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Lower White River pH Total Maximum Daily Load – Technical Analysis and TMDL Allocations

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Cover photo: The Lower White River at ~River Mile 25 taken by Nuri Mathieu.

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Lower White River pH Total Maximum Daily Load

by

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Water Quality Program

Washington State Department of Ecology

Olympia, Washington

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Introduction

Overview

The federal Clean Water Act (CWA) requires that a Total Maximum Daily Load (TMDL) be developed for each of the water bodies on the 303(d) list. The Act requires states to prepare the 303(d) list, which is a list of water bodies that do not meet state water quality standards. The TMDL study identifies pollution problems in the watershed and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Then, the Washington State Department of Ecology (Ecology), works with local governments, tribal governments, agencies, and the community, to develop an implementation plan that describes actions to control the pollution and a monitoring plan to assess the effectiveness of the water quality improvement activities.

This TMDL is co-written by the Environmental Protection Agency (EPA), Muckleshoot Indian Tribe (MIT), and Ecology. This was necessary as the TMDL includes parts of the White River that flow through MIT land. Because Washington State Department of Ecology does not have jurisdiction on MIT lands or facilities, the EPA will be responsible for developing and administering any future permits associated with discharges from MIT facilities.

In 1990, Ecology collected data showing that pH levels in the Lower White River exceeded Washington State water quality standards. pH is a measure of how acidic/basic water is. pH is measured on a logarithmic scale, from 0-14. A pH of 7 is neutral, less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base. The pH of water can change throughout a season or even within a day. The optimal pH range for aquatic life is around 6.5 to 8.5. Highly acidic or basic water is usually lethal to fish and other aquatic organisms.

In 1996, based on multiple exceedances of water quality standards, Ecology placed the Lower White River on the Washington State 1996 303(d) list of impaired waters. Monitoring conducted from 1996-2003 documented continued pH exceedances and a TMDL study was started in 2000. Significant hydrologic changes in the watershed after the study began necessitated additional monitoring and modeling work which started in 2012. The 2012 study and continuous monitoring of pH by USGS (USGS gage 12100490 on the White River at R Street near Auburn) show that pH continues to not meet water quality standards under certain conditions (see Appendix A –Background, Appendix F- 2012 Study Results, and Appendix J- Historic data for more detailed discussions).

Between June 2013 and October 2021 (period of applicable USGS approved data after the TMDL data collection), pH has reached or exceeded 8.3 on 104 days in the months of May through October. This includes pH values as high as 9.4, which occurred as recently as September 2018. A threshold of 8.3 was used because data collection and modeling suggest pH can be greater in the stretch that extends downstream of the USGS gage at RM 7.6 to the Lake Tapps Tailrace at RM3.7. In this 9-year period, for the months of May through October, 13% of these months have demonstrated one or more days with pH of 8.5 or greater.

A comparison of the existing critical low flow conditions in the model, compared to system potential pH conditions, predicted that the human caused impact to pH was:

- Between 0.01 and 0.15 between river miles (RM) 26.4 and 14.6 with the magnitude of impact increasing in the downstream direction. Loading in this stretch of the river had a significant influence on the human-caused impact in reaches downstream of RM 14.6.
- Between 0.2 and 0.38 between RM 14.6 and RM 4.4 with the magnitude of impact increasing in the downstream direction.
- Between 0.18 and 0.40 between RM 4.4 and the mouth of the river. In this stretch of the river, up to 0.50 human-caused impact is allowed.
- A peak human caused impact exceedance of 0.38 was predicted in the model segment from RM 5.1 to RM 4.4, with a maximum pH of 8.65.
- The pH also exceeded 8.5, between RM 4.4 and RM 3.6, with a maximum of 8.64.

Using the results from this study, Ecology determined the wasteload and load allocations needed to meet water quality standards for the Lower White River and its tributaries. This report contains those allocations. This TMDL, based on the study findings, states actions needed to bring the Lower White River into compliance with the state water quality standards. This includes descriptions of the roles and authorities of cleanup partners. The TMDL is significant because it protects an important recreational, cultural and economic resource in a highly populated and growing area.

The White River is a large tributary to one of the largest basins draining to southern Puget Sound, the Puyallup River Basin. The aquatic life present in the river, particularly salmonids, is an especially important resource for local communities, including the MIT.

Scope

The White River is in Water Resource Inventory Area (WRIA) 10 (for a map of WRIAs see Appendix A). It originates at glaciers on Mt. Rainier and flows approximately 85 miles to its confluence with the Puyallup River. The White River drainage basin consists of approximately 740 square-miles. The river emerges from its upper watershed near the city of Buckley and ends at its confluence with the Puyallup River in the city of Sumner, 23 miles downstream of Buckley. The Lower White River watershed is approximately 90 square miles and extends from just below Mud Mountain Dam to the mouth of the river near its confluence with the Puyallup River. The White River flows through the MIT reservation between RM 15.5 and 8.9. Just upstream of RM 24 there is a diversion that feeds Lake Tapps. The following describes the geographic context for this TMDL project (Figure 1) including the area that was studied, the extent of the TMDL, and the area of implementation:

- **Ecology study area**: The White River and all contributing drainage area between the confluence with the Puyallup River (RM 0.0) and just downstream of Mud Mountain Dam (RM 28) where data collection, analysis, and modeling occurred to evaluate the extent of the pH impairment.
- **TMDL reach**: The White River mainstem between RM 3.6 and RM 28 where pH is impaired (or where discharges contribute to a downstream impairment) and to which the load capacity applies. Allocations apply to point and non-point discharges to the river at the location of discharge. Note this reach includes the Reservation Reach (RM 15.5 to 8.9)

where allocations do not apply, but a reserve capacity has been included in the TMDL. Note this does not include contributing drainage area between RM 3.6 and RM 28.

- **The TMDL implementation area**: The contributing drainage area to the White River between RM 3.6 and RM 28 where phosphorus management practices are necessary to meet allocations for discharges to the river and the TMDL load capacity of the river itself.

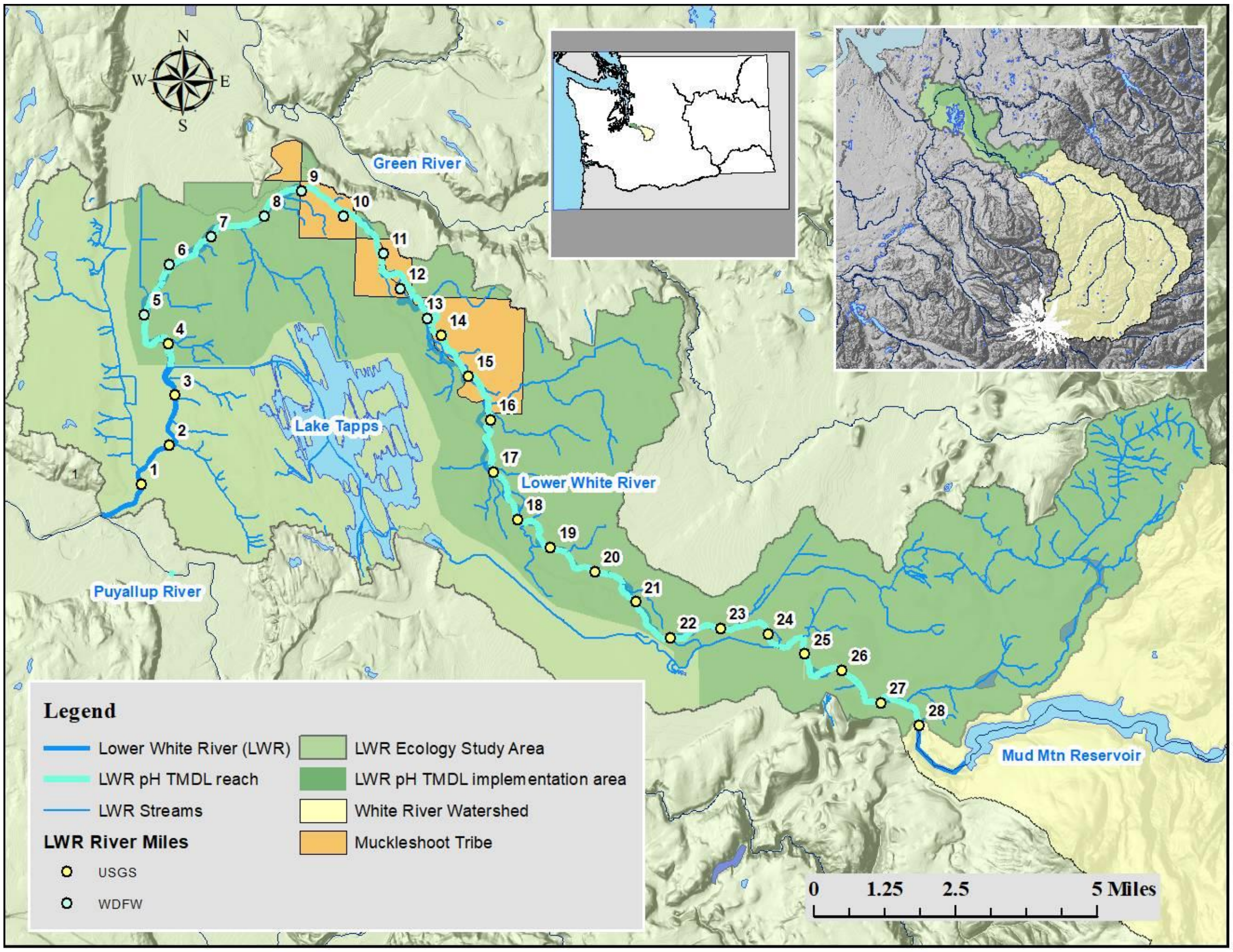

Figure 1. The White River watershed and the 2012 Lower White River pH TMDL project area.

Table 1 includes a list of the White River Category 5 water body segments on the current approved Washington State 303(d) list for pH.

Table 1. Category 5 water bodies on the current approved 303(d) list addressed by this TMDL.

Listing ID	Water body Name	Pollutant	Medium	Assessment Unit ID
7524	White River	pH	Water	17110014005509_001_007
7525	White River	pH	Water	17110014000437_001_001
7526	White River	pH	Water	17110014000436_003_003

Once a TMDL is approved by EPA for the water body segments in Table 1, they will be placed into Category 4a of the Integrated Report. Additional water body segments are addressed by this TMDL (see Table 2) because the TMDL analysis predicted that the segment is either impaired under critical conditions or contributes to a downstream segment impairment. These segments are currently in Category 1 (no impairment) or Category 3 (insufficient data to make an impairment decision) of the Integrated Report. Ecology is including load and wasteload allocations for these water body segments to ensure water quality goals are met for impaired water body segments of the Lower White River. Based on Ecology's current policy the listings in Table 2 should also be moved to Category 4a once the TMDL is approved.

Table 2. Additional water body segments addressed by this TMDL that are impaired or that contribute to a downstream impairment, based on the TMDL analysis, but not currently on the 303(d) list.

Listing ID	Water body Name	Pollutant	Medium	Category	Assessment Unit ID
10857	White River	pH	Water	3	17110014000472_001_001
14783	White River	pH	Water	3	17110014000471_001_001
14785	White River	pH	Water	3	17110014000237_001_001
71269	White River	pH	Water	3	17110014000235_001_001
71270	White River	pH	Water	3	17110014000463_002_002
80717	White River	pH	Water	3	17110014000436_001_003

Additional water body segments below the Lake Tapps Diversion (RM3.6) are categorized for pH as Category 2 (waters of concern) or Category 3 (insufficient data to make an impairment decision) of the Integrated Report. The TMDL analysis found that these segments were not currently impaired and therefore were not included in the TMDL reach.

There are other segments in the watershed on the candidate 303(d) list, but this report does not address them (Table 3).

These exceedances have a different cause and seasonality from those addressed by this TMDL or represent parameters other than pH and are thus beyond the scope of this TMDL project.

The TMDL study found that bottom algae growth, and the associated pH increases that result in impairment, are not sensitive to instream temperatures. Therefore, the temperature impairments in the Lower White River are not strongly linked to the pH impairments. A good example of this is that on the most critical day of the study year (10/11/2012), when pH exceeded numeric criteria, the instream temperature in the river stayed below 13°C for the entire length of the study area (see Appendix I, Figure I-72). This finding is supported by previous studies that showed significant bottom algae growth and numerous pH exceedances during winter months when instream temperatures were below numeric criteria and flows were artificially low (see Appendix J for detail).

Table 3. Study area Category 5 water bodies on the 303(d) list not addressed by this TMDL.

Listing ID	Water body Name	Pollutant	Medium	Assessment Unit ID
35337	Boise Creek	pH	Water	17110014000475_001_002
10854	WHITE RIVER	DO	Water	17110014005509_001_007
14775	WHITE RIVER	DO	Water	17110014000471_001_001
14777	WHITE RIVER	DO	Water	17110014000237_001_001
17511	WHITE RIVER	DO	Water	17110014000436_003_003
17512	WHITE RIVER	DO	Water	17110014000233_001_001
47554	WHITE RIVER	DO	Water	17110014000437_001_001
81171	WHITE RIVER	DO	Water	17110014000472_001_001
81795	WHITE RIVER	DO	Water	17110014000234_002_002
9383	BOWMAN CREEK	DO	Water	17110014001317_001_001
10848	WHITE RIVER	Temp	Water	17110014000232_001_001
12574	WHITE RIVER	Temp	Water	17110014000471_001_001
14793	WHITE RIVER	Temp	Water	17110014000237_001_001
17513	WHITE RIVER	Temp	Water	17110014000233_001_001
17515	WHITE RIVER	Temp	Water	17110014000436_003_003
73820	WHITE RIVER	Temp	Water	17110014000463_002_002
7522	WHITE RIVER	Temp	Water	17110014000437_001_001
7523	WHITE RIVER	Temp	Water	17110014005509_001_007
93244	WHITE RIVER	Temp	Water	17110014000242_001_001
93631	WHITE RIVER	Temp	Water	17110014000436_001_003

Listing ID	Water body Name	Pollutant	Medium	Assessment Unit ID
73830	UNNAMED CREEK (TRIB TO WHITE RIVER)	Temp	Water	17110014001322_001_001
7496	BOISE CREEK	Temp	Water	17110014010591_001_001
93443	SECOND CREEK	Temp	Water	17110014000632_002_002
9382	BOISE CREEK	Temp	Water	17110014000473_001_001
9385	BOWMAN CREEK	Temp	Water	17110014001317_001_001
78303	UNNAMED CREEK (TRIB TO WHITE RIVER)	Copper	Water	17110014001411_001_001
96272	SECOND CREEK	Copper	Water	17110014000632_002_002
79794	UNNAMED CREEK (TRIB TO WHITE RIVER)	Mercury	Water	17110014001411_001_001
78732	UNNAMED CREEK (TRIB TO WHITE RIVER) (Government Canal)	DDT	Water	17110014001322_001_001

Boise Creek (Listing 35337) is listed for both low and high pH. This TMDL only addresses exceedances of the upper pH range in the mainstem Lower White River.

Low pH can result from a number of factors including impairment from mining activities or industrial discharge, but it can also occur due to natural sources including groundwater, wetlands, and naturally acidic rain combined with poorly buffered soils.

The low pH condition in Boise Creek is most likely either natural or impaired by a source other than nutrients (the focus of this TMDL). A separate investigation of runoff conditions and upstream sources is necessary to confirm these results and determine whether there is an impairment or not.

This TMDL does not address pH in the tributaries, and therefore, cannot take credit for the candidate 303(d) pH listing there (Table 3). The tributaries will be assigned phosphorus load reductions (Table 19) at the mouths to address downstream impairments in the mainstem. The remaining parameters were not addressed for a variety of reasons. For example, they were not all on the 303(d) list when the TMDL study was designed. Also, the temperature impairments are not linked to the same causes/sources as the pH problem. Ecology has limited resources for TMDL development and wanted to focus on the longest standing impairments. Finally, several of these listings occur downstream of the TMDL reach, in a stretch of the river that is not impaired for pH.

Uses of the water bodies

The Water Quality Standards for Surface Waters of the States of Washington, Chapter 173-201A WAC (Adopted August 1, 2016, Revised March 2017, Publication no 06-10-091) shows the beneficial uses for the TMDL project areas as follows (Table 602, pg. 85):

White River from mouth to latitude 47.2438 longitude -122.2422 (Sect.1 T20N R4E) (RM 0 to RM 4.4).

- Aquatic Life Uses
    - Salmonid spawning, rearing, and migration
- Recreation Uses
    - Primary contact
- Water Supply Uses
    - Domestic Water
    - White River Hatchery water supply
    - Industrial Water
    - Agricultural Water
    - Stock Water
- Miscellaneous Uses
    - Wildlife Habitat
    - Harvesting
    - Commerce/Navigation
    - Boating
    - Aesthetics

From latitude 47.2438 longitude -122.2422 (Sect.1 T20N R4E) to Mud Mountain dam (including tributaries) (RM 4.4 to RM 28) the uses are the same except for Aquatic Life Uses, which change to **Core Summer Salmonid Habitat.** See map in Figure 2.

The key identifying characteristics of the **Core summer salmonid habitat** use are summer (June 15 - September 15) salmonid spawning or emergence, or adult holding; use as important summer rearing habitat by one or more salmonids; or foraging by adult and sub-adult native char. Other common characteristic aquatic life uses for waters in this category include spawning outside of the summer season, rearing, and migration by salmonids. The key identifying characteristics of the **Salmonid spawning, rearing, and migration** use is salmon or trout spawning and emergence that only occurs outside of the summer season (September 16 - June 14). Note: while the above aquatic life uses are characterized by activity within or outside the summer season, the numeric pH criterion for these uses apply year-round. Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids. The other designated use categories are self-explanatory. The Recreational and Water Supply Uses aren’t impaired by the pH impairments this TMDL addresses.

Water quality criteria

Washington’s administrative code outlines water quality standards for the state of Washington (WAC 173-201A). Beneficial uses are shown in Figure 2 and the associated applicable criteria within the TMDL study area are shown in Table 4.

Table 4. Washington State water quality criteria for pH in the Lower White River.

Segment of River	Beneficial Use	Parameter	Applicable Criteria
Mouth to RM 4.4	Salmonid spawning, rearing, and migration	pH	Must be kept within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.5 units.
RM 4.4 to RM 28	Core summer salmonid habitat	pH	Must be kept within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units.

The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. pH is an important factor in the chemical and biological systems of natural waters. pH both directly and indirectly affects the ability of waters to have healthy populations of fish and other aquatic species. Changes in pH affect the degree of dissociation of weak acids or bases. This effect is important because the toxicity of many compounds is affected by the degree of dissociation. While some compounds (e.g., cyanide) increase in toxicity at lower pH, others (e.g., ammonia) increase in toxicity at higher pH.

While there is no definite pH range within which aquatic life is unharmed and outside which it is damaged, there is a gradual deterioration as the pH values are further removed from the normal range. However, at the extremes of pH, lethal conditions can develop. For example, high pH values (>8.5) may transform a sufficient amount of ammonium ions in the water into unionized ammonia which can cause lethal effects to fish.

In addition to the beneficial uses and associated numeric criteria described above, downstream water body criteria and aesthetic uses must also be protected. Protection of downstream criteria is discussed in Appendix A. Per WAC 173-201A-260 2(b) ‘Aesthetic values must not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste’. TMDL analysis suggests that increased periphyton growth caused by excessive phosphorous inputs is the primary cause of pH exceedances within the TMDL boundary. Periphyton are a group of organisms, which grow or accumulate on the bottom of a stream, which consists of mostly algae with some bacteria and other microscopic life. These algae need sunlight and nutrients to grow, and excessive nutrient levels can lead to excessive growth. As excessive plant growth is also the most likely aesthetic use impairment associated with the pH problem, the phosphorus wasteload and load allocations assigned in this TMDL should also be protective of aesthetic uses, given that model-predicted algal growth is well below what are considered nuisance levels.

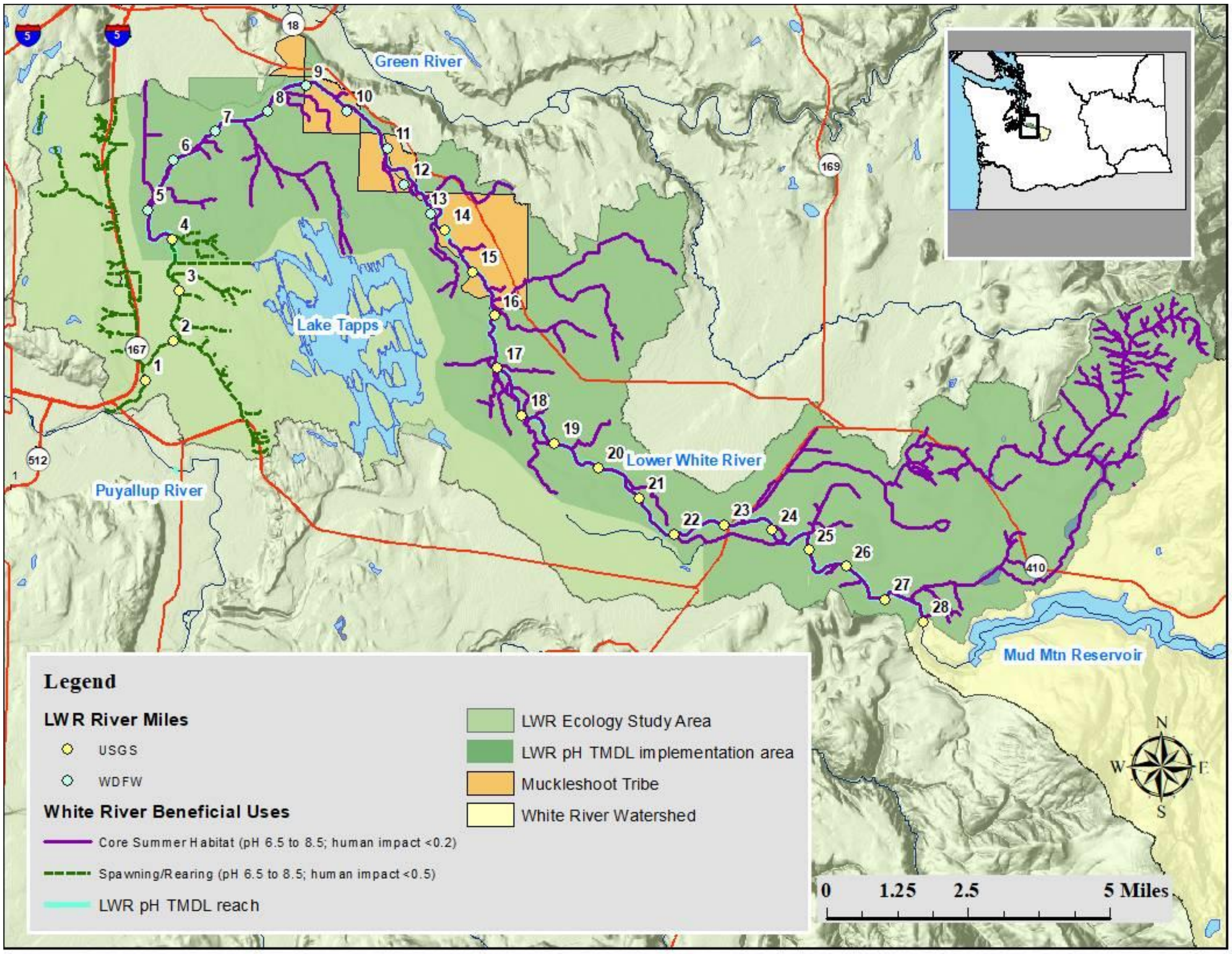

Figure 2. Beneficial uses for the Lower White River pH TMDL project area

Ecology's antidegradation policy is described in WAC 173-201A-300 (Publication no 06-10-091, pg. 43-48). The antidegradation policy is guided by chapter 90.48 RCW, Water Pollution Control Act, chapter 90.54 RCW, Water Resources Act of 1971, and 40 C.F.R. 131.12. (2) The purpose of the antidegradation policy is to:

(a) Restore and maintain the highest possible quality of the surface waters of Washington;

(b) Describe situations under which water quality may be lowered from its current condition;

(c) Apply to human activities that are likely to have an impact on the water quality of a surface water;

(d) Ensure that all human activities that are likely to contribute to a lowering of water quality, at a minimum, apply all known, available, and reasonable methods of prevention, control, and treatment (AKART); and

(e) Apply three levels of protection for surface waters of the state, as generally described below:

> (i) Tier I is used to ensure existing and designated uses are maintained and protected and applies to all waters and all sources of pollution.
>
> (ii) Tier II is used to ensure that waters of a higher quality than the criteria assigned in this chapter are not degraded unless such lowering of water quality is necessary and in the overriding public interest. Tier II applies only to a specific list of polluting activities.
>
> (iii) Tier III is used to prevent the degradation of waters formally listed in this chapter as "outstanding resource waters," and applies to all sources of pollution.

Only Tier 1 is relevant to surface waters within the TMDL reach. The purpose of this TMDL is to bring surface waters back into compliance, i.e., meeting Tier 1. None of the actions proposed in this TMDL are expected to further degrade surface waters within the TMDL area or downstream uses (explained in more detail in Appendix A).

Targets

This TMDL sets soluble reactive phosphorous (SRP) allocations in order to limit periphyton growth and meet the numeric water quality criteria for pH in the White River. The TMDL analysis and historical investigations suggest phosphorous is the pollutant of concern that is causing pH exceedances in the project area. Periphyton need sunlight and a balance of nutrients (including carbon, nitrogen, and phosphorus) in order to grow. If one of these nutrients is in short supply, relative to the others, it can limit or stop growth, this is referred to as the limiting nutrient. Phosphorous is generally considered to be the most common limiting nutrient in freshwater ecosystems. This TMDL is designed to limit periphyton growth by limiting phosphorus.

Periphyton growth is linked to high pH during the day, because the algae consume carbon from the water during growth. This carbon largely comes from dissolved carbon dioxide (CO_2) in the water and is replenished constantly by the air as it mixes with water. Excessive growth can cause this dissolved CO_2 to be consumed at a faster rate than the air can naturally replenish it. The removal of dissolved CO_2 from the water increases the pH, because when CO_2 dissolves in water it creates more hydrogen ions (H^+) and bicarbonate. So less dissolved CO_2 leads to fewer H^+ ions which leads to higher pH. The reverse of this atmospheric carbon process is what leads to ocean acidification, where higher concentrations of CO_2 in our atmosphere lead to more dissolved CO_2 in the water. This leads to more H^+ ions and bicarbonate, which in turn lowers pH in the ocean.

A more detailed discussion of the relationship between SRP loading, periphyton growth, and pH can be found in Appendix A (Background), Appendix F (2012 Study Results), Appendix I (Model Documentation), and Appendix J (Historic data).

TMDL Allocations

TMDL formula

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 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 future growth allocation for future pollutant sources can also be included in the load or wasteload allocations.

The loading capacity for the receiving water is calculated by summing the waste load allocations (i.e., the allocations to point sources), the load allocations (i.e., the allocations to nonpoint sources), and a margin of safety. The loading capacity is often described in units of pounds per day. The TMDL must be equal to or less than the loading capacity. The short-hand formula that describes the TMDL is given by:

$$\mathbf{LC = \sum WLA + \sum LA + MOS.}$$

where "∑" stands for "summation." This formula, in words, states that the loading capacity (LC) equals the sum of the wasteload allocations (WLA) plus the sum of the load allocations (LA) plus a margin of safety (MOS).

Loading capacity

The TMDL loading capacity is shown in Table 5. The basis for the loading capacity is described in Appendix D and E. Appendix D also describes how seasonal variation and critical conditions were incorporated into the modeling and TMDL calculations. The loading capacity applies when flows are less than 2,000 cfs, and only during May – October. Further explanation of the flow tiers is provided below in the "Wasteload Allocations and Muckleshoot Indian Tribe Reserve" Section.

This TMDL allocates the loading capacity among a variety of sources including diffuse (nonpoint) sources and discrete, state or EPA permitted (point) sources, with consideration of the margin of safety and future growth. Ecology calculated the loading capacity for the entire TMDL reach, from river mile 3.6 upstream to Mud Mountain Dam. The Muckleshoot Indian Tribe has reservation land that intersects the study area and has jurisdiction over the Lower

White River from river mile 15.5 to 8.9 (Figure 3). Because Ecology's authority to develop TMDLs and assign loads extends only to waters within its jurisdiction (i.e., state waters), this TMDL ensures that the overall loading capacity will be met by making certain assumptions about loading at the upstream and downstream extent of reservation boundaries. Those boundary assumptions allow for loading to reservation waters, referred to as the 'MIT reservation capacity.' Ecology worked with EPA and the Muckleshoot Indian Tribe to develop the boundary assumptions and identify the loading capacity for reservation waters. The MIT reservation capacity accounts for growth that may occur on the reservation in the next 20 years and could be used for future permitted sources such as municipal, industrial, aquaculture, or other potential discharges related to the Muckleshoot Indian Tribe within the TMDL reach.

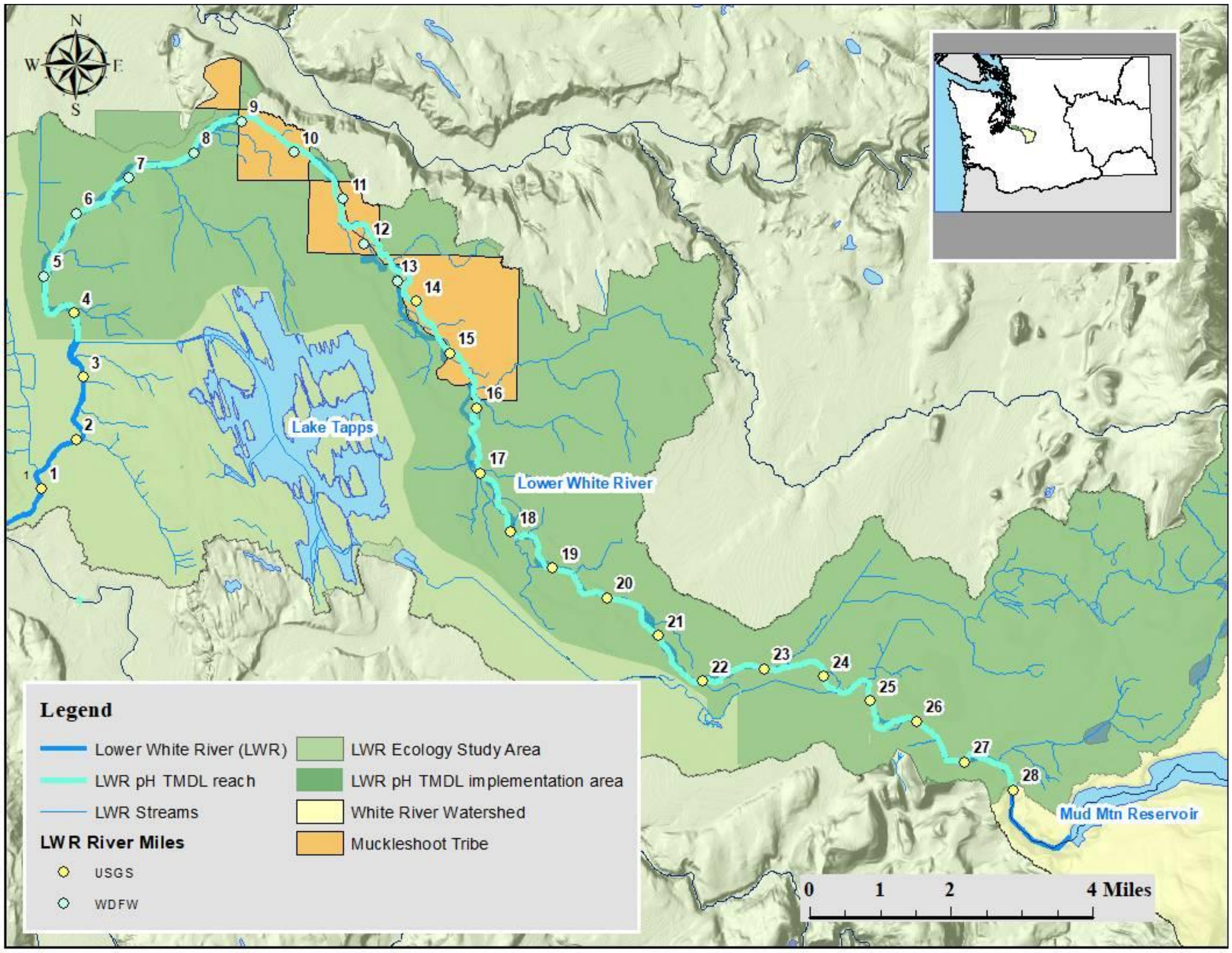

Figure 3. Muckleshoot Indian Tribe Reservation in the White River watershed

Together, this TMDL's allocations and the MIT reservation capacity meet the loading capacity for the river and, when implemented, will result in the attainment of water quality standards. The TMDL loads that become effective upon EPA approval include load and WLAs, both upstream of the reservation and downstream of the reservation. EPA's approval of the TMDL would include the understanding that the MIT reservation capacity serves to protect the river and keep it from exceeding its loading capacity. More specifically, the TMDL is developed based on the assumption that the MIT reservation capacity will not be used by any sources not discharging to tribal waters (except for the White River Hatchery, which is on tribal trust land but discharges to state waters and any future facilities on trust land that discharge to state waters). MIT and EPA will manage access to the MIT reservation capacity in order to secure and preserve the loading capacity set aside for tribal waters.

Table 5. Lower White River pH TMDL reach (RM 3.6 to 28) Loading Capacity

Low Flow Tier (< 900 cfs) SRP load (lbs/day)	Medium Flow Tier 900 – 2000 cfs) SRP load (lbs /day)	Critical Condition Period
10.05	20.69	May 1st – October 31st

Loading from upstream of RM28 was not included as part of the TMDL loading capacity, because it is not within the boundary addressed by the TMDL analysis. Any loading from upstream of this boundary likely represents phosphorus loads derived primarily from glacial melt and large areas of relatively un-impacted public forest and national park. These upstream loads may include some phosphorus from anthropogenic activities, but this impact has not been quantified and there are relatively few identifiable sources.

Wasteload Allocations and Muckleshoot Indian Tribe Reservation Capacity

WLAs will be given to municipal wastewater treatment plants and other facilities regulated under Ecology's NPDES program, including WWTPs, the White River Hatchery, one industrial facility, cities, and other permittees with stormwater permits. Specific permit names and numbers are included in Tables 6-14. The municipal WWTPs and the industrial stormwater permittee operate under individual permits issued by Ecology.

The White River Hatchery is covered under EPA's NPDES General Permit for Federal Aquaculture Facilities and Aquaculture Facilities Located in Indian Country within the boundaries of the State of Washington (EPA's NPDES Aquaculture GP, Permit No. WAG130000). This hatchery expects to increase production in the coming years, at which point it may access the MIT reservation capacity for phosphorus to cover the increased production.

Ecology also issues several different types of general permits relating to stormwater. These include the municipal stormwater permits under Phase I and Phase II, as well as the Washington Department of Transportation (WSDOT) municipal stormwater permit. Other stormwater general permits included in this TMDL are the construction, industrial, and sand and gravel permits. However, since construction and sand and gravel permittees should not discharge when it is not raining, they are assigned WLAs of zero during non-runoff conditions.

Ecology has chosen to assign WLAs based on flow tiers (measured at USGS gage 12100490

WHITE RIVER AT R STREET NEAR AUBURN, WA) as follows:

Tier 1 High Flow: daily average White River flow exceeds 2,000 cfs

Tier 2 Medium Flow: daily average White River flow is between 900 cfs and 2,000 cfs

Tier 3 Low Flow: daily average White River flow is less than 900 cfs

Higher flows accommodate larger loads and larger WLAs. Tier 1 flows are high enough that phosphorous loading has insignificant impacts on pH, hence no WLAs are assigned for this flow tier. Only the loadings associated with the medium flow tier shall apply in the months of May and June, even if the flow is less than 900 cfs. Any river flows below 900 cfs in these months would be below the historical 7Q10 low flow (950 cfs) for these months. Therefore, when river flow is less than 900 cfs in May and June, the medium flow SRP load will apply.

Load capacity and the associated TMDL analysis for the low flow tier are based on a more sensitive condition (very low flows, low turbidity, and increased algal productivity) at a different time of year (late summer/early fall); therefore, low flow SRP allocations are not appropriate for the spring condition. Medium flow capacity is based on conditions more representative of these spring months and a critical flow condition for this time period (950 cfs); more extreme spring low flows (<900 cfs) are not evaluated as part of the loading capacity for these conditions, but pH impacts are mitigated by meeting the medium flow SRP loads.

Permits should include an allowable season-averaged load for Tier 2 and Tier 3. At Tier 1 flows, permittees are expected to continue discharging at existing permit limits and/or implement existing best management practices (BMPs). WLAs apply only during the critical period (May 1st – October 31st), not year-round. Outside the critical period, permittees are expected to continue to meet current permit limits and follow existing permit requirements. TMDL analysis (Appendix E) shows that stormwater sources are only likely to contribute to pH exceedances during non-runoff conditions. Therefore, stormwater WLAs are further narrowly defined as only applying during these non-runoff conditions (defined below). As above, stormwater discharges during runoff conditions are allowed, consistent with exiting permit conditions.

Any future point sources, or growth of an existing point source, accessing the MIT reservation capacity would discharge to MIT waters instead of state waters (with the exception of the White River Hatchery and potentially another future facility on trust land discharging to state waters). Therefore, they are not given a state issued WLA. Any future point source accessing the MIT reservation capacity for phosphorus would be regulated by an EPA-issued permit consistent with the TMDL's loading capacity.

The method for calculating the MIT reservation capacity was to estimate loadings associated with three sub-components – future growth, hatcheries, and stormwater. These are described individually in the following sub-sections. However, these loads do not reflect specific facility plans and they do not limit MIT from using the reservation capacity for other purposes between RM 15.5 and 8.9, as long as the overall load is not exceeded. The MIT reservation capacity may also be transferred to the White River Hatchery WLA; however, additional water quality analysis would need to be conducted by EPA and MIT, in coordination with Ecology, to demonstrate that the pH water quality standards would still be met along the TMDL reach and the loading capacity would not be exceeded. In the first two years of TMDL implementation, MIT and EPA, in coordination with Ecology, will set up a management system for tracking use of the reservation capacity.

The text accompanying the WLAs and MIT reservation capacity within the tables below should be incorporated in facilities' respective permits. This clarifies TMDL requirements and simplifies permit writing. While this TMDL does not require the text be transferred to permits verbatim, future permit language must be "consistent with the assumptions and requirements of [these] wasteload allocation[s]" 40 CFR 122.44(d)(1)(vii). In addition to the TMDL requirements, the permit writer has the discretion to add any extra measures to the permit they deem to be appropriate.

Municipal Wastewater Treatment Plant WLAs

Wasteload allocations are shown in Table 6. No WLAs are assigned for either facility when White River flows are 2000 cfs or greater as pH standards are not violated and SRP impact on pH is negligible during high flow conditions. When the flow is 2000 cfs or greater, the facilities are allowed to discharge at existing permit limits with no additional requirements. Permit managers and facility managers are advised to review Appendix E for recommendations on implementing the WLAs. The WLAs for the Enumclaw and Buckley wastewater treatment plants allow for future population growth and economic development. The WWTPs are expected to achieve compliance with the WLAs and associated permit limits within 10 years of TMDL approval. Permittees are encouraged to begin work towards WLA compliance in advance of the deadline. Monitoring to evaluate performance and the achievement of performance benchmarks will be required during this time. Permittees must demonstrate optimization of enhanced biological phosphorus removal (EBPR) and chemical polishing within the first two years, followed by two years of optimized performance data. If optimized performance is not meeting the seasonal limits at the end of the first five years, the WWTPs will have the second five years to implement additional treatment or other improvements. Even where permittees are discharging to reaches that aren't impaired, load reductions, WLAs and associated permit limits are still required to protect downstream water quality as TMDL analysis shows.

Permittee Name: Enumclaw STP (WA0020575), Buckley STP (WA0023361)

Permit Type: Municipal NPDES Individual Permit

Water body Names: White River

Listing ID of Receiving Water: No impaired waters None for pH at facility discharge locations. Allocations to protect downstream impairments (see Table 1).

Table 6. Enumclaw and Buckley WWTP WLAs

Permittee	WLA	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
Enumclaw WWTP	0.62	lbs/ day	SRP	< 900 cfs: July 1- October 31	see footnote*
Buckley WWTP	0.36	lbs/ day	SRP	< 900 cfs: July 1- October 31	see footnote*
Enumclaw WWTP	1.5	lbs/ day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
Buckley WWTP	0.87	lbs/ day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*

*WLA applies during entire critical period

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

- Daily average river flows must be obtained for the White River at USGS gage 12100490 WHITE RIVER AT R STREET NEAR AUBURN, WA.
- SRP loads for a given day will be categorized in a high, medium, or low flow tier based on the daily average flow.
- SRP WLAs will be expressed as seasonal limits in facilities' respective permits. In November of each year, the arithmetic mean SRP load must be calculated for each flow tier based on assigned classification (described above) for all SRP samples between May 1st and October 31st.

Muckleshoot Indian Tribe future growth reserve

The Muckleshoot Indian Tribe future growth reserve is shown in Table 7. Part of the MIT reservation capacity is established based on an example of a WWTP. This was done to allow for MIT's future growth and economic development that may occur on the reservation in addition to the White River Hatchery development and/or expansion (discussed further in the next section). The TMDL's loading capacity will be met if future permits follow the assumptions formed to calculate the MIT future growth reserve.

The MIT future growth reserve is calculated using the same SRP concentrations and assumptions about flows used for calculating the WLAs for the WWTPs of the Cities of Enumclaw and Buckley. The MIT future growth reserve does not reflect specific facility plans or limit in any way the future type of use of the reserve. It may be used for point sources other than a WWTP, based on MIT priorities. These other point sources may include the White River Hatchery expansion and/or the planned Coal Creek Springs Fish Facility.

The MIT future growth reserve includes an allowable season-averaged load for Tier 2 and Tier 3 flow conditions. Relevant best management practices will be followed for discharges associated with the MIT future growth reserve under Tier 1 flow conditions. Loading limits associated with the MIT future growth reserve apply only during the critical period (May 1st – October 31st). Relevant BMPs will be followed for discharges associated with the MIT future growth reserve that occur outside the critical period.

Table 7. MIT Future growth reserve

Permittee	Reserve	Unit	Pollutant	Flow Tier and Period for Reserve	Additional Information
MIT Future Growth Reserve	0.53	lbs/ day	SRP	< 900 cfs: July 1- October 31	Reserve limit applies during entire critical period
MIT Future Growth Reserve	1.31	lbs/ day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	Reserve limit applies during entire critical period

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

- Daily average river flows must be obtained for the White River at USGS gage 12100490 WHITE RIVER AT R STREET NEAR AUBURN, WA.
- SRP loads for a given day will be categorized in a high, medium, or low flow tier based on the daily average flow.
- SRP loads will be expressed as seasonal limits. In November of each year, the arithmetic mean SRP load must be calculated for each flow tier based on assigned classification (described above) for all SRP samples between May 1st and October 31st.

White River Hatchery WLA and Coal Creek Springs Fish Facility Reserve

The White River Hatchery WLA and Coal Creek Springs Fish Facility reserve are shown in Table 8. The White River Hatchery is located on the right bank of the White River at River Mile 24.3. The only fish hatchery in operation on the White River, it is owned and operated by the Muckleshoot Indian Tribe and has been in operation since 1989. Currently, the White River Hatchery produces juvenile White River spring Chinook (Oncorhynchus tshawytscha) for release from the hatchery and from several upriver sites located in the upper watershed. Puget Sound Chinook Salmon, including White River spring Chinook, were listed as threatened under the Endangered Species Act (ESA) in March 1999 (64 FR 14308) and reaffirmed as threatened in May 2016 (81 FR 33468). Both the naturally-spawning and the hatchery White River spring Chinook are included in the ESA listing. The Coal Creek Springs Fish Facility is planned for location within the MIT Reservation to provide additional rearing capacity to supplement fish production for the White River Hatchery.

Estimates of phosphorus loadings were developed for future fish production scenarios at the existing White River Hatchery and for the planned Coal Creek Springs Fish Facility. The estimates were derived using available data and information to evaluate different fish production scenarios and to calculate phosphorous discharge loadings and concentrations on a weekly basis (see appendix D for additional detail). A scenario based on future plans for increased fish production and industry standard phosphorus removal practices was chosen as the basis for calculating these estimates of future hatchery phosphorus loadings.

This TMDL assigns a WLA to the existing White River Hatchery for future estimated loads because this hatchery discharges to state waters. Since the planned Coal Creek Springs Fish Facility would discharge to MIT waters, this TMDL incorporates a reserve load for this facility as part of the MIT reservation capacity. Permit limits for both the White River Hatchery and the Coal Creek Springs Fish Facility will be net loads. The net loads represent how much SRP can be added to the influent of the facility and not how much total SRP is in the effluent from the facility. For state waters, intake credits are allowable under WAC 173-201A-460. The TMDL development workgroup determined that the White River Hatchery meets these criteria as part of the TMDL analysis.

The WLA for the White River Hatchery and estimated loads for the planned Coal Creek Springs Fish Facility were determined with estimated future fish production levels for each facility. With uncertainty on exact fish production levels and goals over the next 20 years, the permits for each facility may need to allow for flexibility. For example, loads may be moved between the Coal Creek Springs Fish Facility and the White River Hatchery facilities. Loads from the overall MIT reservation capacity may also be used for the Coal Creek Springs Fish Facility and the White River Hatchery facilities. Future implementation of these transfers would include analyses by EPA and MIT, in coordination with Ecology, to ensure the TMDL loading capacity is met and pH water quality standards are met along the TMDL reach.

Loading limits associated with the White River Hatchery and Coal Creek Springs Fish Facility apply only during the critical period (May 1st - October 31st). All loads from the White River Hatchery and Coal Creek Springs Fish Facility that occur under Tier 3 flow conditions during May and June will be counted as Tier 2 loads, and not as Tier 3 loads. General NPDES permit limits for other pollutants, as well as aquaculture specific BMPs, will still apply to discharges associated with the White River Hatchery and Coal Creek Springs Fish Facility that occur outside the critical period.

Table 8. White River Hatchery Wasteload Allocations and Coal Creek Fish Facility Reserve

Permittee	WLA or Reserve	Unit	Pollutant	Flow Tier and Period for WLA or Reserve	Additional Information
MIT White River Fish Hatchery WLA (WAG130000)	0.94	Net lbs / day	SRP	< 900 cfs: July 1- October 31	see footnote*
MIT Coal Creek Springs Fish Facility Reserve	0.86	Net lbs / day	SRP	< 900 cfs: July 1- October 31	see footnote*
MIT White River Fish Hatchery WLA (WAG130000)	2.43	Net lbs / day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
MIT Coal Creek Springs Fish Facility Reserve	0.99	Net lbs / day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*

* WLA or reserve applies during entire critical period

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

- Daily average river flows must be obtained for the White River at USGS gage 12100490 WHITE RIVER AT R STREET NEAR AUBURN, WA.
- SRP loads for a given day will be categorized in a high, medium, or low flow tier based on the daily average flow.
- SRP loads will be expressed as seasonal limits in facilities' respective permits. In November of each year, the arithmetic mean SRP load must be calculated for each flow tier based on assigned classification (described above) for all SRP samples between May 1st and October 31st.
- Only the loadings associated with the medium flow tier shall apply in the months of May and June, even if the flow is less than 900 cfs. Any river flows below 900 cfs in these months would be below the historical 7Q10 low flow (950 cfs) for these months. When river flow is less than 2,000 cfs in May and June, hatchery SRP loads will only be assigned to the medium flow tier.
- Permits for both the White River Hatchery and the Coal Creek Springs (CCS) Fish Facility will be net loads. The loads represent how much SRP can be added to the influent concentration of the facility and not how much total SRP is in the effluent of the facility. The influent may be derived from both groundwater and surface water sources.

Stormwater WLAs and Muckleshoot Indian Tribe Stormwater Reserve

TMDL analysis shows that stormwater likely does not contribute to pH excursions during runoff conditions and is not a significant loading of phosphorous to the Lower White River during non-runoff conditions for the May 1st – October 31st critical period (see Appendix E for detail). Non-runoff conditions are defined as no rain locally, <0.2” rainfall in past 48 hours. Consequently, stormwater dischargers are not a focus of this TMDL, and permittees are assigned WLAs that represent a relatively small portion of the total Loading Capacity. However, the White River is sensitive to even small amounts of phosphorus loading during low flow, non-runoff conditions. For this reason, it is important that all permitted entities within the allocation area verify either no discharge or concentrations below the target, on an ongoing basis.

Because excursions of the upper pH range only occur during low flow, non-runoff conditions when stormwater permittees aren’t typically discharging, it was not deemed appropriate to assign stormwater permittees allocations for the entire critical period. However, modeling suggests that it’s possible that stormwater discharges during non-runoff conditions could cause pH exceedances if soluble reactive phosphorus (SRP) concentrations are high. During the 2012 study, Ecology did investigate whether it is possible that stormwater permittees within the study area may discharge during non-runoff conditions.

Monitoring surveys for this TMDL found one municipal stormwater permittee (Auburn) had a stormwater pump station that discharges year-round and was observed to occasionally discharge during dry periods. TMDL monitoring did not find other stormwater discharges during non-runoff conditions in 2012. However, this survey was conducted during only one year and did not include screening of permitted outfalls to the tributaries of the White River. It is possible that other discharges have occurred during non-runoff conditions in other years, or could in future years, either from outfalls directly to the river, or from the unscreened tributary outfalls. The Auburn stormwater pump station discharge demonstrates they can discharge water (storm and ground) during non-runoff conditions, particularly in low-gradient, high-impervious areas where natural drainage may be impeded. For these reasons it was deemed necessary to assign all stormwater permittees allocations for the non-runoff period. Since not assigning an allocation in a TMDL would be treated as an allocation of zero (making any discharge a violation), assigning allocations allows permittees to discharge in the future, even if such an event is unlikely.

Allocations for each flow tier are expressed as the seasonal average for the respective flow tier, in the same manner as for the WWTPs. Limits are expressed as the seasonal average daily load in pounds of SRP/day. For example, if samples were collected on 5 days over the course of the dry season, 5 daily loads would be calculated and then the arithmetic mean of the daily loads would be compared to the seasonal average WLAs. It is important to note that these draft allocations represent loads for the “typical” non-runoff daily conditions that occur in the dry season, not the loading from one or more runoff events. The stormwater WLAs are not annual, and they only apply during non-runoff conditions (<0.2” rainfall in past 48 hours) within specific WLA period timeframes which are defined in table below all of which are within the TMDL’s May 1st – October 31st critical period.

The below WLAs apply to all permittees discharging between RM 3.6 (confluence with Lake Tapps Tailrace) and RM 28 below Mud Mountain Dam (including tributaries and all contributing watershed areas).

TMDL monitoring and analysis shows that the reach downstream of RM 3.6, (confluence with Lake Tapps Tailrace) is not exceeding standards. Permittees discharging to this reach are not contributing to a violation of water quality standards addressed by this TMDL. Therefore, it is deemed unnecessary to assign these permittees WLAs and they are not shown in the allocation tables that follow. If a permittee is not shown below, they are not assigned an allocation. They are expected to comply with their existing permits, with no additional requirements assigned. This TMDL expects that the following WLAs, along with the accompanying text, are implementable using existing regulatory authorities provided in permits. The language in the tables that follow is intended to clarify for state permittees and state permit managers what is needed to achieve compliance with the TMDL. It is not meant to be permit language, nor does it imply permit manager's normal regulatory jurisdictions are superseded. Permit managers are still responsible for addressing TMDL needs by developing permit language and permit limits as per usual.

Municipal Stormwater WLA

Municipal stormwater WLAs are shown in Table 9.

