Quality Assurance Project Plan

Palouse River Temperature Total Maximum Daily Load Study

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303(d) Listings Addressed in this Study

Listing ID	Category	Waterbody Description	New Waterbody ID	Old Waterbody ID	Listing Cycle
40638	5	Cow Creek	OW46XT		2004
3723	5	Palouse River	NX00WG	WA-34-1030	2004
11130	5	Palouse River	NX00WG	WA-34-1030	2004
8115	5	Palouse River	NX00WG	WA-34-1030	2004

Project Code: 05-008-20

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List of Acronyms

7DADMax	7-day average of the daily maximum temperature
7DADMin	7-day average of the daily minimum temperature
DMax	Daily maximum temperature
DMin	Daily minimum temperature
EAP	Environmental Assessment Program, Washington State Department of Ecology
EIM	Environmental Information Management (system)
EPA	US Environmental Protection Agency
IDEQ	Idaho Department of Environmental Quality
NFPR	North Fork Palouse River (Palouse River from Idaho border to Colfax)
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
ODEQ	Oregon Department of Environmental Quality
PCD	Palouse Conservation District
PST	Pacific Standard Time
PDT	Pacific Daylight Savings Time
QA	Quality assurance
SHU	Stream Hydrology Unit, Washington State Department of Ecology
TI	Temperature instrument
TIR	Thermal infra-red remote sensing
TMDL	Total Maximum Daily Load
USGS	US Geological Survey
WSDOT	Washington State Department of Transportation
WRIA	Watershed Resource Inventory Area
WWTP	Wastewater treatment plant

Abstract

Section 303(d) of the federal Clean Water Act requires Washington State to prepare a list of all surface waters in the state for which beneficial uses of the water are impaired by pollutants. Waterbodies placed on the 303(d) list require the preparation of a Total Maximum Daily Load study to identify and quantify sources of the impairments and to recommend implementation strategies for reducing point (discrete) and nonpoint (diffuse) source loads.

The Palouse River is listed on the 303(d) list of impaired waterbodies for high instream temperatures. This Quality Assurance Project Plan describes the technical study that will (1) evaluate temperatures in the Palouse River during 2007, and (2) build on previous data collection efforts conducted by a variety of governmental and private organizations.

The study will be conducted by the Washington State Department of Ecology, Environmental Assessment Program.

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act Requirements

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, each state is required to have water quality standards designed to protect, restore, and preserve water quality. Water quality standards are set to protect designated uses such as cold water biota and drinking water supply. The TMDL is a watershed plan designed to improve water quality.

Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list. To develop the list, Ecology compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list.

Water Quality Assessment / Categories 1-5

The 303(d) list is part of the larger Water Quality Assessment. The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's water. This list divides waterbodies into five categories:

- Category 1 – Meets standards for parameter(s) for which it has been tested.
- Category 2 – Waters of concern.
- Category 3 – Waters with no data available.
- Category 4 – Polluted waters that do not require a TMDL because:
  - 4a – Has a TMDL approved and it is being implemented
  - 4b – Has a pollution control plan in place that should solve the problem
  - 4c – Is impaired by a non-pollutant such as low water flow, dams, culverts
- Category 5 – Polluted waters that require a TMDL – on the 303d list.

TMDL Process Overview

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the waterbodies on the 303(d) list. The TMDL identifies pollution problems in the watershed and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Then Ecology works with the local community to develop an overall approach to control the pollution, called the Implementation Strategy, and a monitoring plan to assess effectiveness of the water quality improvement activities. Once the TMDL has been approved by EPA, a *Water Quality Implementation Plan* must be developed within one year. This Plan identifies specific tasks, responsible parties, and timelines for achieving clean water.

Elements Required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem (the technical study) and an implementation plan based on the recommendations of the technical study. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete (point) source such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If it comes from a set of diffuse (nonpoint) sources such as general urban, residential, or farm runoff, the cumulative share is called a load allocation.

The TMDL must consider seasonal variations and system potential water temperatures. The TMDL must also 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 loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety and any reserve capacity must be equal to or less than the loading capacity.

Total Maximum Daily Load Analyses: Loading Capacity

Identification of the contaminant loading capacity for a waterbody is an important step in developing a TMDL. The U.S. Environmental Protection Agency (EPA) defines the loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a waterbody into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

TMDL = Loading Capacity = sum of all Wasteload Allocations + sum of all Load Allocations + Margin of Safety

Why is Ecology Conducting a TMDL study in This Watershed?

The Washington State Department of Ecology (Ecology) is conducting a TMDL study in the Palouse River watershed because there are three reaches on the Palouse River exceeding water temperature standards. Furthermore, temperature standard exceedances occur in sections of Cow Creek.

There is high interest in water quality issues in this basin, demonstrated by the level of cooperative sampling and water management currently occurring. Ecology hopes to build on previous efforts and work cooperatively with all contributing entities to generate a better understanding of stream temperatures in this watershed.

As part of this TMDL, Ecology will conduct field work during the summer of 2007 to characterize water temperatures. The study will also establish load and wasteload allocations to reduce heat sources in the system to meet Washington State water quality standards for surface water temperature. The TMDL will use effective shade as a surrogate measure of heat flux to fulfill the requirements of the federal Clean Water Act Section 303(d) for a temperature TMDL. Effective shade is defined as the fraction of incoming solar shortwave radiation that is blocked by vegetation and topography.

This Quality Assurance (QA) Project Plan will describe the study design for the Palouse River temperature TMDL. Topics discussed include the watershed study area, project objectives, historical data, influential thermal processes, field data collection plan, and computerized modeling.

Overview

The Palouse River and its tributaries flow through 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 part of the Palouse River watershed, but not 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 into 2007 for a related TMDL study. The South Fork Palouse River meets the mainstem Palouse River immediately downstream of Colfax at river mile 89.6.

This TMDL primarily addresses the 2004 303(d) listings for temperature in the Palouse River watershed (Category 5 temperature waterbody segments in Washington's Water Quality Assessment). Implementation activities which should address temperature impairments in Cow Creek have been ongoing. An evaluation of these efforts is underway to determine if these listings can be reclassified to Category 4B (addressed by a water pollution control plan).

An additional eight sites are listed as waters of concern (Category 2) for temperature on Washington's 2004 Water Quality Assessment. Four of these are on the Palouse River and will be assessed during this study. Additionally, the mouths of Rebel Flat Creek and Union Flat Creek will be assessed during this study; an assessment of Pine Creek is outside the scope of the study area and will not be assessed.

Table 1 summarizes Category 5 and 2 listed waterbodies within WRIA 34, not including the South Fork Palouse River subbasin which was addressed in Bilhimer et al. (2006).

Table 1: WRIA 34 Temperature 303(d) listings and waters of concern not including South Fork Palouse River subbasin.

Listing ID	Category	Waterbody Description	New Waterbody ID	Old Waterbody ID	Listing Cycle
40634	5	Cow Creek	OW46XT		2004
40635	5	Cow Creek	OW46XT		2004
40636	5	Cow Creek	OW46XT		2004
40637	5	Cow Creek	OW46XT		2004
40638	5	**Cow Creek**	OW46XT		2004
40639	5	Cow Creek	OW46XT		2004
40640	5	Cow Creek	OW46XT		2004
3723	5	**Palouse River**	NX00WG	WA-34-1030	2004
11130	5	**Palouse River**	NX00WG	WA-34-1030	2004
8115	5	**Palouse River**	NX00WG	WA-34-1030	2004
16923	2	Palouse River	NX00WG	WA-34-1030	2004
8114	2	Palouse River	NX00WG	WA-34-1030	2004
8117	2	Palouse River	NX00WG	WA-34-1030	2004
8123	2	Palouse River	NX00WG	WA-34-1010	2004
11126	2	Pine Creek	JH09DA	WA-34-1017	2004
8149	2	Pine Creek	JH09DA	WA-34-1017	2004
8152	2	Rebel Flat Creek	MT96QP	WA-34-4010	2004
8157	2	Union Flat Creek	HA80OL	WA-34-3010	2004

Bold represents temperature listing directly addressed by this study.

Project Objectives

1. Characterize stream temperatures and processes governing the thermal regime in the Palouse River including the influence of tributaries, point sources, and groundwater/surface water interactions on the heat budget.

2. Develop a predictive temperature model for the Palouse River. Using critical conditions in the model, determine the Palouse River's capacity to assimilate heat. Evaluate the system potential temperature (approximated natural temperature conditions) for the Palouse River. The calibrated temperature model will be used to evaluate future water quality management decisions in the Palouse River basin.

Watershed Description

The Palouse River basin is located primarily in Whitman County, Washington, and its headwaters are in Latah County, Idaho (Figure 1). The Palouse River flows along the border of Whitman, Adams, and Franklin Counties near its confluence with the Snake River. The Snake River flows into the Columbia River that flows into the Pacific Ocean at the Washington/Oregon state border. Palouse Falls (198 foot cliff) occurs six river miles upstream of the Palouse River's mouth. The section upstream of the South Fork Palouse River confluence is locally referred to as the North Fork Palouse River that extends roughly 54 river miles upstream from the South Fork Palouse River confluence. Palouse River headwaters start within the Hoodoo Mountains in the St. Joe National Forest (Henderson, 2005).

The Palouse River is approximately 144 miles long, 120 miles of which is within Washington State. Its watershed area within Washington is approximately 3281 square miles (2,099,832 acres). The North Fork Palouse River basin area is approximately 495 square miles (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 (219,943 acres) and joins the Palouse River at Colfax (Bilhimer et al., 2006).

