods for data collection, compilation, and assessment were governed by the data requirements for the temperature model and are described in the Quality Assurance Project Plan (Kardouni et al., 2007). A number of different types of data were collected and are described briefly in the following sections.

Water temperature data – continuous dataloggers

Ecology installed a network of continuous temperature dataloggers in the Palouse River watershed. Dataloggers were located at regular intervals along the Palouse River and at the mouths of major tributaries (Figure 4). Loggers were deployed from May through October of 2007 and logged temperature at 30-minute intervals.

Streamflow data

Ecology's Stream Hydrology Unit[1] installed five continuous flow measurement stations in the study area during 2007 (Figure 5). These stations recorded stage height continuously from May to November 2007 and February to June 2008, except for the station on the Palouse River at Shields Road (34A085), which recorded continuously from May 2007 to June 2008. Instantaneous flow measurements were also taken at these five continuous flow-monitoring stations at approximately monthly intervals during this time period by the Stream Hydrology Unit.

Additional flow measurements were taken approximately monthly from May through October 2007 at temperature monitoring stations. Flow measurements were also taken twice per month from June 2007 through May 2008 at most temperature monitoring stations between Colfax and Hooper, except for when conditions prevented wading. Flow measurements were taken at all stations during July 30-August 1, 2007 and August 27-29, 2007.

The USGS measured flows at one long-term gage in the study area during 2007: Palouse River at Hooper (ID 13351000). The USGS also measured flows at another gage just upstream from the study area: Palouse River at Potlatch, Idaho (ID 13345000). USGS has historically gaged five additional locations: Palouse River at Palouse (ID 13345300), Palouse River near Colfax (ID 13346000), Palouse River at Colfax (ID 13346100), Palouse River below South Fork at Colfax (ID 13349210), and Palouse River near Winona (ID 13350000).

[1] Now called the Freshwater Monitoring Unit

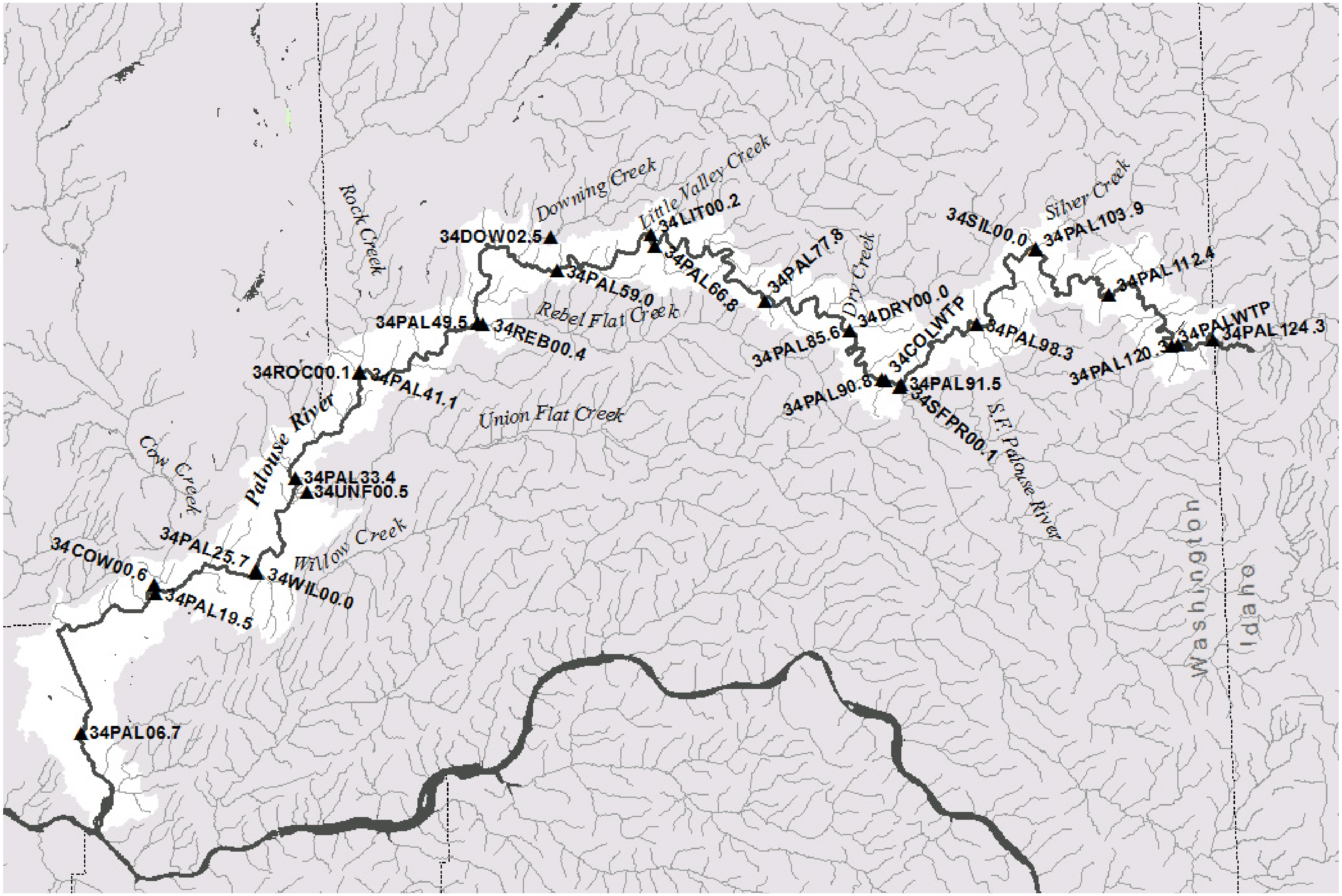

Figure 4. Locations and station IDs of Ecology's temperature monitoring stations in the Palouse River watershed.

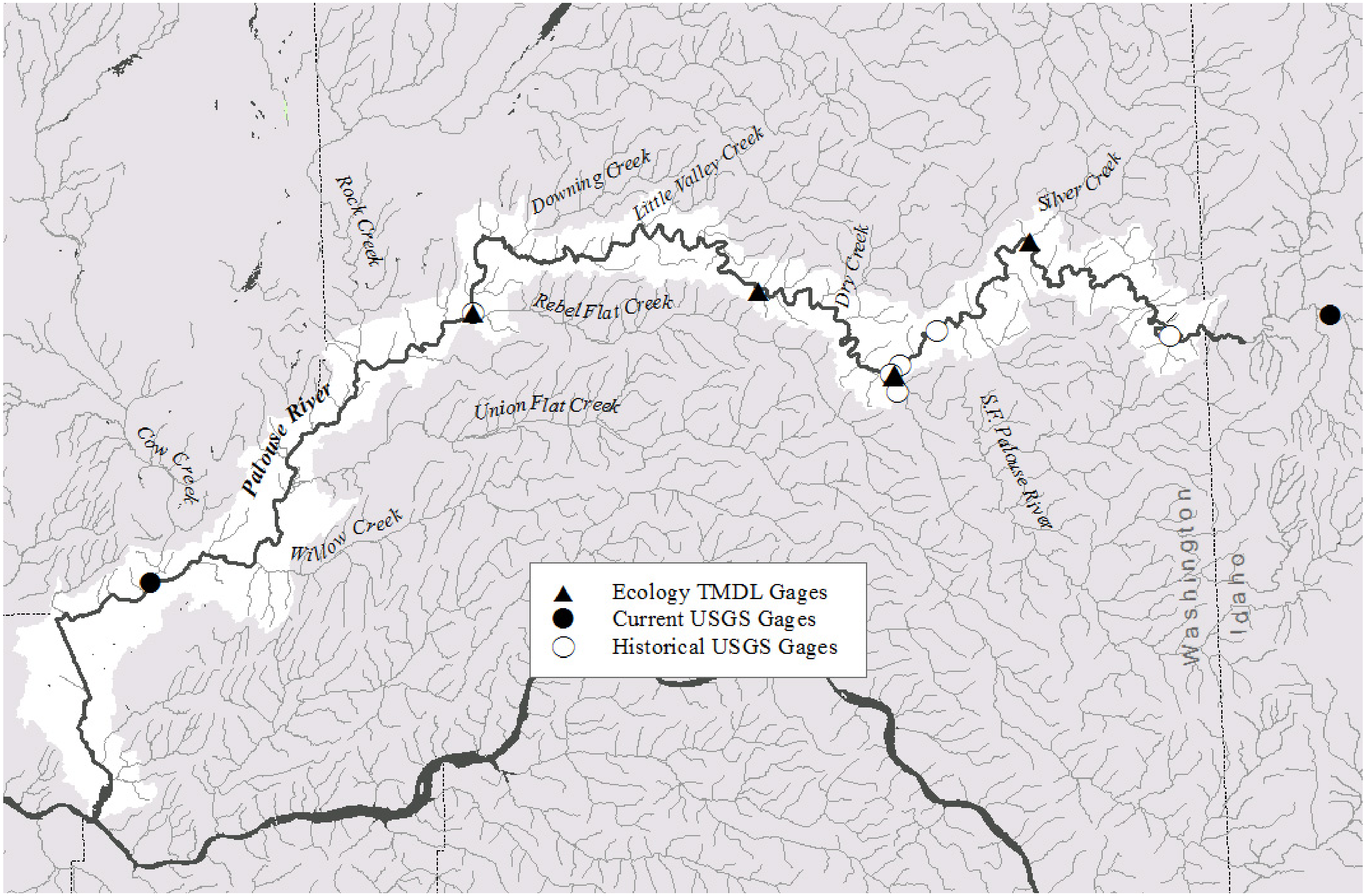

Figure 5. Continuous flow gaging stations operating in the Palouse River basin during summer 2007 and historically.

The black triangle at Colfax represents two gages, one on the Palouse River and one on the South Fork Palouse River.

Groundwater data

A separate study of groundwater and surface-water interactions was conducted concurrently with the Palouse TMDL study. The results of the groundwater study are presented in a separate report (Sinclair and Kardouni, 2009). The following is a brief summary, focusing on how groundwater data were used in this temperature TMDL study.

From July 30-August 1 and August 27-29, 2007, flow data were taken throughout the Palouse basin during nutrient surveys for a future dissolved oxygen and pH TMDL. These data, along with USGS and Ecology gage data, assisted in determining the influence of groundwater in the basin and developing a water balance for the low-flow season. In addition, a network of instream piezometers was installed in June 2007. Vertical hydraulic gradients at each piezometer were measured monthly until piezometer removal in November 2007. Flow data and piezometer data together determined reaches that gain and lose groundwater.

Thermistors were also installed in the upper, middle, and bottom part of the piezometers to help characterize the groundwater temperatures. Piezometers that had a positive vertical hydraulic gradient were used to represent groundwater. A positive hydraulic gradient means that the stream was gaining flow from groundwater at these locations. The temperatures recorded by the bottom thermistors (ranging from 2.1 to 4.0 ft below the streambed) were used as an estimate of groundwater temperature. Further groundwater temperature measurements were also provided by thermistors placed in four domestic wells throughout the Palouse basin.

Several piezometers indicated gaining reaches (flow from groundwater to the river). These were located at Palouse River at Altergott Rd. (34PAL112.4), Palouse River at St. John-Endicott Rd. (34PAL66.8), and Palouse River at Hwy 26 (34PAL25.7).

Hydraulic geometry

The channel width, depth, and velocity have an important influence on the sensitivity of water temperature to the flux of heat. Each of these was determined separately as described in the following sections.

Width

High resolution color digital orthophotos were created from aerial photos flown for Ecology on May 31 and August 31, 2006. The wetted banks were digitized at a 1:3000 scale for each of these dates, and wetted widths were calculated for each 100-meter segment using the TTools extension for ArcGIS (Ecology, 2008).

Depth

A Hydrolab® Minisonde® equipped with a depth probe was mounted snugly inside a length of PVC pipe and dragged along the bottom of the channel behind an inflatable raft. The minisonde was attached to a Surveyor® deck unit equipped with a GPS, which recorded location coordinates and a corresponding depth measurement every 30 seconds. The raft was navigated along the center of the channel. Depth data was collected between Colfax and the mouth of Willow Creek from May 23 to June 1, 2007 (Figure 6). Depth data collection was limited to this reach due to limited resources and the extremely short window of time each year when stream flows permit floating. For reaches where depth data were not collected using the minisonde, channel depth was estimated using the average depths recorded during measurements of the river cross-section taken during flow measurements.

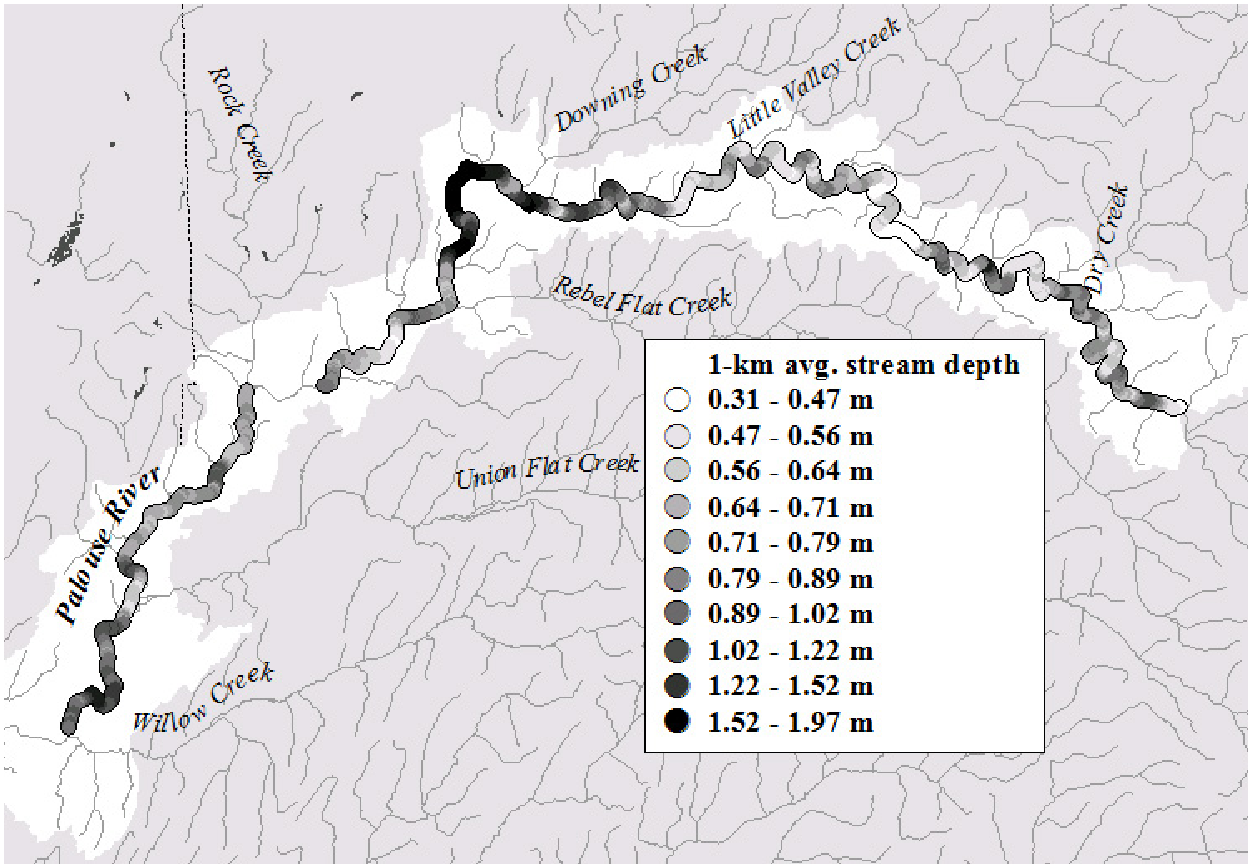

Figure 6. Depths recorded by Hydrolab® dragged behind raft, May 23-June 1, 2007.

Velocity

Time-of-travel studies using rhodamine, a fluorescent, non-toxic dye, were conducted on the Palouse River to estimate velocities. Dye studies are used to estimate travel times by measuring the time it takes for a slug of the dye to reach specific downstream locations.

A survey conducted from May 23 through June 6, 2007 covered the entire distance from Colfax to the mouth of Willow Creek. A second survey was conducted August 13-26, 2007, which generally covered the area from the Idaho state line to Hooper. Because of the slow travel times in the Palouse River during summer low-flow conditions, the August survey analyzed several representative reaches, each 5-10 miles long. Travel times for reaches that were not surveyed were estimated based on results from the reaches that were surveyed. This was done by assuming that velocities would be similar to those measured in nearby reaches, while accounting for differences such as stream gradient or depth.

At the upper end of each reach, a slug of dye was added to the river. A Hydrolab® Datasonde® equipped with a rhodamine sensor was deployed at the lower end of each reach. The travel time of the reach was calculated as the time elapsed between the dye release and the moment when the greatest rhodamine concentration was recorded at the downstream end of the reach. The average velocity of the reach was calculated as the length of the reach divided by the travel time.

Meteorological data

Hourly air temperature, humidity, wind speed, and cloud cover data were used from the National Weather Service station at the Pullman-Moscow Regional Airport. In addition, Ecology established two Onset® temporary weather stations in or near the study area. One was located near the temperature monitoring site at the Palouse River above Union Flat Creek (34PAL33.4), and the other was located along the South Fork Palouse River near Colfax. The weather stations recorded wind speed and direction, solar radiation, relative humidity, and air temperature. Also, Ecology installed a network of data loggers to continuously monitor near-stream air temperature at the same locations where there were instream continuous temperature dataloggers, and to monitor relative humidity at five locations throughout the study area.

Study quality assurance evaluation

The Onset StowAway Tidbits©, Hobo Water Temp Pro©, and Hobo Water Level Logger© instruments were calibrated pre- and post-study in accordance with Ecology Temperature Monitoring Protocols (Bilhimer and Stohr, 2009) to document instrument bias and performance at representative temperatures. A National Institute of Standards and Technology (NIST)-certified reference thermometer was used for the calibration.

Out of 76 temperature loggers used during the study, all had post-season checks within manufacturer-stated accuracy (i.e., ±0.2°C or ±0.4°C) except for four water thermistors located at 34DOW02.5, 34PAL124.3, 34PAL33.4, and 34SFPR00.1. Three of these thermistors were operating with ±0.3°C of actual temperature; however, the thermistor at 34SFPR00.1 was found to be operating at 0.74°C below the actual temperature. For the four instruments that differed from the NIST-certified thermometer by more than the manufacturer-stated accuracy, the data were qualified as estimates, and the error was taken into account when using the data for modeling and analysis.

Variation for field sampling of instream temperatures and potential thermal stratification was addressed with a field check of stream temperature at all monitoring sites upon deployment, during regular site visits, and during instrument retrieval at the end of the 2007 study period. Instantaneous temperature measurements agreed well with continuous data at all stations, typically within ±0.5°C for water thermistors. The average difference between instantaneous temperature measurements and thermistor temperatures exceeded ±0.5°C at 34PAL112.4, possibly due to thermal stratification. Instantaneous temperature measurements tend to be further off for air thermistors because of the inherent difficulties of taking instantaneous air temperature measurements.

Air temperature data and instream temperature data for each site were compared to determine if the instream temperature instrument (TI) was exposed to the air due to stream stage falling below the installed depth of the instream TI.

The Onset Hobo Water Level Logger© pressure transducers were also checked for measurement accuracy both pre- and post-study by (1) comparing each instrument to a graduated vertical water column and comparing the accuracy of the water level instrument over the range of expected depths and (2) developing a calibration curve if the instrument did not meet the manufacturer-specified accuracy of measurement (i.e., ±0.07 ft). Barometric pressure was recorded at representative stations to compensate for atmospheric pressure effects on the water level loggers.

Conductivity meters were calibrated in the field using a conductivity standard according to the manufacturer's specifications each day before data collection began.

All data used throughout this study are quality assured and considered to be adequate for TMDL development, taking the quality of the data, including any data qualifications, into account.

Modeling methods

Analytical framework

Data collected during this TMDL study were used to simulate water temperature continuously along the Palouse River, using a methodology that is both spatially continuous and spans full-day timeframes. The GIS and modeling analysis was conducted using four specialized software tools:

1. The Oregon Department of Environmental Quality (ODEQ) and Ecology's TTools extension for ArcView (Ecology, 2008) was used to sample and process GIS data for input to the QUAL2Kw model.
2. Ecology's Shade.xls model (Ecology, 2003) was used to estimate effective shade along the mainstem of the Palouse River. Effective shade was calculated at 100-meter intervals along the streams and then averaged over 1000-meter intervals for input to the QUAL2Kw model. The Shade model was adapted from a program also originally developed by the ODEQ as part of the HeatSource model. The Shade model uses (1) mathematical simulations to quantify potential daily solar load and generate percent effective shade values, and (2) an effective shade algorithm, modified from Boyd (1996) using the methods of Chen et al. (1998a and 1998b).
3. The QUAL2Kw model (Chapra, 2001; Chapra and Pelletier, 2003; and Pelletier and Chapra, 2003) was used to calculate the components of the heat budget and simulate water temperatures. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw was applied by assuming that flow remains constant for a given condition such as a 7-day or 1-day period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures were specified or simulated as diurnally varying functions.

   QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget that are shown in Figure B-2 in Appendix B and described in Chapra (1997). Complete model documentation and software can be found at www.ecy.wa.gov/programs/eap/models/index.html. Diurnally varying water temperatures at

1000-meter intervals along the streams in the Palouse River basin were simulated using a finite difference numerical method. The water temperature model was calibrated and confirmed to instream data.

4. The rTemp model (Pelletier, 2004) was used to model diel variations in water temperatures throughout an entire season at a single site and to confirm QUAL2Kw model results at select sites. The rTemp was also used to model conditions upstream of the Palouse wastewater treatment plant discharge using system potential shade to predict *background* or *system potential* temperature within the vicinity of this point source. The rTemp models response temperatures at a site based on meteorological and physical data and does not include the effects of advective transport. This limitation is not a problem for the Palouse River because slow travel times mean that there is not much advective transport anyway.

Vegetation and shade analysis

Current riparian vegetation and effective shade

Near-stream vegetation cover, along with channel morphology and stream hydrology, represents the most important factor that influences stream temperature. To obtain a detailed description of existing riparian conditions in the Palouse River basin, a combination of GIS analysis, interpretation of aerial photography, and hemispherical photography was used.

GIS coverages of riparian vegetation in the study area (Figure 7) were created from analysis of the color digital orthophotos flown during May and August 2006. Polygons representing different vegetation types were mapped within a 500-foot buffer on either side of the river at a 1:2000 scale using GIS. Riparian vegetation was classified into the following *current vegetation* categories, some of which were developed by Gilmore (2005), with additional categories as needed:

- Grasses
- Grasses and scattered conifers
- Conifers
- Grasses and shrubs (dominated by grasses with scattered shrubs)
- Coniferous forest
- Shrubs and grasses (dominated by shrubs with grasses interspersed)
- Reed canary grass
- Shrub steppe
- Scabland
- (Several additional categories for human-made features such as roads, railroads, fields, etc.)

Each vegetation category was assigned three characteristic attributes: maximum height, average canopy density, and streambank overhang.

Figure 7. Example of the color digital orthophoto quad for the Palouse River between Colfax and Palouse showing digitized vegetation areas and wetted edges.

To increase the accuracy of the image vegetation interpretation and to ground truth the Shade model outputs, hemispherical vegetation photographs (Figure 8) were taken during June and July 2007. At each temperature monitoring location, photographs were taken from the center of the channel and from the right and left banks. Hemispherical photographs were analyzed using HemiView canopy analysis software (University of Kansas, 1996).

After the vegetation polygons were delineated, a longitudinal profile of the Palouse River was created by sampling information along the right and left banks of the stream at 100-meter intervals using GIS. This was done using the TTools extension for ArcView that was developed by ODEQ, and maintained by ODEQ and Ecology (Ecology, 2008). Stream aspect, elevation, and topographic shade angles to the west, south, and east were also calculated at each 100-meter interval using a digital elevation model (DEM).

The output from TTools was then used as an input into Ecology's Shade model (Ecology, 2003) to estimate effective shade along the Palouse River. Effective shade is defined as the fraction of incoming solar shortwave radiation above the vegetation and topography that is blocked from reaching the surface of the stream. Effective shade estimated by the Shade Model was compared to that measured by hemispherical photos to confirm model accuracy (Figure 9).

Figure 8. Example of a hemispherical vegetation photograph taken at the center of the Palouse River.

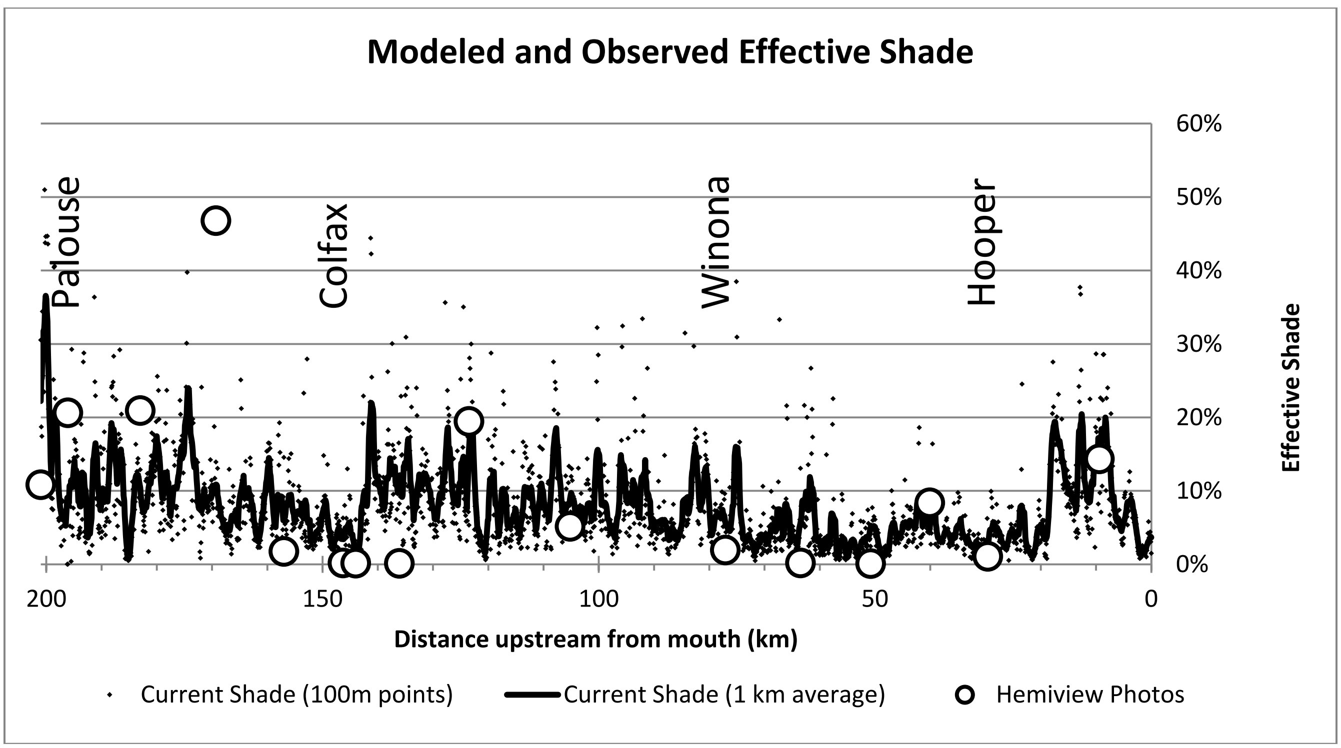

Figure 9. Modeled and observed current effective shade on the Palouse River.

Effective shade was modeled every 100 meters along the length of the river (small black points), but is most easily understood as a 1-km rolling average of those points (line).

Potential riparian vegetation and effective shade

System-potential riparian vegetation was also predicted for the Palouse River and the mouths of tributaries. A soils-based approach similar to that used by Gilmore (2005) was used. First, GIS soil survey coverages of Whitman, Adams, and Franklin Counties U.S. Department of Agriculture (USDA) were obtained. Within a 500-foot mapping area along the right and left banks, vegetation classes were assigned to individual soil-types-based weight of evidence from the following sources:

- USDA Ecological Site Association plant breakdowns.
- Current vegetation in undisturbed examples of that soil type.
- Classifications made by Gilmore (2005) for soil types also present in the South Fork Palouse basin.

Second, notes made by surveyors for the General Land Office (GLO) were consulted. GLO surveys were conducted in the late 1800s to delineate township and section boundaries. Surveyors often made notes referring to observed vegetation. At each point where a section line crosses the Palouse River, GLO records were searched for notes pertaining to vegetation. Where present, these notes were used to estimate a vegetation classification. These classifications were used as a check against the maximum potential riparian vegetation coverage made from USDA soil survey data. GLO surveys are available online at www.blm.gov/or/landrecords/survey/ySrvy1.php.

The soil type potential vegetation definitions were used to create a map of potential near-stream land cover in the Palouse basin. This map includes a description of potential vegetation (1) in the near-stream disturbance zone (NSDZ); (2) in the area extending back from NSDZ defined by a high water table and riparian shrubs and trees; and (3) in the upland areas.

Near-stream disturbance zone

Springtime high flows result in a near-stream disturbance zone along the edges of the summer low-flow channel. In general, large trees and shrubs cannot grow in this area. However, unlike many rivers, the NSDZ is not bare and rocky, but instead is covered mostly in reed canary grass (*Phalaris arundinacea*), a widespread exotic invasive species. It is unknown what the NSDZ would have looked like before Euro-American settlement, but it may have included reeds, sedges, and/or native grasses. It is expected that these would provide a similar amount of shade as reed canary grass. For this reason, the potential vegetation in the NSDZ is mapped as being the same as current vegetation.

Riparian vegetation strip

Potential riparian vegetation types, consisting of tree and shrub species, were mapped in a 30-meter strip extending back from the edge of the NSDZ. This 30-meter width represents the typical distance back from the edge of the NSDZ in which the high water table would allow riparian, as opposed to upland, vegetation to grow under natural conditions.[2] For the lower portion of the Palouse River represented by the willow brush vegetation zone, no NSDZ was mapped. Instead, the 30-meter buffer extends back from the water's edge. This is because the

[2] This is not necessarily the same as the buffer width needed during implementation in order to meet water quality standards. Buffer widths are discussed in the Implementation Plan section of this report.

riparian vegetation in this zone (mainly coyote willow) can survive inundation during high water and often occurs to the very edge of the low-flow channel.

Nearly all of the additional shade that is expected to result from system potential vegetation would be the result of these trees and shrubs.

Upland areas

Behind the 30-m riparian vegetation strip, the upland vegetation that would be expected to grow under natural conditions was mapped. In the eastern portion of the study area, this generally means conifer forest, and in the western portion of the study area, this generally means prairie or shrub-steppe. Upland vegetation was classified using some of the same categories used for mapping current vegetation:

- Grasses
- Grasses and scattered conifers
- Conifers
- Grasses and shrubs (dominated by grasses with scattered shrubs)
- Coniferous forest
- Shrubs and grasses (dominated by shrubs with grasses interspersed)
- Shrub steppe
- Scabland

Potential upland vegetation would be not expected to contribute much to stream shade.

Calibration of the QUAL2Kw model

The hottest 7-day period of 2007 occurred either from July 4-10 or from July 9-15, depending on the site. The period from July 6-12, which represented a period of stable temperatures and approximately represented the hottest temperatures of 2007, was used for calibration of the Palouse River QUAL2Kw model. The period from August 25-31 was used to further refine the model calibration. Temperatures during the August 25-31 period were stable and representative of somewhat cooler late-summer weather. Flows during the August 25-31 period were lower than during the July 6-12 period, near their seasonal minimum.

The following data sources were used for model inputs:

- Stream depths were derived from depth values recorded by the Hydrolab® Minisonde® pulled behind a raft along the Palouse River.
- Stream widths were given by TTools as described previously.
- Hydraulic geometry (wetted width, depth, and velocity as a function of flow) for the Palouse River was developed from width and depth data as described previously, and from time-of-travel data based on two dye studies. Relationships between wetted width, average depth, average velocity, and flow obtained from repeated flow measurements at temperature monitoring stations were also taken into consideration.
- Effective shade values were calculated by Ecology's Shade model as described previously.
- Stream elevation was sampled from two DEMs using TTools. One was the statewide 10-meter DEM. The other was a 20-foot DEM made from the high-resolution orthophotos of

the Palouse River flown during 2006. Gradient was calculated from stream elevations and longitudinal distance, using a smoothing equation to remove spurious jolts resulting from data coarseness.

- Flow balances for the QUAL2Kw model reaches on the Palouse River were estimated using gauged and instantaneous flows measured by Ecology and the USGS.
- Groundwater temperatures were based on temperatures recorded by the lower thermistor located inside of appropriate instream piezometers, and by thermistors located in near-stream domestic wells. Values from 12-18°C were used for the Palouse River. These values are in the normal range for groundwater temperatures throughout the Palouse watershed (Sinclair and Kardouni, 2009).
- Air temperature, relative humidity, cloud cover, wind speed, and solar radiation were estimated from meteorological data. The observed air temperatures, relative humidity, wind speed, and solar radiation collected at Ecology stations during the 2007 study year were used to represent the conditions for calibration periods. Cloud cover data came from the Pullman-Moscow Regional Airport.
- Hourly observed temperatures were used for the boundary conditions at the upstream end of the QUAL2Kw model reaches.

The primary model input parameters used to calibrate the model were channel geometry and shade. The shade inputs needed to correctly calibrate the models agreed well with effective shade measurements made using hemispherical photography (Figure 9). Groundwater temperature, which is often used to refine calibration, was not used in this way for this project. This is because the model was not found to be very sensitive to groundwater temperature (see Appendix E).

QUAL2Kw model predictions were compared to observed values to evaluate model performance using two different goodness-of-fit measures: the root mean squared error (RMSE) and overall bias (Table 4). The RMSE and overall bias were calculated as:

$$RMSE = \sqrt{\frac{\Sigma(T_{\text{mod}\,eled} - T_{observed})^2}{n}} \qquad Bias = \frac{\sum(T_{\text{mod}\,eled} - T_{observed})}{n}$$

Several sensitivity analyses were run to test various assumptions made during model calibration, and to determine the relative importance of various factors that affect stream temperatures. The results of the sensitivity analyses are presented in Appendix E.

Table 4. Root mean squared error (RMSE) and overall bias of differences between QUAL2Kw predicted and observed daily maximum and average temperatures (°C) in the Palouse River.

Water Body	Statistic	July 6-12, 2007		August 25-31, 2007	
		RMSE	Overall Bias	RMSE	Overall Bias
Palouse River	Maximum	0.83	+0.28	0.80	+0.25
	Average	0.57	-0.03	0.51	-0.17

Figures 10 and 11 show modeled vs. observed temperatures for the Palouse River.

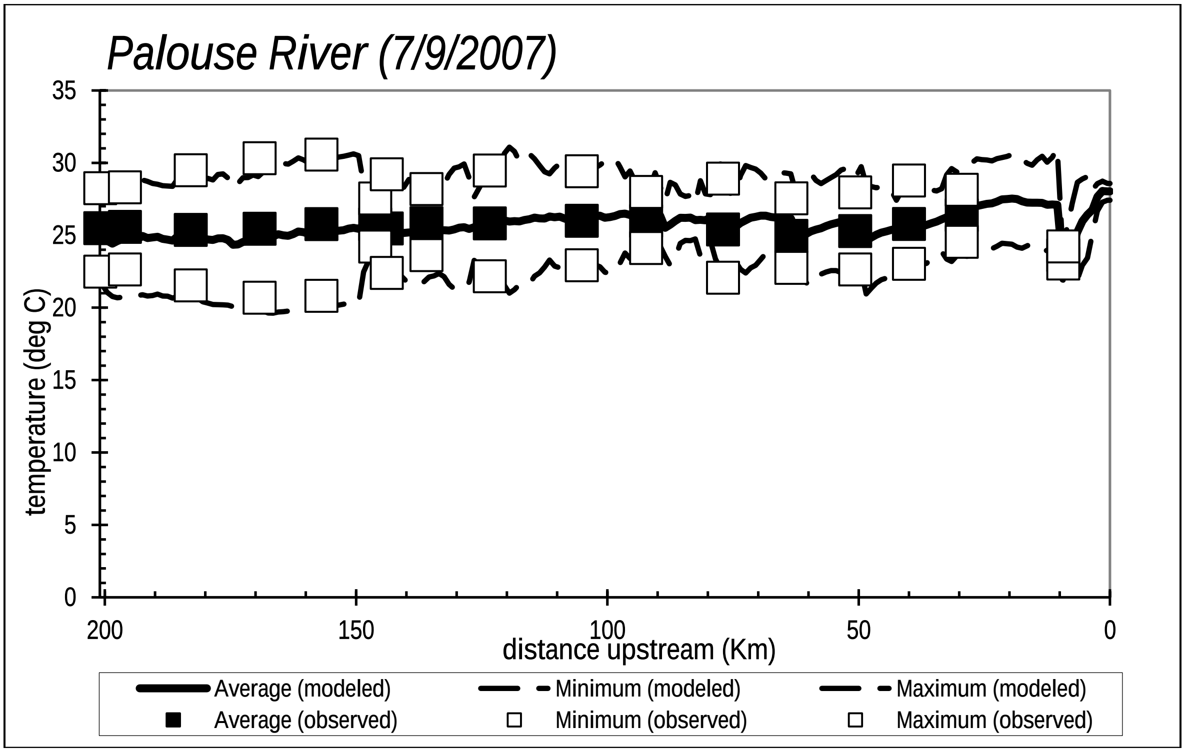

Figure 10. Modeled and observed temperatures in the Palouse River during July 6-12, 2007.