Permittee Name: WSDOT (WAR043000), Pierce County (WAR044002), King County (WAR044501), Cities of Auburn (WAR045502), Buckley (WAR045003), Enumclaw (WAR045514), Pacific (WAR045535), Sumner (WAR045019), and Algona (WAR045500)

Permit Type: WSDOT Municipal SW GP, Municipal SW Phase I Western WA GP, Municipal SW Phase II Western WA GP

Water body Names: White River, multiple locations
Listing IDs of Receiving Waters: 7524, 7525, 7526

Table 9. Municipal Stormwater WLAs

Permittee	WLA	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
WSDOT	0.010	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
King County	0.035	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
Pierce County	0.035	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
City of Auburn	0.035	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
City of Buckley	0.035	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
City of Enumclaw	0.035	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
City of Pacific	0.010	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
City of Sumner	0.010	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
City of Algona	0.010	Lbs/day	SRP	< 900 cfs: July 1- October 31	see footnote*
WSDOT	0.105	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
King County	0.368	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
Pierce County	0.368	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
City of Auburn	0.368	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
City of Buckley	0.368	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
City of Enumclaw	0.368	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
City of Pacific	0.105	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
City of Sumner	0.105	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*
City of Algona	0.105	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	see footnote*

* WLA applies during entire critical period
SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

1. The Municipal Stormwater Permits require Permittees to implement a Stormwater Management Program (SWMP) that employs different management programs and techniques to prevent and reduce pollutants from entering the stormwater system. In particular, the Illicit Discharge Detection and Elimination (IDDE), MS4 mapping, source control, and controlling runoff programs will need to focus on how to prevent and reduce phosphorus to the Lower White River which is impaired.
2. The following program enhancements are needed in order to meet the TMDL WLA for direct discharges to the Lower White River:
    a. For at least one dry season within a permit cycle, screen piped outfalls once a month, from May 1st – October 31st, for the presence of a discharge. All outfalls may be screened within the same year or divided into groups and rotated through during multiple years.
        i. Screen every piped outfall discharging to the Lower White River, and its primary tributaries, within the project area: Boise Creek, Second Creek, Pussyfoot Creek, Bowman Creek, and Government Canal. Outfalls that discharge to other watercourses not listed above are not included in the screening program. The screening program is limited to "piped outfalls" which means only outfalls that are made of pipe material (e.g., corrugated metal, concrete, etc.). It does not include open pervious conveyances, such as ditches.
        ii. Actively controlled stormwater discharges (e.g., pump stations, batch treatment systems) are included in the screening program, but they have slightly different sampling requirements as described in (2)(b)(iv).
        iii. If outfall screening finds no discharge during the first permit cycle, reduce inspections to once in May and again once in October or as close to these months as practicable, preferably during low flow tier conditions (i.e., <900 cfs), for future permit cycles.
    b. If a discharge is present and estimated to be more than 2.24 gallons per minute, sample for soluble reactive phosphorus (SRP).
        i. Sampling may be incorporated in permittees IDDE and source tracing programs.
        ii. Sampling is restricted to May 1st - October 31st when there is little to no rain locally (<0.2" rainfall in past 48 hours).
        iii. Sampling is restricted to when the daily average flow in the White River is lower than 2000 cfs (USGS gage 12100490 at R Street near Auburn).
        iv. For all actively controlled stormwater discharges (e.g., pump stations, batch treatment systems), monthly sample events must be scheduled for dates/times when discharge is known to occur within the May 1 – October 31 period. If monthly sampling meets SRP requirements (any one of the conditions in section 4 a-d) in the one season sampled during first permit

        cycle, sampling may be reduced to once in May and once in October or as close to these months as practicable, preferably during low flow tier conditions (i.e., <900 cfs), for future permit cycles.
    c. Mapping MS4 tributary conveyances to all piped outfalls to the Lower White River and specific tributaries named in the WLA (2.a.i.).
    d. Controlling runoff from new and redevelopment: Phosphorus Treatment BMPs as described in Ecology's stormwater management manual and highway runoff manual are needed for new development or redevelopment projects within the watershed of the TMDL that trigger Minimum Requirement #6 and #5 respectively.
    e. Annual reporting to describe the status of implementation and the actions taken to address TMDL parameters.

3. SRP concentrations during the Lower White River critical period should not exceed the values in (3)(a) and (b) below. Analytical methods should follow approved methods (as listed in 40 CFR Section 136.3) for Ortho-phosphate (parameter #44 in Table 1B). Standard Method 4500-P G-2011 is recommended for obtaining reporting limits needed for (3)(a) and (b) below. For direct discharges, these must be attained by the end of the 10-year TMDL implementation period, post TMDL approval:
    a. 7.5ug/L of SRP (when the daily average White River flow is less than 900 cfs at USGS gage 12100490) or,
    b. 79 ug/L of SRP (when the daily average river flow is between 900 cfs and 2000 cfs at USGS gage 12100490) or,
    c. The load of SRP is less than the WLA.

4. Permittees are meeting TMDL requirements, and no additional source tracing is required, if outfall screening and sampling results find any one of the following:
    a. There is no discharge or, where it is not feasible to measure flow, there is no visible or measurable surface velocity (i.e., stagnant water).
    b. The flow of any discharge is less than 0.005 cfs (2.24 gallons per minute).
    c. The flow of any discharge is less than 0.9 cfs (400 gpm) and the concentration of discharge is less than 7.5ug/L of SRP (when the daily average White River flow is less than 900 cfs at USGS gage 12100490) or 79 ug/L of SRP (when the daily average river flow is between 900 cfs and 2000 cfs at USGS gage 12100490) during the critical period.
    d. The flow of any discharge is greater than 0.9 cfs (400 gpm) and the load of SRP is less than the WLAs in pounds per day as specified above. A load should only be calculated if none of the above (4 a through c) conditions apply.
5. Outfall screening and sampling may be discontinued under any one of the following:
    a. This optional exemption requires additional screening up front. Permittees must screen every outfall described in section 2a every month within the dry season, for

two consecutive years in a row, and both years show outfalls meeting requirements in section 4.

b. Outfalls are meeting requirements in section 4 for four consecutive permit cycles.

Muckleshoot Tribe Stormwater Reserve

A stormwater reserve load is established for the Muckleshoot Indian Tribe within MIT waters (Table 10). The MIT stormwater reserve is established for discharge of stormwater during non-runoff conditions. The MIT stormwater reserve is equal to the load allocated to the major municipal NPDES stormwater permittees within the study area (i.e., King and Pierce Counties and the Cities of Auburn, Buckley, and Enumclaw). The MIT stormwater reserve was calculated using assumptions and numeric factors consistent with other stormwater point loads within the TMDL reach. Appendix E includes further description of these calculations. The loads associated with the MIT stormwater reserve only apply during non-runoff conditions within the May 1st – October 31st critical period.

Table 10. MIT stormwater reserve

	Reserve	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
MIT Stormwater Reserve	0.035	Lbs/day	SRP	< 900 cfs: July 1- October 31	Reserve load applies only during non-runoff conditions
MIT Stormwater Reserve	0.368	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	Reserve load applies only during non-runoff conditions

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

1. The following program enhancements are needed in order to meet the TMDL WLA for direct discharges to the Lower White River:
    a. For at least one dry season within a permit cycle, screen piped outfalls once a month, from May 1st – October 31st, for the presence of a discharge. All outfalls may be screened within the same year or divided into groups and rotated through during multiple years.
        i. Screen every piped outfall discharging to the Lower White River, and its primary tributaries, within the MIT project area: Second Creek and Pussyfoot Creek. Outfalls that discharge to other watercourses not listed above are not included in the screening program. For the purposes of the screening program, "piped outfalls" means only outfalls that are made of pipe material (e.g., corrugated metal, concrete, etc.) and does not include open pervious conveyances, such as ditches.
        ii. Actively controlled stormwater discharges (e.g., pump stations, batch treatment systems), are included in the screening program, but have slightly different sampling requirements as described in (2)(b)(iii).

        iii. If outfall screening finds no discharge during the first permit cycle, reduce inspections to once in May and again once in October or as close to these months as practicable, preferably during low flow tier conditions (i.e., <900 cfs), for future permit cycles.
        iv. Stormwater retention facilities and other similar facilities that do not discharge during non-runoff periods are exempt from the screening requirement.
    b. If a discharge is present and estimated to be more than 2.24 gallons per minute, sample for soluble reactive phosphorus (SRP).
        i. Sampling is restricted to May 1st - October 31st when there is little to no rain locally (<0.2" rainfall in past 48 hours), and
        ii. Sampling is restricted to when the daily average flow in the White River is lower than 2000 cfs (USGS gage 12100490 at R Street near Auburn).
        iii. For all actively controlled stormwater discharges (e.g., pump stations, batch treatment systems), monthly sample events must be scheduled for dates/times when discharge is known to occur within the May 1 – October 31 period. If monthly sampling meets SRP requirements (any one of the conditions in section 3 a-d) in the one season sampled during first permit cycle, sampling may be reduced to once in May and once in October or as close to these months as practicable, preferably during low flow tier conditions (i.e., <900 cfs), for future permit cycles.
    c. Controlling runoff from new and redevelopment: Phosphorus Treatment BMPs are needed for new development or redevelopment projects within the watershed of the TMDL.

2. Soluble reactive phosphorus concentrations during the Lower White River critical period should not exceed the following. Analytical methods should follow approved methods (as listed in federal register 40cfr part 136.3 Table 1B) for Ortho-phosphate (parameter #44 in Table 1B). Standard Methods SM4500-P G is recommended for obtaining reporting limits needed for (2)(a) below. For direct discharges, these must be attained by the end of the 10-year TMDL implementation period, post TMDL approval:

    a. 7.5ug/L of SRP (when the daily average White River flow is less than 900 cfs at USGS gage 12100490) or,
    b. 79 ug/L of SRP (when the daily average river flow is between 900 cfs and 2000 cfs at USGS gage 12100490) or,
    c. The load of SRP is less than the wasteload allocation.

3. TMDL requirements are met, and no additional source tracing is required if outfall screening and sampling results find any one of the following:

    a. There is no discharge or, where it is not feasible to measure flow, there is no visible or measurable surface velocity (i.e., stagnant water).
    b. The flow of any discharge is less than 0.005 cfs (2.24 gallons per minute).

    c. The flow of any discharge is less than 0.9 cfs (400 gpm) and the concentration of discharge is less than 7.5ug/L of SRP (when the daily average White River flow is less than 900 cfs at USGS gage 12100490) or 79 ug/L of SRP (when the daily average river flow is between 900 cfs and 2000 cfs at USGS gage 12100490) during the critical period.
    d. The flow of any discharge is greater than 0.9 cfs (400 gpm) and the load of SRP is less than the wasteload allocations in pounds per day as specified above. A load should only be calculated if none of the above (3 a through c) conditions apply.
4. Outfall screening and sampling may be discontinued under any one of the following:
    a. This optional exemption requires additional screening up front. Every outfall described in section 2a must be screened every month within the dry season, for two consecutive years in a row, and both years show outfalls meeting requirements in section 4.
    b. Outfalls are meeting requirements in section 4 for four consecutive permit cycles.

Construction stormwater WLA

Construction stormwater WLAs are shown in Table 11. Construction stormwater permittees should not be discharging stormwater during non-runoff conditions. Therefore, they are assigned an SRP wasteload allocation of 0, (i.e. a no-discharge allocation). This allocation only applies during non-runoff conditions, meaning during runoff conditions (i.e., when there is greater than or equal to 0.2" of rainfall in past 48 hours) permittees may continue to discharge stormwater in accordance with their current permits. The SRP wasteload allocation of 0 applies to all current or future construction stormwater permittees that discharge within the TMDL implementation area (Figure 1) (from RM 3.6 to RM 28). Permittees that meet the requirements detailed below are in compliance with the TMDL (i.e., not responsible) even if other permittees do not meet the requirements of the TMDL. However, in the event that exceedances are found within the construction site due to exceedances by other permittees, all parties are encouraged to work together to resolve the issue. Construction sites do occasionally need to remove water off-site that isn't process wastewater or stormwater. For example, groundwater intrusion and pooling are fairly common in areas with a high groundwater table. Such discharges, as defined in the Construction Stormwater General Permit (S1, C3 of the general permit, effective May 5th, 2017) are permissible under this WLA, even during non-runoff periods. However, SRP concentrations may not exceed the limits established in Table 11 below. This concentration is the groundwater input assigned in the TMDL model, based on the 25th percentile of measured groundwater data collected during the 2012 study. See Appendix H for further information.

Permittee Name: Multiple Permittees

Permit Number: Multiple Permit Numbers

Permit Type: Construction SW GP

Water body Names: The White River, multiple locations

Listing IDs of Receiving Waters: 7524, 7525, 7526

Table 11. Construction stormwater WLAs.

	WLA	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
Wasteload Allocation - Stormwater	0	Lbs/day	SRP	< 900 cfs: July 1- October 31	WLA applies only during non-runoff conditions
Wasteload Allocation - Stormwater	0	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	WLA applies only during non-runoff conditions
Wasteload Allocation – Groundwater dewatering	0.005	Lbs/day	SRP	< 900 cfs: July 1- October 31	WLA applies only during non-runoff conditions
Wasteload Allocation – Groundwater dewatering	0.053	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	WLA applies only during non-runoff conditions

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

1. During runoff conditions in the critical period, May 1st to October 31st, permittees must meet the more restrictive turbidity limit and pH monitoring requirements under the current NPDES Construction Stormwater General Permit. See section S8 of the general permit, specifically C1, C2 and D.
2. With the exception of 1 above, permittees have no other additional TMDL requirements under any of the following conditions (i.e., they may discharge as allowed for under the Construction Stormwater GP):
    A. Daily average river flow is greater than 2000 cfs.
    B. Discharges during runoff conditions (defined as any 24-hour period with >0.2" of rainfall and the subsequent 24-hour period)
    C. Discharges between November 1st and April 30th.
3. For all other (non-runoff) events not covered by (2), the following conditions apply:
    A. No stormwater discharge is allowed.
    B. For non-stormwater discharge (as described under S1, C3 of the current Construction Stormwater General Permit):
        i. When the daily average White River flow is less than 900 cfs (at USGS gage 12100490), the discharge limit is 10.5 ug/L of SRP.
        ii. When the daily average river flow is between 900 cfs and 2000 cfs (at USGS gage 12100490), the discharge limit is 79 ug/L of SRP

Industrial Stormwater WLA

As mentioned previously, other individual and general permittees discharge to the White River within the study area, but outside of the TMDL implementation area. Those discharging outside of the TMDL implementation area have not been assigned a WLA because they're not contributing to exceedances of the State's water quality standards for pH addressed by this TMDL. If a permittee is not listed below, they are not assigned additional TMDL requirements here and should continue to follow their existing permits.

Individual Permit

There is only one individual industrial stormwater permitted facility within the project area, namely Manke Lumber. Table 12 shows the WLAs assigned to this facility.

Permittee Name: Manke Lumber Co. Superior Wood

Permit Number: WA0040339

Permit Type: Industrial NPDES Individual Permit

Water body Names: The White River

Listing ID of Receiving Water: 7526

Table 12. Manke Lumber Industrial Stormwater WLAs

	WLA	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
Wasteload Allocation	0.010	lbs/day	SRP	< 900 cfs: July 1- October 31	WLA applies only during non-runoff conditions
Wasteload Allocation	0.105	lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	WLA applies only during non-runoff conditions

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

1. Permittee has no additional requirements than what is in their existing permits under the following conditions:
    A. Daily average White River flow is greater than 2000 cfs (measured at USGS gage 12100490, White River at R Street near Auburn).
    B. Discharges during runoff conditions (defined as any 24-hour period with >0.2" of rainfall and the subsequent 24-hour period).
    C. Discharges between November 1st and April 30th.
2. For stormwater discharges with any actively controlled stormwater infrastructure (e.g., pump stations, batch treatment systems), permittees are in compliance with the TMDL if there is no discharge at the outfall from May 1st to October 31st during non-runoff conditions. If there is a discharge during a non-runoff condition from May 1st to October 31st permittees are required to sample at the outfall. This sampling must meet the concentrations under 4. Sampling is required as follows:

   A. For medium daily White River flows (900 cfs – 2000 cfs), the first batch release for the May 1st – October 31st period (i.e., not the 'first flush' of each storm event), during non-runoff conditions.
   B. At least once per week when non-runoff discharge occurs during low daily White River flow (< 900 cfs) conditions.
3. For all other (non-runoff) passive discharges (e.g., stormwater ponds) not covered by 1 or 2, permittees must inspect outfalls to determine if there is a discharge from outfalls.These inspections must occur at least once a month from May 1st to October 31st for the first permit year the requirement is implemented. Permittee is in compliance if there is no discharge from May 1st to October 31st during non-runoff conditions. If outfall inspection finds no discharge during the first permit year, permittee may reduce inspections to once in May and again once in October, or as close to these months as low flow conditions allow, for the remainder of the permit cycle. If inspection finds a non-runoff discharge, from May 1st to October 31st, permittee is required to sample the discharge at the end of pipe to demonstrate the concentration WLAs under 4 are met.
4. The concentrations for discharges described in 2 and 3 are:
   A. When the daily average White River flow is less than 900 cfs (at USGS gage 12100490), the discharge limit is 7.5ug/L of SRP.
   B. When the daily average river flow is between 900 cfs and 2000 cfs (at USGS gage 12100490), the discharge limit is 79 ug/L of SRP.
   C. Permittee is required to report results of field screening and any associated SRP sampling with their discharge monitoring reports (DMRs)

General Permit

Given the large number of general industrial stormwater permittees, it is impractical to assign each general industrial permittee separate WLAs. Instead, the WLAs apply to all current and future general industrial stormwater permittees collectively within the TMDL implementation area (RM 3.6 to RM 28 and contributing watershed area). Permittees that meet the requirements detailed below, are in compliance with the TMDL (i.e., not responsible) even if other permittees do not meet the requirements. Table 13 shows the industrial stormwater general permit WLAs.

Permittee Name: Multiple Permittees

Permit Number: Multiple Permit Numbers

Permit Type: Industrial SW GP

Water body Names: The White River, multiple locations
Listing IDs of Receiving Waters: 7524, 7525, 7526

Table 13. Industrial Stormwater General WLAs

	WLA	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
Wasteload Allocation	0.010	lbs/day	SRP	< 900 cfs: July 1- October 31	WLA applies only during non-runoff conditions
Wasteload Allocation	0.105	lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	WLA applies only during non-runoff conditions

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

1. Permittees have no additional requirements than what is in their existing permits under the following conditions:
    A. Daily average White River flow is greater than 2000 cfs (measured at USGS gage 12100490, White River at R Street near Auburn).
    B. Discharges during runoff conditions (defined as any 24-hour period with >0.2" of rainfall and the subsequent 24-hour period).
    C. Discharges between November 1st and April 30th.
2. For stormwater discharges with any actively controlled stormwater infrastructure (e.g., pump stations, batch treatment systems), permittees are in compliance if there is no discharge at the outfall from May 1st to October 31st during non-runoff conditions. If there is a discharge during a non-runoff condition from May 1st to October 31st, permittees are required to sample at the outfall. This sampling must meet the concentrations under 4. Sampling is required as follows:
    A. For medium daily White River flows (900 cfs – 2000 cfs), the first batch release for the May 1st – October 31st period (i.e., not the 'first flush' of each storm event), during non-runoff conditions.
    B. At least once per week when non-runoff discharge occurs during low daily White River flow (< 900 cfs) conditions.
3. For all other (non-runoff) passive discharges (e.g., stormwater ponds) not covered by 1 or 2, permittees must inspect outfalls to determine if there is a discharge from outfalls. These inspections must occur at least once a month from May 1st to October 31st for the first permit year the requirement is implemented. Permittees are in compliance if there is no discharge from May 1st to October 31st during non-runoff conditions. If outfall inspection finds no discharge during the first permit year, permittees may reduce inspections to once in May and again once in October, or as close to these months as low flow conditions allow, for the remainder of the permit cycle. If inspection finds a non-runoff discharge, from May 1st to October 31st, permittees are required to sample the discharge at the end of pipe to demonstrate the concentration WLAs under 4 are met.
4. The concentrations for discharges described in 2 and 3 are:

A. When the daily average White River flow is less than 900 cfs (at USGS gage 12100490), the discharge limit is 7.5ug/L of SRP.
B. When the daily average river flow is between 900 cfs and 2000 cfs (at USGS gage 12100490), the discharge limit is 79 ug/L of SRP.
C. Permittee is required to document field screening and report any associated SRP sampling with their discharge monitoring reports (DMRs).

Other Permittees

Sand and Gravel WLA

Sand and gravel operations should not be discharging stormwater during non-runoff conditions and are thus assigned a WLA of 0. Permittees may discharge during runoff conditions as allowed under their current permit. The WLAs apply to all current and future sand and gravel permittees collectively within the TMDL implementation area (RM 3.6 to RM 28 and contributing watershed area). Permittees that meet the requirements detailed below, are in compliance with the TMDL (i.e., not responsible) even if other permittees do not meet the requirements. Some permittees may discharge process water or mine dewatering water. This is permitted, so long as SRP concentrations do not exceed the limits established below (see 2 in Table 14 below). All other limits or conditions associated with this discharge described under the current Sand and Gravel permit still apply.

Permittee Name: Multiple Permittees

Permit Number: Multiple Permit Numbers

Permit Type: Sand and Gravel GP

Water body Names: The White River, multiple locations

Listing IDs of Receiving Waters: 7524, 7525, 7526

Table 14a. Sand and Gravel Stormwater WLAs.

	WLA	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
Wasteload Allocation	0	lbs/day	SRP	< 900 cfs: July 1- October 31	WLA applies only during non-runoff conditions
Wasteload Allocation	0	lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	WLA applies only during non-runoff conditions
Wasteload Allocation - Process Water	0.005	lbs/day	SRP	< 900 cfs: July 1- October 31	WLA applies only during non-runoff conditions
Wasteload Allocation - Process Water	0.053	lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	WLA applies only during non-runoff conditions

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

1. Permittees have no additional requirements than what is in their existing permits under the following conditions (i.e., they may discharge as allowed for under the Sand and Gravel Stormwater GP):
    A. Daily average river flow is greater than 2000 cfs.
    B. Discharges during runoff conditions (defined as any 24-hour period with >0.2" of rainfall and the subsequent 24-hour period).
    C. Discharges between November 1st and April 30th.
2. For all other (non-runoff) events not covered by (1), the following conditions apply:
    A. No stormwater discharge is allowed.
    B. For all non-stormwater discharge (e.g., process waste water and mine dewatering):
        i. When the daily average White River flow is less than 900 cfs (at USGS gage 12100490), the discharge limit is 10.5 ug/L of SRP.
        ii. When the daily average river flow is between 900 cfs and 2000 cfs (at USGS gage 12100490), the discharge limit is 79 ug/L of SRP.

Concentrated Animal Feeding Operations (CAFOs)

At the time of writing, there were no facilities in the Lower White River watershed covered by the CAFO General Permit. However, facilities may be covered in the future, so a wasteload allocation is provided. This TMDL assigns all CAFO permittees an SRP wasteload allocation of 0 lbs / day SRP (i.e., a no-discharge allocation) consistent with the CAFO permit. The SRP wasteload allocation of 0 applies to all future CAFO permittees that discharge within the TMDL implementation area (Figure 1) (from RM 3.6 to RM 28).

Permittee Name: None currently, but covers future facilities

Permit Number: None currently, but covers future facilities

Permit Type: CAFO GP

Water body Names: None currently, but covers future facilities

Listing IDs of Receiving Waters: None currently, but covers future facilities

Table 14b. CAFO WLAs

	WLA	Unit	Pollutant	Flow Tier and Period for WLA	Additional Information
Wasteload Allocation	0	Lbs/day	SRP	< 900 cfs: July 1- October 31	BMPs should be implemented year-round
Wasteload Allocation	0	Lbs/day	SRP	<2000 cfs: May 1 – June 30 & 900 – 2000 cfs: July 1 - October 31	BMPs should be implemented year-round

SRP = Soluble Reactive Phosphorus

Other Load Limits and Requirements:

1. The 0 lbs/day WLA means permittees are prohibited from discharging manure, litter, feed, process wastewater, other organic by-products, or water that has come into contact with manure, litter, feed, process wastewater, or other organic by-products as defined by the CAFO General Permit (currently condition S3).

2. WLAs are established from May – October. To meet the WLAs, BMPs must be implemented year-round in order to prevent winter discharges from contributing to nutrient sinks exacerbating summer exceedances. In addition, implementers are strongly encouraged to review and implement the nonpoint BMPs given in the TMDL implementation plan, especially Appendix D, when those activities are more stringent than what the CAFO permit requires.

3. Appropriate fertilizer application practices must be implemented at CAFOs. No land application of manure, litter, process wastewater, or other organic byproducts may occur after October 1 and prior to T-SUM 200[1] unless it is demonstrated to be necessary because current soil nitrogen and phosphorus plus estimated nitrogen mineralization will not provide the nutrients necessary for the double crop, winter cover crop, or perennial crop. No additional phosphorus can be applied during this time if soil phosphorus will meet crop needs.

4. Pursuant to Ecology's TMDL Implementation Plan, the following apply: At a minimum, permitted CAFOs must implement 50-foot vegetative buffers along all perennial, intermittent and ephemeral streams. A 100-foot buffer consisting of native trees and shrubs are recommended along perennial streams or intermittent and ephemeral streams with current or historical anadromous fish presence. At a minimum, permitted CAFOs must implement 35-foot buffers along artificial ditches and drainages. Native trees and shrubs are recommended; however, grass filters strips that meet Natural Resource Conservation Service standards may be used in lieu of native vegetation. Livestock must be prohibited from entering vegetative buffers.

5. CAFOs must apply manure at agronomic rates based on nutrient budgets using spring annual soil testing for nitrogen and phosphorus. CAFOs must not apply phosphorus above the amount that can be utilized by crops in a single growing season. Fertilizer application may not exceed phosphorus needs, regardless of nitrogen status.

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[1] The 'T-Sum' value is the accumulated mean daily temperatures (in ° C) above zero, starting on January 1, once the sum of those values reaches 200, TSUM 200 is reached.

Load Allocations

Load Allocations (LA) are shown in Table 15. Appendix E describes the bases for these allocations. These apply to nonpoint sources discharging to the TMDL reach (RM 3.6 to 28) during the critical period (May 1st to October 31st). Nonpoint source reductions will occur throughout the TMDL implementation area (contributing drainage area to the TMDL reach) to achieve necessary reductions at the locations where nonpoint sources discharge to the river.

Because Ecology's authority to develop TMDLs and assign loads extends only to waters within its jurisdiction (i.e., state waters), this TMDL ensures that the load allocations will be met by reducing nonpoint sources within catchment areas. Although there are limited areas on the MIT Reservation that discharge to tributaries included in the Implementation Plan, these areas do not represent significant nonpoint sources. (The Implementation Plan includes two watersheds that discharge to the White River on the MIT Reservation: Pussyfoot Creek and Second Creek. The total area of these two watersheds is approximately 7.9 acres. The large majority of these two watersheds (approximately 7.6 acres or 96% of the total area) is on state lands. Furthermore, the small areas that are on the Reservation are primarily wooded and do not represent significant nonpoint source areas for phosphorus loadings.)

The Implementation Plan describes best management practices (BMPs) to reduce nonpoint sources. Relative SRP loading from individual tributaries and expected load reductions are also described in the Implementation Plan.

Table 15. Lower White River Load Allocations

Description	LA	Sub-category Load	Unit	Pollutant	Flow Tier and Period for LA	Reductions Needed to Meet Allocation
Low Flow Load Allocation	6.46	NA	lbs / day	Soluble Reactive Phosphorus	< 900 cfs, July 1st- October 31st	0.137
Estimated natural background	NA	5.79	lbs / day	Soluble Reactive Phosphorus	< 900 cfs, July 1st- October 31st	0
NPS	NA	0.67	lbs / day	Soluble Reactive Phosphorus	< 900 cfs, July 1st- October 31st	0.137
Medium Flow Load Allocation	10.65	NA	lbs / day	Soluble Reactive Phosphorus	< 2000 cfs, May 1st – June 30th and 900 cfs – 2000 cfs, July 1st- October 31st	0.320
Estimated natural background	NA	9.33	lbs / day	Soluble Reactive Phosphorus	< 2000 cfs, May 1st – June 30th and 900 cfs – 2000 cfs, July 1st- October 31st	0
NPS	NA	1.32	lbs / day	Soluble Reactive Phosphorus	< 2000 cfs, May 1st – June 30th and 900 cfs – 2000 cfs, July 1st- October 31st	0.320

The estimated natural background is a sub-set of the total load allocation (Table 16). The total low flow natural background load allocation is 5.79 lbs SRP/day. The total medium flow natural background load allocation is 9.33 lbs SRP/day. As these allocations capture the estimated natural background loading, no reductions are required. Appendix I contains further information on how natural background loads were estimated.

Table 16. Lower White River Natural Background Load Allocations

	LA	Unit	Pollutant	Flow Tier and Period for LA	Reductions Needed to Meet Allocation
Low Flow Natural Groundwater Load Allocation	5.07	Pounds / day	Soluble Reactive Phosphorus	< 900 cfs, July 1st- October 31st	0
Low Flow Natural Surface Water Load Allocation	0.72	Pounds / day	Soluble Reactive Phosphorus	< 900 cfs, July 1st- October 31st	0

	LA	Unit	Pollutant	Flow Tier and Period for LA	Reductions Needed to Meet Allocation
Medium Flow Natural Groundwater Load Allocation	7.87	Pounds / day	Soluble Reactive Phosphorus	< 2000 cfs, May 1st – June 30th and 900 cfs – 2000 cfs, July 1st- October 31st	0
Medium Flow Natural Surface Water Load Allocation	1.46	Pounds / day	Soluble Reactive Phosphorus	< 2000 cfs, May 1st – June 30th and 900 cfs – 2000 cfs, July 1st- October 31st	0

Margin of Safety

The margin of safety accounts for uncertainty about the pollutant loading and water body response and must be included in all TMDL projects to ensure water quality standards are met, given the uncertainty. The margin of safety may be either implicit or an explicit portion of the loading capacity. In this TMDL report, an implicit margin of safety is being applied by using conservative modeling and analytical assumptions:

- Although critical conditions (7Q10 flow with low turbidity) typically occur in September and October, the applicable TMDL window has been expanded from May 1st to October 31st to cover less frequent conditions that may occur in the spring. The TMDL is designed to address two different critical conditions, spring loading and critical low flow in the summer and fall.
- The flow threshold for when allocations apply was set at 2,000 cfs, significantly higher than the highest flow that exceedances of the pH water quality criteria have been observed (~1,500 cfs).
- The load capacity in medium flow condition is determined at flows of 900-1,000 cfs, the bottom of the medium flow range (900-2,000 cfs). Given that load capacity increases with flow, these loads will likely have a smaller impact on pH when flows are at the upper range of this flow tier.
- Given that load and wasteload allocations are based on the <0.2 pH human impact portion of the standards, the maximum predicted pH is below the numeric criterion of 8.5 for both medium flow conditions (8.02) and low flow conditions (8.45).
- Wasteload allocations for the wastewater treatment plants were developed based on a scenario where biological phosphorus treatment was disrupted and largely ineffective. Chemical polishing is applied to much higher incoming phosphorus loads than what typically occur with functioning biological phosphorus treatment. This treatment upset occurs during 7Q10 low flow and very low turbidity in the river. This represents a worst-case scenario critical condition.

> In addition, the 2012 data used to estimate functioning biological phosphorus treatment represents potentially non-optimized treatment levels that occurred while WWTPs were not required to remove phosphorus. It is likely that WWTPs will be able to optimize biological phosphorus removal over time.

The model used to develop allocations was dynamic and had low error and bias for daily maximum pH (RMSE= 0.17; Bias = 0.04) across a wide range of flow, turbidity, nutrient, and temperature conditions , which suggests the implicit margin of safety does not need to be overly conservative. As a predictive tool, a dynamic model provides more confidence in the modeling results and allocations, compared to a model that only predicts pH under steady-state conditions.

TMDL calculation

The elements described above are consistent with the standard TMDL equation LC=∑WLA+∑LA+MOS. For this TMDL, there is an additional term needed in the TMDL equation to ensure the loading capacity is not exceeded. This term is the MIT Reservation capacity, which includes the MIT future growth reserve, Coal Creek Fish Facility reserve, and MIT stormwater reserve. Table 17 lists all the elements included in the TMDL calculation. The summation of these elements equals the loading capacity.

Table 17. TMDL equation elements and allocation totals

Low Flow Tier (< 900 cfs) TMDL Element	Low Flow Tier (< 900 cfs) SRP Load (lbs/day)
∑Waste Water Treatment Plant WLA	0.98
MIT Future Growth Reserve	0.53
White River Fish Hatchery WLA	0.94
Coal Creek Fish Facility Reserve	0.86
∑Stormwater WLA	0.245
MIT Stormwater Reserve	0.035
Margin of Safety	implicit
Load Allocation	6.46
Total	**10.05**

Medium Flow Tier (900 to 2000 cfs) TMDL Element	Medium Flow Tier (900 to 2000 cfs) SRP Load (lbs/day)
∑Waste Water Treatment Plant WLA	2.37
MIT Future Growth Reserve	1.31
White River Fish Hatchery WLA	2.43
Coal Creek Fish Facility Reserve	0.99
∑Stormwater WLA	2.576
MIT Stormwater Reserve	0.368
Margin of Safety	implicit
Load Allocation	10.65
Total	**20.69**

The totals match the Loading Capacity (LC) figures given previously, i.e., low flow LC = 10.05 lbs/day, medium flow LC = 20.69 lbs/day.

Monitoring

Effectiveness monitoring (EM) is a critical component to successful TMDL implementation, and without it there would be no way to determine project outcomes. Ecology's TMDLs have traditionally called for one year of EM study roughly 20 to 30 years post TMDL completion/adoption. While this provides a useful means of assessing long-term project success, these authors believe that more can be accomplished with a more rigorous and robust EM strategy and by better integrating EM into other facets of TMDL implementation. Therefore, this TMDL proposes supplementing the traditional post project EM. This TMDL has attempted to establish an EM program that not only assesses long-term trends, but also provides a 'real-time' feedback mechanism to measure progress. EM that is focused on point sources within the mainstem of the White River is discussed below. Additional discussions related to EM for nonpoint sources are included in the Implementation Plan. This TMDL proposes EM be split into two broad efforts, monitoring and analysis while TMDL implementation is in effect, and monitoring that happens after the 10-year implementation period is completed.

Monitoring during implementation

Continuous pH monitoring

Within 3 years after the TMDL is approved by EPA, begin conducting continuous monitoring of pH for 1 to 2 weeks during critical periods at the four locations described below. Ideally this monitoring would be conducted on an annual basis. The ability to conduct monitoring in a given year will be dependent on available staff and equipment resources. The work may be conducted by MOA agency staff, local watershed partners, or under contract (USGS, consultant) and may be sponsored by agency, grant, or other sources of funding. The continuous pH monitoring must be conducted under an approved Quality Assurance Project Plan or equivalent document. This work may also be conducted under Ecology's programmatic water quality impairment QAPP (McCarthy and Mathieu, 2017), provided an approved project workplan memo is completed.

Critical periods are defined as periods between May 1st and October 31st when flow levels have been in Tier 3 for three or more days, when flows are expected to continue in Tier 3 for at least 2 additional days, and when river turbidity levels are less than 50 FNU based on either of these USGS water quality gages:

- RM24.2: USGS Current Conditions for USGS 12098700 WHITE RIVER AT HEADWORKS AB FLUME NR BUCKLEY, WA[2].
- RM7.6: USGS Current Conditions for USGS 12100490 WHITE RIVER AT R STREET NEAR AUBURN, WA[3]

No more than one continuous monitoring period per location will occur in each calendar year. Continuous pH data will be collected during the critical periods at the following four locations: RM 25.2, RM 20.4, RM 7.5, and RM 4.4. Data will be collected at RM 25.2 and RM 7.5 only if the current USGS water quality gages at RM 24.2 and 7.6 are discontinued.

Ecology has many competing monitoring priorities and limited staff and financial resources with which to do this work. Unfortunately, Ecology can therefore provide no assurances that it will be able to do this continuous pH monitoring regularly, if at all.

Opportunistic data collection

This TMDL recommends ongoing 'opportunistic' data collection to characterize nutrient and pH changes within the White River:

- Conducted jointly by Ecology's Environmental Assessment Program (EAP) and/or Southwest Regional Office (SWRO) monitoring staff, consistent with the staff assignments for implementation monitoring.
- Before scheduled field run staff should check flow in the White River to see if the river is in a medium or low flow tier and check the USGS gage to see if pH is greater than 8.2.
- If yes, and there is enough available time and sample budget, collect:
    - up to 2-3 additional nutrient (total phosphorus, soluble reactive phosphorus, total nitrogen, ammonia, and nitrate-nitrite) samples (headwaters and RM 4.4, and maybe RM 20.4 downstream of known major sources). Dissolved parameters should be prioritized over total nitrogen and total phosphorus.
    - Discrete afternoon pH measurements at RM 7.6 (USGS gage) and RM 4.4 (and preferably RM 6.3 if time). This would both corroborate the high pH readings from USGS gages and assess how much higher the pH was downstream.

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[2] https://waterdata.usgs.gov/wa/nwis/uv/?site_no=12098700&PARAmeter_cd=00095,00400,00010,00300,63680

[3] https://waterdata.usgs.gov/wa/nwis/uv/?site_no=12100490&PARAmeter_cd=00095,00400,00010,00300,63680

- Ideally perform this ‘opportunistic’ monitoring at least once before or at the interim 3-year milestone assessment and again before or at the 7-year milestone assessment.

If possible, opportunistic data collection should be conducted concurrent with continuous pH monitoring described under Section 2.6.1.

Interim 5-year data assessment

At the project implementation halfway point, (i.e., at year 5) collate and summarize all data gathered to date:

- Conduct a data quality assessment and analyze all USGS, Ecology, MIT, and other pH/nutrient/water quality data collected in the Lower White River.
- Summarize findings/recommendations in a report, made available to TMDL implementers/stakeholders and Lower White River TMDL Workgroup members.
- Conducted by Ecology SWRO monitoring staff if available.

Post implementation monitoring

The primary purpose of this monitoring is to assess the efficacy of implementation efforts more broadly throughout the Lower White River watershed. Once all necessary BMPs and controls have been installed, a traditional one-year EM study shall be conducted to assess the overall success of the TMDL. The goal for this monitoring is to occur after 10 years of TMDL implementation, but it may occur slightly after (e.g., year 12) if not all BMPs and controls have been installed by the 10-year point (see Adaptive Management).

This TMDL recommends that monitoring staff integrate pH synoptic surveys into the traditional EM protocol to ensure that not only phosphorus is characterized, but the impact on pH is understood such that the conclusions of the TMDL model can be tested.

As part of EAP’s regular post-TMDL implementation EM effort - conduct a minimum of two synoptic surveys, one each during low and medium flow conditions which shall include continuous pH monitoring and nutrient sampling throughout the TMDL area. Includes the following important elements:

- To be conducted by Ecology’s EAP EM unit.
- 1-2 week sonde deployments to measure continuous pH.
- Nutrient sampling for total phosphorus, soluble reactive phosphorus, total nitrogen, ammonia, and nitrate-nitrite.
- Flow measurements at ungauged tributaries and point sources.
- Table 18 contains locations and parameter recommendations.
- Depending on project planning and implementation progress, surveys may occur 10-12 years after approval.

Table 18. Proposed synoptic survey locations and monitoring parameters

Study ID	Location Type	Location Description	Latitude	Longitude	Nutrients	pH	Flow
W28	Mainstem	White River below Mud Mtn Dam	47.15486	-121.95206	C	C	
W25.2	Mainstem	White River at Rainier School	47.16706	-121.99320	R		
NA	Mainstem	White River Upstream of Diversion Dam	47.16981	-122.00285		USGS	USGS
W20.4	Mainstem	White River below Buckley	47.18685	-122.06509	R	R	
W7.5	Mainstem	White River at R St SE	47.27482	-122.20858	R	USGS	USGS
W6.3	Mainstem	White River above A Street	47.26633	-122.22891	C	C	
W5	Mainstem	White River at 8th St	47.24987	-122.24383	C	C	
W4	Mainstem	White River downstream of 16th St E	47.24137	-122.23445	R	R	R*
MFH	Point source	White River Hatchery	47.16986	-122.00362	R		R
EC	Point source	Enumclaw WWTP	47.18811	-122.00521	R		DMR
BK	Point source	Buckley WWTP	47.16807	-122.03517	R		DMR
SW6.2	Point source	Stormwater outfall at ~RM 6.2	47.26678	-122.22877	R		R
MNL	Point source	Manke Lumber outfall	47.24406	-122.24357	R		R

C = conditional, R = required; DMR = discharge monitoring report

* Acoustic Doppler Current Profilers (ADCP) necessary during higher flow or Bridge Flow at RM3.3 (subtract USGS tailrace flow to estimate RM4).

Special emphasis has been placed on establishing monitoring locations that can differentiate between the impacts from the point and nonpoint source discharges to the extent practicable. Timing of monitoring in relation to permit compliance is key, and monitoring staff are directed to reach out to permit managers and/or the TMDL lead to confirm permit status.

Adaptive management

The monitoring activities identified above will be applied, resources permitting, in an adaptive management strategy. 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. The results from the monitoring activities will be used to 1) highlight or evaluate progress in achieving load and WLAs to the extent possible with the monitoring resource available, 2) assist in identifying and setting new priorities for future actions, 3) promote accountability, and 4) increase stakeholder awareness, participation, and support. Additional discussions related to adaptive management for nonpoint sources are included in the Implementation Plan.

As noted in the discussions on EM in the section above, emphasis has been placed on establishing monitoring locations to differentiate between the impacts, from the point and nonpoint source discharges to the extent practicable. Should the monitoring data show that changes to the point source WLAs are necessary, the TMDL will need to be revised and resubmitted. This would need to include a repeat of the formal public comment and EPA review/approval processes. Additional modeling may also be needed to evaluate necessary changes to point source WLAs. This would likely be a resource intensive exercise and need to be integrated into other existing TMDL development priorities and schedules. Thus, Ecology can provide no assurances at this time as to when such re-assessment work could be done.

Appendices

Appendix A. Background

Clean Water Act and TMDLs

What is a Total Maximum Daily Load (TMDL)?

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.

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 develop and maintain water quality standards that protect, restore, and preserve water quality. Water quality standards consist of (1) a set of designated uses for all water bodies, such as salmon spawning, swimming, and fish and shellfish harvesting; (2) numeric and narrative criteria to achieve those uses; and (3) an antidegradation policy to protect high quality waters that surpass these conditions.

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, Ecology compiles its own water quality data along with data from local, state, and federal governments, tribal governments, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The 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:

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

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

Further information is available at Ecology's Water Quality Assessment website[4].

The CWA requires that a TMDL be developed for each of the water bodies on the 303(d) list.

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[4] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d

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, tribal governments, agencies, and the community, then develops a plan to control and reduce pollution sources, as well as a monitoring plan to assess effectiveness of the water quality improvement activities. The implementation plan identifies specific tasks, responsible parties, and timelines for reducing or eliminating pollution sources and achieving clean water.

Because the White River is both a state and tribal resource, Ecology, the Muckleshoot Indian Tribe (MIT), and the U.S. Environmental Protection Agency (EPA) signed an agreement to jointly develop a pH TMDL for the White River in October 2001 (MIT et al., 2001).

After the public comment period, Ecology addresses the comments. Then, Ecology submits the TMDL to EPA for approval. The Muckleshoot Indian Tribe has reservation land that intersects the study area and has jurisdiction over the Lower White River from river mile 15.5 to 8.9. Because Ecology’s authority to develop TMDLs and assign loads extends only to waters within its jurisdiction (i.e., state waters), this TMDL ensures that the overall loading capacity will be met by making certain assumptions about loading at the upstream and downstream extent of reservation boundaries.

Watershed description

Geography

The White River originates at the Winthrop, Emmons, Inter, and Fryingpan Glaciers in Mount Rainier National Park and flows approximately 85 miles to its confluence with the Puyallup River. The White River drainage basin consists of approximately 740 square-miles. Major tributaries include the Clearwater and Greenwater Rivers. The river emerges from its upper watershed near the city of Buckley and flows through the MIT reservation through a rolling, low-elevation plateau underlain by unconsolidated glacial deposits. The river ends at its confluence with the Puyallup River in the city of Sumner, 23 miles downstream of Buckley. The Puyallup River flows into Puget Sound. The study area is in Water Resource Inventory Area (WRIA) 10 (Figure A-4).

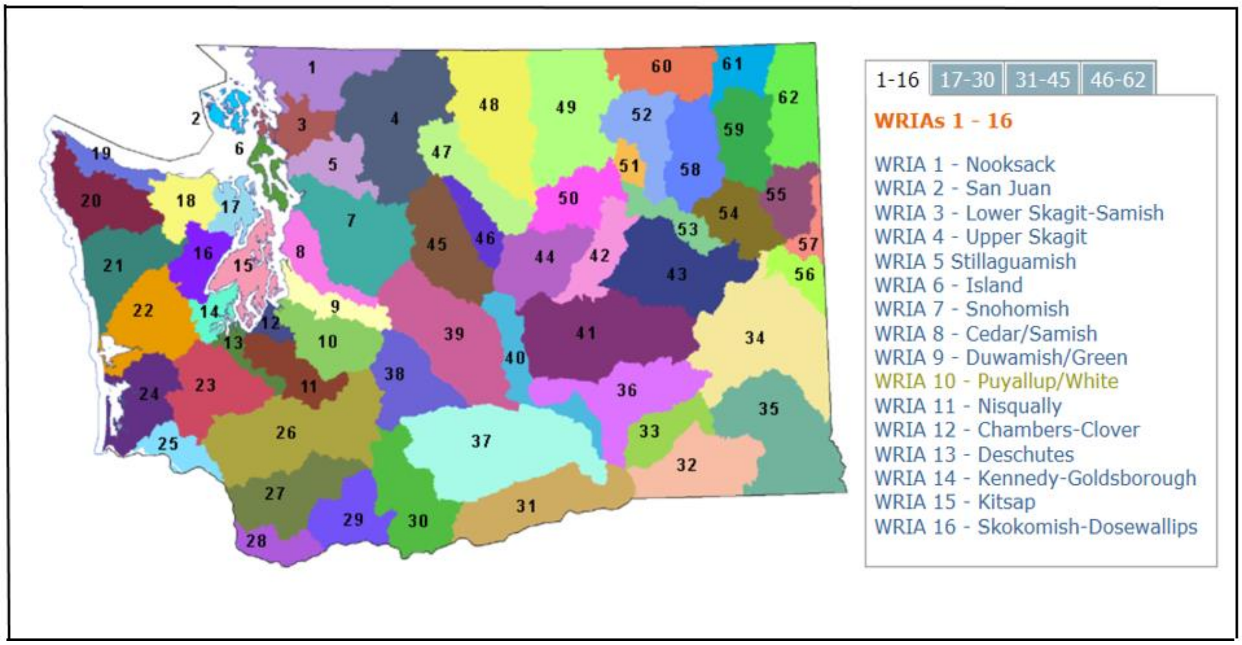

Figure A-4. Watershed Resource Inventory Area Map of Washington State

Climate

The climate is dominated by the mild, wet maritime weather regime typical of lower elevation areas of western Washington. The air temperatures in Buckley reach an average daily high of 76.4°F (24.7°C) in July and August with the average daily low dropping to 32.4°F (0.2°C) in January. Buckley receives an average of 48 inches of precipitation annually, almost half of which falls from November through February (WRCC, 2011).

Higher elevations on Mount Rainier receive heavy snowfall throughout the late fall, winter, and spring, with an annual average of over 110 inches of precipitation and over 650 inches of snowfall at Paradise (WRCC, 2011).

Geology/hydrogeology

Appendix H describes the geologic history and hydrogeologic setting of the study area in greater detail. Ecology compiled this information from several sources (Welch et al., 2015; CWA, 2010; PGG, 1999; PGG, 2000). To summarize the information pertinent to the study area and TMDL:

- The retreat of glaciers from the Fraser glaciation formed the Puyallup and White River valleys. The lower portions of these valleys were initially arms of Puget Sound.
- These valleys eventually filled with sediment from the rivers and lahars from Mount Rainier.
- The largest of these lahars, the Osceola Mudflow, filled valleys in the White River with deposits of clay-rich sediments that formed a poorly drained, hydrogeologic unit which limits downward groundwater movement.

- The Lake Tapps Reservoir Uplands provide baseflow to a portion of the river within the study area. The surface of the uplands is covered with glacial till. Beneath the till lies a sequence of aquifers and confining units. The aquifer units supply baseflow to the White River, as well as water supply to private and municipal wells, local springs, and tributaries (e.g., Salmon Creek).
- A small stretch of the river north of Lake Tapps is likely a seasonally “losing” reach where the river provides recharge to the aquifer.
- The alluvial aquifer units likely have a flowpath which directs groundwater north toward the Green River along the historic path of the White River through Auburn (Welch et al., 2015).

Soils and vegetation

The predominate soils in the TMDL study area are classified as Buckley and Alderwood series soils. The valley floor, however, consists of alluvial soils. The Buckley series consists of moderately deep and poorly draining soils that formed on the surface of the Osceola Mudflow. The soils occupy nearly level plains between elevations of 500 to 700 feet above sea level. In many areas, the lands underlain by Buckley soils have been cleared and drained to grow pasture, hay, and grain.

The Alderwood series consists of moderately drained soils with depths of 24 to 40 inches underlain by consolidated glacial till. The underlying glacial till, also known as hardpan, has low permeability. The Alderwood soils, located on glacially modified foothills and valleys with slopes of 0 to 65%, formed in glacial deposits at elevations between 100 and 800 feet. Presently, local land areas underlain by the Alderwood series are used for woodland, field crops, hay, pasture, and non-farm uses.

Native vegetation along the White River, and in the adjacent valley bottom, was dominated by hardwoods, most frequently red alder, black cottonwood, willow, and big leaf maple. However, although much less frequent, conifers such as western red cedar, Sitka spruce, and Douglas-fir accounted for a significant portion of the basal area, due to their larger diameters and heights. On the valley slopes and upland terrace, conifers such as western red cedar, western hemlock, Sitka spruce, and Douglas-fir were historically dominant in both frequency and basal area (Collins et al., 2003).

Hydrology

Local precipitation (in fall, winter, and spring), high elevation snowmelt (in spring) and glacial melt from Mt. Rainier (primarily in summer) heavily influence seasonal streamflow patterns in the White River. Typically, the lowest flows occur in the month of October.

The Morse Lake Snotel station records snowfall and snowmelt near the upper White River watershed at (elevation 5410 ft). On average, the snowpack at Morse Lake peaks at approximately 55 inches of snow water equivalent (SWE) in March and is followed by rapid snowmelt during May and June.

Typically, there is less than 5 inches SWE remaining by early July and, historically, all snow (at this elevation) has melted by early August (NOAA, 2012). Glacial melt continues from the Emmons, Winthrop, and Fryingpan glaciers of Mount Rainier intermittently through summer and early fall depending on daily temperatures, cloud cover, and solar radiation.

Mud Mountain Dam provides flood control for the White and Puyallup River valleys and can affect flows in the White River downstream. However, it is typically managed as a "run-of-the-river" dam, whereby the reservoir is left empty, and the river flow is not impeded. The U.S. Army Corps of Engineers (USACE) operates the dam to provide flood control for the Puyallup River to limit peak discharge to below 45,000 cubic feet per second (cfs) at the U.S. Geological Survey (USGS) station (12101500) on the Puyallup River at Puyallup, WA.

At RM 24.3, another dam, originally constructed in 1914, diverts a controlled volume of river flow to Lake Tapps through a man-made channel. Historically, Puget Sound Energy (PSE) diverted water for hydropower generation from the river into Lake Tapps upstream of the two municipal discharges. These diversions resulted in significantly lower river flows, with mean monthly flows below 200 cfs in September and October, in the 20 miles of river between Buckley at RM 24 and Sumner at RM 3.6. In January 2004, PSE ceased operating the hydropower generation facility.

Since hydropower operations ceased, water diversions to Lake Tapps have decreased, and river flows have increased accordingly. In 2009, PSE sold its water rights to Cascade Water Alliance, a municipal corporation composed of five cities (Redmond, Issaquah, Kirkland, Bellevue, Tukwila) and two water and sewer districts (Skyway and Sammamish Plateau). Cascade Water Alliance plans to eventually use the water for domestic supply to urban areas in east King County but must first design, permit, and construct a water treatment plant and distribution system.

As part of an agreement between Cascade Water Alliance, the Muckleshoot Indian Tribe, and the Puyallup Tribe of Indians, flow may not be diverted from the river at the Lake Tapps diversion when upstream flows fall below a minimum range (CWA, 2008). The minimum flow ranges vary by time of year, with an absolute minimum low flow of 500 cfs. The 7Q10 flow at RM 28 for the time period 1977-2002 is approximately 250 cfs. (The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every ten years on average.) Given that the 7Q10 is less than the minimum flow agreement, no diversions would be allowed during the most critical conditions in the river.

Land use and fisheries resources

Current land use

Land use in the study area is mixed urban, residential, agricultural, and forest. The mixed urban residential areas include the cities of Auburn, Edgewood, Pacific, Algona, Sumner, Enumclaw, and Buckley, the Muckleshoot Indian Tribe Reservation, highway corridors, and homes surrounding Lake Tapps (Figure 2). Agricultural areas are located on the remaining uplands of the Enumclaw plateau. Intermittent tree cover exists on the valley floor upstream of Auburn and forested areas cover the watershed upstream of the study area. The valley broadens as the river moves downstream, with steep forested hills partially covered by deciduous and coniferous trees.

The area is experiencing rapid residential growth, generally into areas that were recently used for agricultural purposes. The upper portion of the study area consists primarily of rural residential and agricultural land use, with relatively low housing densities. This includes areas of unincorporated King and Pierce Counties and areas of the cities of Buckley and Enumclaw.

Within the lower portion of the study area, housing densities are typically higher and mixed with more commercial and industrial properties. This includes the cities of Algona, Auburn, Edgewood, Pacific, and Sumner. A zone of large warehouses and industrial operations is concentrated around the final 6 miles of the Lower White River. This zone dominates the valley floor and extends from the mouth of the river in Sumner to the northern bounds of the study area in Auburn and Algona, in the Government Canal and Milwaukee Ditch drainage areas.

Puyallup Tribe of Indians

As part of ongoing efforts to protect treaty fisheries as well as recover endangered salmon fisheries in the Puyallup River watershed, the Puyallup Tribe has spent a large amount of time on the White River, conducting surveys, enumerating fish at the USACE Buckley fish trap (located at RM 24.3), working to restore habitat, and operating acclimation ponds on tributaries of the White River. The Puyallup Tribe of Indians also regulates downstream water quality through promulgated water quality standards, within the reservation reach of the Puyallup River, between RM 1 and approximately 7.3. The reservation reach is approximately 3 miles downstream of the confluence with the White River.