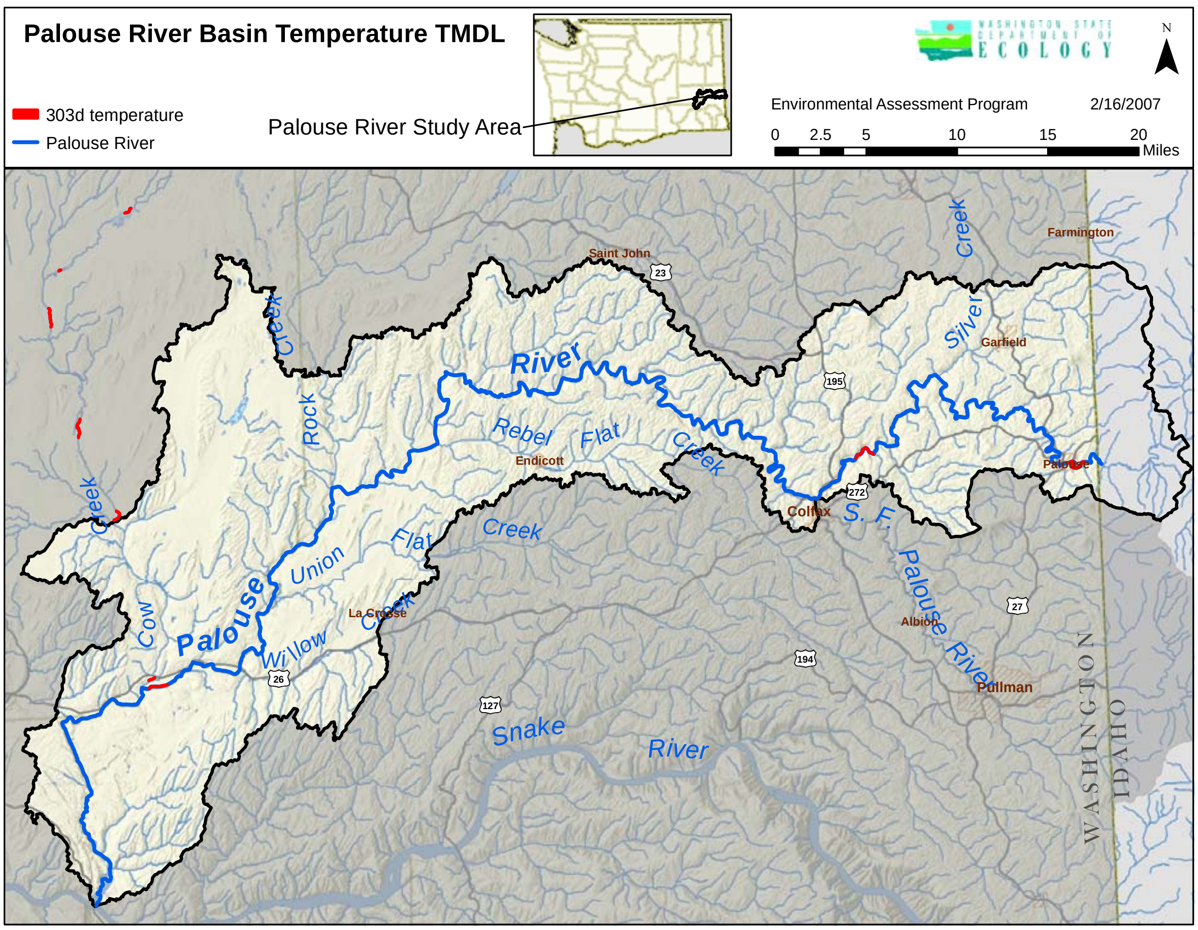

Figure 1: Palouse River Temperature TMDL study area.

Hydrology

The Palouse River system includes over 398 miles of streams. Major tributaries and their relative percent contribution of drainage area are as follows:

- Cow Creek 22.4%
- Palouse River Mainstem 17.2%
- North Fork Palouse River 14.9%
- Rock Creek 12.1%
- Union Flat Creek 9.6%
- Pine Creek 10.8%
- South Fork Palouse River 8.9%
- Cottonwood Creek 4.2%

(Golder Associates Inc., 2004)

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

- USGS streamflow gage station #13351000 is located near Hooper, WA 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 began recording in 1897, ceased during 1916, then started again in 1951 till 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 mean monthly flow of the Palouse River recorded at Hooper and Potlatch. Peak flows typically occur from January through March, and baseflows from August through September.

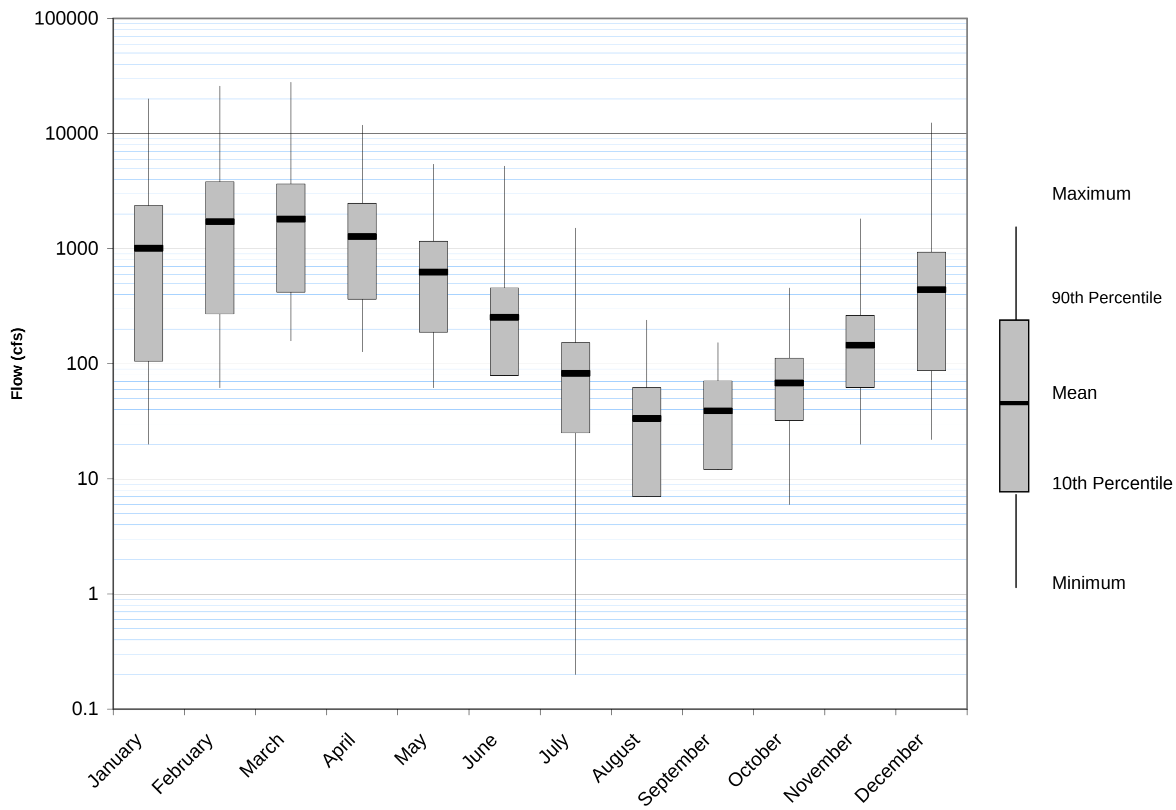

Figure 2: USGS stream gage mean monthly flows for the Palouse River near Hooper, WA.

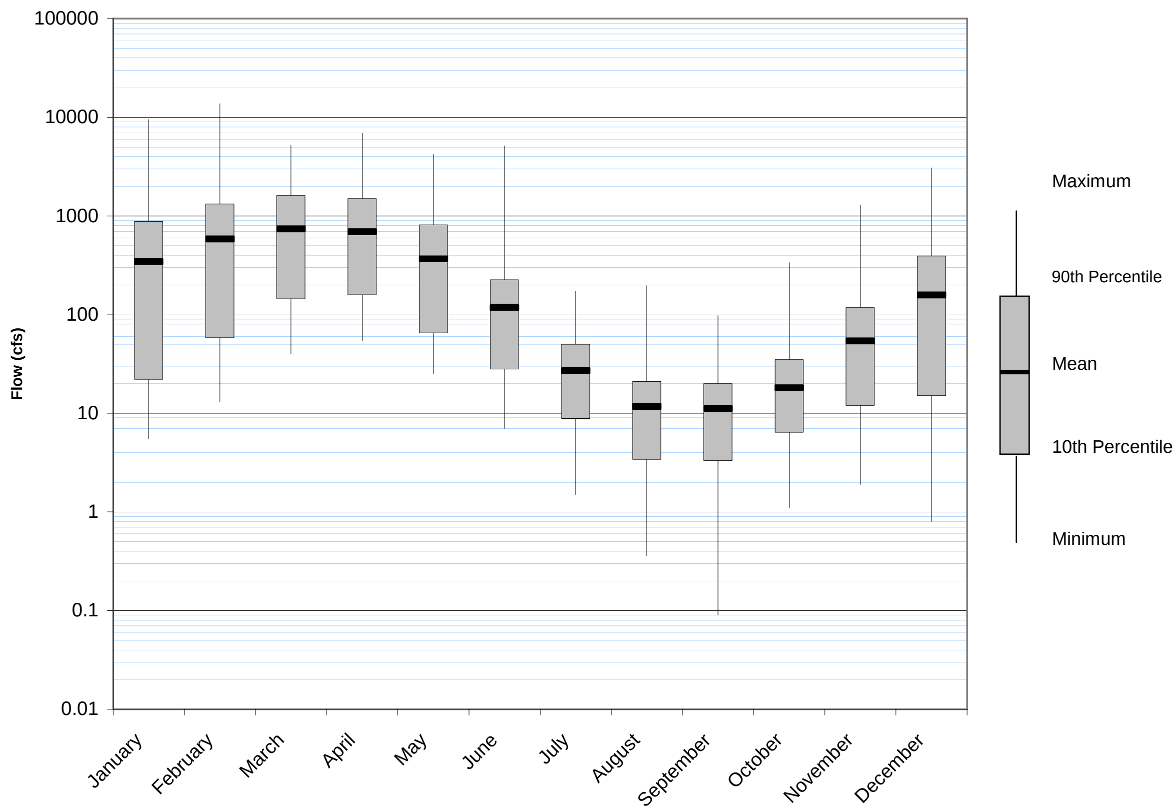

Figure 3: USGS stream gage mean monthly flows for the Palouse River near Potlatch, ID.