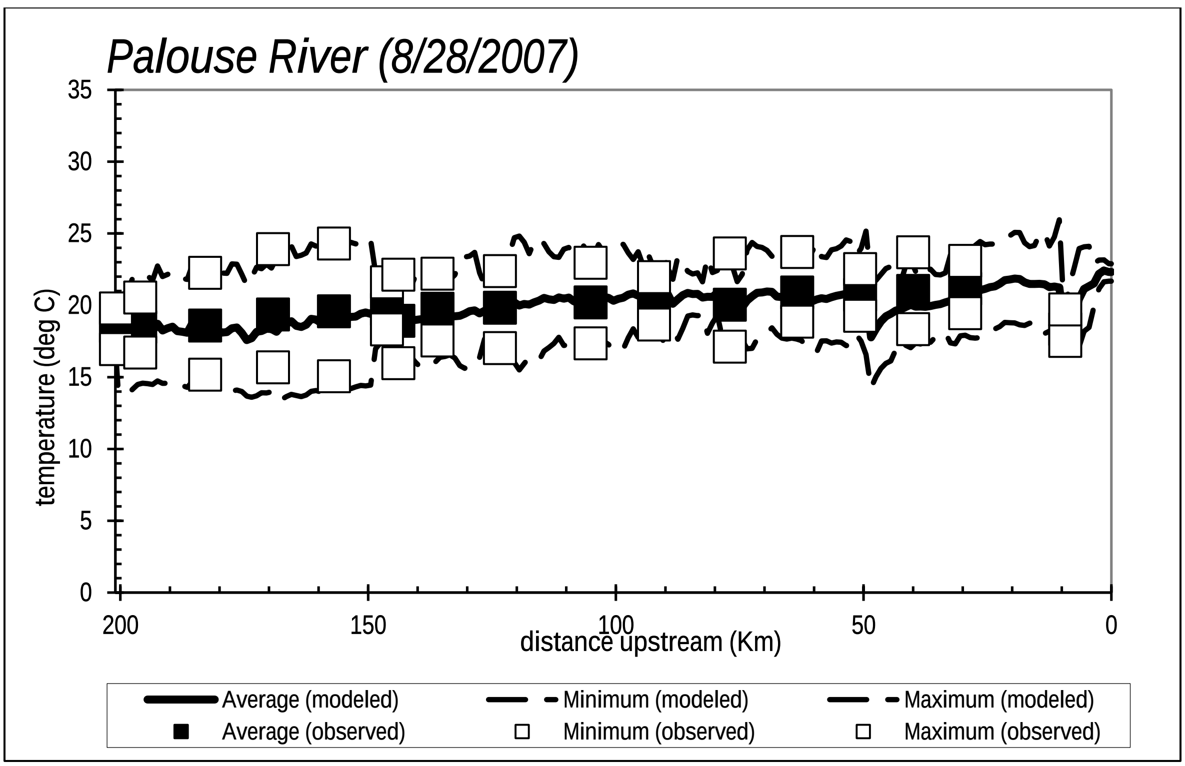

Figure 11. Modeled and observed temperatures in the Palouse River during August 25-31, 2007.

Calibration of rTemp model

An rTemp model was calibrated to a long-term record of continuous water temperature data for the purpose of being able to model stream temperatures over a long (multi-year) period of time. Ecology's Freshwater Monitoring Unit (FMU) maintains an ambient monitoring station at Bridge St. in Palouse (34A170, same as 34PAL120.3). This station is located about 600m upstream of Palouse WWTP's outfall. FMU has collected continuous temperature data at this site throughout the summer months from 2001 through present. Data from 2001-2011 were used for model calibration. For 2007, data collected as part of this study were used instead of the ambient data, because that datalogger was deployed for a longer portion of the year.

Model inputs are summarized in Table 5. Shade inputs change somewhat throughout the season, reflecting changes in the effective shade produced by vegetation as the sun traverses a lower path later in the summer.

Table 5. Calibration inputs used for rTemp model above Palouse WWTP.

Calibration Input	Data Source or Value Used
Shade	Shade model of current conditions. Varies from 6.5% (summer solstice) to 19.4% (end of October)
Depth	0.55m
Groundwater	None
Air temperature, dew point, cloud cover, wind speed	Pullman/Moscow Regional Airport

The goodness-of-fit for the rTemp model was summarized using the RMSE and overall bias as measures of the deviation of model-predicted stream temperature from the measured values (Table 6). Because rTemp is a spatially discrete model that predicts temperatures continuously, the RMSE and overall bias were calculated by comparing predicted and observed daily maximum and average temperatures for all dates from 2001-2011 when continuous water temperatures were recorded. Observed and predicted temperatures for a small portion of the modeled period are shown in Figure 12.

Table 6. Root mean squared error (RMSE) and overall bias of differences between the predicted and observed daily maximum and average temperatures (°C) for rTemp model.

Site Location	RMSE		Overall Bias	
	Maximum	Average	Maximum	Average
Palouse River at Bridge St. in Palouse (34A170, a.k.a. 34PAL120.3)	1.25	0.97	-0.03	+0.01

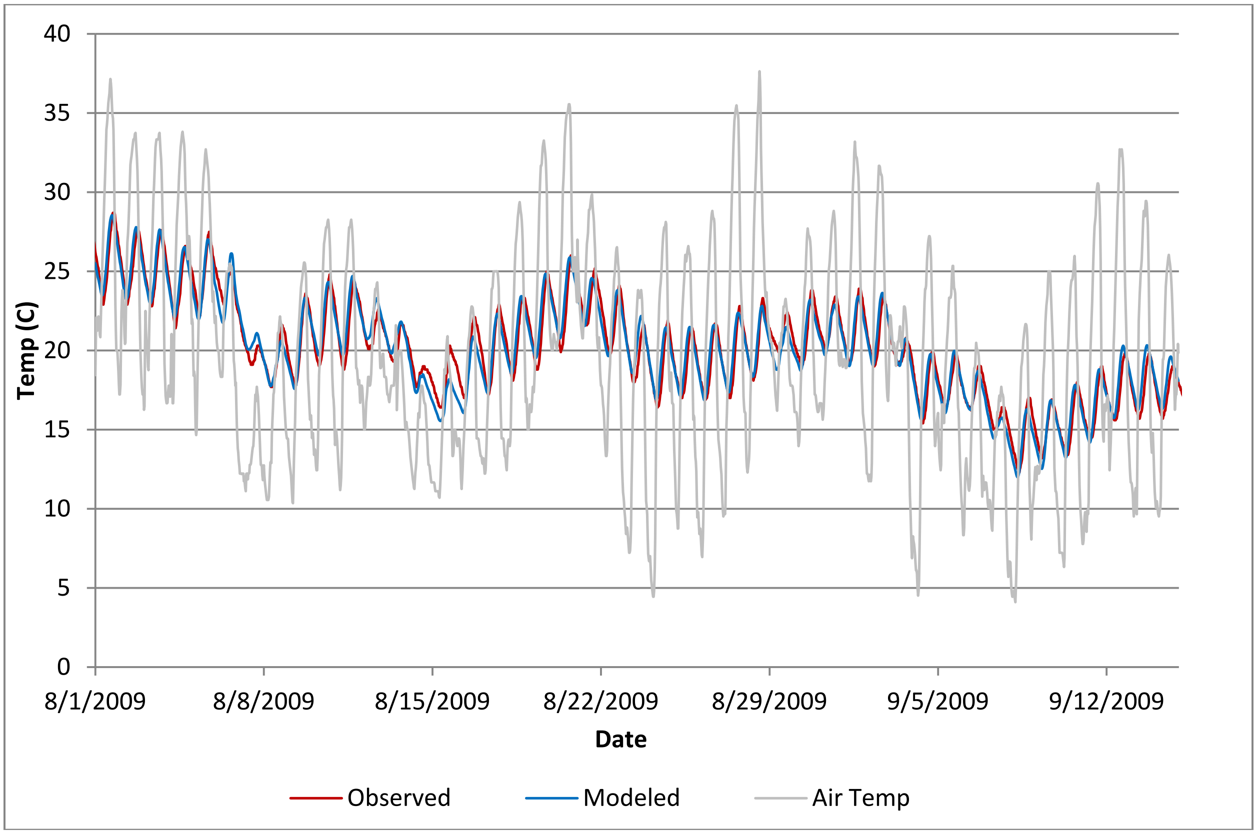

Figure 12. Modeled (rTemp) and observed temperatures in the Palouse River at Bridge St.

In order to model multiple years together, it was necessary to build the model to include the entirety of each year, including the winter months. However, the model calibration is only expected to be valid from May-October of each year, for two reasons:

- Continuous temperature data were not available before May or after October. Therefore, those periods of the model could not be calibrated to observed data.
- The shade model is only valid when deciduous trees and shrubs have their leaves on.

Therefore, only those model outputs from May-October are used.

Comparison of temperatures at Bridge St. and Hayton Green City Park

The Palouse River at Bridge St. site was chosen for rTemp calibration because it is located a reasonably short distance upstream of Palouse WWTP's outfall and because it has a multi-year dataset of continuous temperatures, ideal for calibrating a model to be used to evaluate multiple years of conditions. However, at very low flows the velocity of Palouse River becomes extremely sluggish. At around 3 cfs, typical velocities in the Palouse River between the Idaho state line and Colfax are estimated at around 0.08 ft/s (See "Time of Travel" section). At 0.08 ft/s, it would take about 7 hours for water to travel the 600m distance from Bridge St. to the Palouse WWTP outfall. There is considerable potential for temperatures to change in that distance.

In 2007, continuous stream temperatures were also collected at a piezometer site located at Hayton Green City Park, just upstream of the WWTP outfall. Figure 13 compares the daily maximum stream temperatures at these two sites. At low flows, daily maximum temperatures at the City Park site tend to be warmer than at Bridge St., probably because of a difference in stream depth. During August and September 2007, the average difference in daily maximum temperatures between the two sites was 1.0°C. The largest difference, which occurred on 9/3/2007, was 2.3°C.

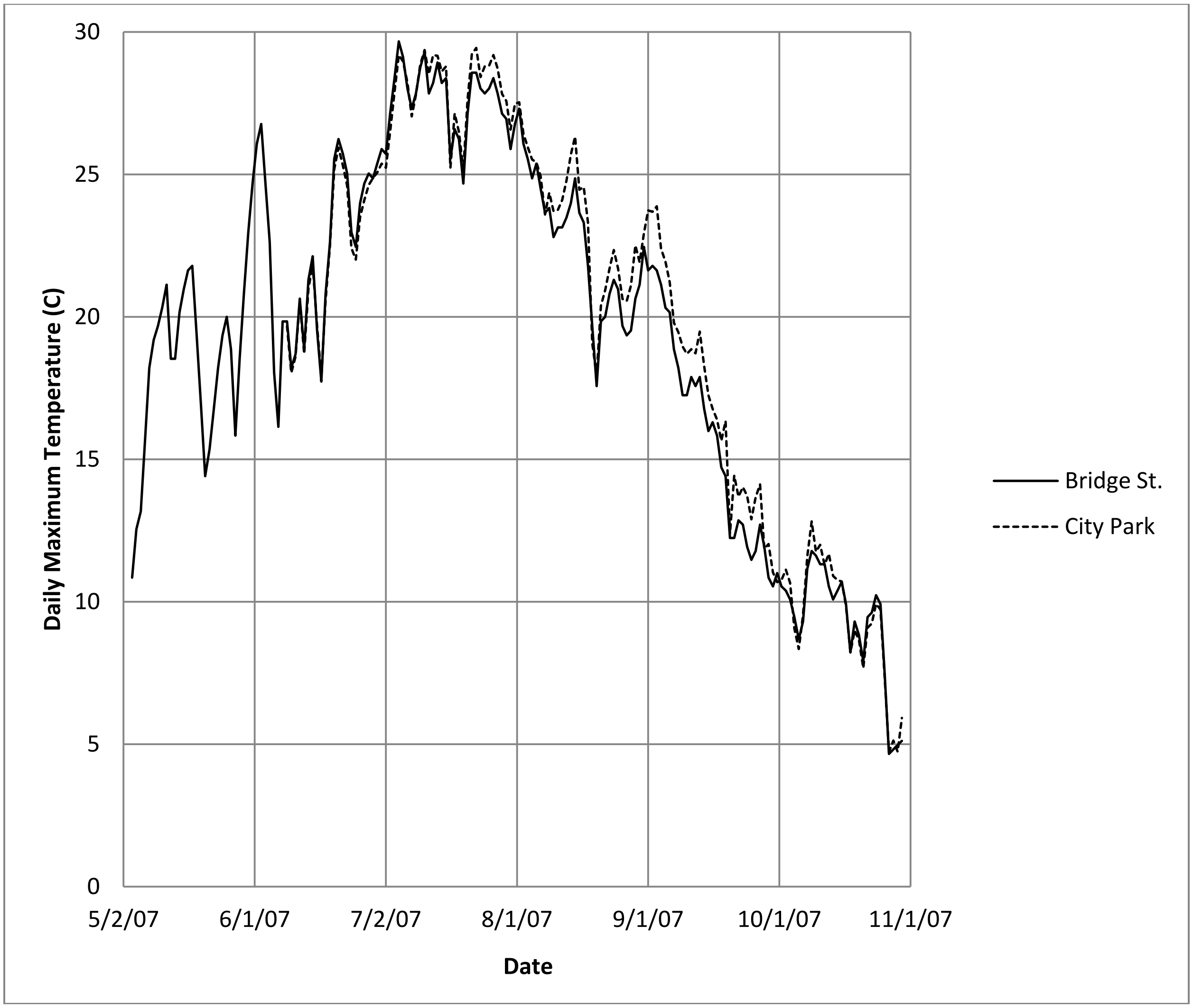

Figure 13. Comparison of daily maximum water temperatures in the Palouse River at Bridge St. and at Hayton Green City Park.

It is expected that rTemp model-predicted daily maximum temperatures, while accurately describing conditions at Bridge St., will be slightly cooler than summertime daily maximum temperatures directly above the outfall of the WWTP. For purposes of analyzing the effects of Palouse WWTP's effluent on stream temperatures, a tendency to under predict upstream background temperature is a conservative (more protective) assumption. Cooler background temperatures result in a need for cooler, and therefore more stringent effluent temperature controls. One way to think of this is that the difference between daily maximum temperatures observed at Bridge St. and the City Park, approximately 1-2°C at low flows, is similar in magnitude to the uncertainty (RMSE) of the rTemp model. The temperature difference between sites can be viewed as a margin of safety that erases the risk that model uncertainty might allow too permissive effluent temperature requirements at critical low flows.

Results and discussion

Water temperature data

Data from the 2007 TMDL study show that water temperatures in excess of the applicable 17.5°C and 20.0°C water quality standards are common throughout the Palouse watershed (Table 7, Figures 14-15). Water temperatures in excess of 29°C during the hottest time periods were observed in all parts of the Palouse River except for the monitoring station directly below Palouse Falls. The highest temperatures observed in the Palouse River were in the reach upstream of Colfax and downstream from Palouse, known locally as the North Fork Palouse River. Temperatures in excess of 30°C were observed at three stations in this reach, with one station recording temperatures over 33°C. Part of the reason for this is that the channel in that reach is exceptionally shallow, resulting in a large diel temperature range. The two Palouse River sites that typically had the highest daily maximum temperatures (34PAL103.9 and 34PAL98.3) also typically had the lowest daily minimum temperatures.

Temperatures at the mouths of the two largest tributaries of the Palouse River, the South Fork Palouse River and Rock Creek, were also quite warm, in excess of 27°C observed for the hottest time periods. Temperatures at the mouths of most of the other tributaries, including Union Flat Creek, which is a fairly large tributary, were somewhat cooler, generally less than 24°C. This is probably attributable to: (1) groundwater cooling and (2) the fact that riparian vegetation provides more effective shading to narrower streams. Downing Creek was observed to be much cooler than the other tributaries, with temperatures always below 18°C and usually below 17.5°C.

Table 7. Highest daily maximum temperatures in the Palouse River and its tributaries during 2007.

Sites are listed in downstream order.

Station ID	Station description	Latitude (decimal degrees)	Longitude (decimal degrees)	1-D Max[1] (ºC)	7-DAD Max[2] (ºC)	Temperature Criteria (ºC)
34PAL124.3	Palouse R at WA/ID state border	46.91232	-117.03821	29.08	28.33	20.0
34PAL120.3	Palouse R at Palouse off Bridge St (34A170)	46.90901	-117.07604	29.67	28.57	20.0
34PAL112.4	Palouse R at Altergott Rd	46.94714	-117.14549	30.82	30.28	20.0
34PAL103.9	Palouse R above Silver Ck in Elberton	46.98182	-117.22010	31.95	30.77	20.0
34SIL00.0	Silver Ck at Elberton near mouth	46.98199	-117.22019	23.17	21.99	17.5
34PAL98.3	Palouse R at Glenwood Rd	46.93021	-117.2851	33.06	31.18	20.0
34PAL91.5	Palouse R at Colfax, above South Fork Palouse R	46.88965	-117.36588	29.05	27.78	20.0
34SFPR00.1	South Fork Palouse at Colfax near mouth	46.88805	-117.36620	27.11	26.38	17.5
34PAL90.8	Palouse R below Colfax WWTP	46.89352	-117.38570	30.37	29.58	17.5
34PAL85.6	Palouse R at Manning, above Dry Ck	46.92902	-117.41676	29.24	28.65	17.5
34DRY00.0	Dry Ck at Manning near mouth	46.93171	-117.40809	31.24*	30.09*	17.5
34PAL77.8	Palouse R at Shields Rd Bridge (34A085)	46.95276	-117.50401	31.05	29.74	17.5
34PAL66.8	Palouse R at Endicott-St John Rd	46.99461	-117.61671	30.99	29.66	17.5
34LIT00.2	Little Valley Ck at Jones Rd near mouth	47.00422	-117.61807	23.09	22.45	17.5
34PAL59.0	Palouse R at Kackman Rd	46.98014	-117.71900	29.34	28.24	17.5
34DOW02.5	Downing Ck at Kackman Rd near mouth	47.00429	-117.72435	17.72	17.13	17.5
34PAL49.5	Palouse R above Rebel Flat Ck, Winona (34A080)	46.94487	-117.80351	30.86	29.64	17.5
34REB00.4	Rebel Flat Ck near mouth (34K050)	46.94324	-117.79787	18.91	17.67	17.5
34PAL41.1	Palouse R above Rock Ck	46.91156	-117.92780	31.36	29.00	17.5
34ROC00.1	Rock Ck near mouth	46.92979	-117.92287	27.77	26.43	17.5
34PAL33.4	Palouse R above Union Flat Ck	46.83805	-117.99717	29.94	28.14	17.5
34UNF00.5	Union Flat Ck at Wise Rd near mouth (34J050)	46.82805	-117.98643	23.08	21.32	17.5
34PAL25.7	Palouse R above Willow Ck, at Hwy 26	46.77349	-118.04175	30.14	28.96	17.5
34WIL00.0	Willow Ck near mouth	46.77124	-118.04116	22.58	22.01	17.5
34PAL19.5	Palouse R at Hooper (34A070)	46.75860	-118.14741	29.64	28.29	17.5
34COW00.6	Cow Ck near mouth at Grey Rd (34L050)	46.76566	-118.14721	35.03*	32.87*	17.5
34PAL06.7	Palouse R below falls at Palouse Falls State Park	46.66119	-118.22788	25.17	24.49	17.5

*Cow Creek and Dry Creek were dry during portions of the season. Cow Creek in particular was prone to go dry intermittently even before it completely went dry at the beginning of August. Although temperature measurements taken when the creek was intermittently dry were removed from the temperature record, it is possible that the high temperatures given could reflect stagnant water and/or air.

[1] 1-DMax = highest daily maximum temperature during 2007.
[2] 7-DADMax = highest 7-day average of daily maximum temperatures during 2007.

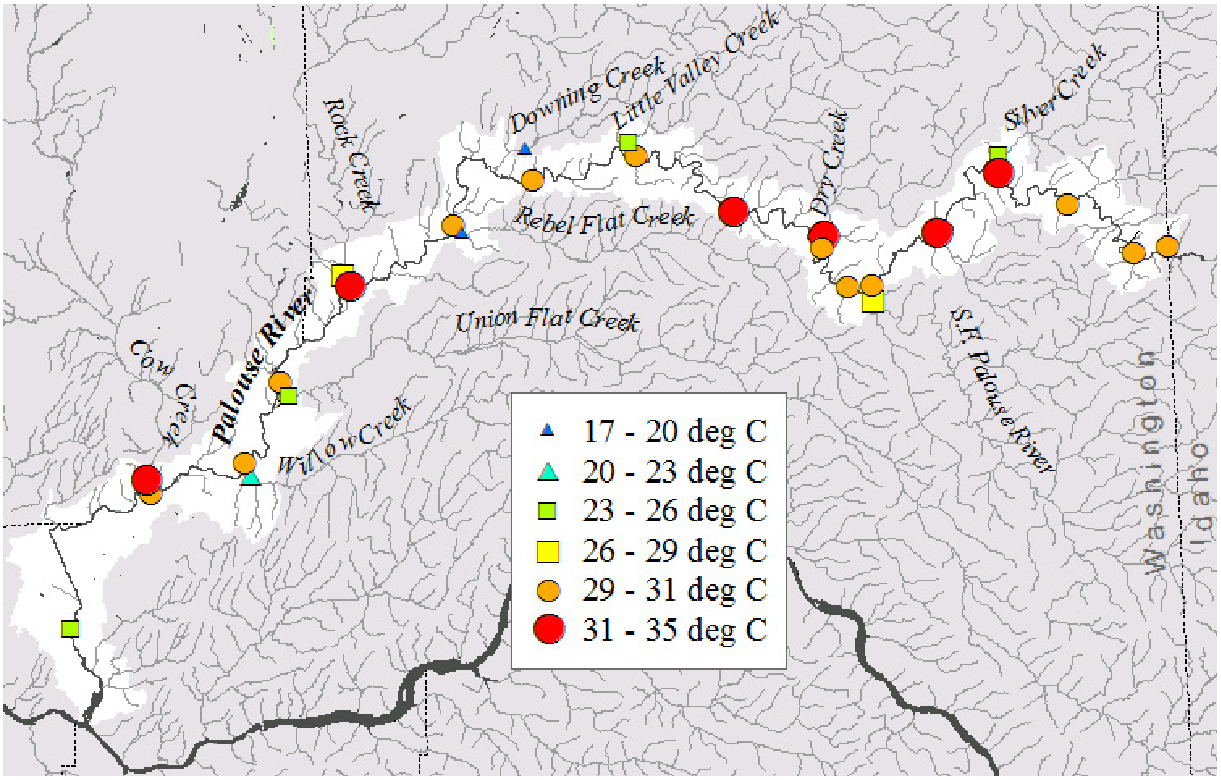

Figure 14. The highest daily maximum water temperatures in the Palouse River study area during 2007.

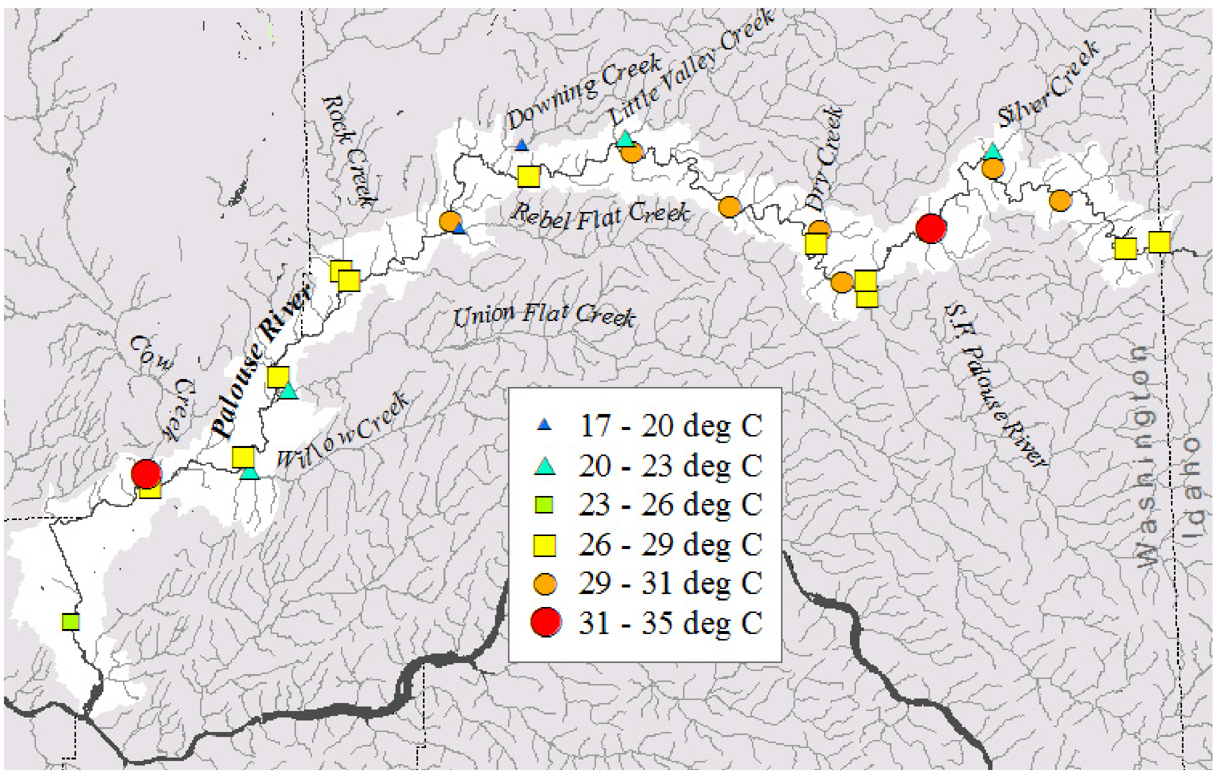

Figure 15. The highest 7-day averages of daily maximum water temperatures in the Palouse River study area during 2007.

Streamflows

Streamflows in the Palouse River have large seasonal variations. Average streamflows during March are 50-70 times those found during August. Additionally, it is common for short-duration flow spikes, often associated with rain-on-snow events, to occur January through March. The flow during these events can reach over 200 times the typical August flow commonly recorded at the USGS gage at Hooper. As streamflows subside during late spring and early summer, they leave behind a series of long pools through which water moves very sluggishly.

During low-flow conditions, streamflows in the Palouse River are generally higher further downstream. The South Fork Palouse River and Rock Creek each contribute a significant amount of flow, with flows in each of these two tributaries occasionally exceeding flows in the Palouse River upstream of the tributary.

It is expected that streamflows in the Palouse River would be significantly higher if it were not for irrigation withdrawals. Sinclair and Kardouni (2009) estimated a total of 37.5 cfs in active permitted withdrawals from the Palouse River. For comparison, the lowest flow recorded by the USGS gage at Hooper in 2007 was 7.8 cfs.

Figure 16 shows flow conditions in the study area during August 27-29, 2007.

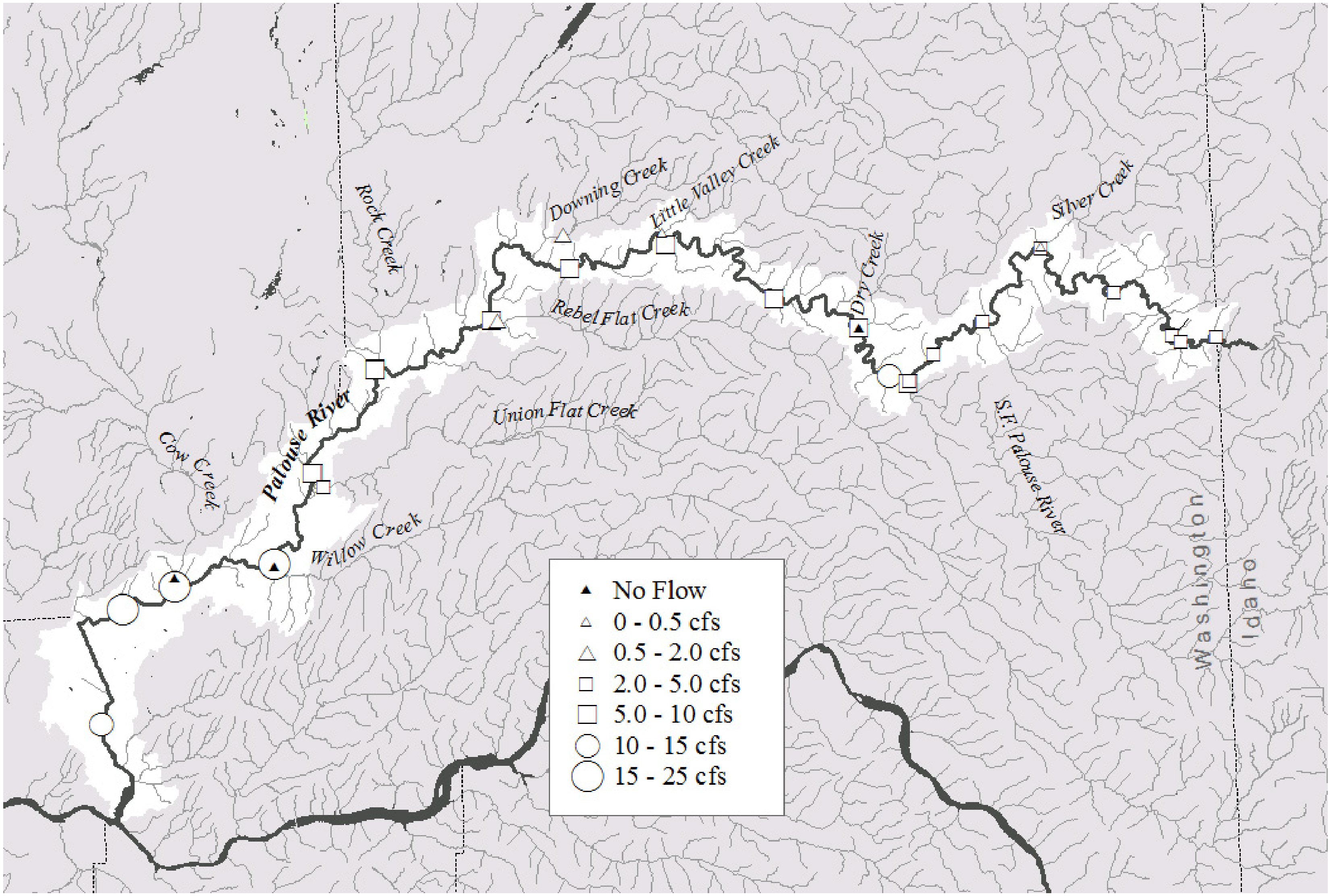

Figure 16. Measured and gaged streamflows, August 27-29, 2007.

Time of travel

The time of travel for the Palouse River, which is the average amount of time it would take for a drop of water to move from the Idaho/Washington state line near Palouse to the mouth at Lyons Ferry, is presented in Table 8 under moderate and low-flow conditions. Complete dye study data are available in Appendix D.

Table 8. Time-of-travel and average velocity estimates for the Palouse River.

Palouse River Reach Description	May 23-25, 2007		August 16-26, 2007	
	Time of Travel (days)	Average Velocity (ft/s)	Time of Travel (days)	Average Velocity (ft/s)
WA/ID state line to S. Fork Palouse confluence in Colfax	2.7**	0.73**	26*	0.08*
S. Fork Palouse confluence in Colfax to Rebel Flat confluence at Winona	3.5*	0.74*	31*	0.08*
Rebel Flat confluence at Winona to mouth at Lyons Ferry	2.3**	1.29**	21*	0.14*
Total distance from state line to mouth	8.5	0.88	78	0.10
Avg. streamflow at USGS Potlatch Gage	73 cfs		3.1 cfs	
Avg. streamflow at USGS Hooper Gage	233 cfs		13 cfs	

*The time of travel and velocity estimates for these reaches are based partially on dye measurements. Velocities for portions of these reaches not covered by the dye study were estimated based on reaches that were measured, while accounting for known stream gradient, channel depth, etc.

**These time of travel and velocity estimates were estimated by comparison to measured reaches. This was done by assuming that the ratio of velocities observed in two different reaches during August (e.g., 0.08 ft/s : 0.08 ft/s = 1:1) would stay constant during May. These estimates should be used with caution.

The time of travel measurement at low flow, 78 days, is so long as to be a somewhat meaningless abstraction. In reality, the period of extreme low flows does not last 78 days. At low flow, the forward motion of water down the course of the river comes almost to a stop except at riffles and glides. Therefore, a drop of water in the Palouse River at the Washington/Idaho state line at the beginning of the low-flow period will not reach the mouth of the river before flows increase in the fall and flush it out.

Because summertime velocities in the Palouse River are so low and times of travel so long, stream temperatures during the critical period were not found to be very sensitive to changes in flow. Extremely low velocities, and therefore minimal advective transport, mean that water temperatures in a given location are the result of extremely localized influences of weather, shade, and groundwater interaction, and have little to do with upstream conditions. Even at times during late spring and early summer when flows are higher, temperatures in the upstream part of the river are already so warm that downstream transport of water does not improve temperatures. To the extent that changes in streamflow do affect temperature, they do so by altering the depth of the stream and therefore the size of diel temperature fluctuations.

Seasonal variation

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

Existing conditions for stream temperatures in the Palouse River watershed reflect seasonal variation. Cooler temperatures occur in the winter, while warmer temperatures are observed in the summer. Table 7 and Figures 14 and 15 summarize the highest daily maximum and the highest 7-day average maximum water temperatures for 2007. These figures include all data gathered by Ecology. The highest temperatures typically occur during July and August. This timeframe is used as the critical period for development of the TMDL.

Seasonal estimates for streamflow, solar flux, and climactic variables for the TMDLs are taken into account to develop critical conditions for the TMDL model. The critical period for evaluation of solar flux and effective shade was assumed to be July 6-12. This time was chosen to represent extreme climactic conditions. This week corresponds to a stable period of temperatures representing the highest air and water temperatures observed during 2007. These temperatures were abnormally hot, being near the 90th percentile for July average air temperatures.

The time period from August 25-31 was chosen to represent a less extreme, but still very warm, climactic condition with critical low flows. Flows throughout the basin were below average during 2007. Streamflows upstream of Colfax during mid-August were equivalent to the lowest 7-day average streamflow that could be expected to occur once every ten years (7Q10).

Loading capacity

The loading capacity is the maximum amount of a given pollutant that a water body can receive without violating water quality standards. Loading capacities for the Palouse River are the solar radiation heat loads that either allow stream temperatures to stay below the numeric criteria, or else not exceed the natural condition by more than 0.3°C.

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

Palouse River

A system potential temperature is estimated for both a critical climactic condition, represented by July 6-12, 2007, and for a critical low-flow condition, represented by August 25-31, 2007. The system potential temperature approximates natural conditions. The water quality standards require streams to meet their assigned numeric criteria or natural conditions. Therefore, when modeling predicts the river cannot meet temperature numeric criteria under system potential conditions, then the system potential temperature plus 0.3 degrees must be met. If the system potential temperature is below the numeric criteria (at other times of the year or at other less extreme low flows and warm climatic conditions), then the numeric criteria apply.

At locations and times where the system potential temperature is predicted to be greater than the numeric criterion assigned to the water body (i.e., 20ºC in the mainstem Palouse upstream of the South Fork Palouse River and 17.5ºC everywhere else), the loading capacity and load allocations in this TMDL are to be based on not allowing human sources to warm the water by more than an additional 0.3°C. However for this TMDL, in all waters where the system potential temperature is predicted to be higher than the assigned criterion, maximum riparian shade appropriate for the reach and the best channel and flow conditions possible are needed as a margin of safety to ensure compliance with standards.

The calibrated QUAL2Kw model was used to predict the loading capacity for effective shade for the Palouse River. Loading capacity was established based on prediction of water temperatures under critical conditions combined with predicted system potential shade conditions.

The results of the model runs at current and system potential shade conditions are presented in Figures 17 and 18 for two different dates. The current condition in the Palouse River results in daily maximum temperatures that not only exceed the 17.5ºC and 20.0ºC standards, but are in excess of 27ºC in nearly all reaches during July 6-12, 2007 climate and flow conditions. Under current riparian conditions, the entire river is known to be hotter than the approximate lethality threshold of 22ºC for salmonids. The lethality threshold refers to the following excerpt from an Ecology study (Hicks, 2002) that evaluates lethal temperatures for coldwater fish:

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

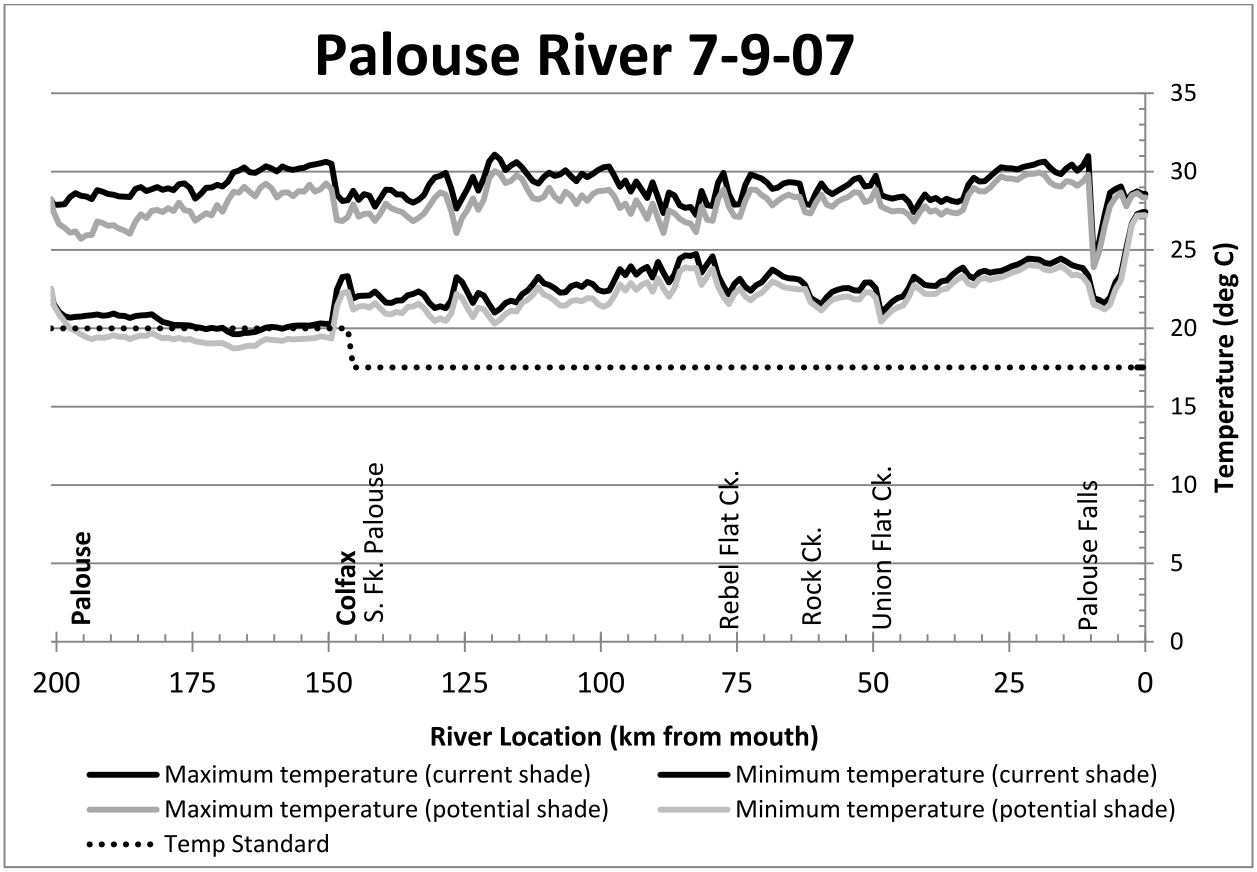

Figure 17. Predicted 7-day maximum and minimum temperatures in the Palouse River for July 6-12, 2007.