Muckleshoot Indian Tribe

The White River flows within the Muckleshoot Indian Tribe Reservation from RM 15.5 to 8.9. The river and its tributaries support salmonids that are of cultural, subsistence, and economic value to the Tribe. Coho, Chinook, pink, and chum salmon, steelhead, and other trout species utilize habitats in the White River for spawning, rearing, and migration. The entire White River watershed is a portion of the Tribe’s Usual and Accustomed Fishing Area (U & A), as defined in U.S. v. Washington, 384 F. Supp. 312, 367 (W.D. Wash. 1974). Within the U & A, the Tribe has the authority to exercise commercial, subsistence, and ceremonial treaty fishing rights, as well as the authority and responsibility to co-manage shared natural resources with Washington State.

White River Hatchery

The White River Hatchery is located on the right bank of the White River at River Mile 24.3. The only fish hatchery in operation on the White River, it is owned and operated by the Muckleshoot Indian Tribe and has been in operation since 1989. The hatchery was constructed as part of a 1986 settlement agreement between the Muckleshoot Indian Tribe and PSE related to damages to tribal fisheries. The purpose of this hatchery is to help restore indigenous salmon in the White River to levels providing sufficient harvest opportunity. The harvest of fish under this hatchery program is an essential part of the Tribe’s federally recognized treaty fishing rights reserved by the Treaties of Medicine Creek and Point Elliott. The role of the Tribe’s hatchery program is to support four basic values recognized by the Federal Courts: (1) resource conservation, (2) ceremonial, religious, and spiritual values, (3) subsistence values, and (4) commercial values.

Currently, the White River Hatchery produces juvenile White River spring Chinook (Oncorhynchus tshawytscha) for release from the hatchery and from several upriver sites located in the upper watershed. Puget Sound Chinook Salmon, including White River spring Chinook, were listed as threatened under the Endangered Species Act (ESA) in March 1999 (64

FR 14308) and reaffirmed as threatened in May 2016 (81 FR 33468). Both the naturally-spawning and the hatchery White River spring Chinook are included in the ESA listing. The White River spring Chinook population is one of 22 independent populations that comprise the Puget Sound Chinook salmon Evolutionary Significant Unit (ESU) (Ruckelshaus et al., 2006) listed under ESA. Further, the National Marine Fisheries Service has identified the White River spring Chinook to be one of two populations in central/south Puget Sound that must achieve a low risk of extirpation for the viability of the Puget Sound Chinook ESU as a whole (NMFS, 2006).

The White River Spring Chinook population is genetically unique and is the last remaining spring-run Chinook stock in central and south Puget Sound. The Hatchery Scientific Review Group (2004) cites the White River spring Chinook program as an example of a successful hatchery program:

> *"In 1977, fewer than 50 naturally spawning spring chinook returned to spawn in the White River. Responding to this crisis, a multi-agency recovery effort…developed the White River Chinook Recovery Plan. This plan has used captive breeding and multiple juvenile rearing and release strategies to increase the number of adults returning to spawn. As a direct result of this program, nearly 1,000 adults returned to spawn naturally in each of the last two years. Without intervention, this unique stock of chinook would be extinct today."*

To date, the White River Hatchery spring Chinook program has largely functioned as a conservation and recovery program and is not yet producing enough fish to support more than a small ceremonial and subsistence harvest. The hatchery provides juvenile spring Chinook to supplement natural adult returns and to contribute to the rebuilding of natural-origin spawners, and ultimately is intended to provide a sustainable fishery on the White River, sufficient to satisfy treaty obligations.

The long-term goal stated in the White River Spring Chinook Recovery Plan (WDFW et al., 1996) is to restore the native population of White River spring Chinook population in the White River watershed to a healthy, productive condition capable of supporting a full complement of directed and incidental harvest in sport, commercial, and tribal fisheries. Only fish confirmed to be White River spring Chinook are used in the hatchery broodstock, and natural origin fish are incorporated into the broodstock.

As with all salmon and steelhead hatchery programs that operate in regions with ESA listed populations, the White River Hatchery is evaluated and permitted through the federal government to assure consistency with ESA. Measures are taken to limit adverse effects on natural populations. In addition to supporting salmon recovery, and eventually tribal harvest goals in the White River and sport fisheries in Puget Sound, the hatchery and contributes to the preferred prey base (Chinook salmon) of the endangered Southern Resident Killer Whale. (NOAA and WDFW 2018).

Habitat loss and degradation

In addition to their more recent role in the conservation of at-risk salmon stocks, hatchery programs have served a mitigating function to replace naturally produced fish lost as a result of habitat degradation since their inception in 1895 (United States v. Washington, 759 f.2d 1353m 1360 (9th Cir)(en banc), cert. Denied, 474 U.S. 994 (1985)). The natural production of salmon and steelhead in the White River has been diminished by numerous sources of habitat loss and degradation in the White-Puyallup River basin since the late 1800s.

Commencement Bay, once a highly productive estuary, has lost over 98 percent of its historical intertidal and subtidal habitat to industrial and port development (Kerwin 1999). The remaining estuarine habitats are in many places contaminated with chemicals that further reduce their value to aquatic organisms and biological processes. Estuaries are critical habitats for juveniles of several Pacific salmon species during their transition from life in freshwater to life in the ocean (Healy 1982). Estuarine habitats provide refuge from predators, a rich food supply to support rapid growth, and are where juvenile salmon make the transition from freshwater to marine conditions.

The estuary and nearshore habitats of the Hylebos Waterway/Puyallup system have been intensively studied to measure contaminant exposure in juvenile Chinook salmon and other fish species (Collier et al. 1998, Stehr et al. 2000, O'Neill et al. 2015). Juvenile Chinook salmon spend weeks in estuaries before moving seaward, and those migrating through contaminated estuaries have been found to have a lower overall survival rate compared to Chinook from uncontaminated estuaries (Meador 2015).

Historically productive floodplain habitat has been dramatically reduced by flood control infrastructure and urbanization. The lower Puyallup and White rivers flow through urban areas and are contained within revetments and levees for 26 and eight miles, respectively (Kerwin 1999). Off-channel floodplain rearing habitat is documented to promote growth of juvenile Chinook salmon (Sommer et al. 2001, Jeffres et al. 2008).

The USACE's Mud Mountain Dam at RM 29.6 on the White River was completed in 1948 to control flooding along the urban lower White and Puyallup rivers and limits the natural production of salmonids in several ways (Kerwin 1999). The dam interrupts the river's natural processes including its hydrologic regime, the recruitment of large woody debris, the transport of sediment, and upstream and downstream fish passage (Kerwin 1999, NMFS 2014). Because the dam is a complete barrier to upstream fish migration, the USACE provides fish passage by capturing migrating fish at the Lake Tapps diversion dam at RM 24.3 (adjacent to the White River Hatchery) for trucking and release upstream of the dam; however, these fish passage facilities have historically been inadequate and unsafe.

Spawning habitat in the 5.5-mile reach between the diversion dam and Mud Mountain Dam is not accessible to anadromous fish, and approximately another 5 miles of historic spawning habitat in the reservoir inundation zone above Mud Mountain Dam is no longer suitable for spawning and incubation (NMFS 2014) given the periodic containment of floodwater and settling of fine sediment in the riverbed. Numerous other barriers to adult and juvenile salmonids exist on tributary streams throughout the White River watershed (Kerwin 1999).

As noted in Kerwin (1999), timber operations and road construction in much of the upper White River watershed have historically reduced the ability for riparian areas to provide wood and shade to the river channel and tributary streams. This has increased the contribution of fine sediment from road and landslides.

In recent years, streamflows in the White River downstream of the Lake Tapps diversion dam at RM 24.3 have been improved to more closely resemble a natural flow regime after more than 90 years of severe alteration. Streamflow has been described as a “master variable” (Poff et al. 1997) controlling a wide range of physical variables and ecological functions that influence the reproduction, growth, and survival of fish. Examples include light penetration, water temperature, rates of erosion and sedimentation (Lewis et al. 2007), invertebrate abundance and diversity, fish behavior and energetics (Caldwell et al. 2018), and rates of predation.

Climate change is predicted to have adverse effects on salmon in the Pacific Northwest (Crozier 2016). Climate change is projected to further increase summer water and air temperatures, decrease snowpack and summer streamflow, increase winter flow rates, and raise sea levels, all of which are likely to affect salmon populations with impacts at all life history stages (Mauger et al. 2015). The effects of climate change on freshwater and marine environments are expected to add to those of non-climate related effects from habitat loss and degradation, further reducing the abundance and survival of natural and hatchery origin salmon and steelhead in Puget Sound watersheds including the White-Puyallup River basin.

Water quality issues

Multiple organizations have documented exceedances of the 8.5 pH standard in the Lower White River from July 1971 to October 2018. These exceedances have occurred intermittently in all months, except February, at monitoring points from river miles (RMs) 4.9 to 19.8.

In September and October of 1990, the Washington State Department of Ecology (Ecology) measured pH levels that exceeded (did not meet) Washington State water quality standards (WAC 173-201A) in the Lower White River RMs 4.9, 6.3, and 8.0 during a TMDL study conducted on the Puyallup River watershed (Pelletier, 1993). Subsequent monitoring, conducted from 1996-2003, documented continued exceedances of pH standards in the Lower White River (Pelletier, 1993; Erickson, 1999; Ecology, 2015b; Stuart, 2002; Ebbert, 2003). Based on these pH exceedances, the White River was placed on Washington State’s 303(d) list of impaired water bodies.

In 2001, EPA, the Muckleshoot Indian Tribe, and Ecology signed a memorandum of agreement (MOA) describing the process that would be used to respond to the 303(d) pH listings. The primary purpose of the MOA was to establish a TMDL drafting committee consisting of members of each party who would draft and finalize the TMDL. Subsequently, the MOA parties developed a periphyton and pH model for the Lower White River, in support of a TMDL, using a 2000-2001 dataset collected for a University of Washington thesis project (Stuart, 2002).

Since the 2000-01 dataset was collected, two major changes have occurred within the Lower White River:

- The flow regime has changed dramatically now that PSE has sold their water rights and is no longer diverting large amounts of water to Lake Tapps for power generation.

- The Buckley and Enumclaw wastewater treatment plants (WWTPs), the 2 major point sources within the area of concern, have upgraded their nutrient removal capabilities.

Given these significant changes within the Lower White River, Ecology conducted additional monitoring (in 2012; see Appendix F) and modeling (see Appendix I) to provide a more current basis for TMDL allocations and recommendations. In addition, USGS maintains several continuous water quality gages on the river (Table A-19), with continuous pH records available starting in 2010.

Table A-19. USGS Continuous water quality gages on the Lower White River.

Station Number	Station Name	Period of Record
12098700	White River At Headworks Ab Flume Nr Buckley, WA	May 2010 - present
12100490	White River At R Street Near Auburn, WA	May 2010 - present
12101100	Lake Tapps Diversion At Dieringer, WA	May 2010 - present
12101102	White River At 24th St E At Dieringer, WA	June 2016 - present

The results of the 2012 study, as well as the USGS water quality gages, generally show lower pH maximums compared to data collected prior to 2003; however, the White River has continued to reach or exceed the maximum pH criterion of 8.5 in all years between2012 and 2018, with the exception of 2013. More detailed summary and analysis of historic and current water quality issues are included in Appendix F: Study Results and Appendix J: Historic Data Summary.

Protection of designated uses and downstream water bodies

Washington water quality standards require upstream actions to be conducted in manners that meet downstream water body criteria. The standards also require that the most stringent water quality criteria apply where multiple criteria for the same water quality parameter are assigned to a water body to protect different uses and at the boundary between water bodies protected for different uses.

The water quality standards language in WAC 173-201A-260(3)(b)-(d) states:

> *"(b) Upstream actions must be conducted in manners that meet downstream water body criteria. Except where and to the extent described otherwise in this chapter, the criteria associated with the most upstream uses designated for a water body are to be applied to headwaters to protect nonfish aquatic species and the designated downstream uses.*
>
> *"(c) Where multiple criteria for the same water quality parameter are assigned to a water body to protect different uses, the most stringent criterion for each parameter is to be applied.*
>
> *(d) At the boundary between water bodies protected for different uses, the more stringent criteria apply."*

In developing TMDLs, Ecology routinely identifies and considers all designated uses (also described as beneficial uses) of the impaired water body and water bodies directly downstream of the impairment. This is done to ensure the chosen TMDL target and associated allocations will protect all designated uses and downstream designated uses.

The section titled 'Uses of the Water bodies' under the Introduction of this TMDL report, lists all designated uses that apply to the Lower White River. Of those uses, only the aquatic life uses have specific criteria for pH. These are listed in Table 4 of the TMDL, and include the aquatic life uses of salmonid spawning, rearing, and migration (which applies to the Lower White River from Mouth to river mile (RM) 4.4), and core summer salmonid habitat (which applies to the Lower White River from RM 4.4. to RM 28).

Those two aquatic life uses have slightly different criteria for pH (Table A-20). The section of the White River addressed by this TMDL spans from RM 3.6 to RM 28. The river upstream of RM 4.4 has the more stringent criterion. It allows an anthropogenic increase of pH of only 0.2 above the numeric limit of 6.5 to 8.5, compared to the 0.5 allowance for the other reach below RM 4.4. Thus, the overall TMDL target for phosphorus was selected to be protective of the pH criteria for core summer salmonid habitat, and the most sensitive designated use is being protected. The TMDL analysis described in Appendix E also found that if pH criteria are met at RM 3.6, additional nutrient loading downstream of this point does not significantly affect pH levels.

Table A-20. Stringency comparison of designated uses and criteria for the White River and downstream Puyallup River.

	White River – RM 4.4 to RM 28	White River – mouth to RM 4.4	Puyallup River – RM 1.0 to confluence with White River (*Downstream Reach*)
Designated Use	Aquatic life – core summer salmonid habitat	Aquatic life – salmonid spawning, rearing, and migration	Aquatic life – core summer salmonid habitat
Water Quality Criteria	pH within a range of 6.5 to 8.5 Anthropogenic increase allowance of 0.2	pH within a range of 6.5 to 8.5 Anthropogenic increase allowance of 0.5	pH within a range of 6.5 to 8.5 Anthropogenic increase allowance of 0.2

In addition to protecting the designated uses of the impaired water bodies addressed by the TMDL, Ecology considered whether or not the TMDL was protective of downstream waters. The White River flows into the Puyallup River, which is designated for core summer salmonid habitat. Also, the Puyallup River is not currently impaired for pH. The low flow model demonstrates that below RM 4.4, the impacts to pH decrease (Table A-21). In the reach of the White River right above the confluence with the Puyallup River (at RM 0.1), the pH minimum and maximum are within the water quality criterion allowed pH range. In addition, the human impact is 0.05, well below the allowed increase of 0.5 in that segment of the White River, and

0.2 for the Puyallup River. After mixing with the larger Puyallup River, this impact would be even less and therefore, less than 0.2. In the medium flow model, the impacts were even less than the low flow model.

The reach downstream of RM 3.6 does not have pH exceedances of the water quality standards primarily because the river geometry changes dramatically downstream of the Lake Tapps tailrace return (RM 3.6). It becomes narrower, much deeper, and the substrate quality shifts to mostly fine substrates. The light limitation from increased depth, combined with poor quality substrate for periphyton growth, results in dramatically improved pH levels.

Table A-21. Low Flow model results downstream of White River RM 4.4.

Location	Model Segment	TMDL pH min	TMDL pH max	Anthropogenic Impact (TMDL – Natural)	Anthropogenic Increase Allowance
RM 4*	28	7.69	8.45	0.21	0.50
RM 0.1**	33	7.22	7.34	0.05	0.50

*Largest impact downstream of the criteria change from 0.2 to 0.5 anthropogenic increase allowance.

**Representative of discharge to Puyallup River under critical conditions

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Appendix B. Public Participation

Public Comments

Ecology held a 45-day public comment period for this TMDL from June 16 through July 31, 2022. The public comment period was initially intended to last 30 days, but Ecology extended the comment period an additional 15 days at the request of the City of Enumclaw. Ecology sent targeted announcements concerning the comment period and the subsequent extension to key stakeholders, and more general announcements to Ecology's GovDelivery contact list. Ecology also held a virtual public workshop on June 28, 2022 at 2 pm. Information about this TMDL is available on Ecology's Puyallup River Basin TMDL website.

Comments and Response

Ecology received comments from one individual, the City of Enumclaw, the City of Buckley, the Washington State Department of Transportation, and the Washington State Department of Agriculture. The full text of most of the comments are reproduced below. Where Ecology made only minor revisions in response to suggested document edits, Ecology did not include a response below. Salutations and closings have been removed and formatting where appropriate has been reproduced. Ecology's response follows the comment. Page numbering in comments and responses may no longer be accurate due to subsequent report edits.

Comments from Don Russell- Individual (I-1)

Comment #I-1-1 (Russell)

Assign the designated beneficial use of the LWR TMDL Implementation Plan

The Plan identifies the Lower White River's designated beneficial uses as salmonid spawning, rearing, and migration, primary contact recreational use, and water supply use, without mentioning its use as a salmonid hatchery water supply source.

Response to Comment# I-1-1 (Russell)

Ecology agrees that this beneficial use should be identified more specifically in the TMDL. We have added a sub-bullet under the 'Water Supply Uses' bullet at the following location 'Overview > Use of the waterbodies' titled "White River Hatchery water supply."

Comment #I-1-2 (Russell)

Establish numeric or narrative standards that assure designated beneficial use

Whereas the Lower White River pH Total Maximum Daily Load -Technical Analysis and TMDL Allocations and the Lower White River pH Total Maximum Daily Load - Implementation Plan does cite exceedances of Ecology's surface water quality standard for pH that require action be taken, Ecology's existing surface and groundwater quality standards do not contain a standard for Soluble Reactive Phosphorus (SRP).

Yet the Lower White River pH Total Maximum Daily Load - Technical Analysis and TMDL Allocations study concludes that pH exceedances are due {linked) to the biological response of stream bottom benthic Periphyton (i.e., filamentous diatom and green algae and cyanobacteria) growth that is stimulated by the presence of soluble reactive phosphorus {SRP) contained in the development impacted reaches of the tributaries that discharge into the lower reaches of the White River.

The Lower White River pH Total Maximum Daily Load - Technical Analysis and TMDL Allocations study goes on to state that SRP is a pollutant and that any SRP concentration in exceedance of 7.5 or 10.5 micrograms {ug}/Liter discharged into the tributaries of the lower While river will result in (be linked to) exceedance of existing Ecology promulgated surface water quality standards for pH.

Whereas the Lower White River pH Total Maximum Daily Load - Implementation Plan presents a compelling argument for this linkage, there is no reference to studies or USEPA approved water quality standards for SRP concentration that support the TMDL's claim that SRP is a pollutant or that exceedance of 7.5 or 10.5 ug/L will result in exceedance of Ecology's pH water quality standard.

Orthophosphate expressed as SRP (the P portion of PO4---) is an ionic (chemical) constituent found in ground and surface water. Its concentration is determined by many factors such as water's exposure time to and solubility of minerals contained in soil, dissolved oxygen concentration, contributing anthropogenic P inputs, adsorption and chemical reactions with aluminum, calcium, iron to form insoluble inorganic compounds, and its rapid assimilation by algae and plants to become insoluble organic bound P.

The highest SRP concentrations {>10.5 ug/L) are found in development affected nutrient (P and N) polluted groundwater that discharges as base flow into streams and discharges into lakes. Once exposed to sun light and oxygenated surface water conditions orthophosphate ions are rapidly converted to insoluble inorganic or organic P bound compounds by the processes identified in the paragraph above. Therefore, orthophosphate ion concentrations measured as SRP will likely decrease in surface water to less than 10.5 ug/L. This will give the false impression that there is no SRP water quality problem when adsorption, chemical conversion or assimilation of the SRP has occurred. Yet SRP assimilation by algae and aquatic plants lead to their daytime photosynthetic activity, nighttime respiratory activity and subsident death and decay which results in extreme high {>8.5) and low (<6.5) fluctuations in surface water pH.

The highest SRP concentrations {>100 ug/L) are found above P polluted bottom sediments in the summertime anoxic hypolimnetic water of deep lakes. Development impacted P polluted shallow aquifer groundwater discharging into our urban streams and lakes typically has SRP concentrations that range of from 20 to 75 ug/L, well above the LWR pH TMDL Study's and Implementation Plan's assigned 7.5 and 10.5 ug/L SRP water quality standards.

SRP concentrations in groundwater discharging into streams as base flow and into shallow lakes will give rise to excessive algal and aquatic plant growth, harmful cyanobacteria blooms and exceedances of Ecology's water quality standard for pH when SRP concentrations exceed 20 ug/L.

Thus, Ecology should develop and adopt an SRP water quality standard of 20 vs. 7.5 and 10.5 ug/L.

Response to Comment# I-1-2 (Russell)

The TMDL does not establish numeric or narrative water quality standards. States establish water quality standards as part of the larger Clean Water Act process (40 CFR 131.11(a)(1)). TMDLs are sometimes expressed through surrogate measures which may be more easily implementable or more directly address the water quality issue. TMDL modeling demonstrates pH standards can be achieved in-stream by reduction of SRP to the allocated amounts. Concentrations of 7.5 and 10.5 ug/L SRP are not numeric standards, but rather targets for monitoring of specific stormwater sources. The TMDL ultimately establishes load and wasteload allocations, not concentrations, as part of the TMDL; however, these also do not constitute numeric standards.

The commenter does not present sufficient technical basis for the suggested 20 ug/L SRP target. This concentration is greater than most observed stormwater baseflow and groundwater concentrations measured in the watershed during the study and would cause an exceedance in the TMDL model if assigned to all potential stormwater discharges.

Comment #I-1-3 (Russell)

Monitor water bodies for compliance with established water quality standards

There are many studies that have monitored SRP concentration in natural (unpolluted) and development impaired polluted surface and groundwater. SRP concentrations range from non-- detect to several hundred ug/L. Dependent upon its concentration algal and aquatic plant growth response can range from minimal to extreme with attendant adverse impact on pH and salmon habitat and hatchery water supply conditions.

The first Ecology application of the TMDL model to restore salmon habitat and its water as a suitable hatchery water supply source for WDFW's and the Puyallup Tribe of Indian's salmon hatcheries was the Clarks Creek DO and sediment TMDL Implementation Plan.

Its implementation has failed to improve salmon habitat in Clarks Creek or the quality of its base flow water as a salmon hatchery water supply source. Why? Because of the TMDL's study's misdiagnosis of Clarks Creek's fundamental water quality problem. That problem is SRP, nitrate- nitrogen and iron pollution of Clarks Creek's groundwater supplied base flow.

The below listed reference papers describe why the TMDL model is fatally flawed as a water quality and salmon habitat restoration technique.

Response to Comment #I-1-3 (Russell)

Comment noted. The Clarks Creek DO and Sediment TMDL is different from the Lower White River pH TMDL in many aspects. While Ecology disagrees with the assertion that the Clarks Creek TMDL has failed, the greater issue is that this comment presents a false equivalence based on the fact that both support salmon habitat and have hatcheries with water supply from the impaired waterbodies. This comparison is not supported by any factual information related to pH in the Lower White River.

Comment #I-1-4 (Russell)

Exceedance of any standard requires that remedial action be taken

The SRP water quality standard proposed in the Lower White River TMDL Implementation Plan of 7.5 and 10.5 ug/L is exceeded many times over in Clarks Creek as described in the below referenced papers. Yet no effective remedial action has been taken to date, despite repeated pleas to USEPA, Ecology and the Puyallup Tribe of Indians to take appropriate remedial action to address Clarks Creek's fundamental base flow SRP, nitrate-nitrogen and iron pollution problem.

The below referenced Clarks Creek TMDL comment papers stress the adverse impact that on-site septic system drain field effluent has on the SRP concentration of shallow aquifer groundwater. SRP polluted shallow aquifer groundwater that is in continuity with and discharges into stream reaches and lakes is the leading cause of excessive algal, cyanobacteria and aquatic plant growth and attendant exceedance of Ecology's DO and pH water quality standards.

Unfortunately, the Plan prescribed BMP septic tank inspections, repair and maintenance only slightly mitigate the adverse ecological effect of P saturated drain field effluent pollution of underlying shallow aquifer groundwater.

Response to Comment #I-1-4 (Russell)

As noted in the response to comment #I-1-2, the concentration of 7.5 and 10.5 ug/L SRP are targets for baseflow from stormwater sources and are not proposed water quality standards. These targets are not applied unilaterally to all sources, in fact the TMDL does not prescribe any reduction in SRP loading from nonpoint SRP groundwater discharge to the mainstem river and reserves a large portion of the load capacity for this loading, based on extensive groundwater monitoring and assessment completed for the project. Potential SRP discharge to tributaries from septic effluent is a small part of the implementation plan, but not the focus in this TMDL. Again, the commenter is presenting a false equivalence between the two TMDLs.

Comment #I-1-5 (Russell)

Utilize the TMDL or Straight to Implementation (STI) remediation model

The Lower White River pH Total Maximum Daily Load-Technical Analysis and TMDL Allocations report and the Lower White River pH Total Maximum Daily Load - Implementation Plan assumes that Ecology's surface water and groundwater quality standards recognize SRP as a pollutant and that SRP concentration exceedance in excess of 7.5 and 10.5 ug/L requires a TMDL water quality improvement action plan.

This is an erroneous assumption that undermines the validity of USEPA/Ecology applying the TMDL model to address the Lower White River pH Total Maximum Daily Load - Technical Analysis and TMDL Allocations study and Implementation Plan or, for that matter, the Clarks Creek DO and sediment TMDL and East Fork Lewis River Alternative TMDL studies and water quality improvement Plans.

That problem in all these Plans is the adverse water quality impact of elevated concentrations of SRP in our streams and lakes. These impacts include excessive aquatic plant and filamentous diatom and green algae growth, harmful cyanobacteria blooms that release potent nerve and liver toxins into State surface water and groundwater, alternating high and low dissolved oxygen (DO) concentrations, and pH exceedances in SRP affected steam and lake water quality.

I have pointed out on many occasions (notably the Clarks Creek DO and sediment TMDL) that until Ecology's surface and groundwater quality standards include and address all the physical, chemical and biological requirements for the protection of salmon and other forms of aquatic life that the only effective water quality restoration model to apply is the Straight to Implementation model.

Response to Comment #I-1-5 (Russell)

Ecology's STI approach was developed to address impairments in predominately rural watersheds, dominated by nonpoint sources. The premise being that where pollution problems are simpler and fixes largely self-evident, sophisticated TMDL analysis is unnecessarily time consuming and resource intensive. The Lower White River is not a good fit for this approach as it's a complex system, with dense urban development in its lower reaches and significant point source discharges. As explained in response to comment I-1-2, this TMDL uses SRP as a surrogate measure, it makes no assumption regarding recognition of SRP as a pollutant under the water quality standards. And concentrations of 7.5 and 10.5 ug/L SRP are not numeric standards, but rather monitoring targets for permit compliance purposes.

Comment #I-1-6 (Russell)

Monitor effectiveness - utilize adaptive management to make course corrections

Highly touted but seldom practiced by Ecology, WDFW, DNR, DOH, Conservation Districts, Counties, Cities, and even Tribes much to the consternation and denial of safe beneficial uses of our freshwater resource by salmon (thus Orcas), stream side and lake shoreline landowners and concerned citizen stakeholders and would be responsible stream and lake stewards.

Response to Comment #I-1-6 (Russell)

Comment noted. The TMDL Implementation Plan details Ecology's effectiveness monitoring and adaptive management strategy. Ecology has already begun engagement with permit managers and permittees to expedite adoption of the TMDL's WLAs. Similarly, Ecology's nonpoint inspectors are already focusing their corrective efforts in the priority sub-watersheds identified in the Implementation Plan.

Comment #I-1-7 (Russell)

Concluding commentary

USEPA's TMDL model was effective in addressing point source water pollution problems. However, it has proven ineffective in addressing non point water quality pollution problems for a variety of reasons as cited in the above and below referenced papers.

It is interesting to note that none of the below referenced papers sent to USEPA Region 10 or Ecology personnel resulted in any acknowledgement of their receipt or any adaptive management action response.

The Clarks Creek DO and Sediment TMDL Implementation Plan was the first USEPA Region 10/Ecology attempt to restore salmon habitat and water quality in the State of Washington. It has been a costly failure as will be the East Fork Lewis River Alternative TMDL and Lower White River temperature and bacteria TMDL Implementation Plans for reasons cited above and in the below References.

Response to Comment #I-1-7 (Russell)

The federal Clean Water Act mandates TMDLs. Ecology does not have discretion to decide whether to conduct TMDLs or not, we can only prioritize when and where we do them. Washington State TMDLs typically establish an initial implementation period of 20 to 50 years, depending on the parameter. In most cases, our TMDLs have not been implemented long enough to draw definitive conclusions regarding their efficacy. The Clarks Creek DO and Sediment project referenced was not the first state TMDL, there are several others that predate it. The Lower White River pH TMDL differs significantly from the others the commenter mentions, they are not comparable.

Comments from City of Enumclaw - Agency (A-1).

Comments A-1-1 through A-1-15 submitted via letter signed by Mayor Jan Molinaro, Comment A-1-10 submitted via e-comments by Scott Woodbury. Comments on the Implementation Plan are A-1-11 through A-1-15.

Comment # A-1-1 (Enumclaw Letter):

The City of Enumclaw waste load allocation (WLA) is based on year 2012 daily flows plus a 2-percent increase per year for 20 years through year 2032. The growth rate of 2-percent per year is consistent with the City of Enumclaw's 2015 Comprehensive Plan. The City has only been given 10 years of growth until it will likely need to construct very expensive tertiary treatment upgrades to its wastewater treatment plant. It would be more appropriate to base the City of Enumclaw's WLA on the most recent year of flows multiplied by a 2-percent per year growth factor.

The City of Buckley WLA is based on the City of Enumclaw flows multiplied by a service area scalar factor rather than current populations to allow Buckley to achieve a population density comparable to Enumclaw. The WLA for Buckley should be calculated in the same manner as for Enumclaw with the same initial year of flows plus the growth rate used in the City of Buckley's most recent Comprehensive Plan for 20 years.

The MIT reservation WLA is also based on the City of Enumclaw flows multiplied by a service area scalar factor. This WLA assumes that there will be loading from a future WWTP. Currently, the MIT does not require its own WWTP and there is no confirmation that this WWTP will be needed in the next 20 years. The MIT should be required to prepare a planning document that demonstrates the need for a WLA from a future WWTP due to population growth in the next 20 years prior to being issued a WLA. However, even before undertaking such a planning exercise it must be asked why would consideration be given to a new waste discharge into the White River several miles upstream from the Puget Sound if waste from the MIT is currently being directed to the King County treatment plant at Renton and from there directly to Puget Sound without being conveyed there by a river. If such a new waste discharge is allowed, it should be located as far down the TMDL reach as practical to reduce biomass in the upper portion of the TMDL reach (see last paragraph p. 97). Add failing sewer systems as a source of phosphorus.

Response to Comment # A-1-1 (Enumclaw Letter):

While future flow projections could potentially be updated, changing the wasteload allocations is difficult considering the limited loading capacity available. The commenter provides no analysis supporting the need for adjustments to the WLA assignments. Ecology's informal analysis suggests that the TMDL's current WLAs are still achievable even if more recent flow data are used. Due to the conservative assumptions used in developing the wasteload allocations, it appears possible, even likely, that when City of Enumclaw effluent flows exceed the future flow projections in the TMDL, the SRP concentrations necessary to meet the WLA will continue to be achievable with chemical polishing. There is no evidence presented to suggest that tertiary treatment will be necessary after 10 years.

Figure E-13 provides information about future effluent flow compared to mean effluent SRP concentration, in the context of the WWTP wasteload allocations, and includes a point for 2035 flow, which is consistent with the future year used for the City of Enumclaw population targets in the current (2015) comprehensive plan.

Ecology chose an equal population density (service area scalar) approach to ensure equity amongst tribal and non-tribal communities for this WLA category, particularly given that there is not an existing Muckleshoot Indian Tribe (MIT) effluent flow to base potential growth on.

The MIT Reservation Capacity is not a WLA. Ecology has no jurisdiction to set WLAs for discharges to tribal waters. The MIT Reservation Capacity accounts for growth that may occur on the MIT Reservation in the next 20 years and could be used for future permitted sources such as municipal, industrial, aquaculture, or other potential discharges related to the Muckleshoot Indian Tribe within the TMDL reach. It was calculated using the same SRP concentrations and assumptions about flows used for calculating the WLAs for the WWTPs of the Cities of Enumclaw and Buckley. The MIT Reservation Capacity does not reflect specific facility plans or limit in any way the future type of use of the reserve. It may be used for point sources other than a WWTP, based on MIT priorities. MIT may choose to use this reserve or may continue to have no discharge at all and may instead keep the reserve as an additional margin of safety to protect the quality of the river. We agree any new discharge should undergo careful planning and be located as far downstream as possible, as indicated in the discussion of future fish production facilities.

Comment # A-1-2 (Enumclaw Letter):

The WLA for the White River Hatchery and estimated loads for the planned Coal Creek Springs Fish Facility were determined with estimated future fish production levels for each facility over the next 20 years. The existing fishery WLA should be based on the same 20-year period as the Cities of Enumclaw and Buckley WWTPs, beginning on the same year. Furthermore, a WLA should not be allowed for the future Coal Creek Springs Fish Facility considering that there is no future commercial or industrial allocation reserved for other entities.

Response to Comment # A-1-2 (Enumclaw Letter):

Ecology did not treat the Muckleshoot Indian Tribe (MIT) White River Hatchery WLA and Coal Creek Springs Fish Facility reserve as belonging in the future growth, commercial, or industrial discharge categories. These loads support salmon recovery efforts. The natural production of salmon and steelhead in the White River has been diminished by numerous sources of habitat loss and degradation in the White-Puyallup River basin since the late 1800s. Currently, the White River Hatchery produces spring Chinook sub-yearlings for release from the hatchery and from upriver acclimation sites. Spring Chinook salmon are a special part of the Tribe's cultural and religious practices; however, they were nearly extirpated in the White River by the late 1970s after decades of habitat impairment from hydropower operations, dam construction, and other actions. While the TMDL includes a large relative portion of the load capacity for these categories, the TMDL analysis suggests that this load distribution is achievable with other TMDL allocations successfully implemented.

Comment # A-1-3 (Enumclaw Letter):

The text states that "The estimated natural background is a sub-set of the total load allocation (Table 16). The total low flow natural background load allocation is 5.77 lbs SRP/day. The total medium flow natural background load allocation is 9.29 lbs SRP/day." However, Table 16 lists 5.07 pounds/day for the low flow natural groundwater load allocation and 0.72 pounds/day for the low flow natural surface water load allocation which together would equal 5.79 pounds per day instead of 5.77 pounds per day.

Similarly, Table 16 lists 7.87 pounds/day for the medium flow natural groundwater load allocation and 1.46 pounds/day for the medium flow natural surface water load allocation which together would equal 9.33 pounds/day instead of 9.29 pounds per day.

Response to Comment # A-1-3 (Enumclaw Letter):

The numbers in Table 16 were changed due to a minor update in previous draft revisions. Ecology failed to update the corresponding in-text numbers; this error has been corrected in the final TMDL.

Comment # A-1-4 (Enumclaw Letter):

For the hatcheries, loading scenarios were taken from a report developed by the Muckleshoot Indian Tribe (MIT) titled: Summary Evaluation of Potential Soluble Phosphorus Loads from Fish Hatcheries for the Lower White River Cleanup Plan (MIT, 2019). This document should be posted on Ecology's Lower White River TMDL website for public review.

The Enumclaw and Buckley WWTPs are required to implement all known, available, and reasonable methods of prevention, control, and treatment (AKART) and it is not clear that the WLA for the hatcheries was calculated based on AKART being implemented.

Response to Comment # A-1-4 (Enumclaw Letter):

The hatchery report is available for public review at request[5]. Ecology did not treat these load categories as permitted commercial/industrial sources, but rather left a reserve for the general category (see response to comment #A-1-2). Hatchery WLAs were calculated taking into account fish production needs and available loading capacity. Existing and future EPA permits require AKART.

Comment # A-1-5 (Enumclaw Letter):

The report states "Loading from upstream of RM28 was not included as part of the TMDL loading capacity, because it is not within the boundary addressed by the TMDL analysis and likely represents phosphorus loads derived primarily from glacial melt and large areas of relatively un-impacted public forest and national park. These upstream loads may include some phosphorus from anthropogenic activities, but this impact has not been quantified and there are relatively few identifiable sources. It is important to note that the loads from upstream are considerably larger than the load capacity within the TMDL study area, 0.2 lbs SRP/day under low flow conditions and 55.4 lbs SRP/day under medium flow conditions."

These loads should be included as part of the TMDL study due to their magnitude and the potential for these loads to prevent the Lower White River from eventually complying with water quality standards. Furthermore, wastewater treatment and discharge at the Crystal Mountain Resort complex should address SRP removal at a level comparable to those facilities impacted by this TMDL if such anthropogenic discharges contribute to the upstream SRP loading levels that are as stated above "...considerably larger than the load capacity within the TMDL study area...".

Response to Comment # A-1-5 (Enumclaw Letter):

The TMDL text acknowledges that the magnitude of this loading is significant. However, there is no evidence of significant anthropogenic SRP loading, from May to October, upstream of the study area. The Crystal Mountain Resort has no discharge to surface water, but rather a permit for discharge to groundwater.

While there is some potential for the resort to contribute SRP loading via groundwater discharge to the adjacent Silver Creek, this potential is reduced during the TMDL critical season of May to October due to decreased activity at the resort and the associated loading, as well as seasonal dropping of the surficial groundwater water table. There is no evidence of any potential dry season SRP loading that may end up in Silver Creek, via groundwater discharge, reaching the Upper White River over 5 miles downstream of the potential discharge, let alone reaching the Lower White River more than 30 miles downstream. Incoming SRP concentrations at RM 28 remain relatively low during the dry season and those concentrations are unlikely to change much, if at all, unless major load reductions are accomplished upstream. Again, a large anthropogenic source to target for reduction has not been identified upstream of RM28.

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[5] https://ecology.wa.gov/Footer/Public-records-requests

Comment # A-1-6 (Enumclaw Letter):

The report states "The hatcheries' SRP effluent samples should ideally be collected at least once per week to track SRP load trends and collect enough samples to calculate seasonal averages for each flow tier. Sample collection should occur routinely on the same day of the week (for example every Monday).

Based on the Buckley WWTP draft NPDES permit, the WWTPs will be required to collect SRP effluent samples twice per week. The hatcheries should be required to collect samples at the same frequency as the WWTPs.

Response to Comment # A-1-6 (Enumclaw Letter):

Comment noted, the TMDL can only provide recommendations for permit conditions. The sampling frequency included in subsequent permits is determined by the permitting authority and assigned permit writer.

Comment # A-1-7 (Enumclaw Letter):

The City of Enumclaw Comprehensive Plan was updated in 2015 and can be found at the following website: https://www.cityofenumclaw.net/216/Comprehensive-Plan.

Response to Comment # A-1-7 (Enumclaw Letter):

The growth rate for the future flow analysis was taken from the previous comprehensive plan, thus the 2005 reference. Ecology added language to clarify that 2015 is the current comprehensive plan, contains a similar rate for growth projections, and added the 2015 reference.

Comment # A-1-8 (Enumclaw Letter):

The Enumclaw and Buckley UGA areas should be added to Figure 1.

Response to Comment # A-1-8 (Enumclaw Letter):

Ecology attempted adding the UGA areas, but we think this makes the already busy map harder to read. In addition, given the map scale, it is not clear that delineating the UGAs adds much value here.

Comment #A-1-9 (Enumclaw Letter):

We suggest that the Enumclaw WWTP 1.5 lbs/day applies:

< 2000 cfs May 1-Jun 30

900-2000 cfs Jul 1-Oct 31

This seems to be a better way of stating the flow tier and seasonal period than currently shown in Table 6 as it would not have overlapping periods of different flow tiers. The same would apply to Buckley for its 0.87 lbs/day flow tier and period.

Response to Comment # A-1-9 (Enumclaw Letter):

Ecology agrees this revised way of presenting the categories improves clarity and the final TMDL has been edited accordingly.

Comment # A-1-10 (Woodbury e-comment):

The federal standard for pH is 6.0-9.0. Please explain why a TMDL rule for pH that has its basis on the lower state standard of 6.5-8.5 has triggered federal (EPA) involvement if the federal standard has not been exceeded.

Response to Comment # A-1-10 (Woodbury e-comment)

According to section 304(a) of the Clean Water Act (CWA), EPA must publish recommended ambient water quality criteria. For freshwater, the 304(a) criteria recommendation for pH is 6.5 – 9.0. As described in 40 CFR section 131.4(a), states, territories, and authorized tribes (shortened to 'states' in this document for brevity) "are responsible for reviewing, establishing, and revising water quality standards. As recognized by section 510 of the Clean Water Act, States may develop water quality standards more stringent than required by this regulation."

States adopt water quality criteria to protect the designated uses of a water body (40 CFR 131.11(a)(1)). Water quality criteria can be numeric (e.g., the maximum pollutant concentration levels permitted in a water body) or narrative (e.g., a criterion that describes the desired conditions of a water body being "free from" certain negative conditions). States typically adopt both numeric and narrative criteria. The numeric criteria can be established directly from the 304(a) criteria recommendations, modified to reflect site-specific conditions, or derived using other scientifically defensible methods (40 CFR 131.11(b)(1)).

States must monitor the quality of waters under their jurisdictions and report violations of their adopted water quality standards in what is known as a 303(d) list, or the list of impaired waterbodies (40 CFR section 130.7(b)(1)). For those impaired waterbodies, states must establish total maximum daily loads (TMDLs) at "at levels necessary to attain and maintain the applicable narrative and numerical WQS" (40 CFR section 130.7(c)(1)). States then submit the TMDL to EPA, and EPA must either "approve or disapprove…loadings not later than 30 days after the date of submission" (40 CFR section 130.7(d)(2)).

EPA's involvement in this State TMDL project is two-fold. In addition to EPA's regulatory responsibility to act on the TMDL submission from the State, EPA also has a unique role in the Lower White River pH TMDL as a member of the workgroup formed during the development of the TMDL. This is documented in a 2001 memorandum of agreement (MOA) between EPA, the Washington Department of Ecology, and the Muckleshoot Indian Tribe.

Comment # A-1-11 (Enumclaw Letter – Implementation Plan)

Relevant Sections:

- Organizations that implement the TMDL (Page 17)
- Outreach (Page 35)
- Appendix F: Organizations that implement the TMDL (Pages 85 to 91)

Why isn't the City of Buckley listed as an organization that implements the TMDL or as a key stakeholder?

Response to Comment # A-1-11

This is an oversight. The City of Buckley has been added to the sections referenced.

Comment # A-1-12 (Enumclaw Letter – Implementation Plan)

The costs in Table 9 for upgrading the Enumclaw and Buckley WWTPs are in 2016 dollars. The current capital only cost for Enumclaw in Table 9 (page 31) is estimated at $1.8M. This will add bulk chemical storage of 4000 gals each of alum and sodium hydroxide and related injection and life safety systems. This will change the cost for Enumclaw in Table 7 to be "high" and affect the text in the paragraph above Table 9. The City is still paying debt service on the plant upgrade completed in 2009 that added enhanced biological phosphorus removal (EBPR) treatment facilities. Only $0.75M of the $32M project to install EBPR was funded by a DOE grant. The rest has been paid by City sewer utility rate payers, making City sewer rates among the highest in the region.

Response to Comment # A-1-12

Ecology acknowledges that the costs given in Table 9 are no longer current. Ecology will add a footnote to the table clarifying this for the sake of transparency. However, costs are changing more rapidly than TMDL edits can keep pace with. Furthermore, updating the cities' costs would be problematic at this stage in the TMDL development process, as all other costs would need to be similarly updated and these data are not readily available. Most importantly, as the 'high' designation in Table 7 is *relative* to other costs, it's unclear whether these updates would ultimately change the cities' designation.

Ecology is appreciative of the financial burden facing Enumclaw and Buckley. One of the primary reasons for the tiered, flow based WLA assignments adopted in the TMDL is to maximize the limited loading capacity so as to avoid the necessity of tertiary treatment. Ecology understands the costs of chemical polishing will be substantial, but they are far less than those that would be associated with further plant upgrades.

Comment # A-1-13 (Enumclaw Letter – Implementation Plan)

Page[sic] 46 and 123. Golf course staff are trained in fertilizer application and follow the BMPs identified in page 61 of the IP. Also, Boise Creek will be relocated to no longer flow through the golf course but will be along the east edge in a former channel with a protective buffer from the golf course itself. This should help to achieve the targeted load reductions.

Response to Comment # A-1-13

Comment noted. Ecology appreciates proactive local partner and stakeholder efforts to improve water quality and restore habitat.

Comment # A-1-14 (Enumclaw Letter – Implementation Plan)

Page 4, 3rd paragraph and Page 55, pt bullet. Discontinuation of sediment removal practices of the past without alternative mitigation measures being taken have resulted in increasingly frequent flooding events that wash overland, and flush contaminates into streams at a much higher level than would occur otherwise. Boise Creek overbank floods into the City of Enumclaw itself and not from rainfall anywhere near a 100-year event. Action on a holistic level not just focused on habitat and water quality is needed and quickly and can only be spearheaded by state and county agencies that have jurisdiction.

Response to Comment # A-1-14

Comment noted. TMDLs are watershed scale corrective plans that attempt to identify and correct all sources of pollution in a holistic fashion. If the BMPs prescribed in the TMDL are fully implemented, many nutrient sources that could possibly be transported in a flooding event, should be significantly reduced if not eliminated. The commenter does not provide specific suggestions on what more the TMDL should do to address the issue raised.

Comment # A-1-15 (Enumclaw Letter – Implementation Plan)

Page 22, 23, and 93. Need reference to the 3rd paragraph on page 93 in the discussion on page 22. The title for Figure 9 should be "Septic Systems in and Near Enumclaw in Relation to ..." and use different color for septic systems inside Enumclaw city limits. See also the attached notes on Figure 9 that also are applicable to Fig 3.

Response to Comment # A-1-15

The report mentioned on pg. 22-23 is referenced in the third paragraph under Reach Scale in Appendix G. The publication details are included in the reference list at the end of Appendix G. The report was retrieved from King County's Department of Natural Resources and Parks website, this note has been added to the Appendix G reference list.

The TMDL includes Figure 9 to provide a broad overview of septic systems in the vicinity of Enumclaw in relation to water quality monitoring data. The TMDL does not assume this is proof of system failure or illicit discharge, and the authors did not intend for this information to serve as the basis for regulatory action. Given this, and the fact that status of septic systems will likely continue to change in the near future, we see little value in editing the map as suggested. However, we have edited the figure title and added a footnote clarifying the above for transparency.

Comments from City of Buckley - Agency (A-2)

Submitted by Jay Swift, P.E., Gray and Osborne.

Comment #A-2-1 (Buckley):

The TMDL Analysis would benefit from the inclusion of more recent data showing pH excursions above the 8.5 threshold; doing so could make a stronger case that high pH excursions are currently occurring and are a problem worth committing significant local resources to fix. The majority of the tables and figures show data well below pH 8.5 for diurnal maxima. In some instances, this is because the pH data were not taken at critical periods or locations. In the figures that do show excursions above pH 8.5 (such as Figure F-33), the data is from many years ago and/or the excursions are so rare and brief that they could be considered spurious outliers. Figure D-8, the most current data, does show a couple of pH excursions between 8.5 and 8.6. However, those are from 2015, and the rest of the data is from 2012 (10 years back) or earlier. Appendix J shows data that were collected 20 to 40 years ago.

All of this old data may still be representative of current conditions; however, the TMDL Analysis does not address whether that is the case, and the reader is left wondering if it is. Tables and graphs clearly showing that pH is a current problem (exceeding pH 8.5), including some data from the last few years if available, should be included, in an expanded "Problem Statement" section near the beginning of the document. This would be particularly useful in justifying the effort to comply with the WLAs, because of the inherent uncertainty in the modeling that supports the other claim that water quality standards are being exceeded, and WLAs are necessary (the 0.2 pH unit human-caused increase).

Response to Comment # A-2-1 (Buckley):

Ecology included the statements "continuous monitoring of pH by USGS (USGS gage 12100490 on the White River at R Street near Auburn) show that pH continues to not meet water quality standards under certain conditions" (Introduction-Overview) and "the White River has continued to reach or exceed the maximum pH criterion of 8.5 in all years between 2012 and 2018, with the exception of 2013" (Appendix A – Water Quality Issues).

We have added the statement "Between June 2013 and October 2021 (period of applicable USGS approved data after the TMDL data collection), pH has reached or exceeded 8.3 on 104 days in the months of May through October. This includes pH values as high as 9.4, which occurred as recently as September 2018. A threshold of 8.3 was used because data collection and modeling suggest pH can be greater in the stretch that extends downstream of the USGS gage at RM 7.6 to the Lake Tapps Tailrace at RM3.7. In this 9-year period, for the months of May through October, 13% of these months have demonstrated one or more days with pH of 8.5 or greater."

Comment # A-2-2 (Buckley):

Similar to the above comment, in an expanded "Problem Statement" in the beginning of the document, the modeling that shows that the 0.2 pH unit human caused increase should be clearly summarized, with a graph and table. The data showing the magnitude and locations of the modeled exceedances of the 0.2 pH unit criterion are buried in the current draft TMDL Analysis.

Response to Comment # A-2-2 (Buckley):

Ecology has added the following language to the overview section at the beginning of the TMDL analysis: "A comparison of the existing critical low flow conditions in the model, compared to system potential pH conditions, predicted that the human caused impact to pH was:

- Between 0.01 and 0.15 between river miles (RM) 26.4 and 14.6 with the magnitude of impact increasing in the downstream direction. Loading in this stretch of the river had a significant influence on the human-caused impact in reaches downstream of RM 14.6.
- Between 0.2 and 0.38 between RM 14.6 and RM 4.4 with the magnitude of impact increasing in the downstream direction.
- Between 0.18 and 0.40 between RM 4.4 and the mouth of the river. In this stretch of the river, up to 0.50 human-caused impact is allowed.

- A peak human caused impact of 0.38 was predicted in the model segment from RM 5.1 to RM 4.4, with a maximum pH of 8.65.
- The pH also exceeded 8.5, between RM 4.4 and RM 3.6, with a maximum of 8.64."

Comment # A-2-3 (Buckley):

This paragraph does provide a good basic description of the negative impacts of extreme levels of pH on aquatic biota. However, it then cites an example of toxic effects caused by low pH, instead of high pH. Since this TMDL is primarily focused on preventing high pH excursions, it would seem that a better example would be to cite the impacts of pH excursions that are higher than the range specified in the water quality standards. For example, the section could elaborate on increasing ammonia toxicity at increasing pH, if that were considered significant in these types of river environments, generally, or specifically in the White River.

If there are, in fact, no data on deleterious impacts from diurnal pH excursions in the 8.5 to 9.0 range, it is suggested that Ecology and EPA consider further evaluating potential impacts (or lack thereof) in future water quality standard revisions and consider adjusting water quality standards accordingly if appropriate. A slightly higher upper range for pH water quality criteria for rivers could have minor localized benefits where the rivers discharge into Puget Sound, neutralizing some of the acidification that is occurring in embayments due to climate change.

Response to Comment # A-2-3 (Buckley):

Ecology appreciates the suggestion to switch from a low pH to high pH toxicity example and has edited the text accordingly.

Ecology TMDL staff will pass your comment, related to pH between 8.5 and 9.0, on to our Water Quality Standards team. Changes to the water quality standards are outside of the scope of the TMDL. Ecology encourages the City to actively participate in the triennial water quality standards review and engage in a discussion of this topic in that forum. Please visit our Updates to the Standards website[6] for more information.

Comment # A-2-4 (Buckley):

The numbering of figures and tables in the document is confusing and should be fixed. For instance, in Appendix A, the first figure is A-4. In Appendix E, the first figure is E-11. Some of the figures are out of order. Similar issues exist for the tables.

Response to Comment # A-2-4 (Buckley):

Comment noted. We have worked to fix any issues with figure references and numbers in the final TMDL.

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[6] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-quality-standards/Updates-to-the-standards#triennial

Comment # A-2-5 (Buckley):

On Page 98, there appears to be a typo, or broken link, on this page (Error! Reference source not found).

Response to Comment # A-2-5 (Buckley):

Comment noted. We have worked to fix this issue in the final TMDL.

Comment # A-2-6 (City of Buckley):

The first paragraph on page 111 of this section states that "the expected sampling frequency will likely be within the range of 1 to 3 samples per week". It is recommended that the monitoring frequency be changed to weekly or monthly, as more frequent monitoring puts an undue burden on the City, which is already facing significant increased costs due to compliance with the TMDL WLAs as well as other new requirements proposed in the City's draft NPDES permit.

Response to Comment #A-2-6 (Buckley):

Ecology appreciates this concern and understands that frequent monitoring represents a financial burden on the City; however, given the tiered-flow format, more frequent sample collection is necessary to generate enough data points to assess mean seasonal effluent SRP loads for the medium and low flow tiers respectively. The tiered, flow based WLA approach is necessary to avoid plant upgrades to tertiary treatment. Upgrade costs would be significant, likely far higher than those associated with increased sampling. The sampling frequency included in subsequent permits is determined by the permitting authority and assigned permit writer.

Comments from Washington State Department of Transportation -Agency (A-3)

Submitted by Tony Bush and Elsa Pond.