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), followed by Garfield (population 630). Smaller towns, with populations not exceeding 350, are located within the watershed as well (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).

Geology

Around 110 million years ago, geologic activity forced giant granite slabs upward initiating the features of southeast Washington. Eventually regional volcanic activity began. Fissures opened as the Palouse River basin received intermittent lava flows 10-30 million years ago that filled 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 (Resource Planning Unlimited, Inc., 2004 and Kuttel Jr., 2002).

Vegetation

Historically the Palouse River watershed supported a variety of vegetation depending on sub-regional climate. 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*) 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.

Historically, wetlands existed across the watershed with the greatest amount in the northwest region. The highly diverse wetland vegetation was dominated by camas, forbs, sedges, rushes, and grasses.

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).

Climate

The Palouse River watershed has a semi-arid climate. Annual precipitation in this watershed can range from 10 inches in the western region to 50 inches in the eastern region mountains of Idaho. Along the more mountainous eastern region, 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). A drought was declared in 2001 and 2005. Summer daily maximum air temperatures can range from mid-70ºF to mid-90ºF (around 21ºC to 35ºC) and occasionally over 100ºF (37.8ºC).

Sources of Pollution

Point Sources

Wastewater treatment plants (WWTPs) are the primary point source contributors in the Palouse River watershed. Point source contributors relative to this TMDL study include sources that discharge either into an immediate tributary of the Palouse River near the confluence, or directly into the Palouse River (Table 2).

Table 2: Point sources that discharge into the Palouse River or into an immediately associated tributary near its confluence with the Palouse River.

WWTP	Facility Type	Permit Type	City	Permit #	Discharges to	Year-round/ seasonal
COLFAX	Municipal	Minor	Colfax	WA0020613B	Palouse River	Year-round
ENDICOTT	Municipal	Minor	Endicott	WA0023981C	Rebel Flat Creek	Year-round
GARFIELD	Municipal	Minor	Garfield	WA0044822C	Silver Creek	Year-round
PALOUSE	Municipal	Minor	Palouse	WA0044806C	Palouse River	Year-round

Nonpoint Sources

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

1. Riparian vegetation disturbance and loss of shade due to:
   - Removal of trees and shrubs for pasture, crops, timber harvest, roads, or buildings.
   - Heavy grazing by livestock and wild animals.

- Alteration of the local hydrograph to such an extent that riparian vegetation cannot complete its life history requirements.

2. Channel morphology (widening) impacts resulting from:
   - Increased sediment loading from agriculture and roads.
   - Channel constraint/diking for agriculture, flood control, and roads.
   - 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. 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.

Water Quality Standards and Beneficial Uses

In July 2003, the state Department of Ecology (Ecology) made significant revisions to the state's surface water quality standards (Chapter 173-201A WAC). These changes included eliminating the classification system the state used for decades to designate uses (e.g., swimming, boating, fishing, aquatic life habitat, water supplies) for protection through the application of water quality criteria (e.g., temperature, dissolved oxygen, turbidity, bacteria). Ecology also revised the numeric temperature criteria assigned to waters to protect specific aquatic species and their use of streams during sensitive live stages.

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

Ecology responded to the EPA disapproval by initiating a corrective state rule revision. The rulemaking addressed the changes EPA described as necessary in their disapproval. The state concluded its corrective rulemaking proceedings in October 2006, and expects to have approved state standards by October 2007. The result of the corrective state rulemaking will be that a number of streams and stream segments would receive more stringent temperature and dissolved oxygen criteria.

Ecology developed an implementation plan that describes when to use the new 2006 state standards while the state awaits formal EPA approval of those standards:

- TMDLs completed before December 2006, or whose fieldwork was largely completed before October 2006, will be based on the 1997 version of the state standards. These studies must also include:
  - A scenario evaluating what would be required to meet the 2006 standards where the existing data allows.
  - An implementation plan designed to assess compliance with the 2006 standards.

- TMDLs initiated after December 2006 will be based on meeting the new 2006 standards.

The revised water quality standards can be found online at Ecology's water quality standards website at www.ecy.wa.gov/programs/wq/swqs/index.html. Table 3 provides a general structure for understanding how the 1997 standards were revised in the 2006 rule revision including certain classifications that apply to the Palouse River watershed:

Table 3: Expected Water Quality Standard changes for temperature in Class A and B waters

1997 Standards Classification	Water Quality Parameter	1997 Criteria[2]	2003 Use Revision	2003/2007 Criteria[2]
Class A[1]	Temperature	18°C 1-Dmax[4]	Salmonid Spawning, Rearing, and Migration	17.5°C 7-DADMax[3, 5]
Class B	Temperature	21°C 1-Dmax[4]	Salmonid Rearing and Migration only	17.5°C 7-DADMax[3, 5]

1. Class A waters were categorized into "salmonid spawning, rearing, and migration" designated use type during the 2003 revision to the water quality standards regulation.
2. Criteria have been established in the existing water quality standards for specific waterbodies that differ from the general criteria shown in the above table. These special conditions can be found in WAC 173-201A-130 of the 1997 version, and WAC 173-201A-602 of the 2003 version of the standards.
3. The 2007 corrected water quality standards rule will contain supplemental spawning and incubation temperature criteria (13°C for salmon and trout, and 9°C for native char) that will be applied to specific portions of waters of the state.
4. 1-DMax means the highest annual daily maximum temperature occurring in the waterbody.
5. 7-DADMax means the highest annual running 7-day average of daily maximum temperatures.

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 temperature 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 waterbody.

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) (WAC 173-201A-200; 2003 edition).

Table 4 describes the water quality standards and aquatic use for temperature on the Palouse River TMDL. The Palouse River is an interstate waterbody. The federal Clean Water Act requires that the downstream receiving state's water quality standard be met at the state line.

Table 4: Water Quality Standards for temperature in the Palouse River

Stream Name and Segment	1997 Classification	2003 Aquatic Life Use	2003/2007 Temperature Standard
Palouse River from Palouse Falls to south fork (Colfax, river mile 89.6)	B	Rearing and Migration Only	17.5 °C 7DADMax
Palouse River mainstem from mouth to Palouse Falls	B	Spawning, Rearing and Migration	17.5 °C 7DADMax
Palouse River from south fork (Colfax, river mile 89.6) to Idaho border (river mile 123.4)[1]	A, Special condition[1]	Spawning, Rearing, and Migration	20.0°C[1]
Palouse River from Washington - Idaho border to Hatter Creek (river mile 139)	Idaho Cold Water criteria classification - Water temperatures of 22 °C or less with a maximum daily average of no greater than 19 °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 temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed $t = 34/(T + 9)$.

The following defines aquatic life uses specific to the Palouse River TMDL study area.

- To protect the designated aquatic life use of "Salmonid Spawning and Rearing, and Migration," the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F).
- To protect the designated aquatic life use of "Salmonid Rearing and Migration Only," the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F).

The state uses the criteria described above to ensure that where a waterbody 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 waterbody is naturally warmer than the above-described criteria, the state provides an allowance for additional warming due to human activities. In this case, the combined effects of all human activities must also not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

In addition to the maximum criteria noted above, compliance must also be assessed against criteria that limit the incremental amount of warming due to human activities of otherwise cool waters. When water is cooler than the criteria noted above, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to:

- Incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T+7 as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge).
- Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the waterbody must not at any time exceed 2.8°C (5.04°F).

Global Warming

Changes in climate associated with global warming are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005). Summer stream flows depend on the snowpack stored during the wet season. Studies of the region's hydrology indicate a declining tendency in snow water storage, coupled with earlier spring snowmelt and earlier peak spring stream flows (Hamlet et al., 2005). Factors affecting these changes include climate influences at both annual and decadal scales, and air temperature increases associated with global warming. Increases in air temperatures result in more precipitation falling as rain rather than snow and earlier melting of the winter snowpack.

Ten climate change models were used to predict the average rate of climatic warming in the Pacific Northwest (Mote et al., 2005). The average warming rate is expected to be in the range of 0.1-0.6°C (0.2-1.0°F) per decade, with a best estimate of 0.3°C (0.5°F) (Mote et al., 2005). Eight of the ten models predicted proportionately higher summer temperatures, with three indicating summer temperature increases at least two times higher than winter increases. Summer stream flows are also predicted to decrease as a consequence of global warming (Hamlet and Lettenmaier, 1999).