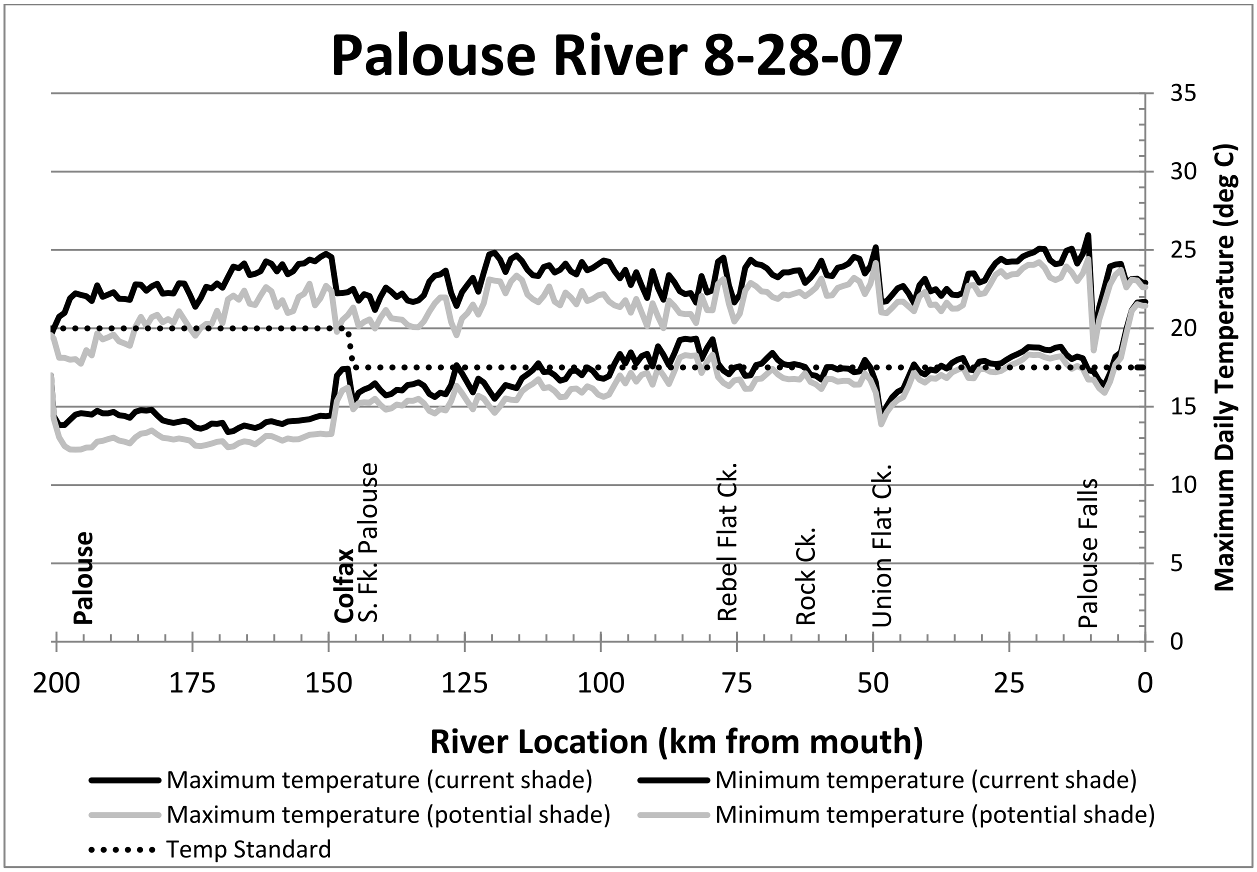

Figure 18. Predicted 7-day daily maximum and minimum temperatures in the Palouse River for August 25-31, 2007.

Moderate reductions in water temperature are predicted for hypothetical conditions with system potential mature riparian vegetation. Potential reduced maximum temperatures under critical conditions are still predicted to exceed both the 17.5ºC and 20 ºC criteria and the 22ºC salmonid lethality limit. However, under the more moderate summertime conditions represented by August 25-31, 2007, system potential mature riparian vegetation is expected to result in maximum temperatures that do not exceed 22ºC on many parts of the Palouse River.

The reach extending from Palouse to Colfax is expected to realize the largest reductions of 1.6°C for July 6-12, 2007 conditions, and 2.2°C for August 25-31, 2007 conditions. The reach from Colfax to the mouth of Rebel Flat Creek at Winona is expected to cool by 1.2°C for July 6-12, 2007 conditions, and 1.7°C for August 25-31, 2007 conditions. The reach from Winona to the mouth at Lyons Ferry is expected see the smallest temperature reductions, 0.8°C for July 6-12, 2007 conditions, and 1.0°C for August 25-31, 2007 conditions.

The reason that larger temperature reductions are expected under August 25-31, 2007 conditions is that riparian vegetation is more effective at providing shade to the stream surface later in the summer when the sun traces a lower path through the sky. This means that although system potential shade may not result in water temperatures that meet standards during the critical period, this shade can bring temperatures into compliance earlier in September than under current shade conditions.

Larger temperature reductions are expected in some of the upstream reaches of the Palouse River for two reasons. First, riparian areas in the eastern part of the watershed are capable of supporting vegetation that is better able to provide stream shading (Figure 19, Table 9). Second, the river channel is narrower further upstream, increasing the effectiveness of shading from riparian vegetation in these reaches. The low-flow river channel width averages about 15 meters (49 ft) in the reach from the Idaho state line to Colfax, about 19 meters (62 ft) in the reach from Colfax to the mouth of Rebel Flat Creek, and about 23 meters (75 ft) in the reach from the mouth of Rebel Flat Creek to the mouth.

Potential temperature reductions are limited along the entire Palouse River because of two factors. First, the river channel widths previously mentioned are wide relative to the height of potential vegetation. Second, the high springtime streamflows, which as previously mentioned are many times greater than summertime low flows, create a near-stream disturbance zone which is typically vegetated by reed canary grass during the summer. This area is covered with deep and/or swift water during spring runoff, so few shrubs or trees grow there. Thus, even the maximum potential vegetation would be set back from the edges of the water, further limiting its effectiveness at shading an already wide river. One exception to this is that certain species of native willows can handle springtime inundation. These species are the primary contributors of shade on the lower reaches of the Palouse River.

Tributaries

Within the QUAL2Kw model, tributaries were modeled only as inputs into the mainstem Palouse River, with a specified flow and temperature. Separate temperature models were not created for tributaries, and system potential temperatures were not estimated. However, it is expected that larger temperature reductions are possible in the tributaries than in the Palouse River with the implementation of system potential riparian vegetation. This is because riparian vegetation is more effective at shading narrower stream channels.

Load allocations

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

Since it is predicted that system potential temperatures would not meet numeric water quality standards during the hottest period of the year throughout most of the Palouse River basin, there is a widespread need to achieve maximum protection from direct solar radiation. While all tributaries should also have system potential vegetation to ensure water quality standards are met for those streams, the lower two miles of each tributary are important to the Palouse River achieving water quality standards.

The load allocation for the mainstem Palouse River below the Washington/Idaho state line, and the two miles of each study area tributary nearest its mouth, is the potential shade that would occur from system potential mature riparian vegetation. *System-potential mature riparian vegetation* is defined as *that native vegetation which can grow and reproduce on a site, given: climate, elevation, soil properties, plant biology, and hydrologic processes.*

Because of the inherent uncertainties in estimating system potential shade, the 0.3°C that would normally be assigned to human sources is retained as a margin of safety and/or assigned to the stormwater and wastewater discharge point sources.

Load allocations for effective shade are quantified in Appendix C for the Palouse River and for the lower two miles of each tributary in the watershed. The load allocations are based on the estimated relationship between shade, channel width, and stream aspect at the maximum riparian vegetation condition (shown in Figure 19 and Table 9). The importance of shade decreases as the width of the channel increases. Figure 20 presents predicted system potential and current effective shade on the Palouse River.

The load allocations are expected to result in water temperatures that are equivalent to the temperatures that would occur under natural shade conditions. Because anthropogenic changes to stream temperature can result from causes other than the removal of shade, the implementation plan for this TMDL also includes a variety of measures to address channel widening, hydrograph changes, and other factors. Implementation of these measures, as well as system potential vegetation, will help ensure that water temperatures will approach natural conditions.

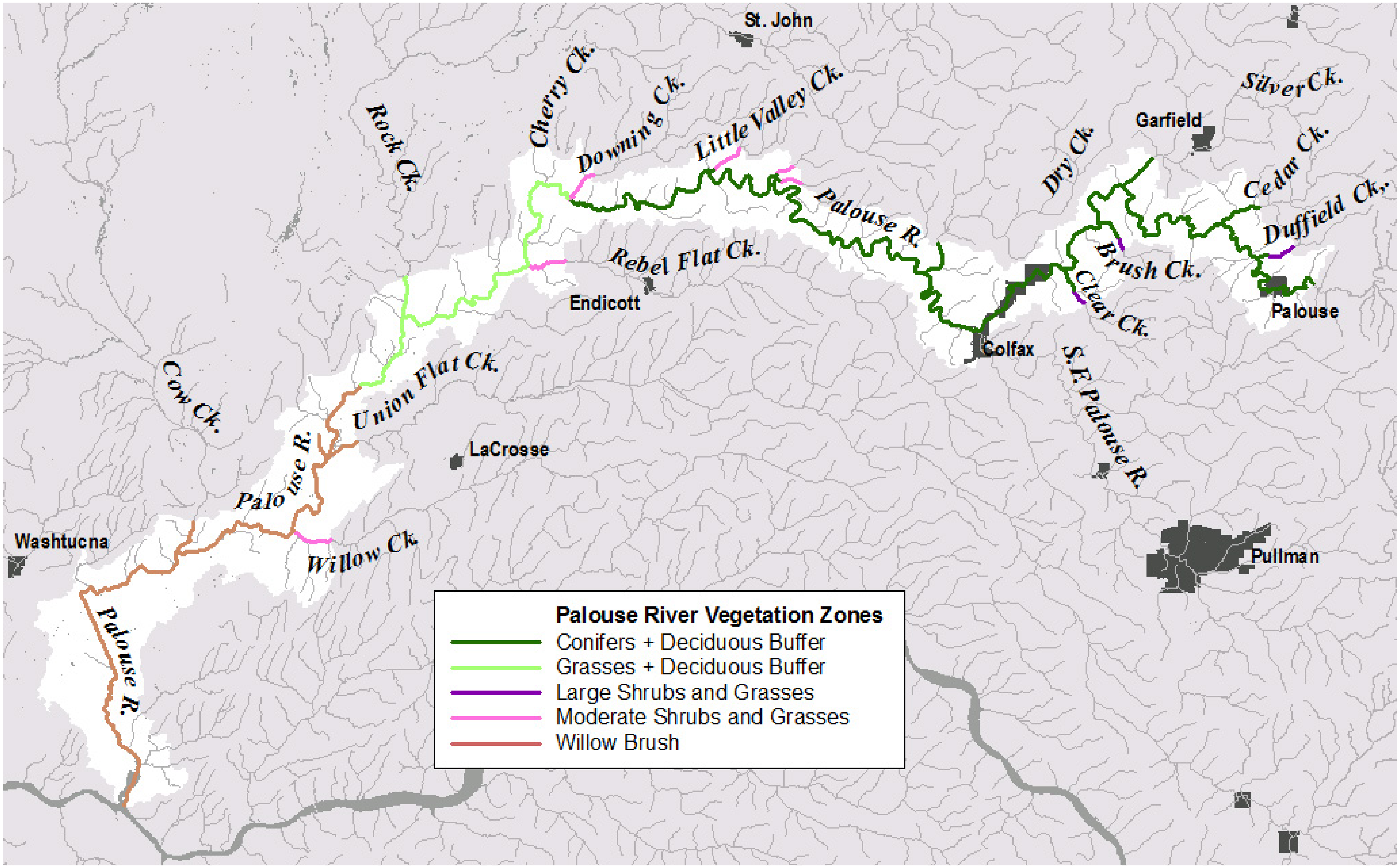

Figure 19. Map of potential vegetation zones in the Palouse River basin.

Refer to Table 9 for a description of zones.

Table 9. Description of potential vegetation zones for the Palouse River basin.

Potential Vegetation Zone	Height Dominant Plants	Max Height (m)	Canopy Density	Overhang Distance (m)	Height Rationale	Density Rationale
Conifers + Deciduous Buffer	*First 30m back from NSDZ[1]:* Black cottonwood, quaking aspen, ponderosa pine, black hawthorn, birch, alder, willow	28	30%	2.2	Based on 90th percentile of heights of black cottonwoods measured during vegetation surveys for the S.F. Palouse	Based on cottonwoods with ~90% canopy density[3] × ~30% bank coverage ~30% density
	After 30m back from NSDZ: Ponderosa pine (west of Colfax); ponderosa pine + Douglas-fir (east of Colfax)[2]	30	15%	2.0	Soil survey site index values for ponderosa pine and Douglas-fir	Based on open ponderosa pine forest
Grasses + Deciduous Buffer	*First 30m back from NSDZ:* Black cottonwood, quaking aspen, black hawthorn, birch, alder, willow	28	20%	2.2	Based on 90th percentile of heights of black cottonwoods measured during vegetation surveys for the S.F. Palouse	Based on cottonwoods with ~90% canopy density[3] × ~20% bank coverage ~20% density
	After 30m back from NSDZ: Grasses[2]	0.5	50%	0.1	Typical grass height	Grasses; this area may also include sagebrush and other desert shrubs
Large Shrubs and Grasses	Black hawthorn, mixed alders, and willows	10	55%	1.0	Measured height of mature hawthorns along S.F. Palouse near Pullman	~75% canopy density[4] × ~70% bank coverage ~55% density
Moderate Shrubs and Grasses	Black hawthorn, mixed alders, and willows	7	38%	0.7	Estimated height of shrubs in drier parts of the watershed	~75% canopy density[4] × ~50% bank coverage ~38% density
Willow Brush	Coyote Willow	4	38%	0.4	Estimated typical height of coyote willow	~50% canopy density[5] × ~75% bank coverage ~38% density

[1] NSDZ = Near-Stream Disturbance Zone. In most systems, the NSDZ consists of areas where no riparian vegetation grows due to springtime high flows. For the Palouse River, the term NSDZ is being used to include areas where reed canary grass grows, but where shrubs and trees cannot.
[2] These represent upland potential vegetation types, as described in the Methods section.
[3] This canopy density is estimated from hemispherical photos taken under cottonwoods foliage in the Ellensburg, Washington area, as no hemispherical photos were taken under cottonwoods during this project. For these two vegetation zones, the deciduous buffers would actually consist of somewhat scattered cottonwoods with a more continuous band of shorter vegetation including hawthorn, alder, and willow. This could alternately be represented as Height = 9.1, Density = 75%, as was done for the Hangman Creek TMDL (Joy et al. 2009). Hangman Creek is in the same ecoregion as the eastern part of the Palouse River and would have similar vegetation. The Hangman Creek parameters were also tried in the Shade model and found to provide a very similar amount of shade to the stream as the parameters shown here.
[4] This canopy density is estimated from hemispherical photos taken underneath hawthorn brush near the South Fork Palouse River.
[5] This canopy density is estimated from hemispherical photos taken at the banks of the Palouse River under coyote willow foliage, at 34PAL06.7, 34PAL19.5, and 34PAL25.7.

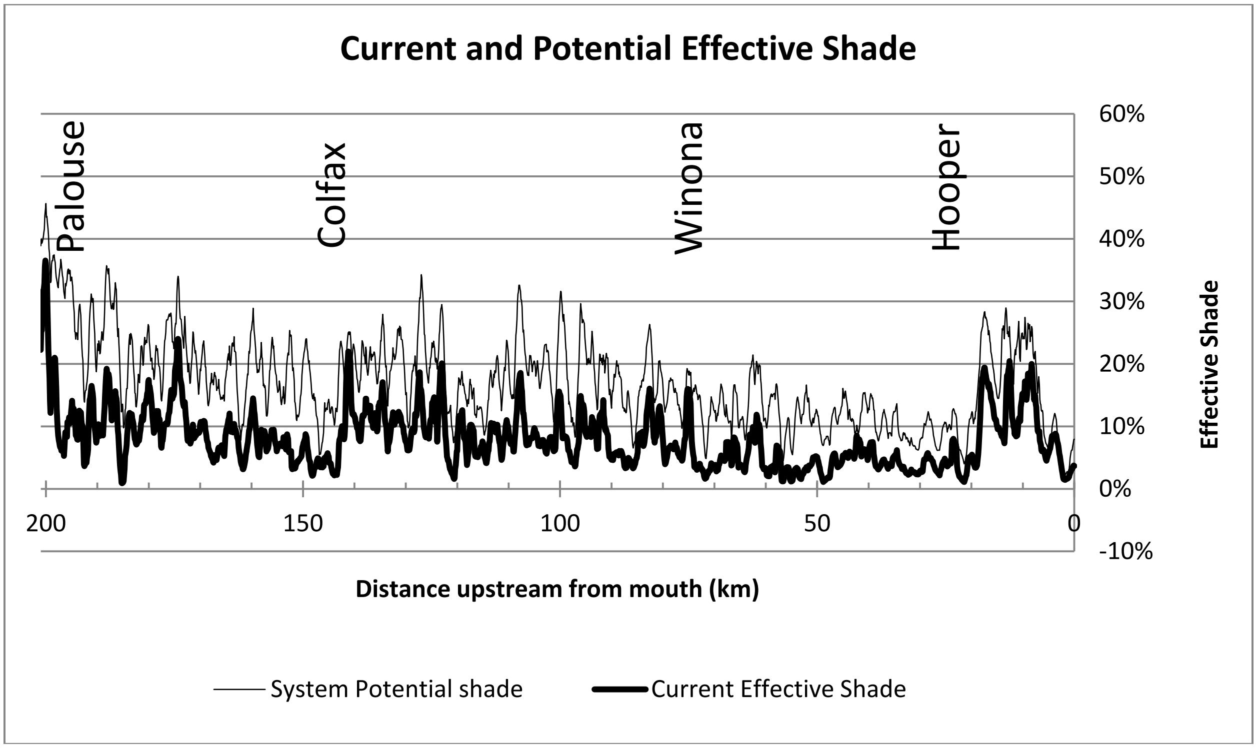

Figure 20. 1-km rolling average of effective shade from current and potential mature vegetation on the Palouse River, calculated for the July 9, 2007 time period.

Washington Department of Transportation

In Washington the Department of Transportation's (WSDOT) stormwater is considered both nonpoint source and point source. It is a point source in areas covered by their NPDES Municipal Stormwater Permit and nonpoint outside the coverage area. WSDOT's permit coverage includes all Phase I and Phase II municipal areas and it can include TMDL areas if Ecology assigns wasteload allocations and/or specific implementation actions in the TMDL to WSDOT. Since the TMDL critical period is during the drier summer months when rainfall is limited, the highways and facilities do not have significant quantities of standing water during this time that warm up and discharge to the river. Stormwater discharges from these highways/roadways are not expected to result in a violation of standards. Therefore, WSDOT is being given a load allocation instead of a wasteload allocation for any stormwater discharges within the TMDL area.

To meet water quality standards, human caused discharges must not cumulatively raise the 7-DADMax temperature 0.3˚C above natural conditions. Therefore, WSDOT's load allocations for stormwater are based on not causing more than a 0.2°C cumulative increase in the background (upstream) receiving water 7-DADMax temperature. The remaining 0.1°C is retained as a margin of safety. When the background (upstream) receiving water temperature exceeds or is within 0.3°C of 17.5°C or 20˚C (depending on point of compliance and water quality standards at that location), the cumulative discharge from all WSDOT sources may not cause the 7-DADMax to increase more than 0.2°C. This is expressed by the following equation:

$$LA_{crit} = \frac{\sum_{N=1}^{7}(\Delta T * Q_N * C_F)}{7}$$

Where:
LA_{crit} = the critical period wasteload allocation in Kilocalories/day
ΔT = allowable cumulative temperature increase for point sources = 0.2°C
Q_N = daily receiving water flow, in cfs
N = day 1 through 7 or the 7DAD averaging period
C_F = 2,446,665 (kcal·sec)/°C·ft^3·day (a conversion factor to transform the units to Kilocalories/day)

Since it is unlikely a storm event will result in enough thermal pollutant loading to violate this load allocation, compliance with this Palouse TMDL will be met by following the recommendations outlined in the implementation plan at the end of this report. The load allocations (LA) equation will be used for determining compliance for any stormwater monitoring conducted. If new evidence reveals WSDOT stormwater is a source of heating that results in raising stream temperature, this load allocation will be changed to a wasteload allocation.

Wasteload allocations

NPDES dischargers in the study area are listed in Table 10. Each of these facilities is regulated under a National Pollutant Discharge Elimination System (NPDES) permit which sets limits on the discharge to meet water quality standards. Wasteload allocations (WLA) have been given to the cities of Palouse and Colfax as well as to stormwater general permittees. No wasteload allocation has been given to the Sand and Gravel general permittees, as they do not discharge to a water body.

Table 10. Point source permits that discharge to, or are adjacent to, the Palouse River.

Facility	Facility Type	Permit #	Discharges to	Discharge Frequency
Palouse WWTP	Municipal IP	WA0044806C	Palouse River	Year-round, continuous
Colfax WWTP	Municipal IP	WA0020613B	Palouse River	Year-round, continuous
Empire Disposal	Industrial Stormwater GP	WAR010082	Palouse River via City of Colfax municipal storm system	Occasional
WA DOT QS-P-34 Wilbur-Ellis	Sand and Gravel GP	WAG507132	Does not discharge	
Seubert Excavators Portable Crusher 1	Sand and Gravel GP	WAG500055		

IP: Individual Permit. GP: General Permit.

Palouse Wastewater Treatment Plant

The Palouse WWTP discharges water to the Palouse River at river mile 120, approximately 4 miles downstream of the Washington/Idaho state line.

It is expected, based on modeling predictions, that summertime stream temperatures at the point of discharge would exceed the 20°C numeric criterion even under system potential (natural) conditions. The maximum allowable effluent temperature needs to ensure the stream temperature under natural conditions would not be increased by more than 0.3°C [WAC 173-201A-200(1)(c)(i)]. At times when the stream temperature is cooler than 20°C, incremental temperature increases are not allowed to exceed 34/(T+9), where T is the upstream temperature (WAC 173-201A, Table 602, WRIA 34).

Palouse WWTP NPDES discharge is assigned a conditional maximum temperature wasteload allocation, based on upstream flow:

$$T_{NPDES} = [20°C – 0.3°C] + [\textit{dynamic dilution factor}] * 0.3°C$$

The dilution factor is the reciprocal of the volume fraction of effluent contained in the diluted plume at the edge of the mixing zone. An equivalent way of expressing this is the ratio of effluent volume plus volume of ambient dilution water to the effluent volume. The dynamic dilution factor is recalculated each day depending on effluent and receiving water flow conditions. Ecology follows Washington State's mixing zone regulations (WAC 173-201A-400) when determining the allowable extent of the mixing zone. It is outside the scope of this study to develop a dilution model that would be valid over a range of flow and temperature conditions. Therefore, 25% of the upstream flow, as stipulated in the regulation, is used for mixing at all times.

The dynamic dilution factor is recalculated daily as:

$$\textit{Dynamic dilution factor} = \frac{(0.25 \times \textit{Upstream flow}) + (\textit{Effluent flow})}{\textit{Effluent flow}}$$

Where:

Upstream flow is the daily average flow measured at the USGS gage in Potlatch.
Effluent flow for a given month is the highest monthly average flow for that month measured in the previous three years.

Table 11 presents the highest monthly average effluent flows at Palouse WWTP from 2010-2012.

Table 11. Highest monthly average effluent flows at Palouse WWTP from 2010-2012.

Month	Effluent Flow (cfs)
January	0.17
February	0.13
March	0.22
April	0.20
May	0.13
June	0.10
July	0.088
August	0.087
September	0.084
October	0.091
November	0.11
December	0.13

Maximum effluent temperatures are never allowed to exceed 33°C to avoid creating areas in the mixing zone that would cause instantaneous lethality to fish and other aquatic life.

Table 12 presents the flow-conditional temperature wasteload allocation that would occur during different months at various streamflows. The wasteload allocations in this table are calculated using the previous two equations and the effluent flows in Table 11. If there is a change in the highest monthly average effluent flows at the Palouse WWTP, the values in Table 12 will need to be recalculated. In this event, the wasteload allocation should be considered the value that results from the equations rather than the values in Table 12.

Table 12. Flow-conditional effluent temperature wasteload allocation for Palouse WWTP, based on month and river flow.

Month		May	June	July	August	September	October	November-April*
Potlatch Q		*Effluent Limits in degrees C*						
0.2		20.1	20.2	20.2	20.2	20.2	20.2	20.1
0.4		20.2	20.3	20.3	20.3	20.4	20.3	20.1
0.6		20.3	20.5	20.5	20.5	20.5	20.5	20.2
0.8		20.5	20.6	20.7	20.7	20.7	20.7	20.3
1		20.6	20.8	20.9	20.9	20.9	20.8	20.3
1.2		20.7	20.9	21.0	21.0	21.1	21.0	20.4
1.4		20.8	21.1	21.2	21.2	21.3	21.2	20.5
1.6		20.9	21.2	21.4	21.4	21.4	21.3	20.5
1.8		21.0	21.4	21.5	21.6	21.6	21.5	20.6
2		21.2	21.5	21.7	21.7	21.8	21.6	20.7
2.5		21.4	21.9	22.1	22.2	22.2	22.1	20.9
3		21.7	22.3	22.6	22.6	22.7	22.5	21.0
3.5		22.0	22.6	23.0	23.0	23.1	22.9	21.2
4		22.3	23.0	23.4	23.4	23.6	23.3	21.4
4.5		22.6	23.4	23.8	23.9	24.0	23.7	21.5
5		22.9	23.8	24.3	24.3	24.5	24.1	21.7
5.5		23.2	24.1	24.7	24.7	24.9	24.5	21.9
6		23.5	24.5	25.1	25.2	25.4	24.9	22.0
6.5		23.8	24.9	25.5	25.6	25.8	25.4	22.2
7		24.0	25.3	26.0	26.0	26.3	25.8	22.4
7.5		24.3	25.6	26.4	26.5	26.7	26.2	22.6
8		24.6	26.0	26.8	26.9	27.1	26.6	22.7
10		25.8	27.5	28.5	28.6	28.9	28.2	23.4
15		28.7	31.3	32.8	32.9	33.0	32.4	25.1
20		31.5	33.0	33.0	33.0	33.0	33.0	26.8
40	+	33.0	33.0	33.0	33.0	33.0	33.0	33.0

*For simplicity, the November-April period is treated together. Effluent flows from March (0.22cfs) are used. This will not make a difference, as effluent temperatures do not exceed 20°C during this time period.

Key:

Dark gray	Potlatch Q has never been low enough during this month to require these effluent temperatures.
Light gray	Effluent temperature has never been this high during this month.
Orange	River flow is less than seasonal 1Q10 (1.69cfs) which means these conditions are likely to only be encountered one day in every 10 years.
White	River flow is greater than seasonal 1Q10 (1.69cfs), and there is a potential for violation given historical effluent temperatures.

Ultimately a temperature wasteload allocation is a limit on heat load. Table C-8 of Appendix C shows the allowed heat load based on the upstream temperature. The expression of the wasteload allocation as an allowed temperature based on flow described previously is one way to achieve this limit. An alternative expression of the wasteload allocation as a flow limit based on effluent temperature is shown in Table C-9.

Evaluation of protectiveness

To ensure that the flow-based conditional wasteload allocations are adequately protective of the water quality standards, a continuous simulation analysis was used to evaluate the wasteload allocations. First, the shade model was used to calculate system potential shade in the vicinity of Palouse, continuously throughout the course of a summer. Then, this system potential shade was input to the calibrated rTemp model of the Palouse River at Bridge St. The entire available weather record from Pullman-Moscow Regional Airport, 39 years dating back to 1974, was also input to the model. Finally, the rTemp model was used to simulate a 39-year record of system potential temperatures. System potential temperatures provide an estimate of the temperatures that would be expected to occur under natural conditions.

For each day during May-October of 1974-2012, the daily average streamflow at the Potlatch USGS gaging station was used to calculate the flow-conditional wasteload allocation (T_{NPDES}) that would have applied that day. Then, given that daily T_{NPDES} value, that day's daily maximum stream temperature under system potential conditions, the applicable effluent flow from that month, and 25% of the daily streamflow, a mass-balance mixing equation was used to calculate the temperature change that would have been expected to occur at the edge of the mixing zone.

By comparing edge-of-mixing-zone temperature change that would result from the flow-conditional effluent temperature wasteload allocation (WLA) with the requirements of the water quality standard, it is possible to test the protectiveness of the WLA under a realistic variety of weather and streamflow conditions. Thirty-nine years provides a more than sufficient record to elucidate any instances where the WLA might not be protective enough, and to indicate how often those instances might be expected to occur (EPA, 1991). The water quality standards allow for an exceedance to occur no more than one day out of every 10 years on average [WAC 173-201A(1)(c)(iii)].

It should be emphasized that this simulation was *not* intended to portray any circumstance that actually occurred – e.g. system potential temperatures did not actually occur from 1974-2012; also the current treatment plant was built in 1995, so effluent flows were probably different before this time.

The continuous simulation analysis showed that:

- At times when the daily maximum system potential temperature exceeds 20°C, the flow-conditional WLA never allows a temperature increase of more than 0.3°C at the edge of the mixing zone. Because the WLA is formulated to protect the numeric criterion, it is intuitive that it should be more than protective when naturally warmer conditions occur. Since the dilution factor dynamically adjusts to reflect streamflow, the WLA will always protect the numeric criterion, no matter how low the streamflow drops.
- At times during May – October when daily maximum system potential temperatures are less than 20°C, the flow-conditional WLA only once in a 39-year simulation allowed a temperature increase of more than 34/(T+9) at the edge of the mixing zone. The simulation did not include November-April because system potential temperatures could not be confidently modeled for that period. Low flows have on rare occasions occurred during November and December. A conservative screening of the November-April time period,

performed by assuming background stream temperatures always equaled 0°C, revealed two additional days when the incremental warming allowance *might* have been exceeded.

To summarize, the continuous simulation showed that in 39 years, it might be expected that the flow-conditional effluent temperature WLA would never allow an exceedance of the 0.3°C limit for naturally warm conditions, and might allow up to 3 exceedances of the incremental warming limit. Because a total of 3 exceedances in 39 years is less than one exceedance per 10 years, the flow-conditional effluent temperature WLA for Palouse WWTP is considered protective of all elements of the water quality standard for temperature.

Evaluation of restrictiveness

The flow-conditional effluent temperature WLA for Palouse WWTP was compared to recorded effluent temperatures to indicate whether effluent cooling will be needed to comply with the WLA, and if so, how much. Continuous effluent temperature data were collected during the summer of 2007 and again during the summer of 2012. Additionally, the WWTP operator has recorded instantaneous effluent temperature measurements daily since the facility came online in late 1995. Although these instantaneous measurements were generally taken during the morning (Don Myott, personal communication) and do not reflect daily maximum effluent temperatures, the consistency and completeness of this record make it easy to relate these measurements to daily maximum effluent temperatures recorded simultaneously during 2007 and 2012. Figure 21 shows the relationship between daily maximum effluent temperatures recorded by continuous dataloggers during 2007 and 2012, and corresponding daily effluent temperature measurements recorded by the plant operator.

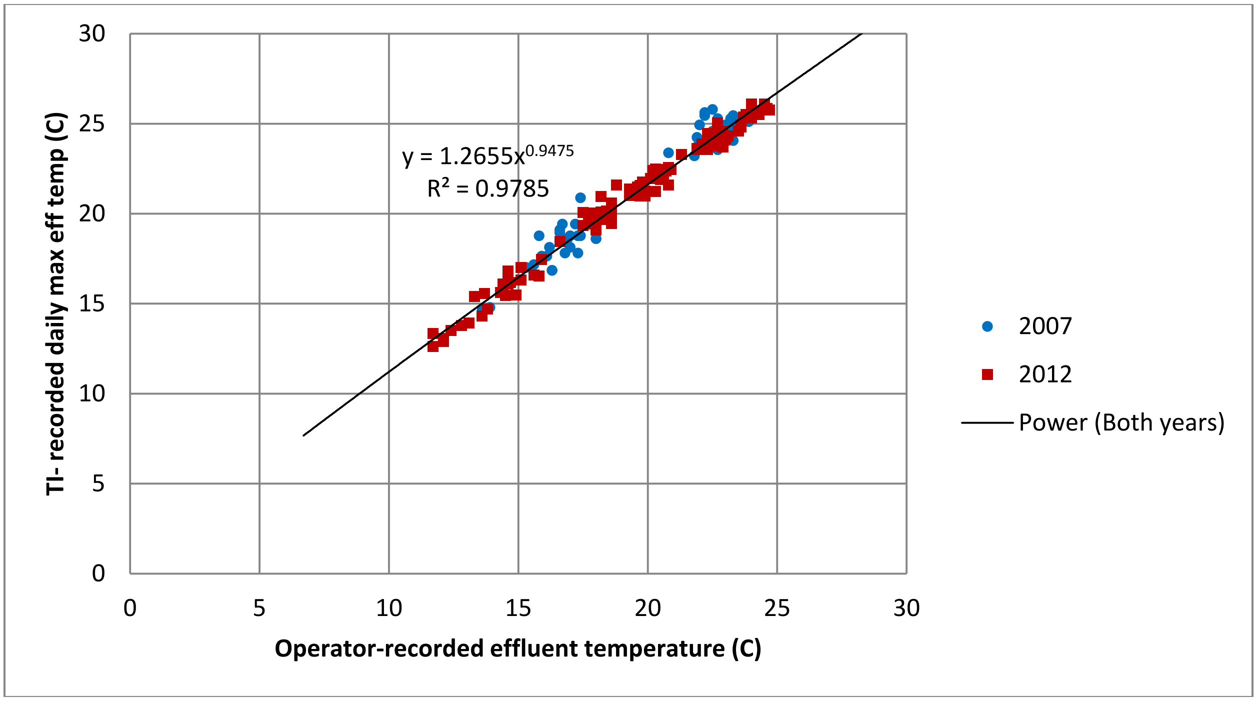

Figure 21. Relationship between operator-recorded effluent temperatures and corresponding daily maximum effluent temperatures recorded by dataloggers in 2007 and 2012.

This relationship, along with the complete record of operator-recorded effluent temperatures, was then used to surmise the probable daily maximum effluent temperature for each day from 1996-2012. For each day, this “reconstructed” daily maximum effluent temperature value was compared to the flow-conditional effluent temperature WLA that would have applied, had the WLA been in force at that time.

Based on this comparison, Ecology predicts that to comply with this WLA, Palouse WWTP will need effluent temperature reductions of about 2.5°C during the most critical times of low stream flow.

Colfax Wastewater Treatment Plant

The city of Colfax discharges to an unlined lagoon on the bank of the Palouse River. Effluent reaches the river through groundwater seepage. Ecology has estimated a chronic dilution factor of 3.02 for the Colfax WWTP. Temperatures in the monitoring well that is used to test effluent seepage stayed between 11-13°C during the summer of 2007. The Colfax WWTP is therefore not expected to have any potential to contribute to stream temperature impairment or additional warming. However, a wasteload allocation is necessary for continued discharge. The Colfax WWTP is therefore assigned a wasteload allocation equivalent to the water quality criterion for the segment of the river that receives the discharge (Table 13).

Table 13. Temperature wasteload allocation (°C) for Colfax WWTP.

T_{NPDES} = Maximum allowable effluent temperature WLA
17.5

The 0.3°C allowance for warming that is often calculated into temperature wasteload allocations is not given to Colfax for two reasons:

1. The Colfax WWTP is not expected to cause any warming.
2. The water quality standards allow 0.3°C of human-caused warming when natural conditions are warmer than the numeric criteria. In the vicinity of Colfax, this 0.3°C is allocated to stormwater discharges and to an explicit margin of safety, leaving no capacity for warming as the result of Colfax WWTP.

The Colfax WWTP is currently operating within its wasteload allocation.

Empire Disposal Stormwater

The permitted stormwater discharger in the study area is Empire Disposal located in Colfax. Wasteload allocations are necessary for permitted stormwater discharges if the discharges are a potential source of pollutant loading to the stream when receiving waters are impaired. Since stormwater can occur at any time, there is a potential that these sources could contribute thermal pollution during the critical period, although it is unlikely to be a significant source (Table 14). Therefore, Empire Disposal must be provided with wasteload allocations.

Washington State's water quality standards require that discharges to surface water:

1) Not cause the 7-DADMax temperature of the receiving water to exceed the numeric criteria; or
2) Cumulatively raise the 7-DADMax temperature of the receiving water more than 0.3°C when the water is warmer than the numeric criteria due to natural conditions.

The highest water temperatures in eastern Washington typically occur in July and August. These water temperatures are caused by a combination of hot, dry weather conditions and lower summer streamflows. Table 14 shows that average precipitation is extremely low during the hottest months of July and August, as well as during September. Considering these conditions, storm events should run off or infiltrate quickly, negating the potential for sufficient heating to occur before discharge of the stormwater to a stream, to result in a significant instream temperature rise. Although it should be noted, most events during the summer can be intense, short-duration events such as thunderstorms.

Table 14. Monthly average precipitation at Pullman-Moscow Regional Airport.

Month	Avg Precip (inches)
January	2.44
February	2.09
March	2.01
April	1.73
May	1.77
June	1.30
July	0.79
August	0.91
September	0.87
October	1.50
November	2.83
December	2.80
Total	21.04

Empire Disposal is a very small (2.4-acre) facility located inside the city of Colfax. It does not have a stormwater outfall, but any standing water which runs off during a storm event enters a city of Colfax storm drain which discharges to the Palouse River. (The city of Colfax is not a phase II community; therefore its storm system does not require a permit.) It is unlikely that any stormwater runoff from Empire Disposal would contribute to temperature violations.

Since Ecology's 2007 study did not directly sample outfalls from Empire Disposal, numeric wasteload allocations are not assigned for specific outfalls. However, to meet water quality standards, these discharges must not cumulatively raise the 7-DADMax temperature 0.3˚C above natural conditions. Therefore, wasteload allocations for stormwater are based on not causing more than a 0.2°C cumulative increase in the background (upstream) receiving water 7-DADMax temperature. The remaining 0.1°C is retained as a margin of safety. When the background (upstream) receiving water temperature exceeds or is within 0.3°C of 17.5°C or 20˚C (depending on point of compliance and water quality standards at that location), the cumulative discharge from all permitted sources may not cause the 7-DADMax to increase more than 0.2°C. This is expressed by the following equation:

$$WLA_{crit} = \frac{\sum_{N=1}^{7}(\Delta T * Q_N * C_F)}{7}$$

Where:
WLA_{crit} = the critical period wasteload allocation in Kilocalories/day
ΔT = allowable cumulative temperature increase for point sources = 0.2°C
Q_N = daily receiving water flow, in cfs
N = day 1 through 7 or the 7DAD averaging period
C_F = 2,446,665 (kcal·sec)/°C·ft^3·day (a conversion factor to transform the units to Kilocalories/day)

Since it is unlikely a storm event will result in enough thermal pollutant loading to violate this wasteload allocation, compliance with this Palouse TMDL will be met by following the requirements of the industrial stormwater permit. Empire Disposal should also consider actions recommended in the Implementation Plan to further reduce any potential impacts to the stream. The wasteload allocations (WLA) equation will be used for determining compliance for any stormwater monitoring conducted.