Comment #A-3-1 (WSDOT):

The Implementation Plan states, "Point source wasteload allocations (WLAs) will be largely self-implementing through the administration of the NPDES Program." That statement is not true for WSDOT based on the draft TMDL. There are numerous important reasons why WSDOT's MS4 Permit is separate and different from the Phase I and II MS4 Permits. Because our MS4 Permit is very different from the Phase I and II MS4 Permits, our associated work and approach to compliance is also very different. Ecology should consider WSDOT's existing requirements (including existing TMDL specific actions) and associated work when developing new TMDL specific actions.

Further clarity is needed as to whether it is Ecology's intention to require WSDOT to develop a new program to comply with this TMDL. While other MS4 permittees may have existing programs or framework to perform the proposed actions, WSDOT does not. WSDOT does have extensive monitoring requirements that change over-time but have never included outfall screening, outfall monitoring, or source tracing. Based on discussions with Ecology on past draft TMDLs, it continues to be WSDOT's understanding that Ecology is the appropriate agency to perform such actions as part of TMDL development and implementation.

Additionally, Ecology's original request for outfall information identified specific river miles on the Lower White River and we reported only one known outfall within that scope. The scope has expanded and the definition of "piped outfall" raises some questions. WSDOT does not yet know whether these factors will increase the number of qualifying outfalls.

Recommendation: Just as WSDOT's MS4 Permit is different and separate from the Phase I and II Permits, TMDL actions should also be different and separate to account for the fundamental differences between jurisdictional areas, existing permit requirements, and compliance frameworks. Within that context, we ask that Ecology consider making the actions for WSDOT more consistent with other TMDLs, our existing requirements and SWMPP. For example, several existing TMDLs across the state use the same language to describe additional actions related to identifying sources over background that enable us to use our existing Illicit Discharge Detection and Elimination (IDDE) program to help meet additional requirements.

Additionally, WSDOT would like to reiterate the recommendations from the 2024 Western Washington Municipal Stormwater General Permit Reissuance Ad Hoc White Paper for TMDLs1 submitted to Ecology. To highlight a few:

- Provide opportunities for MS4 Permittees and stakeholders engagement and involvement in the development of the MS4 Permit's TMDL-related obligations in advance of the release of the MS4 permit public review draft.

- Clarify ongoing TMDL-related programmatic obligations that don't sunset (e.g., operations & maintenance) vs. those that are more discrete in time and space with a specific endpoint (e.g., installing a prescribed stormwater capital facilities project). This information has value for informing Permittee's planning, program development, and budgeting in deploying these actions.

Response to Comment # A-3-1 (WSDOT):

The 'self-implementing' statement is a broad reference to the role the NPDES program plays in the implementation of point source wasteload allocations and other associated TMDL requirements. It is not a commentary on MS4 permits specifically, but rather meant to contrast point source compliance with nonpoint source controls, which are not regulated by permit.

The TMDL's task is to describe the pollution problem(s) of interest and the measures needed to restore and protect water quality. The TMDL makes no assumptions or recommendations concerning new MS4 programs. Permittees should work with their permit managers to resolve future TMDL compliance questions.

This TMDL was developed using standard state tools and protocols. However, there are limits to the consistency possible between TMDL projects, as they must be tailored to the unique characteristic and needs of each watershed. Permittees, including WSDOT, were consulted during TMDL development and permittee engagement is an element of Ecology's MS4 permit renewal process.

Comment #A-3-2 (WSDOT):

(p. 42, bullet d) "Controlling runoff from new and redevelopment: Phosphorus Treatment BMPs as described in Ecology's stormwater management manual are needed for new development or redevelopment projects within the watershed of the TMDL that trigger Minimum Requirement #6: Runoff Treatment."

Comment: This action will create confusion for WSDOT projects, again because WSDOT's requirements differ from Phase I and II MS4 permittees' requirements. In accordance with WSDOT's MS4 Permit, WSDOT projects use the Highway Runoff Manual, which has been deemed equivalent to Ecology's Stormwater Management Manual. One main point of confusion may stem from the differences between the manuals used. In the Highway Runoff Manual, the minimum requirement for runoff treatment is Minimum Requirement 5, not 6. Further, the action should clarify the "trigger" is also the existence of a surface water discharge. For example, a phosphorus treatment BMP would not be required (according to the Highway Runoff Manual) if there is a discharge to a dispersion BMP because it assumes there would be no surface water discharge from the BMP).

Recommendation: To prevent confusion this action should allow the use of equivalent manuals and clarify the "trigger" that requires action. WSDOT recommends this action be edited to state, "Phosphorus Treatment BMPs as described in Ecology's stormwater management manual, or equivalent manual, are required for new development or redevelopment projects that have Threshold Discharge Areas (TDAs) with a surface water discharge to the White River Watershed AND those TDAs exceeds the thresholds for the Minimum Requirement for Runoff Treatment."

Response to Comment # A-3-2 (WSDOT):

Comment noted, the TMDL text has been edited to include reference to the Highway Runoff Manual minimum requirement 5.

Comment #A-3-3 (WSDOT):

(pp. 45-46, Construction Stormwater WLA section)

Comment: As written, this section will raise numerous questions for project planning, permitting, and compliance expectations during construction.

We interpret the primary compliance expectations of this draft TMDL to be summarized as follows: Stormwater discharges are prohibited during non-runoff conditions year-round. Non-stormwater discharges defined in the NPDES Construction Stormwater General Permit (CSWGP) S1.C3.f, g, and h are allowed year-round if they meet the groundwater dewatering WLA in Table 11. All other non-stormwater discharges authorized by the CSWGP are prohibited year-round. Stormwater discharges during runoff conditions in the critical condition period (May 1st – October 31st) must meet the turbidity and pH requirements in Special Condition S8 of the CSWGP. Please clarify it we have misinterpreted.

We interpret the language to mean projects are eligible year-round for coverage under the CSWGP despite Special Condition 8.E.1.d. However, the compliance implications of a zero WLA during non-runoff conditions could be clearer. Consider clarifying the following points:

• The draft TMDL appears to prohibit 8 of 11 non-stormwater discharges authorized by the CSWGP. If such discharges constitute a noncompliance event, that should be made clear.

• The draft language speaks to expectations when a noncompliance event is caused by another permitted entity, however it does not describe expectations in the event the noncompliance is due to a non-regulated entity or unanticipated event that may occur during non-runoff conditions shortly after a large rain event (e.g., stormwater treatment system upsets or illicit discharges/connections from private landowners). • In a noncompliance event, clarify how this should be reported (e.g., is a call to Environmental Report Tracking System under the CSWGP adequate for notification?).

The expectations for monitoring daily average river flow and sampling for soluble reactive phosphorus are generally unclear. The CSWGP uses turbidity as a surrogate test measure for phosphorus, is the draft TMDL proposing a new test measure? If so, the compliance expectations should be clearer.

The Notice of Intent (NOI) process for projects in Indian Country is already confusing for projects, and the presence of 303(d) listings and TMDLs increase confusion. The Environmental Protection Agency Construction General Permit (CGP) and Ecology's CSWGP are different in significant ways that also add to the confusion (e.g., they speak differently to pollutants like pH, phosphorus, and nutrients). WSDOT would be happy to provide more details about the challenges projects face during the NOI process if regulators are interested in improving process clarity. Our hope is that construction project staff will be able to understand both the Ecology CSWGP and the EPA CGP (including the language in 9.10.3 and 9.10.4) to get through the NOI process correctly, plan for and meet compliance expectations.

Recommendations: Use plain talk principles to clarify expectations to facilitate project planning, permitting procedures, and compliance efforts. For example:

• Confirm projects are eligible for CSWGP coverage year-round despite the zero WLA.

• Define "non-runoff conditions" and "runoff conditions" in the glossary. It appears that both are solely based on precipitation and time, and neither are based on the critical condition period (May 1st – October 31st).

• Work with the EPA and tribal governments to help clarify permitting procedures and compliance expectations for projects in Indian Country.

• Clarify compliance expectations when caused by a non-regulated entity or unanticipated event.

• Clarify what constitutes a noncompliance event.

• Clarify reporting and notification procedures if a noncompliant discharge occurs.

• The compliance expectations behind number 2 and 3 in the "Other Load Limits and Requirements" are generally unclear. The bullets suggest the construction project must know the daily average river flow and potentially sample for soluble reactive phosphorus even though the CSWGP uses turbidity as a surrogate for phosphorus. If this is the expectation, we have more questions. • The word "compost" does not show up in either the draft TMDL or Implementation Plan, yet it is a known source of phosphorus and commonly used in stormwater best management practices (BMPs). Phosphorus treatment BMPs, as triggered for use in the MS4 stormwater WLA section do not use compost. Clarify whether there are material prohibitions during construction, such as using compost based BMPs.

Response to Comment # A-3-3 (WSDOT):

Construction stormwater wasteload allocations detailed in this TMDL only apply during the TMDL critical period, i.e., May – October, not year-round (see Table 11 of the Allocations document). The rest of the year standard permit conditions apply, there are no additional TMDL requirements. Runoff and non-runoff definitions have been added to the Glossary per the commenter's recommendation.

The TMDL did not intend to prohibit certain types of non-stormwater groundwater discharges. The text has been edited to reference S1, C3 of the CSWGP in its entirety. The TMDL explains what is needed to protect water quality, but permit managers set permit conditions. Permittees should consult with their permit managers for clarity on future permit compliance expectations. Ecology has no legal authority to oversee Tribal or EPA permit management activities.

Comment #A-3-4 (WSDOT):

Comment: As represented in the Implementation Plan, cities and counties regulated by MS4 Permits implement numerous actions to address nonpoint sources of pollution because their jurisdictional areas include commercial, residential, and agricultural properties. WSDOT's jurisdictional area is fundamentally different, and our agency does not use codes/ordinances to minimize incoming sources. Beyond our Illicit Discharge Detection and Elimination (IDDE) program and utility permitting pathway, WSDOT has limited authority for controlling sources of pollution in overland flows that enter our narrow jurisdiction and MS4 system. For nonpoint challenges, WSDOT very much relies on the successful implementation of the numerous regulatory and voluntary programs such as those listed in the Implementation Plan. Coordination amongst the various actors (regulatory, regulated, voluntary) remains challenging, partly because roles and responsibilities are often unclear.

Recommendation: Continue efforts to clarify roles and responsibilities to help improve coordination amongst the various actors (regulatory, regulated, voluntary) to help ensure the successful implementation of the numerous programs aimed at minimizing pollution from nonpoint sources.

Response to Comment # A-3-4 (WSDOT):

Commented noted.

Comments from Washington State Department of Agriculture - Agency (A-4)

Submitted by Michael Isensee.

Comment #A-4-1 (WSDA):

Unfortunately, in my review of the documents, I did not find any clear description of how Pussyfoot and Second Creeks, in particular, are sources of SRP during most of this time frame as both waterways are seasonal and have no flow in most or all of their watersheds for the latter portion of the medium flow scenario and the vast majority of the low flow scenario until fall rainfall is sufficient to restart flows. Flows in the lowermost reaches of these streams are not present further upstream in the watershed, limiting the geographic area where SRP would enter these streams during the critical time periods.

- The plan should quantify what portion of the critical time periods (low flow and medium flow) overlaps with active flow in the targeted watersheds.

Response to Comment # A-4-1 (WSD WSDA OT):

It should be noted there is an error in the sample results table that likely occurred during formatting that incorrectly displayed low results for these sites. The sample results, although limited, are elevated in these waterbodies compared to other non-point sources (229, 48, and 48.5 ug/L SRP). This error has been fixed in the final TMDL. Ecology is aware that Pussyfoot and Second Creeks flows can be highly variable during much of the critical period. However, TMDL analysis (see Table 2 of the Implementation Plan) shows that the combined anthropogenic SRP loading from Pussyfoot, and Second Creeks is over 15% of the total from all tributaries sampled during low flow conditions and nearly 11% in medium flow conditions. When combined with the loading from nearby Boise Creek, these three creeks represent roughly 40% of the total anthropogenic nonpoint loading. In short, our data suggest loading from these creeks is significant and warrants focusing nonpoint implementation in these drainages, regardless of seasonal flow patterns. Furthermore, TMDL analysis shows that the greatest likelihood of exceeding water quality standards is during low flow conditions at the start and end of the TMDL critical period (i.e., in May and October) when Pussyfoot and Second Creeks are more likely to be flowing.

Comment #A-4-2 (WSDA):

The primary rationale that is expressed in the document is during higher flows adhered-P enters sediment sinks and, under lower base-flow conditions where groundwater and not overland flow is the water supply, this P dissolves and enters the streamflow as SRP. If this is true for agricultural sources of SRP, then stormwater from all other sources (including both rural residential land uses and municipalities) are likely a substantial source of SRP via stormwater flows.

However, unlike livestock agriculture, stormwater is largely dismissed as a substantial source requiring correction (TATA pgs. 38, 117). A waste load allocation (WLA) is assigned, and testing is required only of actively flowing stormwater pipes and only during the critical time periods. Testing is not required in any open conveyances [ditches] and only during low flow conditions. If no discharge is occurring during low flow conditions or if the discharge meets the specified SRP value (TATA pg. 42), no additional measures are needed.

- Is there a reason why a similar mechanism is not applied to the three identified waterways? If there are no flows or the SRP in the flow meets the allocation, why are implementation measures necessary in that waterway?

Response to Comment # A-4-2 (WSDA):

See response to comment A-4-1 (WSDA) in regard to corrected tributary concentrations. Limited monitoring in these tributaries suggests they definitively can have elevated SRP concentrations when flowing. The Implementation Plan explains (e.g., the *Pollution transport pathways* section) that in a nonpoint context, runoff is typically the chief pathway for dissolved phosphorus to enter surface water. In discussing nutrient sinks, Ecology was simply proposing an additional mechanism for phosphorous storage/delivery. We did not mean to suggest the latter was more significant than the former.

TMDL analysis shows that most of the anthropogenic SRP point source loading to the Lower White River is from Buckley and Enumclaw's wastewater treatment plants discharge. In comparison to *these point sources*, contributions from urban stormwater are smaller during the critical season. The TATA text referenced does not draw comparisons between urban stormwater loading specifically and that from nonpoint sources. It's not possible to manage urban stormwater and nonpoint sources in the same way because pollution origin and transport differs and the former is regulated via permit, the latter is not. Permit authorities and structure provide regulatory options that would be difficult to implement in a nonpoint context. The TMDL acknowledges that urban stormwater is a possible additional source of SRP loading, hence the need for the stormwater WLAs and enhanced inspection and monitoring requirements provided in the TATA.

Comment #A-4-3 (WSDA):

- There is very limited data presented on the flow, pH or nutrients at the mouths of the three identified waterways (TATA Table 1, TATA Tables G-62 and G-65). The table G-62 has only a single date of date[sic] collected in Pussyfoot Creek and two in Second Creek, all collected a decade ago. The data presented in this table do not suggest either are substantial sources of orthophosphate or total phosphorus compared to numerous other listed contributors. Boise Creek has a more robust dataset, but it only consists of eight data points collected on four days in 2012. There is no means to determine if the measures proposed in the TMDL IP result in improved water quality.

Response to Comment # A-4-3 (WSDA):

Ecology appreciates the concern about lack of data on these tributaries. See response to comment A-4-1 (WSDA) in regard to corrected tributary concentrations. Due to resource constraints, we were not able to perform exhaustive monitoring of tributaries for the TMDL. However, the TMDL data we do have supports focusing implementation efforts on the Enumclaw Plateau tributaries. In addition, preliminary data from Ecology's recently started implementation monitoring efforts also appear to suggest continued phosphorus inputs from Pussyfoot and Second Creeks. A demonstration of discharge with significant SRP loading, albeit during limited sampling and not for the full season, necessitates an allocation and load reduction. The White River is very sensitive to nutrient loading and this level of discharge could contribute to an exceedance of maximum pH criteria. The Adaptive Management section of the Implementation Plan details how Ecology intends to assess implementation success.

Comment #A-4-4 (WSDA):

- The highest concentrations of orthophosphate were immediately downstream of a gold[sic] course that is no longer in operation at RM 3.7 (TATA pg. 245).

Response to Comment # A-4-4 (WSDA):

The site referenced is on the White River mainstem, downstream of what was the Sumner golf course. It is unclear how this is related to the tributaries in the Enumclaw Plateau which appear to be the commenter's focus in the preceding paragraph and are quite some distance away.

Comment # A-4-5

The TMDL IP appears to conflate zoning as shown in Figures 1 and 2 with the actual use of land. These maps show "industrial land uses" where there are farms and schools. The bottom of page 2 states that the Middle Watershed is dominated by nonpoint *agricultural* and *onsite septic* pollution sources. Figure 2 shows that by area, Boise Creek is dominated by *forestry* followed by *residential* uses with what appears to be <u>about 5% of the land used</u> for *agriculture*. Pussyfoot and Second Creek watersheds appear dominated by *residential* uses (approximately two-thirds of the land) followed by *agriculture*. Accurately conveying this information is important as it forms the basis of conclusionary statements about dominant sources that then are used to determine the implementation plan.

By IP pg. 6, the document has concluded that livestock agriculture is the apparent ["is thought to be"] dominant nonpoint source of phosphorus in the Enumclaw plateau "given the land uses described earlier." If the land uses more accurately convey the acreage of non-sewered residential development and quantified potential sources, including residential and commercial uses of fertilizer, pet waste, soil disturbance, improperly disposed greenwaste and disturbed soil, a more holistic picture of potential sources would be presented.

Response to Comment # A-4-5

Figures 1 and 2 are meant to provide the reader with a broad, general overview of land uses for introductory purposes, not to serve as the basis for rigorous technical analysis. Due to resource constraints, it was not possible to conduct a sophisticated quantitative analysis of land uses. Consistent with the approach adopted in other Washington State TMDLs, Ecology's decision on where to focus implementation efforts was based on a combination of loading analysis (see Response to Comment # A-4-1), review of satellite imagery, and a knowledge of site conditions gleaned from fieldwork. We acknowledge that zoning does not always clearly articulate land use realties on the ground. For example, many parcels zoned 'residential', house livestock and/or are managed for grazing Agricultural activities are not restricted solely to those parcels zoned for commercial agriculture.

Comment #A-4-6 (WSDA):

IP pg. 10 references irrigation runoff as a likely significant transport vector for phosphorus.

- Is there documented irrigation of farmlands in the Enumclaw area, particularly in quantities sufficient to generate flows in generally dry areas during the summer months?

Response to Comment # A-4-6 (WSDA):

Satellite imagery and visual observation during fieldwork in the Enumclaw Plateau confirm there is irrigation. The text states "During the drier summer months of concern in this TMDL, reduced surficial runoff from rainfall is likely supplemented by irrigation. During the driest periods of late summer, irrigation runoff may be as or more significant a transport vector as precipitation." These statements do not characterize irrigation as likely a significant transport vector, but rather say that it likely supplements precipitation in the dry season and may be more significant at times, a relative description, but only during the driest parts of the summer.

Comment #A-4-7 (WSDA):

IP pg. 11 concluding sentence about groundwater is confusing.

- Is it stating that the reason why groundwater is important is that groundwater with little P allows previously deposited sediment-based P to move into this groundwater?

Response to Comment # A-4-7 (WSDA):

The statement was referencing research showing a significant linear relationship between soil phosphorus and dissolved phosphorus concentrations in runoff. Detail concerning this research was omitted from the main body of the TMDL for the sake of brevity but the Groundwater section under Appendix D provides more detail concerning runoff and groundwater interactions. In summary, research suggests groundwater may significantly increase that phosphorus which is transported via runoff, especially in spring when soils are still wet.

Comment # A-4-8

The implementation plan is intended to provide a rationale for agricultural source control that is likely to include various actions that have real-world costs to individuals, whether OSS or livestock owners, but the basis for conclusions in the document are repeatedly presented as speculative. For example, the Groundwater section (IP pg. 11) includes the following qualifying clauses: research <u>suggests</u>, transport <u>may</u> become (twice), discharge <u>appears</u> to, it's <u>unlikely</u>, and <u>suggesting</u>.

There is nothing in the implementation plan that shows why the specific five management practices were chosen as the mechanisms to reduce loading of SRP to the White River. There are a multitude of other management practices for livestock agriculture that are relevant and not listed. These include the following NRCS practices under the following general headings:

1. livestock exclusion: fence (382), field border (386), filter strip (393), forage harvest management (511), hedgerow planting (422), riparian forest buffer (391), riparian herbaceous cover (390), vegetative barrier (601)
2. tile drainage systems: drainage water management (554), and denitrifying bioreactors (605), subsurface drain (606), underground outlet (620)

3. irrigation runoff: irrigation and drainage tailwater recovery (447), irrigation land leveling (464), and irrigation water management (449)
4. livestock & manure management besides manure storage (313) and nutrient management (590): animal mortality facility (316), composting facility (317), comprehensive nutrient management plan (101 & 102), heavy use area protection (561), roof runoff structure (558), roofs and covers (367), short term storage of animal waste and by-products (318), structure for water control (649), surface drain-field ditch (607), trails and walkways (575), vegetated treatment area (635), waste separation facility (632), waste transfer (634)
5. pasture management (besides waterway exclusion): access control (472), livestock pipeline (516), pasture and hay planting (512), prescribed grazing (528), stream crossing (578)
6. farmland erosion: amending soil properties with gypsum products (333), cover crop (340), conservation cover (327), sediment basin (350)

The Implementation document notes that the five BMPs: manure storage, nutrient management, livestock exclusion, riparian buffers, and OSS tank inspection, repair and maintenance, are considered compliance minimums and “will need to be installed if TMDL nonpoint load reductions are to be achieved” but no evidence is provided to support this statement. Why these five specific management practices, in most cases these practices have one or more supporting practices required for successful implementation.

Response to comment # A-4-8

As noted in Response to Comment # A-1-5, resource constraints precluded a detailed analysis of nonpoint source contributions and land uses. The BMPs in the implementation plan are tried and tested practices known to be effective at controlling nutrient inputs. Furthermore, many of these recommendations are consistent with those made in other Washington State TMDLs, and the guidance Ecology’s nonpoint inspectors already provide during technical assistance visits.

The five BMPs described as compliance minimums are those research and field experience suggest are most effective at addressing typical nutrient sources. The NRCS codes provided in the TMDL represent those practices the authors deem most closely aligned with the BMPs discussed in the TMDL. NRCS codes and other BMP details given in the TMDL were kept to a minimum for the sake of brevity. Our general intent was to provide a broad overview and direct those readers wanting more detail to an alternate resource, rather than duplicate existing materials. The authors understand that BMPs are typically implemented holistically, in combination, rather than singularly, and we did not intend omission to be interpreted as exclusionary or prohibitive.

Comment # A-4-9

The prioritization of stream reaches upon fecal coliform bacteria (FCB) loadings identified in the 2006 Puyallup Fecal Coliform TMDL presumes FCB correlates with [sic] well with SRP. I was unable to locate evidence in the TMDL documents to corroborate this presumption.

Phosphorus from commercial fertilizer use on lawns and landscaped areas including school and golf turf including in stormwater systems that discharge to Boise Creek would not correlate to FCB, nor would soil disturbance of the increase in impervious surfaces that increases sedimentation and runoff that will include phosphorus from a wide variety of anthropogenic activities. On-site septic systems are not designed to substantially treat dissolved nutrients including SRP, and any effluent from drainfields that enters drainpipes or discharges directly to surface waters could but would not necessarily contain FCB. It seems likely that many gravity systems installed in Enumclaw's poorly drained soils are seasonal sources of nutrients to surface waters.

Response to Comment # A-4-9

Because TMDL implementation resources are also limited, correction activities must be prioritized to be most effective. Due to resource constraints, the TMDL was unable to sample SRP in tributaries upstream of the mouths. The TMDL uses bacteria data in lieu of SRP data for prioritization purposes only, because our field experience suggests the types of practices typically responsible for bacterial exceedances are often similar to or the same practices responsible for nutrient inputs. The authors do not assume quantitative correlations, rather we contend it is reasonable to expect the absence of the key BMPs identified in the TMDL where bacterial inputs are higher. Ecology acknowledges that this may not be the case in urban areas for the reasons the commenter mentions, however the focus of nonpoint implementation efforts in this TMDL is the *rural* Enumclaw Plateau.

Comment #A-4-10

Priority parcels shown on IP Figure 7 do not take into account the existing known and mapped public and private ditch system to these waterways. A much wider network of waterways acts as conveyances in these watersheds. The map does not accurately depict the watershed boundaries of the branch of Second Creek or the extent of Pussyfoot Creek. IP Figure 9 is outdated and shows several properties with OSS that have been converted to urban residential development in Enumclaw.

Response to Comment# A-4-10

The TMDL Implementation Plan acknowledges that artificial drainage can serve as a conduit for nutrients, sometimes bypassing streamside BMPs (see the Artificial Drainage subheading under the Pollution Transport Pathways section), and the TMDL warns implementers to be on the lookout for these conveyances when in the field. However, given the extent of the ditch system in the Enumclaw Plateau, expanding geographic priorities to include all areas draining to these ditches would likely include most of the Plateau, defeating the purpose of prioritization. The authors contend that all things being equal, parcel proximity to streams remains the most useful prioritization tool for nonpoint inspection purposes, because research suggests surficial runoff from adjacent land is the primary nonpoint SRP transport pathway.

GIS hydrography is the basis for the watershed boundaries in Figure 7. The authors acknowledge that GIS layers are not always accurate, especially at a fine scale. However, this was the best information available at the time of writing. We understand that the status of

OSS has evolved since Figure 9 was created several years ago and is no longer accurate, we have added a clarifying footnote, see our Response to Comment #A-1-15.

Comment #A-4-11

As noted, the IP focuses on three watersheds, ignoring the remaining areas in the Lower White River that contribute 77-83% of the SRP as noted in Table 2 (pg. 7). From data presented in the TATA, it appears that other waterways and, perhaps, groundwater conveyances, are the dominant source of SRP entering the White River. It seems like the proposed IP places a substantial burden on a limited set of property owners to implement management practices that their neighbors will not be required to implement. Without an IP that asks everyone to contribute to the solution, my experience is that there will be little public buy-in to the proposed plan.

Response to Comment #A-4-11

We suspect the commenter is referencing *total* SRP loading, which includes natural loading. The focus of the TMDL's corrective efforts is on reducing excess human-made nutrient inputs only. As explained in Response to Comment #A-4-1, from Table 2 of the Implementation Plan, the combined *anthropogenic* nonpoint SRP loading from the Enumclaw Plateau tributaries is roughly 40% of the total for the entire TMDL project area in both low and medium flow conditions. Furthermore, satellite imagery and fieldwork confirm this is an agricultural hub, therefore the authors contend it is appropriate to focus nonpoint corrective efforts here. Commercial and industrial point source discharges in the urbanized lower watershed are regulated by permit, and much of the diffuse runoff here is captured by municipal stormwater infrastructure, also regulated by permit. Forestry activities in the upper watershed must follow state Forest Practice Rules. In contrast, with few exceptions the agricultural activities in the rural middle reaches are largely unregulated, governed neither by permit nor subject to industry specific rules. In addition, the protections offered under state law (i.e. RCW 90.48) lack the detail needed to guide site-specific BMP application. The Implementation Plan focuses on agricultural activities because the relative paucity of existing guidance and lack of regulatory structure necessitates it. The Implementation Plan explains that *all* properties adjacent to the tributaries in question are expected to implement the BMPs prescribed (see the Parcel Scale subheading under the Priorities section, the Reasonable Assurances section, and Appendix L), therefore concerns regarding inequitable application are unfounded.

Comment #A-4-12

Regarding costs estimates (IP Table 10 pg. 32), the estimated costs of various practices does not appear to include any ongoing operation and maintenance costs associated with the listed practices, not any costs of foregone income from the specific practice of riparian buffers that would convert agricultural lands to habitat.

For a 2022 TMDL with a 10-year life, the cost estimates should be based upon more recent (2022) costs: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/?cid=nrcseprd1328418

Based upon costs listed, *Manure storage structures* as a management practices appears to assume no livestock operation needs new or additional liquid manure storage in a tank or earthen structure. Such facilities typically cost in excess of $300,000 and require associated pipelines, pumps, and ongoing operations and maintenance.

The document misunderstands the term <u>nutrient management</u> as a practice standard (590). As used in NRCS PS 590, it is simply defined as good agronomy, or the use of appropriate source of crop nutrients used in the right amount, at the right time and correctly placed to support crop growth and avoid environmental impacts. A nutrient management <u>plan</u>, by comparison, is the process and document that describes the systems, infrastructure, land and decision making needed to implement good nutrient management. It is reasonable to assume the cost associated with the development of a plan is a once every decade cost while the cost of nutrient management is ongoing and involves an ongoing labor and equipment cost.

- Does livestock exclusion fencing include the estimated cost of appropriate livestock crossings where needed?

Finally, the IP appears to assume that management measures can be paid for and installed once but that there is no requirement to operate and maintain them in perpetuity, or at least there is no cost associated with the ongoing responsibilities of the five BMPs. Solving nonpoint pollution sources only occurs when the public understands the problem, understands their role in the solution, and believes they are working with the entire community on a sustainable solution.

Thank you for the opportunity to comment on the proposed TMDL plans. Despite concerns about the process used to reach the conclusions presented in the IP, WSDA's Dairy Nutrient Management Program (DNMP) is well aware that numerous livestock operations in the Enumclaw area, including dairies, have management practices that fall short of protecting water quality. The DNMP is committed to working with the farms we inspect and regulate to provide meaningful technical assistance as well as a regulatory backstop when there is evidence of discharges that violate state water quality laws. The DNMP would like to work with Ecology and other partners on improved livestock practices that can improve water quality and, in some cases, also improve livestock health and productivity. Such work requires the development of relationships and trust with land owners and managers along with working through often challenging bureaucracies to obtain funding assistance.

Response to Comment #A-4-12

The costs presented in the Implementation Plan are *estimates* based on fairly rudimentary calculations as explained in the Costs section. The numbers provided are not meant to be the basis for sophisticated economic analysis. They serve primarily to provide a simple, brief overview of *relative* implementation effort, to prioritize implementation tasks, and speak to general feasibility. The omissions underscored and the issues the commenter raises (e.g. lost revenue and long-term maintenance costs) imply a detailed and comprehensive cost calculation effort beyond the scope of the TMDL and out of step with the stated purpose.

Ecology acknowledges that some of the cost estimates provided in the Implementation Plan may no longer be accurate (see Response to Comment #A-1-12). However, given the above purpose and that current inflationary pressures mean costs will likely continue to change quickly in the short-term, the authors see limited value in an exhaustive revisionary effort now. For the sake of transparency, text has been added to the section clarifying the above.

Appendix C. Glossary, Acronyms, and Abbreviations

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.

Analyte: Water quality constituent being measured (parameter).

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

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

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

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

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.

Exceeded criteria: Did not meet criteria.

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

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.

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.

Non-runoff conditions (in context of this TMDL only): Between May 1st and October 31st when local measurable precipitation is less than 0.2 inches in the preceding 48-hour period.

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

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

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

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

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

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or 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.

Runoff conditions (in context of this TMDL only): Between May 1st and October 31st when local measurable precipitation is greater than or equal to 0.2 inches in the preceding 48-hour period.

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

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

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

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

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

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.

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.

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

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.

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

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

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

System potential: The design condition used for TMDL analysis.

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

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

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

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

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

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

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every 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.

Acronyms and abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMPs	best management practices
cfs	cubic feet per second
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
LWR	Lower White River
MIT	Muckleshoot Indian Tribe
NAF	new approximation flow
NPDES	National Pollutant Discharge Elimination System
RM	river mile
SRP	soluble reactive phosphorus
TMDL	total maximum daily load (water cleanup plan)
USGS	United States Geological Survey
WRIA	Water Resources Inventory Area
WWTP	wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cms	cubic meters per second, a unit of flow.
dw	dry weight
ft	feet
g	gram, a unit of mass
km	kilometer, a unit of length equal to 1,000 meters.
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
s.u.	standard units
µg/g	micrograms per gram (parts per million)
µg/L	micrograms per liter (parts per billion)
µS/cm	microsiemens per centimeter, a unit of conductivity

Appendix D. Analytical Framework

Approach

Ecology used the QUAL2Kw 6.0 modeling framework (Pelletier and Chapra, 2008), in conjunction with other tools, to develop the loading capacity for nutrients and to make predictions about water quality under various scenarios (see Appendix I for details). Ecology used three main analytical tools, described in detail in this appendix, as the basis for the TMDL analysis:

1. Low Flow QUAL2Kw model (Low Flow model)
2. Medium Flow QUAL2Kw model (Medium Flow model)
3. Seasonal hatchery and WWTP loading spreadsheet (Seasonal Load Estimates)

The QUAL2Kw water quality model was used to dynamically simulate the effects of nutrients on periphyton growth and, in turn, pH in the White River over an 89-day period from August 2 to October 30, 2012. It was calibrated to existing conditions based on data collected in 2012. Although it starts in August when flows are moderate, the most critical conditions in the model occur during early October when flows are lowest. This model is hereafter referred to as the "Low Flow model." Ultimately, the calibrated Low Flow model was used to estimate the assimilative load capacity for inorganic phosphorus (hereafter referred to as SRP) in the White River, which is the basis for load and WLAs assigned in this TMDL for low flow critical conditions.

After the TMDL study was completed in 2012, data collected by USGS in 2014 and 2015 revealed a previously unobserved critical condition during the spring (May/June), when loading is greater, and flows are moderate (~1,000-1,500 cfs). Because the original model did not capture these months, a subset of the Low Flow model (from Aug 2 to 17) was altered to test the load capacity under moderate flows similar to those that occur during the spring critical condition (Figure D-5).

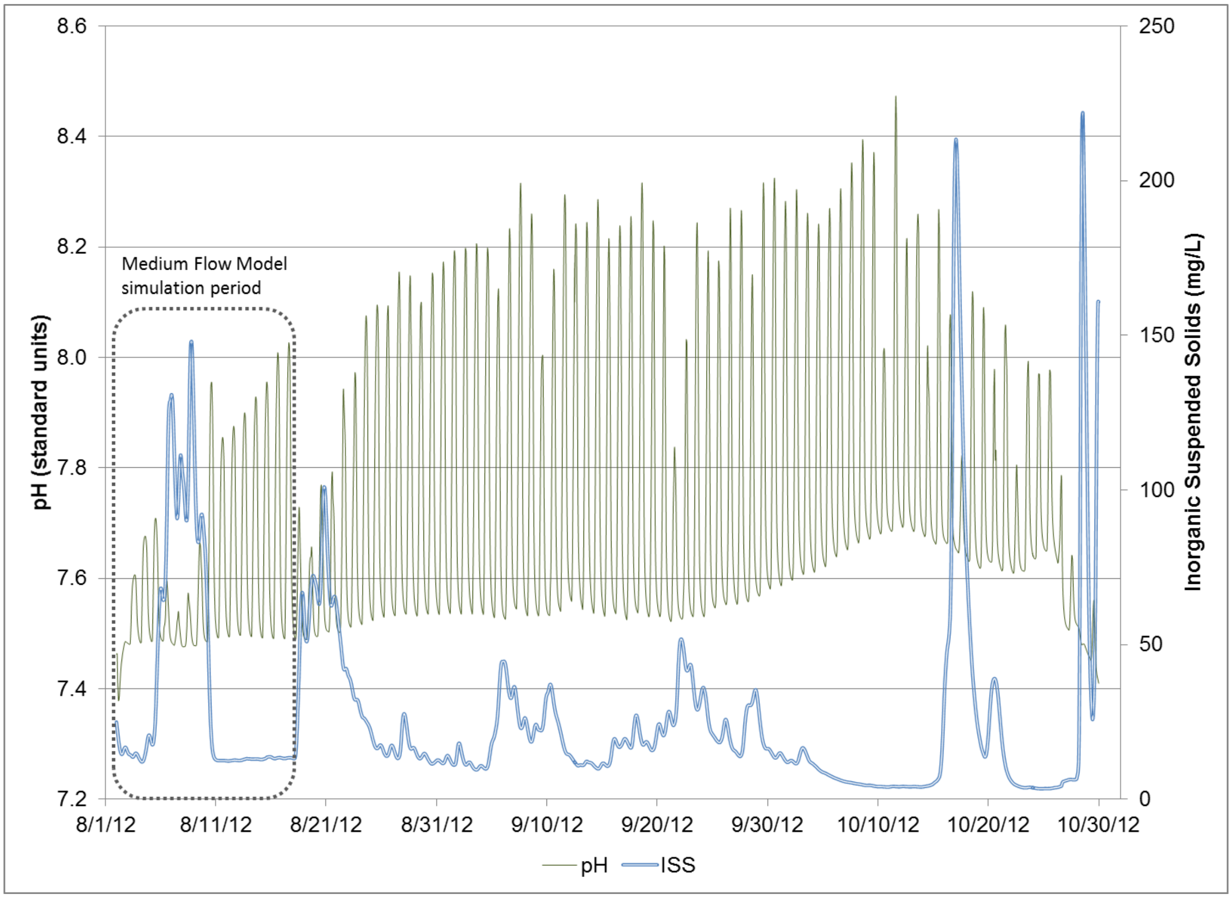

Figure D-5. The "Medium Flow Model" simulation period, a subset of the QUAL2Kw model used to determine load capacity under medium flow conditions.

This period was selected because the flow and turbidity are similar to what is often seen during spring conditions. This model is hereafter referred to as the "Medium Flow Model" and provides the basis for load and wasteload allocations assigned in this TMDL for medium flow critical conditions. Monitoring and modeling results show that SRP concentrations likely have little to no influence over periphyton growth in the White River when the river flow is above 2,000 cfs (see *Seasonal Variation and Critical Conditions*). This is due to decreased SRP concentrations due to dilution, increased periphyton scouring (loss), and increased water depth at these flows (which reduces the light available to periphyton for growth).

Given the White River has very different assimilative capacities of SRP at different flow conditions, as described in the previous paragraph, the TMDL evaluates load capacity and allocations in this TMDL for three separate flow tiers:

- Low Flows: Less than 900 cfs
- Medium Flows: Between 900 and 2,000 cfs
- High Flows: Greater than 2,000 cfs

A seasonal hatchery and WWTP loading spreadsheet, hereafter referred to as "seasonal load estimates" was also created to develop dynamic SRP loads for the major point sources from

May 1st to Oct 31st. The spreadsheet loads are based on monitoring data and assumed loading under various treatment scenarios. This spreadsheet was used to a) develop loading inputs for TMDL scenarios in the QUAL2Kw models and b) assess whether seasonal average limits could be met under variable seasonal flow patterns.

Appendix E (TMDL analysis) provides more detailed documentation of how load capacity and allocations were developed. Appendix I describes the modeling framework, inputs, calibration, and error/sensitivity analysis in detail.

Model Overview

The Low Flow model

The QUAL2Kw v6.0 model framework and complete documentation are available at Models & tools for TMDLs - Washington State Department of Ecology[7]. Unlike previous versions of QUAL2Kw, version 6 is capable of simulating a river continuously throughout the course of a season or year. This is useful because it allows one model scenario to simulate conditions during different parts of the critical season, and to be calibrated to multiple datasets collected at different times.

QUAL2Kw was used to model the lower reaches of the White River from just below Mud Mountain Dam (RM 28) to its confluence with the Puyallup River (RM 0).

Appendix I describes the modeling framework in greater detail. In general Ecology:

- Used the U.S. Army Corps of Engineers computer model, the Hydrologic Engineering Centers River Analysis System (HEC-RAS), to develop the channel geometry for the QUAL2Kw model.
- Used the Oregon Department of Environmental Quality (ODEQ) and Ecology's TTools extension for ArcView (Ecology, 2015) to process GIS data for input to the shade model.
- Used Ecology's Shade.xlsm model (version 40b04a06; Ecology, 2015c) to estimate effective shade along the mainstem of the White River.
- Collected/compiled time series data and developed time series records from discrete data using linear interpolation or regression.
- Populated the QUAL2Kw model with time series data records and outputs from the HEC-RAS and Shadel.xlsm models.

Figure D-6 depicts a conceptual diagram of the modeling inputs and framework.

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[7] https://ecology.wa.gov/Research-Data/Data-resources/Models-spreadsheets/Modeling-the-environment/Models-tools-for-TMDLs

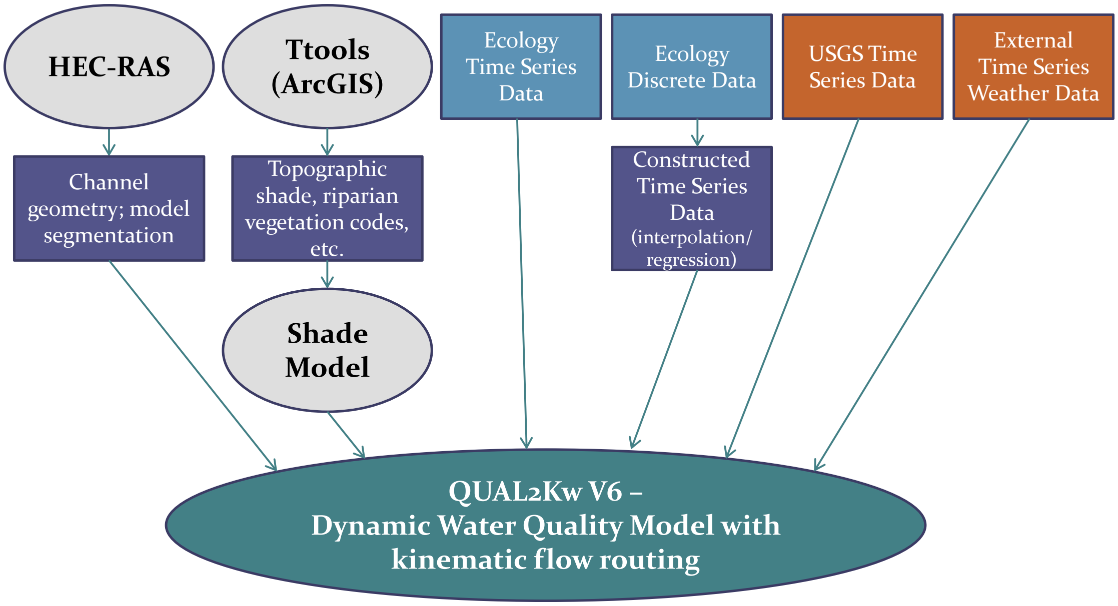

Figure D-6. Conceptual diagram of the modeling inputs and framework.

QUAL2Kw V6 is an appropriate choice for determining the nutrient loading capacity for the TMDL for multiple reasons including that the model is:

- Capable of simulating advanced periphyton dynamics including growth, respiration, scouring, nutrient/light/temperature limitation, and (importantly) internal cell nutrient concentrations and quotas.
- Capable of simulating dynamic conditions for a full periphyton growth season, including flow, temperature, and (importantly) solar radiation/shade. An hourly time series input may be used for each reach of the model.
- Well-documented and routinely used for nutrient TMDL development in EPA region 10.
- Actively enhanced and maintained by Greg Pelletier, a member of Ecology’s modeling staff.

There are three scenarios/versions of the Low Flow Model:

- Existing conditions (sometimes referred to as scenario A in project documentation)
- Natural conditions (referred to as scenario B17)
- TMDL allocations (referred to as scenario F28)

The Medium Flow model

The Medium Flow model is a subset of the Low Flow model that starts on Aug 2nd and is unaltered from the Low Flow model through Aug 8th. This allows the model to “equilibrate” from initial conditions and allows periphyton growth/loss to stabilize.

The model is then run from Aug 9th to 17th during a period of relatively steady flow of ~950 cfs. During this period the model is altered by reducing inorganic suspended solids (ISS) concentrations to a consistently low value to reduce light limitation.

This represents a critical condition for the medium flow tier (900 – 2,000 cfs). Loading from various sources is increased for the whole model period to test the load capacity at medium flow.

There are two scenarios/versions of the Medium Flow Model:

- Natural conditions (referred to as scenario B18)
- TMDL allocations (referred to as scenario F29)

The results of the TMDL allocations scenario are compared to the results from the natural conditions scenario to determine the amount of SRP load that causes a 0.2 change (from natural) at these flow conditions. It is important to note that this results in a maximum pH near 8.0 (below numeric criterion of 8.5) on August 17th in the TMDL allocations scenario.

Seasonal Load Estimates

Hourly time series loads were developed for the WWTPs and fish hatcheries in an Excel spreadsheet for the full periphyton growth season, May 1st to Oct 31st. The spreadsheet also contains White River flow data for several years including 1994 (critical low flows), 2012 (study year), and 2014 (lower spring flows).

For the hatcheries, loading scenarios were taken from a report developed by the Muckleshoot Indian Tribe (MIT) titled: *Summary Evaluation of Potential Soluble Phosphorus Loads from Fish Hatcheries for the Lower White River Cleanup Plan* (MIT, 2019).

Ecology developed WWTP loading scenarios using:

- Phosphorus data collected by the Enumclaw WWTP while utilizing EBPR treatment for the years of 2011-2015.
- Estimated treatment capability from an additional treatment step of adding a chemical coagulant (such as aluminum phosphate, aka alum), followed by settling in an additional clarifier.

Details and assumptions for this alum treatment, hereafter referred to as chemical polishing, were obtained from technical memorandums prepared by Esvelt Environmental Engineering for the cities of Enumclaw and Buckley titled:

- Soluble Reactive Phosphorus Removal Alternatives: Range of Potential Performance Expectations (Esvelt Environmental Engineering, 2016).
- Cities of Enumclaw and Buckley Wastewater Treatment Plant Response to Ecology - Soluble Reactive Phosphorus (SRP) Discharges from WWTPs (Esvelt Environmental Engineering, 2017).

The spreadsheet can be filtered by date (for input into QUAL2Kw models) or by flow range (to average phosphorus loading by flow tier).

Nutrient Limitation

Periphyton growth is the primary cause of high pH in the White River. Thus, the degree, if any, to which nutrients limit periphyton growth, is an important assumption in the model. Numerous factors can limit or stimulate growth of periphyton in rivers and streams, including available light and nutrient supply, temperature, grazing and excretion from primary consumers, as well as changes in velocity or mobilization of substrate (Larned, 2010). When nutrient limitation is evident, one theory is that periphyton growth follows Liebig's Law of the Minimum and that the nutrient in shortest supply controls growth, typically either nitrogen (N) or phosphorus (P), although carbon, silica, iron, and other micronutrients can potentially also limit growth (De Baar, 1994).

Many recent studies of nutrient limitation in freshwater systems have indicated co-limitation of autotrophic organisms through response to nutrient enrichment of both N and P simultaneously. Several meta-analysis studies of nutrient enrichment experiments have found little evidence of single nutrient limitation in freshwater and terrestrial systems (Elser et al 2007, Harpole et al, 2011, Bracken et al, 2015); but, rather, that both N and P generally limit primary production, either through biochemically dependent co-limitation or community co-limitation.

Based on nutrient and periphyton data collected in the White River, it is unclear whether N, P, or both nutrients limit periphyton growth during the critical season, which includes a dynamic range of growth conditions.

Another complicating factor is that when nitrogen or phosphorus concentrations reach levels that saturate periphyton growth rates, neither N nor P will be limiting, regardless of the ratio. Bothwell (1985) demonstrated that diatom growth rates could be saturated at ambient levels of phosphorus as low as 3-4 ug/L SRP. However, other researchers have observed diatom growth rate saturation at ~16 ug/L SRP (Rier and Stevenson, 2006) and ~25 ug/L SRP (Hill et al., 2009). Rier and Stevenson (2006) also found that diatom growth rates saturated at ~86 ug/L DIN.

In the 2012 study, SRP concentrations ranged from 8.2 to 17.1 ug/L, with medians around 12 ug/L in the areas with the highest pH values; this falls between the upper and lower potential saturation points from the literature. In 2012, median DIN concentrations were approximately 60 ug/L in the most critical segments of the TMDL reach. Ecology performed a study in the mid-1990s which observed that pH levels above 9.0 could occur at nitrogen levels as low as 17 ug/L and phosphorus levels as low as 11 ug/L (Erickson, 1999). The study suggested that this finding indicates there is no evidence of nutrient limitation at these low levels but acknowledged that the periphyton photosynthesis may have been driven by previously stored nutrients, as ambient concentrations were not always low during other sampling events.

Definitive empirical evidence of nutrient limitation is difficult to obtain, due to the challenges in isolating other factors while measuring limitation in situ. Many researchers have used a type of bioassay known as nutrient diffusing substrata (NDS) to assess periphyton nutrient limitation in stream (Francoeur, 2001).

The NDS provide an artificial nutrient-enriched substrate for periphyton to colonize. Four NDS are typically deployed per site: one control with no nutrient enrichment, one N-enriched, one P-enriched, and one enriched with both N and P. Periphyton biomass is measured frequently over the course of a growing period and growth rates are calculated. Significant differences from the control indicate N, P, or co-limitation, while no difference indicates growth rate saturation. While NDS are affordable and commonly used tools, one NDS method comparison study found that the limiting nutrient identified could vary based on the method used (Caps et al., 2011).

Near-stream or in-stream, nutrient-enriched experimental troughs have also been used to study limitation (Peterson et al., 1983; Bothwell, 1985; Grimm and Fisher, 1986). These likely provide a more controlled experimental setting than NDS but are more costly to construct and logistically challenging to deploy.

Ecology did not conduct an in-stream nutrient limitation study for the TMDL due to resource limitations and the uncertainty in the potential results, particularly for NDS. A future in-stream trough experiment in the White River, as an adaptive management action, could provide valuable information about nutrient limitation and growth rate saturation.

In 2000, Eugene Welch, Professor Emeritus at University of Washington and internationally recognized expert on periphyton, was asked to provide input on nutrient limitation and periphyton growth in the White River. He concluded that the river was probably nitrogen limited but should be managed for phosphorus reductions in wastewater effluent inputs (Ecology, 2000). Stuart (2002) supported this conclusion suggesting that "phosphorus is the nutrient which should be targeted for nutrient controls in the WWTPs."

Phosphorus, compared to nitrogen, is more easily managed in both wastewater effluent and the environment because it can sorb to particulate matter in the water column and to iron or other metals in sediments, which is not the case for DIN. In addition, effluent SRP levels can more easily be reduced to near in-stream background levels; whereas, even with significant treatment improvements, effluent DIN is often 100x higher (3- 5 mg/L) compared to background concentrations in the White River.

The conclusions of Welch, recommendations from previous studies (Erickson, 1999; Stuart 2002), and the likelihood of some level of co-limitation led Ecology to pursue a model calibration where some level of phosphorus limitation occurs in response to reductions in phosphorus loading.

Ecology calibrated the Lower White River model in a manner that provided an optimal goodness of fit with observed data and in which the predicted nutrient limitation reflected the ambiguity of nutrient limitation in the river and allowed for the likely possibility of co-limitation under critical conditions. Appendix F (2012 Study Results), Appendix I (Model Documentation), and Appendix J (Historical Data) contain further information on nutrient limitation in the White River.

Model inputs and assumptions

Ecology used the following key data inputs and assumptions to build the TMDL models.

The Low Flow model

A more complete documentation of model inputs and assumptions is included in Appendix I. Key data inputs to the existing conditions version of the model include:

- Continuous water quality (pH, temperature, DO, and specific conductance) collected by Ecology at RM 28 and 3.7 and by USGS at RM 24 and 7.6.

- Continuous flow and turbidity data collected by USGS at RM 24 and 7.6.
- Additional 2012 data collected by Ecology:
  - Discrete nutrient and water quality data from 4 intensive surveys.
  - Periphyton biomass and light extinction data.
  - Groundwater quality data.
  - Water/air temperature, riparian tree height, and shade data.
- Meteorological data collected by Ecology, NWS, and WSU Puyallup.

The natural conditions scenario of the Low Flow model contains the following key changes to data inputs:

- Channel geometry in the model was altered to estimated geometry based on a pre-levee survey (1907) of the river.
- A new shade analysis was conducted with riparian trees at system potential height and density within a 150 ft buffer of the White River's near stream disturbance zone. System potential riparian shade from this new analysis was included in all reaches of the White River, as well associated microclimate effects (reduced air temperatures). This analysis included altered channel widths and near-stream disturbance zone, based on a pre-levee survey (1907) of the river.
- Reductions in boundary condition temperature and nutrient loads.
- Removal of point sources including WWTPs, hatcheries, and stormwater inputs.
- The estimated anthropogenic nonpoint phosphorus loads were removed from surface and groundwater tributary inputs.
- Upstream boundary flow was reduced to critical 7Q10 low flow conditions.

The TMDL scenario of the Low Flow model contains the following key changes to data inputs:

- Reductions in boundary condition temperature and nutrient loads.
- Hatchery loads (from spreadsheet) based on estimated future fish production and industry standard or optimized hatchery phosphorus removal treatment, for August 2nd to October 30th.
- WWTP loads (from spreadsheet) based on estimated treatment efficiency from adding 100 gpd of alum.
- Anthropogenic nonpoint phosphorus loads are reduced by 25% in surface water tributary inputs but were not reduced in groundwater loads.
- Upstream boundary flow was reduced to critical 7Q10 low flow conditions.
- Added small stormwater loads for each permitted source/entity.
- Channel geometry was restored to natural conditions for two model reaches at ~RM5-6 based on a recently completed levee setback and floodplain restoration project.

Key model assumptions for the Low Flow model include:

- The channel is well mixed and can be represented in a one-dimensional model.
- Photosynthesis and respiration from periphyton are primarily responsible for daily swings in pH.
- During periods of lower flow and turbidity, periphyton is primarily limited by a single limiting nutrient at any given time, either phosphorus or nitrogen, depending on whichever nutrient is currently in the shortest supply relative to the cellular needs of the periphyton.
- Chronic and acute scour is a significant source of periphyton loss, particularly during rapid and large increases in flow (i.e., runoff events, dam releases).