The expected changes coming to our region's climate highlight the importance of protecting and restoring the mechanisms that help keep stream temperatures cool. Stream temperature improvements obtained by growing mature riparian vegetation corridors along streambanks, reducing channel widths, and enhancing summer baseflows may all help offset the changes expected from global warming. It will take considerable time, however, to reverse those human actions that contribute to excess stream warming. The sooner such restoration actions begin and the more complete they are, the more effective we will be in offsetting some of the detrimental effects on our stream resources.

These efforts may not cause streams to meet the numeric temperature criteria everywhere or in all years. However, they will maximize the extent and frequency of healthy temperature conditions, creating long-term and crucial benefits for fish and other aquatic species. As global warming progresses, the thermal regime of the stream itself will change due to reduced summer streamflows and increased air temperatures.

The state is writing this TMDL to meet Washington State's water quality standards based on current and historic patterns of climate. Changes in stream temperature associated with global warming may require further modifications to the human-source allocations at some time in the future. However, the best way to preserve our aquatic resources and to minimize future disturbance to human industry would be to begin now to protect as much of the thermal health of our streams as possible.

Natural Conditions

Water quality criteria are set at levels that fully protect designated uses. This ensures that these uses will be fully protected wherever doing so is an attainable condition. However, setting fully protective criteria means that for some water quality parameters, especially temperature and dissolved oxygen, some waterbodies will fail to meet the criteria even under natural conditions (absent any contributing human effects). To account for this condition, the standards contain both narrative provisions and numeric allowances for considering the effect of natural conditions. A general narrative provision in the state standards is that when and where under natural conditions a waterbody would fail to meet the assigned numeric criteria, those measured or estimated natural conditions are used as alternate water quality criteria. In some cases, such as with the dissolved oxygen and temperature criteria, a small additional cumulative allowance for degradation beyond naturally poor conditions is provided for human activities.

In assessing what is and is not natural, Ecology will use historic data and water quality modeling as appropriate to ascertain what the water quality conditions would be without human sources of degradation. Using this approach does not infer that Ecology believes that systems can or should be returned to pre-historic conditions. The water quality standards and the federal regulations governing those standards contain numerous provisions and tools for setting water quality-based limitations. These provisions, when followed, allow states to identify and protect the highest attainable uses.

Historical Data

Data relevant to this TMDL study have been collected for the last several years under the direction of the Palouse Watershed Planning Unit. Implementation plans have been made to restore and preserve the Palouse River watershed's proper ecological function and condition. Ongoing monitoring of stream temperatures has been conducted by the Palouse Conservation District and Ecology's ambient monitoring stations in the WRIA. Studies used to develop this study plan include:

Golder Associates Inc. Phase II – Level 1 Technical Assessment for the Palouse Basin (WRIA 34).

This document provides information fulfilling the Watershed Planning Act (RCW 90.82) submitted to the Palouse Watershed Planning Unit. Data include surface water, groundwater, climatology, water allocation, and water quality.

Airborne TIR Survey

An airborne Thermal Infra-Red (TIR) survey was conducted on July 30 and 31, 2005 on the North Fork Palouse River. Data products from the TIR survey included geo-referenced and ortho-rectified full-color and thermal infrared images of the study streams, and longitudinal profiles of median stream temperatures derived from the TIR data. The TIR imagery will help guide investigation of probable groundwater seeps, and the full-color imagery will facilitate the mapping of existing vegetation along the North Fork Palouse riparian corridor.

Ecology Ambient Water Quality Monitoring Stations

Ecology's ambient monitoring program for Washington State includes two relevant stations on the Palouse River, one in Palouse (34A170) and the other in Hooper (37A070). From late spring to fall, 30-minute interval temperature data collection occurred from 2001 to the present at the Palouse station. Figure 4 depicts 2006 data from station 34A170. During 2006 the water temperatures at this station exceeded the 20° C "special condition" temperature criterion from May through August. Water temperatures were elevated compared to the air temperature, possibly due to upstream heating processes.

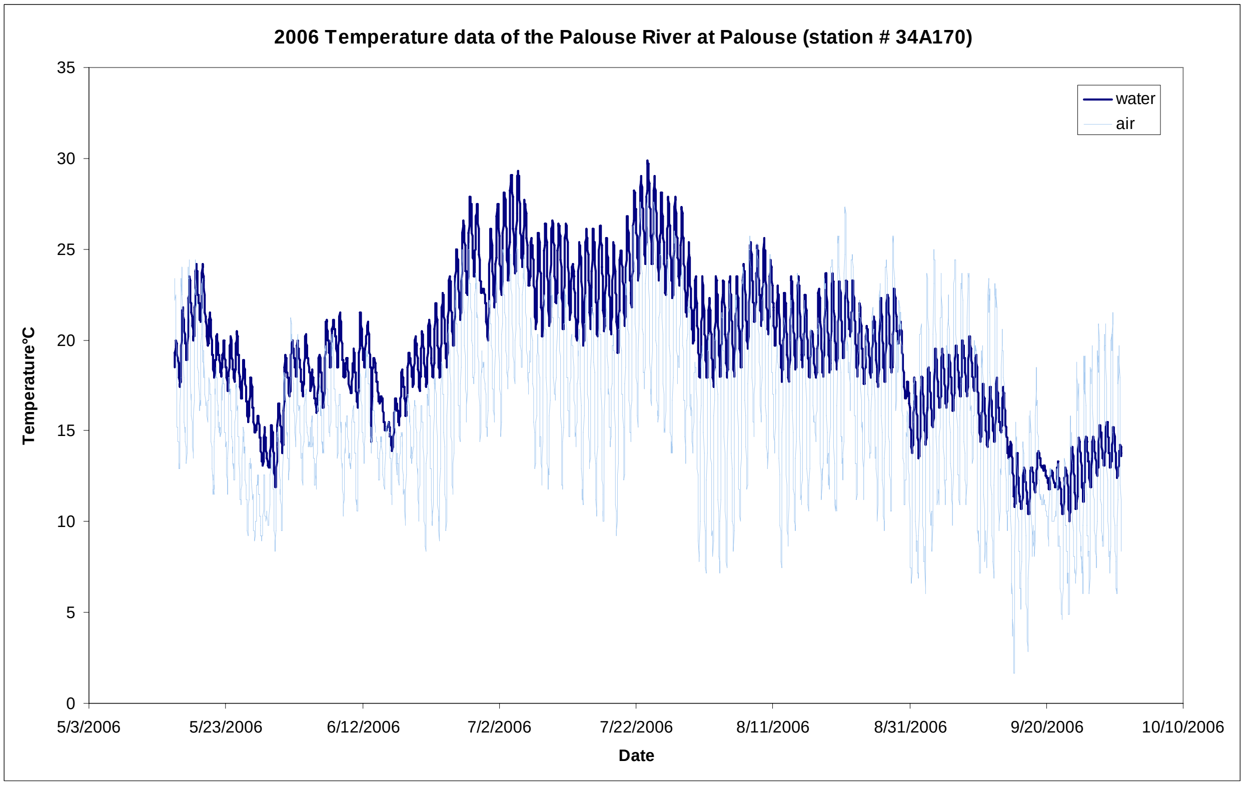

Figure 4: Continuous monitoring data charts for 2006 at Ecology's Ambient Monitoring Program.

Project Description

Study Approach

The Palouse River temperature TMDL will be developed for heat (i.e., incoming solar radiation). Heat is considered a pollutant under Section 502(6) of the Clean Water Act. The transport and fate of heat in natural waters has been the subject of extensive study. Edinger et al. (1974) provide an excellent and comprehensive report of this research. Thomann and Mueller (1987) and Chapra (1997) have summarized the fundamental approach to the analysis of heat budgets and temperature in natural waters that will be used in this TMDL.

Figure 5 shows the major heat energy processes or fluxes across the water surface and streambed.