Margin of safety

The margin of safety accounts for uncertainty about the pollutant loading and water-body response and must be included in all TMDLs to ensure water quality standards are met, despite these uncertainties. In this TMDL, the margin of safety is addressed in two ways.

Implicit

An implicit margin of safety is being applied by using conservative modeling assumptions:

- Flows in the Palouse River were below normal during the year analyzed, 2007. 7Q10 flow conditions were reached during that year in the reach of the Palouse River upstream of Colfax. These conditions were included in the August conditions that were modeled.
- Critical climate conditions represented by July 6-12, 2007 were used for modeling analysis. These conditions were extreme; July 2007 was near the 90^{th} percentile for July average air temperatures.

Explicit

An explicit margin of safety is being applied by setting load allocations based on the effective shade provided by full mature riparian vegetation, which represents the maximum achievable shade values. The water quality standards allow human activities to raise the natural temperature by 0.3°C. In areas where all thermal impacts come from nonpoint sources, this 0.3°C is being retained as a margin of safety. In areas where point sources contribute to thermal impacts, some or all of the 0.3°C allowance is allocated to the point sources.

Conclusions and recommendations

- System-potential mature riparian vegetation is needed along the Palouse River and its tributaries to ensure that system-potential temperatures are achieved.
- A buffer of mature riparian vegetation along the banks of the Palouse River is expected to decrease the average daily maximum temperatures. Reductions of up to 2.2°C are expected.
- Larger temperature reductions are expected in the upstream reaches of the Palouse River than in downstream reaches with the implementation of system-potential effective shade. Larger temperature reductions are also expected in the later part of the summer than in the earlier part of the summer.
- Palouse WWTP discharge will need temperature permit limits and appropriate best management practices to avoid creating or contributing to temperature impairments.

Reasonable Assurance

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint sources) in the water body. For the Palouse River Temperature TMDL, both point and nonpoint sources exist. TMDLs (and related implementation plans) must show "reasonable assurance" that these sources will be reduced to their allocated amount. Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of this TMDL are met. Ecology believes that the following activities already support this TMDL and add to the assurance that temperature in the Palouse River will meet conditions provided by Washington State water quality standards. This assumes that the activities described below are continued and maintained:

- In 2008 the Palouse Conservation District received a grant for implementation on the North Fork of the Palouse River (the Palouse River from Colfax to the Idaho/Washington border). With this grant the Conservation District established or enhanced 80,500 feet (15.3 miles) of stream buffers. Approximately 31,500 plants were installed. The Conservation District will continue to make site visits to these buffers and perform maintenance. As these plants mature they will help the river achieve system-potential shade.

- The Adams Conservation District has been working on implementation on the lower Palouse River for at least a decade. These efforts include over 15 miles of livestock exclusion fencing on the Palouse River and additional exclusion fencing on the tributaries, especially Cow Creek. The removal of livestock will allow riparian vegetation to grow back and in some reaches the Adams Conservation District has installed riparian buffers. This activity assures progress toward the system-potential mature riparian vegetation goal of this TMDL.

- The Palouse-Rock Lake Conservation District has provided technical and financial assistance for agricultural and streamside best management practices (BMPs) from 5 grants since 2008. These grants paid for livestock exclusionary fencing, riparian buffers, and the conversion of conventionally-tilled agricultural land to direct seed techniques. The near stream BMPs will provide shading to the stream, and the direct seed operations will increase infiltration which may increase water quantity release to the streams. Within the TMDL study area the Palouse-Rock Lake Conservation District has planted almost 16 miles of riparian buffers. In addition, the Conservation District has installed approximately another 16 miles of buffers in the tributaries outside of the TMDL study area. Another 3 miles of riparian buffers along the Palouse River are planned between 2012 and 2014. The Conservation District has also assisted numerous agricultural producers to convert thousands of acres to direct seed farming. They will continue this effort in both Whitman and Adams counties with a new grant partnership with Adams Conservation District, set to begin in 2012.

- Local governments are required by the Shoreline Management Act (RCW 90.58) to develop regulations to protect the shorelines of major water bodies. These regulations are described in county and city Shoreline Master Programs (SMPs). In Whitman County streams over 20 cubic feet per second mean annual flow, like the Palouse River, are covered by SMPs. Whitman County and the cities of Colfax and Palouse will begin updating their Shoreline

Master Programs in 2013. The SMPs will be an important component of providing reasonable assurance for achieving temperature standards. State rules require that these programs ensure no net loss of ecological function; therefore, SMPs should require no net loss of riparian shade. In addition, SMPs should provide goals, policies, and coordinated programs that provide for the restoration of impaired ecological functions.

Ecology will continue to encourage riparian landowners to seek technical and financial assistance from their conservation districts to restore their riparian areas and enhance native shade providing vegetation. The goals of this TMDL will also be considered when awarding grants for projects in the Palouse Watershed.

While Ecology is authorized under Chapter 90.48 RCW to impose strict requirements or issue enforcement actions to achieve compliance with state water quality standards, it is the goal of all participants in the Palouse River TMDL process to achieve clean water through cooperative efforts.

Implementation Plan

Introduction

This *implementation plan* was developed by Ecology with assistance from interested and responsible parties. It describes what will be done to improve water quality to meet state water quality standards. It explains the roles and authorities of the organizations with jurisdiction, authority, or direct responsibility for improving stream temperature and water quality. It also provides information on the programs or other means through which they will address these water quality issues. It prioritizes specific actions planned to improve water quality and achieve water quality standards. It expands on the recommendations made in the first part of this report.

Typically, Ecology produces an implementation strategy, which is submitted with the technical analysis to the U.S. Environmental Protection Agency (EPA) for approval of the TMDL. Then, following EPA's approval, Ecology and interested and responsible parties develop a water quality implementation plan. However, this section of this water quality improvement report will serve as both the implementation *strategy* and the implementation *plan*.

This implementation plan describes how instream temperature in the Palouse River (including the North Fork Palouse River) will be reduced to meet water quality standards. Temperature TMDL reductions should be achieved by 2072, assuming 100% of areas needing riparian buffers are restored by 2022. This timeframe is estimated based on the time needed for vegetation in all portions of the watershed to mature to maximum shade potential. However, areas predicted as supporting only large or moderate shrubs and grasses or willow brush (see Figure 19 and Table 9) should reach system-potential shade within a shorter timeframe because this shorter vegetation will achieve maximum heights sooner. These reaches are estimated to reach system potential shade 10 to 15 years after the necessary riparian buffers are restored.

Activities to address pollution sources

To achieve water quality standards for temperature in the Palouse River, system-potential riparian vegetation will need to be established along all reaches. System-potential riparian vegetation will provide the maximum natural stream shading appropriate for the river. System-potential vegetation is based on the native vegetation that would naturally occur along the streams if humans had not altered the riparian areas. If the river does not meet the numeric water quality standard once full system-potential riparian vegetation is restored, Ecology will assume the stream temperature is elevated due to the natural conditions of climate, hydrology, geography, and geology. Natural condition temperatures are considered in compliance with the water quality standards.

The following activities are the primary means by which the Palouse River's stream temperature can be reduced and returned to a natural condition which supports the fish and aquatic insects that live there. Riparian shading is the most well-researched temperature implementation method, and therefore the primary focus of this implementation plan. However, the other activities also play a role in the holistic recovery of stream temperatures and are included in the overall plan to reach water quality standards. Instream cooling from groundwater inputs is an important component to maintaining cool stream temperatures so activities that increase groundwater storage and release are also part of this plan. The relative importance of each of these activities to achieving natural instream temperatures is shown in Table 15.

Table 15. Relative importance of the activities necessary to restore natural instream temperatures in the Palouse River.

Higher importance	Medium importance	Lower importance
Restore and enhance riparian areas	Restore and enhance wetlands	Increase stormwater infiltration
Restore natural stream hydrology	Agricultural best management practices to increase infiltration and reduce erosion	State Environmental Policy Act and land use planning
Convert agricultural acreage conventionally farmed to direct seed or mulch till with accompanying best management practices	Tributary riparian restoration and enhancement	
	Reduce temperature of discharges*	

* Reducing the temperature of wastewater discharge is of high importance locally near the point of discharge.

Restore and enhance riparian areas

Land use practices up to the edge of the river that reduce or prevent riparian shading are counter to the goals of this implementation plan. For this plan to be successful, healthy riparian buffers need to be established to provide shade, microclimate cooling, and increased groundwater recharge to streams. Examples of land uses that need buffers include but are not limited to:

- Development
- Agricultural cropping
- Residential yards
- Livestock grazing and feeding
- Road building

Appendix B summarizes peer-reviewed articles which discuss the effectiveness of various riparian buffer widths for maintaining natural stream water temperature regimes. According to the literature reviewed, wider buffers are needed for larger streams like the Palouse River than for the smaller tributary streams. Since the minimum buffer width eligible for most funding programs is 35 feet, this width should be the minimum for all riparian buffer projects. While this width may be adequate for providing system potential shade for the smaller tributaries, larger buffers will be needed for the much wider Palouse River. Based on the studies cited in Appendix B, riparian buffers on the Palouse River must be at least 50 to 75 feet wide to provide system potential shade. The Natural Resources Conservation Service's (NRCS) Conservation Practice Standard for Riparian Forest Buffers (Code 391) also recommends greater buffer width for streams like the Palouse River. In addition, wider buffers will have even greater effectiveness in restoring natural stream temperatures due to the moderating effects of riparian microclimates (see Appendix B), increased infiltration and soil moisture, and reduced sedimentation.

Restore natural stream hydrology

Several hydrologic features of streams are associated with cooler water. A minimal width-to-depth ratio and the ability of high flows to regularly access the floodplain can all contribute to a more natural flow regime, which can reduce stream heating. Increasing a stream's sinuosity (where appropriate) can also play a role in restoring natural hydrology.

Excessively wide, shallow streams heat much more quickly in the summer because vegetation is less effective in providing shade when the sun is directly overhead for more hours of the day. The increased width-to-depth ratios are often the result of excessive sediment input to the stream from upstream practices and bank erosion due to livestock trampling or other high impacts uses. To reduce the width-to-depth ratio (make the stream deeper and narrower), sediment input to the stream must be reduced as well. Sediment input to a stream or river generally comes from two sources: bank erosion or overland flows of sediment-laden runoff. Bank stabilization is an effective method of slowing or stopping streambank erosion. Healthy, thriving riparian vegetation can help hold a bank in place. In addition, installation of bank structures, such as rootwads and barbs, can redirect stream flow and reduce erosion. Bank stabilization with native mature riparian vegetation is preferable to constructed means of bank protection. Locking streambanks in place with hardened measures such as rock prevents beneficial fluvial processes from taking place. Overland flow of sediment can be reduced through best management practices at the source of the erosion, and its deposition to streams can be reduced with riparian buffers.

Stream channels with greater sinuosity have increased stability and connection to the hyporheic zone, which results in cooler streams. The hyporheic zone is the area beneath and alongside the stream bed where shallow groundwater mixes with the stream water. Added sinuosity increases stream length, decreases stream slope, and allows a stream to dissipate energy during high flows. It also allows greater surface area for hyporheic exchange.

Flooding of a river or stream's floodplain during spring snowmelt recharges the adjacent hyporheic zone. This in turn promotes the consistent entry of cool water into the stream during the dry season. A stream with a properly functioning hydrology should access its floodplains every two years on average.

Restore and enhance wetlands

The restoration of near-stream wetlands can contribute to reducing instream water temperatures. Wetlands store water during the wet season and release it during the dry season. Water released through the ground to a stream can provide stream cooling and/or temperature moderation. The restoration and enhancement of wetlands can contribute to the stream temperature goals of this implementation plan.

Increase stormwater infiltration

Since the release of groundwater to streams can be a cooling factor, methods to increase stormwater infiltration can help moderate instream temperatures. Impervious surfaces result in fast runoff of stormwater, which if flowing to a storm catch basin or directly to water has little moderating temperature effect. However, if the stormwater is allowed to infiltrate, contact with the soils transfers heat from the water so when it is slowly released to the stream it can have a cooling affect. Water stored in soils around streams can also contribute additional flow during the dry season; higher flows are less affected by ambient temperature. Development and construction activities should implement methods that reduce runoff and increase infiltration.

Convert agricultural acreage conventionally farmed to direct seed or mulch till

When coupled with supporting BMPs, the conversion of conventionally farmed acreage to direct seed (NRCS practice standard 329) or mulch till (NRCS practice standard 345) methods can benefit instream temperature in two ways. First, these production practices increase organic materials in the soil, which increases infiltration and moisture storage. Like infiltration discussed previously, this can result in more stream flow during the dry season. Second, direct seed and mulch till reduce erosion and therefore potential stream sedimentation. Sedimentation of a stream can cause it to widen and become shallower (aggradation), which increases the area for solar input, reduces the area of effective shade, and the shallower water will heat faster and more uniformly than deeper water. Efforts to convert conventionally tilled acres to these conservation tillage practices support the goals of this implementation plan; however, to be fully effective they must be accompanied by supporting practices, including but not limited to riparian buffers, contour farming, and grassed waterways. Because mulch till is not as protective at reducing erosion as direct seed, a more comprehensive suite of accompanying BMPs may be necessary for mulch till than for direct seed.

Agricultural best management practices to increase infiltration and reduce erosion

Agricultural ditches are designed to remove water from land quickly. However, traditional trapezoidal ditches devoid of vegetation can be detrimental to water quality, including affecting instream temperatures. When water runs off quickly, there is less storage in the soil to be released to the stream during the drier periods. In addition, these traditional ditches can lead to increased erosion, which delivers more sediment to streams. This in turn can cause the stream to widen and shallow. Wider shallower streams will heat more rapidly. Alternatives to traditional agricultural ditches, such as grassed waterways and two-stage ditch channel designs, should be implemented to increase infiltration and reduce erosion.

Tributary riparian restoration and enhancement

While the tributaries upstream of the lowest two miles are outside of the scope of this TMDL, efforts to restore and enhance these riparian areas can benefit the overall health of the watershed, resulting in cooler stream temperatures. If all tributaries are contributing cooler water to the

Palouse River, it may have a temperature moderating or cooling affect. Many of the tributaries are narrower in width than the mainstem Palouse River; therefore, there is greater potential to shade more of the stream with riparian vegetation. Appendix C contains information that can be used to guide riparian restoration efforts in the tributaries. Table C-7 identifies the appropriate vegetation community for each of the tributaries. Figures C-1 through C-5 provide shade curves which indicate the shade target that should be achievable for each stream reach based on the appropriate community and stream aspect (its orientation north-south, east-west, or diagonal to these directions).

Reduce temperature of discharges

Several entities have permits to discharge stormwater or treated wastewater to the Palouse River. BMPs and treatment methods will need to be implemented to ensure discharges are cool enough to not contribute to instream temperature increases above natural conditions.

State Environmental Policy Act and land use planning

Permitting agencies must consider TMDLs during State Environmental Policy Act (SEPA) and other local land use planning reviews. If the land use action under review is known to potentially impact instream water temperature or is counter to the goals of this TMDL, then the project may have a significant adverse environmental impact. SEPA lead agencies and reviewers are required to look at potentially significant environmental impacts and alternatives and to document that the necessary environmental analyses have been made. Land-use planners and project managers should consider findings and actions in this TMDL to help prevent new land uses from violating water quality standards. Ecology recently published a focus sheet on how TMDLs play a role in SEPA impact analysis, threshold determinations, and mitigation (https://fortress.wa.gov/ecy/publications/SummaryPages/0806008.html). Additionally, the TMDL should be considered in the issuance of land use permits by local authorities.

Organizations' actions, goals, and schedules

Many entities have a role in reducing temperature in the Palouse River. The following is a description of the activities to be performed by various organizations to reduce instream temperature. This list is not exhaustive and other ideas should be investigated.

Several of the entities in the "Activities to address pollution sources" section are involved with similar and overlapping activities. When possible, these entities should partner or coordinate efforts to improve efficiency and effectiveness. Since much of the needed implementation includes riparian restoration and agricultural BMPs, this is especially true for the five conservation districts with jurisdiction in the study area. Figure 22 shows the boundaries of the conservation districts and the TMDL study area.

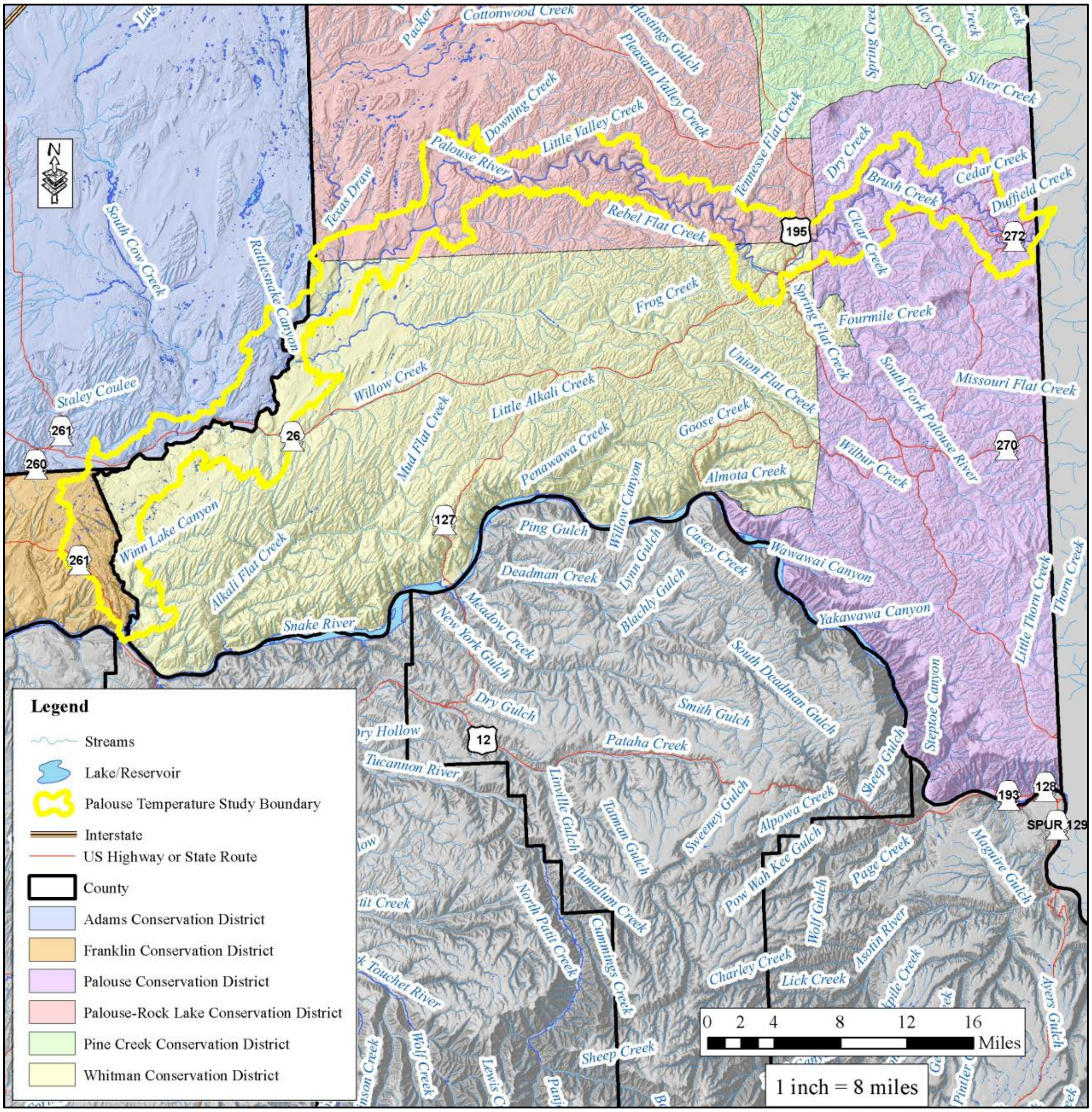

Figure 22. Palouse Temperature TMDL Study area showing area conservation district boundaries.

Activities to address pollution sources

Adams Conservation District

The Adams Conservation District (ACD) is a non-regulatory organization that assists land managers with implementing conservation practices. ACD provides technical and financial assistance to landowners to restore riparian areas and protect water quality in the lower watershed (see Figure 22). ACD has an agreement in place with the Franklin Conservation District to provide services to landowners on the lower Palouse River. ACD is also discussing options with the Whitman Conservation District for providing services to landowners that have property in both districts.

Currently the ACD has two grants for implementation on the Palouse River. The grants focus on livestock BMPs such as exclusion fencing, off-stream watering, and riparian buffer installation. In addition, the ACD will conduct a riparian buffer characterization survey to determine the current conditions of native riparian vegetation and develop a strategic plan for future plantings to move the river towards system-potential vegetation. ACD is establishing a local nursery to grow plants adapted to the unique climate and geological conditions in this portion of the watershed. The ACD will continue these efforts into the future and will seek funding when necessary to support additional implementation.

City of Colfax Wastewater Treatment Plant

The treatment plant for the city of Colfax is authorized by an NPDES permit from Ecology to infiltrate treated wastewater through the ground to the Palouse River near river mile 90. Because the wastewater passes through the ground, heat is lost to the soil. The TMDL study found the temperature of the water in the treatment plant's monitoring wells to be consistently protective of instream temperatures. Therefore, it is not anticipated temperature reductions will be necessary for the Colfax Treatment Plant. The treatment plant will need to monitor temperature to ensure it stays at or below the WLA of the 17.5˚C.

City of Palouse Wastewater Treatment Plant

The city of Palouse discharges treated wastewater to the Palouse River (North Fork Palouse River) near river mile 120 under an NPDES permit issued by Ecology. Ecology must ensure this discharge does not contribute to water quality impairments, including instream temperature. Therefore, the wasteload allocations (WLA) described earlier or in Appendix C will be incorporated into the Palouse's NPDES permit (see Table 12, Table C-8, and Table C-9). The city will need to incorporate treatment plant operation changes, improvements, or upgrades to reduce the temperature of the discharge during the critical period (mid May through August). Several options to reduce temperature discharges can be found in the manual "Methods to Reduce or Avoid Thermal Impacts to Surface Water" (Jenkins, 2007). A compliance schedule for meeting these WLAs can be included in the NPDES permit in accordance with WAC 173-201A-510(4).

Ducks Unlimited

Ducks Unlimited (DU) is a private, non-profit conservation organization dedicated to working with partners across North America to preserve and restore important wetlands for waterfowl and other wildlife. Ducks Unlimited has been working with landowners in eastern Washington since 1988 and has helped conserve thousands of acres of important wetlands in the area. Ducks Unlimited biologists and engineering staff in the Spokane area will assist with habitat conservation and restoration in the Palouse Region when opportunities arise that are consistent with the DU mission. DU can provide technical and logistical support to partner organizations implementing riparian and wetland restoration projects. While DU's resources are currently dedicated to projects outside the Palouse TMDL study area, in the future DU may seek opportunities for funding wetland and riparian restoration projects along the Palouse River and its tributaries.

Empire Disposal

Empire Disposal is covered by an Industrial Stormwater permit to regulate stormwater that leaves their site. Stormwater from Empire Disposal mixes with other stormwater from the city of Colfax prior to discharge to the Palouse River. The city of Colfax is not regulated under a stormwater permit. Empire Disposal's footprint is too small to individually collect and heat enough stormwater to result in a discharge during the summer critical period that would elevate the instream temperature. Therefore, Empire Disposal will be considered in compliance with this TMDL if all required measures in their stormwater permit are carried out and up to date. Empire Disposal may be able to implement additional measures, such as increasing infiltration or reducing runoff, to reduce stormwater impacts to the Palouse.

Franklin Conservation District

The west shoreline of the Palouse River approximately 5.5 miles above the Palouse Falls to the mouth (approximately 12 miles total) is bordered by Franklin County (see Figure 22). The Franklin Conservation District (WCD) is a non-regulatory organization that assists land managers with implementing conservation practices in Franklin County. This portion of the Palouse River is in a steep ravine mostly used as range land. Through a partnership with the Adams Conservation District the majority of the river in Franklin County has been fenced to exclude livestock activity near the river. This will allow vegetation to reestablish in the riparian area. The Franklin Conservation District will promote activities that will restore native riparian vegetation along the Palouse River and assist landowners, directly or through partnerships with the Adams Conservation District, with implementation of riparian restoration and planting projects.

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) administers several programs, including the Environmental Quality Incentives Program (EQIP), which provides technical and financial assistance to agricultural producers. These programs focus on implementing BMPs to conserve natural resources, including protecting water quality. NRCS will continue to offer these programs for Palouse River as long as funding continues.

Palouse Conservation District

The Palouse Conservation District (PCD) is a non-regulatory organization that assists land managers with implementing conservation practices. PCD provides technical and financial assistance to landowners to restore riparian areas and protect water quality. The section of the Palouse River, known locally as the North Fork Palouse River, is within the PCD area. Since 2008, the PCD has been actively assisting landowners with riparian buffers and plantings which, if successful, will provide shade to the stream and help reduce instream temperatures. PCD will continue to maintain these previously planted areas to ensure survival of the plantings. PCD will also seek additional opportunities to assist landowners with riparian restoration and enhancement.

To assist landowners toward this TMDL's goals of decreasing erosion and increasing infiltration, PCD will promote direct seed technology and assist landowners with the implementation of agricultural BMPs. PCD has a grant from Ecology to assist landowners with the costs of converting from conventional tillage to direct seed. This grant will be available while funds remain up until December 2013.

Palouse Land Trust

The Palouse Land Trust is a 501 (c)(3) non-profit organization that helps landowners conserve open space, scenery, wildlife habitat, and water quality of the Palouse region. The Palouse Land Trust establishes conservation easements to enable farmers and other private landowners to protect and conserve the natural resources of their land. These easements can provide income and tax incentives to the landowner. In response to this TMDL, the Palouse Land Trust will increase efforts to work with landowners to establish conservation easements along the Palouse River and its tributaries.

Palouse-Rock Lake Conservation District

The Palouse-Rock Lake Conservation District (PRLCD) is a non-regulatory organization that assists land managers with implementing conservation practices. The portion of the Palouse River a few miles downstream of Colfax to the confluence with Rock Creek is within the PRLCD (see Figure 22). PRLCD provides technical and financial assistance to landowners to restore riparian areas and protect water quality. PRLCD currently has a grant from Ecology to address riparian area impacts due to livestock. This grant extends to December 2013 and is used to assist landowners with livestock fencing and riparian buffer installation. PRLCD also has four grants for implementing direct seed technology along the Palouse and in the tributary watersheds.

To work toward the goals of this TMDL, PRLCD will continue to assist landowners with riparian restoration, agricultural BMPs, and conversion to direct seed practices. As their funding is exhausted, PRLCD will seek additional funding sources to support the goals of the TMDL implementation plan.

The Planning Departments of Whitman County, City of Colfax, and City of Palouse

Planning Departments, Commissions, or designees for the municipalities in the study area will consider the findings and requirements of this TMDL for land use decisions. The TMDL provides some of the best available science for determining if a land use action has a potential to be detrimental to the stream environment and water quality. Land use reviews will ensure activities are carried out in a manner consistent with this and other TMDLs for the Palouse River.

Whitman County, city of Colfax and city of Palouse will be updating their Shoreline Master Programs (SMP) between 2013 and 2016. SMPs are local land use policies and regulations designed to manage shoreline use. These programs are required by the Shoreline Management Act to protect natural shoreline resources, provide for public access to water and shores, and plan for water-dependent land uses. The shoreline requirements and projections in the updated SMP will be consistent with the requirements in this and other TMDLs within the SMP jurisdictional areas.

Residents and Landowners

Streams in Washington are considered waters of the state and belong to all citizens of the state; therefore, it is everyone's responsibility to protect the health of these systems for current uses and future generations. Landowners can protect streams running through their property by planting riparian buffers to shade the stream and to slow and filter storm runoff. Many of the agencies and organizations in this plan can provide technical and/or financial assistance for the implementation of riparian buffers and other BMPs to protect streams from upland activities that could potentially damage streamside vegetation and increase erosion.

Washington Department of Ecology

Ecology will oversee and track the implementation of this TMDL plan to ensure the activities are on schedule, pollution sources are being addressed, and progress is being made toward meeting water quality standards. Ecology's TMDL coordinator for this project will review implementation progress and water quality data. If the Palouse River is not on track for meeting water quality and implementation targets, the coordinator will apply adaptive management (see section later in this document).

Ecology will ensure WLAs and activities necessary to comply with this TMDL are incorporated into NPDES permits for discharges to the Palouse River.

Ecology will provide funding, through its competitive water quality grant and loan funding cycle, to projects that address the goals of this plan and rank high enough to receive funding. Points are awarded during the application evaluation for projects implementing TMDLs.

Ecology may refer nonpoint sources of pollution to an appropriate entity, such as a conservation district for assistance. Ecology and these entities will work together to determine the necessary actions needed to protect water quality and will assist landowners with obtaining technical and financial assistance. If necessary, Ecology will use its authority under Revised Code of Washington (RCW) 90.48 to enforce water quality regulations.

Washington Department of Transportation

Ecology did not directly measure WSDOT stormwater outfalls during the TMDL study. Because WSDOT highways or facilities border or cross only a small portion of the Palouse River, Ecology determined it is unlikely WSDOT stormwater outfalls would be a significant source of heating. Therefore, WSDOT will be considered in compliance with this temperature TMDL unless subsequent monitoring of WSDOT stormwater outfalls indicates that they do contribute to violations of the temperature standard. To stay in compliance with the TMDL, riparian and stormwater management activities outlined in WSDOT's Highway Runoff Manual must be implemented in the study area. When planning upgrades or new construction, WSDOT should seek opportunities to increase stream shading in areas where their road right-of-way borders the Palouse River. Planning for stormwater systems and construction projects within the study area should include designs and methods to increase stormwater infiltration rather than runoff off to ditches and streams. If WSDOT is found to be a source of heating to the Palouse River or its tributaries, wasteload allocations and implementation actions will be developed for inclusion in WSDOT's stormwater permit.

Washington Department of Natural Resources and Forest Practitioners

While there is not much forest practice activity within the study area, if activity does occur it must comply with the state's forest practices regulations to ensure 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 (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 streambank 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: 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 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 a manner that does not cause or contribute to a violation of the state water quality standards.

Whitman Conservation District

The Palouse River around Colfax and the lower reaches downstream of the Rock Creek confluence are within the Whitman Conservation District (see Figure 22). The Whitman Conservation District (WCD) is a non-regulatory organization that assists land managers with implementing conservation practices. WCD provides technical and financial assistance to landowners to restore riparian areas and protect water quality.

Measuring Progress toward Goals

A monitoring program for evaluating progress is an important component of any implementation plan. Monitoring is needed to keep track of what activities have been done, measure the success or failure of actions, and evaluate if water quality standards are achieved. Monitoring should continue after water quality standards are obtained to ensure implementation measures are effective and standards continue to be met.

Ecology will monitor the progress of implementation and resulting instream water quality conditions. Ecology will use this information to make sure the Palouse River is on track for meeting the temperature water quality standards.

A quality assurance project plan (QAPP) should be prepared before any water quality monitoring is conducted by Ecology or others. The QAPP should follow Ecology guidelines (Lombard and Kirchmer, 2004), paying particular attention to consistency in sampling and analytical methods.

Performance measures and targets

The activities listed in this implementation plan need to be tracked to determine:

- What activities were performed and where.
- Whether the actions worked and could be applied elsewhere.
- What practices should be considered for adaptive management, if necessary.
- If resources or some other factor are preventing some actions from occurring.
- Whether this implementation plan is adequate to meet water quality standards.

Ecology's TMDL coordinator will work with the organizations outlined in this document to track implementation activities occurring in the watershed. Depending on Ecology's resources and current implementation tracking tools, the coordinator will either use an Excel© spreadsheet, Ecology's TMDL management database or geographic information system (GIS) mapping to track where implementation has occurred or is planned.

Each organization should track the progress they have made on implementation.

Effectiveness monitoring plan

Effectiveness monitoring determines if the interim targets and water quality standards are being met. This monitoring (i.e. the instream water quality monitoring) usually begins five years after the water quality implementation plan is completed, assuming enough implementation has occurred in the watershed to result in changes and resources are available. Effectiveness monitoring of TMDLs is usually conducted by Ecology's Environmental Assessment Program through the ambient monitoring network.

The Ecology TMDL coordinator will recommend monitoring schedules and locations based on this report and completed implementation. At a minimum the sites in Table 16 should be included in any future effectiveness monitoring. The coordinator will use the results of monitoring by Ecology and others to determine if this plan is working as written. If sufficient progress is not made, the coordinator will begin adaptive management (discussed in the "Adaptive management" section).

Table 16. Sites recommended for effectiveness monitoring.

Site	Reasoning
34PAL120.3 (at Palouse) (aka 34A170)	Long term station; upstream of Palouse WWTP, near state line
34PAL98.3 (at Glenwood)	Upstream of South Fork Palouse River influence; modeling predicts greater potential temperature reductions
34PAL66.8 (Endicott-St. John Rd)	Mid-watershed; modeling predicts slightly greater potential temperature reductions
34PAL49.5 (at Winona) (aka 34A080)	Mid-watershed; upstream potential for significant riparian improvement; long term site.
34PAL19.5 (at Hooper) (aka 34A070)	Long term station; lower end of watershed with greater accessibility

Other monitoring

Any organization conducting innovative or significant BMP implementation projects should have a monitoring component to evaluate the effectiveness of the BMP. These project-specific monitoring plans will consist of a small-scale evaluation program setup for each site to compare water quality.

Other long-term monitoring will continue, and presently consists of Ecology ambient monitoring, and USGS stream gage monitoring.

Stormwater permit holders will be responsible for any monitoring requirements in their permits. Wastewater treatment plants are responsible for monitoring effluent and reporting the results to Ecology on their discharge monitoring reports (DMRs).

Adaptive management

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

TMDL reductions (temperature water quality standards) should be achieved by 2072. However, significant implementation that provides stream shading, increased infiltration of stormwater, and decreased erosion, must be underway by 2022 for this goal to be realized. In addition, the implementation of measures to address water quality should continue past this date, and maintenance of past implementation projects must be continued. Partners will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the implementation strategy as needed.

Ecology will use adaptive management when water monitoring data show that the TMDL targets are not being met or implementation activities are not producing the desired result. A feedback loop (Figure 23) consisting of the following steps will be implemented:

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

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

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

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

If wasteload and load allocations are not met, but water quality standards are achieved, the goals of this TMDL will be considered satisfied. Since the TMDL study indicated that the numeric water quality standards for temperature are unlikely to be achieved during the hottest, driest period, the ultimate goal of this TMDL is to meet natural conditions. Natural conditions will be satisfied when full system potential shade has been achieved. It is ultimately Ecology’s responsibility to assure that implementation is being actively pursued and water quality standards are achieved.

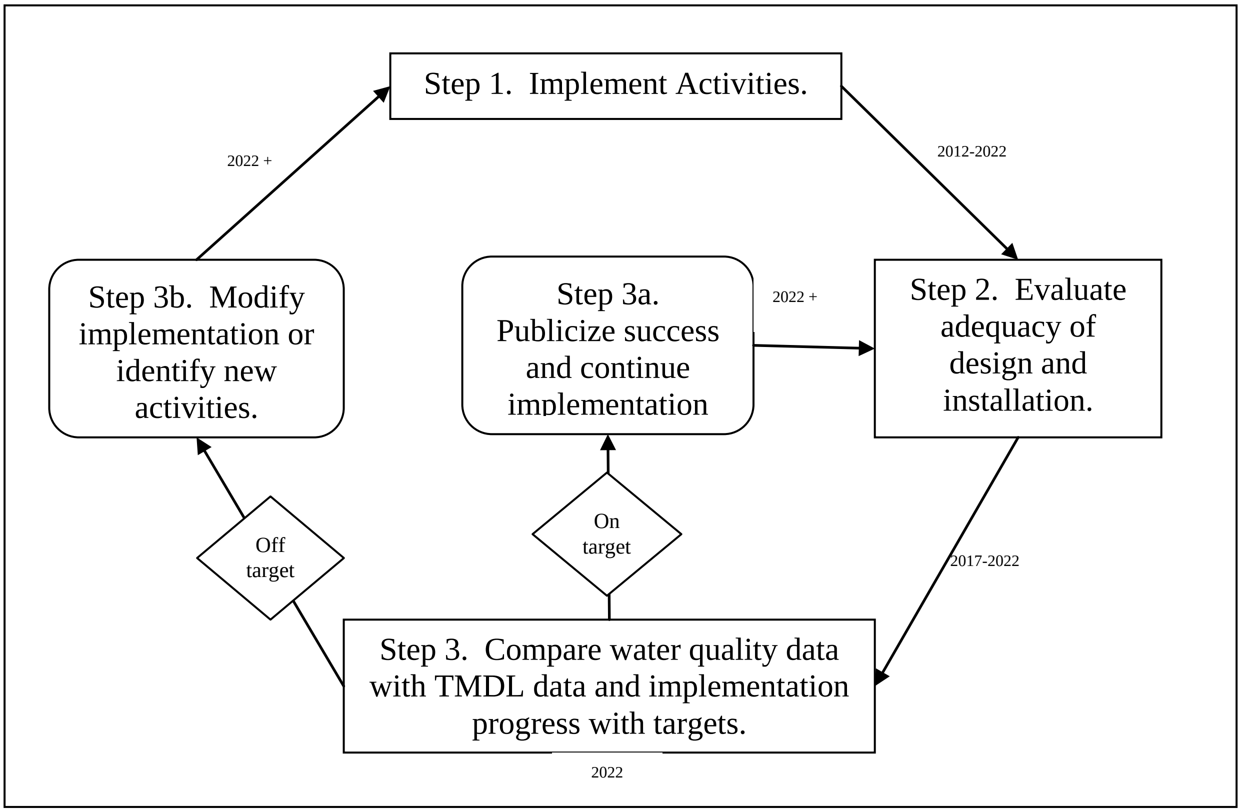

Figure 23. Feedback loop for determining need for adaptive management.

Dates are estimates and may change depending on resources and implementation status.

Funding Opportunities

Multiple sources of financial assistance for water quality improvement activities are available through Ecology's grant and loan programs, local conservation districts, and other sources. Refer to the website (www.ecy.wa.gov/programs/wq/tmdl/TMDLFunding.html) for a list and descriptions of funding sources.