The Medium Flow model

Inputs to the Natural Conditions and TMDL Allocations versions of the Medium Flow model are identical to the Low Flow model versions with the following exceptions:

- Both scenarios:
    - The boundary condition ISS values for 8/9/12 to 8/17/12 were reduced to a constant 20 mg/L, a value that represents a relatively clear river for Medium Flow months, to create a critical medium flow condition (Figure D-7). This results in ISS values of ~12-13 mg/L in the downstream reaches (~RM 5 to 11).
- TMDL Allocations version:
    - Hatchery loads were increased above the low flow model levels.
    - WWTP plant loads were also increased above the low flow model levels. These loads were increased to reflect less efficient alum dosing at higher effluent flows and the challenge of consistently maintaining biological phosphorus removal at high flows and during shoulder months (May and October).
    - Nonpoint surface water loads were increased by ~75% to reflect increase in flows/loads from tributaries at higher river flows.
    - Stormwater loads were increased by a factor of ~10 to reflect the increase in precipitation and runoff at higher river flows.

Further details on load capacity numbers and allocations are contained in Appendix E.

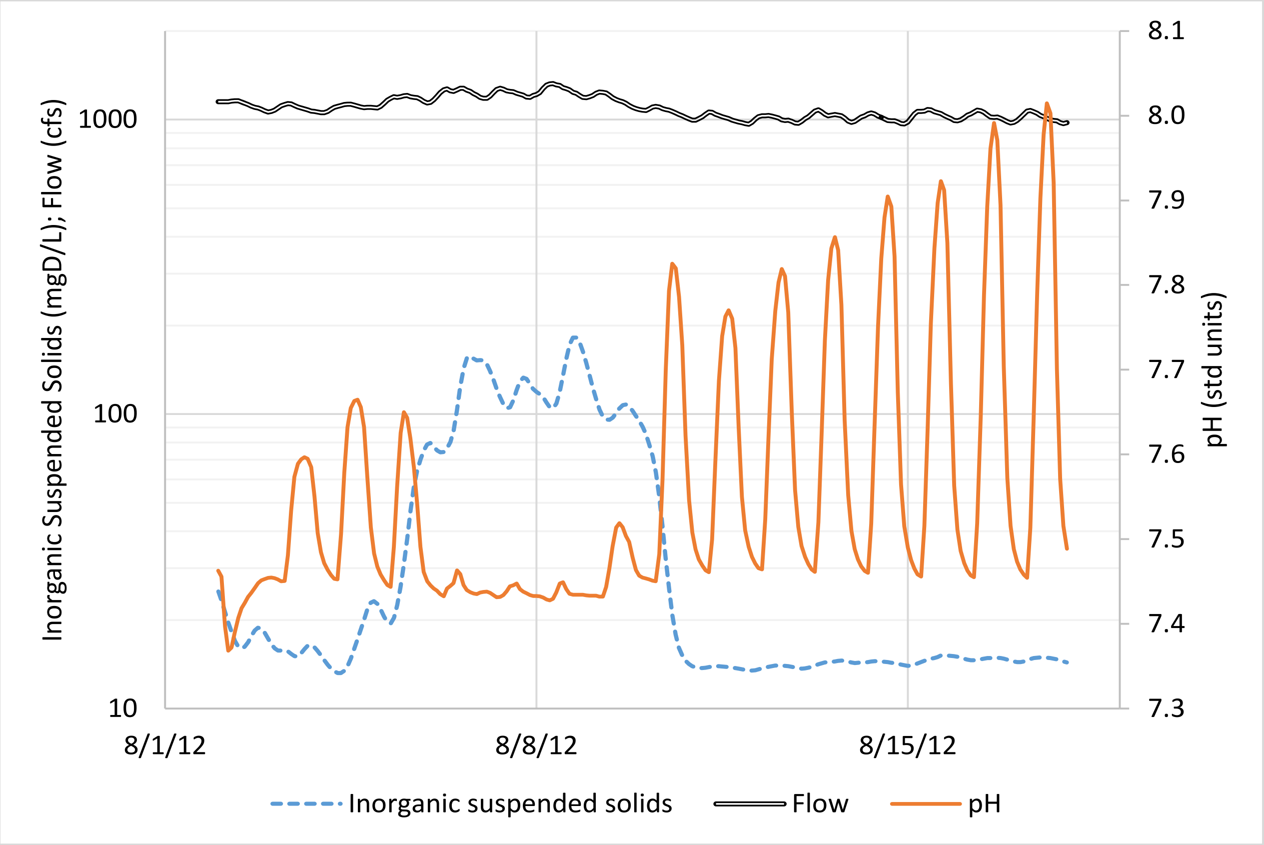

Figure D-7. Inorganic suspended solids, flow, and pH in the Medium Flow TMDL allocations model (at model reach 27).

Seasonal Load Estimates

Key data inputs for the WWTP seasonal load estimates include:

- Effluent flow data obtained from DMR reports and via email (Woodbury, 2017) for the city of Enumclaw WWTP.
  - 2012 daily flows were increased by ~50% (2% population growth over 20 years) to represent future flows.
- Total and soluble reactive phosphorus data collected by the Enumclaw WWTP from 2011-2016 using biological phosphorus removal treatment obtained via email (Esvelt, 2016).
  - 2012 phosphorus data from Enumclaw was the primary input, given it was collected during the Ecology study year and included a biological treatment upset during critical conditions.
- Total and soluble reactive phosphorus data collected during a pilot study (Esvelt EE, 2014) of phosphorus removal treatment options conducted at the Spokane WWTP and obtained via email (Esvelt, 2016). Data from the tertiary chemical polishing and settling option was used (Pilot units S1 and S2).

Key assumptions for the seasonal load estimates include:

- For WWTPs:
    - Phosphorus removal based on linear regression between the influent molar ratio of total phosphorus to aluminum (alum dose) and treated effluent SRP concentration from pilot study.
    - This removal efficiency was reduced by 4 (low flow) and 25 (medium flow) times from the pilot study to provide a margin of safety based on scaling up treatment and implementing at a site specific WWTP.
    - Molar ratio of total phosphorus to aluminum based on a constant alum feed rate of 100 gals/day.
    - This equates to two 350 gallon totes a week, which is the current storage capacity at the WWTPs.
- For hatcheries:
    - A future satellite hatchery near Coal Creek using water rights obtained in an agreement with the City of Auburn (3.9 cfs).
    - Future increase in Chinook salmon hatchery production.
    - Future production of Coho salmon.
    - Phosphorus removal based on industry standards and optimal treatment as described in the report (MIT, 2019).

Seasonal Variation and Critical Conditions

The federal Clean Water Act Section 303(d)(1) requires that TMDLs "*be established at the level necessary to implement the applicable water quality standards with seasonal variations*." The implementing regulations also state that determination of "*TMDLs shall take into account critical conditions for streamflow, loading, and water quality parameters*" [40 CFR 130.7(c)(1)].

As previously mentioned, there are two separate and different critical conditions that occur in the White River: 1) moderate flows and high loading (typically in May or June) and 2) low flows and moderate loading (typically in September or October).

The TMDL addresses seasonal variations in two ways:

1. By assigning variable load and wasteload allocations based on the flow conditions in the river, which addresses the different load capacities at different times of the season.
2. By evaluating dynamic loads over a longer period of time in the model and averaging loads over the course of the entire season, which reflects the fact the periphyton accumulation occurs over a period of weeks or months.

Periphyton growth and changes in diel pH in the White River are dependent on a number of factors including river flow (shallow depths, stable velocities, scouring events), available light (solar radiation and turbidity), nutrient loading, air and water temperatures, and algal biomass (recent growth). Given the complexity of these conditions, periods of steady algal growth are typically limited to 3 weeks or less at a time.

The following provides a description of flow, turbidity, and algal growth in the White River during a "typical" year:

- January through April – Frequent small to moderate precipitation events, coupled with one or more extreme precipitation events, result in catastrophic periphyton scour. Turbidity is intermittently high due to heavy runoff volumes and rain-on-snow events. During periods of low turbidity, the deeper water depths, weaker incoming solar radiation, cooler temperatures, and lack of standing periphyton crop (biomass) typically result in little to no algal growth/productivity and relatively small variations in diel pH.
- May through June – The combination of high-elevation snowmelt and fairly frequent precipitation events keep river flows elevated and provide a fairly consistent source of turbidity to the water. Solar radiation is strong, but clear sunny days are limited in the study area. Algal growth typically remains limited.
- July to Mid-September – Solar radiation is strong, ambient air temperatures are at their annual peak, and sunny days are frequent; however, these conditions lead to increased melting of glaciers on Mount Rainier. This sustains flow and provides the “white” glacial turbidity for which the river is named. Algal growth remains limited, although there are some small windows of less turbid conditions that allow for minor periphyton accrual.
- Mid-September to Mid-October – When high elevation temperatures begin to cool off, the glacial melt subsides, and the river clears up. This phenomenon generally aligns with the lowest flows of the year. Most commonly this is the window where rapid algal growth occurs, and exceedances of the pH water quality criteria are possible.
- Mid-October through December – Very large precipitation events result in catastrophic scour events and an order of magnitude increase in flow. The first large event typically reduces the standing periphyton crop, to the point where productivity/growth is limited and pH criteria are met, even if stable low-flow conditions return for a period of time.

Less commonly, the timing of the conditions that result in pH exceedances can occur earlier (for example during a cool late summer when glacial melt halts early) or later (for example during a very dry fall where there are no major precipitation events in October or November).

Spring/ Medium Flow Critical Conditions

In a mild, dry year with low snowpack and little precipitation, conditions that result in pH exceedances can occur in the spring, as early as May. This is primarily the result of the lack of high elevation snowmelt that typically maintains turbid conditions in the river at this time.

The spring of 2015 is an example of such a year, where pH exceedances occurred in May, before glacial melting on Mount Rainier began (Figure D-8).

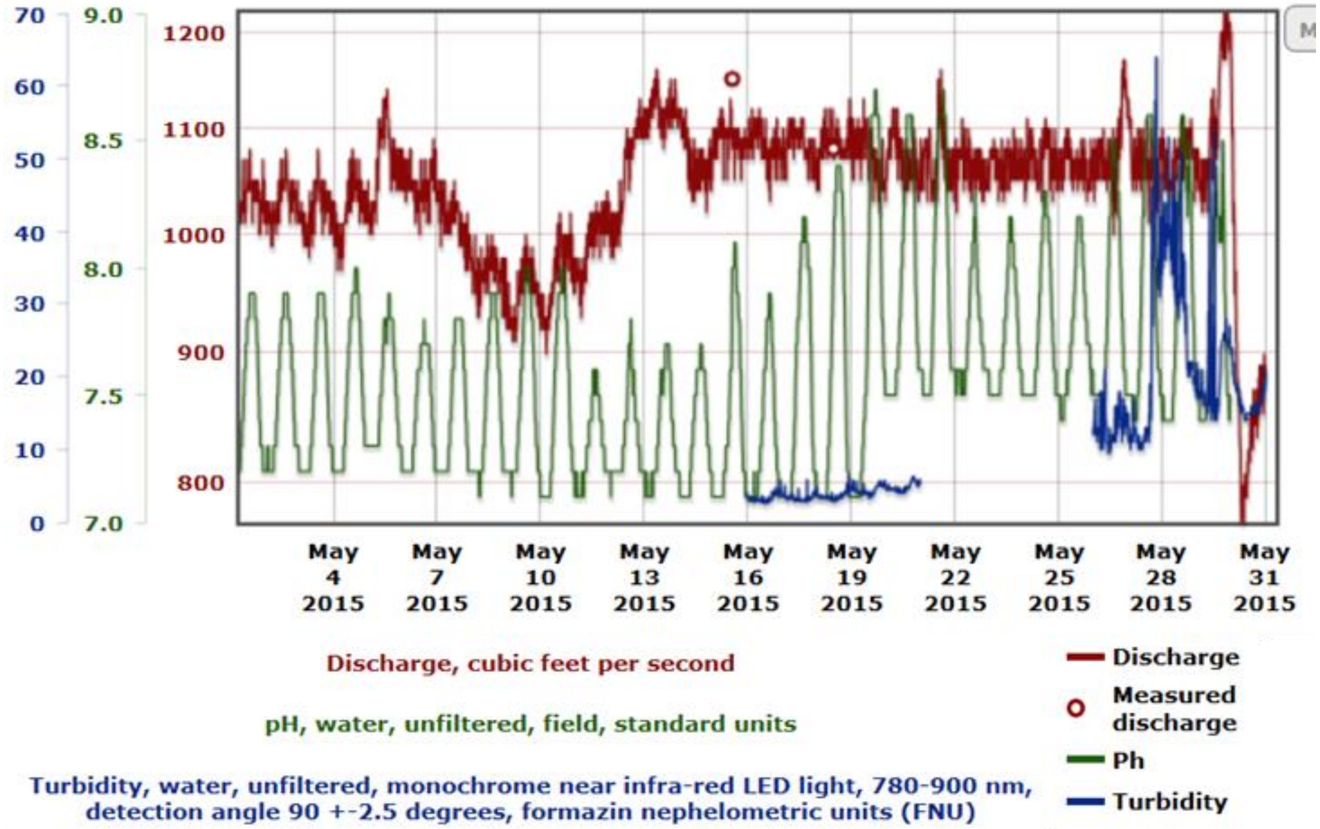

Figure D-8. pH in May 2015 at USGS station 'White River at R St' (#12100490).

In order to protect against exceedances of the water quality criteria in both spring and low flow critical conditions, the period where seasonal allocations shall apply extends from May 1st through October 31st.

High flow conditions

The TMDL does not include numeric allocations for seasonal "high" flow conditions when the White River flow is greater than 2,000 cfs. The flow rule is designed to allow the permitted dischargers some flexibility in treatment operations during sustained periods of higher flow when increased loading does not negatively affect pH in the river.

Based on a 70-year historical flow record on the White River (USGS station 12098500), the median daily flow is greater than 2000 cfs between May 17th and June 26th or on 41 of 184 days (22%) of the seasonal allocation period. The 10th percentile daily flows (low flow) are never greater than 2000 cfs; while the 90th percentile flows (high flow) are greater than 2000 cfs from May 1st to July 22nd, or on 83 of 184 days (45%) of the seasonal allocation window. In other words, during a very dry low flow year the high flow exemption will not apply at all and during a wet, high flow year the exemption would apply for about half of the periphyton growth season.

Based on the 5-year period of record for the White River at R St (USGS Station 12100490), the highest flow where pH was 8.5 or greater occurred in June of 2014. Figure D-9 illustrates how pH steadily increased, under conditions of low turbidity, once the flow decreased below ~1700 cfs and peaked at 8.5 for one day when flow was ~1,500 cfs.

The “high” flow threshold of 2,000 cfs was deemed conservative given that no exceedances have been observed above 1,500 cfs and the June 2014 pH did not exceed 8.0 when turbidity was very low and flow was near 2,000 cfs.

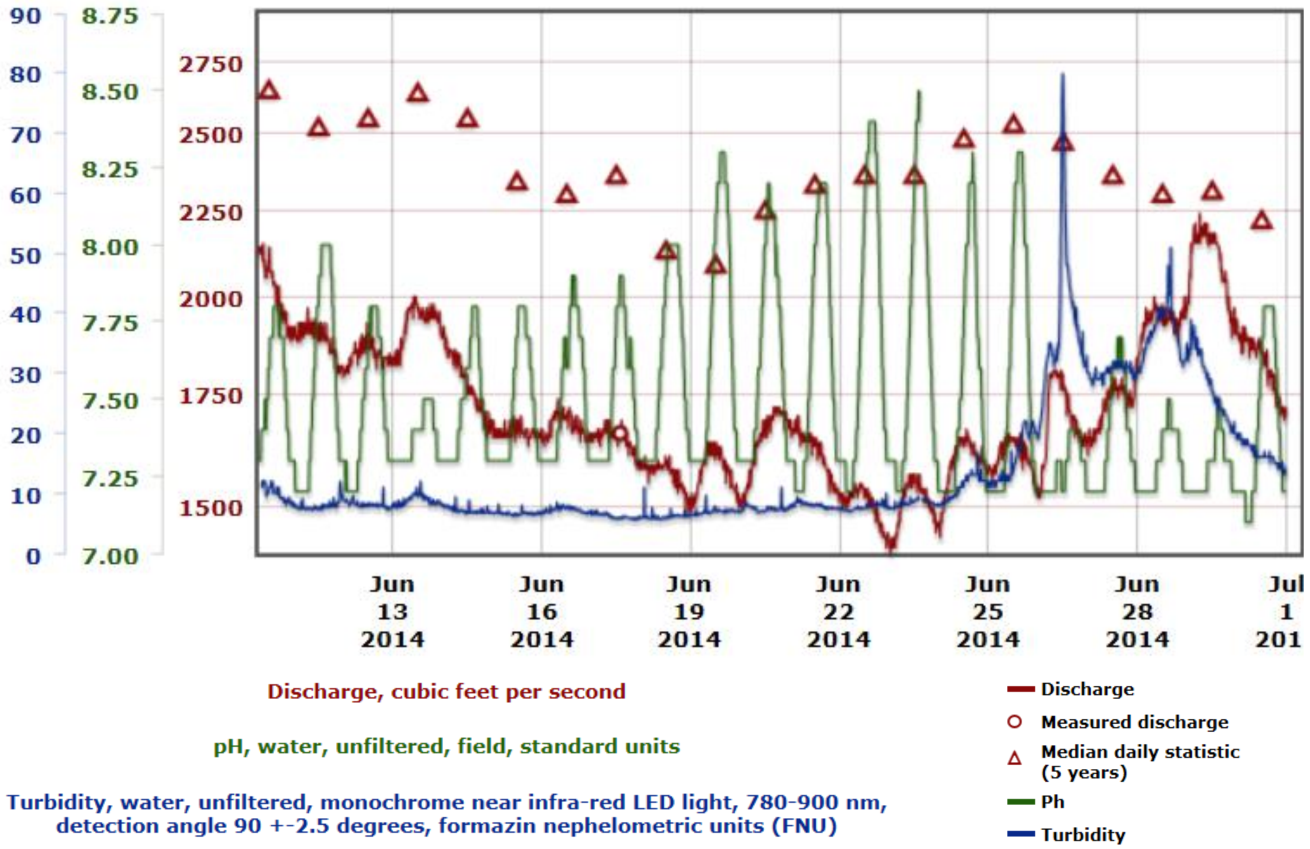

Figure D-9. Flow, turbidity, and pH in June 2014 at USGS station ‘White River at R St’ (#12100490).

Critical Low Flow Conditions

In order to represent low flow critical conditions in the TMDL scenarios, the headwater flows were reduced from 2012 values (7-day low flow of 412 cfs) to values from the year 1994 (7-day flow of 250 cfs) to represent 7Q10 flow conditions.

Ecology plotted the 7-day flows from the four lowest 7-Day flow years from the 7Q10 analysis for USGS station 12098500, for the period of 1977-2002 (Figure D-10).

Of these years, 1983 is the outlier, it has a 27-year recurrence interval (lowest 7day flow on record) and an atypical pattern with higher flows than other years in August and September and then a very steep decline and short baseflow period. Ecology also explored scaling the 2012 flow record down to get to a 7Q10 flow (Figure D-10; black dotted line); however, this method produced historically low (unrealistic) flows in the months of August and September.

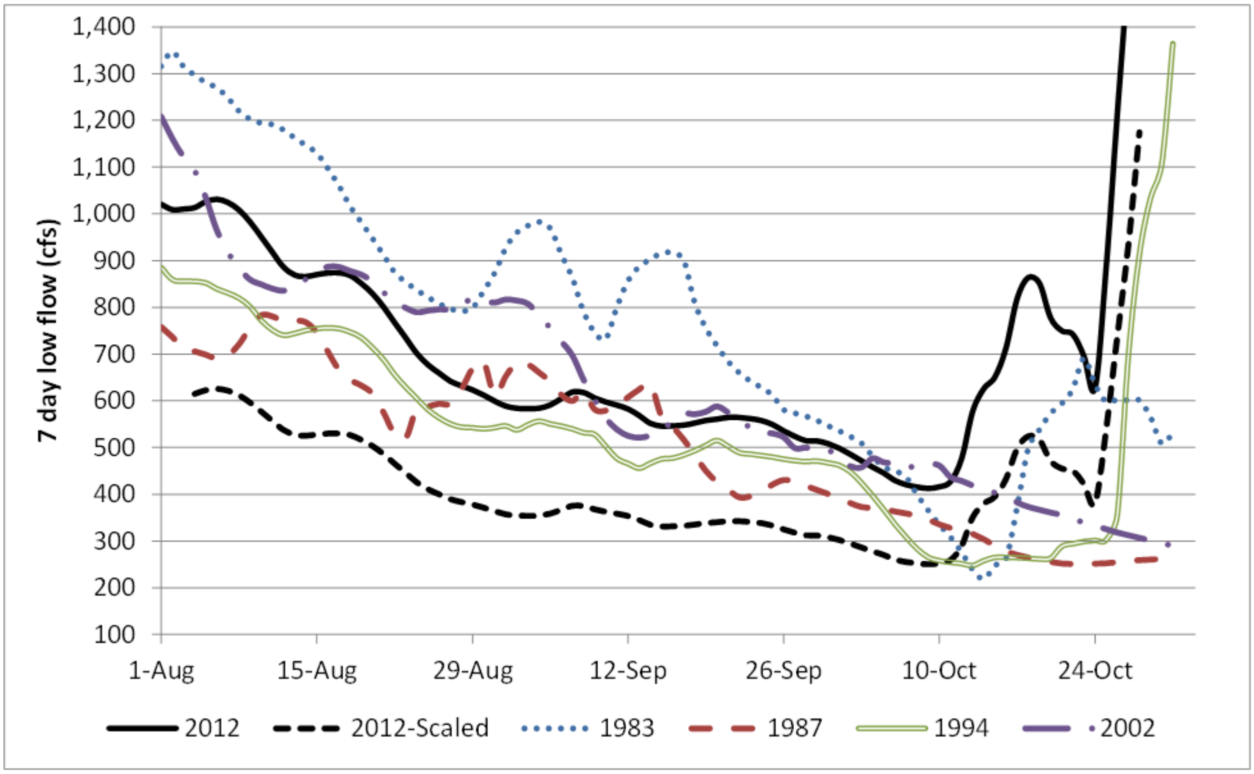

Figure D-10. Comparison of 7Q10 flow years for USGS station 12098500.

Of the remaining years, 1987 and 1994 appeared to be the most similar to 2012 and displayed a more typical flow pattern for this time of year. Ultimately, 1994 was selected because it mirrored the 2012 pattern well and had lower flows in early October, when conditions were critical in the 2012 model.

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Appendix E. TMDL analysis

Loading capacity

The loading capacity of a river system is the amount of a pollutant that can be added to the river without causing an exceedance of water quality standards. The water quality standards for pH have two parts. The first part requires that the pH shall be within the range of 6.5 and 8.5 standard units. The second part requires that human-caused variation within this range be less than 0.2 units. pH is predicted to be within the range of 6.5 and 8.5 during the critical season under natural conditions. Therefore, the loading capacity for this TMDL is based on ensuring both parts of the standards are met (i.e., that pH be within the range of 6.5 and 8.5 and that Δ pH <0.2 from human-caused variation).

Ecology determined the loading capacity based on the amount of soluble reactive phosphorus (SRP) loading. Ecology chose SRP, instead of total phosphorus (TP), for several reasons including:

- SRP provides a better representation of the amount of phosphorus that is available for biological uptake by periphyton and other organisms.
- TP values are often an order of magnitude greater than SRP values in the White River. High TP is derived from the glacial meltwater origin of the river, where much of the phosphorus is likely present in a poorly weathered and non-bioavailable form (Hodson et al., 2004).
- Some pollutant sources have variable SRP:TP ratios, which are sometimes high (i.e., greater than 90%). Providing limits based on TP could cause an impairment in the river when the ratio is too high; and could be infeasible when a source has a naturally high amount of non-bioavailable phosphorus. SRP provides a more direct link to the impairment.
- Residence time is relatively short from the upstream boundary of the study area (~RM 28) to the downstream boundary of the TMDL reach (~RM 3.6), at approximately half of a day at 7Q10 flow conditions. The calibrated model predicts that there is relatively little conversion of organic, or non-bioavailable, phosphorus to SRP in this time period.

Under dynamic conditions, the phosphorus loading capacity of the White River can change based on the flow levels, timing, location, and magnitude of sources. Two periphyton growth factors heavily influence daily pH fluctuations:

- Periphyton biomass accrual over the entire growing season.
- The pH impacts of periphyton growth in a particular reach are carried to downstream locations.

For example, the loading capacity is higher when sources are either spread out over the entire river (diffuse) or concentrated closer to the lower, more critical, end, ~RM 3.6, of the TMDL reach. The load capacity is less when sources are concentrated closer to the upper end of the reach, RM 28, because there is more opportunity for the periphyton to take up the phosphorus loads.

For this TMDL there are two loading capacities identified, one during medium flows and one during low flows. Ecology considered the distribution of current and anticipated future sources when evaluating these loading capacities. Table E-22 provides the loading capacities at low and medium river flows estimated for the Lower White River pH TMDL. Appendix D provides a detailed description of the analytical framework and models used to estimate these capacities.

Table E-22. Load capacity for soluble reactive phosphorus for the Lower White River pH TMDL reach (RM 3.6 to 28) during low and medium flows.

Low Flow Tier SRP load (lbs/day)	Medium Flow Tier SRP load (lbs/day)
10.05	20.69

Both the Low and Medium Flow models' TMDL scenarios suggest that the most critical point for pH along the river occurs from ~RM 5.1 to RM 4.4 (Model Reach 27), just upstream of the point where the pH criterion changes from 0.2 to 0.5 allowed human impact. In order to meet water quality standards at this location in the river, nutrient loading must be reduced upstream of RM 4.4. These upstream reductions result in pH levels that are below criteria downstream of RM 4.4.

Due to relatively fast travel times and deeper water depths, if pH criteria are met at RM 4.4, additional nutrient loading below this point does not significantly affect pH levels. However, the TMDL analysis shows the segment of the river between RM 4.4 and 3.6 is impaired under current critical conditions, due to upstream nutrient loading. Monitoring and modeling below the Lake Tapps Tailrace return has not identified a pH impairment. Therefore, the TMDL only includes allocations for RM 28 to 3.6, referred to in this TMDL as the "TMDL reach.

Once the loading capacity is determined, the TMDL allocates the available capacity, after considering margin of safety and future growth, among load and wasteload sources. Load allocations are set for diffuse (nonpoint) sources, and WLAs are set for discrete, permitted (point) sources.

Loading from upstream of RM28 was not included as part of the TMDL loading capacity, because it is not within the boundary addressed by the TMDL analysis and likely represents phosphorus loads derived primarily from glacial melt and large areas of relatively un-impacted public forest and national park. These upstream loads may include some phosphorus from anthropogenic activities, but this impact has not been quantified and there are relatively few identifiable sources.

It is important to note that the loads from upstream are considerably larger than the load capacity within the TMDL study area, 40.2 lbs SRP/day under low flow conditions and 55.4 lbs SRP/day under medium flow conditions.

Wasteload allocations and Muckleshoot Indian Tribe reservation capacity

The general strategy for developing WLAs was to:

- Evaluate the respective needs, challenges, and treatment capabilities of the WWTPs and hatcheries.
- Compare those needs to those estimated for permitted stormwater and nonpoint sources.
- Determine a balance between the major point sources that would be feasible for all entities, while still meeting water quality standards in the river, and divide accordingly.

Table E-23 summarizes the permitted, and potentially future permitted, point source dischargers within the TMDL study area. Each permittee is assigned two numeric WLAs, one for medium flows and one for low flows. The City of Edgewood is not assigned WLAs in the TMDL, because all of their potential stormwater discharges occur outside the allocation reach. The City of Edgewood primarily discharges stormwater to the Milwaukee Ditch drainage system, which discharges to the White River at ~RM 1.4, below the TMDL reach.

Table E-23. Current permitted, and potentially future-permitted, discharges.

Permittee Name and ID	Type	Permit Number	Permit Management
Enumclaw WWTP	M; I; WW	WA0020575	Ecology
Buckley WWTP	M; I; WW	WA0023361	Ecology
MIT Future Growth Reserve[1]	Reserve	n/a	EPA[1]
MIT Stormwater Reserve [1]	Reserve	n/a	EPA[1]
MIT 'Coal Creek Springs Fish Facility' Reserve – not constructed[1]	Hatchery (fin fish)	n/a	EPA[1]
MIT White River Hatchery covered by the EPA's NPDES Aquaculture GP[2]	Hatchery (fin fish)	WAG130000	EPA[2]
WSDOT	M; I; SW; Phase 1	WAR043000A	Ecology
King County	M; G; SW; Phase 1	WAR044501	Ecology
Pierce County	M; G; SW; Phase 1	WAR044002	Ecology
City of Auburn	M; G; SW; Phase 2	WAR045502	Ecology
City of Buckley	M; G; SW; Phase 2	WAR045003	Ecology
City of Enumclaw	M; G; SW; Phase 2	WAR045514	Ecology
City of Pacific	M; G; SW; Phase 2	WAR045535	Ecology
City of Sumner	M; G; SW; Phase 2	WAR045019	Ecology
City of Algona	M; G; SW; Phase 2	WAR045500	Ecology
Manke Lumber Co Inc. Superior Wood -Sumner	IND; I; SW	WA0040339	Ecology
Industrial Stormwater General Permit- Multiple, semi-transient	IND; G; SW	Multiple	Ecology
Construction Stormwater General Permit- Numerous, transient	G; SW	Multiple	Ecology

Permittee Name and ID	Type	Permit Number	Permit Management
Sand and Gravel General Permit-Multiple, semi-transient	G	Multiple	Ecology

M=Municipal; I=Individual; WW=Wastewater; SW=Stormwater; G=General; IND=Industrial

Footnote 1:
This TMDL includes a reservation capacity for future municipal, industrial, or other discharges related to the Muckleshoot Indian Tribe. A reservation capacity is established for the portion of the White River that flows through the reservation to allow for future growth and economic development that may occur on the reservation in the next 20 years. The reservation capacity is divided into a future growth reserve, a stormwater reserve, and a reserve for the Coal Creek Springs Fish Facility.

The future growth reserve for tribal waters was calculated by estimating potential flows of a future potential WWTP (see future effluent flow section) and assigning an SRP concentration equal to the concentrations assigned to the wastewater treatment facilities for the Cities of Enumclaw and Buckley. The future growth reserve serves only to establish the quantity of reserve load and does not reflect specific MIT facility plans. The reserve was calculated with assumptions and numeric factors consistent with other similar point sources within the TMDL study area.

The Coal Creek Springs Fish Facility reserve was calculated based on future fish production scenarios and available data to estimate loadings.

The stormwater reserve was calculated with assumptions and numeric factors consistent with stormwater loads from other entities within the TMDL study area. These sub-components of the reservation capacity are described in detail in subsequent sections of this appendix.

Footnote 2:
The White River Hatchery, which discharges to state waters, received a WLA based on future estimated loads. The calculation of the WLA is described in subsequent sections. The White River Hatchery discharge is currently covered under EPA's NPDES General Permit for Federal Aquaculture Facilities (EPA's NPDES Aquaculture GP) and located in Indian Country within the boundaries of the State of Washington.

Future effluent flows for Enumclaw WWTP, Buckley WWTP, and MIT future growth reserve

Future wastewater treatment flows were developed with two goals: 1) to account for potential growth over a 20-year timeline and 2) to provide an equitable allocation to each entity. The following method was used to estimate these flows:

- Enumclaw's current effluent discharge and projected growth were used as the basis for the flow estimate for other wastewater treatment facilities. Enumclaw was chosen because they have data available describing their historic effluent flows, they represent the largest current discharge and, in recent history, they have experienced the most population growth.

- For months with relatively stable effluent flows (August, September), starting with the Enumclaw daily WWTP flows from 2012 DMRs, a 2% growth annually for a period of 20 years (~50% total population growth) was applied to each daily flow value based on the moderate growth projection in the 2005-2020 City of Enumclaw comprehensive plan (City of Enumclaw, 2005). The 2005 comprehensive plan was the applicable plan at the time of this analysis. The current Enumclaw comprehensive plan was updated to apply to the period of 2015 to 2035 (City of Enumclaw, 2015) and contains similar growth rates projections to the 2005 plan.
  - $\text{Future daily flow} = \text{2012 daily flow X } (1 + \text{rate of growth})^{\text{number of years}}$
  - $\text{Future daily flow} = \text{2012 daily flow} \times 1.02^{20} = \text{2012 daily flow} \times 1.48947$
- For the months with large variations in the effluent flow record (May, June, July, and October), 2% over 20-year growth was applied based on the minimum flow value for the month, to avoid inflated growth during precipitation driven high influent (infiltration and inflow) events.
  - $\text{Future daily flow} = \text{2012 daily flow} + (\text{Minimum Monthly Effluent Flow} \times 1.02^{20})$
- Growth was applied over a 20-year period based on the typical timeline for initial TMDL implementation.

Figure E-11 compares City of Enumclaw WWTP effluent flows in 2012 to estimated future flows.

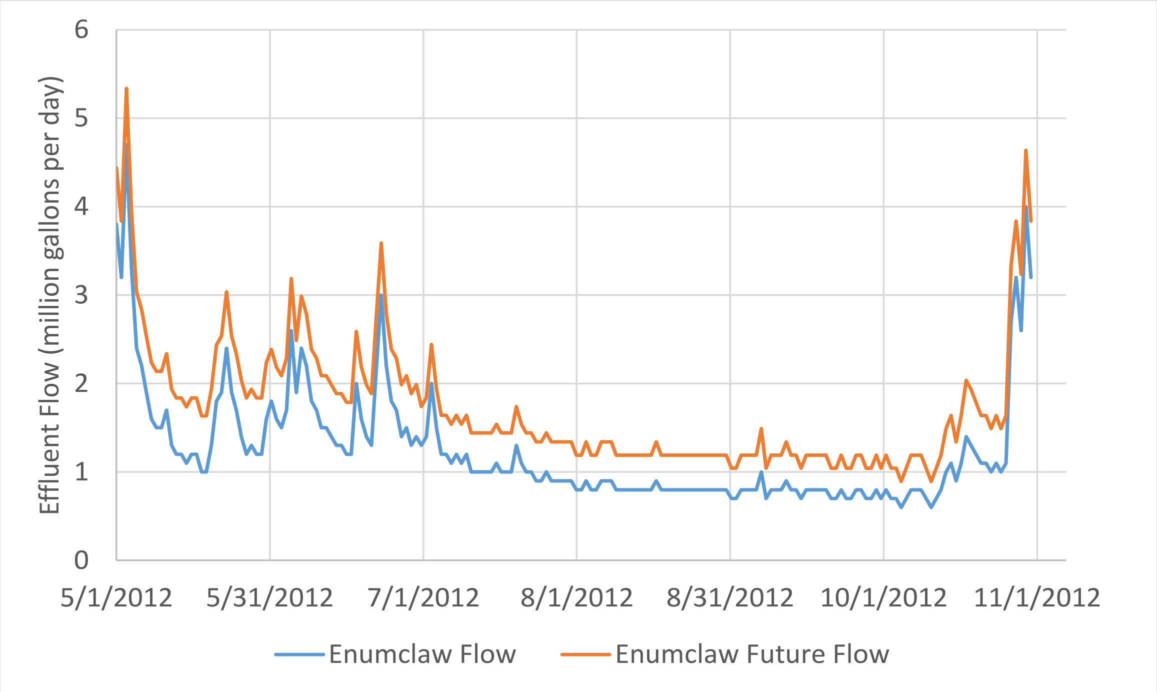

Figure E-11. Comparison between City of Enumclaw WWTP effluent flows in 2012 and estimated future flows based on 20-year growth.

Next, potential future service areas were determined for each entity (Table E-24):

- For Enumclaw, the current city boundary plus urban growth area boundaries.

- For Buckley, the current city boundary (no urban growth area).
- For the MIT future growth reserve, the current census area for MIT based on the American Indian Areas GIS layer obtained from US Census Bureau (TIGER/Line Geodatabases (census.gov)[8]).

A service area scalar was then developed for Buckley and MIT based on the ratio of their service area relative to Enumclaw's service area (Table E-24).

The final future effluent flows used in the TMDL model were:

- For Enumclaw, the 2012 daily flows with 2% growth over 20 years.
- For Buckley, the Enumclaw future flows multiplied by 0.58 (service area scalar).
- For the MIT future growth reserve, the Enumclaw future flows multiplied by 0.87 (service area scalar).

Table E-24. Service area total areas, and service area scale factors for the cities of Buckley and Enumclaw and for the MIT future growth reserve.

Entity	City area (sq.mi)	UGA (sq.mi.)	Total area (sq.mi.)	Service Area Scale Factor
Enumclaw	4.6	2.3	6.9	1
Buckley	4.0	n/a	4.0	0.58
MIT	n/a	n/a	6.0*	0.87

*census area; see description in text

The service area scale factor for Buckley (0.58) is greater than the current ratio of population and the current ratio of effluent flow between the two cities. Basing flows on service areas rather than current populations was done to allow Buckley to achieve a population density comparable to Enumclaw.

Table E-25 summarizes the estimated monthly average effluent flows used in the TMDL analysis for Enumclaw, Buckley, and the MIT future growth reserve.

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[8] https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-geodatabase-file.html

Table E-25. Estimated monthly average effluent flows used in the TMDL analysis for Enumclaw, Buckley, and MIT future growth reserve.

Month	2012 Enumclaw Average Effluent Flow (mgd)	TMDL flow- Enumclaw Average Future Effluent Flow (mgd)	TMDL flow- Buckley Average Future Effluent Flow (mgd)	TMDL flow- MIT Future Growth Reserve Average Future Effluent Flow (mgd)
May	1.80	2.44	1.41	2.12
June	1.71	2.30	1.33	2.00
July	1.10	1.54	0.89	1.34
August	0.82	1.22	0.71	1.06
September	0.78	1.16	0.67	1.01
October	1.27	1.75	1.02	1.52

For reference: 1 mgd = ~1.55 cfs; TMDL monthly average effluent flow range = ~1.0 to 3.8 cfs

Wastewater Treatment Plant WLA development

For the existing WWTPs, Ecology first requested that the cities of Buckley and Enumclaw examine their current phosphorus treatment, as well as options for improving treatment. In response, the cities had Esvelt Environmental Engineering prepare several technical memos which contained information vital to developing the WLAs for these TMDL. The memos included assessments of four treatment options:

1. An optimized version of the existing EBPR system.
2. Tertiary phosphorus removal using existing chemical clarifiers (chemical polishing).
3. Additional tertiary phosphorus removal alternatives via filtration through different types of media (granular, membrane, cloth).
4. Reclaimed water to eliminate or reduce SRP loading.

The TMDL analysis was developed assuming a combination of both option 1 and 2, EBPR with chemical polishing in an existing clarifier, is used for treatment. This combination of treatment was selected for these estimated WLAs because the cities already have the necessary infrastructure, expected performance is projected to generate loads within the river’s available loading capacity, and it is significantly less expensive compared to options 3 and 4.

Ecology also took into account several requests from the cities and incorporated them into the WLAs and associated permit recommendations. The requests included seasonal average limits, an extended compliance schedule, no requirement for use of the chemical clarifier at high effluent flows and increased allowed loading during shoulder months (to allow for more flexibility during higher river flows in these months).

Information from the Esvelt technical memos specific to the chemical polishing option was used to develop seasonal loading estimates for the WWTPs. This included data and discussion of potential treated SRP effluent concentrations based on the molar ratio of a chemical coagulant metal (aluminum) to total phosphorus in the influent. The data came from a series of pilot studies conducted in Spokane from two chemical polishing units that used alum to reduce phosphorus in secondary effluent. This relationship between molar ratio and effluent SRP was used to help generate the seasonal loading estimates by applying a reduction to the Enumclaw 2012 phosphorus data based on the molar ratio of aluminum to total phosphorus. A more conservative version of the pilot study equation (i.e., one that would predict higher effluent SRP values) was used to represent treatment at low flows and an even more conservative version was used to represent treatment at medium flows (Figure E-12; Table E-26).

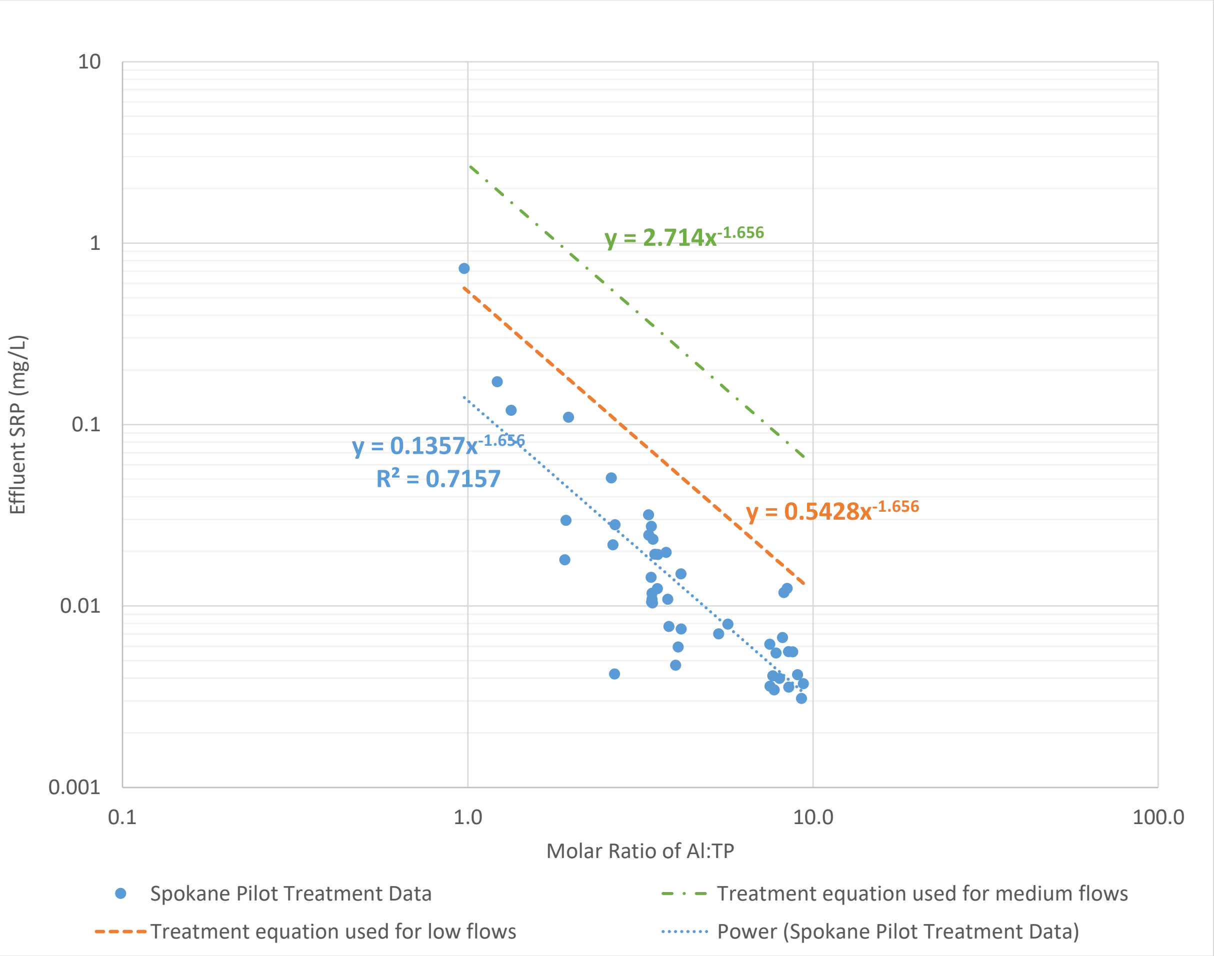

Figure E-12. Relationship between molar ratio of aluminum to total phosphorus and effluent SRP concentration from City of Spokane pilot data (from units S1 and S2; only results with molar ratio of less than 10 included). Includes conservative equations used to estimate treatment in the TMDL analysis.

Table E-26. Equations used to estimate effluent SRP for WWTPs after chemical alum treatment.

Name	Equation	Description
Pilot Study	$SRP_{effluent} = 0.1357 * MR_{AL:TP}{}^{-1.656}$	Derived from Spokane Pilot Study Data
Low Flow	$SRP_{effluent} = CF_{4x} * 0.1357 * MR_{AL:TP}{}^{-1.656}$	Used to estimate effluent SRP concentrations after chemical treatment with alum under low flow conditions; conservative factor of 4 applied.
Medium Flow	$SRP_{effluent} = CF_{20x} * 0.1357 * MR_{AL:TP}{}^{-1.656}$	Used to estimate effluent SRP concentrations after chemical treatment with alum under low flow conditions; conservative factor of 20 applied.

Where:
$CF_{\#x}$ = Conservative Factor; multiplied by 4 for Low Flow and 20 for Medium Flow.
$SRP_{effluent}$ = Estimated effluent SRP concentration in mg/L
$MR_{AL:TP}$ = Molar Ratio of Aluminum to Effluent Total Phosphorus

There are multiple reasons for applying conservative factors to these equations. The actual SRP concentrations in effluent from the WWTP's may be higher than the values from the Spokane pilot study for the following reasons:

- The Spokane pilot data represents the geometric mean of 10-12 composite (24hr) samples collected over a period of 2-4 weeks. Tis represents a relatively short period of time.
- The data was collected "in a pilot situation, where variables tightly controlled, and less subject to process irregularities experienced in a full-scale installation subject to continuously variable flows, loads, environment, etc." (Esvelt EE, 2014).
- Initial mixing conditions at Enumclaw and Buckley may be less optimal than the Spokane pilot.
- For medium flows, the equation is even more conservative, given the challenges in EBPR and plant operation in general at higher effluent flows and during shoulder months of May and October. This was possible because more loading capacity was available at this flow range.

Recognizing the limitations associated with the pilot studies and applying conservative factors to estimate effluent concentrations from the WWTP's will result in overall WLAs that will be more protective of the river.

For the TMDL analysis, the molar ratio of aluminum to phosphorus was determined based on the following equation:

- Molar Ratio Al:TP = (Aluminum Dose(mg/L) / 26.982) / (Effluent Total Phosphorus (mg/L) / 30.974)

- Where:
    - 26.982 = the molecular weight of aluminum
    - 30.974 = the molecular weight of phosphorus
    - Aluminum Dose (mg/L) = Alum Dose (mg/L) *0.0810810
    - Where:
        - 0.0810810 = molar ratio of aluminum to alum
        - Alum Dose (mg/L) = (378.5*624,000)/(Effluent Flow (mgd)* 3,785,000)
        - Where:
            - 378.5 = chemical feed setting in L/day (equals 100 gallons/day)
            - 624,000 = estimated liquid alum concentration (mg/L); most solutions are 48% alum; Alum can have either 14 or 18 moles of water, depending on source
            - 3,785,000 = conversion factor to convert from mgd to liters

An estimate of the attainable effluent SRP after chemical polishing was then obtained by inserting the molar ratio of Al:TP into the equations 2 and 3 (Figure E-12).

For estimates where the molar ratio was greater than 10:1, static values of 11.9 ug/L (low flow) and 59.9 ug/L (medium flow) SRP were used. This was done because the Spokane pilot study data showed that the effluent SRP appeared to bottom out (was no longer decreasing) above this molar ratio.

Prior to this exercise, Enumclaw weekly TP data was converted to an hourly record, via linear interpolation in order to create an hourly SRP record. This represented EBPR with chemical polishing treatment for input into the Low Flow and Spring models.

A chemical feed setting of 378.5 L/day, or 100 gals/day, was used based on a discussion of coagulant feed capacity in the Esvelt memos. This is based on a rate that is practical for daily plant operation. For 7 out of the 122 days in the season, the feed rate was temporarily increased by 50 gals/day to 150 gals/day to mitigate high loading events. The feed rate increase was implemented ~1 week after the TP exceeded 2 mg/L, to simulate the possibility of an operational delay in responding to EBPR treatment failure. This temporary feed rate increase equates to using one 350-gallon reserve tote over the course of the season.

This chemical feed rate results in variable alum concentrations in the effluent, depending on effluent flow, with a seasonal average of 42 mg/L for 2012. The maximum alum concentration is 69 mg/L, however these higher concentrations occur when the effluent flow is at its lowest. For example, when the alum concentration is above 60 mg/L, the Enumclaw WWTP future effluent flow average was 1.2 mgd, with a max of 1.4 mgd.

Given this inverse relationship between effluent flow and alum concentration, higher alum concentrations are not expected to cause TSS removal efficiency problems, because the hydraulic loading will be at its lowest. When effluent flows are greater than 2 mgd, alum concentrations would average 24 mg/L, with a maximum of 31 mg/L.

Converting Enumclaw SRP load to Buckley and MIT future growth reserve SRP load estimate

The same SRP concentrations time series that Ecology developed based on Enumclaw data was also used for Buckley and for the MIT future growth reserve. Enumclaw's future effluent flow time series was scaled down by a factor of 0.58 to develop the future effluent flow time series for Buckley and by a factor of 0.87 for the MIT future growth reserve (see future flow estimates section).

Municipal Individual WWTP Discharge Wasteload Allocations

The hourly "treated" SRP record and future flows were tested in the two models in an iterative process, along with loading scenarios for other sources, until the models showed compliance with water quality criteria.

Ecology used the following equation to calculate hourly WWTP loads from TMDL model inputs:

- SRP effluent concentration estimate (ug/L) x Future Flow Estimate (m^3/s) x 0.18650916
    - Where 0.18650916 = a conversion factor to convert from and to lbs/day, when units are ug/L and m^3/s:
        - 1000 (L/m^3) x 84,600 (sec/day) x 2.2046 x 10^{-9} (lb/ug)

The seasonal average WLAs and MIT future growth reserve (Table E-27) were then estimated as:

- The Medium Flow Tier WLA = the arithmetic mean of WWTP hourly loads from Aug 9th to Aug 17th in the medium flow ("spring") model.
- The Low Flow Tier WLA = the arithmetic mean of WWTP hourly loads from Aug 2nd to Oct 30th in the low flow model, excluding loads when the river flow is greater than 900 cfs.

Table E-27. Wasteload allocations for the cities of Enumclaw and Buckley WWTPs and Future Growth Reserve for the Muckleshoot Indian Tribe.

Facility	Type	**Medium Flow Tier** *(lbs SRP/day)*	**Low Flow Tier** *(lbs SRP/day)*
City of Enumclaw WWTP	Wasteload Allocation	1.50	0.62
City of Buckley WWTP	Wasteload Allocation	0.87	0.36
Muckleshoot Indian Tribe	Future Growth Reserve	1.31	0.53

Figure E-13 depicts how the WLAs for the WWTPs translate to mean SRP concentration at a range of recent and future effluent flows. Finally, the seasonal loading estimates spreadsheet was used to calculate the seasonal arithmetic mean for the period of May 1st to October 31st,

2012. Ecology compared these values to the assigned WLA for each flow tier, to test whether the WLA would be attainable over the full season. Figure E-14 depicts an example of hypothetical SRP loading under the proposed WWTP treatment scheme for 2012.

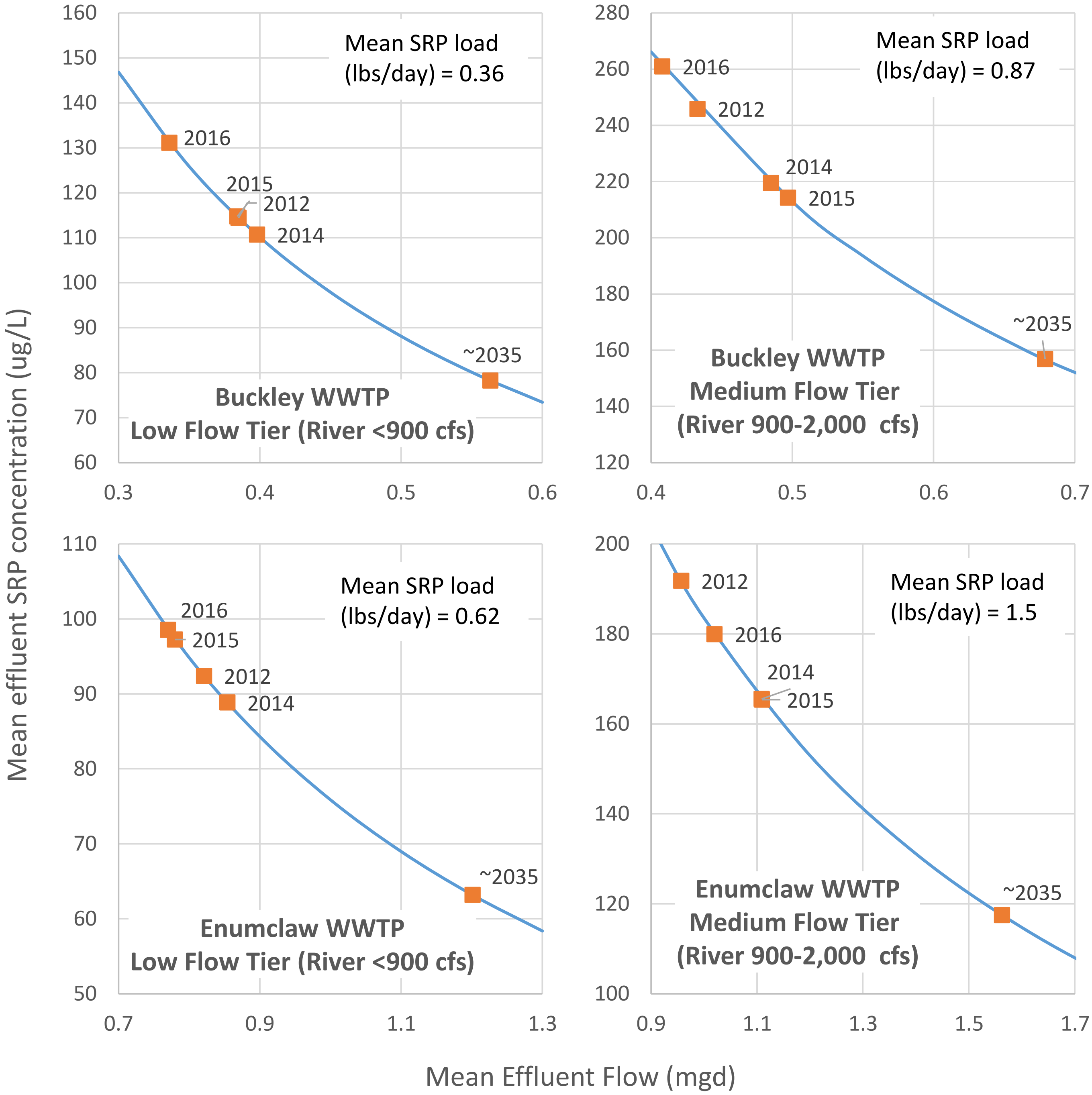

Figure E-13. Effluent SRP concentration vs effluent flow curves based on seasonal, river flow-based phosphorus WLA estimates for the Cities of Buckley and Enumclaw WWTPs.