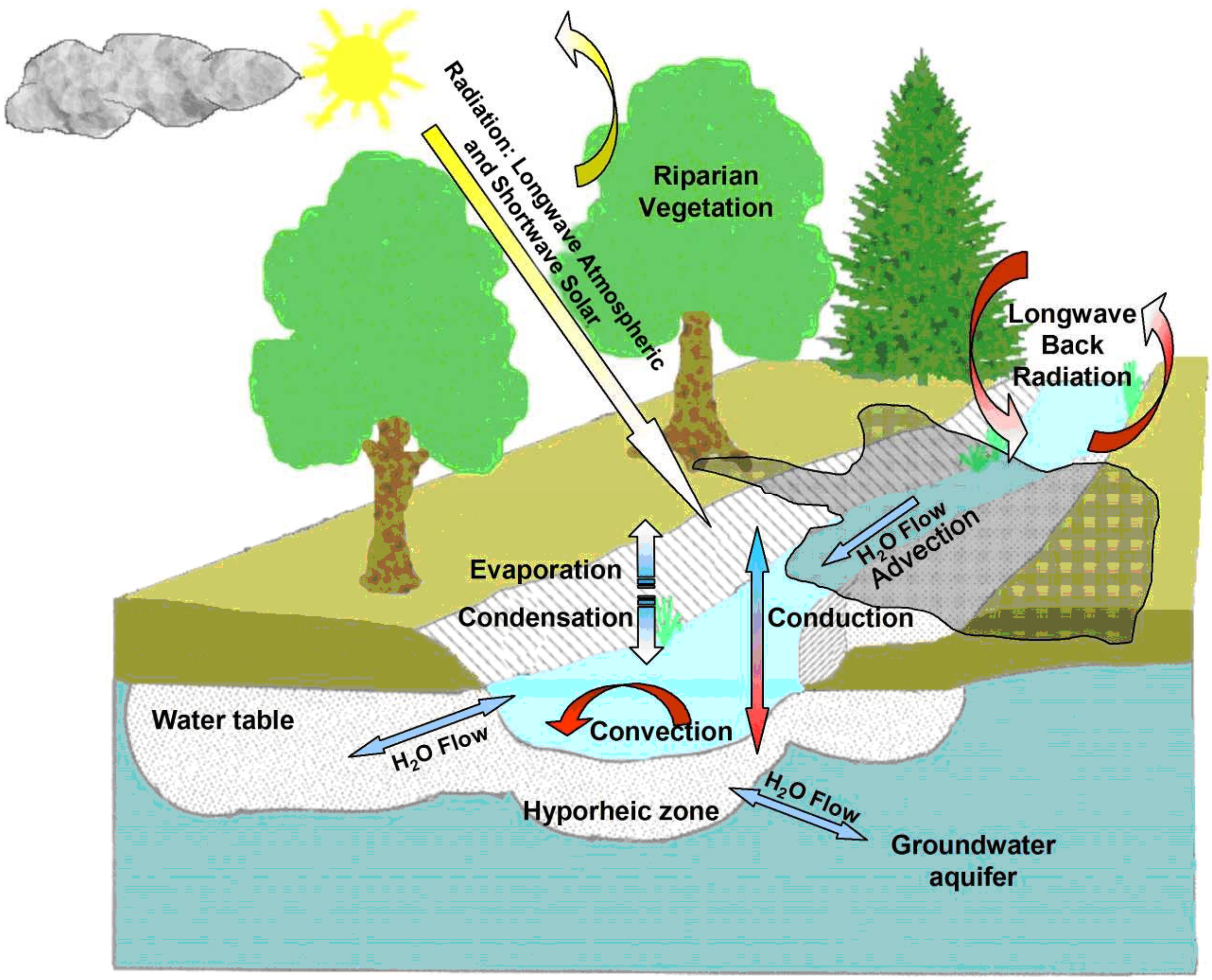

Figure 5: Surface heat transfer processes that affect water temperature.

Adams and Sullivan (1989) reported that the following environmental variables are the most important drivers of water temperature:

- **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.

- **Solar radiation and riparian vegetation**: The daily maximum temperatures in a stream are strongly influenced by removal of riparian vegetation because it blocks and/or reduces the amount of radiation reaching the stream and establishes a micro-climate along the stream that may be cooler than that experienced without the vegetation. 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.

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 that passes directly from the sun to the earth. It constitutes the major thermal input to an unshaded body of water during the day when the sky is clear.
- **Longwave atmospheric radiation**: 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.
- **Longwave back radiation from the water to the atmosphere**: Water radiates heat energy back to the atmosphere in the form of longwave radiation. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases.

Rates of heating to the stream surface can be dramatically reduced when high levels of shade are produced and heat flux from solar radiation is minimized. There is a natural maximum level of shade that a given stream is capable of attaining, which is a function of species composition, soils, climate, and stream morphology.

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. A reduction in the amount of warming or cooling of a stream as it flows depends on the balance of all of the heat exchange and mass transfer processes in the stream.

Mass transfer processes refer to the downstream transport and mixing of water throughout a stream system and inflows of surface water and groundwater. The downstream transport of dissolved/suspended substances and heat associated with flowing water is called advection. Dispersion results from turbulent diffusion that mixes the water column. Due to dispersion, flowing water is usually well-mixed vertically. Stream water mixing with inflows from surface tributaries and subsurface groundwater sources also redistributes heat within the stream system.

These processes (advection, dispersion, and mixing of surface and subsurface waters) redistribute the heat of a stream system via mass transfer. Tributaries and groundwater inflows can change the temperature of a stream segment when the inflow temperature is different from the receiving water.

Data Needs

Since temperature is a measure of heat content, the Palouse River temperature TMDL will be developed for heat. Temperature is an indication of heat content of the material. If heat accumulates in the waterbody due to the processes discussed above, there will be a net increase in temperature of the water column, and vice versa.

Stream temperatures will be modeled using a stream water quality model such as QUAL2K (Chapra, 2003) or GEMSS (Edinger and Buchak 1980, 1995). QUAL2Kw is a one-dimensional (completely-mixed vertically and laterally) model with steady-state hydraulics and diurnal water quality simulation capabilities. GEMSS is a one-dimensional model with dynamic hydraulics and water quality simulation.

Effective shade produced by current riparian vegetation will be estimated using Ecology's Shade model (Ecology, 2003a). The Shade model is a spreadsheet model that calculates effective shade by using the HeatSource model developed by Oregon Department of Environmental Quality (ODEQ, 2003). Data needs for temperature modeling are listed in Table 5.

Table 5. Temperature Data Requirements.

	Parameter	Model Requirement		Data Source		
		Shade	Temperature model	Ecology Field Studies	Other Data Contributor	GIS Analysis
Flow	discharge - tributary		x	x		
	discharge (upstream & downstream)		x	x		
	flow velocity		x	x		
	groundwater inflow rate/discharge		x	x		
	travel time		x	x		
General	calendar day/date	x	x	x		
	elevation - downstream	x	x			x
	elevation - upstream	x	x			x
	elevation/altitude	x	x			x
	latitude	x	x	x		x
	longitude	x	x	x		x
Physical	channel azimuth/stream aspect	x	x			x
	cross-sectional area	x	x	x		
	Manning's n value	x	x	x		
	reach length	x	x			x
	width - bankfull	x				x
	width - stream	x	x			x
Temperature	temperature - groundwater		x	x		
	temperature - tributaries		x	x		
	temperature - water downstream		x	x		
	temperature - water upstream		x	x		
	temperature - air		x	x		
	temperature - point sources			x	x	
Vegetation	% riparian cover on each side	x		x	x	x
	canopy-shading coefficient/veg density	x			x	
	diameter of shade-tree crowns	x				x
	distance to shading vegetation	x		x		x
	topographic shade angle	x				x
	vegetation height	x		x	x	
	vegetation shade angle	x				x
	vegetation width	x		x	x	x
Weather	dewpoint temperature		x	x	x	
	% possible sun/cloud cover		x		x	
	wind speed and direction		x	x	x	
	barometric pressure			x	x	
	precipitation			x		
	solar radiation		x	x		
	temperature - air		x	x		
	wind speed/direction		x	x		

Study Design

The TMDL technical assessment for the Palouse River will use effective shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d) of the Clean Water Act. Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade accounts for the interception of solar radiation by vegetation and topography.

Heat loads to the stream will be calculated in this TMDL study using a heat budget that accounts for surface heat flux and mass transfer processes. Heat loads are of limited value in guiding management activities needed to solve identified water quality problems. Shade will be used as a surrogate to thermal load as allowed under EPA regulations (defined as "other appropriate measure" in 40 CFR § 130.2(i)). A decrease in shade due to inadequate riparian vegetation causes an increase in solar radiation and thermal load upon the affected stream section. Other factors influencing the distribution of the solar heat load also will be assessed, including increases in streamflow and groundwater interactions.

Representativeness and Completeness

Representativeness of the data is achieved by a sampling scheme that accounts for land practices, flow contribution of tributaries, groundwater, point sources, and seasonal variation of instream flow and temperatures in the watershed. Stream temperature measurements will be made in the well-mixed portion of the streamflow where there is no thermal stratification and no direct influence from standing water in pools or the stream margins. Five types of field studies will be conducted to measure physical processes in the river system: (1) temperature monitoring network, (2) groundwater/surface water interactions, (3) stream gauge and flow, (4) stream velocity, and (5) riparian habitat and channel geometry.

Comparability

This Palouse River temperature TMDL study compares closely to the South Fork Palouse River temperature TMDL and other similar studies. For example, most investigations take place over one year, including project scoping, data research, and writing of the Quality Assurance Project Plan. Investigations occasionally occur over two years (for example, Wenatchee River and Deschutes River TMDL studies).

Field data collection spans the warm seasons such as late spring, all summer, and early fall. Field data collection efforts may vary from watershed to watershed because they build off of existing data. Temperature TMDL studies build on the inter-relationship between temperature, surface water, groundwater, point sources, riparian vegetation, weather, and time of travel. The Palouse River has high quality aerial photos, which are useful when assessing riparian vegetation and stream-wetted widths. However, not many temperature data, or continual stream flow stations, exist in the watershed. Also, investigations about groundwater and time of travel have not been completed along the mainstem Palouse River. These data are necessary to complete this TMDL study. Therefore, field data collection will emphasize constituents (data parameters) where more information is needed to appropriately assess the status of the watershed.

Emphasizing data needs is common practice in all temperature TMDL studies. When considered together, data sets for the Palouse River and South Fork Palouse River will help to provide a better understanding of natural river systems.

Establish a temperature monitoring network

Continuously recording temperature instruments (TI) will be deployed at approximately 30 key locations along the mainstem Palouse River and at the mouths of perennial tributaries. Each TI will measure temperature at 30-minute intervals. Monitoring locations will typically consist of an air TI (measuring air temperature near the edge of the stream) and an instream TI. Instream TIs are deployed in the thalweg of a stream such that they are suspended off the stream bottom and in a well-mixed portion of the stream, typically in riffles or swift glides.

It is possible during days of extreme high temperature and extreme low flow to have a vertical gradient of very warm water temperature at the surface that decreases in temperature 1-3°C with 1.5 to 2 feet of depth. Stream temperature stations will be thoroughly checked for vertical stratification during field checks. The intent is to avoid measurement bias from vertical and horizontal temperature stratification.