Ecology's Centennial Clean Water Fund, Section 319, and State Water Pollution Control Revolving Fund grants and loans can provide funding to help implement this TMDL. In addition to Ecology's funding programs, there are many other funding sources available for watershed planning and implementation, point and nonpoint source pollution management, fish and wildlife habitat enhancement, stream restoration, and water quality education. Public sources of funding include federal and state government programs, which can offer financial as well as technical assistance. Private sources of funding include private foundations, which most often fund nonprofit organizations with tax-exempt status. Forming partnerships with other government agencies, nonprofit organizations, and private businesses can often be the most effective approach to maximize funding opportunities. Some of the most commonly accessed funding source for TMDL implementation efforts are shown in Table 17 and are described following the table.

Table 17. Potential funding sources for implementation projects.

Fund Source	Type of Project Funded	Maximum Amounts
Centennial Clean Water Fund	Watershed planning, stream restoration, & water pollution control projects.	$500,000
Section 319 Nonpoint Source Fund	Nonpoint source control; i.e., pet waste, stormwater runoff, & agriculture, etc.	$500,000
State Water Pollution Control Revolving Fund	Low-interest loans to upgrade pollution control facilities to address nonpoint source problems; failing septic systems.	10% of total SRF annually
Conservation Reserve Program (CRP)	Establishes long-term conservation cover of grasses, trees and shrubs on eligible land.	Rental payments based on the value of the land; plus 50% - 90% cost share dependent on practices implemented
Environmental Quality Incentives Program (EQIP)	Natural resource protection.	Dependent on practices implemented
Wildlife Habitat Incentive Program (WHIP)	Provide funds to enhance and protect wildlife habitat including water.	$25,000 dependent on practices implemented
Wetland Reserve Program (WRP)	Wetland enhancement, restoration, and protection by retiring agricultural land.	Dependent on appraised land value

Centennial Clean Water Fund (CCWF)

A 1986 state statute created the Water Quality Account, which includes the Centennial Clean Water Fund (CCWF). Ecology offers CCWF grants and loans to local governments, tribes, and other public entities for water pollution control projects. The application process is the same for CCWF, 319 Nonpoint Source Fund, and the State Water Pollution Control Revolving Fund.

Section 319 Nonpoint Source Fund

The 319 Fund provides grants to local governments, tribes, state agencies and nonprofit organizations to address nonpoint source pollution to improve and protect water quality. These organizations can apply to Ecology during the annual combined funding cycle for funding through a 319 grant to provide additional implementation assistance.

State Water Pollution Control Revolving Fund

Ecology also administers the Washington State Water Pollution Control Revolving Fund. This program uses federal funding from U.S. Environmental Protection Agency and monies appropriated from the state's Water Quality Account to provide low-interest loans to local governments, tribes, and other public entities. The loans are primarily for upgrading or expanding water pollution control facilities, such as public wastewater and stormwater plants, and for activities to address nonpoint source water quality problems.

Conservation Reserve Program (CRP)

The CRP is a voluntary program for agricultural landowners. Through CRP, landowners can receive annual rental payments and cost-share assistance to establish long-term, resource conserving vegetative or vegetation covers on eligible farmland. Included under CRP is the Continuous Conservation Reserve Program (CCRP), which provides funds for special practices for both upland and riparian land. Landowners can enroll in CCRP at anytime. There are designated sign up periods for CRP.

The Commodity Credit Corporation (CCC) makes annual rental payments based on the agriculture rental value of the land, and it provides cost-share assistance for 50 to 90 % of the participant's costs in establishing approved conservation practices. Participants enroll in CRP contracts for 10 to 15 years.

The program is administered by the CCC through the Farm Service Agency (FSA), and program support is provided by Natural Resources Conservation Service, Cooperative State Research and Education Extension Service, state forestry agencies, and local conservation districts.

Environmental Quality Incentives Program (EQIP)

The federally funded Environmental Quality Incentives Program (EQIP) is administered by NRCS. EQIP is the combination of several conservation programs that address soil, water, and related natural resource concerns. EQIP encourages environmental enhancements on land in an environmentally beneficial and cost-effective manner. The EQIP program:

- Provides technical assistance, cost share, and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm.
- Has 75 percent cost-share, but allows 90 percent if the producer is a limited resource or beginning farmer.

- Has contracts lasting five to ten years.
- Has no annual payment limitation; sum not to exceed $450,000 per farm.

Wildlife Habitat Incentive Program (WHIP)

WHIP is administered by NRCS and is a voluntary program for people who want to develop and improve wildlife habitat primarily on private land. Through WHIP, NRCS provides both technical assistance and up to 75 percent cost-share assistance to establish and improve fish and wildlife habitat. WHIP agreements between NRCS and the participant generally last from five to ten years from the date the agreement is signed.

Wetland Reserve Program (WRP)

WRP is a voluntary program administered by NRCS to restore and protect wetlands on private property (including farmland that has become a wetland as a result of flooding). The WRP provides technical and financial assistance to eligible landowners to address wetland, wildlife habitat, soil, water, and related natural resource concerns on private lands. The program offers three enrollment options: permanent easement, 30-year easement, and restoration cost-share agreement. Landowners receive fin

Under WRP, the landowner limits future use of the land, but retains ownership, controls access, and may lease the land for undeveloped recreational activities and possibly other compatible uses. Compatible uses are allowed if they are fully consistent with the protection and enhancement of the wetland.

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Summary of Public Involvement Methods

Planning for this and other Palouse River watershed TMDLs began in 2005. At this time and for several years after, the Palouse Watershed Planning Unit, established under Chapter 90.82 of the Revised Code of Washington (RCW), was meeting regularly to plan, discuss, and develop management plans for watershed issues. Ecology staff regularly attended these monthly meetings and presented information on the TMDLs underway and scheduled.

Prior to starting the study and data collection for the temperature TMDL, Ecology held a public meeting on April 25, 2007 in Colfax, Washington. This meeting was publicized via direct mailings to the Palouse Watershed TMDL mailing list, a news release, and advertisements in area newspapers. Approximately 12-15 people attended the meeting with 10 signing in. Information was presented about the Clean Water Act requirement to develop TMDLs for the Palouse River and specifics about the study design.

Several letters including updates on the status of the project were sent to the Palouse Watershed TMDL mailing list during the course of its development. Information about the project was also included in a presentation at the Palouse Basin Summit in October 2009.

Organizations outlined as having a role in implementing this TMDL were invited to review and provide input on the implementation plan during its development.

A 30-day public comment period was held on this TMDL and implementation plan from May 16, 2013 to June 14, 2013. A press release to local media and advertisements in the Moscow-Pullman Daily News and Whitman Gazette newspapers announced the public comment period. Nine sets of comments were received. Ecology's response to these comments and any resulting changes in the TMDL are described in Appendix F.

Information about this TMDL has been available on the *Palouse River – Water Quality Improvement Project Website* since the start of project:
www.ecy.wa.gov/programs/wq/tmdl/palouse/palouse_mainstem.html

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Appendices

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Appendix A. Glossary, acronyms, and abbreviations

Glossary

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

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

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every 10 years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q10 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

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

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

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

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

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

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

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

Dilution factor: A measure of the amount of mixing of effluent and receiving water that occurs at the boundary of the mixing zone. Expressed as the inverse of the effluent fraction e.g., a dilution factor of 16 means the effluent comprises 6.25% by volume and the receiving water 93.75% at the compliance boundary or volume restriction (DF = 1/.0625). The applicable dilution factor is the minimum of volume/volume fraction or effluent concentration at the distance boundary.

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

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

Exceeded criteria: Did not meet criteria.

Hyporheic: The area beneath and adjacent to a stream where surface-water and groundwater intermix.

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

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

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

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

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

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

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

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

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

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

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

Reach: A specific portion or segment of a stream.

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

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

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

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

Surrogate measures: To provide more meaningful and measurable pollutant loading targets, EPA regulations [40 CFR 130.2(i)] allow other appropriate measures, or surrogate measures in a TMDL. The Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

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

System potential: The design condition used for TMDL analysis.

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

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

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

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

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

Acronyms and Abbreviations

BMP	best management practice
CWA	Clean Water Act
DEM	digital elevation model
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
GLO	General Land Office
GP	general permit
GPS	global positioning system
IDEQ	Idaho Department of Environmental Quality
IP	individual permit
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
NSDZ	near-stream disturbance zone
ODEQ	Oregon Department of Environmental Quality
RM	river mile
RMSE	root mean squared error
S.F.	South Fork
TI	Temperature Instrument
TMDL	total maximum daily load (water cleanup plan)

USDA	United States Department of Agriculture
USGS	United States Geological Survey
WAC	Washington Administrative Code
WLA	wasteload allocation
WQIR	water quality improvement report
WQA	water quality assessment
WRIA	water resources inventory area
WSDOT	Washington State Department of Transportation
WWTP	wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
°F	degrees Fahrenheit
ft	feet
ft/s	feet per second
in	inch
km	kilometer, a unit of length equal to 1,000 meters.
m	meter
mi	mile
mgd	million gallons per day
s	second
um	micrometer
W/m^2	watts per square meter

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Appendix B. Overview of stream heating processes

The temperature of a stream reflects the amount of heat energy in the water. Changes in water temperature within a particular segment of a stream are induced by the balance of the heat exchange between the water and the surrounding environment during transport through the segment. If there is more heat energy entering the water in a stream segment than there is leaving, the temperature will increase. If there is less heat energy entering the water in a stream segment than there is leaving, then the temperature will decrease. The general relationships between stream parameters, thermodynamic processes (heat and mass transfer), and stream temperature change is outlined in Figure B-1.

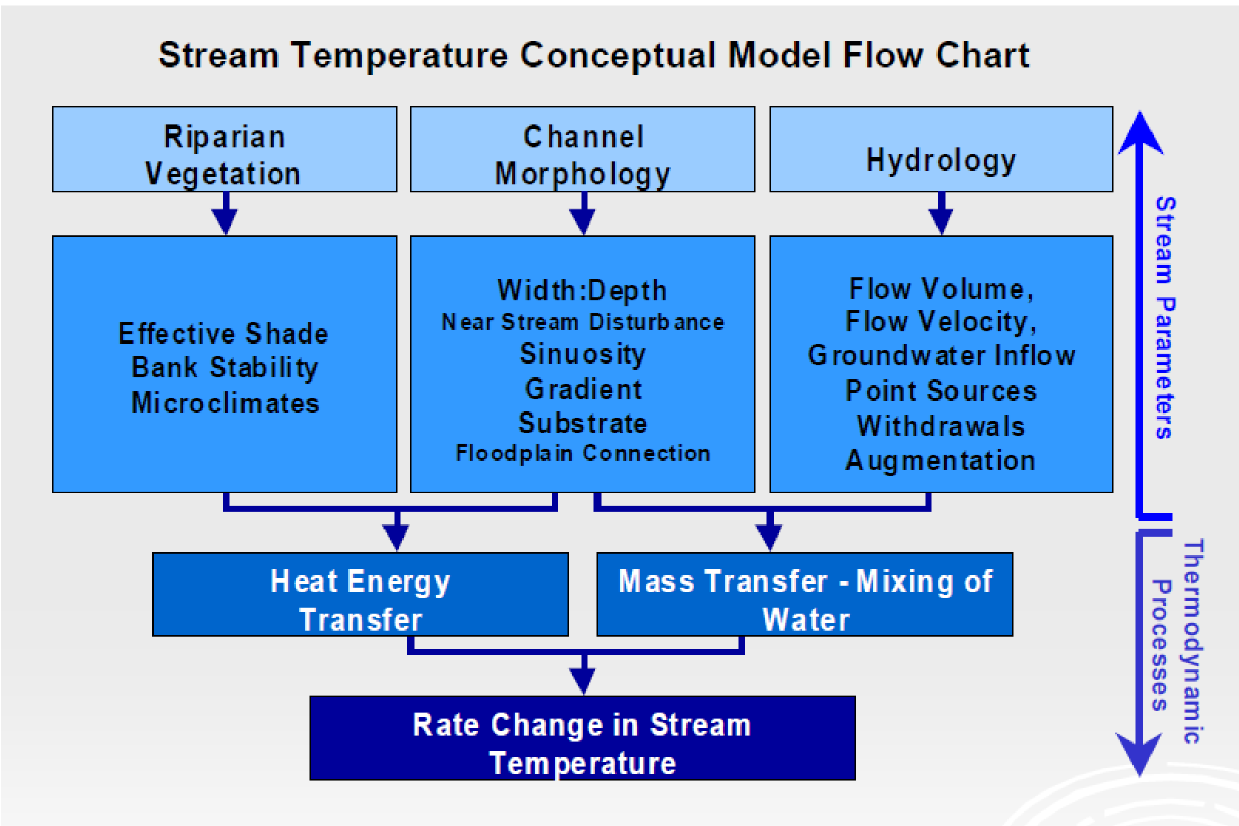

Figure B-1. Conceptual model of factors that affect stream temperature.

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

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

Water temperature can also be strongly affected by tributaries and human discharges, depending on their temperature. In lakes and reservoirs, water temperatures can be affected by thermal stratification and wind.

Heat budgets and temperature prediction

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

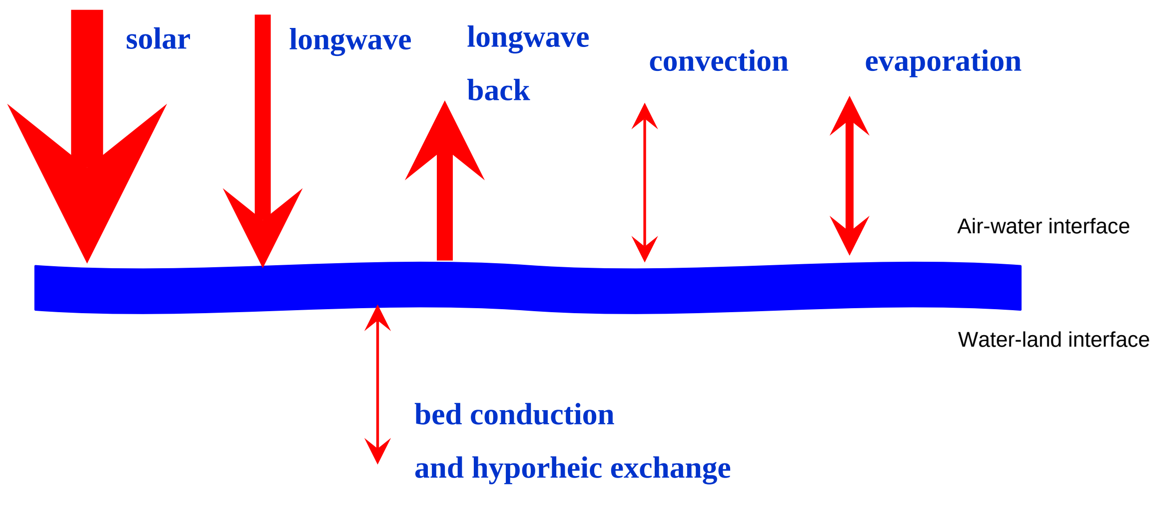

Figure B-2. Surface heat exchange processes that affect water temperature (net heat flux = solar + longwave atmosphere + longwave back + convection + evaporation + bed). Heat flux between the water and streambed occurs through conduction and hyporheic exchange.

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. Shortwave solar radiation is contained in a wavelength range from 0.14 um to about 4 um. At Ecology's weather station on the Palouse River near the mouth of Union Flat Creek (34PAL33.4), the daily average global shortwave solar radiation for July-August 2007 was 271 W/m^2. 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 unshaded 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.** The longwave radiation from the atmosphere ranges in wavelength from about 4 to 120 um. 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 to 120 um. 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/m^2 (Edinger et al., 1974).

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

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

  Hyporheic exchange can be an important mechanism for stream cooling in some basins (Johnson and Jones, 2000; Poole and Berman, 2000; Johnson, 2004). The hyporheic zone is defined as the region of saturated substrate 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. For example, studies in the Walla Walla River in Oregon have shown water temperatures declining downstream in a section of the river as hyporheic interstitial flow cools in a riffle reach and then remixes into the stream in a pool reach.

Figures B-3 and B-4 show surface heat flux in a relatively unshaded stream reach and in a more heavily shaded stream reach, respectively.

Figure B-3 shows an example of the estimated diurnal pattern of the surface heat fluxes in one of Washington's coastal rivers for the week of August 8-14, 2001. The daily maximum temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar shortwave heat flux (Adams and Sullivan, 1989). The solar shortwave flux can be controlled by managing vegetation in the riparian areas adjacent to the stream.

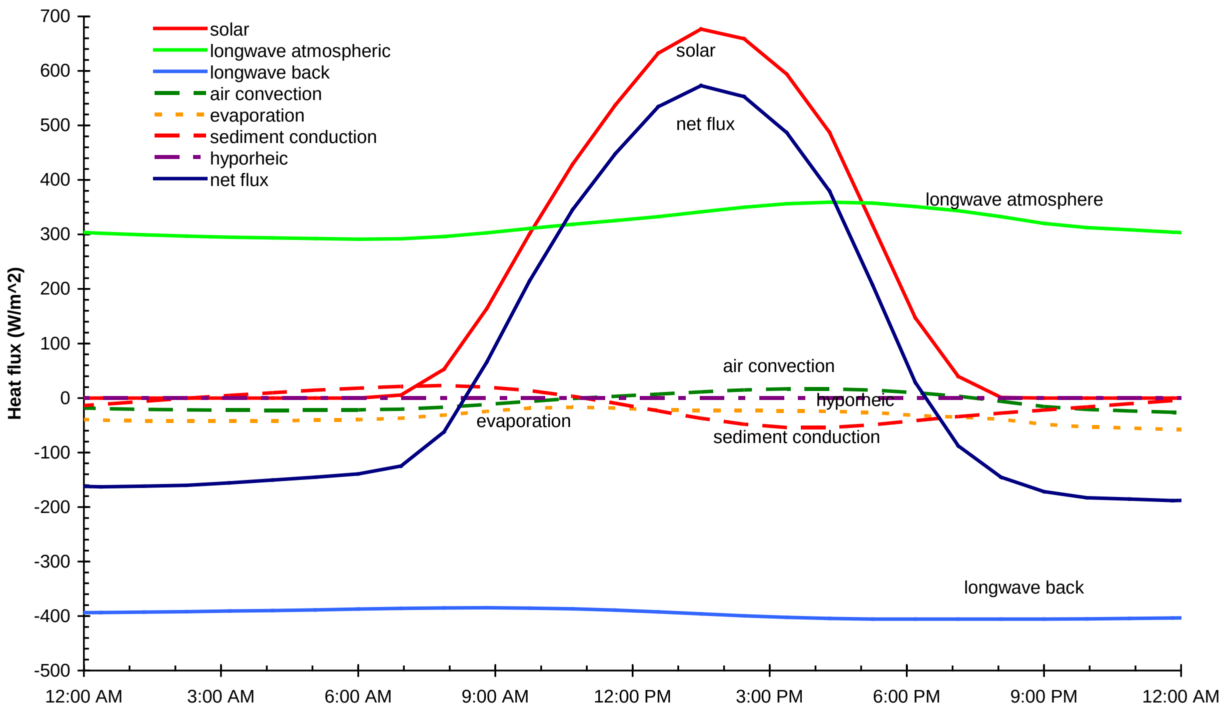

Figure B-3. Estimated heat fluxes in a river during August 8-14, 2001.

Net heat flux = solar + longwave atmosphere + longwave back + air convection + evaporation + sediment conduction + hyporheic.

Figure B-4 shows an example of the estimated diurnal pattern of the surface heat fluxes in a more heavily shaded location in the same river. Shade that is produced by riparian vegetation or topography can reduce the solar shortwave flux. Other processes – such as longwave radiation, convection, evaporation, bed conduction, or hyporheic exchange – also influence the net heat flux into or out of a stream.

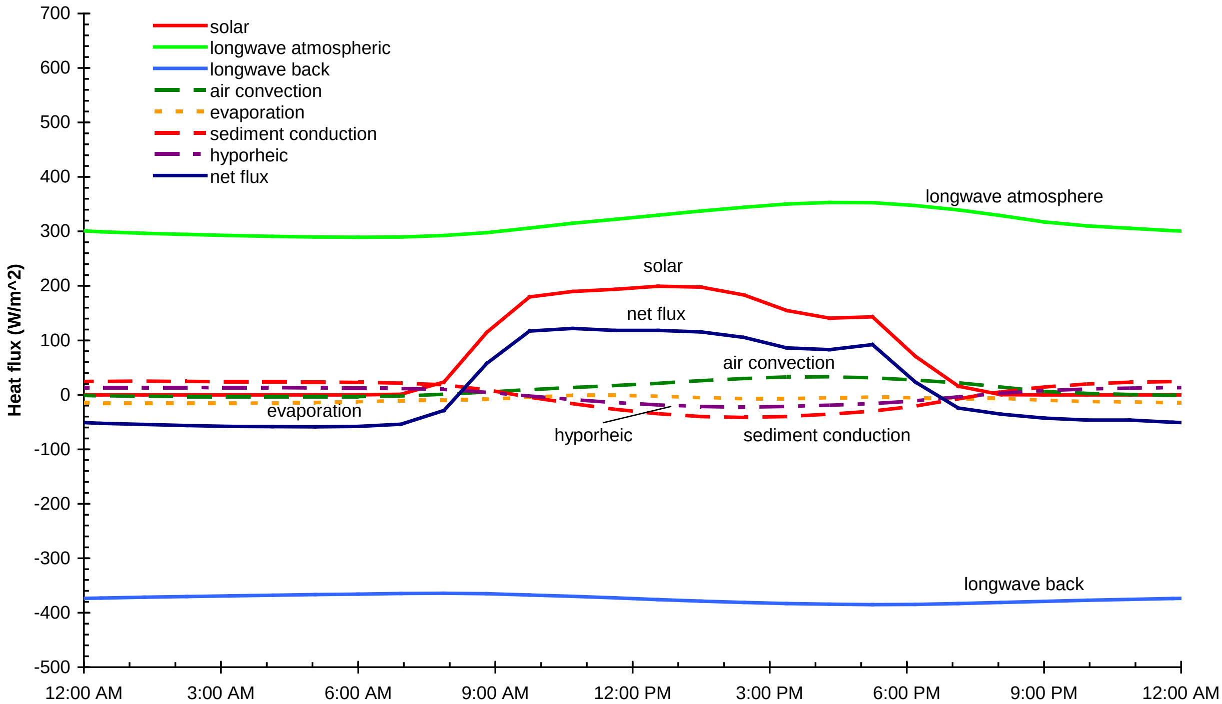

Figure B-4. Estimated heat fluxes in a more shaded section of a river during August 8-14, 2001.

Net heat flux = solar + longwave atmosphere + longwave back + air convection + evaporation + sediment conduction + hyporheic.

Heat exchange between the stream and the streambed has an important influence on water temperature. The temperature of the streambed is typically warmer than the overlying water at night and cooler than the water during the day (Figure B-5). Heat is typically transferred from the water into the streambed during the day, then back into the stream during the night (Adams and Sullivan, 1989). This has the effect of dampening the diurnal range of stream temperature variations without affecting the daily average stream temperature.

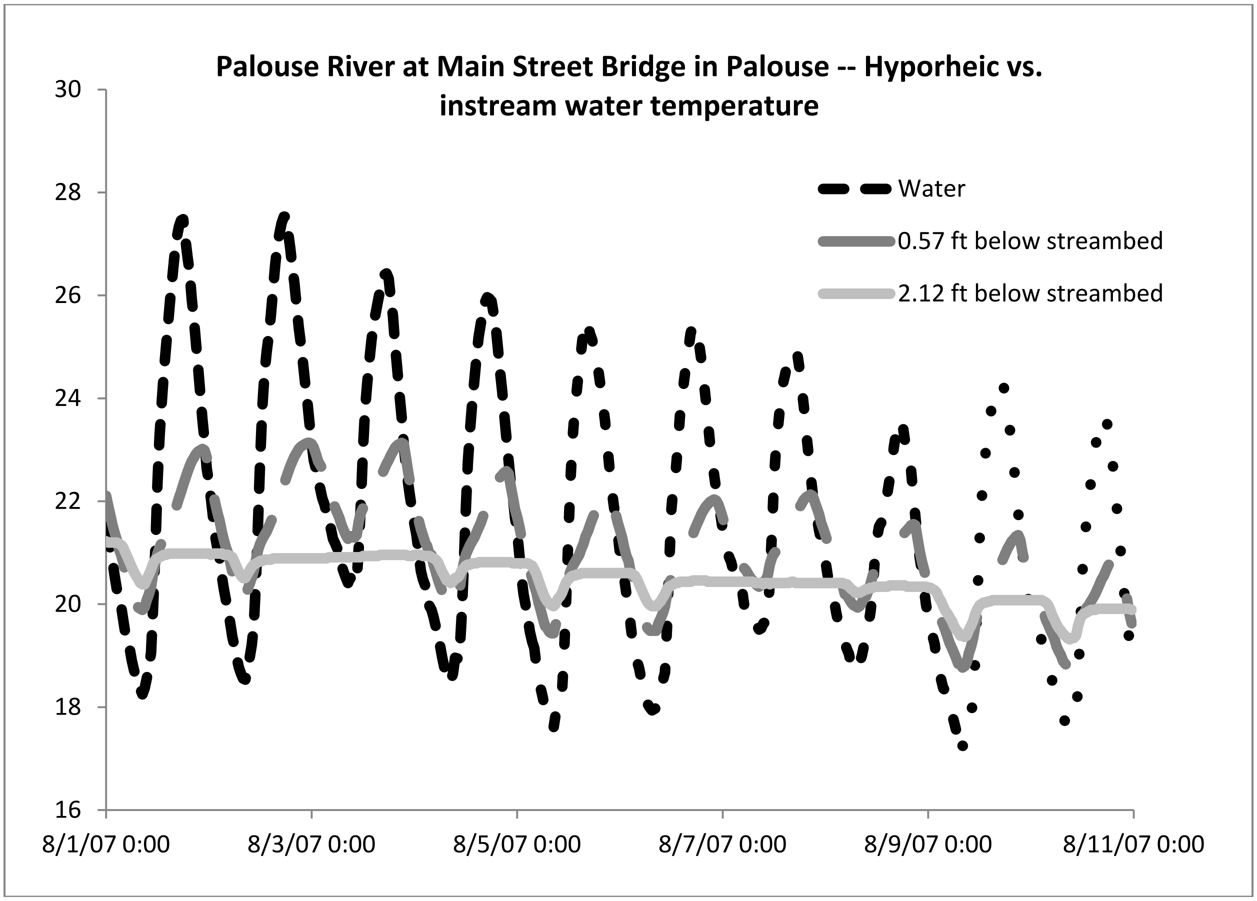

Figure B-5. Water and streambed temperatures in early August 2007 in the Palouse River at Main Street Bridge in Palouse (station 34PAL120.0).

The bulk temperature of a vertically mixed volume of water in a stream segment under natural conditions tends to increase or decrease with time during the day according to whether the net heat flux is either positive or negative. When the sun is not shining, the water 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; 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, human discharges and withdrawals, 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 are 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 direct, unobstructed solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al., 1992; Beschta et al., 1987; Bolton and Monahan, 2001; Castelle and Johnson, 2000; CH2M Hill, 2000; GEI, 2002; Ice, 2001; and Wenger, 1999. All of these summaries recognize that the scientific literature indicates that riparian vegetation plays an important role in controlling stream temperature. Important benefits that riparian vegetation has upon 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.
- Channel morphology can be strongly affected by near-stream vegetation. Specifically, stream vegetation is often part of human impacts on land-cover type and condition, which can affect flood plain and instream roughness, the contribution of coarse woody debris, sedimentation, stream substrate composition, and streambank stability.

Although the warming of water temperatures as a stream flows downstream can be a natural process, the rates of heating can be dramatically lower when high levels of shade exist and heat flux from solar radiation is minimized. There is a natural maximum potential level of vegetation and associated shade that a given stream is capable of attaining in an undisturbed situation. In general, 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

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). Effective shade is defined as the fraction or percentage of the total possible solar radiation heat energy that is prevented from reaching the surface of the water:

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

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

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 the summer, allowing longer day length and higher solar altitude. Both are functions of solar declination, a measure of the earth's tilt toward the sun (Figure B-6). Latitude and longitude positions fix the stream to a position on the globe, while aspect provides the 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, producing shade (Table B-1). The solar position has a vertical component – solar altitude – and a horizontal component – solar azimuth – that are both functions of time, date, and the earth's rotation.

While the interaction of these shade variables may seem complex, the mathematics that describes them is relatively straightforward geometry. Using solar tables or mathematical simulations, the potential daily solar load can be quantified. The shade from riparian vegetation can be measured with a variety of methods, including:

- Hemispherical photography
- Angular canopy densiometer
- Solar pathfinder

(Ice, 2001; OWEB, 1999; Boyd, 1996; Teti, 2001; Teti and Pike, 2005.)

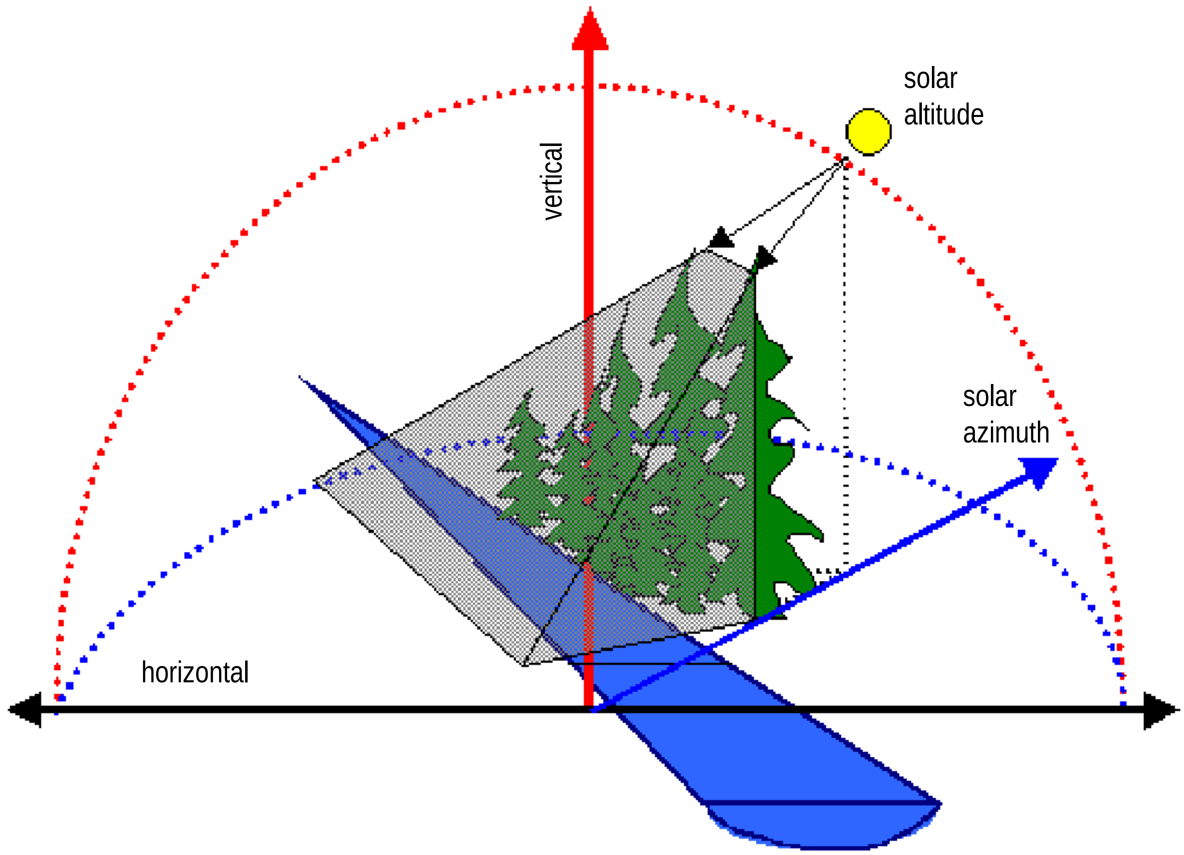

Figure B-6. Parameters that affect shade and geometric relationships. *Solar altitude* is a measure of the vertical angle of the sun's position relative to the horizon. *Solar azimuth* is a measure of the horizontal angle of the sun's position relative to north. (Boyd and Kasper, 2003.)

Hemispherical photography is generally regarded as the most accurate method for measuring shade, although the equipment that is required is significantly more expensive compared with other methods. Angular canopy densiometers (ACD) and solar pathfinders provide a good balance of cost and accuracy for measuring the importance of riparian vegetation for preventing increases in stream temperature (Beschta et al., 1987; Teti, 2001, 2005). Whereas canopy density is usually expressed as a vertical projection of the canopy onto a horizontal surface, the ACD is a projection of the canopy measured at an angle above the horizon at which direct beam solar radiation passes through the canopy. This angle is typically determined by the position of the sun above the horizon during that portion of the day (usually between 10 A.M. and 2 P.M. in mid to late summer) when the potential solar heat flux is most significant. Typical values of the ACD for old-growth stands in western Oregon have been reported to range from 80% to 90%. (Brazier and Brown, 1973; Steinblums et al., 1984).

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

Table B-1. Factors that influence stream shade.

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

Bold indicates influenced by human activities.

Riparian buffers and effective shade

Trees in riparian areas provide shade to streams and minimize undesirable water temperature changes (Brazier and Brown 1973; Steinblums et al., 1984). The shading effectiveness of riparian vegetation is correlated to riparian area width (Figure B-7). The shade as represented by angular canopy density (ACD) for a given riparian buffer width varies over space and time because of differences among site potential vegetation, and 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 B-7.

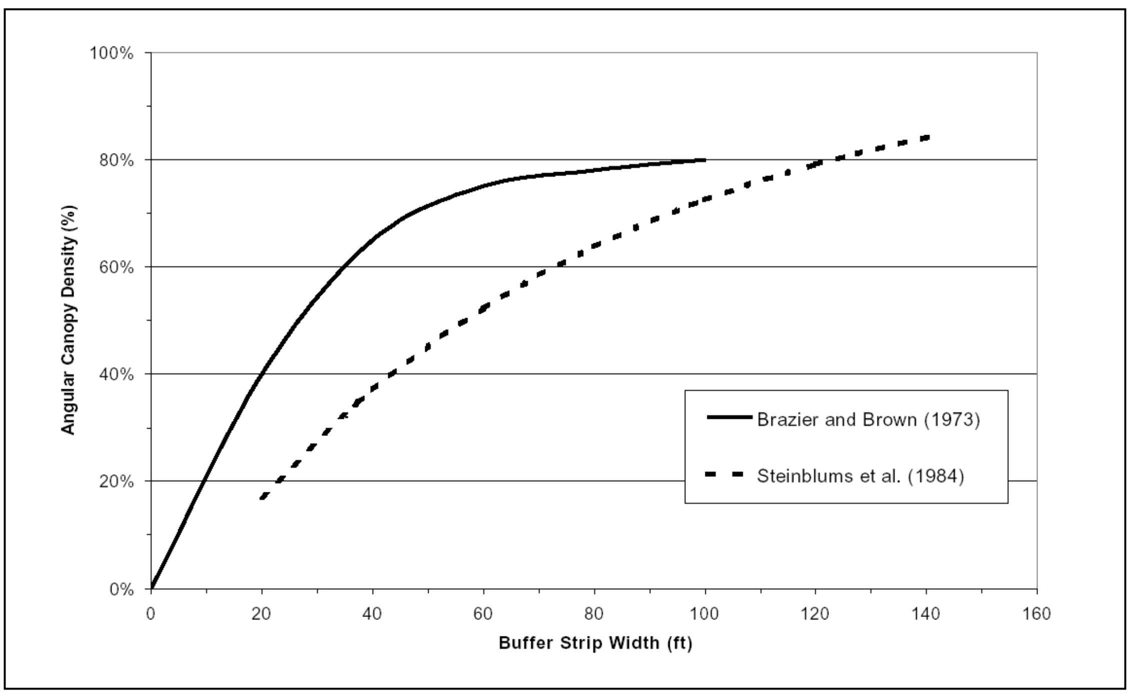

Figure B-7. Relationship between angular canopy density and riparian buffer width for small streams in old-growth riparian stands (after Beschta et al., 1987; and CH2M Hill, 2000).

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

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

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

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

Steinblums et al. (1984) concluded that shade could be delivered to forest streams from beyond 75 feet (22 m) and potentially out to 140 feet (43 m). In some site-specific cases, forest practices between 75 and 140 feet from the channel have the potential to reduce shade delivery by up to 25% of maximum. However, any reduction in shade beyond 75 feet would probably be relatively low on the horizon, and the impact on stream heating would be relatively minimal 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. Evapotranspiration by riparian plant communities increases relative humidity. Physical blockage by riparian vegetation reduces wind speed.

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, estimated at 7% during the day and 6% at night. 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 an estimated 0.7 to 1.2 meters per second.

Thermal role of channel morphology

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

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

Channel 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. Channel straightening can increase flow velocities and lead to deeply incised streambanks and washout of gravel and cobble substrate. 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 can also be the result of upland land practices or disconnection of the flood plain. Erosion in the watershed can result in high bed load and shallower, wider channels downstream. The separation of the flood plain from the main channel of a river can result in sediment being carried in the channel that would otherwise be deposited in the flood plain. It can also increase velocities and bank erosion.

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

- **Building streambanks**. Traps suspended sediments, encourages deposition of sediment in the flood plain, and reduces incoming sources of sediment.

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

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Appendix C. Load and wasteload allocations

This appendix contains numerical load allocations for effective shade to address 303(d) listings in the Palouse River Basin and alternative expressions of the wasteload allocation for the Palouse wastewater treatment plant (WWTP). Contents of this appendix:

- Table C-1. Load allocations for effective shade in the mainstem Palouse River.
- Table C-2 through C-6. Load allocations for effective shade for miscellaneous perennial streams in the Palouse River watershed, based on bankfull width, stream aspect, and potential vegetation type (See Table 9 and Figure 17).
- Table C-7. Potential vegetation types by reach.
- Table C-8. Palouse WWTP wasteload allocations expressed as heat load.
- Table C-9. Palouse WWTP wasteload allocations expressed as a flow limit.

Table C-1. Load allocations for effective shade in the Palouse River.