Figure E-13 notes:

- Daily effluent flows (for the period of May 1st to October 31st) from the years 2012, 2014, 2015, and 2016 were sorted into low and medium flow tiers, based on the river flow during the corresponding year. The effluent flows were then averaged within each flow tier.
- An estimate of future flow, labeled ~2035, was determined by taking the average flow of these 4 years and applying 2% growth annually for a 20-year period.
- The estimates of potential SRP concentrations were derived based on the estimated SRP load limit and the associated effluent flow for each year presented.

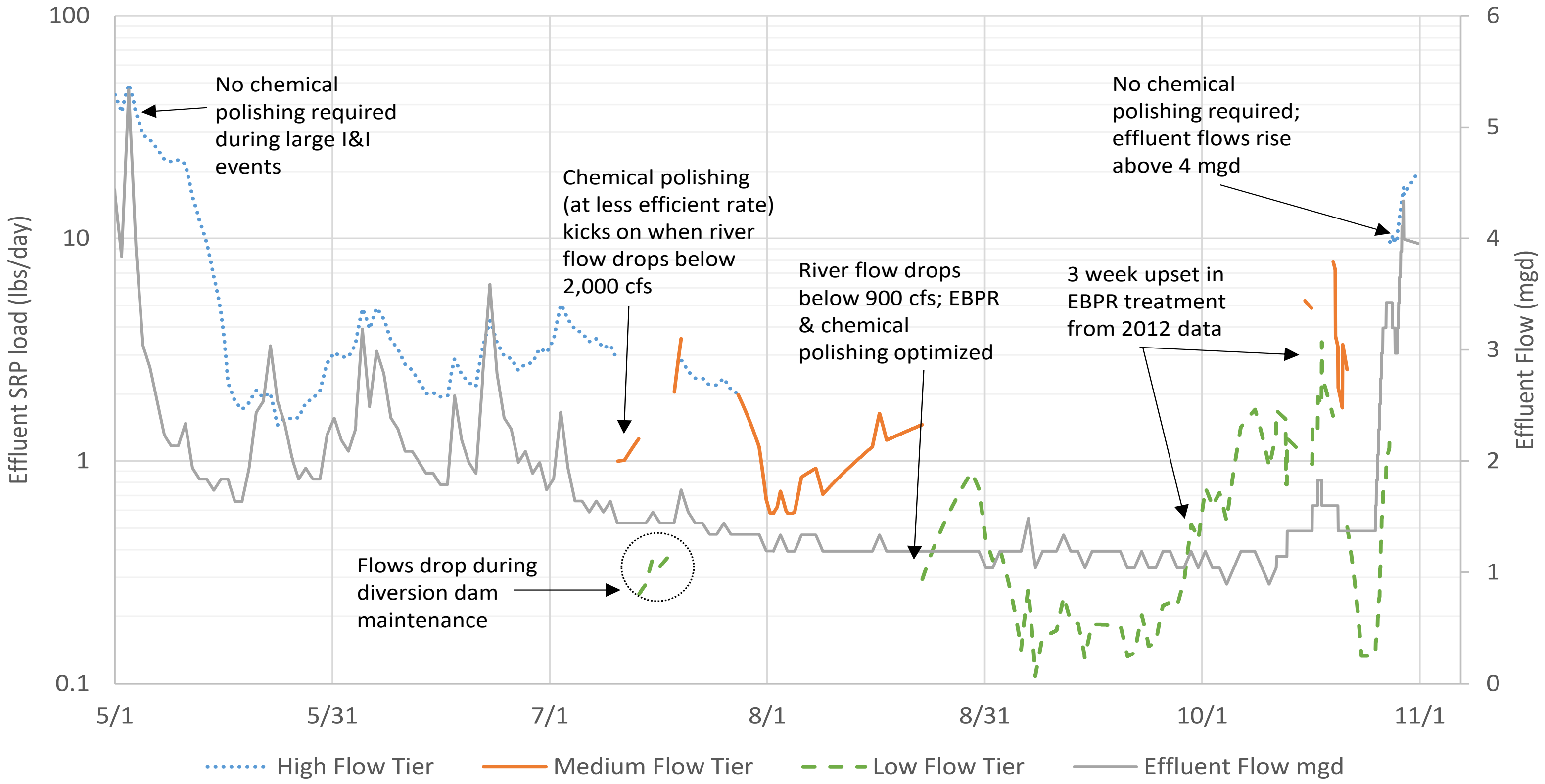

Figure E-14. Seasonal SRP load estimates (lbs/day) for the Enumclaw WWTP, by river flow tier. Estimates are based on 2012 total phosphorus data, future (20-year growth) effluent flows, and chemical polishing treatment equations.

Figure E-14 supplemental information:

- Average SRP load for High Flow Tier = 7.21 lbs/day (no WLA set)
- Average SRP load for Medium Flow Tier = 1.38 lbs/day (WLA = 1.5 lbs/day)
- Average SRP load for Low Flow Tier = 0.55 lbs/day (WLA = 0.62 lbs/day)

Preliminary recommendations for implementing WLAs in the municipal wastewater NPDES permits

Ultimately, WLAs and associated requirements will be implemented in the facilities' NPDES permits by Ecology's municipal permit writing staff. The following provides guidance and recommendations for the permit writer.

SRP sampling schedule

SRP effluent samples should be collected and analyzed on a routine basis. The expected sampling frequency will likely be within the range of 1-3 samples per week. Sample collection should occur routinely on the same days of the week (for example, Mondays and Thursdays). Sample collection should not occur on two consecutive days.

Daily average flow and SRP loads

Daily average river flows should be obtained for the White River at USGS gage 12100490 WHITE RIVER AT R STREET NEAR AUBURN, WA. SRP loads for a given day will be categorized in a high, medium, or low flow tier based on the daily average flow.

The facility operators should keep track of what flow tier the river is currently in and anticipate changes in operations based on forecasted weather events, trends in declining flow, or scheduled dam releases/storage.

Mean seasonal SRP load by flow tier

In November of each year, the arithmetic mean SRP load would be calculated for each flow tier based on assigned classification (described above) for all SRP samples between May 1st and October 31st.

Permit requirements during high flow tier

Although the TMDL does not include numeric WLAs for the high flow tier (>2,000 cfs), the following actions should be implemented during these conditions from May 1st to October 31st:

- The WWTPs should continue to employ enhanced biological phosphorus removal to reduce phosphorus loads to the White River. Chemical polishing with alum is not required.
- Phosphorus monitoring should continue. The target mean SRP concentration for the high flow tier should be less than 1 mg/L. Two consecutive SRP results of greater than 2 mg/L should require a written explanation from the operator and technical assistance from Ecology.

Low flows in May and June

Only the loadings associated with the medium flow tier shall apply in the months of May and June, even if the flow is less than 900 cfs. Any river flows below 900 cfs in these months would be below the historical 7Q10 low flow (950 cfs) for these months. Therefore, when river flow is less than 900 cfs in May and June, the medium flow SRP load will apply.

Reserve alum supply and operational timing for increased feed rate

As noted above, the estimated rate of alum use under normal operating conditions is approximately 100 gals/day. This estimate is based on a rate that is practical for daily plant operation. However, additional alum may be required under some situations. It is recommended that at least one 350-gallon tote of alum is reserved for treatment during transitional flow periods or difficulties with EBPR treatment.

On some occasions, flow increases in the White River appear to lag behind infiltration and inflow related increases in the Enumclaw WWTP. When WWTP flows rises above 2 mgd while the river is still in the low flow tier, it may be necessary to temporarily increase the alum feed rate until the river responds to upstream runoff and moves to the medium or high flow tier.

When EBPR treatment fails or is significantly impaired, total phosphorus concentrations prior to chemical polishing can exceed 2 mg/L. During the low or medium flow tiers this could lead to an exceedance of seasonal WLAs set in Table E-27, if the alum feed rate remains at 100 gals/day.

From the 2012 dataset, it is estimated that TP exceeded 1 mg/L for ~23 consecutive days and 2 mg/L for ~13 days during an EBPR upset in the early fall. If the alum feed rate was increased to 150 gals/day for 6 of the days (an extra 300 gallons of alum) when TP was greater than 2 mg/L, then the high SRP loading would likely have been effectively mitigated and compliance with seasonal WLAs is predicted based on treatment equations and seasonal loading estimates.

For this reason, it is also recommended that periodic (ideally weekly) samples for total phosphorus be collected in-process, immediately prior to alum addition, to track the trend of EBPR performance.

Compliance Schedule

It is recommended that the WWTPs be given 10 years (from when the existing permits are updated) to achieve compliance with the WLAs and associated permit limits. Interim permit limits should be required within the first 5 years. Monitoring to evaluate performance and the achievement of performance benchmarks will be required during this period. The first 5 years requires optimization of EBPR and chemical polishing within the first two years, followed by three years of optimized performance data. If optimized performance is not meeting the seasonal interim limits at the end of the first 5 years, the WWTPs would have from years 6 to 10 to implement additional treatment or other improvements.

White River Fish Hatchery wasteload allocation and Coal Creek Springs Fish Facility Reserve development

A WLA was developed for the existing White River Hatchery, which is covered by EPA's NPDES Upland Aquaculture General Permit (WAG130000). However, the joint Ecology/MIT/EPA workgroup recognized the need to also develop a reserve for the planned Coal Creek Springs Fish Facility.

The Muckleshoot Indian Tribe contracted with Montgomery Watson Harza (MWH) to develop and apply a fish rearing model to estimate phosphorus loadings from the White River Hatchery and the planned Coal Creek Springs Fish Facility. The study relied on available data and information to model different fish production scenarios and to calculate phosphorous discharge loadings and concentrations on a weekly basis (MIT, 2019).

Ecology used the phosphorus discharge loadings from the MWH fish rearing model scenarios directly in the TMDL analysis to evaluate several scenarios that considered different fish production and phosphorus removal options. The chosen scenario was based on industry standard phosphorus removal practices, considered future plans for Chinook production, and included other potential species production. This scenario was chosen as the basis for allocations because it was feasible in combination with chemical polishing at the WWTPs.

The weekly SRP loads from the fish rearing model were converted to hourly records, via linear interpolation, for use in the QUAL2Kw models. These loads represent *net* loads (loads produced from fish production only, influent load not included) so they were also converted to *gross* concentrations for the model. Ecology first converted the net load to a net concentration and then added the influent concentration to get the gross concentration for input into the models.

Ecology tested the hourly "treated" SRP records in the two models in an iterative process, along with loading scenarios for other sources, until the models showed compliance with water quality criteria. Ultimately, the low-flow model used the gross concentrations for the MWH future modeled fish production scenario without further modification. For the medium flow (spring) model, in a similar manner to the WWTPs, the concentrations from the MWH future modeled fish production scenarios were increased (by an overall factor of 1.9) to provide an additional margin of safety during transitional fish production periods in the spring and early summer, when hatchery SRP loads are decreasing from their seasonal peak. This increase was possible due to the additional loading capacity available in the medium flow tier.

Finally, the seasonal loading estimates spreadsheet was used to calculate the seasonal arithmetic average for the period of May 1st to October 31st. These values were compared to the assigned WLA or reserve for each flow tier, to ensure that the WLA or reserve would be attainable over the full season. This was done for the years 2012 (study year), 2014 (medium tier flows in May/June), and 1994 (7Q10 flow year) to evaluate variable annual flow patterns. In each case, the calculated May to October seasonal average was less than the assigned seasonal average WLA or reserve.

The seasonal loading estimates and WLA/reserve represent the *net* load contributed by the hatchery or fish facility (total effluent load minus influent load). The influent load was calculated by multiplying 10.9 ug SRP/L (influent concentration) by the influent flow, based on data collected in the 2012 study. Table E-28 shows the WLA and reserve for the MIT hatchery and fish facility, respectively, based on the TMDL analysis.

To summarize how Ecology calculated model values and WLA for each facility (White River Hatchery and Coal Creek Future Facility) using the following assumptions and equations:

- MWH model weekly industry standard *net* load estimate, for each facility, (lbs SRP/day) first interpolated to hourly *net* MWH loads (lbs SRP/day).
- Hourly net Low-Flow Tier TMDL loads (lbs SRP/day) = Subset of hourly net MWH loads (lbs SRP/day) that includes days when daily 2012 flow was less than 900 cfs.
- Hourly net Medium-Flow Tier TMDL loads (lbs SRP/day) = Subset of hourly net MWH loads (lbs SRP/day) that includes days where daily 2012 flow was between 900 and 2000 cfs x 1.9.
    - Where 1.9 = increased safety factor, similar to WWTP WLAs, during period of greater uncertainty for loading.

- Hourly TMDL *net* concentrations (ug SRP/L) =
  - Hourly TMDL *net* loads (lbs/day) / Hatchery Facility Flow (m^3/s)/ 0.18650916
  - Where 0.18650916 = a conversion factor used for converting from and to lbs/day, when units are ug/L and m^3/s:
    - 1000 (L/m^3) x 84,600 (sec/day) x 2.2046 x 10^{-9} (lb/ug)
  - Hatchery Flows in cubic meters per second (cms or m^3/s) in Table E-28.
- Hourly *gross* concentrations (ug/L) used in models = Hourly *net* concentrations + 10.9 (ug SRP/L)
  - Where 10.9 ug SRP/L = typical influent concentration from 2012 study
- Low Flow Tier WLA (lbs SRP/day)=
  - Arithmetic mean of Hourly Low Flow-Tier TMDL *net* loads (lbs SRP/day) from Aug 2nd to Oct 30th.
- Medium Flow Tier WLA (lbs SRP/day)=
  - Arithmetic mean of Hourly Medium Flow-Tier TMDL *net* loads (lbs SRP/day) from Aug 9th to Aug 17th.

Table E-28. Recommended wasteload allocation and reserve for the MIT hatcheries based on the TMDL analysis.

Hatchery	**Medium Flow Tier**	**Low Flow Tier**
Net loads (recommended WLA/reserve)(lbs SRP/day)		
White River Hatchery WLA	2.43	0.94
Coal Creek Springs Fish Facility Reserve	0.99	0.86
Flow used to calculate loads in cfs (and cms)		
White River Hatchery	10.0 (0.2831)	10.0 (0.2831)
Coal Creek Springs Fish Facility	3.9 (0.1105)	3.9 (0.1105)

As with the WWTPs, only the loadings associated with the medium flow tier shall apply in the months of May and June, even if the flow is less than 900 cfs. Any river flows below 900 cfs in these months would be below the historical 7Q10 low flow (950 cfs) for these months. Therefore, when river flow is less than 900 cfs in May and June, the medium flow SRP load from Table E-28 will apply.

Preliminary recommendations for implementing WLAs in the hatchery NPDES permits

Ultimately, WLAs and associated requirements will be implemented in the MIT facilities' NPDES permits issued by EPA. The following provides guidance and recommendations for the permit writer.

Recommendations for the hatchery permits are equivalent to those previously described for the municipal wastewater facilities in respect to daily averaging of flow and SRP loads, mean seasonal SRP load by flow tier, and flows <900 cfs in the months of May and June.

The hatcheries' SRP effluent samples should ideally be collected at least once per week to track SRP load trends and collect enough samples to calculate seasonal averages for each flow tier. Sample collection should occur routinely on the same day of the week (for example every Monday).

Although the TMDL does not include numeric WLAs for the high flow tier (>2,000 cfs), the following actions should ideally be implemented during these conditions from May 1st to October 31st:

- The hatcheries should continue to employ industry standard phosphorus removal to reduce phosphorus loads to the White River.
- Phosphorus monitoring should continue when flows are near the 2,000 cfs threshold, but it is not required for this tier. It should be the responsibility of the permittee to ensure that a sample was collected if the average daily flow falls slightly below 2,000 cfs.

Stormwater wasteload allocation and MIT stormwater reserve development

Ecology also analyzed potential stormwater impacts and included numeric WLAs for permitted stormwater sources in the TMDL. Table E-29 includes all stormwater-related NPDES permittees discharging within the TMDL study area (including tributaries and all contributing watershed areas) and their associated wasteload allocations. It also includes a stormwater reserve for stormwater discharges associated with the Muckleshoot Indian Tribe's reservation, which is equal to the load allocated to the "major" municipal NPDES stormwater permittees within the study area. The MIT stormwater reserve was calculated using assumptions and numeric factors consistent with other stormwater point loads within the TMDL study area.

Ecology used the following equation to calculate stormwater WLAs from TMDL model inputs (see Table E29):

- SRP concentration in model (ug/L) x Flow rate in model (m^3/s) x 0.18650916
    - Where 0.18650916 = a conversion factor to convert from and to lbs/day, when units are ug/L and m^3/s:
        - 1000 (L/m^3) x 84,600 (sec/day) x 2.2046×10^{-9} (lb/ug)

Table E-29. Wasteload allocations for NPDES stormwater and Sand and Gravel permittees.

Permittee	Flow rate in model (cubic meters/ second)*	SRP concentration in Low-Flow Model (ug/L)	Low-Flow Tier load (lbs SRP/ day)	SRP concentration in Medium-Flow Model (ug/L)	Medium Flow Tier load (lbs SRP/ day)	% of Total (Other NPDES category)
Major NPDES Stormwater Permittees and MIT Stormwater Reserve						
MIT Stormwater Reserve	0.025	7.5	0.035	79	0.368	12.5%
Auburn	0.025	7.5	0.035	79	0.368	12.5%
Buckley	0.025	7.5	0.035	79	0.368	12.5%
Enumclaw	0.025	7.5	0.035	79	0.368	12.5%
King	0.025	7.5	0.035	79	0.368	12.5%
Pierce	0.025	7.5	0.035	79	0.368	12.5%
Minor NPDES Stormwater Permittees						
Pacific	0.00714	7.5	0.010	79	0.105	3.6%
Sumner	0.00714	7.5	0.010	79	0.105	3.6%
Algona	0.00714	7.5	0.010	79	0.105	3.6%
WSDOT	0.00714	7.5	0.010	79	0.105	3.6%
Manke	0.00714	7.5	0.010	79	0.105	3.6%
Industrial SW GP	0.00714	7.5	0.010	79	0.105	3.6%
Additional non-stormwater permitted discharges						
Construction SW GP -Dewatering	0.00357	10.5	0.005	79	0.053	1.8%
Sand and Gravel GP- Process Water	0.00357	10.5	0.005	79	0.053	1.8%
Total =	**0.20**	**n/a**	**0.280**	**n/a**	**2.944**	100%

*For reference: 0.025 cms = 0.88 cfs; 0.00714 cms = 0.25 cfs; 0.00357 cms = 0.13 cfs

Allocations or reserves for each flow tier are expressed as the seasonal average for the respective flow tier, in the same manner as for the WWTPs and hatcheries. It is important to note that these allocations represent loads for the "typical" non-runoff daily conditions that occur in the dry season, not the loading from one or more runoff events. The stormwater allocations or reserves do not apply annually. They only apply during non-runoff conditions (see TMDL Allocations for additional detail) within the May 1st – October 31st critical period

For the TMDL analysis, Ecology classified major municipal permittees as municipalities with greater than 1,000 acres of total jurisdiction area (within the TMDL allocations boundary) and more than 250 acres of impervious area; and minor permittees as those below these thresholds (Table E-30). Ecology obtained estimates of the impervious cover by clipping the National Land Cover Dataset (NLCD) 2006 impervious layer to the TMDL jurisdiction areas.

Table E-30. Estimated jurisdiction and impervious area for municipal stormwater permittees within the TMDL allocations boundary.

Permittee	~Site Area (acres)	~Impervious Area (acres)	Impervious Area (%)
King County	22196	575	3
Pierce County	5801	256	4
City of Auburn	4622	1096	24
City of Buckley	1564	289	18
City of Enumclaw	1079	318	30
City of Pacific	726	247	34
City of Sumner	700	224	32
City of Algona	291	79	27

Stormwater loads during runoff events are not included in the model because increased phosphorus loading from stormwater runoff generated during large precipitation events is not expected to directly lead to increased periphyton growth. The following factors reduce the impact of phosphorus loads during these runoff events:

- Increased periphyton loss from scour (greater shear stress from increased velocity).
- Faster travel times and less time for uptake (increased velocity).
- Less light reaching the bottom of the river (increased depth and decreased solar radiation due to cloud cover).

However, some phosphorus may be taken up during smaller runoff events and utilized by the periphyton later (luxury consumption). In addition, particulate organic phosphorus deposited on the streambed can potentially later be converted to SRP via hydrolysis. The model addresses the possible contribution from luxury consumption during small runoff events by including a constant stormwater flow. While this constant flow is less than what a single runoff event might generate, the effect of constant discharge provides more overall opportunity for nutrient uptake (longer period of exposure).

Stormwater infrastructure can actively discharge stormwater during baseflow conditions. For example, the City of Auburn operates a stormwater pump station that discharges stormwater collected from the city's infrastructure into the White River just upstream of the A St Bridge (~ RM 6.3). Phosphorus loads from the Auburn stormwater pump station were measured twice during the 2012 study and were relatively low with concentrations of 6 and 12 ug SRP/L.

During the 2012 study, Ecology routinely checked all known stormwater outfalls to the White River, within the study area; these outfalls were dry during non-runoff conditions with the exception of the Auburn pump station and two outfalls in the City of Sumner, below RM 3.6. Given that little to no stormwater is generally discharged during low-flow, non-runoff, dry-season conditions, only a small amount of phosphorus loading is assigned to each stormwater permittee, for low flow conditions (river flow less than 900 cfs), based on measured flows from the City of Auburn.

In addition, Manke Lumber Co. Superior Wood (Manke) discharges stormwater to the White River just downstream of the 8th Street bridge (~RM 4.8) in Sumner near the downstream critical end of the TMDL reach for the TMDL. Manke stores and discharges stormwater via two bioswales with associated outfalls 001 and 002. Outfall 001 and the associated bioswale drain ~9.6 acres of the western portion of the facility and create a passive discharge to the White River during runoff conditions that result in water storage levels above the outfall level. Outfall 001 is unlikely to discharge during non-runoff conditions. Outfall 002 drains ~6.9 acres of the eastern portion and receives some stormwater treatment. Treated stormwater is actively discharged (pumped) to the White River in batches, which can be discharged during non-runoff conditions. Ecology did not observe any discharge from either outfall 001 or 002 to the White River during the 2012 study period (August through October); Ecology reviewed pump records for outfall 002 provided by Manke that showed no discharge during that period, likely due in part to the relatively low amount of precipitation.

"Major" permittees were assigned a flow "share" equal to the City of Auburn's 2012 flow of 0.025 cms. A "double-share" of 0.050 cms was divided amongst the remaining minor and non-stormwater permittees, with each minor permittee assigned 1/7th of the flow and the two non-stormwater discharges assigned 1/14th of the flow each.

Different SRP concentrations for each permittee were tested in the low flow model in an iterative process, along with loading scenarios for other sources, until the model showed compliance with water quality criteria. The result of this process was a concentration of 7.5 ug/L SRP for stormwater inputs and 10.5 ug/L for the non-stormwater inputs. Non-stormwater inputs were set at 10.5 ug/L SRP because these discharges primarily represent groundwater de-watering during non-runoff conditions for construction and sand and gravel operations. 10.5 ug/L represents the estimated natural groundwater concentration for the TMDL (see Appendix I: Model Documentation).

For medium flow-conditions (river between 900-2,000 cfs), each permittee's WLA is increased by ~10x, to accommodate the increase in stormwater loading during these conditions. This was accomplished by increasing the concentration, but not the flow of the permittees. This provides a margin of safety because it represents the maximum potential pH impact from these loads, given that a higher stormwater flow (and thus lower concentration) would increase the loading capacity slightly in the river. Under high flow conditions (river >2,000 cfs), no numeric WLA limit is assigned to permittees.

The increased SRP concentrations were tested in the medium-flow model, along with loading scenarios for other sources, to confirm compliance with water quality criteria.

Future NPDES permitted discharges

Any potential future individual or general NPDES permitted discharges within the study area which have the potential to discharge SRP and do not have a WLA or reserve in this TMDL would need to fall into one of the following categories in order to be in compliance with this TMDL:

- Have zero discharge during non-runoff conditions from May to October when the river flow is less than 2,000 cfs.
- Discharge to the stormwater infrastructure of one of the permittees listed above. In this case facilities do not receive individual allocations, but rather are included within the allocation for the receiving stormwater infrastructure.
- Replace one of the permittees listed above. For example, an individual permittee transfers ownership of their parcel.
- A stormwater source is newly designated or permitted, and its magnitude, character, and location remain unchanged. In this case the allocation would be re-categorized from the LA to the WLA but the overall TMDL loading capacity remains the same.

If the permittee does not fall into one of the above categories, the TMDL would need to be revised or the permittee cannot discharge SRP.

Load allocations

This TMDL assigns a load allocation to nonpoint sources of phosphorus in the Lower White River watershed within the TMDL reach. The load allocation is based on the available loading capacity of the river and takes into account WLAs for permitted point sources. Load allocations for significant tributaries are provided as percent reductions of the phosphorus load above the estimated system potential phosphorus levels and the resultant seasonal average SRP load for the medium and low flow tiers (Table E-31). Because Ecology's authority to develop TMDLs and assign loads extends only to waters within its jurisdiction (i.e., state waters), this TMDL ensures that the load allocations will be met by reducing nonpoint sources within catchment areas.

Load allocations for diffuse sources (upwelling groundwater, seeps, very small tributaries/drainages, etc.) are set as the existing loading from the 2012 study year. No percent reduction is set for groundwater, recognizing that nonpoint sources of phosphorus to groundwater can be very difficult to locate and control. No increase in current nonpoint sources is allowed under this TMDL and nonpoint programs within the allocation area should aim to implement BMPs to ensure that a net increase in nonpoint phosphorus loading to these diffuse sources does not occur.

Ecology used 2012 tributary flows and concentrations from the low flow model to develop low flow tier allocations (See Appendix F: Study Results and Appendix I: Model Documentation).

Ecology estimated an increase in tributary flows for the medium flow model using the following process:

1. Determine the range of Boise Creek flows (using USGS gage record) when the White River flow is between 900 and 1000 cfs (critical conditions in medium flow model). Figure E-15 depicts the range and cumulative frequency of these flows.
2. Compare 75th percentile of Boise Creek flows from step 1 (15 cfs) to the average Boise Creek flow from August through October 2012 (10 cfs).
3. Use the ratio of the two flows in step 2 (1.5) to increase all tributary flows in the medium flow model.

Diffuse groundwater flows were already significantly higher in the medium-flow model, so Ecology did not apply an increase to those. Appendix H: Groundwater Assessment provides a detailed description of groundwater flows in the study area.

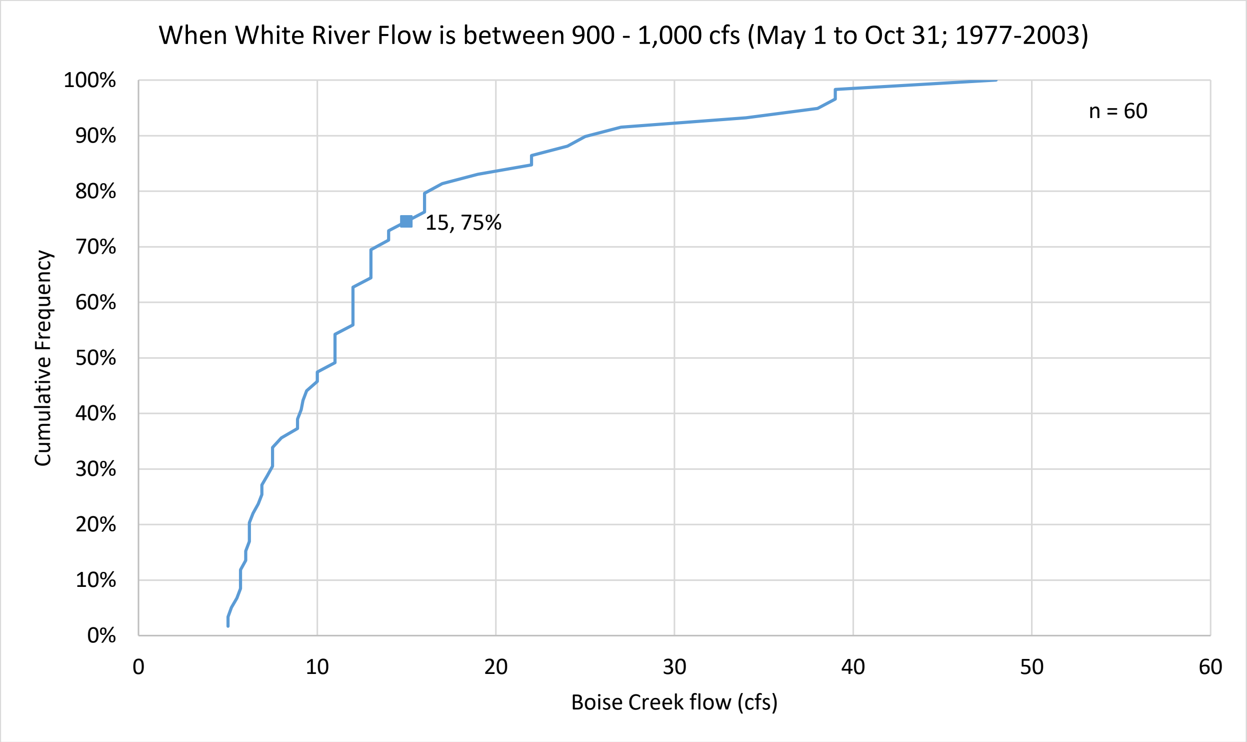

Figure E-15. Cumulative frequency of Boise Creek flows when the White River flow is between 900-1,000 cfs.

Nonpoint reductions were applied only to the estimated anthropogenic portion of the nonpoint load using equation 6:

$$Load\ Reduction = (SRP_{exist} - SRP_{natural}) \times NP_{red}\% \times Flow \times 0.18650916$$

Where SRP_{exist} = SRP concentration in the existing conditions model, $SRP_{natural}$ = SRP concentration used in the natural conditions model (13 ug/L SRP for tributaries); $NP_{red}\%$ = nonpoint percent reduction; Flow = tributary flow in the model in cubic meters per second; 0.18650916 = conversion factor to lbs per day.

Table E-31. Load allocations for nonpoint sources in the Lower White River pH TMDL.

~River Mile	Model Reach	Applicable Nonpoint Sources from Water Quality model	Nonpoint Reduction %	Medium Flow LA (lbs SRP/day)	Low Flow LA (lbs SRP/day)	Nonpoint Reduction Needed to meet LA (lbs SRP/ day)	
						Medium Flow	Low Flow
27	1	Red Creek	0%	0.230	0.116	0	0
23	5	Boise Creek	50%[1]	1.317	0.623	0.257	0.097
15.7	13	Second Creek (aka Trib15.7)	35%[1]	0.024	0.016	0.012	0.008
15.6	14	Pussyfoot Creek (aka Trib15.6)	35%[1]	0.141	0.098	0.051	0.035
7.6	23	Bowman Creek	0%	0.055	0.030	0	0
5.4	25	Government Canal	0%	0.241	0.070	0	0
4.3	28	Tributary at RM4.3	0%	0.095	0.054	0	0
28 to 3.6	1 to 28	All other diffuse sources	0%	8.55	5.45	0	0
>28	n/a	Upstream of TMDL boundary	5%[2]	n/a	n/a	n/a	n/a
Total =				**10.65**	**6.46**	**0.320**	**0.14**

[1] Percent reduction applied to estimated anthropogenic portion of the load only.

[2] This is not an allocation assigned by this TMDL, it is the assumed reduction in existing phosphorus loading associated with long-term implementation actions taken as part of the Upper White River TMDL and the State of Washington Forests and Fish Rule.

Loading summary

Table E-32 provides a summary of allocated loads or reserve loads in lbs SRP/day within the TMDL study area.

Table E-32. Summary of load allocations, reserves, and estimated background loads in lbs SRP/day for point and nonpoint sources.

Load Category	**Low Flow (Tier 3)**	**Medium Flow (Tier 2)**
	Point Sources	
Enumclaw WWTP	0.62	1.50
Buckley WWTP	0.36	0.87
MIT Future Growth Reserve	0.53	1.31
White River Hatchery (net)	0.94	2.43
Coal Creek Springs Fish Facility Reserve (net)	0.86	0.99
MIT Stormwater Reserve	0.035	0.368
Other NPDES WLAs*	0.245	2.576
Subtotal	3.59	10.04
	Nonpoint Sources	
Anthropogenic groundwater	0.38	0.68
Natural groundwater	5.07	7.87
Anthropogenic surface water (tribs)	0.29	0.64
Natural surface water (tribs)	0.72	1.46
Subtotal	6.46	10.65
	Summary of Loading	
Point Sources	3.59	10.04
Anthropogenic Nonpoint Sources	0.67	1.32
Natural Background	5.79	9.33
Total Load	**10.05**	**20.69**

*Includes various stormwater (municipal, industrial, individual) permittees, as well as dewatering or process water discharges from construction and sand and gravel permittees

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[9] https://www.cityofenumclaw.net/216/Comprehensive-Plan

Appendix F. 2012 TMDL Study Results

Introduction

In 2012, Ecology conducted a field study to provide a more current basis for Lower White River pH TMDL allocations. The Quality Assurance Project Plan (QAPP) describes the methods that were used for data collection and analysis (modeling) in further detail (Mathieu and Pelletier, 2012). Appendix A provides additional background on the watershed and TMDL process.

Study goal

The goal of the 2012 study was to collect a dataset of sufficient quality and quantity to calibrate a water quality model of the Lower White River that is capable of simulating dynamic changes in pH. The model setup and calibration are discussed in detail in Appendix I: Model Documentation. How the model was used to develop the analytical framework and phosphorus allocations are described in Appendix D (Analytical Framework) and E (TMDL Analysis).

Study area and locations

The White River drains a 740 square-mile basin with a total length of ~85 miles. Mud Mountain Dam, just upstream of river mile (RM) 28, provides flood control for the river valley and can affect flows in the river downstream. The Ecology study area for this project is approximately 90 square miles and extends from RM 28 to the mouth of the river near its confluence with the Puyallup River (Figure F1).

The Muckleshoot Indian Tribe (MIT) owns and governs reservation land along the Lower White River within the study area. The White River flows through Muckleshoot land between river miles (RM) 15.5 and 8.9. Surface waters that flow into the reservation boundaries are considered waters of the state upstream of the boundary and tribal waters downstream of the boundary. The opposite applies to waters flowing out of tribal land.

Lake Tapps was not directly included in the study or water quality model. The Lake Tapps diversion from the White River at RM 24 was treated as a withdrawal/abstraction in the model and the tailrace of the diversion near RM 4 of the river was treated as a tributary input in the model. See Appendix I for further detail.

Ecology collected samples and measurements from 12 locations on the mainstem White River, 4-point source inputs, 13 tributaries, 3 diversion canal sites, and 3 baseflow stormwater inputs (Figure F-16; Table F-33).

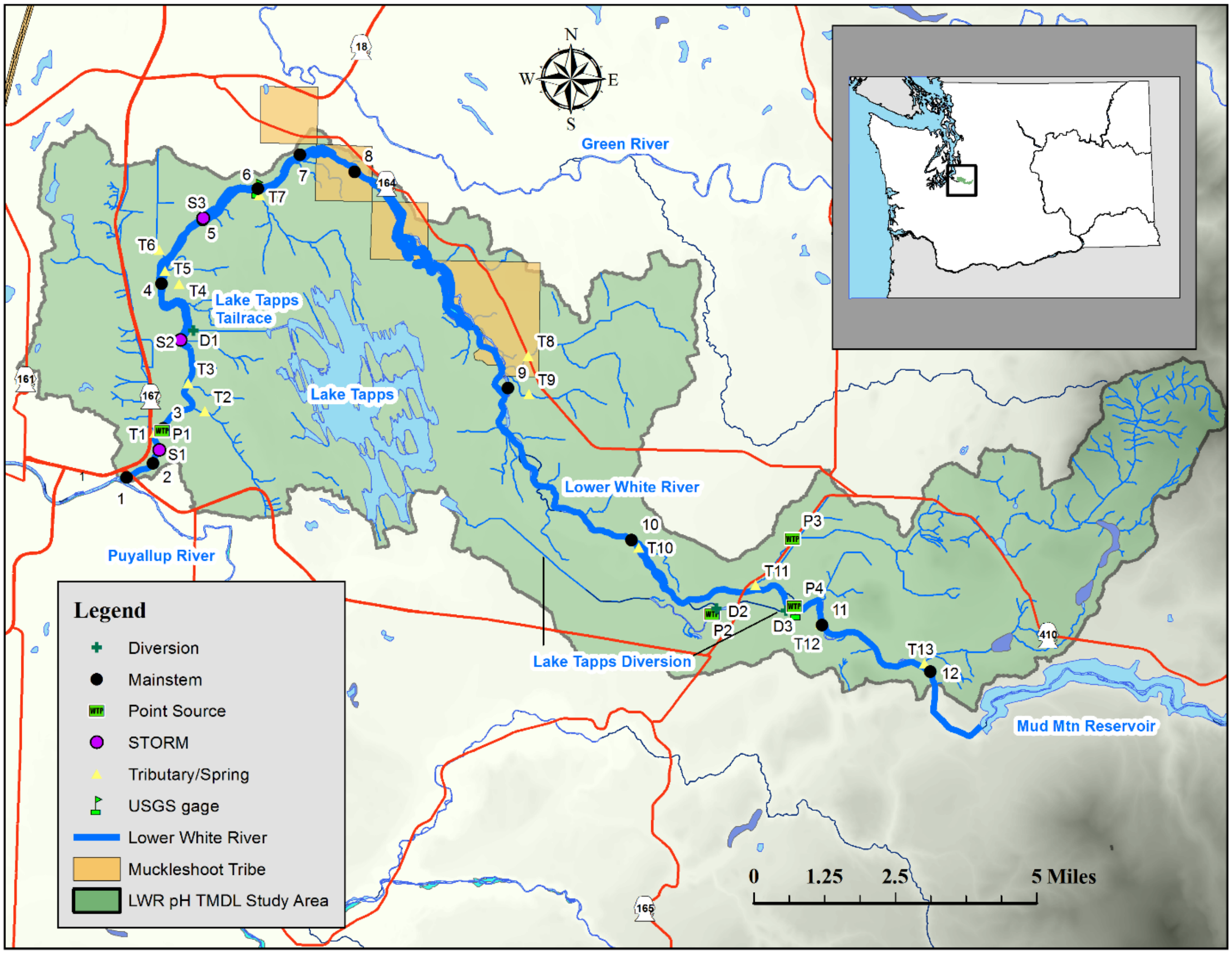

Figure F-16. Study area and locations for the Lower White River pH Total Maximum Daily Load study.

Table F-33. Ecology sampling locations for the 2012 TMDL study.

Map Code	Location ID	Study Location ID	Location Description	Latitude	Longitude
Mainstem					
12	10-WHT-28	W28	White River below Mud Mtn Dam	47.154860	-121.952060
11	WHI25.2	W25.2	White River at Rainier School	47.167059	-121.993199
10	WHI20.4	W20.4	White River below Buckley	47.186853	-122.065091
9	10-WHT-16.2	W16.2	White River above Muckleshoot Reservation	47.225674	-122.112891
8	10-WHT-10.3	W10.3	White River off Stuck River Dr	47.279810	-122.173510
7	10-WHT-8.5	W8.5	White River at east end of Game Farm Park	47.283494	-122.192876
6	10-WHT-7.5	W7.5	White River at R St SE	47.274820	-122.208580
5	WHI06.3	W6.3	White River above A St/ E Valley Hwy E	47.266334	-122.228909
4	10-WHT-4.8	W5	White River at 8th St E/ Stewart Rd	47.249870	-122.243830
3	10-WHT-1.4	W1.4	White River upstream of Fryar Ave	47.212660	-122.242220
2	WHI00.7	W0.5	White River at Pacific Ave	47.204127	-122.245761
1	10-WHT-0.1	W0.1	White River at mouth	47.200730	-122.253930
Point Sources					
P4	MUCEFF	MFH	White River Hatchery	47.169860	-122.003620
P3	10-EC-WWTP	EC	Enumclaw WWTP	47.188110	-122.005210
P2	10-BK-WWTP	BK	Buckley WWTP	47.168070	-122.035170
P1	SONOCO	SON	Sonoco Products Co.	47.213063	-122.241869
Tributaries/Diversion/Stormwater					

Map Code	Location ID	Study Location ID	Location Description	Latitude	Longitude
T13	10-RED-0.1	TR27.6	Red Creek near mouth	47.156890	-121.954590
T12	10-RSSW-0.01	SW25.1	Old Rainier School WWTP outfall	47.166825	-121.994012
D3	10-LTD-DIV	LTD-DIV	Lake Tapps Canal at Diversion Dam	47.169790	-122.006030
T11	10-BOI-0.1	BOI	Boise Creek near mouth	47.176050	-122.018600
D2	10-LTD-FISH	LTD-FISH	Lake Tapps Canal fish return	47.169910	-122.032930
T10	10-UNW-TRIB20.6	TR20.6	Unnamed trib at ~RM 20.6	47.185080	-122.062460
T9	10-UNW-TRIB15.7	TR15.7	Second Creek downstream of SR164	47.223850	-122.104680
T8	10-UNW-0.1	TR15.6	Pussyfoot Creek at SR164	47.233450	-122.105540
T7	BOWMAN	TR8	Bowman Creek at mouth	47.274553	-122.210295
S3	10-UNW-SW6.2	SW6.2	Stormwater outfall at ~RM 6.2	47.266780	-122.228770
T6	10-GOVT-0.3	TR5.3	Government Canal at Butte Ave	47.258500	-122.245060
T5	10-UNW-TRIB5.1	TR5.1	Wetlands outlet to White R. at ~RM 5.1	47.253190	-122.242710
T4	10-UNW-TRIB4.3	TR4.3	Unnamed trib at Stewart Rd	47.250260	-122.236950
D1	LTD03.6	LTD-TAIL	Lake Tapps Power Flume Outlet	47.238076	-122.231429
S2	10-UNW-SW3.3	SW3.3	Stormwater outfall at 24th St E bridge	47.235580	-122.236310
T3	10-UNW-TRIB2.9	TR2.9	Unnamed trib at E Valley Hwy & 29th St E	47.231190	-122.225330
T2	10-SAL-0.2	TR2.6	Salmon Creek at E Valley Hwy	47.217490	-122.226140
T1	WTR01.3	TR1.3	Unnamed Trib @ White RM 1.3	47.212641	-122.245921
S1	10-UNW-SW0.9	SW0.9	Stormwater Outfall at ~RM 0.9	47.207470	-122.243350

Study Methods

Ecology's study design, data collection, and data quality methods are described in detail in the Quality Assurance Project Plan (QAPP) (Mathieu and Pelletier, 2012).

In general, data collection followed the plan outlined in the QAPP, with a few notable exceptions:

- The QAPP prescribed up to four full synoptic survey events, however, a large rainstorm occurred the weekend before the third scheduled synoptic survey in mid-October 2012.
    - As a result, field staff organized a scaled-back synoptic survey on 10/11/12 in place of the full synoptic survey. The goal of this effort was to capture the period of peak pH before the storm arrived. The amount of data collected had to be scaled back due to the lack of available staff, laboratory capacity, and equipment on 10/11/12.
    - Increasingly frequent precipitation and an unstable hydrograph for the rest of October 2012 led to another scaled back synoptic survey on 10/25/12, during a brief period of lower flows.
- Macroinvertebrate and periphyton identification sampling were scheduled for low-flow conditions in October but had to be canceled due to rising flows. This sampling was not necessary to meet project objectives, so it was not rescheduled, due to time and resource constraints.
- Similarly, a second low-flow time of travel study scheduled in October 2012 was canceled due to rising flows.
    - A replacement low-flow dye study was conducted the following year, in October 2013.

Data quality assurance methods included:

- Field Quality Assurance (QA) Methods:
    - Duplicate samples, streamflow, periphyton, and water quality measurements.
    - Calibration of water quality instruments (including sondes and thermistors), prior to use or deployment, using NIST-certified standards and manufacturer or Ecology procedures. Deployed sondes were also post-checked using the same procedures.
    - Long term water quality sonde deployments were visited every 2-4 weeks (or as needed) for cleaning, calibration, and re-deployment.
- Lab QA Methods:
    - Manchester Environmental Laboratory (MEL) analyzed duplicates, blanks, matrix spikes, and laboratory control samples for each batch of samples analyzed, following routine laboratory procedures.

Information and data sources from outside Ecology

Information from two external sources was used for the model development and calibration, as well as general validation of Ecology data: USGS and MIT.

Streamflow and stage data were utilized from the USGS stations (USGS, 2015) listed in Table F-34. Continuous water quality data was utilized from the stations listed in Table F-35.

Table F-34. USGS hydrology stations/gages used to support or develop the model.

Station ID	Station Name	Flow	Stage
12097850	WHITE RIVER BELOW CLEARWATER RIVER NR BUCKLEY, WA	X	X
12098500	WHITE RIVER NEAR BUCKLEY, WA		X
12098920	WHITE RIVER FLUME AT BUCKLEY, WA	X	X
12099200	WHITE RIVER ABOVE BOISE CREEK AT BUCKLEY, WA	X	X
12099600	BOISE CREEK AT BUCKLEY, WA	X	X
12100490	WHITE RIVER AT R STREET NEAR AUBURN, WA	X	X
12100494	WHITE RIVER AT ROEGNER PARK NEAR AUBURN, WA		X
12100496	WHITE RIVER NEAR AUBURN, WA		X
12100498	WHITE RIVER AT PACIFIC, WA		X
12100500	WHITE RIVER NEAR SUMNER, WA		X
12101100	LAKE TAPPS DIVERSION AT DIERINGER, WA	X	X

Table F-35. USGS water quality stations/gages used to support or develop the model.

Station ID	Station Name
12098700	WHITE RIVER AT HEADWORKS AB FLUME NR BUCKLEY, WA
12100490	WHITE RIVER AT R STREET NEAR AUBURN, WA
12101100	LAKE TAPPS DIVERSION AT DIERINGER, WA

MIT deployed continuous temperature instruments at three locations within the reservation boundary:

- White River mainstem at ~RM 10;
- Unnamed Tributary to White River at RM 15.6;
- Unnamed Tributary to White River at RM 15.7 (locally known as Second Creek).

MIT also collected continuous water quality data, using a multi-parameter sonde, on the White River mainstem at ~RM10 on 8/17/2012 - 8/24/2012, 9/20/2012 - 9/28/2012, and 10/11/12 – 10/12/12.

Study results and discussion

During the 2012 study Ecology, USGS, and MIT collected flow, pH, temperature, groundwater, turbidity, light, periphyton, and nutrient data. The goal of this effort was to characterize and model the response of pH in the water column to increased uptake of inorganic carbon by periphyton during periods of increased algal growth.

Complete data tables for the project are located in Appendix G.

Quality assurance results

In 2004, Washington State enacted a law entitled the Water Quality Data Act. It relates to collecting and using water quality data. The law requires that the data used in certain water quality activities meet its credible data principles. The law further requires that Ecology develop a policy regarding the use and collection of water quality data. The three main goals of the policy are:

1. to explain how data is used to inform decisions about water quality and water quality improvement projects,
2. to describe criteria to establish data credibility, and
3. to recommend appropriate training and experience for data collection.

Ecology's policy: "Ensuring Credible Data for Water Quality Management" is available online at: Water Quality Policy 1-11 Chapter 2 - Ensuring Credible Data for Water Quality Management[10].

Overall, Ecology found the study data to be of acceptable quality and useable based on the study objectives. Some results were qualified or rejected based on failure to meet measurement quality objectives or other issues. Appendix G provides more detailed data quality results.

Due to rapidly rising flows in October, the project did not meet the completeness goal of collecting and analyzing at least 95% of the data outlined in the QAPP. However, scaling back the two October synoptic surveys allowed the project staff to respond quickly to several narrow critical conditions windows and target the most important sites and parameters. As a result, enough data was collected to meet the project objectives, including development and calibration of the water quality model.

Ecology reviewed the data quality methods and results from the USGS and MIT sources and determined the data used was of acceptable quality and met the requirements of the Credible Data Policy. A description of USGS and MIT data quality methods and results is included in Appendix G.

Hydrology and Meteorology

Streamflow in the White River followed a relatively typical pattern (near historical median) in the summer and fall of 2012 (Figure F-17). Flows steadily receded through August and September due to gradually decreasing glacial meltwater contributions from Mt. Rainier, dropping from ~1,000 to 500 cfs during this period. A baseflow of ~400-450 cfs was reached during the first two weeks of October, (when glacial melt reached seasonal lows) and was accompanied by dramatically reduced turbidity. Several significant precipitation events between mid to late October increased flows to over 1,000 cfs for several days at a time, before decreasing rapidly for brief periods. A large precipitation event in the final days of October signaled the end of fall baseflow conditions for the river, as well as data collection for the TMDL.

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[10] https://apps.ecology.wa.gov/publications/SummaryPages/2110032.html

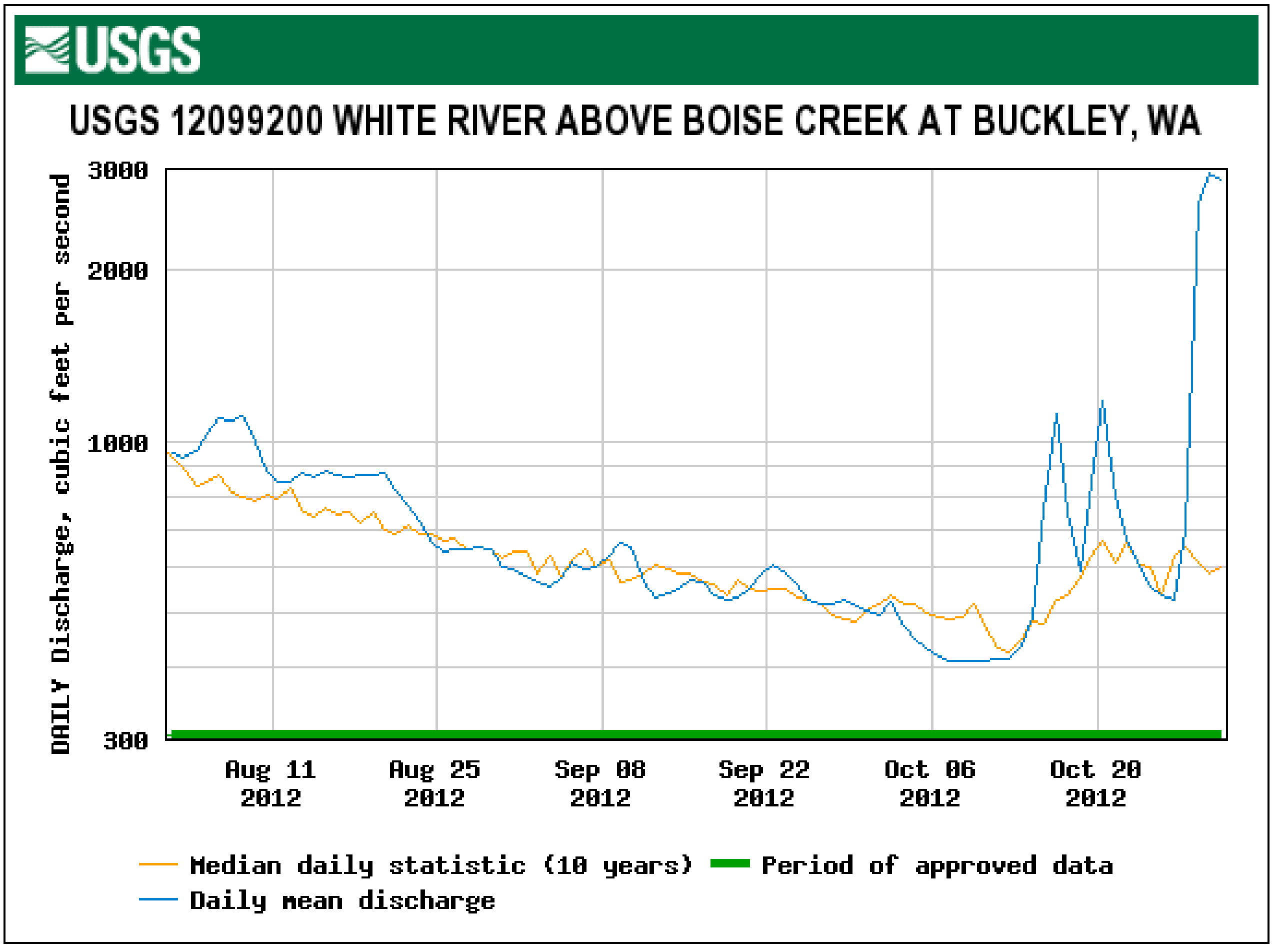


Figure F-17. Streamflow during the 2012 study for the USGS station: White River above Boise Creek at Buckley, WA.