Instream TIs will be co-located with the core piezometers and will also be deployed at key locations on the Palouse River to account for land-use changes; stream morphology changes; temperature mixing zones; at tributary confluences; and point sources. Air TIs will be co-located with all instream TIs to provide a quality check for the instream data and a comparison with weather station air temperature data. Figure 6 is an example of a possible monitoring network. Final placement will depend on site access considerations such as having landowner permission and/or using public right of way access at road crossings.

A temporary weather station will be installed in the watershed at a key location yet to be determined. This station will collect the following climate data: air temperature, relative humidity, barometric pressure, total solar radiation, wind speed and direction, precipitation, and soil temperature (at a depth of 2-3 ft). This station will complement the data collected by other existing pertinent weather stations.

Ecology will measure WWTP effluent temperature continuously at Colfax, Endicott, Garfield and Palouse. Coordinated quality assurance efforts with facility managers will help to ensure that all data quality objectives are met including (1) calibration of temperature dataloggers, and (2) documentation of calibration and instrument deployment.

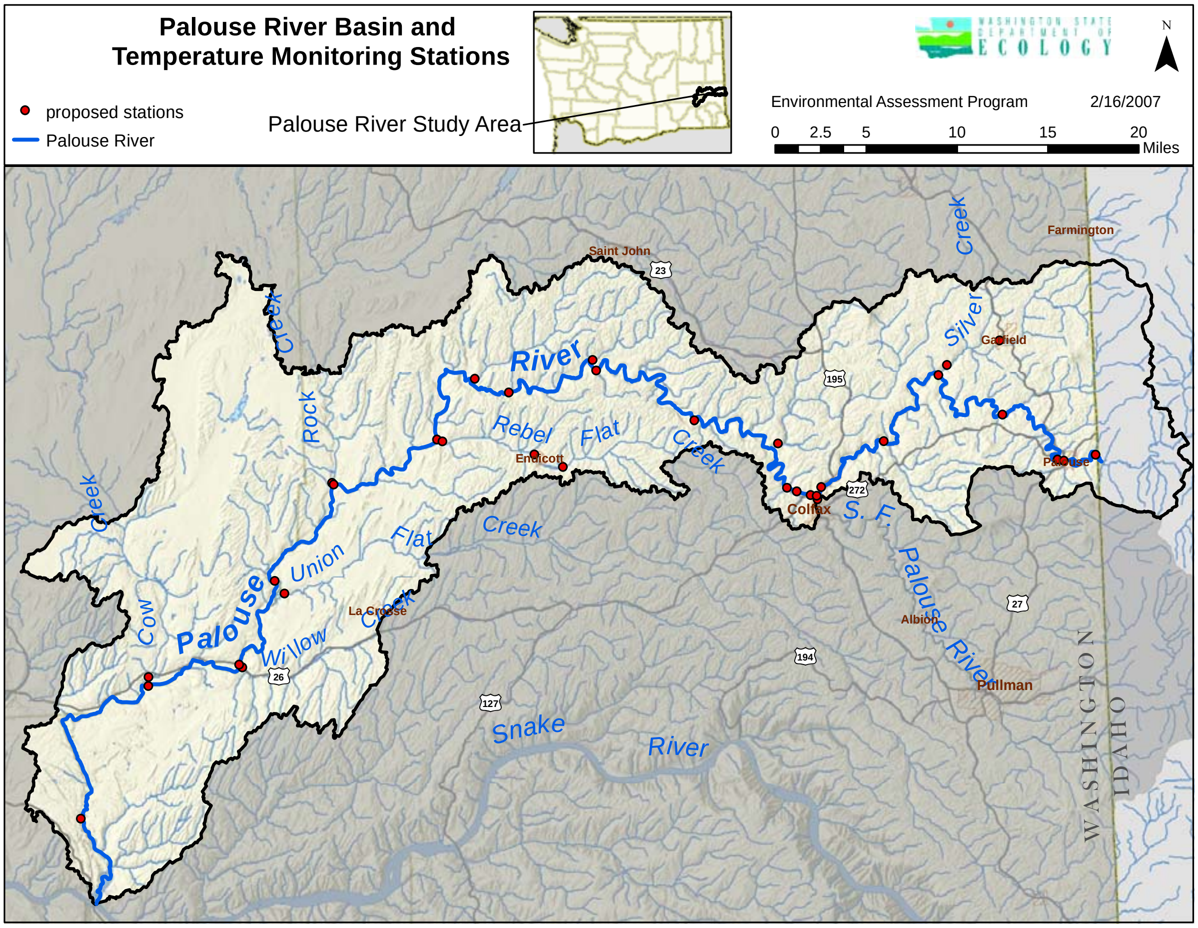

Figure 6: An example of a possible stream temperature monitoring network on the Palouse River and its major tributaries.

Identify and quantify groundwater/surface water interactions with an instream piezometer network

For this study, groundwater and surface-water interactions will be assessed via a combination of common field techniques. Instream piezometers will be installed beginning in May 2007 at selected points along the Palouse River to enable monitoring of surface water and groundwater head relationships, streambed water temperatures, and groundwater quality at discrete points along the river. The piezometers will be distributed to provide point measurements along the length of the river and, where possible, will be co-located with previously deployed instream thermistors.

The piezometers for this study will consist of a five-foot length of 1.5-inch diameter galvanized pipe, one end of which is crimped and slotted. The upper end of each piezometer will be fitted with a standard pipe coupler to provide a robust strike surface for piezometer installation and to enable the piezometers to be securely capped between sampling events. The piezometers will be driven into the streambed (within a few feet of the shoreline) to a maximum depth of approximately 5 feet. Keeping the top of the piezometer underwater and as close to the streambed as possible will reduce the influence of heat conductance from the exposed portion of the pipe. Following installation, the piezometers will be developed using standard surge and pump techniques to assure a good hydraulic connection with the streambed sediments.

Each piezometer will be instrumented with up to three thermistors for continuous monitoring of streambed water temperatures (Figure 7). In a typical installation one thermistor will be located near the bottom of the piezometer, one will be located at a depth of approximately 0.5 feet below the streambed, and one will be located roughly equidistant between the upper and lower thermistors. The piezometers will be accessed monthly to download thermistors and to make spot measurements of stream and ground-water temperature for later comparison against and validation of the thermistor data. The monthly spot measurements will be made with properly maintained and calibrated field meters in accordance with standard Watershed Ecology Section methodology.

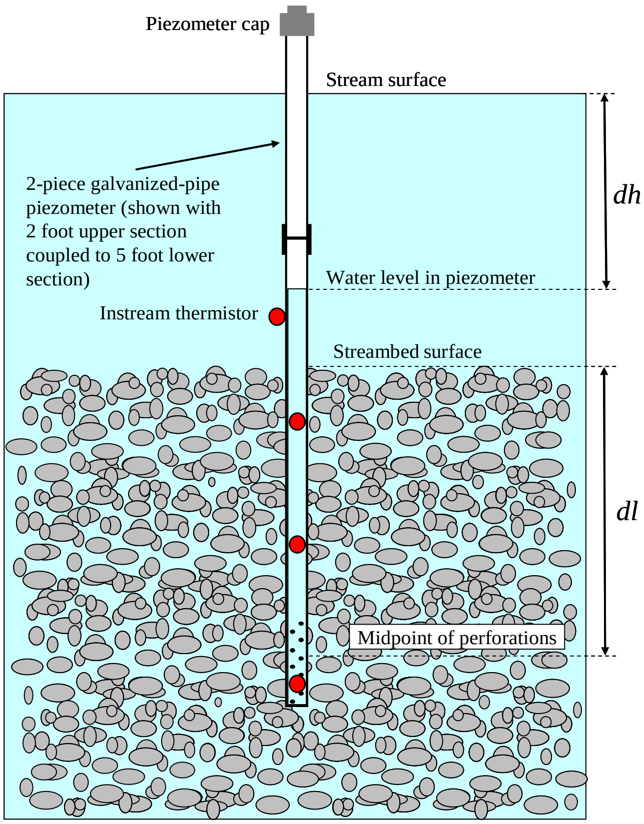

Figure 7: Instream piezometer conceptual diagram (diagram not to scale).

During the monthly site visits, surface water stage and instream piezometer water levels will be measured using a calibrated electric well probe, a steel tape, or a manometer board (as appropriate) in accordance with standard USGS methodology (Stallman, 1983). The water level (head) difference between the internal piezometer water level and the external river stage provides an indication of the vertical hydraulic gradient and the direction of flow between the river and groundwater. When the piezometer head exceeds the river stage, groundwater discharge into the river is inferred. Similarly, when river stage exceeds the head in the piezometer, loss of water from the river to groundwater storage can be inferred.
To provide a secondary confirmation of the instream piezometer dataset, Ecology will also attempt to arrange access to a tandem network of shallow off-stream domestic wells which will be used to monitor "regional" groundwater levels, temperatures, and groundwater quality. When selecting wells, preference will be given to shallow, properly documented wells in close proximity to the Palouse River. Wells selected for monitoring will be visited monthly between May and November 2007 to measure groundwater levels. Where owner permission is granted, and site conditions allow, recording thermistors and water level transducers will be deployed. A subset of the off-stream wells will be sampled in August 2007 for the above listed parameters.

In addition to the above work, Ecology is currently evaluating a method for the direct measurement of streambed sediment permeability using constant head injection tests. The field methods and analytical techniques are based on procedures outlined in Cardenas and Zlotnik (2003). To support the development of this procedure for future Environmental Assessment Program studies, injection tests are proposed for a subset of the piezometers installed during this study. If successful, the test results will be used to augment thermal profiling and gradient measurements for estimation of groundwater/surface water exchange.