Distance from WA/ID state line to:		Landmark	Current effective shade (%)	System-potential effective shade (%)	Increase in % shade needed	Load allocation for daily average shortwave solar radiation on July 9 (watts/m^2)
Upstream (US) segment boundary (km)	Downstream (DS) segment boundary (km)					
0	1	WA/ID State Line along Wellesley Rd. (PAL124.3)	32%	40%	9%	187
1	2		22%	41%	18%	187
2	3		20%	37%	17%	198
3	4		8%	34%	26%	209
4	5	Bridge St. Bridge in Palouse (PAL120.3)	5%	32%	26%	215
5	6	Main St. Bridge in Palouse, Palouse WWTP	11%	34%	23%	206
6	7		12%	28%	16%	226
7	8	Hwy 272 (PAL118.9)	13%	29%	17%	222
8	9		4%	14%	10%	271
9	10		14%	27%	13%	228
10	11	Railroad trestle	10%	25%	15%	236
11	12		8%	22%	13%	246
12	13		15%	31%	16%	218
13	14		14%	30%	16%	219
14	15		16%	33%	17%	211
15	16	Cedar Creek Tributary	3%	16%	13%	263
16	17		6%	13%	7%	274
17	18		11%	25%	13%	236
18	19	Altergott Rd. (PAL112.4)	7%	13%	6%	273
19	20		10%	23%	12%	243
20	21		14%	24%	10%	240
21	22		14%	21%	6%	250
22	23		12%	22%	10%	244
23	24		7%	14%	7%	270
24	25	Lange Rd.	11%	27%	16%	229
25	26		15%	26%	10%	234
26	27		22%	31%	9%	215
27	28		16%	25%	9%	236
28	29		8%	20%	12%	251

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(Table C-1, continued)

US seg bdy. (km)	DS seg bdy. (km)	Landmark	Current shade (%)	Potential shade (%)	% shade increase	Load Alloc. (watts/m^2)
29	30		10%	23%	14%	241
30	31		9%	18%	8%	259
31	32	Oral Smith Rd., Elberton (PAL103.9), Silver Creek Tributary	10%	23%	13%	242
32	33		7%	14%	6%	272
33	34	Elberton Rd. (downstream crossing)	4%	17%	13%	260
34	35		6%	16%	10%	264
35	36		6%	15%	9%	267
36	37		11%	22%	11%	246
37	38		10%	23%	13%	242
38	39		7%	11%	5%	279
39	40		3%	11%	8%	279
40	41		9%	22%	13%	245
41	42		12%	25%	13%	235
42	43		5%	19%	14%	254
43	44		9%	16%	7%	263
44	45	Glenwood Rd. (PAL98.3)	8%	19%	11%	255
45	46		8%	20%	12%	252
46	47		7%	17%	10%	262
47	48		7%	14%	7%	271
48	49		6%	24%	18%	238
49	50		3%	14%	10%	271
50	51		5%	15%	10%	268
51	52	Baseball fields above Colfax (PAL91.7)	9%	24%	15%	239
52	53		3%	18%	14%	259
53	54		4%	13%	9%	275
54	55	Hwy 195 in Colfax, S. Fk. Palouse R. Tributary. (PAL91.5)	3%	6%	3%	295
55	56	Hwy 26 in Colfax, Colfax WWTP	5%	13%	8%	274
56	57	(PAL90.8)	3%	13%	9%	274
57	58		3%	13%	10%	275
58	59		10%	23%	13%	242
59	60		19%	22%	3%	245
60	61		13%	21%	8%	249
61	62	Opening of old railroad tunnel	10%	18%	8%	259
62	63		11%	24%	12%	240
63	64	Other opening of old RR tunnel through hairpin bend in river	12%	19%	6%	255
64	65	Covered bridge at Manning	11%	21%	10%	248
65	66	Dry Creek Tributary (PAL85.6)	9%	17%	7%	261
66	67		17%	28%	11%	227
67	68		6%	13%	7%	273
68	69	Right Bank Tributary	12%	23%	10%	243
69	70		12%	25%	13%	234
70	71		10%	22%	13%	244
71	72		6%	10%	4%	284
72	73		9%	20%	11%	252
73	74		17%	27%	9%	230
74	75	Myers Rd.	10%	27%	17%	230
75	76		8%	18%	10%	257
76	77		15%	23%	8%	242
77	78	Shields Rd. (A085)	15%	25%	9%	237
78	79		12%	21%	9%	249

(continued on next page)

(Table C-1, continued)

US seg bdy. (km)	DS seg bdy. (km)	Landmark	Current shade (%)	Potential shade (%)	% shade increase	Load Alloc. (watts /m^2)
79	80		4%	13%	9%	275
80	81		2%	8%	7%	288
81	82		12%	17%	5%	260
82	83		8%	15%	7%	266
83	84		10%	18%	7%	259
84	85		5%	12%	7%	277
85	86		6%	13%	7%	274
86	87		5%	9%	5%	285
87	88		10%	19%	9%	255
88	89		9%	19%	10%	255
89	90		5%	14%	9%	270
90	91		11%	22%	12%	245
91	92		7%	15%	8%	267
92	93		12%	25%	14%	235
93	94		16%	30%	14%	219
94	95		7%	19%	12%	254
95	96	St. John - Endicott Rd. (PAL66.8)	8%	20%	11%	253
96	97	Little Valley Creek Tributary	9%	20%	11%	252
97	98		8%	19%	11%	255
98	99		6%	22%	16%	245
99	100		8%	15%	7%	269
100	101		14%	22%	8%	246
101	102	Grove Rd. ford	8%	27%	19%	228
102	103		7%	17%	10%	260
103	104		4%	10%	6%	282
104	105		7%	18%	11%	259
105	106		13%	27%	14%	229
106	107	Ford	9%	20%	11%	251
107	108	Ford	11%	22%	11%	246
108	109	Kackman Rd. (PAL59.0)	9%	17%	9%	259
109	110		12%	20%	9%	250
110	111		6%	16%	10%	264
111	112		6%	18%	13%	257
112	113	Downing Creek Tributary	6%	19%	13%	255
113	114		4%	12%	9%	275
114	115		5%	13%	9%	272
115	116		4%	8%	4%	291
116	117		9%	16%	7%	265
117	118		8%	19%	11%	253
118	119		15%	26%	10%	234
119	120		8%	14%	6%	270
120	121		12%	19%	7%	253
121	122	Railroad trestle	4%	13%	9%	274
122	123		7%	18%	11%	259
123	124	Endicott W. Rd., Winona (A080)	7%	15%	9%	266
124	125	Rebel Flat Creek Tributary	5%	11%	7%	278
125	126		12%	16%	4%	265
126	127		10%	16%	6%	263
127	128		3%	16%	13%	264
128	129		3%	12%	9%	276

(continued on next page)

(Table C-1, continued)

US seg bdy. (km)	DS seg bdy. (km)	Landmark	Current shade (%)	Potential shade (%)	% shade increase	Load Alloc. (watts /m^2)
129	130		2%	6%	4%	296
130	131		4%	14%	10%	269
131	132		3%	12%	9%	278
132	133		5%	16%	11%	264
133	134		7%	12%	4%	277
134	135		4%	10%	6%	282
135	136		7%	13%	7%	273
136	137		4%	12%	8%	278
137	138	Rock Creek Tributary (PAL41.1)	6%	12%	6%	277
138	139		10%	21%	12%	247
139	140		10%	18%	8%	256
140	141		3%	12%	9%	276
141	142		2%	12%	10%	276
142	143		4%	15%	11%	267
143	144		6%	13%	7%	273
144	145		2%	5%	3%	299
145	146		3%	11%	8%	279
146	147		3%	9%	6%	287
147	148		2%	13%	11%	274
148	149		3%	14%	11%	270
149	150		4%	12%	9%	276
150	151	(PAL33.4)	5%	11%	7%	278
151	152	Union Flat Creek Tributary	3%	10%	6%	284
152	153		1%	8%	7%	289
153	154		2%	7%	5%	292
154	155		6%	13%	7%	274
155	156		4%	12%	8%	276
156	157		6%	16%	10%	265
157	158		5%	11%	6%	280
158	159		7%	9%	2%	286
159	160		6%	12%	6%	276
160	161		6%	14%	8%	270
161	162	Hwy 26, Willow Creek Tributary (PAL25.7)	7%	15%	8%	267
162	163		4%	9%	5%	286
163	164		4%	10%	6%	283
164	165		4%	11%	7%	281
165	166		4%	8%	5%	288
166	167		6%	14%	7%	271
167	168		3%	8%	5%	290
168	169		3%	8%	6%	289
169	170		3%	7%	4%	292
170	171		2%	6%	4%	295
171	172	Old Hwy 26, Hooper (A070)	3%	8%	5%	289
172	173	Cow Creek Tributary	6%	12%	6%	277
173	174		4%	10%	5%	284
174	175		3%	6%	4%	295
175	176	Railroad trestle	4%	10%	6%	283
176	177		4%	10%	6%	284
177	178	Old Hwy 26, downstream crossing (PAL15.8)	8%	13%	5%	274
178	179		2%	7%	4%	293

(continued on next page)

(Table C-1, continued)

US seg bdy. (km)	DS seg bdy. (km)	Landmark	Current shade (%)	Potential shade (%)	% shade increase	Load Alloc. (watts /m^2)
179	180		1%	4%	3%	301
180	181		5%	10%	5%	282
181	182	Little Palouse Falls	4%	11%	7%	280
182	183		8%	19%	11%	255
183	184		19%	28%	9%	225
184	185		16%	25%	8%	237
185	186		11%	17%	6%	259
186	187		9%	15%	6%	266
187	188	Railroad trestle	9%	26%	18%	232
188	189		20%	24%	4%	239
189	190		9%	22%	13%	244
190	191		11%	20%	10%	250
191	192	Palouse Falls (PAL06.7)	16%	26%	10%	232
192	193		19%	25%	6%	235
193	194		14%	20%	7%	251
194	195		7%	13%	6%	272
195	196		5%	7%	3%	292
196	197		7%	8%	1%	289
197	198		9%	11%	2%	280
198	199	Lagoon and mouth of Palouse River into wide reservoir	4%	4%	0%	303
199	200		2%	3%	1%	306
200	201	Lyons Ferry State Park	3%	6%	3%	295

Table C-2. Load allocations for effective shade in lower two miles of tributaries in the Conifers + Deciduous Buffer potential vegetation type, based on bankfull width and stream aspect.

Bankfull Width (m)	Effective Shade from Vegetation (%) at the Stream Center at Various Stream Aspects (Degrees from N)			Load Allocation for Daily Average Shortwave Solar Radiation (W/M^2) on July 9 at Various Stream Aspects (Degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
0.5	76%	73%	65%	75	84	109
1	75%	73%	65%	77	86	111
1.5	75%	72%	64%	78	87	113
2	75%	72%	64%	80	89	115
3	67%	64%	56%	104	114	140
4	61%	58%	50%	122	132	157
5	57%	54%	46%	134	143	168
6	55%	52%	44%	142	152	177
7	53%	49%	42%	149	159	183
8	51%	48%	40%	154	165	189
9	49%	46%	38%	159	170	194
10	48%	44%	37%	164	175	198
12	46%	42%	34%	171	183	208
14	43%	40%	30%	178	190	220
16	42%	38%	27%	184	196	230
18	40%	36%	24%	189	202	237
20	38%	34%	22%	194	207	244
25	35%	30%	19%	205	219	255
30	32%	27%	16%	214	229	263

Table C-3. Load allocations for effective shade in lower two miles of tributaries in the Grasses + Deciduous Buffer potential vegetation type, based on bankfull width and stream aspect.

Bankfull Width (m)	Effective Shade from Vegetation (%) at The Stream Center at Various Stream Aspects (Degrees from N)			Load Allocation for Daily Average Shortwave Solar Radiation (W/M^2) on July 9 at Various Stream Aspects (Degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
0.5	49%	48%	44%	159	163	177
1	49%	48%	43%	160	164	178
1.5	49%	48%	43%	161	165	179
2	49%	47%	42%	162	166	181
3	43%	42%	37%	178	182	198
4	40%	38%	33%	190	194	209
5	37%	36%	31%	198	202	217
6	35%	34%	29%	203	208	222
7	34%	32%	28%	208	212	226
8	33%	31%	27%	211	216	230
9	32%	30%	26%	214	219	233
10	31%	29%	25%	217	222	237
12	29%	28%	23%	222	228	243
14	28%	26%	20%	226	232	251
16	27%	25%	18%	230	236	257
18	26%	24%	16%	233	240	262
20	25%	22%	15%	237	244	267
25	22%	20%	13%	244	252	274
30	21%	18%	11%	250	258	280

Table C-4. Load allocations for effective shade in lower two miles of tributaries in the Large Shrubs and Grasses potential vegetation type, based on bankfull width and stream aspect.

Bankfull Width (m)	Effective Shade from Vegetation (%) at the Stream Center at Various Stream Aspects (Degrees from N)			Load Allocation for Daily Average Shortwave Solar Radiation (W/m^2) on July 9 at Various Stream Aspects (Degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
0.5	96%	95%	95%	14	15	16
1	95%	94%	94%	16	18	18
1.5	91%	90%	90%	29	31	32
2	85%	83%	81%	49	53	60
3	75%	73%	69%	77	85	98
4	69%	66%	61%	96	106	123
5	65%	61%	52%	111	122	149
6	61%	57%	45%	124	136	173
7	57%	53%	40%	134	148	190
8	54%	49%	36%	144	159	203
9	51%	46%	32%	153	169	213
10	49%	44%	30%	161	177	222
12	44%	39%	25%	175	193	235
14	41%	35%	22%	187	206	244
16	37%	31%	20%	197	216	252
18	34%	28%	18%	206	225	258
20	32%	26%	16%	214	233	263
25	27%	21%	13%	229	247	272
30	23%	18%	11%	241	257	278

Table C-5. Load allocations for effective shade in lower two miles of tributaries in the Moderate Shrubs and Grasses potential vegetation type, based on bankfull width and stream aspect.

Bankfull Width (m)	Effective Shade from Vegetation (%) at the Stream Center at Various Stream Aspects (Degrees from N)			Load Allocation for Daily Average Shortwave Solar Radiation (W/m^2) on July 9 at Various Stream Aspects (Degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
0.5	78%	76%	74%	69	75	82
1	67%	65%	61%	104	111	122
1.5	58%	56%	52%	132	139	150
2	53%	51%	47%	148	155	167
3	47%	44%	40%	168	176	190
4	42%	39%	32%	181	190	214
5	39%	36%	26%	192	202	231
6	36%	33%	23%	201	212	243
7	34%	30%	20%	209	221	251
8	31%	27%	18%	216	228	258
9	29%	25%	16%	222	235	263
10	28%	23%	15%	228	241	267
12	25%	20%	13%	237	251	274
14	22%	18%	11%	245	258	279
16	20%	16%	10%	251	264	283
18	18%	15%	9%	257	269	286
20	17%	13%	8%	262	273	288
25	14%	11%	7%	271	280	293
30	12%	9%	6%	277	285	296

Table C-6. Load allocations for effective shade in lower two miles of tributaries in the Willow Brush potential vegetation type, based on bankfull width and stream aspect.

Bankfull Width (m)	Effective Shade from Vegetation (%) at the Stream Center at Various Stream Aspects (Degrees from N)			Load Allocation for Daily Average Shortwave Solar Radiation (W/m^2) on July 9 at Various Stream Aspects (Degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
0.5	67%	66%	63%	103	107	116
1	52%	51%	48%	150	155	163
1.5	46%	44%	42%	170	175	184
2	42%	40%	36%	183	189	202
3	36%	34%	25%	201	209	234
4	32%	29%	20%	215	224	251
5	28%	25%	17%	226	236	262
6	25%	22%	14%	235	246	269
7	23%	19%	13%	242	253	274
8	21%	17%	11%	248	260	279
9	19%	16%	10%	254	265	282
10	18%	14%	9%	259	269	285
12	15%	12%	8%	266	275	289
14	13%	11%	7%	272	280	292
16	12%	10%	6%	277	284	295
18	11%	9%	6%	280	287	297
20	10%	8%	5%	283	289	298
25	8%	6%	4%	289	294	301
30	7%	6%	4%	293	297	303

Table C-7. Potential vegetation types by stream reach for the Palouse River basin.

Load allocations for tributaries are given in this TMDL only for the two miles nearest the mouth. Potential vegetation described in this table upstream of that point is given for guidance purposes.

Stream and Reach	Potential Vegetation Type
Palouse River	
ID state line to Downing Creek	Conifers + Deciduous Buffer
Downing Creek to Adams/Whitman Co. line (RM 36.5)	Grasses + Deciduous Buffer
Adams/Whitman Co. line to mouth	Willow Brush
Duffield Creek	
Above Howard Rd.	Large Shrubs and Grasses
Below Howard Rd.	Conifers + Deciduous Buffer
Cedar Creek	
Above Grinnell (Cascade Flying Service)	Large Shrubs and Grasses
Below Grinnell (Cascade Flying Service)	Conifers + Deciduous Buffer
Silver Creek	
Above 3rd St. Bridge, Garfield	Large Shrubs and Grasses
Below 3rd St. Bridge, Garfield	Conifers + Deciduous Buffer
Brush Creek	
Above Vantine Rd.	Large Shrubs and Grasses
Below Vantine Rd.	Conifers + Deciduous Buffer
Clear Creek	
Above Hwy 272	Large Shrubs and Grasses
Below Hwy 272	Conifers + Deciduous Buffer
Dry Creek	
Above pt. 1 mi. upstream of Green Hollow Rd.	Large Shrubs and Grasses
Below pt. 1 mi. upstream of Green Hollow Rd.	Conifers + Deciduous Buffer
Unnamed Drainages at Delong Rd.	
Canyon above Delong Rd. (both drainages)	Moderate Shrubs and Grasses
Below Delong Rd. (both drainages)	Conifers + Deciduous Buffer
Little Valley Creek	
Above Jones Rd.	Moderate Shrubs and Grasses
Below Jones Rd.	Conifers + Deciduous Buffer
Downing Creek	
Entire creek	Moderate Shrubs and Grasses
Cherry Creek	
Entire creek above Cherry Cove Lake	Moderate Shrubs and Grasses
Rebel Flat Creek	
Entire creek	Moderate Shrubs and Grasses
Rock Creek	
Rock Lake to pt. 3 mi. upstream of Endicott W Rd.	Moderate Shrubs and Grasses
Below pt. 3 mi. upstream of Endicott W Rd.	Grasses + Deciduous Buffer
Union Flat Creek	
Almota Rd. to WA/ID state line	Large Shrubs and Grasses
Winona South Rd. to Almota Rd.	Moderate Shrubs and Grasses
Below Winona South Rd.	Willow Brush
Willow Creek	
Entire creek	Moderate Shrubs and Grasses
Cow Creek	
Below Hwy 26	Willow Brush

RM: river mile

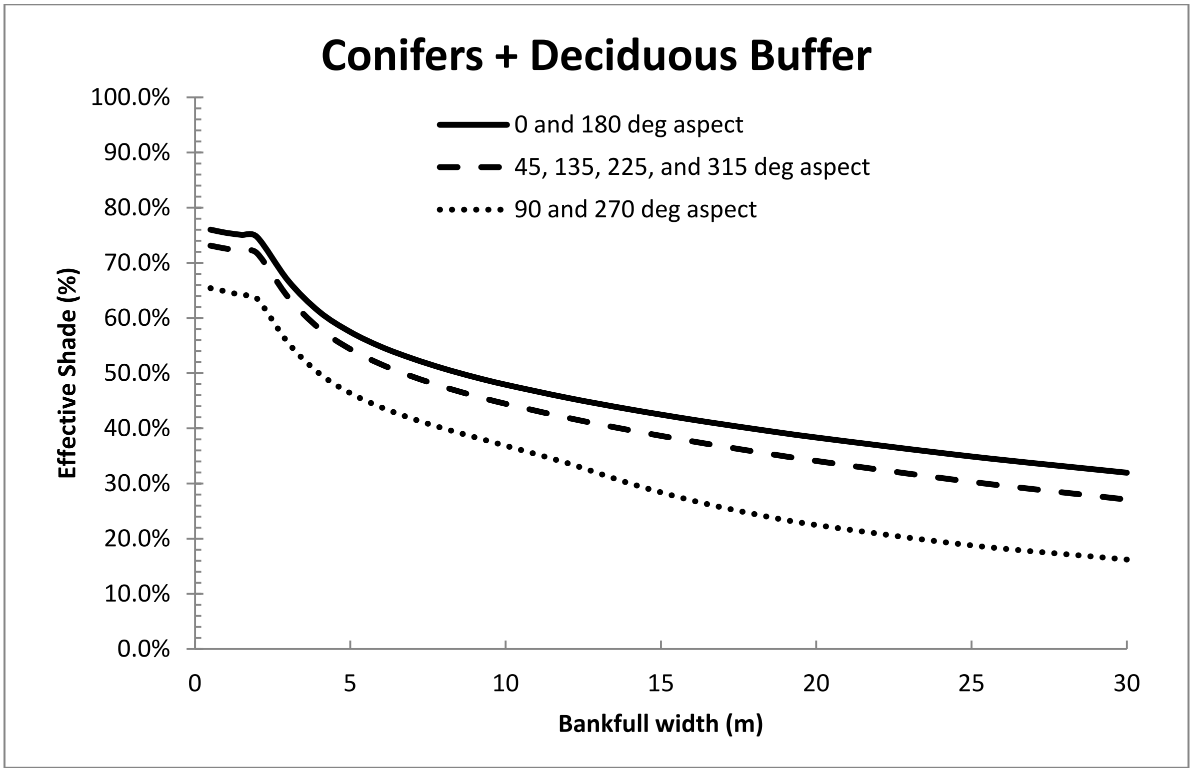

Figure C-1. Potential shade curve for the Conifers + Deciduous Buffer vegetation type.

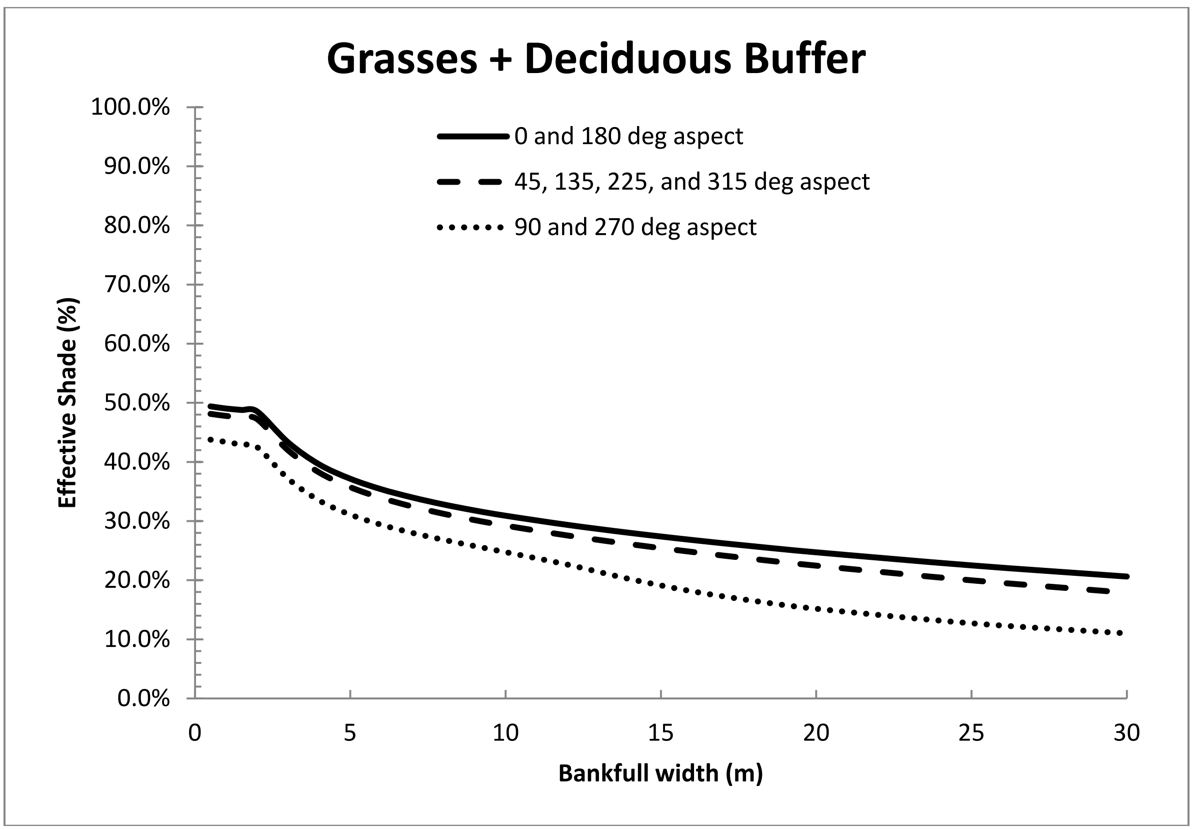

Figure C-2. Potential shade curve for the Grasses + Deciduous Buffer vegetation type.

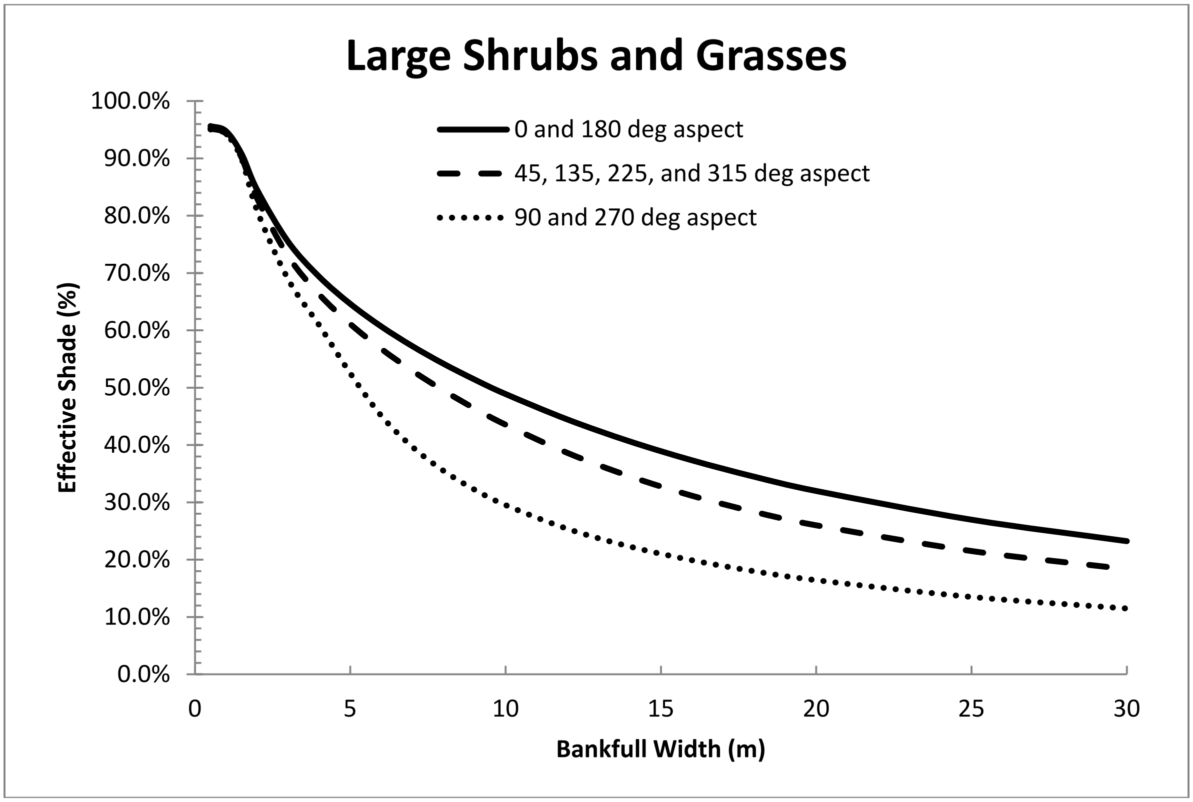

Figure C-3. Potential shade curve for the Large Shrubs and Grasses vegetation type.

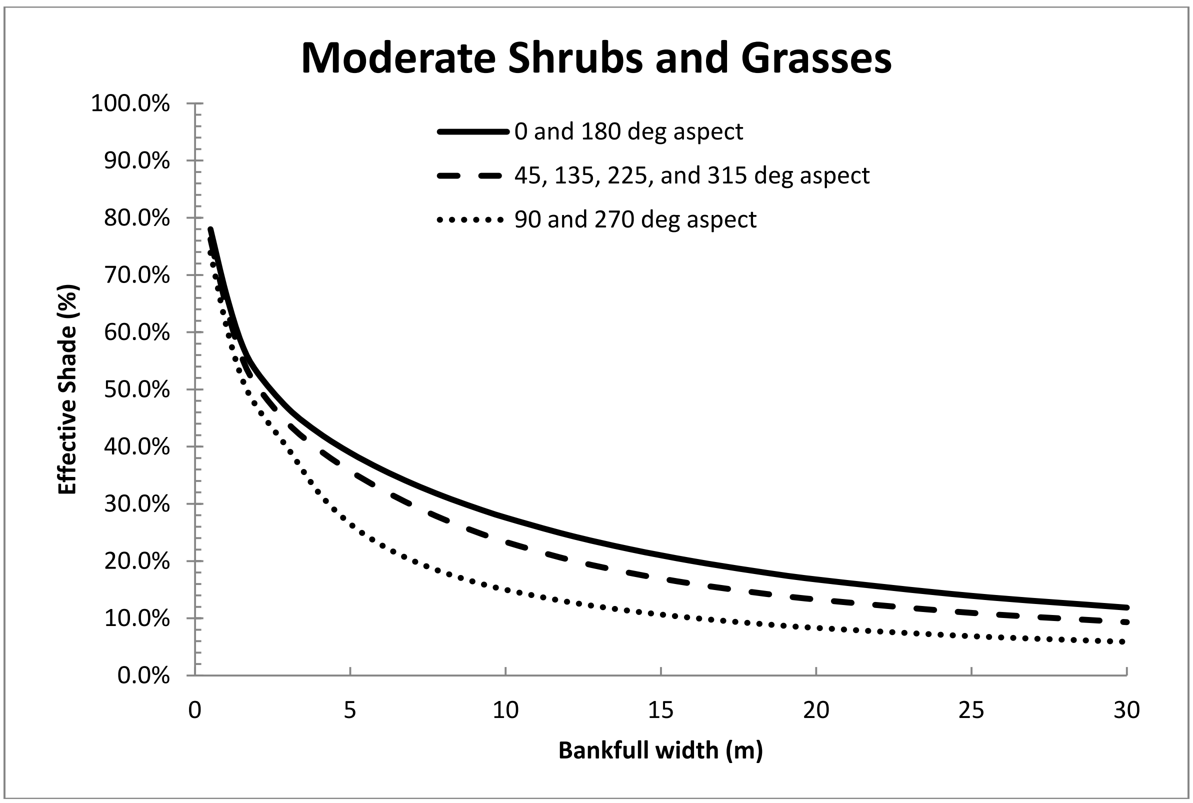

Figure C-4. Potential shade curve for the Moderate Shrubs and Grasses vegetation type.

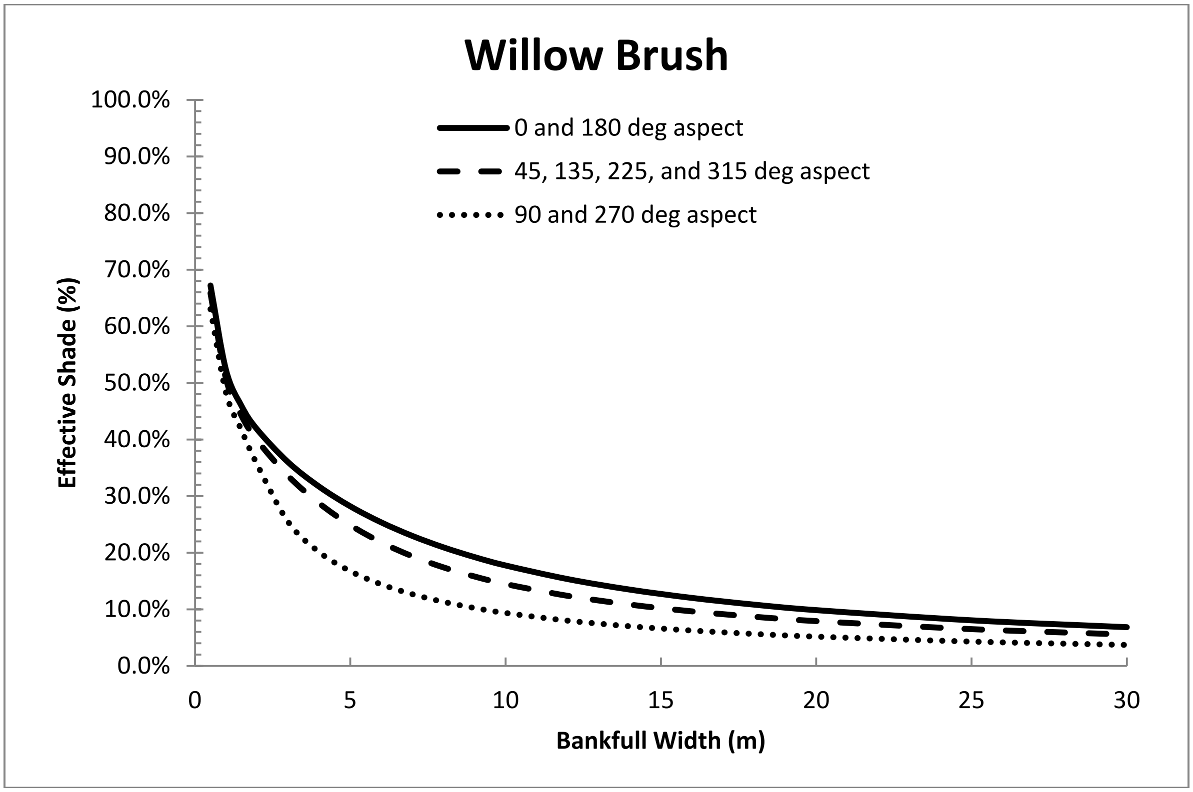

Figure C-5. Potential shade curve for the Willow Brush vegetation type.

Table C-8. Palouse WWTP wasteload allocations expressed as heat load.

Potlatch Q as cubic feet per second (cfs)	WLA as kcal/day
0.2	36699
0.4	73397
0.6	110096
0.8	146794
1	183493
1.2	220191
1.4	256890
1.6	293589
1.8	330287
2	366986
2.5	458732
3	550479
3.5	642225
4	733971
4.5	825718
5	917464
5.5	1009211
6	1100957
6.5	1192704
7	1284450
7.5	1376196
8	1467943
10	1834929
15	2752393
20	3669857
40	7339715

Equation used to calculate head load wasteload allocation:
WLA kcal/day = $0.3*(0.25Q_{US})*(28316.8*86400/1000)$
Q_{US} is upstream flow at the Potlatch USGS gage

Table C-9. Palouse WWTP wasteload allocations expressed as a flow limit.

	Max Daily Effluent Temperature (C)												
Potlatch	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0
Q (cfs)	*Effluent Discharge Limit in mgd*												
0.2	NL	0.019	0.010	0.006	0.005	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002
0.4	NL	0.039	0.019	0.013	0.010	0.008	0.006	0.006	0.005	0.004	0.004	0.004	0.003
0.6	NL	0.058	0.029	0.019	0.015	0.012	0.010	0.008	0.007	0.006	0.006	0.005	0.005
0.8	NL	0.078	0.039	0.026	0.019	0.016	0.013	0.011	0.010	0.009	0.008	0.007	0.006
1	NL	0.097	0.048	0.032	0.024	0.019	0.016	0.014	0.012	0.011	0.010	0.009	0.008
1.2	NL	0.116	0.058	0.039	0.029	0.023	0.019	0.017	0.015	0.013	0.012	0.011	0.010
1.4	NL	0.136	0.068	0.045	0.034	0.027	0.023	0.019	0.017	0.015	0.014	0.012	0.011
1.6	NL	0.155	0.078	0.052	0.039	0.031	0.026	0.022	0.019	0.017	0.016	0.014	0.013
1.8	NL	0.175	0.087	0.058	0.044	0.035	0.029	0.025	0.022	0.019	0.017	0.016	0.015
2	NL	0.194	0.097	0.065	0.048	0.039	0.032	0.028	0.024	0.022	0.019	0.018	0.016
2.5	NL	0.242	0.121	0.081	0.061	0.048	0.040	0.035	0.030	0.027	0.024	0.022	0.020
3	NL	0.291	0.145	0.097	0.073	0.058	0.048	0.042	0.036	0.032	0.029	0.026	0.024
3.5	NL	0.339	0.170	0.113	0.085	0.068	0.057	0.048	0.042	0.038	0.034	0.031	0.028
4	NL	0.388	0.194	0.129	0.097	0.078	0.065	0.055	0.048	0.043	0.039	0.035	0.032
4.5	NL	0.436	0.218	0.145	0.109	0.087	0.073	0.062	0.055	0.048	0.044	0.040	0.036
5	NL	0.485	0.242	0.162	0.121	0.097	0.081	0.069	0.061	0.054	0.048	0.044	0.040
5.5	NL	0.533	0.267	0.178	0.133	0.107	0.089	0.076	0.067	0.059	0.053	0.048	0.044
6	NL	0.560	0.291	0.194	0.145	0.116	0.097	0.083	0.073	0.065	0.058	0.053	0.048
6.5	NL	0.560	0.315	0.210	0.158	0.126	0.105	0.090	0.079	0.070	0.063	0.057	0.053
7	NL	0.560	0.339	0.226	0.170	0.136	0.113	0.097	0.085	0.075	0.068	0.062	0.057
7.5	NL	0.560	0.364	0.242	0.182	0.145	0.121	0.104	0.091	0.081	0.073	0.066	0.061
8	NL	0.560	0.388	0.259	0.194	0.155	0.129	0.111	0.097	0.086	0.078	0.071	0.065
10	NL	0.560	0.485	0.323	0.242	0.194	0.162	0.138	0.121	0.108	0.097	0.088	0.081
15	NL	0.560	0.560	0.485	0.364	0.291	0.242	0.208	0.182	0.162	0.145	0.132	0.121
20	NL	0.560	0.560	0.560	0.485	0.388	0.323	0.277	0.242	0.215	0.194	0.176	0.162
40+	NL	0.560	0.560	0.560	0.560	0.560	0.560	0.554	0.485	0.431	0.388	0.353	0.323
	NL = No limit												
(shaded)	Capped at max design flow of 0.56 mgd												

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Appendix D. Data summary

Data collected by Ecology for the *Palouse River Temperature TMDL* are available in the Environmental Information Management system (EIM). EIM is located online at www.ecy.wa.gov/eim/. The user study ID is JICA0001.

Continuous water temperature monitoring data for 2007

Figures D-1 through D-7 show daily maximum water temperatures measured by Ecology. Temperatures were recorded every 30 minutes by Onset® Stowaway TidbiT and Hobo monitors. See Table 8 for the exact location of each monitoring station.