The 7-day low flow, often in relation to a recurrence interval, is a commonly used low flow metric amongst water resource managers. The 7-day low flow for 2012 reached 412 cfs for the period centered on 10/9/12. This was the lowest 7-day flow during the study period.

The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every ten years on average. Similarly, the 7Q2 has recurrence interval of once every 2 years. Ecology used the 7Q10 in the system potential (see Appendix I) and TMDL (see Appendix D) modeling scenarios.

Based on historical USGS station 12098500 at RM 28, period of record (1928-2003), the 7Q10 is 272 cfs, and the 7Q2 is 407 cfs. Low flow statistics were also calculated for the more recent period of 1977-2003, resulting in a 7Q10 of 250 cfs, and the 7Q2 of 363 cfs. The more recent period was delineated based data analyses completed by the USGS that suggests hydrometeorological conditions in the Pacific Northwest have likely shifted in recent decades because of changes in atmospheric-circulation patterns and sea-surface temperatures. This shift has resulted in less precipitation and streamflow at most locations, based on a comparison of data collected after 1976 versus before 1976 (Vaccaro, 2002).

Ecology used this historical station because it has the longest period of record and is not affected by the very large historical water withdrawals to Lake Tapps. Ecology used a 7Q10 of 250 cfs in the TMDL analysis, because it represents a more recent climate, potential baseflow impacts, more reliable data, and a conservative assumption that provides additional margin of safety.

The 2012 data represents a low-flow regime that would occur commonly, once every 2 years. The 7Q10 flow represents a lower, more critical flow level that is only reached approximately once per decade. Lower flows in the White River result in shallower water depths, which results in more available light reaching the stream bottom and increased algal growth. The 7Q10 flow level, combined with low turbidity, represents a critical condition for pH and phosphorus loading in the White River.

Developing a mass flow balance, the sum of all flow inputs and losses, is a fundamental part of developing a TMDL, calculating source loads, and assigning allocations. Seepage surveys involve measuring flow for multiple, bracketed segments of a water body and all known or accessible inputs or withdrawals. The flow difference between upstream (inflow) and downstream (outflow) stations is compared against the combined inputs (inflow) and withdrawals (outflow) to determine a flow residual (all inflows minus all outflows). The residual from the mass flow balance can be used to infer groundwater gains and losses, or diffuse surface flow inputs or withdrawals if groundwater interaction is not likely.

Ecology conducted seepage surveys during the August and September 2012 synoptic surveys, in order to develop a flow balance for the White River TMDL. Of the two, the September survey was most valuable, as the daily flow in the mainstem White River was more stable throughout the day. Figure F-18 illustrates that the vast majority of the flow originates from the upstream boundary, with only minor surface water inputs. The largest inputs of flow within the study reach were the residuals of the flow balance between RMs 28 and 7.6, which have been interpreted as groundwater input (see next section and Appendix H for further discussion).

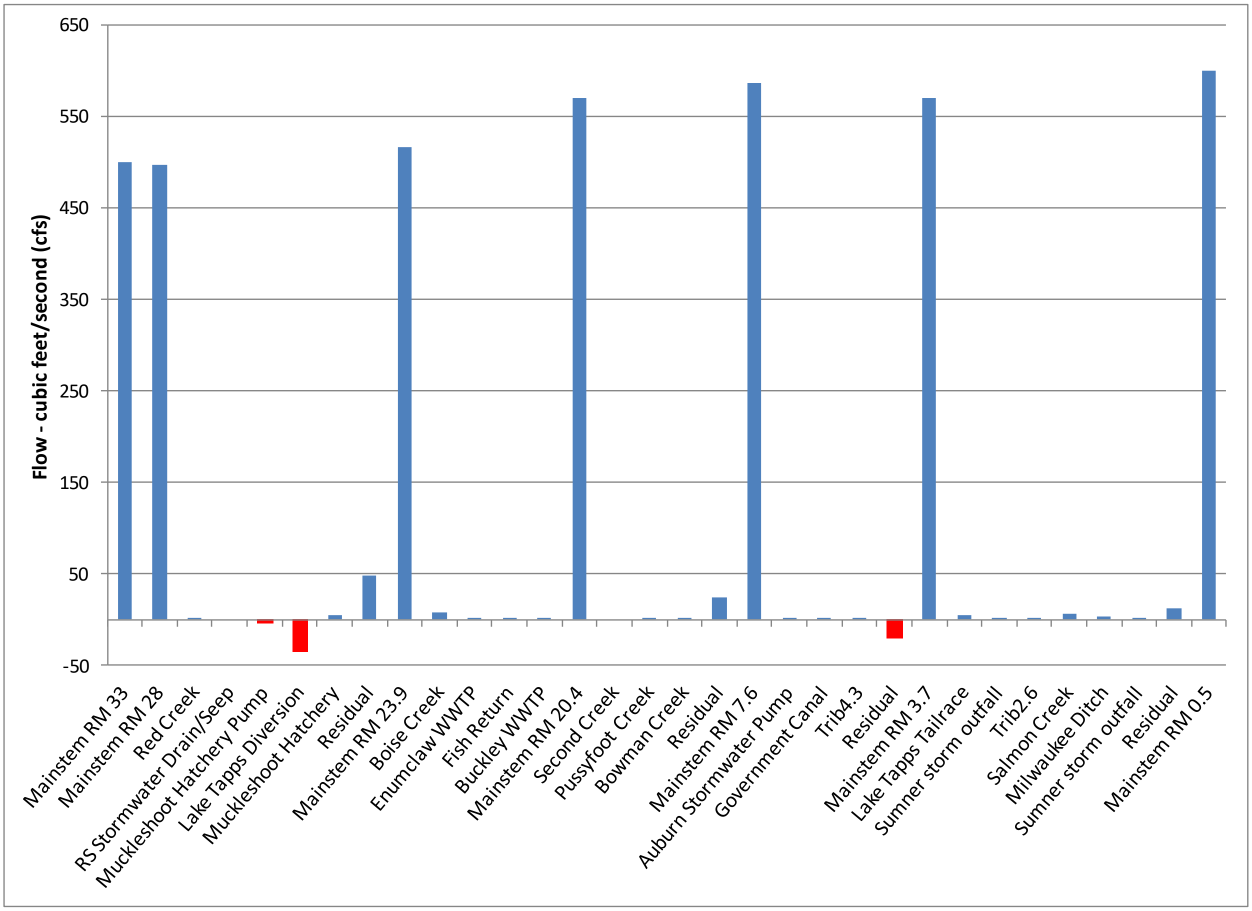


Figure F-18. Flow balance for seepage survey conducted on 9/25/12 - 9/26/12.

Time of Travel (Rhodamine WT Dye) Study

Ecology released 20% Rhodamine WT dye into the Lower White River in August of 2012 and October of 2013 in order to measure the average velocity and time of travel during summer and late fall baseflow. Rhodamine concentrations were measured at downstream locations using Turner Designs Rhodamine-specific Fluorometers installed on Hydrolab sondes. Tables F-36 and F-37 summarize the segment and cumulative travel times and average velocities for the dye releases. Figures F-19 and F-20 illustrate the dye curves measured at each downstream location.

The first survey was conducted on August 8-9th of 2012 at flows ranging from 1,030 to 1,280 cfs. The reach average velocity from ~RM23 (just below the confluence with Boise Creek) to the mouth was measured as 3.91 ft/sec for this survey. Unfortunately, two of the dye clouds inadvertently overlapped and peaked downstream at the mouth at nearly identical times. This was due to unexpectedly fast travel times, combined with difficult access at 10-WHT-16.2 which involved an hour-long hike and navigating a steep game trail. The releases are conducted near dusk to minimize visual, agricultural, and recreational impacts and the 10-WHT-16.2 release was conducted first for safety reasons. When dye was released ~2 hours later at 10-WHT-8.5 (at

Game Farm Park), the upstream cloud had already traveled 7 miles and was peaking at 10-WHT-8.5, although it was not visible to the eye at this point.

The second survey was conducted on October 28-29th of 2013 at flows ranging from 540 to 615 cfs. The reach average velocity from ~RM23 (just below the confluence with Boise Creek) to the mouth was measured as 3.07 ft/sec for this survey. Given the access/logistical issues at 10-WHT-16.2 and how clearly dye peaks were measured during the first survey, only two releases were conducted during the October 2013 study. No dye curves overlapped during this survey. Contrary to expected results, the calculated velocity was much faster than the August (higher flow) survey in the first reach (~RM 23 to 20) at 5.24 ft/sec. It is possible that this particular logger was inadvertently programmed to the wrong time zone. If this were the case the average velocity for this reach would be 2.38 ft/sec, which is more consistent with other results from this survey, but lower than expected.

The upper most segment of each dye release provide the least certain estimate of time of travel, as these reaches have likely not attained full lateral mixing and thus overestimate the average velocity for the segment. The upper most dye releases (at ~RM23) were conducted downstream of the model boundary (~RM28) to avoid dye being introduced to the fish hatchery intake and the diversion to Lake Tapps at ~RM24.

Table F-36. Summary time of travel and average velocity for the August 2012 dye survey.

Location	~RM based on model	Time of Peak <u>(or release)</u>	Segment Peak travel time (days)	Cumulative Peak travel time (days)	Segment Average Velocity (ft/s)	Cumulative Average Velocity (ft/s)
Release #1 - Boise Creek Confluence						
Blw Boise Creek	22.79	**<u>8/8/12 22:10</u>**	n/a	0.0	n/a	
Blw Buckley	19.81	8/8/12 23:10	0.04	0.04	4.37	4.37
Upstream of MIT	15.29	8/9/12 0:40	0.06	0.10	4.42	4.40
Game Farm Park	8.62	8/9/12 3:00	0.10	0.20	4.19	4.30
Mouth	0.14	8/9/12 6:40	0.15	0.35	3.39	3.91
Release #2 - Upstream of Muckleshoot Indian Tribe Boundary						
Upstream of MIT	15.29	**<u>8/8/12 20:40</u>**	n/a	0.1	n/a	4.40
Game Farm Park	8.62	8/8/12 22:50	0.09	0.19	4.52	4.45
Mouth	0.14	8/9/12 2:20	0.15	0.34	3.55	4.07
Release #3 - Game Farm Park						
Game Farm Park	8.62	**<u>8/8/12 22:50</u>**	n/a	0.20	n/a	4.30
Near Mouth	0.14	8/9/12 2:20	0.15	0.35	3.55	3.99

Table F-37. Summary time of travel and average velocity for the October 2013 dye survey.

Location	~RM	Time of Peak (or release)	Segment Peak travel time (days)	Cumulative Peak travel time (days)	Segment Average Velocity (ft/s)	Cumulative Average Velocity (ft/s)
Release #1 - Boise Creek Confluence						
Blw Boise Creek	22.79	**10/28/13 17:30**	n/a	0.0	n/a	
Blw Buckley	19.81	10/28/13 18:20	0.03*	0.03*	5.24*	5.24*
Game Farm Park	8.62	10/28/13 23:30	0.22	0.25	3.18	3.46
8th Street Bridge	4.96	10/29/13 1:20	0.08	0.33	2.93	3.34
Mouth	0.14	10/29/13 4:20	0.13	0.45	2.36	3.07
Release #2 - Game Farm Park						
Game Farm Park	8.62	**10/28/13 18:00**	n/a	0.25	n/a	3.46
8th Street Bridge	4.96	10/28/13 19:30	0.06	0.31	3.58	3.49
Near Mouth	0.14	10/28/13 22:10	0.11	0.42	2.65	3.27

*result inconsistent with other time of travel and velocity data

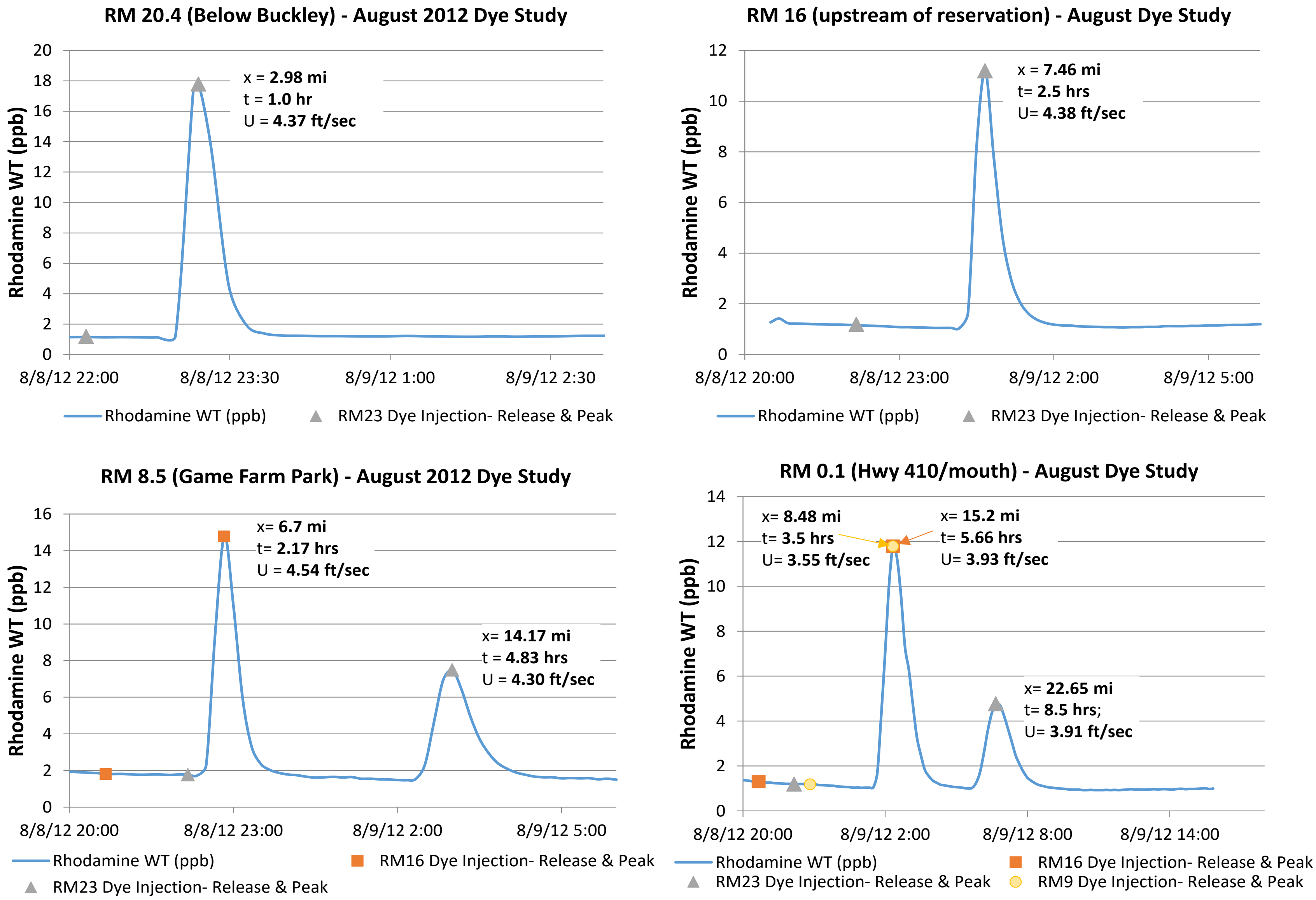


Figure F-19. Rhodamine WT dye curves for the August 2012 Survey. x= distance traveled; t= time from release; U= average velocity.

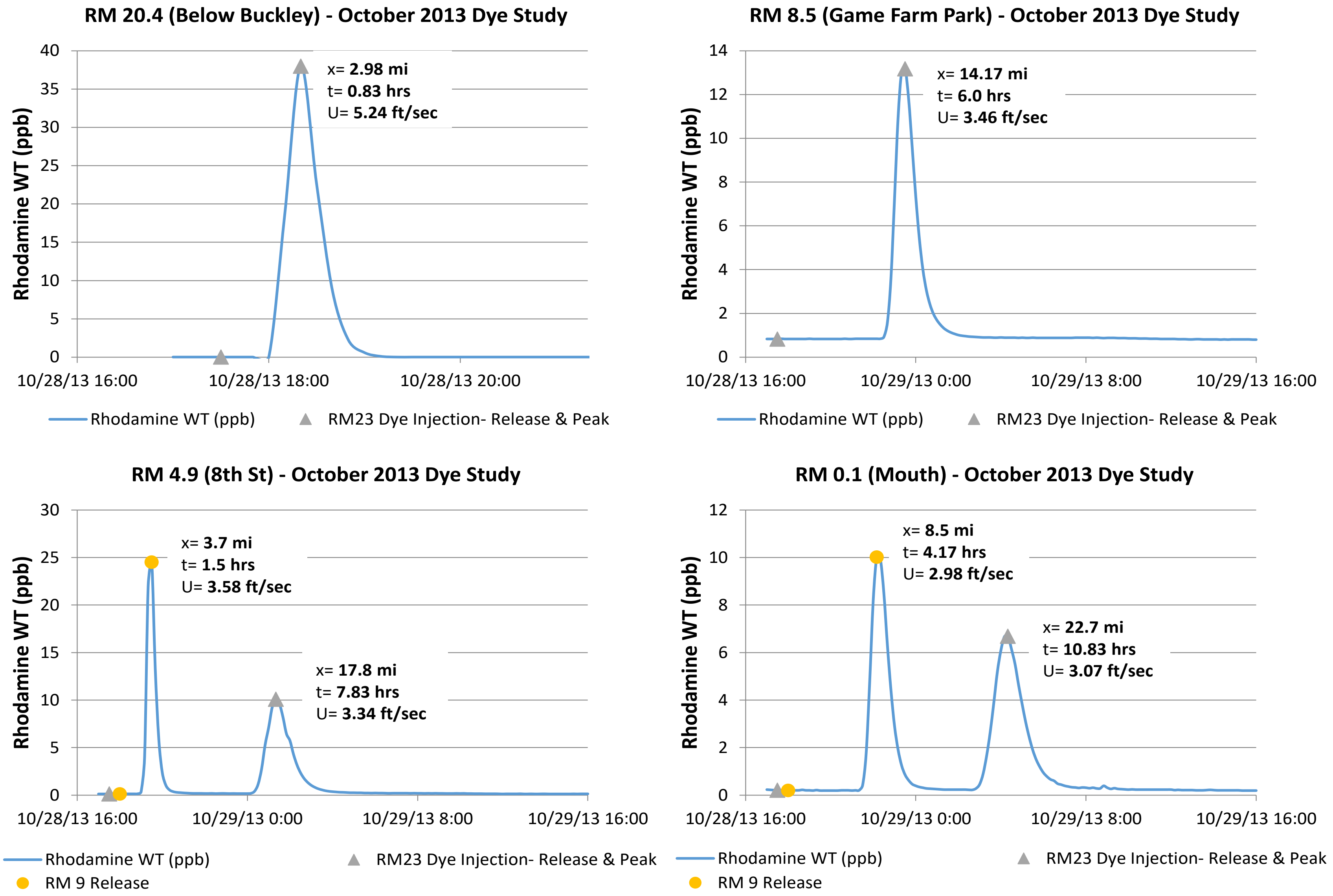


Figure F-20. Rhodamine WT dye curves for the October 2013 Survey. x= distance traveled; t= time from release; U= average velocity.

Hydrogeology

Ecology installed 9 piezometers on the mainstem of the river to assess the potential gains and losses of groundwater or hyporheic flow within the study area. The project hydrogeologist instrumented the piezometers with continuous temperature loggers at multiple depths, monitored water levels, and took water quality measurements and samples. Several local springs and off stream wells were also monitored. The results of this monitoring, along with the flow balance results and knowledge of surficial hydrogeology were used to develop estimates of regional groundwater discharge (or abstractions) and associated water quality. More detailed results of the assessment are included in Appendix H, in summary:

- Reach 1 (RM 28 USGS gage and study boundary to RM23.9 USGS gage): the weight of evidence suggests this reach is likely a gaining reach with groundwater discharge to the river occurring. A 5-day running average of the residual flow balance was used as an input to the model. This residual was assumed to be uniformly distributed along reach 1.
- Reach 2 (RM23.9 USGS gage to RM7.6 USGS gage): Reach 2 was divided into three sub-reaches (<u>2A:</u> RM 23.9 to 18.2; <u>2B:</u> RM 18.2 to 10; <u>2C:</u> RM 10 to 7.6). The weight of evidence suggests Reach 2 is likely a gaining reach overall with discharge of groundwater to river occurring. There is some evidence that SubReach 2C is a losing reach. A 5-day running average of the residual flow balance was used as an input to the model, with gains distributed to Subreaches 2A and 2B, and with losses distributed to Subreach 2C.
- Reach 3 (RM7.6 USGS gage to RM 0.1 mouth): Reach 3 was divided into three sub-reaches (<u>3A:</u> RM 7.6 to 4.0; <u>3B:</u> RM 4.0 to 0.9; <u>3C:</u> RM 0.9 to 0.1). The weight of evidence suggests:
    - SubReach 3A is likely a losing reach overall with discharge from the river to the hyporheic zone occurring. Based on the seepage survey results, a constant abstraction of 19 cfs was used in the model in this sub-reach.
    - Evidence is inconclusive for SubReach 3B, with most evidence indicating gains and some evidence indicating losses. Based on the seepage survey results, a constant input of 7 cfs was used in the model in this sub-reach.
    - The weight of evidence suggests SubReach 3C is likely a gaining reach overall with discharge of groundwater to river occurring. Based on the seepage survey results, a constant input of 5 cfs was used in the model in this subreach.

Light and turbidity

Glacial melt water from Mt. Rainier strongly influences turbidity in the river with large increases in turbidity from late spring to early fall. Within the 2012 study period, turbidity ranged between 30 and 300 formazin nephelometric units (FNU) at USGS station 12098500 (RM 24.2) from early August to the beginning of October, the period of greatest glacial melt (Figure F-22Figure F-22). USGS collects FNU turbidity data because it is the sensor technology equipped on the multi-parameter sondes they have deployed in the river.

FNU differs from Nephelometric Turbidity Units (NTU) in that infrared light (wavelength of 780-900 nm) is used for FNU measurement and white light (400-680 nm) is used for NTU measurement. Suspended particles can scatter light from different wavelengths with varying efficiency, so FNU turbidity data is not directly comparable to NTU turbidity data (USGS, 2013). Based on data collected in 2012, Ecology NTU data (laboratory measured) was approximately 10% higher than USGS FNU data (field measured) (Figure F-21Figure F-21). Ecology analyzed samples using an accredited laboratory and NTU method. The NTU method was chosen by Ecology because it is directly comparable to Washington State Water Quality Standards.

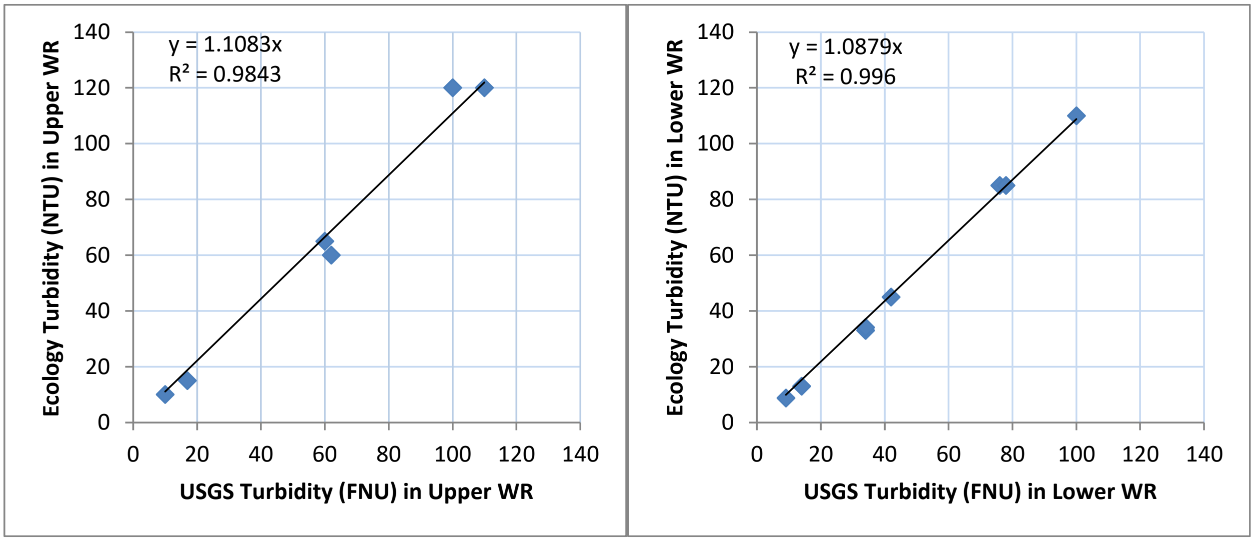


Figure F-21. Relationship between USGS turbidity and Ecology turbidity data during the 2012 study.

Between October 3, 2012, and October 13, 2012, the river turbidity dropped quickly (due to colder temperatures and reduced glacial melt) to a base level of ~12 FNU, before a large precipitation event in mid-October increased the turbidity to levels peaking above 1,000 FNU. The brief period of low turbidity in early October likely resulted in a substantial increase in available light to the bottom substrate of the river.

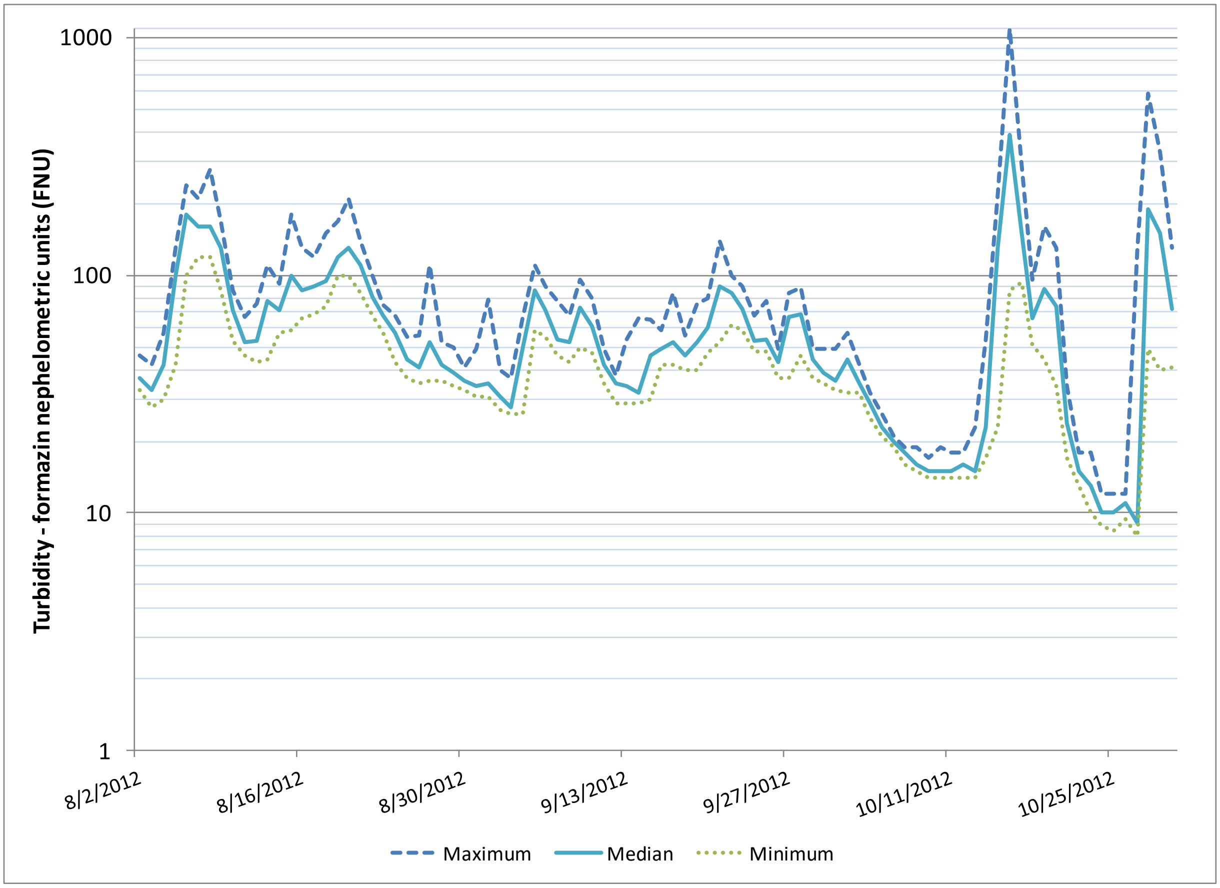


Figure F-22. Turbidity at USGS WQ Station 12098500 at ~RM24.2 during the course of the 2012 study.

During the 2012 study, Ecology conducted eight light extinction surveys, using a Kahl Scientific Irradiameter, to assess the amount of available solar radiation throughout the water column in conditions of variable turbidity and ambient solar radiation. Figure F-23 illustrates a typical light extinction profile for the White River, with solar radiation dropping rapidly within the first 0.5 meters of the water column but decreasing more slowly at deeper depths.

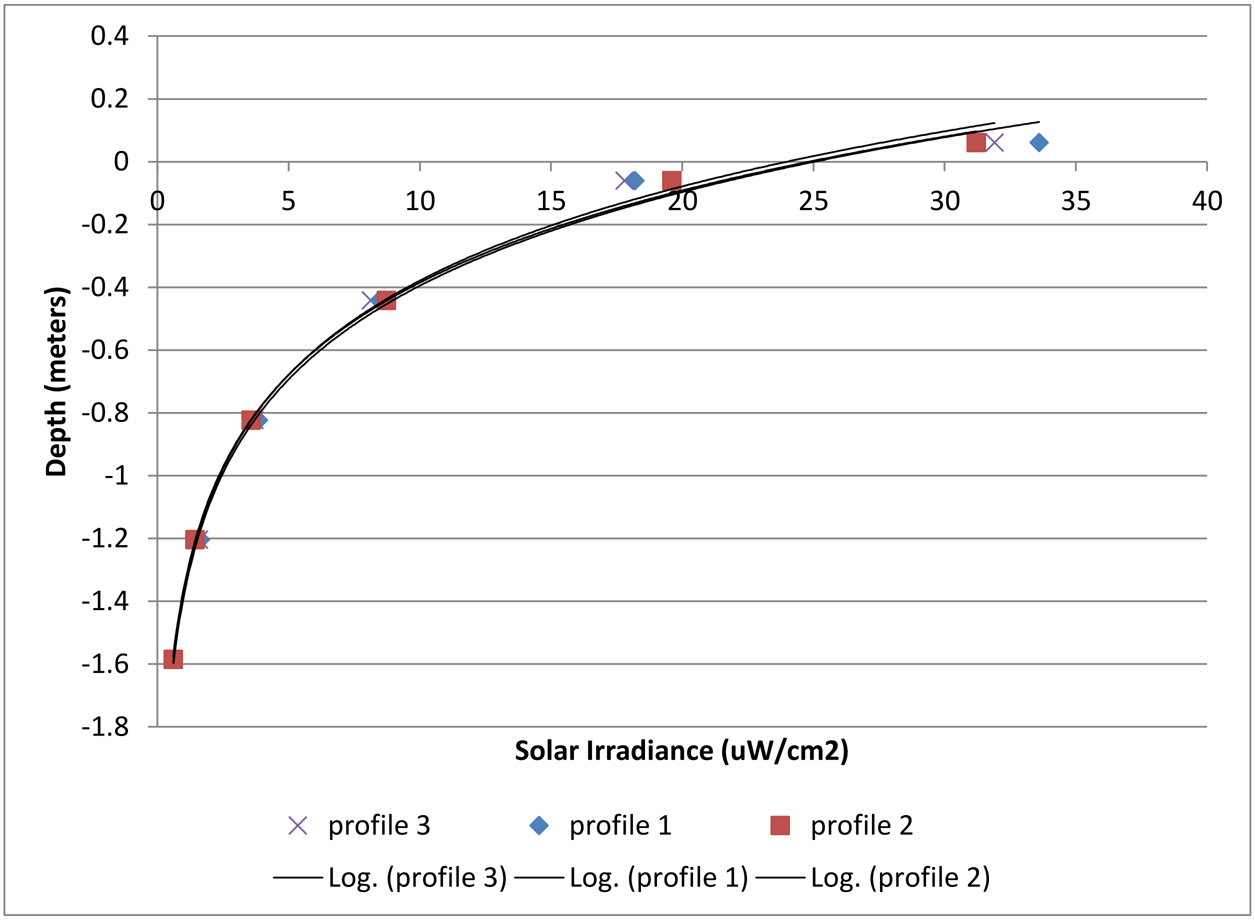


Figure F-23. Example light extinction profiles collected on 9/27/12 on the White River at Pacific Ave Bridge.

Ecology calculated a light extinction coefficient for each extinction profile using the slope of the linear relationship between water depth and the natural logarithm of the measured solar radiation (Figure F-24 shows an example of these calculated extinction coefficients for three profiles collected on 9/27/12). Table F-38 provides the average light extinction coefficient for each survey date. The relationship between the light extinction coefficients and the measured inorganic suspended solids (ISS) was used to determine both the background and ISS light extinction rates for the model (see Appendix I).

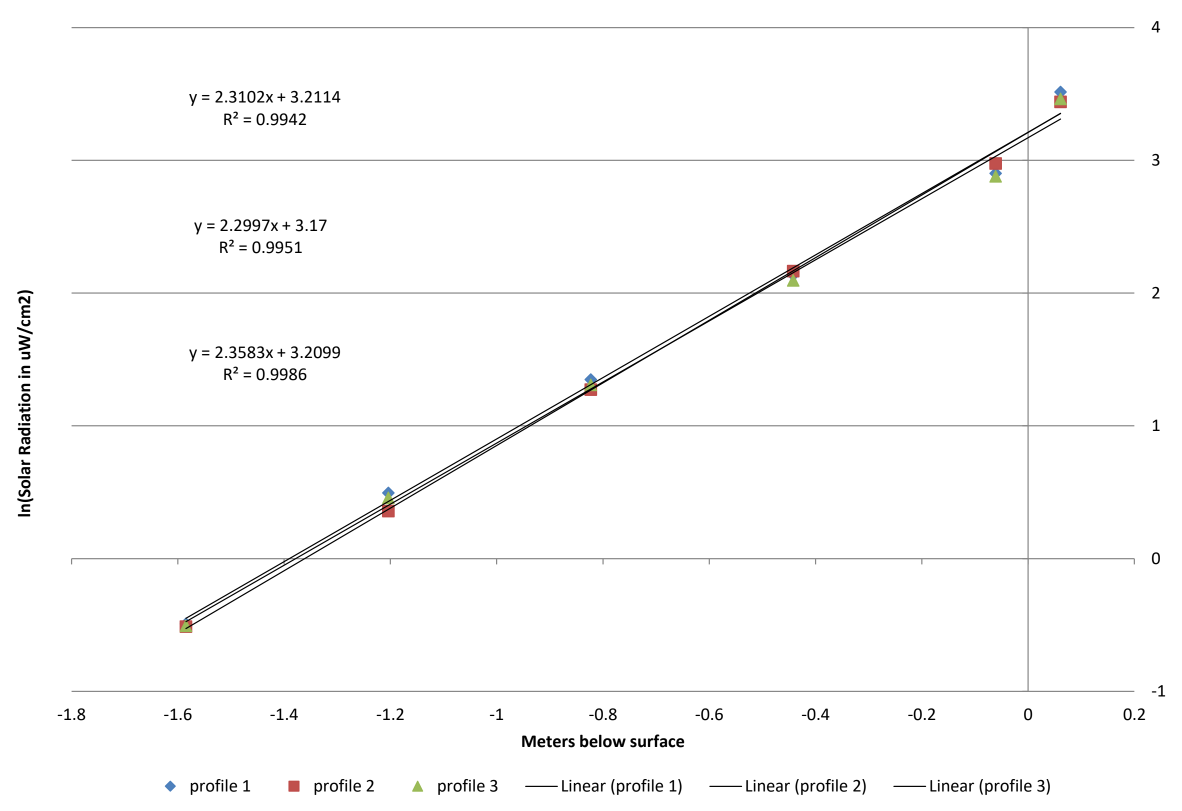


Figure F-24. Example of calculated extinction coefficients for profiles collected on 9/27/12. The extinction coefficient is the slope or "*a*" term in the equation y= *a*x + *b* in the plot.

Table F-38. Summary of 2012 light extinction data.

Date	Time	Average Ambient Solar Radiation (uW/cm2)	Average Light Extinction Coefficient (m^{-1})	Turbidity (NTU)	TSS (mg/L)	ISS (mg/L)
8/2/2012	15:30	89.77	3.46	30	31	29
8/15/2012	11:05	67.64	3.04	58.9	62	57
8/23/2012	14:37	87.92	3.59	60	47	44
9/6/2012	14:05	75.85	3.37	55	28	26
9/20/2012	14:06	52.06	2.88	37	24	22
9/27/2012	15:05	42.37	2.32	36	25	24
10/18/2012	14:22	28.86	4.44	75	55	53
10/25/2012	16:03	4.78	1.64	7.5	10	9

Temperature results

For this project Ecology installed temperature loggers at numerous points along the White River mainstem, and at key tributaries. MIT installed a temperature logger in the White River mainstem at ~RM 10, and at two tributaries that join the White River within the reservation reach (WHT-Trib15.7 and WHT-Trib15.6). Continuous temperature data was also collected from multi-parameter sondes deployed at four locations on the mainstem, two managed by USGS and two managed by Ecology. Table F-39 summarizes the peak daily max and 7-day average daily max (7DADmax) values at these sites.

Table F-39. Peak daily max and 7-day average daily max (7DADmax) values from the 2012 data.

Station	Deployment	Peak 7-DADmax °C	Peak 7-DADmax Day	Peak Daily Max °C	Peak Day
Mainstem					
W28	8/1/12 - 10/30/12	16.59	8/15/2012	17.04	8/4/2012
W25.2	8/21/12 - 11/7/12**	14.45	8/25/2012	14.86	8/25/2012
W24.2-USGS	long-term continuous gage	16.71	8/15/2012	17.3	8/5/2012
W20.4	7/18/12 - 8/21/12 9/18/12 - 10/11/12	16.73	8/15/2012	17.2	8/5/2012
W16.2	7/18/12 - 11/7/12	17.31	8/15/2012	17.72	8/5/2012
W10.3-MIT	8/14/12 - 10/12/12	17.31	8/18/2012	18.63	8/16/2012
W9	8/21/12 - 10/11/12	17.14	9/5/2012	17.92	8/27/2012
W7.6- USGS	complete/ongoing	18.79	8/14/2012	19.2	8/5/2012
W6.3	7/18/12 - 11/14/12	19.09	8/14/2012	19.53	8/5/2012
W4	7/19/12 - 11/14/12	19.31	8/14/2012	19.82	8/5/2012
W3.7	7/20/12 - 11/14/12	19.28	8/14/2012	19.79	8/5/2012
W1.4	7/19/12 - 11/14/12***	19.33	8/14/2012	19.91	8/5/2012
W0.1	7/19/12 - 11/14/12***	19.27	8/14/2012	19.91	8/5/2012
Tributaries					
TR27.6	6/30/12 - 11/6/12	15.09	7/9/2012	15.48	7/12/2012
BOI	6/30/12 - 11/6/12	18.43	8/15/2012	19.1	8/5/2012
TR15.7-MIT	7/12/12 - 10/12/12	16.92	8/15/2012	17.94	8/5/2012
TR15.6-MIT	7/12/12 - 10/12/12	14.7	8/14/2012	15.22	8/5/2012
TR8	6/26/12 - 11/17/12	19.99	8/15/2012	20.72	8/17/2012
TR5.3	6/26/12 - 7/28/12 9/13/12 - 11/15/12	22.7	7/9/2012	23.59	7/8/2012
TR2.1	6/26/12 - 11/15/12	14.11	8/14/2012	14.67	8/5/2012
TR1.3	7/4/12 - 7/11/12 8/23/12 - 11/15/12	16.03	7/7/2012	16.82	7/8/2012

* Grey shading indicates the annual peak temperature was likely not captured due to data loss.

** Original thermistor lost due to high flows and large woody debris from dam during drawdown.

*** Partial record due to thermistor found out of water during low flow period; peak and 7-DADmax temperature were likely still captured, based on other station records.

Figure F-25 illustrates the peak 2012 7-DADmax temperatures by site. Starting at the upstream boundary at RM 28, peak 7-DADmax temperatures are relatively stable for the first 8 miles of the river and then increased steadily by ~2.5°C over the next 14 miles; however, the increase tapered off (0.18°C net increase) within the final 6 miles of the river. The temperature increase between RM 20.4 and 6.2 is most likely driven by a few key factors including: increased width of the nearstream disturbance zone (channel migration zone), a wider and shallower active river channel, and decreasing shade from riparian vegetation.

Peak 7-DADmax temperatures in the White River exceeded numeric temperature criteria from the state water quality standards at all locations measured during the 2012 study, including the upstream boundary at RM 28.

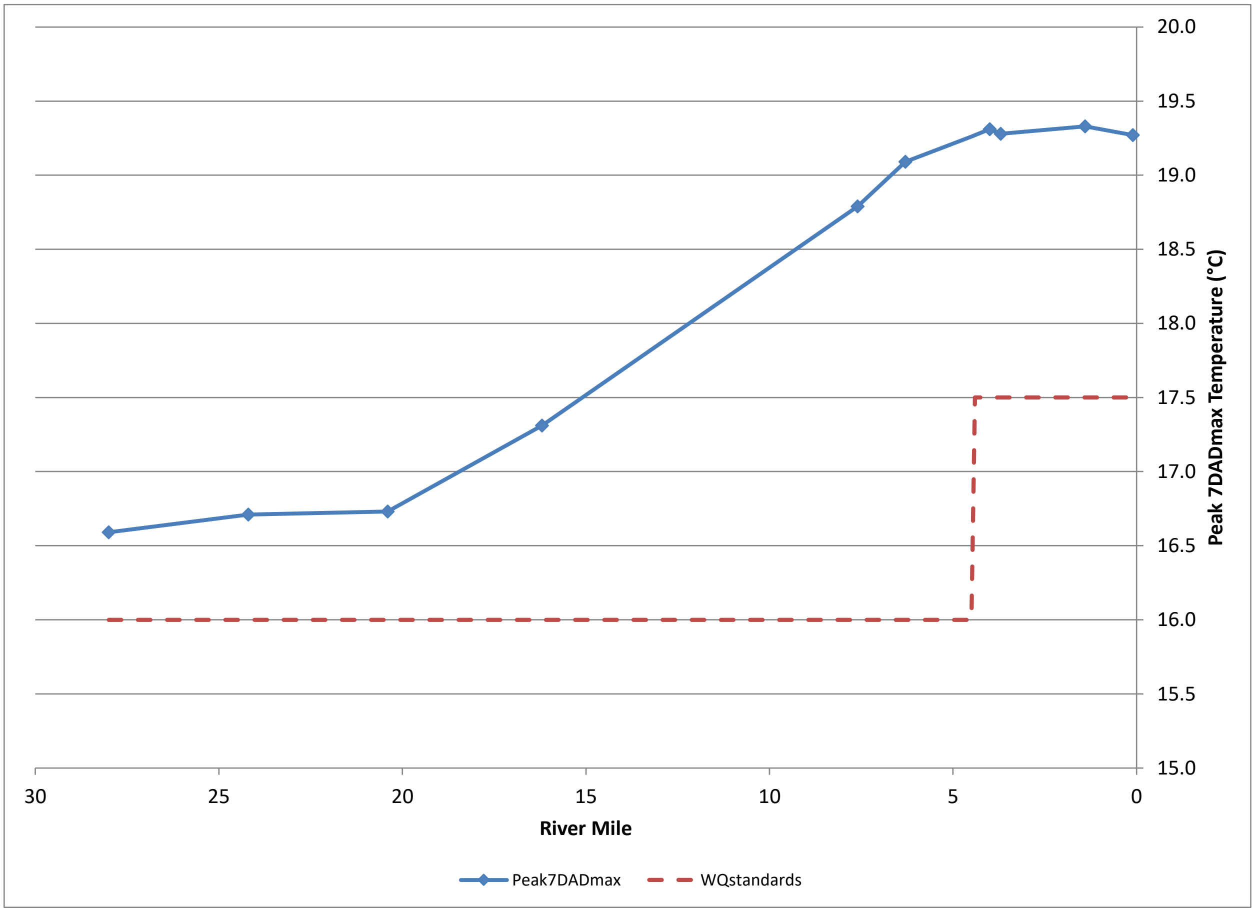


Figure F-25. Peak 7-day average daily maximum of temperatures in the White River for the 2012 study.

Figure F-26 compares continuous temperatures, collected at 30-minute intervals, at the RM 28 upstream boundary and RM 4 in Sumner, upstream in of the Lake Tapps tailrace return. The plot illustrates a consistent diel fluctuation in temperatures between early August and mid-October, with temperatures steadily decreasing over this period. A sudden and relatively large decrease in temperature occurred between October 2, 2012, and October 3, 2012, with the temperature pattern shifting down by ~3-4°C within a few days. This temperature shift also occurred in air temperature, which may have influenced the amount of glacial melt on Mt. Rainier. The decrease in air temperature may also be related to the concurrent decrease in river turbidity. From mid to late October continuous temperatures were highly erratic, with no consistent diel fluctuation, largely due to multiple precipitation events during this time frame.

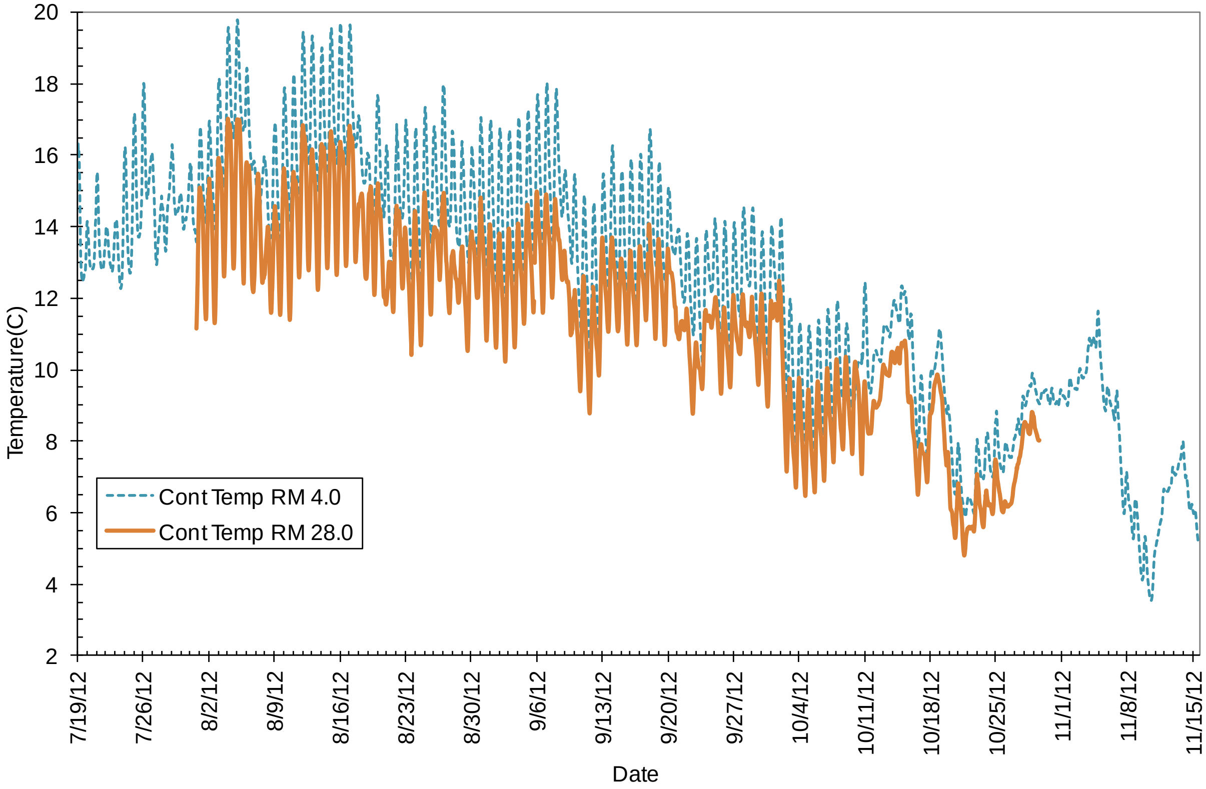


Figure F-26. Continuous temperatures for the 2012 study at RMs 28 and 4.

Periphyton Results

Table F-40 contains the periphyton (bottom algae) biomass results from the 2012 field surveys. In general, the periphyton chlorophyll *a* and ash-free dry weight (AFDW) content were used to assess overall biomass and guide model calibration. Periphyton growth is highly spatially variable within a given reach due to differences in depth, available light, shear stress, grazing, and other factors (Larned, 2010). During the 2012 study, the periphyton biomass data were considered to have greater uncertainty, compared to the pH and dissolved oxygen data, in interpreting algal productivity in the White River.

Table F-40. Periphyton results for the White River 2012 study.

Site ID	Date	Chl-Biomass (mg/m²)	AFDW-Biomass (mg/m²)	Carbon (mg/m²)	Nitrogen (mg/m2)	Phosphorus (mg/m²)
W25.2	8/22/2012	8.2	2,565	549.4	73.9	22.01
W20.4	8/22/2012	15.2	3,533	340.0	40.9	83.44
W16.2	8/22/2012	5.1	1,441	70.2	8.9	59.57
W7.6	8/22/2012	15.5	2,378	136.9	20.5	70.80
W7.6 (QA)	8/22/2012	10.5	1,321	129.2	11.1	21.97
W1.4	8/22/2012	4.2	1,869			
W25.2	9/26/2012	11.2	2,210	466.8	38.3	23.41
W20.4	9/26/2012	11.0	2,204	194.9	41.6	45.09
W16.2	9/26/2012	31.1	5,094			
W7.6	9/26/2012	27.4	2,744	330.7	109.6	37.22
W7.6 (QA)	9/26/2012	20.5	3,471	843.6	73.6	24.71
W6.2	9/26/2012	13.9	2,833			
W1.4	9/26/2012	12.0	2,207			
W20.4	10/11/2012	12.0	7,139	1,074.5	78.7	100.97
W7.6	10/11/2012	27.7	5,109	915.5	70.2	31.08
W6.2	10/11/2012	24.2	3,776	1,442.0	182.5	23.34
W20.4	10/25/2012	35.5	4,992	947.3	68.1	77.41
W7.6	10/25/2012	27.9	9,354	1,238.7	88.0	137.23
W6.2	10/25/2012	8.2	1,704	2,012.7	254.6	10.16

Both parameters showed an increasing pattern of biomass between August and early October. The periphyton results from 10/25/12 were inconclusive as to whether biomass increased or decreased following several runoff events with the potential for periphyton scour.

Figure F-27 illustrates chlorophyll *a* and AFDW biomass results within the most critical stretch of the river (between ~RM 4 and 11 where the maximum pH is most likely to exceed 8.5). The results show a conflicting pattern between samples collected at RM 7.6 and 6.2 on 10/25/12:

- At RM 7.6:
    - Both the AFDW and chlorophyll *a* values increased from 10/11/12 to 10/25/12, contrary to the expected result, which was a decrease due to periphyton scour.
    - Several possibilities could explain this unexpected result:
        - The sample could have been contaminated with biomass from a macroinvertebrate or plant material (leaf or twig).
        - This site could have received more depositional material, compared to RM 6.2, following the mid-October storms.

    - Field staff did not observe any visual increase in periphyton at this location, compared to previous visits.
    - The diel pH results at RM 7.6 on 10/25/12 suggest a decrease in periphyton biomass.
- At RM 6.2:
    - Both the AFDW and chlorophyll *a* values decreased from 10/11/12 to 10/25/12.
    - This result was expected given the multiple storm events that occurred between the 11th and the 25th, the increase in cloud cover, and the lack of solar radiation.

Figure F-28 illustrates why a decrease in periphyton biomass was expected between 10/11/12 and 10/25/12. The most significant parameters influencing periphyton productivity (solar radiation, turbidity, flow, and SRP) were similar on both dates, but the diel pH range on the 25th was ~1/3 of the range on the 11th and the maximum pH decreased by ~0.8. Given other parameters being constant, the most likely explanation appears to be that the periphyton biomass decreased due to scour and sloughing. Appendix J presents historic periphyton biomass data and potential relationships between biomass and scour events.