Establish a continuously recording stream gage network and measure streamflows

Up to 6 continuously recording stream gages, installed and operated by Ecology's Stream Hydrology Unit (SHU) and the USGS, will give us the ability to quantify streamflow conditions on the Palouse River. Piezometers instrumented with water level loggers may be co-located with the stream gages to facilitate the development of continuous vertical hydraulic gradient profiles for each location.

Continuously recorded streamflow data, instantaneous streamflow measurements conducted during baseflow conditions, piezometer vertical hydraulic gradient measurements, and the resulting flow mass balance will be used to determine streamflow lost or gained to groundwater. Surface water inputs to the Palouse River will be instantaneously measured including the mouths of tributaries and point discharges. Surface water withdrawals will be estimated based on water right certificates and claims or by surveying those users to determine how much water they are withdrawing during the flow monitoring periods.

Time of travel studies to determine average stream velocities

Time of travel studies will use a fluorescent dye (20% Rhodamine WT) to trace the movement of a dye cloud from an upstream point to a downstream point to calculate the average velocity of that body of water. Rhodamine WT dye is commonly used by Ecology, the US Geological Survey, and others to safely and effectively measure time of travel. The methods and protocols used in this survey will follow those prescribed by Kilpatrick and Wilson (1982).

Field measurements of dye concentration in the stream will be made using a Hydrolab© datasonde equipped with a rhodamine fluorometer recording measurements every 5-10 minutes at key locations downstream from the initial point of dye release. These studies will occur at several different flow regimes to determine how stream velocity varies with point-source discharge patterns during baseflow conditions.

Ecology will notify local and state emergency contacts before any dye is put into the water so unnecessary emergency actions will not expend valuable resources in the event a spills complaint is submitted (i.e., somebody calls the sheriff or Ecology spills hotline because the river just turned red).

Riparian habitat and channel geometry surveys

Effective shade inputs to the QUAL2K model require an estimate of the aerial density of vegetation shading the stream. A hemispherical lens and digital camera will be used to take 360° pictures of the sky and shading vegetation at the center of the stream. Digital photographs will be taken at stream TI locations and in reference reaches with existing riparian vegetation. The digital images will be processed and analyzed using the Hemiview© software program.

Measurement Procedures

Measurement of relative head conditions between the piezometer and the river stage will be accomplished by direct comparison measurements using standard procedures for calibrated electric well probes (Stallman, 1983, and as described earlier in this document). Direct measurements of relative heads will also serve as reference points for the interpretation of the continuous water level logger data.

Temperature monitoring stations and piezometers will be checked monthly to make field measurements and to clear accumulated debris away from the instruments. Documentation of the temperature monitoring stations will include:

- GPS coordinates and a sketch of the site (during installation only).
- Depth of the instream TI under the water surface and height off stream bottom.
- Stream temperature.
- Serial number of each instrument and the action taken with the instrument (i.e., downloaded data, replaced TI, or noting any movement of the TI location to keep it submerged in the stream).
- The date and time before the dataloggers are installed or downloaded, and the date and time after they have been returned to their location. All timepieces and PC clocks should be synchronized to the atomic clock using Pacific Daylight Savings Time (PDT). Pacific Standard Time (PST) will be reported if instruments are still in place during the time change.

Estimation of instantaneous flow measurements will follow the SHU protocols manual (Ecology, 2000). Flow volumes will be calculated from continuous stage height records and rating curves developed prior to, and during, the project. Stage height will be measured by pressure transducer and recorded by a datalogger every 15 minutes. All dataloggers will be downloaded monthly. Staff gages will be installed at other selected sites. During the field surveys, streamflow will be measured at selected stations and staff gage readings will be recorded. A flow rating curve will be developed for sites with a staff gage or other stream depth reference point so that gage readings can be converted to a discharge value.

Measurement Quality Objectives

The most important detail for using continuously recording dataloggers is to ensure that they are all synchronized to the same time. There is an official U.S. time that is a public service cooperatively provided by the two time agencies of the United States: (1) a Department of Commerce agency, the National Institute of Standards and Technology (NIST), and (2) its military counterpart, the U.S. Naval Observatory (USNO). The official time can be found at: www.time.gov/timezone.cgi?Pacific/d/-8/java. All date and time stamps will be recorded in Pacific Daylight Savings Time (PDT).

Table 6 summarizes the accuracy and reporting limits of the equipment that will be utilized for this study. Certain instruments are used exclusively for water temperature and others for air as noted in the table. A WTW 340i multi-meter will be used to measure water conductivity and temperature.

Table 6: Summary of measurement quality objectives and manufacturer measurement limits of field equipment.

Measurement/ Instrument Type	Accuracy (% Deviation from True Value)	Required Resolution
Stream velocity/ Marsh McBirney Flo-Mate model 2000	±2% of reading; 0.1 ft/s 5%-8% measurement error	0.05 ft/s
Continuous temperature/ Hobo Water Temp Pro	±0.2°C at 0 to 50°C (± 0.36°F at 32° to 122°F)	0.2°C for water temperature
Continuous temperature/ StowAway Tidbits -5°C to +37°C model	±0.4°F (±0.2°C) at +70°F	0.2°C for water temperature
Continuous temperature / StowAway Tidbits -20°C to +50°C model	±0.8°F (±0.4°C) at +70°F	0.4°C for air temperature
Continuous water levels/ Hobo Water Level Logger U-20-001-01	±2.1 cm (0.07 ft) and ±0.37°C at 20°C (0.67°F at 68°F);	0.01 ft
Instantaneous conductivity and temp./ TetraCon 325C probe and WTW 340i multi-meter	±1% of value (conductivity) 0.2°C (temperature)	0.2°C for temperature
Hobo Pro Relative Humidity	±3% RH	n/a
Hobo Wind speed/direction smart sensor	±0.5 m/s (±1.1 mph) for <17 m/s (<38 mph) ±3% for 17 to 30 m/s (38 to 67 mph) ±4% for 30 to 44 m/s (67 to 99 mph)	n/a
Hobo Barometric Pressure smart sensor	±1.5 mbar (0.044 in Hg) over full pressure range at +25°C (+77°F)	n/a
Hobo Rain Gage smart sensor	±1.0% at up to 20 mm or 1" per hour	n/a
Hobo Silicon Pyranometer smart sensor	±10 W/m2 or ±5%, whichever is greater in sunlight. Additional temperature induced error ±0.38 W/m^2 /°C from 25°C (0.21 W/m^2/°F from 77°F)	n/a

Quality Control Procedures

Field

The Onset StowAway Tidbits©, Hobo Water Temp Pro©, and Hobo Water Level Logger© instruments will be calibrated pre- and post-study in accordance with Ecology Temperature Monitoring Protocols (Ward, 2003) to document instrument bias and performance at representative temperatures. A National Institute of Standards and Technology (NIST) certified reference thermometer will be use for the calibration. At the completion of the monitoring, the raw data will be adjusted, based on the pre- and post-study calibration results, if the temperature for the instrument differs from the NIST-certified thermometer by more than the manufacturer-stated accuracy of the instrument (i.e., by more than ±0.2°C or ±0.4°C). The mean difference of the pre- and post-study calibration values from the NIST thermometer reading will be used for calculating the adjusted temperature.

Variation for field sampling of instream temperatures and potential thermal stratification will be 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. Air temperature data and instream temperature data for each site will be compared to determine if the instream TI was exposed to the air due to stream stage falling below the installed depth of the stream TI.

The Onset Hobo Water Level Logger© pressure transducers will also be checked for measurement accuracy both pre- and post-study by 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 developing a calibration curve if the instrument does not meet manufacturer specified accuracy of measurement (i.e., ±0.07 ft). Water levels both in the piezometer and at the stream stage reference point will be measured in the field with an e-tape and steel engineers tape. Barometric pressure will be recorded at representative stations to compensate for atmospheric pressure effects on the water level loggers.

Conductivity meters will be calibrated in the field using a conductivity standard according to the manufacturer’s specifications each day before data collection begins.

Data Management Procedures

All continuous data will be stored in a project database that includes station location information and data quality assurance information. This database will facilitate summarization and graphical analysis of the temperature data and also create a data table to upload temperature data to Ecology's statewide Environmental Information Management System (EIM) geospatial database.

An EIM user study ID (JICA0001) has been created for this TMDL study and all monitoring data will be available via the internet once the project data has been validated. The URL address for this geospatial database is: apps.ecy.wa.gov/eimreporting. EIM will accept the daily maximum, daily minimum, and daily average temperature summary from a continuous temperature data set as well as instantaneous streamflow measurement results. All temperature and streamflow data will be uploaded to EIM by the temperature field investigator once all data have been reviewed for quality assurance and finalized.

All final spreadsheet files, paper field notes, and final GIS products created as part of the data analysis and model building will be kept with the project data files.

Data Analysis and Temperature Modeling Procedures

From the raw data collected at each monitoring location for temperature, the maximum, minimum, and daily average will be determined. The data will be used to characterize the water temperature regime of the basin and to determine periods when the water temperatures are above the state numeric water quality standard. Estimates of groundwater inflow will be calculated by constructing a water mass balance from continuous and instantaneous stream flow data and piezometer studies.

A model will be developed for observed and critical conditions. Critical conditions for temperature are characterized by a period of low-flow and high-water temperatures. The model will be used to evaluate the system potential temperature in the river. Sensitivity analysis will be run to assess the variability of the model results. The model will be used to evaluate various heat budget scenarios for future water quality management decisions in the Palouse River basin.