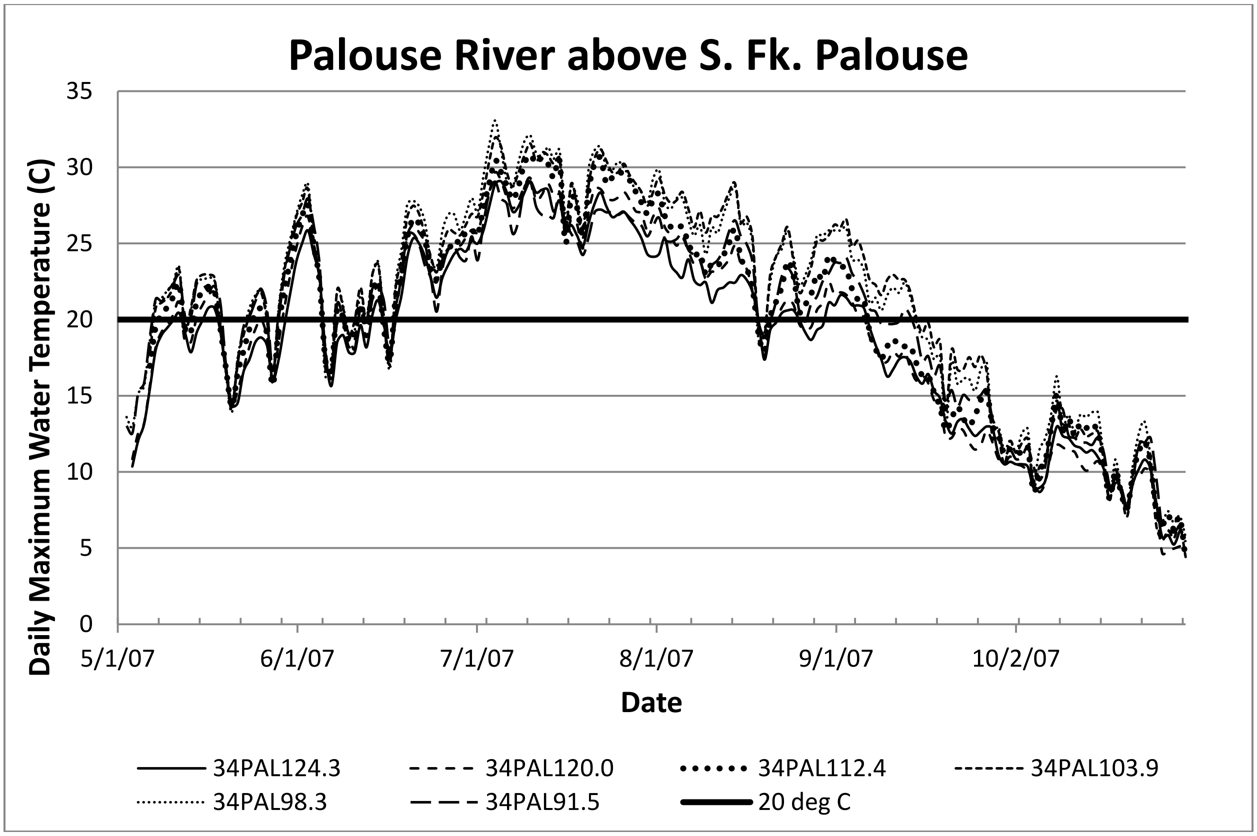

Figure D-1. Daily maximum water temperatures in the portion of the Palouse River (locally referred to as the North Fork Palouse) upstream of the South Fork Palouse River.

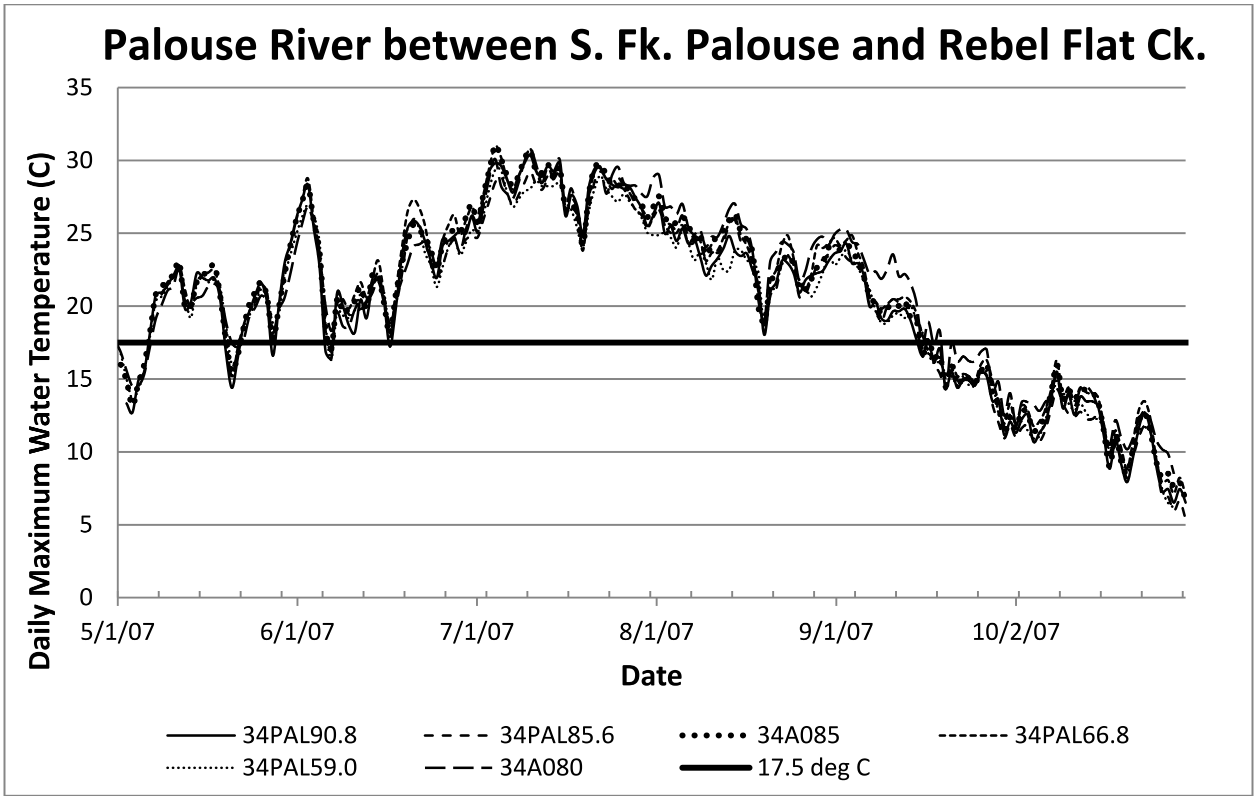

Figure D-2. Daily maximum water temperatures in the portion of the Palouse River extending from the South Fork Palouse River to Rebel Flat Creek.

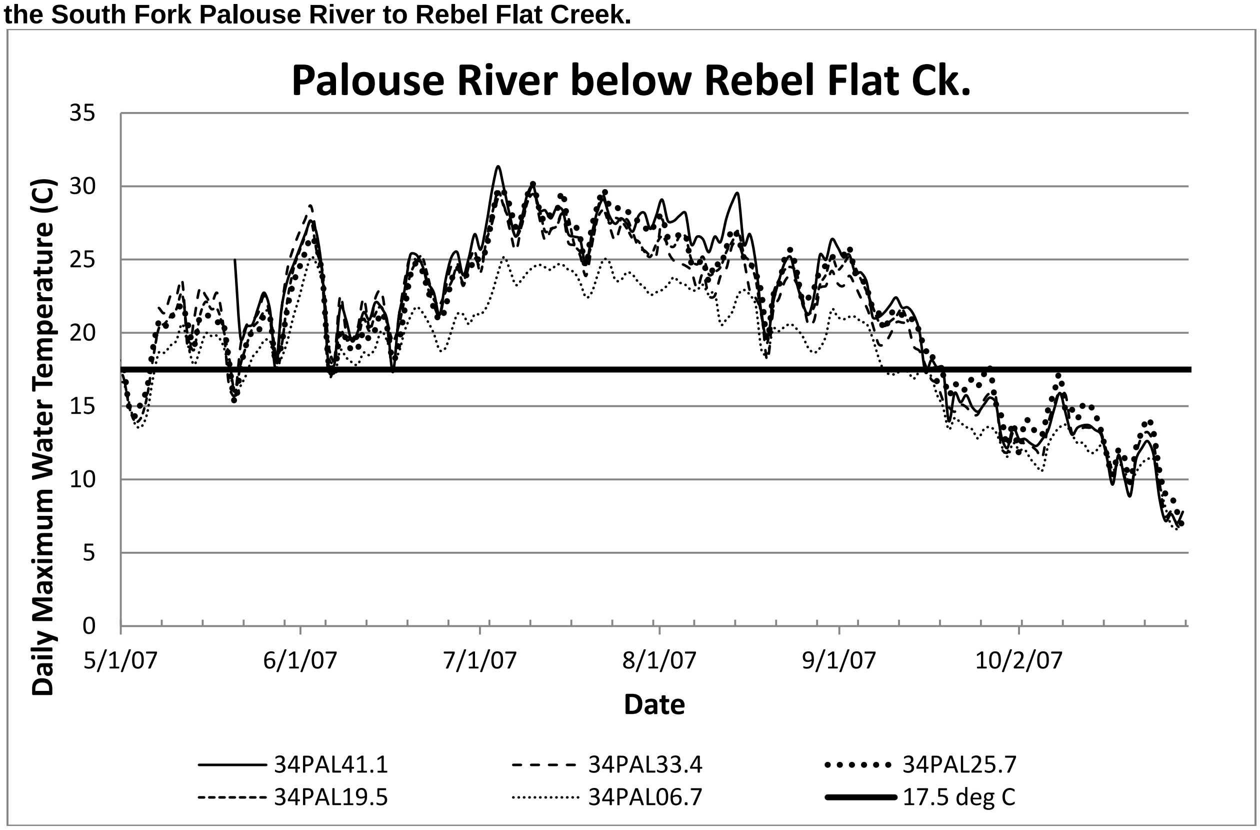

Figure D-3. Daily maximum water temperatures in the portion of the Palouse River downstream of Rebel Flat Creek.

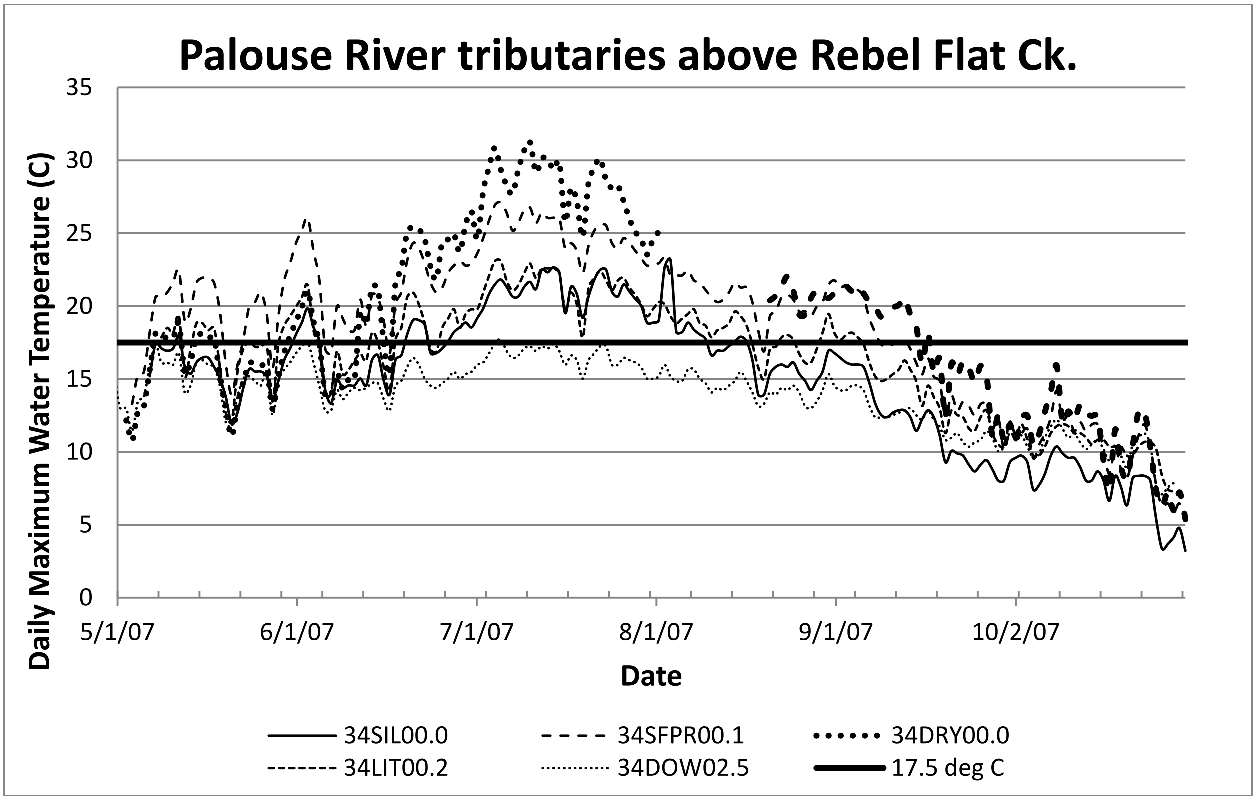

Figure D-4. Daily maximum water temperatures in tributaries to the Palouse River upstream of Rebel Flat Creek.

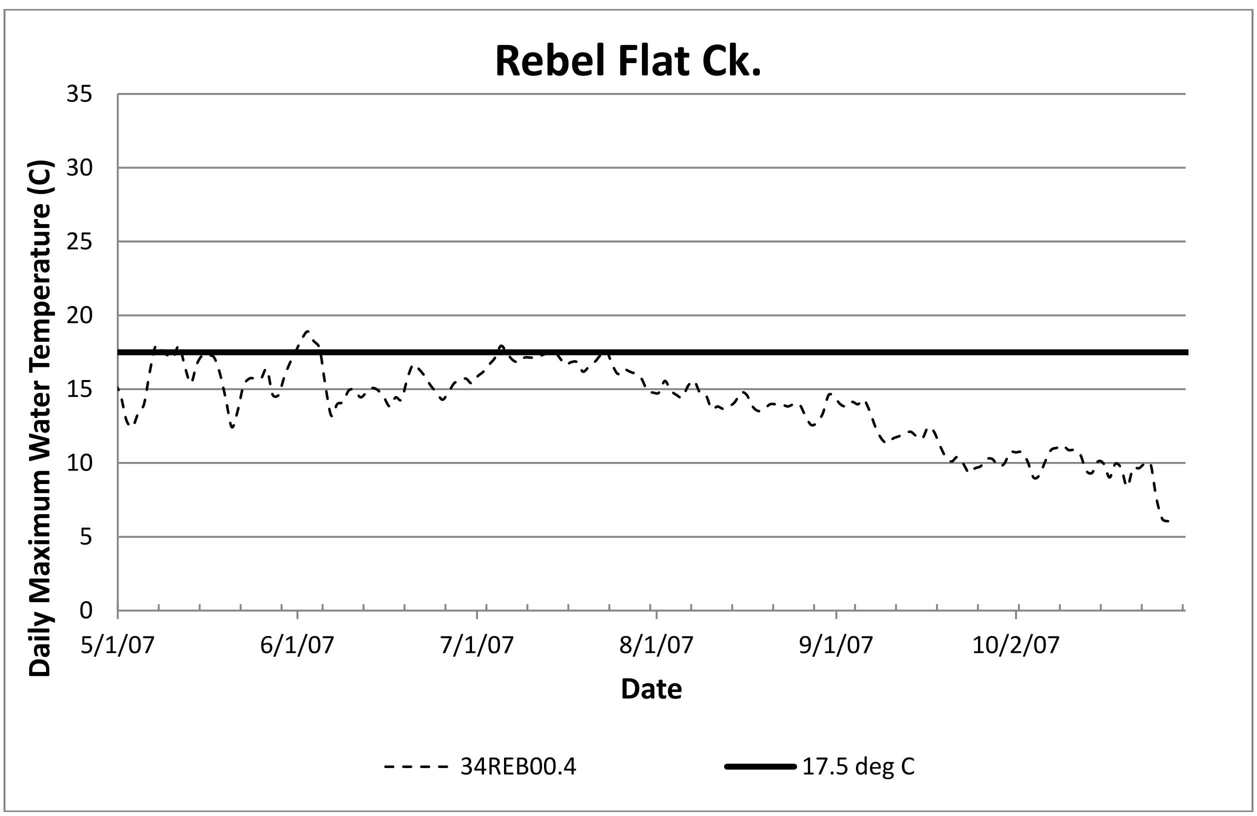

Figure D-5. Daily maximum water temperatures at the mouth of Rebel Flat Creek.

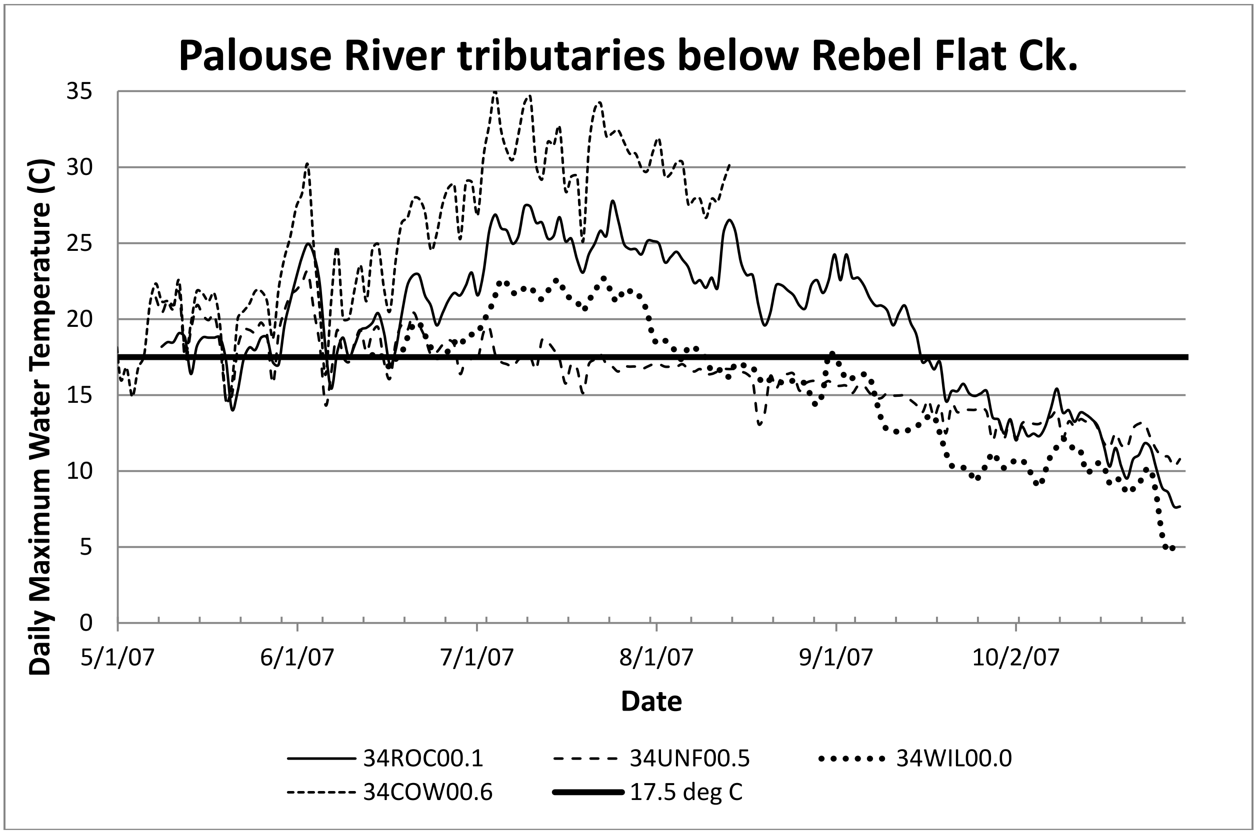

Figure D-6. Daily maximum water temperatures at the mouth of tributaries to the Palouse River downstream of Rebel Flat Creek.

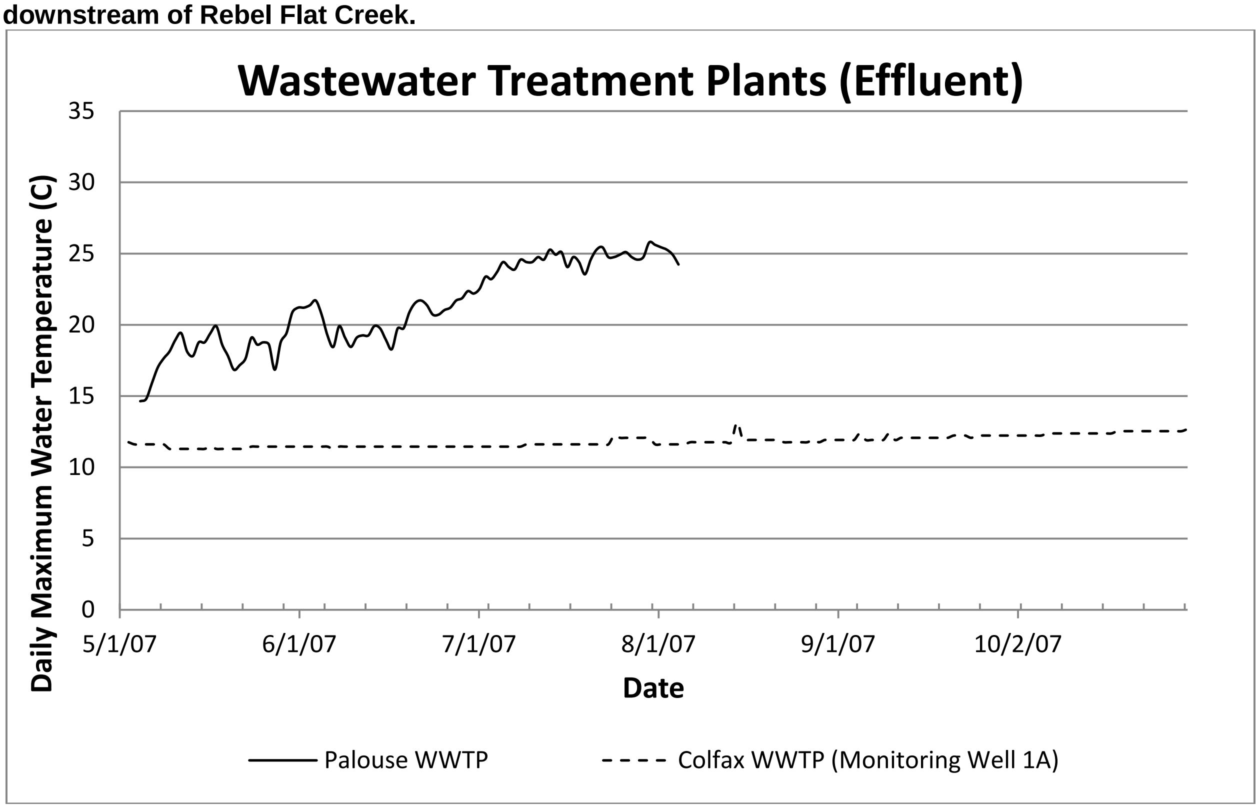

Figure D-7. Daily maximum effluent temperatures for the two wastewater treatment plants (WWTPs) discharging to the Palouse River and its tributaries.

Instantaneous flow measurements

Table D-1 shows instantaneous flow measurements made as part of the *Palouse River Temperature TMDL* study. Additional instantaneous flow measurements were made as part of the concurrent Palouse River Fecal Coliform and Dissolved Oxygen/pH TMDL studies. These data are not shown in this appendix but are available in EIM. Continuous flow data collected by Ecology's Freshwater Monitoring Unit are available online at www.ecy.wa.gov/programs/eap/flow/shu_main.html.

Table D-1. Instantaneous flow measurements made as part of the Palouse Temperature TMDL study.

Site ID	Station Description	Date	Time	Flow (cfs)	Area (ft^2)	Wet Perimeter (ft)	Wet Width (ft)	Avg Velocity (ft/s)	Avg Depth (ft)
34COW00.6	Cow Ck. near mouth at Grey Rd.	4/30/2007	18:05	16	16.9	24.6	27.1	0.92	0.62
34DOW00.5	Downing Ck. at Kackman Rd. near mouth	5/10/2007	16:35	2.3	5.7	4.8	4.4	0.41	1.28
34DRY00.0	Dry Ck. at Manning near mouth	5/3/2007	11:25	6.5	10.2	12.6	13.2	0.64	0.77
34LIT00.2	Little Valley Ck. at Jones Rd. near mouth	5/9/2007	15:30	0.58	1.5	4.5	5.0	0.39	0.30
34PAL06.7	Palouse R. below falls at Palouse Falls State Pk.	6/15/2007	15:00	135	145.9	86.8	86.0	0.92	1.70
34PAL06.7	Palouse R. below falls at Palouse Falls State Pk.	7/13/2007	14:10	32	101.8	64.5	74.0	0.31	1.38
34PAL06.7	Palouse R. below falls at Palouse Falls State Pk.	8/17/2007	11:00	8.6	81.0	63.9	64.6	0.11	1.25
34PAL06.7	Palouse R. below falls at Palouse Falls State Pk.	9/14/2007	12:40	23	89.8	66.2	66.4	0.26	1.35
34PAL06.7	Palouse R. below falls at Palouse Falls State Pk.	10/11/2007	14:00	36	128.2	73.3	72.9	0.28	1.76
34PAL06.7	Palouse R. below falls at Palouse Falls State Pk.	10/19/2007	10:30	58	146.8	65.1	78.5	0.40	1.87
34PAL41.1	Palouse River above Rock Ck.	8/13/2007	14:30	2.5	31.2	61.2	62.8	0.08	0.50
34PAL33.4	Palouse River above Union Flat Ck.	8/13/2007	16:10	6.8	74.4	98.2	105.4	0.09	0.71
34PAL103.9	Palouse River abv. Silver Ck. in Elberton	6/12/2007	11:05	60	69.8	47.2	52.4	0.87	1.33
34PAL103.9	Palouse River abv. Silver Ck. in Elberton	7/12/2007	13:45	10	38.5	49.0	51.0	0.26	0.75
34PAL103.9	Palouse River abv. Silver Ck. in Elberton	8/15/2007	13:15	2.3	12.0	20.1	22.2	0.19	0.54
34PAL103.9	Palouse River abv. Silver Ck. in Elberton	9/10/2007	16:20	2.6	14.8	22.3	23.7	0.17	0.63
34PAL103.9	Palouse River abv. Silver Ck. in Elberton	10/9/2007	13:38	9.0	17.0	30.4	29.4	0.53	0.58
34PAL103.9	Palouse River abv. Silver Ck. in Elberton	10/31/2007	15:00	10	18.4	21.4	28.1	0.57	0.66
34PAL25.7	Palouse River abv. Willow Ck. at Hwy 26	8/13/2007	18:00	16	28.1	32.6	34.1	0.55	0.82
34PAL112.4	Palouse River at Altergott Rd.	6/4/2007	15:45	37	65.7	48.9	51.5	0.57	1.28
34PAL112.4	Palouse River at Altergott Rd.	7/12/2007	12:22	9.9	48.7	50.9	50.8	0.20	0.96
34PAL112.4	Palouse River at Altergott Rd.	8/15/2007	11:30	1.6	42.1	40.1	50.8	0.04	0.83
34PAL112.4	Palouse River at Altergott Rd.	9/12/2007	14:00	1.9	43.7	48.8	48.9	0.04	0.89
34PAL112.4	Palouse River at Altergott Rd.	10/9/2007	12:30	7.5	57.3	50.7	52.6	0.13	1.09
34PAL112.4	Palouse River at Altergott Rd.	10/31/2007	13:00	9.8	54.6	46.5	50.2	0.18	1.09
34PAL66.8	Palouse River at Endicott-St. John Rd.	6/15/2007	17:00	65	52.8	49.8	53.0	1.23	1.00
34PAL66.8	Palouse River at Endicott-St. John Rd.	8/14/2007	12:45	3.5	52.9	46.8	51.8	0.07	1.02
34PAL98.3	Palouse River at Glenwood Rd.	6/12/2007	12:38	72	53.4	38.4	37.9	1.35	1.41
34PAL98.3	Palouse River at Glenwood Rd.	7/12/2007	15:00	8.4	26.2	34.3	33.9	0.32	0.77
34PAL98.3	Palouse River at Glenwood Rd.	8/14/2007	16:00	1.6	15.6	29.3	30.3	0.11	0.51
34PAL98.3	Palouse River at Glenwood Rd.	9/13/2007	14:44	3.3	18.4	29.0	31.5	0.18	0.58
34PAL98.3	Palouse River at Glenwood Rd.	10/9/2007	15:23	9.5	16.6	26.3	25.6	0.57	0.65
34PAL98.3	Palouse River at Glenwood Rd.	10/31/2007	16:45	12	16.8	25.5	26.8	0.70	0.63
34PAL85.6	Palouse River at Manning above Dry Ck.	8/15/2007	14:45	5.0	21.4	31.6	35.6	0.24	0.60
34PAL120.3	Palouse River at Palouse off Bridge St.	6/12/2007	9:50	54	86.9	60.2	62.3	0.62	1.39
34PAL120.3	Palouse River at Palouse off Bridge St.	7/12/2007	10:00	10	55.4	54.2	61.3	0.18	0.90
34PAL120.3	Palouse River at Palouse off Bridge St.	8/15/2007	10:00	2.4	59.4	59.7	61.8	0.04	0.96

(continued on next page)

(Table D-1, continued)

Site ID	Station Description	Date	Time	Flow (cfs)	Area (ft^2)	Wet Perimeter (ft)	Wet Width (ft)	Avg Velocity (ft/s)	Avg Depth (ft)
34PAL120.3	Palouse River at Palouse off Bridge St.	10/9/2007	11:07	7.6	33.3	26.7	27.3	0.23	1.22
34PAL120.3	Palouse River at Palouse off Bridge St.	10/31/2007	11:30	8.3	37.3	26.9	27.3	0.22	1.37
34PAL120.0	Palouse River at Palouse off Main St.	9/13/2007	11:00	3.8	26.7	27.7	28.2	0.14	0.95
34PAL124.3	Palouse River at WA/ID state border	6/4/2007	17:57	32	157.4	59.7	63.3	0.20	2.49
34PAL124.3	Palouse River at WA/ID state border	7/12/2007	10:20	8.9	139.5	61.0	63.6	0.06	2.19
34PAL124.3	Palouse River at WA/ID state border	8/15/2007	9:17	0.95	128.6	56.3	56.5	0.01	2.28
34PAL124.3	Palouse River at WA/ID state border	10/9/2007	9:30	7.4	39.6	39.8	40.4	0.19	0.98
34PAL124.3	Palouse River at WA/ID state border	10/31/2007	10:00	9.2	39.8	42.9	45.2	0.23	0.88
34PAL124.0	Palouse River downstream of state border	9/13/2007	8:45	2.2	31.1	38.1	40.0	0.07	0.78
34PAL124.0	Palouse River downstream of state border	9/13/2007	12:10	4.3	31.6	38.8	40.1	0.14	0.79
34REB00.4	Rebel Flat Ck. near mouth	5/1/2007	15:00	6.8	11.0	10.3	10.4	0.61	1.06
34ROC00.1	Rock Ck. near mouth	6/6/2007	16:10	43	45.8	30.3	32.5	0.94	1.41
34ROC00.1	Rock Ck. near mouth	8/13/2007	14:50	6.3	8.8	23.6	24.0	0.72	0.37
34SIL00.0	Silver Ck. at Elberton near mouth	5/7/2007	17:20	2.4	6.8	13.1	12.8	0.36	0.53
34SIL00.0	Silver Ck. at Elberton near mouth	6/12/2007	11:42	1.2	6.3	8.3	9.0	0.19	0.70
34SIL00.0	Silver Ck. at Elberton near mouth	7/12/2007	14:00	0.45	3.1	6.4	6.5	0.15	0.48
34SIL00.0	Silver Ck. at Elberton near mouth	8/15/2007	12:40	0.46	1.9	4.6	5.5	0.24	0.35
34SIL00.0	Silver Ck. at Elberton near mouth	9/13/2007	14:00	0.45	0.8	3.2	3.4	0.56	0.24
34SIL00.0	Silver Ck. at Elberton near mouth	10/9/2007	14:10	0.47	6.7	10.0	11.7	0.07	0.57
34SIL00.0	Silver Ck. at Elberton near mouth	10/31/2007	15:30	0.75	4.4	9.1	9.6	0.17	0.46
34SFPR00.1	South Fork Palouse R. at Colfax near mouth	5/3/2007	12:20	43	53.6	33.4	35.8	0.81	1.50
34WIL00.0	Willow Ck. near mouth	5/1/2007	13:20	1.8	9.8	9.4	9.5	0.18	1.03

Time of travel data

Table D-2 presents times of travel in the Palouse River measured using rhodamine dye. These data are not available in EIM.

Table D-2. Time of Travel dye study data from the Palouse River and Rebel Flat Creek.

Dates of survey	Reach	Distance (mi)	Result		USGS Flow During Study	
			Travel Time (h:m)	Velocity (ft/s)	Potlatch	Hooper
5/23-24/2007	34PAL90.8 to 34PAL77.8	13.2	20:45	0.93	81 cfs	227 cfs
	34PAL77.8 to 34PAL66.8	11.0	16:15	0.99		
5/24-25/2007	34PAL66.8 to 34PAL59.0	7.8	12:05	0.95	64 cfs	240 cfs
	34PAL59.0 to 34PAL49.5	9.5	dye lost[1]			
6/5-6/2007	34PAL49.5 to 34PAL41.1	8.4	20:45	0.59	39 cfs	133 cfs
	34PAL41.1 to 34PAL25.7	15.4	~32:15[2]	~0.70[2]		
8/21-26/2007	34PAL120.3 to 34PAL112.4	7.9	118:25	0.10	4.3 cfs	15 cfs
	34PAL103.9 to 34PAL98.3	5.6	114:57	0.07		
	34PAL85.6 to 34PAL77.8	7.8	114:25	0.10		
8/21-24/2007	34PAL66.8 to 34PAL59.0	7.8	90:33	0.07	4.8 cfs	16 cfs
8/16-19/2007	34PAL59.0 to 34PAL49.5	9.5	Hydrolab error		1.6 cfs	9.2 cfs
	34PAL49.5 to 34PAL41.1	8.4	71:29	0.17		
8/16-20/2007	34PAL41.1 to 34PAL33.4	7.7	91:58	0.12	1.7 cfs	10 cfs
8/16-17/2007	34PAL25.7 to 34PAL19.5	6.2	85:35	0.11	1.7 cfs	8.5 cfs

[1]This reach contains unusually long, deep, wide pools, likely as a result of mechanical channel modification. See Figure 7 – this reach extends from somewhat upstream of Downing Creek to Rebel Flat Creek. This reach likely has a much slower travel time than adjacent reaches. It is likely that the hydrolab was pulled out of the water before the leading edge of the dye reached the downstream end of the reach. This is also why the Average Velocity listed in Table 8 for "S. Fork Palouse confluence in Colfax to Rebel Flat confluence at Winona" is lower (especially for May) than the velocities measured within that reach. The estimated travel time for the 34PAL59.0-to-34PAL49.5 portion of this reach brings the overall average velocity down.

[2]For these reaches, the hydrolab missed the peak dye concentration but caught either the leading edge or the tail end, so the values in the table are approximate. Travel times are based on the estimated time of peak dye concentration.

Hemispherical photography data

Table D-3 presents effective shade measurements made using hemispherical photography. Effective shade can be calculated for different times of year using a single hemispherical photo, by accounting for the different path the sun takes through the sky on different dates. These effective shade measurements were calculated for July 9, 2007.

Table D-3. Effective shade measurements made from hemispherical photos for July 9.

Station ID	Station description	Effective Shade for July 9		
		Center Channel	Left Bank	Right Bank
34PAL124.3	Palouse R at WA/ID state border	11%	9%	40%
34PAL120.3	Palouse R at Palouse off Bridge St (34A170)	21%	23%	32%
34PAL112.4	Palouse R at Altergott Rd	21%	12%	20%
34PAL103.9	Palouse R above Silver Ck in Elberton	47%	72%	38%
34PAL98.3	Palouse R at Glenwood Rd	2%	1%	1%
34PAL91.5	Palouse R at Colfax, above South Fork Palouse R	0%	4%	27%
34PAL90.8	Palouse R below Colfax WWTP	0%	7%	0%
34PAL85.6	Palouse R at Manning, above Dry Ck	0%	0%	0%
34PAL77.8	Palouse R at Shields Rd Bridge (34A085)	19%	42%	2%
34PAL66.8	Palouse R at Endicott-St John Rd	5%	4%	16%
34PAL59.0	Palouse R at Kackman Rd	no photo	5%	8%
34PAL49.5	Palouse R above Rebel Flat Ck, Winona (34A080)	2%	15%	5%
34PAL41.1	Palouse R above Rock Ck	0%	0%	2%
34PAL33.4	Palouse R above Union Flat Ck	0%	1%	4%
34PAL25.7	Palouse R above Willow Ck, at Hwy 26	8%	2%	47%
34PAL19.5	Palouse R at Hooper (34A070)	1%	62%	3%
34PAL06.7	Palouse R below falls at Palouse Falls State Park	14%	63%	22%
34SIL00.0	Silver Ck at Elberton near mouth	24%	no photo	no photo
34SFPR00.1	South Fork Palouse at Colfax near mouth	7%	no photo	no photo
34DRY00.0	Dry Ck at Manning near mouth	6%	no photo	no photo
34LIT00.2	Little Valley Ck at Jones Rd near mouth	46%	no photo	no photo
34DOW00.5	Downing Ck at Kackman Rd near mouth	17%	no photo	no photo
34REB00.4	Rebel Flat Ck near mouth (34K050)	1%	no photo	no photo
34ROC00.1	Rock Ck near mouth	24%	no photo	no photo
34UNF00.5	Union Flat Ck at Wise Rd near mouth (34J050)	1%	no photo	no photo
34WIL00.0	Willow Ck near mouth	79%	no photo	no photo
34COW00.6	Cow Ck near mouth at Grey Rd (34L050)	2%	no photo	no photo

Appendix E. QUAL2Kw model sensitivity analysis

Several sensitivity analyses were run to test various assumptions made during model calibration and to determine the relative importance of various factors that affect stream temperatures.

The Palouse River has two major tributaries, the South Fork Palouse River and Rock Creek, each of which contributes a large portion of flow during summer low-flow conditions. In some cases, these tributaries contribute more flow than is in the Palouse River upstream where these tributaries enter the mainstem.

Starting with the calibrated QUAL2Kw model for conditions on 7/6-12/2007, the temperatures of these two tributaries were decreased: (1) by 2ºC and (2) to the water quality standard applicable to those tributaries, 17.5ºC (Figure E-1). Decreasing these tributary temperatures by 2ºC resulted in a 0.44ºC decrease in maximum temperatures below the South Fork Palouse and a 1.06ºC decrease in maximum temperatures below Rock Ck. Lowering the temperatures of these tributaries to 17.5ºC (which is considered an extreme and unlikely scenario) had an effect on maximum temperatures of 1.79ºC and 4.32ºC, respectively. The cooling effects of lower tributary temperatures, though substantial, were local and limited to the area just downstream of these tributaries, with temperatures returning to equilibrium conditions within 7-15 km downstream. This is because of the slow travel time of the Palouse River.

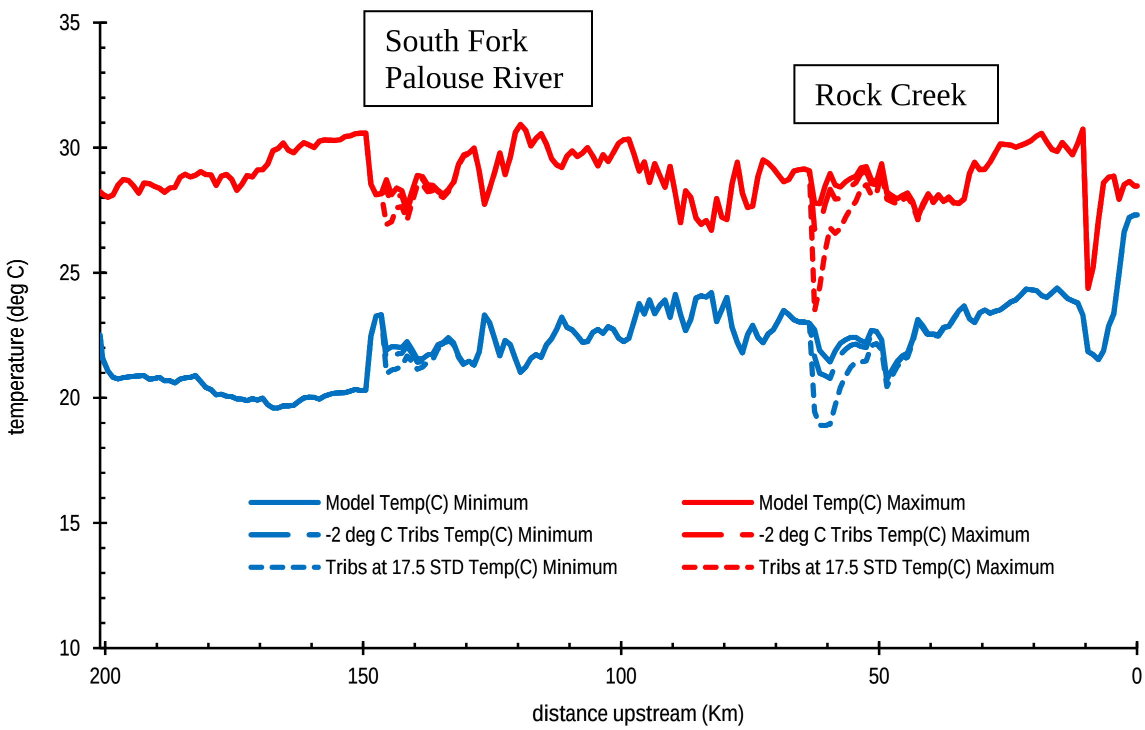

Figure E-1. Effect of reducing temperatures of the South Fork Palouse River and Rock Creek on predicted Palouse River instream temperatures for July 6-12, 2007.
STD: Standard

Groundwater temperatures were increased and decreased by 2ºC throughout the system. Although the Palouse River has some reaches with significant groundwater gains, mainly in the lower half of the system (below 100km), varying groundwater temperatures by 2ºC in either direction had a negligible effect (0.01ºC) on surface water temperature. This probably indicates that any cooling effect provided by groundwater is negated by above ground solar heating.

Because the study area is approximately 100 miles east to west, spanning a range of climate and elevation, climate inputs to the model varied longitudinally, based on data from air temperature and relative humidity dataloggers distributed throughout the system. Varying air temperatures throughout the system by 2ºC resulted in an average increase of 0.67ºC or a decrease of 0.68ºC in maximum temperatures (Figure E-2). Varying dew point temperatures (a measure of relative humidity) throughout the system by 2ºC resulted in an average increase of 0.74ºC or a decrease of 0.70ºC in maximum temperatures (Figure E-3).

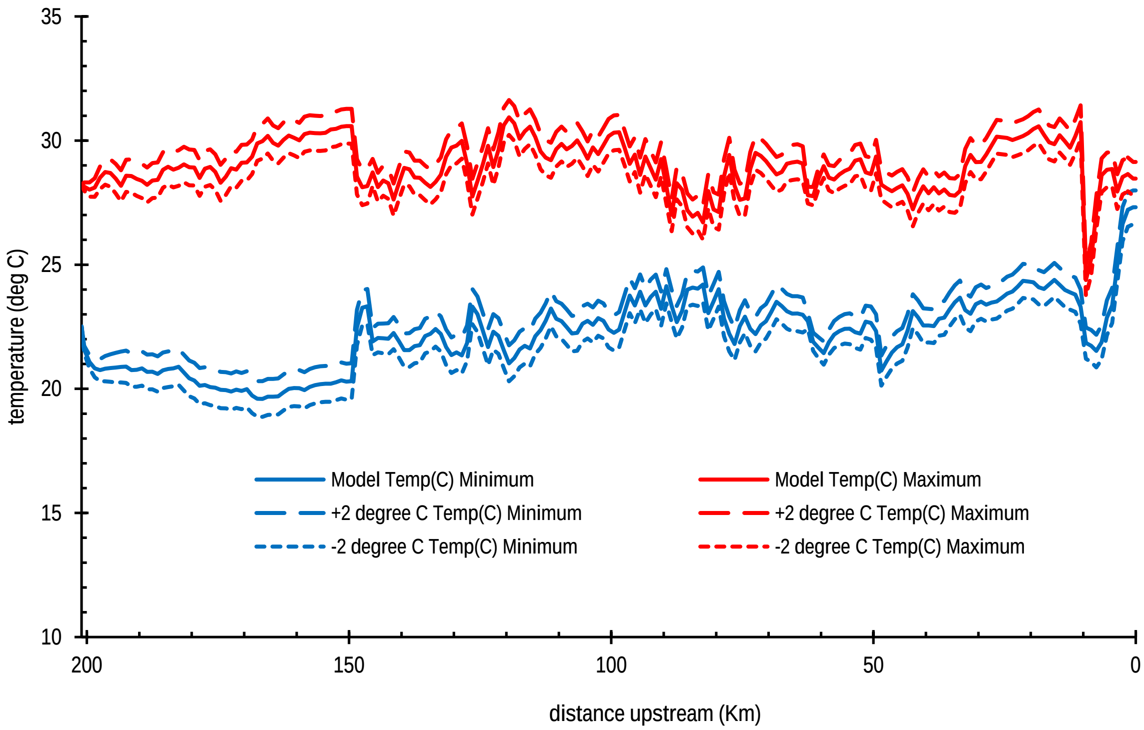

Figure E-2. Effect of varying air temperatures on the Palouse River for July 6-12, 2007.

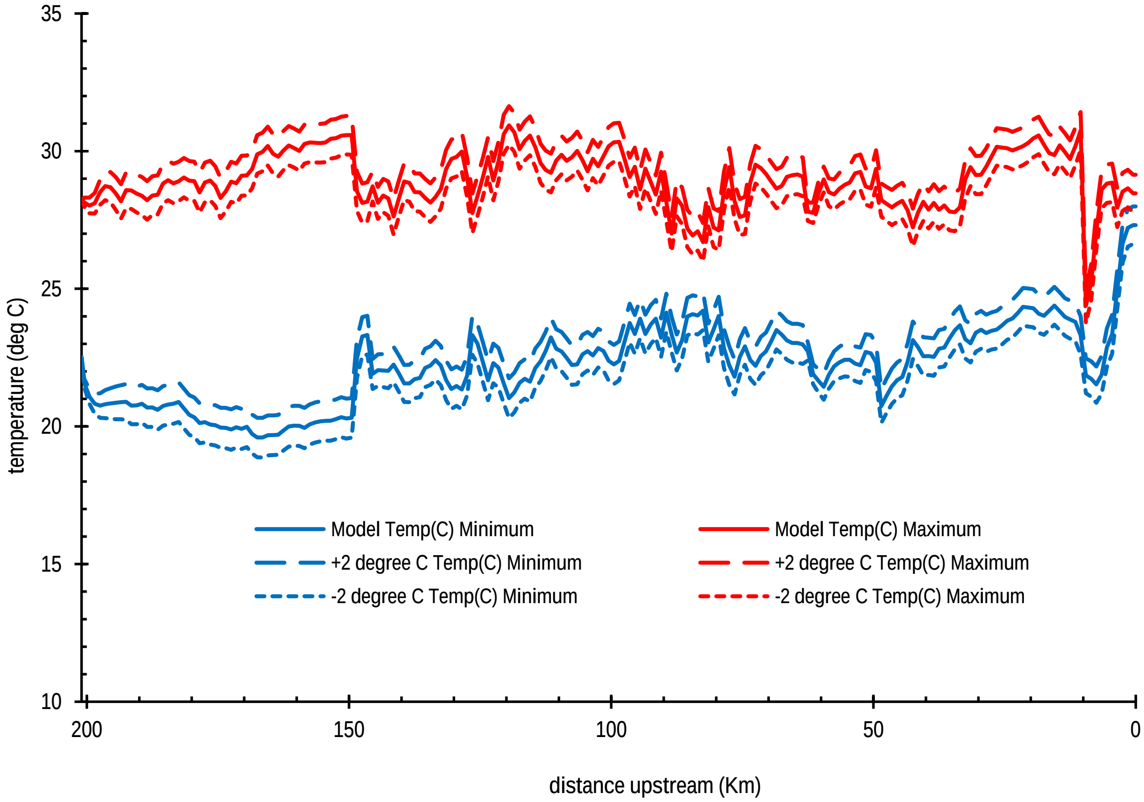

Figure E-3. Effect of varying dew point temperatures on the Palouse River for July 6-12, 2007.

Varying the height, density, and overhang characteristics assigned to each of the vegetation classes used by the Shade model revealed that the QUAL2Kw model is far more sensitive to some of these parameters than to others. The QUAL2Kw model is most sensitive to vegetation density. Varying the density of all vegetation categories by 20% resulted in an average increase of 0.25ºC or a decrease of 0.59ºC in maximum temperatures throughout the system (Figure E-4). This effect was most pronounced in the upper part of the system, where the largest stands of remaining conifer forest are located.

The model was less sensitive to vegetation height and overhang. Multiplying the height of each category by 1.5 or by 2/3 resulted in an average increase of 0.15ºC or a decrease of 0.21ºC in maximum temperatures throughout the system. Doubling or halving the overhang parameter of each category resulted in an average increase of only 0.04ºC or a decrease of -0.07ºC in maximum temperatures throughout the system.

Overall, the Palouse River temperature calibration is robust with regards to most parameters. Because the datasets used for air temperature and dew point were of high quality, with near-stream data available from loggers at many locations throughout the study area, the QUAL2Kw model's sensitivity to these parameters is not a matter of concern. The sensitivity to vegetation density, which mainly appeared as an over-response to *increased* density beyond that which was used for the model calibration, appears to demonstrate the wisdom of using conservative density inputs for most vegetation categories.

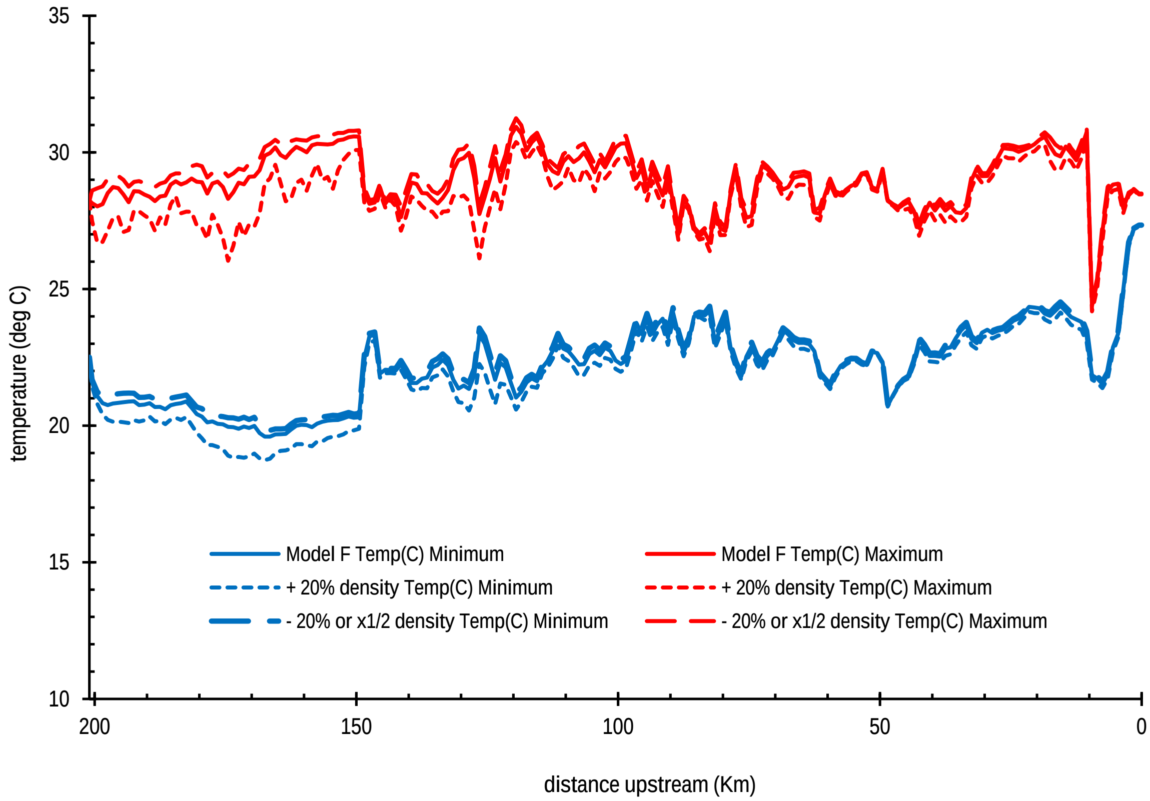

Figure E-4. Effect of varying vegetation density on the Palouse River for the period of July 6-12, 2007.

Appendix F. Response to public comments

A 30-day public comment period was held on this TMDL and implementation plan from May 16, 2013 to June 14, 2013. A press release to local media and advertisements in the Moscow-Pullman Daily News and Whitman Gazette newspapers announced the public comment period. Nine sets of comments were received. The comments and Ecology's response, including any resulting changes in this TMDL, are described here.

Comments from Dr. Mahlon E. Kriebel, Citizen

I would like to make several comments regarding the Palouse River between Palouse and Elberton. Firstly, I grew up on a farm and in Garfield within a few miles of the Palouse. Secondly, I received a Ph.D. in Zoology and Physiology at Un. Wash. in 1967. As a high school student in Garfield (1950-54), I fished for trout in the Palouse River and watched chubs or shiners swim up Cedar Cr. to spawn. My great grandfather and Dad caught these to eat (not sure of species). Nevertheless, these fish have disappeared. Moreover, we caught crayfish to study in high school. Most importantly, we swam in the Palouse River all summer. Today, in late summer, and fall, the Palouse River almost dries. I know that water is taken from the Palouse above Potlatch and the fact that springs and wet regions have been tiled out of farmable ground. I have read the Sohon (with the stevens survey) and other US Army reports from 1854 to the 1870s (I could furnish these reports) which relate that the Palouse River ran about 2 ft deep and was filled with trout. Cedar Creek ran all year and maintained "numerous small lakes" which I conclude were beaver ponds. I conclude that the increase in water temperature of the Palouse River is a simple function of flow rate. The more water in the river, the more evaporation and thus cooling. If water does not evaporate, the reservoir will not cool but will heat.

Ecology's Response:

Thank you for your comments.

The ultimate goal of the Palouse River Temperature Water Quality Improvement Report and Implementation Plan is to return the Palouse River to conditions that support fish species that would be naturally occurring under a natural water temperature regime. It is true that there have been profound changes to the Palouse watershed since pre-European settlement times, and these changes have likely impacted channel morphology and streamflow patterns. Stream flow, along with shade, the stream's width to depth ratio, ground water inputs, and air temperature all affect the temperature of the river. Our study and modeling demonstrated that the most important factors determining stream temperature in the Palouse River are the surrounding air temperature and humidity, and the amount of solar radiation entering the stream. The QUAL2Kw model used in the analysis accounts for evaporative cooling as well as the other heat exchange processes that drive stream temperature (see Appendix B for more information on stream heating processes).

The Implementation Plan includes measures such as improved agricultural tillage practices and drainage ditch designs which will help address impacts to hydrology that have occurred over time. Additionally, as healthy riparian areas are established and mature, many of the factors affecting stream temperature can be affected. Riparian vegetation stabilizes eroding stream banks, even recruiting additional soil and vegetation potentially resulting in a narrower stream over time. This vegetation's roots and addition of organic matter can also help store more water in the soil around the stream releasing it during drier seasons. It provides shade and the microclimate created by a healthy riparian vegetation can reduce the surrounding air temperature.

Comments from Dean Kinzer, Whitman County Commission District 2

I am writing to you in response to the proposed DOE implementation plan to improve water quality of the Palouse River Watershed. To be specific "The Palouse River Temperature Total Maximum Daily Load: Water Quality Improvement Plan and Implementation Report."

I understand that water temperature and dissolved oxygen are issues that need to be addressed for Salmonid Rearing and Migration below Palouse Falls. Your study and proposed solutions would have stream shading where it would have no effect on the temperature and dissolved oxygen going over the Falls. The water temperature and oxygen levels are going to be determined by the last 2-5 miles of stream flow before it gets to Palouse Falls. According to the Chart on Page 62 of your study the water temperature and oxygen levels going over the falls are basically reset from Hooper to the falls.

Knowing that the water temperature and oxygen are determined from Hooper to the falls for fish habitat below the falls, putting shading upstream from Hooper would be a waste of tax payer money. It also increases the habitat for rodents in and near the streams which increase fecal coliform bacteria load. Another issue is that shading the stream in the productive farming areas will usually result in the shading vegetation being killed by herbicides used to control noxious weeds thus resulting in more wasted time and money.

As the research so aptly points out, the proposed shading would have virtually no effect on the water entering the Salmonid habitat which is all below the 198 ft. tall Palouse Falls. The proposed solution in the report would truly be an exercise in futility and a waste of tax payer money. Therefore I would encourage you to "not" implement the plan due to the fact that the proposed solution would be terribly ineffective.

Ecology's Response:

Thank you for your comments.

Ecology is required by law and regulation to develop and implement plans such as this one to protect and restore water quality in the state. This plan only addresses temperature and not dissolved oxygen. Because dissolved oxygen is affected by some different factors than temperature it will be addressed at a later time.

All waters of the state are designated aquatic life uses that must be protected. Below the Palouse Falls the aquatic life use is "salmonid spawning, rearing, and migration." Above the Palouse Falls to the confluence with the South Fork Palouse River at Colfax, the designated aquatic life use is "salmonid rearing and migration." Then from this confluence to the state line, the aquatic life use is again "salmonid spawning, rearing, and migration" (see Table 3). Salmonids refer to all salmon, trout, char, and related fish species; therefore, above the Palouse Falls the Palouse River is designated these aquatic life uses to protect resident trout.

It is correct that the effect of riparian shading has the biggest impact in the immediate vicinity of the shading rather than at locations far downstream. However, warm water temperature must be reduced along the entire length of the Palouse River, not just below the Palouse Falls. The addition of shade in the lower portion of the Palouse River, including the Hooper area and Palouse Falls, will not have a large effect on stream temperature. Much larger improvements are possible in the upper portion of the river, especially upstream of Colfax.

Ecology anticipates that most riparian buffers installed along the river will be funded by state and federal conservation programs. To receive funding or rental payments, these programs typically require a landowner agreement which include requirements for maintaining the riparian plantings. Therefore, any landowner installing buffers would likely be cautious to ensure noxious weed treatments did not damage the desirable native riparian vegetation. Some herbicides also have restrictions for how close they may be applied to surface water.

Comments from William C. Stewart, U.S. Environmental Protection Agency

Thank you for the opportunity to comment on the draft *Palouse River Temperature Total Maximum Daily Load*. The document is well written and well organized. After a thorough review of this document, I only have a few general comments at this time.

- On page 28 under the section Upland Areas there is a list of categories of vegetation for classification in modeling. The fourth one from the top is “Grasses and shrubs” and the sixth one from the top is “Shrubs and grasses.” Is there a difference?
- I appreciate the alternative expressions of your wasteload allocations as a way of covering all bases. I think this puts the wasteload allocations in whatever format practically anyone will want to see.
- Also, this is a good example of documentation of your modeling work and clearly describes what you did to arrive at your conclusions.

Again, thank you for the opportunity to review this TMDL and I look forward to seeing the final version of this document. I would be happy to discuss this project with you at your convenience.

Ecology’s Response:

Thank you for your comments.

There is a difference between the “Grasses and shrubs” and “Shrubs and grasses” categories of vegetation used in the modeling. Essentially, the first plant type listed in the category is dominant. For example in the “Grasses and shrubs” category more of the ground is covered by grass with scattered shrubs. In the “Shrubs and grasses” category, the shrubs are denser. To try to address the confusion between these two categories, parenthetical descriptions were added to each in the text.

Comments from Susan Bangs, Citizen

I agree with the department's plan for trees and other vegetation to be planted in order to cool the water temperature. Purchasing and planting are the first steps to this important project.

Trees and shade benefit the wildlife along the drainage, in addition to the fish. The benefit of this plan expands.

Ecology's Response:

Thank you for your comments and support of our water quality improvement efforts.

Comments from David Lange, Whitman Conservation District

Very interesting draft. I have a few questions:

Are there any successful shadings (nationwide) on such a wide & shallow river as the Palouse?

DOE report and on page 81 it states the following;

"ACD has agreements in place with the Whitman and Franklin conservation districts to provide services to landowners on both sides of the lower Palouse River. Currently the ACD has two grants for implementation on the Palouse River. The grants focus on livestock BMPs such as exclusion fencing, off-stream watering, and riparian buffer installation."

At the last Whitman Conservation District meeting this was discussed and found not to be true.

Page 119, Lynch states a 98' buffer will maintain a 3 meter stream to within 2 degrees. I'm concerned with the practicality (feasibility) of trying to cool a naturally very warm, low flow river.

Ecology's Response:

Thank you for your comments.

The goal of the Palouse River Temperature Water Quality Improvement Plan is to return the river to its natural water temperature. The water quality modeling Ecology conducted takes into consideration the width and depth of the river and provides us with estimates of how much cooling will occur. While the native vegetation will not likely provide extensive shading to the entire stream due to its width in places it will result in reducing temperatures if the appropriate buffers are installed.

The language regarding an agreement between the Adams Conservation District and the Whitman Conservation district on page 67 (page 81 of the PDF file) has been updated.

Comments from Kenneth M. Stone, Washington State Department of Transportation

Thank you for providing the opportunity to review and provide comments on the Palouse River Temperature Total Maximum Daily Load Water Quality Improvement Report and Implementation Plan- Draft- May 2013 (Washington State Department of Ecology Publication No. 13-10-020).

WSDOT remains committed to working collaboratively with Ecology and other stakeholders to address possible contributions from state highways to the Palouse River watershed.

As a general comment, we request Ecology assign WSDOT a load allocation (LA) rather than a wasteload allocation (WLA), given that: 1) runoff from state highways is not considered a significant source of heating in the watershed, as stated on pages 56 and 70; and 2) WSDOT's NPDES Municipal Stormwater Permit (permit) coverage coincides with Phase I and II permit coverage areas, which are not present in the TMDL boundary. As a result, WSDOT does not require a permit for its non-point source discharges. Page 3 states that LAs are assigned to non-permitted, non-point sources, and WLAs to permitted point sources.

This change is supported by Ecology management and would not affect WSDOT's commitment to implement the Highway Runoff Manual, our assigned action in the TMDL. The 2009 *Implementing Agreement Between Washington State Department of Ecology and Washington State Department of Transportation Regarding Application of the Highway Runoff Manual*[1] requires statewide implementation.

We would also like to provide the following specific comments, which include the page number and wording in question or of concern:

1. Page 2, "Point source discharges include...;" Page 14, "In addition, there are two general permits...;" Page 55, "The permitted stormwater dischargers in the study area are...;" and Page 56, "For the Palouse River, this would include..."

   Comment: Suggest deleting text that refers to WSDOT as a permittee in the watershed. WSDOT's permit coverage does not extend into the TMDL boundary.

2. Page 49, Table 10, "NPDES dischargers in the study area are listed in Table 10. Each of these facilities is regulated under a National Pollutant Discharge Elimination System (NPDES) permit which sets limits on the discharge to meet water quality standards. Wasteload allocations have been given to the cities of Palouse and Colfax as well as to stormwater general permittees."

   Comment: Suggest removing WSDOT from Table 10. Refer to general comment.

3. Page 56, "WSDOT's storm water permit covers storm water runoff in Phase I and II areas and extends to state highways and facilities within TMDL boundaries, if the TMDL assigns wasteload allocations or implementation actions."

   Comment: Suggest revising to be more consistent with the permit coverage language, Sl.A and Sl.B.l & 2; "Washington State Department of Transportation's (WSDOT's) permit regulates stormwater discharges from municipal separate storm sewer systems (MS4s) owned or operated by WSDOT within the Phase I and II designated boundaries. WSDOT's permit also covers stormwater discharges to any water body in Washington State for which there is a U.S. Environmental Protection Agency (EPA) approved TMDL with load allocations and associated implementation documents specifying actions for WSDOT stormwater discharges (applicable TMDLs listed in Appendix 3 of the WSDOT permit)."

   When an EPA approved TMDL is added to WSDOT's permit, it does not extend the geographic scope of the permit to require implementation of all municipal permit requirements within the TMDL area. Rather, WSDOT becomes obligated to implement the specific TMDL actions listed in Appendix 3 of the permit.

4. Page 56, "Since the critical period is during the drier summer months when rainfall is limited, the highways and facilities do not have significant quantities of standing water during this time that warm up and discharge to the river. Stormwater discharges from these highways/roadways are therefore not expected to result in a violation of standards.'?

   Comment: WSDOT agrees with these statements. This is the basis for our general comment that stormwater runoff from state highways is not considered a significant source of heating in the watershed.

5. Page 56, "Since Ecology's 2007 study did not directly sample outfalls from WSDOT or Empire Disposal, numeric wasteload allocations are not assigned for specific outfalls.... Therefore, wasteload allocations for stormwater are based on not causing more than a 0.2°C cumulative increase in the background (upstream) receiving water 7-DADMax temperature."

   Comment: Suggest removing WSDOT from the paragraph. Refer to general comment.

Thank you for considering our comments. If you have questions or wish to discuss, please contact WSDOT's TMDL Lead, Jana Ratcliff, at 360-570-6649 (office), 360-701-6353 (cell), or ratclij@wsdot.wa.gov.

[1] Department of Ecology. "Implementing Agreement (2009)." *Municipal Stormwater*. Web. 12 June 2013. <http://www.ecy.wa.gov/programs/wq/stormwater/municipaVWSDOTpermitdocs.html>

Ecology's Response:

Thank you for your comments.

Since our conclusions were that WSDOT's highways and facilities would not produce enough heated stormwater during the critical period to result in a discharge that would impact the temperature of the river, we will allow this TMDL to remain outside the WSDOT stormwater permit coverage. WSDOT is now assigned a load allocation instead of a wasteload allocation. It is Ecology's understanding and expectation that all implementation actions required and recommended in the draft TMDL will be implemented since these actions are also required through our agencies' memorandum of understanding which states the Highway Runoff Manual will be implemented statewide. If new evidence reveals WSDOT's highways or facilities contribute to elevated stream temperatures, the load allocation will be converted to a wasteload allocation and implementation actions will be developed beyond those in the implementation plan for inclusion in WSDOT's stormwater permit. All references to WSDOT as a point source and the permit have been updated to reflect this change.

Comments from John Pearson, Citizen

I have read through the draft and have a few questions.

1) On page 21 it say [*sic*] "Heavy grazing by livestock and Wild animals". Can you please define this term?

2) The report measured cloud cover, air temp and water temps. It has a graph showing the correlation between air temp and water temp. I looked but I could not find a graph showing the correlation between cloud cover and water temp. I am concerned because the BMPs call for shading to reduce temp and so I would like to see what happened to the "Cloud cover data".

3) Page 81 says that Adams Conservation District has an agreement with Whitman Conservation District to implement practices in their district. I am pretty sure this is not true and I suggest you confirm that. I will confirm that Franklin County has an agreement as well.

4) As you probably know there is growing mistrust between cattle producers and certain Conservation Districts. The belief is that these districts do not have the cattle producers interests at heart. To speed this process up and ultimately save large amounts of tax dollars I would strongly suggest that DOE work with groups like the Whitman County Cattlemens Association and the 5 star Stewardship group along with the CD's.

Thank you for your time.

Ecology's Response:

Thank you for your comments.

We were only able to locate the phrase "heavy grazing by livestock and wild animals" on page 13 (page 27 of the electronic .pdf file) of the document. The term "heavy" is subjective resulting in the potential for this phrase to be misinterpreted. “Heavy” has been deleted from the phrase since any animal grazing can result in vegetation disturbance and loss of shade.

1) The report does not include a graph showing the correlation between air and water temperature. Figure 12 (page 32) does show air temperature for reference alongside observed and modeled water temperatures. All of the temperature models used in this assessment require inputs of air temperature, dew point (humidity), wind speed, and cloud cover. These four weather factors all play a role in determining stream temperatures. The role of clouds is complex. Clouds block solar radiation (reducing stream temperatures), but also increase the amount of longwave atmospheric radiation entering the stream (increasing stream temperatures, see Appendix B). Clouds also tend to reduce air temperatures (reducing stream temperatures) and increase humidity (increasing stream temperatures). Shading by riparian vegetation works differently, blocking solar radiation and possibly reducing near-stream air temperatures, but *not* increasing longwave atmospheric radiation. It would therefore be incorrect to compare the effect of cloud cover on stream temperature to the effect of riparian shading on stream temperature. Cloud cover data used in this study was collected by the National Weather Service station at the Pullman-Moscow Regional Airport. This data is available to the public and can be accessed via the web at www.ncdc.noaa.gov or at www.wunderground.com.

2) The language regarding an agreement between the Adams Conservation District and the Whitman Conservation district on page 67 (page 81 of the .pdf file) has been updated.

3) Ecology believes livestock production is an important industry in Washington State. We look to offer technical and financial assistance that not only protects water quality but also can enhance an operation’s economic vitality. We believe we can have clean rivers and streams as well as a healthy livestock industry. Conservation district (CD) staff are often well informed on the best management practices (BMPs) Ecology considers adequate to achieve compliance with state law. As a service to the producer, many CDs offer information on how to implement those practices in ways that also supports the livestock operation. The CDs are non-regulatory and it is always up to the individual livestock producer to decide if they want to use the technical and financial support the CDs provide. While we disagree there is widespread mistrust of CDs, Ecology would welcome opportunities to work with other organizations to provide technical assistance on BMPs that work to eliminate pollution and achieve full compliance with state law. We always remain interested in doing additional coordinated outreach.

Comments from Kara Rowe, Washington Association of Wheat Growers

The Washington Association of Wheat Growers (WAWG) appreciates the opportunity to formally comment on the recent Palouse River temperature TMDL. WAWG understands the vital role that the Washington State Department of Ecology (Ecology) plays to ensure that our waters are healthy.

In the same respect, we hope that it is not Ecology’s intent to place the entire burden of load reduction upon farm landowners. We know there are multiple factors beyond those tied to farming practices that affect water temperature. We also encourage Ecology to look at the historic records and journals of our first citizens to find details about the temperature and nature of the Palouse River in the previous century. There is a lot to learn about the nature of this area prior to farming. With that, WAWG would like Ecology to acknowledge that much progress has been made in the area of farming's best management practices. Voluntary buffers implemented by farmers have cut down on wind and sheet erosion. However, management of natural resources in the state of Washington should not be a one-size-fits-all approach, but should instead be site- specific. Every piece of ground and situation demands different approaches. WAWG's board of directors are against any type of mandated, one-size-fits-all best management practice for the state or specific regions. We feel the best way to ensure clean water and clean air in our state's wheat country is to continue offering voluntary incentives to farmers.

WAWG strongly suggests that you consider, if you haven't already, the science found in the 2012 Agricultural Waterway Buffer Study published by Washington State University. The study was produced by Whatcom County Extension, along with Whatcom and King County Conservation Districts and other collaborators. This work focused on agricultural waterways ranging from four to 13 feet wide, with an average width of eight feet. The summary of their findings concluded that narrow, dense buffers are as effective as wide (35' feet and 180 feet) buffers at reducing air temperature and creating effective shade.

Finally, because this is a two state river, we strongly encourage Ecology to increase their working relationship with their sister agency in Idaho on this issue. We feel this is critical, especially as you move ahead with TMDL work on the South Fork of the Palouse River.

Again, thank you for the opportunity to comment on this work and we ask that you address our suggestions and concerns with earnest. If you have any questions, please contact our office in Ritzville at 509-659-0610.

Ecology's Response:

Thank you for your comments.

All citizens have a responsibility to ensure our shared water resource is protected and landowners along streams need to ensure activities on their land do not negatively impact water quality including stream temperature. Nothing in this plan should be construed as assigning the responsibility to any single group of people.

Similar to your suggestion, we used historical sources of information, specifically the General Land Office survey notes from the late 1800's, to help determine what historic riparian vegetation might have looked like. Shelly Gilmore's (2005) assessment of historical vegetation on the South Fork Palouse River, which looked at GLO surveys as well as historical journal entries, also helped provide some valuable context for the historical character of the eastern part of the Palouse Watershed.

Ecology agrees that there have been significant improvements in agricultural practices that have benefited the environment and water quality. However, many miles of stream still lack the vegetative buffers vital to restoring water quality to historical natural conditions. We recognize that different climates, geology, geography call for different best management practices. For this reason the potential vegetation zone descriptions in Figure 19 and Table 9 have been specifically designed to mimic the historical riparian areas that would have been found naturally along the river.

Ecology also agrees that voluntary incentive programs can help restore riparian buffers and increase the adoption of other agricultural best management practices. Ecology offers funding to implement riparian restoration and assist with the conversion from conventional tillage practices to direct seed/no-till practices. State funding, when coupled with other incentive programs such as Continuous Conservation Reserve Program (CCRP), Environmental Quality Incentive Program (EQIP), and others, can provide 75 to 100 percent of the cost to implement riparian buffers and provide a rental payment to the landowner.

The WSU Agricultural Waterway Buffer study was limited to collecting effective shade and air temperature data at four study sites to test for relationships between buffer width, effective shade, and air temperature differences. Other than air temperature and solar load, this study does not address any stream thermal processes, such as groundwater, weather or water temperature interactions. Therefore, it cannot conclude that narrower buffers will result in natural stream temperatures as is the goal of this project.

Ecology will continue to work with Idaho Department of Environmental Quality and EPA on cross jurisdictional water quality concerns. Because of the urban impacts of the City of Moscow and their wastewater treatment plant this will be of even greater importance for the South Fork Palouse River TMDL efforts.

Comments from Debbie Snyder, North Fork Palouse River Riparian Land Owner

As evidenced by the number of years and meticulous detail in collecting water sample data from 2007 through 2012, researching recorded historical ambient weather data from the Pullman Regional Airport weather station, development of modeling methodology and citations, kinetic formulations, arduous explanation of “Root Mean Squared Error” equations and application relevancy, detailed vegetation maps, various charts both historical and predictive of temperatures, velocities, flow, and conditional effluent temperature waste load allocation, obviously a very detailed and complicated regulatory parameter for river temperature has been developed and is poised for regulatory implementation.

Considerable time, effort, and energy has been spent to create scientific “buy-in” and credibility, yet in complete contrast, draft of publication No. 13-10-020, under the chapter of “Reasonable Assurance”, page 60, final paragraph poses a single nondescript, generalized sentence as a statement of a bullying operative citing Chapter 90.48 RCW to issue enforcement action to achieve compliance. As a regulatory agency, Department of Ecology has the obligation to carefully develop and publicly disclose infraction qualifying specific criteria regarding non-point source and these new “effective shade” parameters.

Department of Ecology set president [*sic*] in treatment of the non-point source sector to “cherry pick” and develop enforcement triggers and parameters – such as “bare ground” and perceived “livestock trails” in a non-disclosed evolutionary manner to livestock operations during the implementation and enforcement of the North Fork Palouse River Bacteria TMDL. Penalties should NEVER be based on individual subjective criteria. In a democratic and civilized society it is not only irresponsible but completely unacceptable to employ a communistic governmental approach. The infraction qualifying specific criteria MUST be thoroughly developed and circulated for public comment.

Ecology's Response:

Thank you for your comments.

A Water Quality Improvement Report and Implementation (known as a Total Maximum Daily Load or TMDL under the Clean Water Act) does not include a plan for enforcement actions because that is outside the regulatory requirements for a TMDL. Ecology's enforcement authority comes from state law (Washington Pollution Control Act, RCW 90.48) not from this or any TMDL.

What is required when a TMDL addresses both point and nonpoint sources is a section describing "reasonable assurance" that nonpoint sources can and will be addressed. If there is not reasonable assurance then the entire burden for meeting water quality standards is placed on the point sources. In the case of the Palouse River the only point sources are the cities of Palouse and Colfax's wastewater treatment plants and an industrial stormwater discharger. There are no actions these dischargers could take that would result in the river meeting temperature criteria for its entire length. Therefore, the reasonable assurance section of the TMDL must describe education, technical and financial assistance, regulatory and enforcement authorities that can be used to ensure nonpoint sources are addressed.

Ecology believes that voluntary incentive programs can help to address nonpoint source water quality problems. Ecology offers funding to implement riparian restoration and assist with the conversion from conventional tillage practices to direct seed/no-till practices. State funding, when coupled with other incentive programs such as Continuous Conservation Reserve Program (CCRP), Environmental Quality Incentive Program (EQIP), and others, can provide 75 to 100 percent of the cost to implement riparian buffers and provide a rental payment to the landowner.

To clarify as of the publication of this document, no livestock water quality enforcement actions have been taken in the North Fork Palouse River watershed. Ecology has notified landowners of water quality concerns and offered technical and financial assistance to address these issues, but no enforcement actions have been initiated. Typically a landowner is notified of their water quality impacts that could be subject to enforcement well in at advance of Ecology taking any enforcement actions. This provides ample time for the landowner to address the issues so water quality can be protected without the need for enforcement. Ecology's communication with a landowner would include a description of the activity or lack of activity that is resulting in a water quality impact.