GIS coverage of riparian vegetation in the Palouse River study area will be created from information collected during the 2007 temperature field study. Furthermore detailed aerial photos will be viewed to assess riparian vegetation. Riparian vegetation coverage will be created by qualifying four attributes: vegetation height, general species type or combinations of species, percent vegetation overhang, and the average canopy density of the riparian vegetation.

Data collected during this TMDL effort will allow the development of a temperature simulation methodology that is both spatially continuous and spans full-day lengths. The model will be calibrated to current (2007) conditions measured by this study design. The GIS and modeling analysis will be conducted using specialized software tools:

- Ecology's Ttools extension for ArcView will be used to sample and process GIS data for input to the shade and temperature models.
- Ecology's shade calculator (Ecology, 2003a) will be used to estimate effective shade along the mainstem Palouse River. Effective shade will be calculated at 50- to 100-meter intervals along the streams, and then averaged over 500- to 1000-meter intervals for input to the temperature model.
- The QUAL2Kw model (Chapra and Pelletier, 2004; Ecology, 2003b) or GEMMS model (Edinger and Buchak, 1995) will be used to calculate the components of the heat budget and simulate water temperatures. Both temperature models simulate diurnal variations in stream temperature using the kinetic formulations for the components of the surface water heat budget that are described in Chapra (1997).

  Model resolution and performance will be measured using the root-mean-square-error (RMSE), a commonly used measure of model variability (Reckhow, 1986). The RMSE is defined as the square root of the mean of the squared difference between the observed and simulated values.

QUAL2K will be applied by assuming that flow remains constant (i.e., steady flows) for a given condition such as a 7-day or 1-day period (using daily average flows), but key variables other than flow will be allowed to vary with time over the course of a day. For QUAL2K temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures are specified or simulated as diurnally varying functions. If model resolution using QUAL2K is too high (measured as RMSE greater than 1.5°C), then GEMSS will be applied using variable flow over the course of a day (i.e., unsteady flow).

Audits and Reports

The project manager will be responsible for submitting quarterly reports and the final technical study report to Ecology's Water Quality Program TMDL coordinator for this project, according to the project schedule.

Data Verification and Review

Data for instream temperature monitoring stations will be verified against the corresponding air temperature station to ensure the stream temperature records represent water temperatures and not temperatures recorded during a time the instream TI is dewatered. Measurement accuracy of individual TIs is verified using a NIST-certified reference thermometer and field measurements of stream temperature at each TI location several times during the study period.

All manually-entered data in spreadsheets will receive a 100% quality check assessment by another technician other than the person who entered the data to ensure accuracy in transcription from field notes to the electronic files. The database will be checked to ensure the data records and serial numbers match the field records.

Data Quality (Usability) Assessment

The field investigator will verify that all measurement and data quality objectives have been met for each monitoring station. If objectives have not been met (such as a TI operating outside of its specifications or recording bad data), the field investigator will decide how to qualify the data and how it should be used in the analysis or whether it should be rejected. Part of this analysis includes graphically comparing each instream TI record to its paired air TI record to see if any of the water data reflects a time when the instrument was dewatered. The field investigator will produce a Station QA report that will include: Site descriptions, data QA notes, and graphs of all continuous data.

Organization and Schedule

The roles and responsibilities of Ecology project staff are as follows:

Environmental Assessment Program

- **Jim Carroll**, *Water Quality Studies Unit, Project Manager*: Responsible for overall project management of the study. Responsible for development of TMDLs for temperature and conventional parameters, including model development and writing the technical report.
- **James Kardouni**, *Nonpoint Studies Unit, Field Investigator:* Responsible for the development of the temperature study, writing the QA Project Plan, temperature field data collection, analysis and data entry to EIM, project database management, and writing sections of the technical report related to temperature data collection and data quality review.
- **Kirk Sinclair**, *Nonpoint Studies Unit, Hydrogeologist:* Provides hydrogeologic assistance with study design including interpretation of historical geology and groundwater data in the basin, groundwater data collection, data analysis, and report writing.
- **Brenda Nipp and Scott Tarbutton**, *Watershed Ecology Section:* Responsible for field data collection and data entry.
- **Chuck Springer and Mitch Wallace**, *Stream Hydrology Unit, Hydrologist*: Responsible for deploying and maintaining continuous flow gages and staff gages. Responsible for producing records of streamflow data at sites selected for this study.
- **Darrel Anderson**, *Nonpoint Studies Unit, Unit Supervisor*: Reviews the QA Project Plan and TMDL report.
- **Karol Erickson**, *Water Quality Studies Unit, Unit Supervisor*: Reviews the QA Project Plan and TMDL report.
- **Will Kendra**, *Watershed Ecology Section, Section Manager*: Approves the QA Project Plan and final TMDL report.
- **Bill Kammin**, *Quality Assurance Officer*: Reviews the QA Project Plan and oversees all Ecology quality assurance programs. Provides technical assistance on QA/QC issues during the implementation and assessment of the project.

Water Quality Program

- **Elaine Snouwaert**, *Eastern Regional Office, TMDL Project Lead*: Acts as point of contact between Ecology technical study staff and interested parties, and coordinates information exchange and meetings. Supports, reviews, and comments on the QA Project Plan and technical report. Responsible for implementation planning and preparation of TMDL submittal document for EPA.
- **Dave Knight**, *Eastern Regional Office, Watershed Unit Supervisor*: Approves the TMDL submittal to EPA.
- **Jim Bellatty**, *Eastern Regional Office, Section Manager*: Approves the TMDL submittal to EPA.

Schedule

Each general study activity and its expected completion date is listed in Table 9. Acquiring landowner permissions for accessing the river in some locations may affect the starting date for monitoring activities.

Table 9: Proposed TMDL schedule.

Document or Activity	**Completion Date**
Final QA Project Plan	June 2007
Monitoring Activities	May 2007 through October 2007
Analyses, Modeling, and Report Writing	October 2007 to October 2008
Environmental Information System (EIM) Data Set	
EIM Data Engineer	James Kardouni
EIM User Study ID	JICA0001
EIM Study Name	Palouse River Temperature TMDL
EIM Completion Due	March 2008
Quarterly Reports	
Report Author Lead	Jim Carroll
Schedule:	
1st Quarter Report	August 2007
2nd Quarter Report	November 2007
3rd Quarter Report	February 2008
4th Quarter Report	May 2008
Report Supervisor Draft Due	September 2008
Final Report	
Report Author Lead	Jim Carroll
Schedule	
Report Supervisor Draft Due	September 2008
Report Client/Peer Draft Due	October 2008
Report External Draft Due	November 2008
Report Final Due (Original)	February 2009

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Appendix.
Response to Comments on the Draft Quality Assurance Project Plan for the Palouse River Temperature TMDL Study

The draft report, *Quality Assurance Project Plan (QAPP) for the Palouse River Total Maximum Daily Load Study*, was distributed to the Technical Advisory Group on April 6, 2007 for a two-week comment period. Comments were due by the April 20, 2006. Written review comments were received from Micheal Isaacs and Don Myott. We appreciate all comments received.

Minor editorial and grammatical comments were incorporated into the final QAPP. The remaining individual comments (*italicized* text) are stated below, followed by our response or action following each comment. Changes will be incorporated into the final QAPP.

<u>Comments by Micheal Isaacs, town of Endicott:</u>

1. *I am interested in how temperature pollution can be controlled.*
2. *I am also interested in finding out the condition of rebel creek, and it's TMDL.*

<u>Response</u>:

1. Temperature pollution can be controlled with shade provided by riparian vegetation.
2. The most recent condition of Rebel Flat Creek is summarized in Table A-1.

Table A-1. Rebel Flat Creek (near mouth) recent data summary provided by Adams County.

Fecal coliform	Geomean Criteria 173*	10% Criteria 38.9%*
pH	% pH > 8.5 5.6%*	% pH < 6.5 0%
Temperature	% Temp >18°C 0%	
Dissolved oxygen	% <8.0 mg/L 11.1%*	

*Exceeds Washington State water quality standards

Rebel Flat Creek also has 303d listed stream segments. Table A-2 summarizes relevant listings.

Table A-2. Rebel Flat Creek 303d listed stream segments.

Listing ID	Category	WRIA	Parameter	Township	Range	Section
8150	5	34	Dissolved Oxygen	17N	40E	29
6715	5	34	Fecal Coliform	17N	41E	31
6714	5	34	Fecal Coliform	17N	40E	25
6716	5	34	Fecal Coliform	17N	41E	33

<u>Comments by Don Myott, city of Palouse:</u>

1. *Check the height the Palouse Falls. My information says that it is 198 feet.*
2. *Under the Land-use Patterns "populations not exceeding 200" needs to be checked, because Garfield and Endicott are bigger.*
3. *Under Non-point Sources #3, my opinion, that rural residential development is changing agricultural, forestry, and grazing areas.*

<u>Response</u>:

1. The height of Palouse Falls is now stated in the QAPP as 198 feet.
2. The text in the QAPP has been changed to reflect the correct 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), followed by Garfield (population 630). Smaller towns, with populations not exceeding 350, are located within the watershed as well.”
3. We agree that rural residential development is changing agriculture, forestry, and grazing areas. Most changes to the land will influence the hydrologic characteristics of nearby waterbodies. The QAPP has been modified as follows:

   “Altered streamflow patterns from urban and rural residential development, timber harvest, and agriculture areas resulting in increased spring runoff and decreased summer baseflows.”