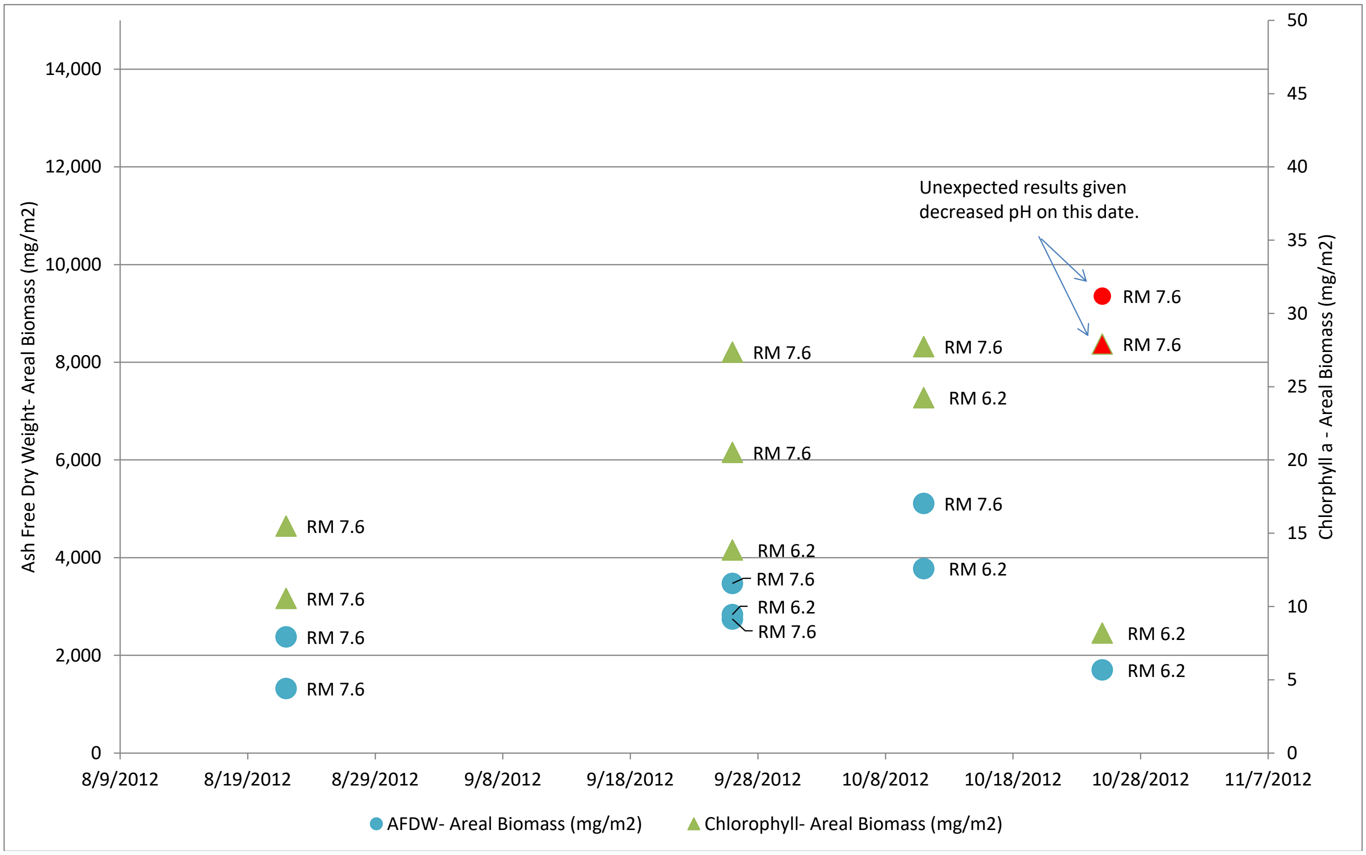


Figure F-27. Periphyton results for the White River 2012 study between RM 6 and 8.

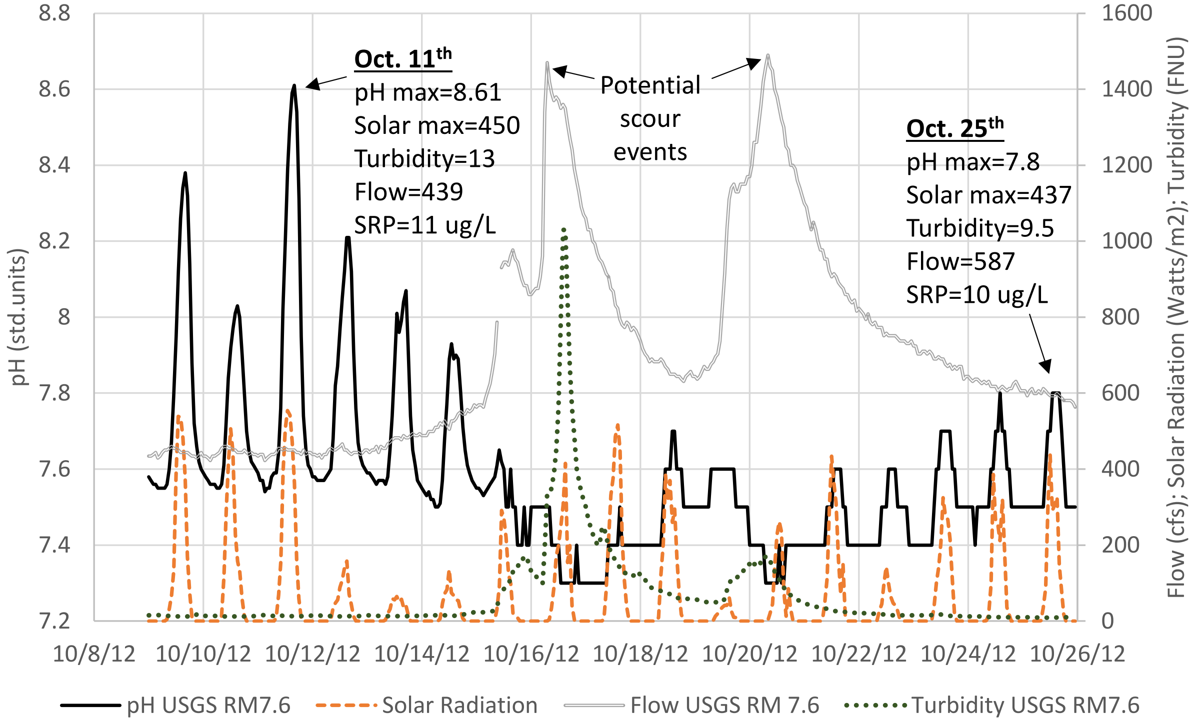


Figure F-28. Continuous pH, flow, turbidity, and solar radiation on and between sample events on October 11th and 25th, 2012.

Nutrient Results

Tables F-41 and F-42 show the median and range of nutrient concentrations for the White River mainstem collected during the 2012 study. The upstream boundary at RM 28 exhibited generally low nutrient concentrations, particularly nitrogen, with a median Nitrite/Nitrate (NO_2/NO_3) concentration of 20.5 ug/L and a median SRP concentration of 13.2 ug/L. For dissolved nutrients, the maximum SRP observed was 17.1 ug/L at White River below Buckley (W20.4) on 10/11/12 and the maximum NO_2/NO_3 observed was 92 ug/L at W20.4 on 10/25/12. Appendix J provide additional historical data over a wider range of conditions for nutrients.

Table F-41. Mainstem White River phosphorus summary statistics for the 2012 study.

	SRP (ug/L)			TP (ug/L)		
	n	median	range	n	median	range
W28	10	13.2	8.2 - 14.8	10	121.0	23.5 - 205
W25.2	4	13.4	12.9 - 13.8	4	135.1	86.5 - 201
W20.4	6	14.4	9.6 - 17.1	6	86.5	24.0 – 201
W16	4	13.3	12.6 - 14.8	4	129.7	73.8 - 180
W10	4	14.2	11.8 - 15.1	4	110.6	69.8 – 151
W9	4	13.9	11.9 – 15.0	4	109.1	69.4 – 169
W8	7	12.3	9.5 - 14.4	7	69.1	21.8 – 253

	SRP (ug/L)			TP (ug/L)		
	n	median	range	n	median	range
W6	5	12.3	8.7 - 14.4	5	70.7	22.2 – 140
W5	7	13.0	9.5 - 14.6	7	59.1	24.8 – 127
W1	4	13.5	12.1 - 14.2	4	103.7	71.0 – 139
W0	4	14.5	13.3 - 15.1	4	111.4	67.8 - 159

Table F-42. Mainstem White River nitrogen summary statistics for the 2012 study.

	NH_3-N(ug/L)			NO_2/NO_3 (ug/L)			TPN (ug/L)		
RM	n	median	range	n	median	range	n	median	range
28	6	< 10.0	<10	10	20.5	13 - 60	10	< 25.0	<25 - 75.5
25.2	4	< 10.0	<10	4	29.0	28 - 30	4	< 25.0	<25 - 29
20.4	6	< 10.0	<10	6	41.0	34 - 92	6	44.5	35 - 100
16.2	4	< 10.0	<10	4	52.5	50 - 57	4	60.0	38 - 71
10.3	4	< 10.0	<10	4	50.0	50 - 53.5	4	51.5	47 - 56
9	4	< 10.0	<10	4	47.5	46 - 51	4	48.0	44 - 56
7.6	6	< 10.0	<10	7	53.0	20 - 89	7	43.0	25 - 112
6.3	5	< 10.0	< 10 - 105	5	54.0	38 - 86	5	84.0	52 - 149
4.9	7	11.0	< 10 - 14	7	55.0	15 - 83	7	60.0	46 - 121
1.4	4	17.5	14 - 23	4	60.5	49 - 71	4	78.5	64 - 106
0.1	4	18.5	13 - 27	4	70.0	55 - 76	4	89.5	75 - 114

Table F-43 contains the effluent nutrient concentrations for the two municipal wastewater treatment plants sampled during the 2012 study.

Table F-43. Nutrient results for Enumclaw and Buckley wastewater effluent from the 2012 study.

Date	EC-SRP (ug/L)	EC – TP (ug/L)	EC-NO_2/ NO_3 (ug/L)	EC-NH_3-N (ug/L)	EC-TPN (ug/L)	BK-SRP (ug/L)	BK - TP (ug/L)	BK-NO_2/ NO_3 (ug/L)	BK-NH_3-N (ug/L)	BK-TPN (ug/L)
8/21/2012	186	301	3,690	197	4,760	1,740	1,940	4,640	5,360	11,200
8/22/2012	193	303	3,820	195	5,070	1,950	2,060	4,800	3,740	9,620
9/25/2012	91	204	4,500	42	5,270	1,710	1,930	5,600	106	7,000
9/26/2012	108	238	4,320	42	5,440	1,990	2,270	4,540	124	5,640
10/11/2012	2,670	2,730	4,660	22	5,860	3,340	3,290	6,320	124	7,600
10/30/2012	168	272	2,120	211	2,890	143	261	3,250	125	3,870
10/31/2012	49.6	131	1,250	112	1,810	1,000	1,140	5,470	190	6,340
11/1/2012	415	505	1,520	89	2,090					
Median	177	287	3,755	101	4,915	1,740	1,940	4,800	125	7,000

Figures F-29 and F-30 are longitudinal profiles of NO_2/NO_3 and SRP, on 9/25/12 – 9/26/12, along the mainstem of the White River in relation to surface and groundwater inputs and abstractions. A steadily increasing pattern of NO_2/NO_3 concentration is apparent along the sections of the river that are gaining streamflow from groundwater discharge. NO_2/NO_3 appear fairly constant or slightly decreasing along the section of the river that is losing streamflow to underlying aquifers. The same increases in SRP are not apparent in gaining sections, although SRP concentration does appear to decrease during the losing reach.

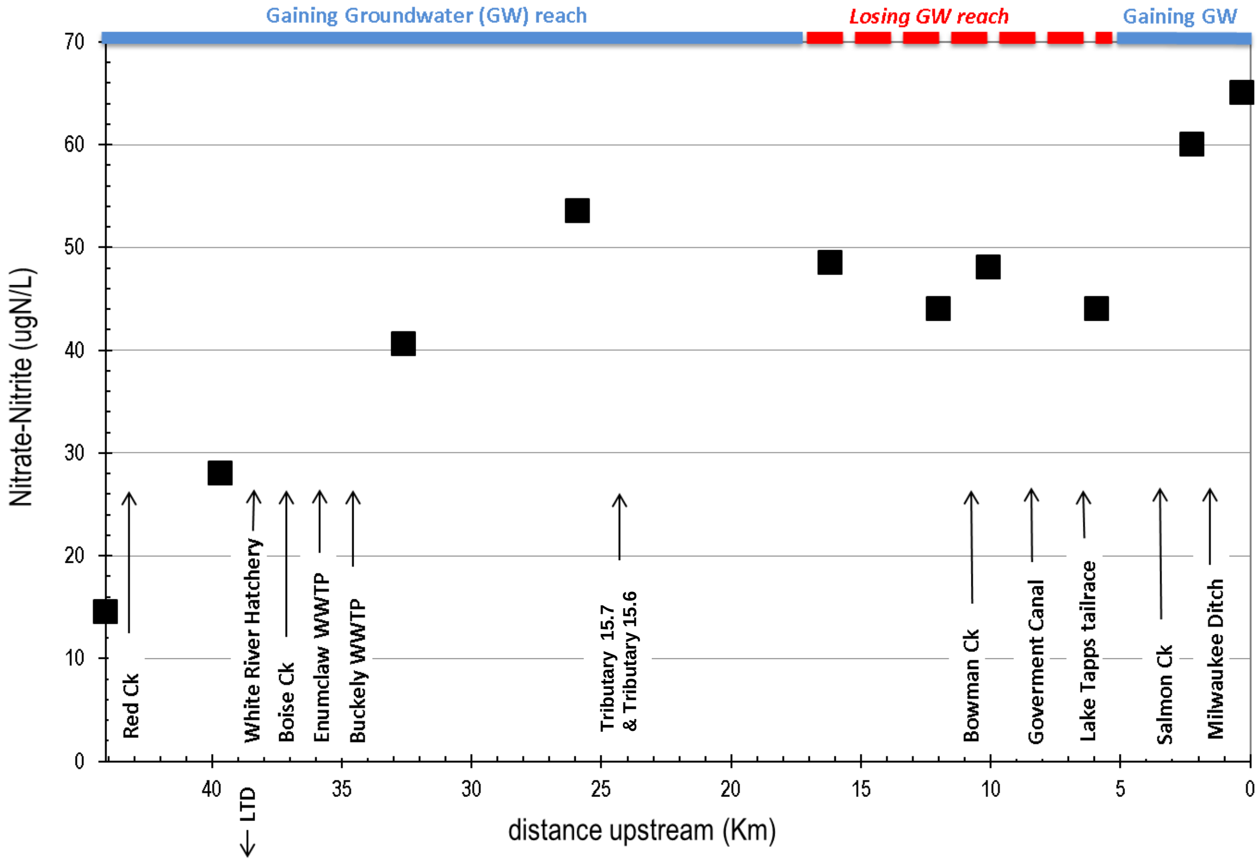


Figure F-29. Longitudinal profile for nitrite-nitrate along the White River on 9/25/12 – 9/26/12.

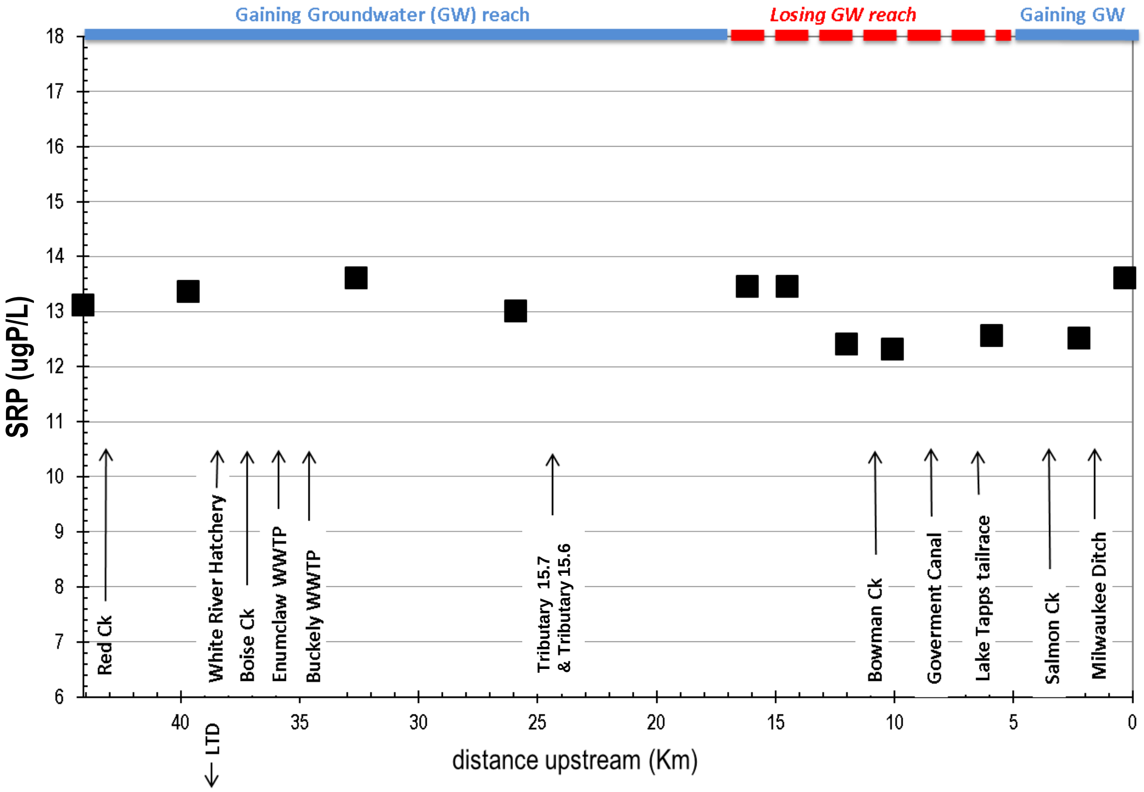


Figure F-30. Longitudinal profile for soluble reactive phosphorus along the White River on 9/25/12 – 9/26/12.

Nutrient limitation

Numerous factors can limit or stimulate growth of periphyton in rivers and streams, including available light and nutrient supply, temperature, grazing and excretion from primary consumers, as well as changes in velocity or mobilization of substrate (Larned, 2010). When nutrient limitation is evident, one theory is that periphyton growth follows Liebig's Law of the Minimum and that the nutrient in shortest supply controls growth, typically either nitrogen or phosphorus, although carbon, silica, iron, and other micronutrients can potentially also limit growth (De Baar, 1994).

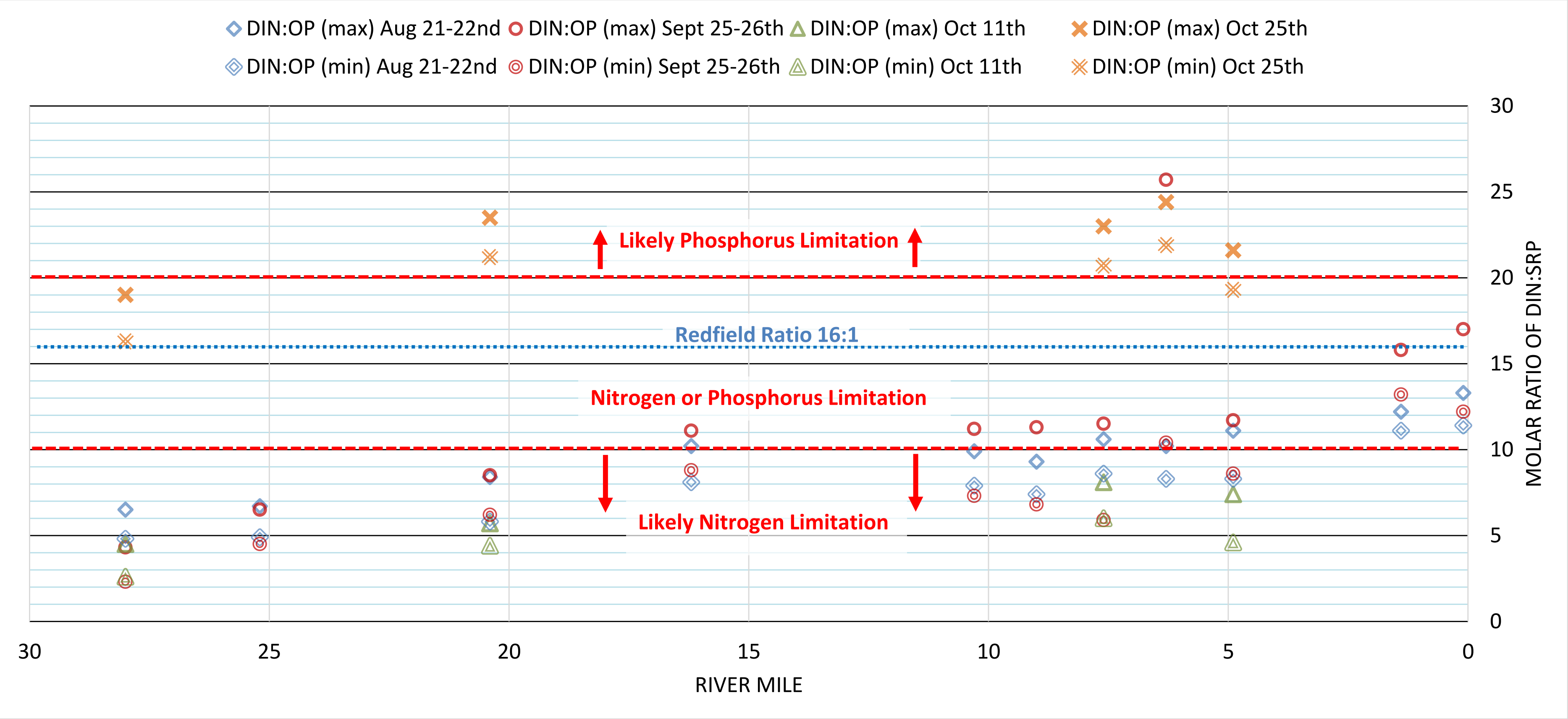
Cellular and in-stream nutrient ratios are often used as an indicator of which nutrient is limiting growth. Nutrient ratios are frequently compared to the Redfield Ratio of 106C : 16N : 1P, a molar ratio derived from an empirical study of average composition of marine organic matter (Redfield, 1934; Redfield 1958). In general, if the molar N:P ratio is greater than 16:1, then it is assumed that P is the limiting nutrient and vice-versa. Others have modified the rule to: > 20:1 indicates P-limitation, <10:1 indicates N-limitation, and between 10:1 and 20:1 either nutrient could be limiting (Shanz and Juon, 1983; Borchardt, 1996).

Figure F-31 depicts in-stream dissolved nutrient ratios in the White River during the 2012 study. These in-stream results indicate that the White River was most likely nitrogen limited, but trending toward phosphorus limitation in downstream reaches, where it starts to reach the uncertain range.

The lowest observed ratios occurred during the 10/11/12 sample event. The largest diel pH swings were also observed on 10/11/12, which could possibly indicate that the river is N limited during more productive conditions. However, the ratios being lowest on Oct 11th could also be a byproduct of the headwater/boundary ratios and not necessarily influenced by increased productivity. The ratio at RM 28 was at its lowest on this date and the water column ratios follow the same general longitudinal pattern (from upstream to downstream) as the other dates, they just start out lower at RM 28.

The sampling on 10/25/12 showed increased nitrogen in the river and likely phosphorus limitation following several large hydrologic events; however photosynthetic activity was minimal and peak pH values were below 8.0. Most likely, the river was limited by physical scour and light during this sampling event, and neither nutrient had a significant effect on growth limitation.

Figure F-31. In-stream nutrient ratios in the White River during the 2012 study.



‘Min’ equals the lowest concentrations observed during a sample event with zero substituted for any non-detect values. ‘Max’ equals highest concentration observed during a sample event with the reporting limit substituted for any non-detect values.

The concept of dissolved nutrient ratios as a predictor of nutrient limitation in benthic algae has received significant criticism (Wold, 1999; Francouer et al, 1999; Dodds, 2003) including:

- Evidence that soluble reactive phosphorus methods tend to overestimate the actual PO_3^{-4} concentration and are a poor indicator of bioavailable phosphorus.
- Evidence that periphyton can consume and store excess nutrients during periods of increased supply (luxury consumption), and thus limitation and growth may be more tied to nutrient uptake rates and internal cellular ratios of N:P, and less so to external concentrations.

Dodds (2003) indicated that the ratio of total nitrogen to total phosphorus is more appropriate to predict trophic state and nutrient limitation, since this represents the total potential nutrient content. However, the use of total nutrient concentrations to predict limitation is problematic on the White River for several reasons:

- Total phosphorus values are often an order of magnitude greater than orthophosphate values in the White River.
- High total phosphorus is derived from the glacial meltwater origin of the river, where much of the phosphorus is likely present in a poorly weathered and non-bioavailable form (Hodson et al., 2004).
- Residence time is relatively short from the upstream boundary of the study area (~RM 28) to the end of the TMDL reach (~RM 3.6), on the order of ~0.5 days at 7Q10 flow conditions. Thus, there is likely relatively little hydrolysis of organic phosphorus.

Several studies (Hillebrand and Sommer, 1999; Kahlert, 1998) have demonstrated that cellular nutrient concentrations in periphyton tissue can be an accurate predictor of nutrient limitation. Limited periphyton nutrient analysis was conducted during the 2012 study (Figure F-33); however, the results are again complicated by the presence of non-bioavailable phosphorus in glacial suspended sediments deposited within the periphyton mat. Thus TN:TP values for tissue likely overestimate the possibility of nitrogen limitation and underestimate the ratio of bioavailable nutrients. In addition, as an analytical matrix, periphyton tissue can be highly variable and thus results have a greater degree of uncertainty compared to in-stream nutrient results (see QA results in Appendix G).

In contrast to the water column DIN:SRP ratios, the ratios in periphyton tissue were highest on 10/11/12 (largest diel pH swings) and 9/26/12 (intermediate diel pH swings) within the stretch of the river most critical for pH, and lowest on 8/22/12 (smallest diel pH swings). The ratio for one sample at RM 6.2 on 10/11/12 exceeded 16:1. The periphyton tissue results suggest a possible correlation between increasing biological productivity (diel pH swings) and increasing N:P ratios, which indicates phosphorus may be limiting to some degree, either through co-limitation or singular limitation. Further discussion of nutrient limitation can be found in Appendix D.

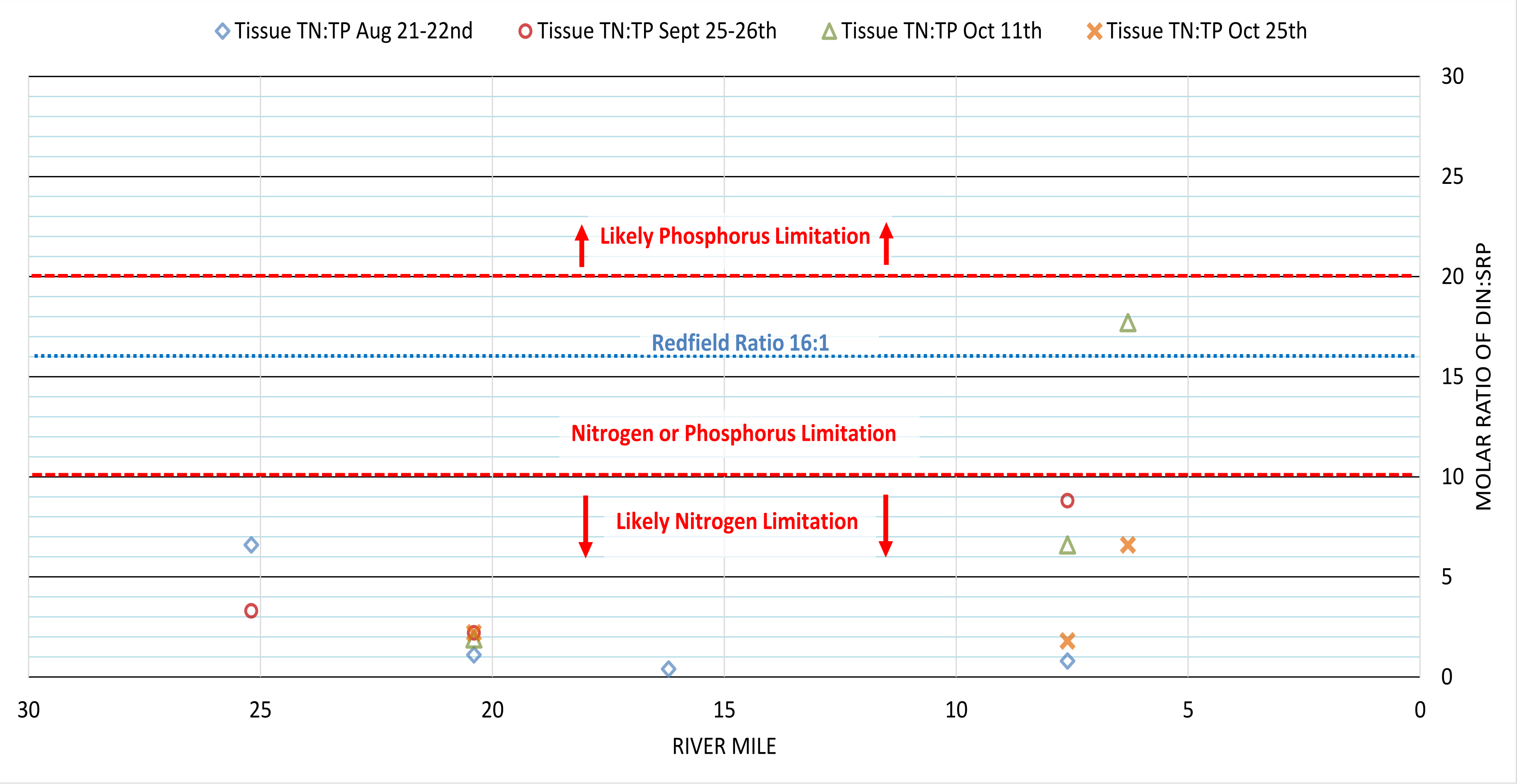


Figure F-32. Periphyton tissue nutrient ratios in the White River during the 2012 study.

pH results

Observed pH at the Ecology boundary station at RM 28 typically fell within 7.3 and 7.7, with a maximum diel range of less than 0.2 during the 2012 study (Figure F-33). The lack of diel pH swing and low peak pH, suggests there was very little primary productivity occurring at the upstream boundary. Appendix J provides additional historical data over a wider range of conditions for pH.

Observed pH at the downstream stations within the TMDL reach (USGS at RM 7.6; Ecology at RM 3.7) ranged between 7.4 and 8.6, with a maximum diel range of 1.0 during the 2012 study (Figure F-33). The larger diel pH swings and maximum pH peaks above water quality standards indicate increased primary productivity within this reach.

Three main periods of increasing diel pH, and likely periphyton growth, are evident in the continuous pH record within the lower end of the TMDL reach: late August to early September, mid-September, and early October. Each of these windows corresponded with periods of lower turbidity in the river, with a prolonged period of the lowest turbidity occurring in early October when pH reached peak levels for 2012. Daily maximum pH was significantly ($p<0.01$) correlated with daily minimum turbidity (Figure F-34).

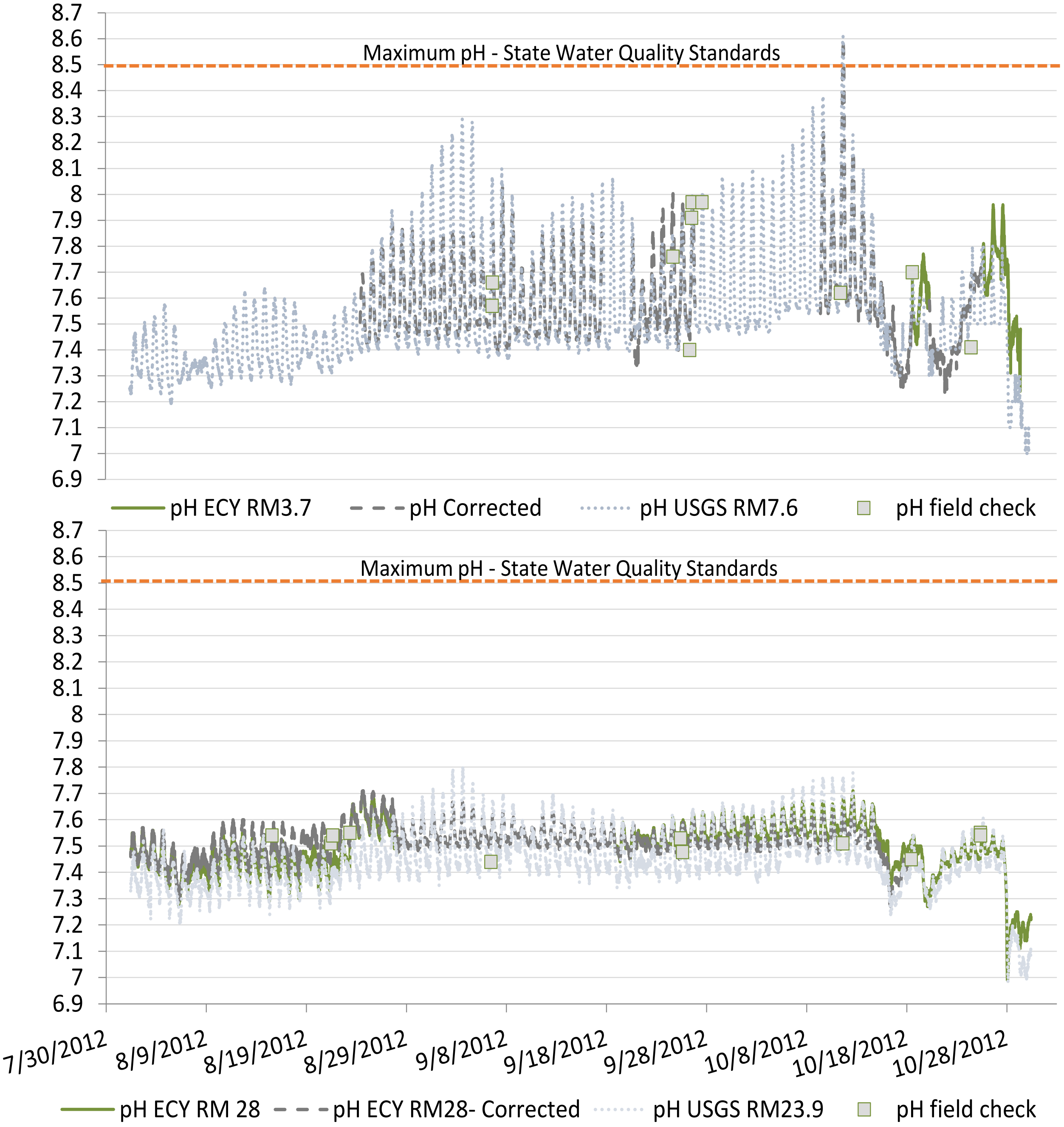


Figure F-33. Continuous pH results for the 2012 study.

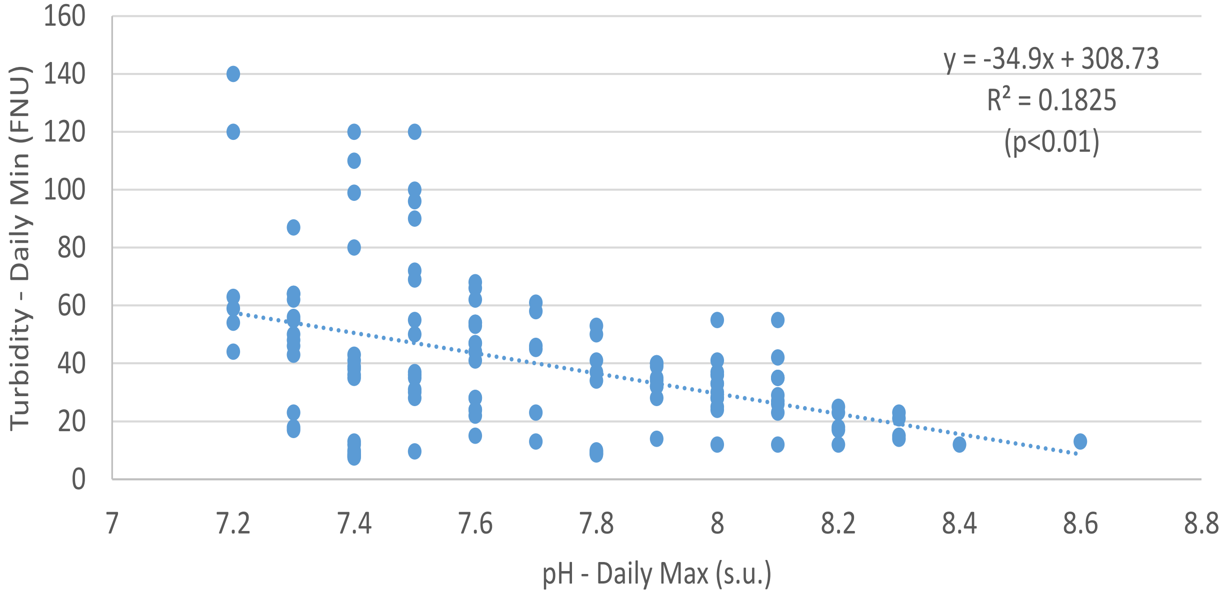


Figure F-34. Regression - pH vs turbidity during the 2012 study period at USGS station (RM7.6).

Conclusions

- pH exceeded water quality standards on 10/11/12 in the lower reaches of the study area (RM 3.7 to 10) with a max pH of 8.6. Spatial and temporal increases in max and diel pH range were observed on the White River during the 2012 study.
- The flow conditions in 2012 were relatively typical, not critically low, and the period (early fall) and timing (lowest flow of the year) were similar to conditions for historical exceedances.
- Periods of increasing pH were significantly correlated with periods of low turbidity.
- Diel pH ranges and peak pH were low at the upstream boundary RM 28, with little evidence of primary production.
- During the majority of the potential periphyton growing season (May through October), primary productivity in the river is primarily light limited with high elevation snow and glacial melt resulting in turbid conditions that limit available light to the bottom of the stream.
- In terms of nutrients, it is uncertain if the river is nitrogen or phosphorus limited. The evidence is not definitive, and the river may be co-limited, rather than limited by a singular nutrient.
- Observed periphyton growth/loss patterns, in general, correlate to increases/decreases in diel pH. Evidence suggests periphyton scour following large storm events, as discussed in Appendix J.
- The 7-day average daily max temperatures exceeded water quality standards at all sites monitored in the watershed, including the upstream boundary. The steepest increase in longitudinal temperature on the river occurred between RM 20 and RM 6 (~2.5 deg C).
- Turbidity conditions were highly dynamic over the course of the study period, ranging two orders of magnitude. Light extinction profiles differ significantly depending on the turbidity of the river. The amount of light available to periphyton is heavily influenced by turbidity.
- There is evidence of both groundwater gains and losses in different reaches of the project area, based on results of flow balances, piezometer water levels and temperatures, and results of historical studies (see Appendix H for detailed analysis).

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Appendix G. Data Tables and Data Quality Analysis

Data quality results

This appendix describes the quality of data that were collected specifically for the Lower White River pH TMDL in the summer and fall of 2012.

All data used for the TMDL analysis were assessed for quality. Typically, this was done by comparing some sort of quality metric such as a replicate precision statistic or an instrument calibration end check to a target Measurement Quality Objective (MQO). The data quality objectives and criteria for the project are described in detail in the project Quality Assurance Project Plan (QAPP) (Mathieu and Pelletier, 2012). All data were found to be of appropriate quality for their use in the TMDL analysis, unless otherwise noted.

In summary:

- For synoptic survey deployments, the Hydrolab sondes met all data quality criteria for end of the day checks against National Institute of Standards and Technology (NIST) thermometer, NIST-certified conductivity and pH standards, and Winkler samples; with a few exceptions (summarized in Tables G-52 to G-54).
- For the continuous water quality stations at RM 28, at the model boundary, (Figures G-44 to G-46) and RM 3.7,at the Sumner golf course, (Figures G-47 to G-49):
    - Rapidly dropping water levels and fine sediment accumulation lead to several data gaps in the continuous data collection, particularly at RM 3.7 (more deposition).
    - For RM 28, a complete record for the modeling period was created using a regression with the nearby USGS station at RM 24.2 to fill data gaps. High quality pH data (no regression necessary) was collected during the critical period (9/19/12 to 10/30/12).
    - For RM 3.7, high quality pH data with no data gaps were obtained during the critical period from 10/9/12 to 10/15/12.
- All thermistor readings fell within specifications (±0.2 °C) when compared to a NIST-certified thermometer in room temperature and ice bath, post-deployment.
- Partial continuous temperature records were obtained at a few locations due to either:
    - The instrument was found out of water due to rapidly changing water levels. Associated data was rejected based on paired air temperature records.
    - The instrument was lost (due to large flow events or snagging by woody debris).
- Replicate precision was evaluated based on percent relative standard deviation (%RSD) targets. The %RSD is calculated as the standard deviation of the paired replicates, divided by their mean, and multiplied by 100. Field replicate samples for all parameters met their respective measurement quality objectives for precision, with one exception: the median % RSD for phosphorus in periphyton tissue was 52% which slightly exceeded the target of 50% RSD.
    - One replicate sample collected on 8/22/12 exceeded 50% RSD (74% RSD) and skewed the median above 50%.

  - Phosphorus in periphyton tissue for this sampling event was qualified as estimates for the five locations sampled on 8/22/12.
  - The cause of the variability is unknown; however, one possible explanation is that the higher glacial turbidity in the water column in August may have resulted in increased deposition of phosphorus early in the study period. Therefore, rocks collected from more depositional areas would contain more phosphorus than those in faster moving water.
- Field blanks for all parameters fell below the method reporting limit.
- Laboratory quality control samples fell within established acceptance limits, with a few minor exceptions.

Discrete data quality

Table G-44 contains results for field replicates collected during the 2012 study. Field replicate samples for all parameters met their respective measurement quality objectives for precision, with one exception: The median % RSD for phosphorus in periphyton tissue was 52% which slightly exceeded the target of 50% RSD.

By comparison, precision results for total phosphorus and orthophosphate of water samples were excellent, with medians of 1% and 2% RSD respectively. A different total phosphorus method was used for the periphyton tissue (EPA 200.7) compared to the water samples (SM4500PF), so either the method or the matrix difference could have been responsible for the greater variability.

All field blanks were below detection limits.

Laboratory quality control samples fell within established acceptance limits, with a few exceptions:

- Duplicates (Table G-45) – Out of 201 duplicate pairs: 1 chlorophyll *a*, 1 phosphorus (periphyton), 1 total phosphorus, 3 total suspended solids (TSS), and 4 total non-volatile suspended solids (TNVSS) failed to meet the MQO (20%RSD). Associated results were qualified as estimates.
- Method blanks (Table G-46) - Out of 267 blanks: 5 chlorophyll *a*, 3 total persulfate nitrogen, 2 total phosphorus, and 4 AFDW had some level of contamination. The level of contamination was typically very low (<5% of lowest batch sample result). The associated samples were qualified as estimates; however, given that contamination levels were very low, the results were deemed useable for study objectives.
- Lab Control Samples (Table G-47) – All 199 lab control samples (batch spikes) were within acceptance limits. Alkalinity sample recoveries were consistently ~90% of the spike amount.
- Matrix Spikes (Table G-48) – Out of 116 spikes: 1 dissolved organic carbon (DOC) and 1 total phosphorus sample were outside acceptance limits. The errant DOC spike result was clearly contaminated, as the recovery was over 200%. The associated sample results were qualified as estimates. The DOC sample results were qualified, but not rejected given that the spike, not the original sample appeared contaminated.

MEL achieved good recoveries on the standard reference material samples run for the phosphorus in periphyton tests using EPA200.7 (Table G-49).

Table G-44. Field replicate results.

Parameter	n	Median RSD%	Target Median RSD%	Range RSD%
Water Column Samples				
Alkalinity	10	1%	10%	0% to 17%
NH3-N	11	0%	10%	0% to 7%
Chloride	10	1%	5%	0% to 4%
Chlorophyll *a*	3	7%	20%	4% to 9%
Dissolved Organic Carbon	5	0%	10%	0% to 17%
Nitrite-Nitrate	11	4%	10%	0% to 57%*
Orthophosphate	11	2%	10%	1% to 5%
Total Non-volatile Suspended Solids	10	0%	15%	0% to 13%
Total Organic Carbon	5	0%	10%	0% to 7%
Total Persulfate Nitrogen	11	3%	10%	0% to 9%
Total Phosphorus	11	1%	10%	0% to 8%
Total Suspended Solids	10	0%	15%	0% to 2%
Turbidity	5	6%	15%	0% to 16%
Periphyton Samples				
Chlorophyll *a* (mg/m2)	2	24%	50%	20% to 27%
Ash Free Dry Weight (mg/m2)	2	29%	50%	17% to 40%
Carbon (mg/m2)	2	33%	50%	4% to 62%
Nitrogen (mg/m2)	2	35%	50%	28% to 42%
Phosphorus (mg/m2)	2	52%	50%	29% to 74%
Water Column Measurements				
Temperature	23	0.01°C	0.2°C	0.00 to 0.14°C
Specific Conductance	23	0.0%	5%	0% to 1%
pH	23	0.01	0.2 s.u.	0.00 to 0.19
Dissolved Oxygen	19	0.2%	5%	0% to 3%
Flow	8	3%	10%	1% to 7%

Table G-45. Laboratory duplicate results.

Parameter	Count	Mean RSD	Median RSD	Min RSD	Max RSD	Target	# of Fails	% Failure
ALK	18	1.1%	0.8%	0.0%	9.3%	20	0	0%
NH3-N	11	0.9%	0.0%	0.0%	4.3%	20	0	0%
BOD5	1	0.0%	0.0%	0.0%	0.0%	20	0	0%
CL	12	1.2%	0.5%	0.0%	6.7%	20	0	0%
CHLPH	13	8.3%	7.8%	0.0%	22.2%	20	1	8%
DOC	3	1.3%	1.0%	0.8%	2.0%	20	0	0%
NO2/NO3	14	2.6%	2.0%	0.0%	7.0%	20	0	0%
OP	18	2.3%	1.6%	0.2%	10.0%	20	0	0%
Alg-P	9	6.1%	2.4%	0.1%	25.0%	20	1	11%
Solids	7	1.4%	0.0%	0.0%	9.5%	20	0	0%
TNVSS	19	8.0%	3.7%	0.0%	24.0%	20	4	21%
TOC	3	3.3%	2.0%	2.0%	6.0%	20	0	0%
TPN	21	5.0%	4.0%	0.0%	19.2%	20	0	0%
TP	14	6.4%	2.6%	0.4%	33.0%	20	1	7%
TSS	19	9.1%	5.3%	0.0%	40.0%	20	3	16%
Turb	12	1.4%	0.0%	0.0%	8.0%	20	0	0%
AFDW	7	2.8%	3.3%	0.2%	4.2%	20	0	0%

Table G-46. Laboratory Blank Results.

Parameter	Count	Number of Contaminated Blanks	Percent Contaminated Blanks	Potential Magnitude of Contamination
ALK	18	0	0%	
NH3-N	14	0	0%	
BOD5	1	0	0%	
CL	10	0	0%	
CHLPH	11	5	45%	0 - 35%
DOC	12	0	0%	
NO2/NO3	15	0	0%	
OP	19	0	0%	
Alg-P	5	0	0%	
Solids	9	0	0%	
TNVSS	26	0	0%	

Parameter	Count	Number of Contaminated Blanks	Percent Contaminated Blanks	Potential Magnitude of Contamination
TOC	9	0	0%	
TPN	25	3	12%	0 - 1476%
TP	15	2	13%	0 - 4%
TSS	26	0	0%	
Turb	12	0	0%	
AFDW	9	4	44%	1%

Table G-47. Laboratory Control Sample Results (Batch Spikes).

Parameter	Count	MEL QC Lower Limit %	MEL QC Upper Limit %	Min %	Max %	Median Recovery %
Alkalinity, Total	21	80	120	81	108	90
Ammonia	13	80	120	97	103	100
Biochemical Oxygen Demand	1	70	130			119
Chloride	10	90	110	98	104	100
Dissolved Organic Carbon	30	80	120	96	100	98
Nitrate-Nitrite as N	16	80	120	95	108	103
Ortho-Phosphate	20	80	120	91	103	96
Phosphorus	5	85	115	100	105	103
Total Organic Carbon	17	80	120	96	101	98
Total Persulfate Nitrogen	22	80	120	90	119	102
Total Phosphorus	16	80	120	96	103	99
Total Suspended Solids	15	80	120	92	111	99
Turbidity	13	95	105	96	99	97

Table G-48. Matrix spike results.

Parameter	Count	MEL QC Lower Limit %	MEL QC Upper Limit %	Min %	Max %	Median Recovery %
Ammonia	13	75	125	87	104	98
Chloride	20	75	125	96	104	99
Nitrate-Nitrite as N	17	75	125	80	105	99
Ortho-Phosphate	20	75	125	77	121	95
Phosphorus	3	75	125	102	110	104
Total Organic Carbon	3	75	125	92	101	95
Total Persulfate Nitrogen	20	75	125	80	112	97
Total Phosphorus	18	75	125	70	104	98

Table G-49. Phosphorus in tissue standard reference material results.

Matrix	Parameter	MEL Spiked Amount	MEL Spike Result Amount	MEL Spike Units of Measure	Result	Result UOM
Tissue	Phosphorus	1370	1280	mg/Kg	93	%
Tissue	Phosphorus	1370	1400	mg/Kg	102	%
Tissue	Phosphorus	1370	1360	mg/Kg	100	%
Tissue	Phosphorus	1370	1330	mg/Kg	97	%

Streamflow data quality

Ecology collected flow measurements using Acoustic Doppler Current Profilers (ADCP) on the White River and magnetic current meters on the tributaries and stormwater inputs. Replicate precision was within the target MQO for median %RSD (Table G-1). ADCP flow measurements had uncertainty estimates ranging from 1 to 7%. No flow measurements were qualified as estimates.

Continuous data quality

All Hobo Water Temp Pro V2 thermistors readings fell within instrument specifications (±0.2 °C) when compared to a NIST-certified thermometer in both a room temperature and ice bath, post-deployment. All deployed thermistors and sondes met field QC check MQOs.

For synoptic survey deployments, the Hydrolab sondes met all data quality criteria for end of the day checks against National Institute of Standards and Technology (NIST) thermometer and NIST-certified conductivity and pH standards, with a few exceptions (Tables G-52 to G-54).

Table G-50 contains the data quality bias objectives for both instrument drift and fouling checks.

Table G-50. Measurement quality objectives for post-deployment, field and fouling checks.

Parameter	Units	Accept (Excellent)	Qualify (Good or Fair)	Reject (Poor)
Temperature	° C	< or = ± 0.2	> ± 0.2 and < or = ± 0.8	> ± 0.8
Conductivity*	uS/cm	< or = ± 5%	> ± 5% and < or = ± 15%	> ± 15%
Dissolved Oxygen**	% saturation	< or = ± 5%	> ± 5% and < or = ± 15%	> ± 15%
pH	std. units	< or = ± 0.2	> ± 0.2 and < or = ± 0.8	> ± 0.8

* Data criteria are expressed as the percentage of variation between readings; for example, buffer = 100.2 uS/cm and Hydrolab = 98.7 uS/cm; (100.2-98.7)/100.2 = 1.49% variation, which would fall into the acceptable data criteria of less than 5% variation.

** When Winkler data is available, it will be used to evaluate acceptability of data in lieu of % saturation data criteria.

Corrected data was assigned an accuracy rating based on combined fouling and calibration corrections applied to the record (Table G-51). Data assigned a ‘poor’ correction rating was not used in data analysis. The accuracy ratings for data corrections provides a qualitative general confidence level in the final adjusted data.

Table G-51. Ratings of accuracy for data corrections based on combined fouling and calibration drift corrections applied to record.

Measured field parameter	Ratings of accuracy for data corrections			
	Excellent	Good	Fair	Poor
Water temperature	≤ ± 0.2 °C	> ± 0.2 – 0.5 °C	> ± 0.5 – 0.8 °C	> ± 0.8 °C
Specific conductance	≤ ± 3%	> ± 3 – 10%	> ± 10 – 15%	> ± 15 %
Dissolved oxygen	≤ ± 0.3 mg/L or ≤ ± 5%, whichever is greater	> ± 0.3 – 0.5 mg/L or > ± 5 – 10%, whichever is greater	> ± 0.5 – 0.8 mg/L or > ± 10 – 15%, whichever is greater	> ± 0.8 mg/L or > ± 15%, whichever is greater
pH	≤ ± 0.2 units	> ± 0.2 – 0.5 units	> ± 0.5 – 0.8 units	> ± 0.8 units

Table G-52. Specific Conductance continuous data quality results for synoptic surveys.

RM	Post-Check Rating	Fouling Check Rating	Field Check Rating	Data Correction Rating	Correction Type	Correction Amount
	August Synoptic (8/19/12 - 8/24/12)					
28	Good	Excellent	Excellent	n/a	n/a	n/a
25.2	Good	Excellent	Excellent	n/a	n/a	n/a
20.4	Excellent	Excellent	Good	Excellent	Bias	-4.40%
16	No data due to sonde failure					
6.2	Excellent	Excellent	Excellent	n/a	n/a	n/a
4.9	Excellent	Excellent	Excellent	n/a	n/a	n/a
1.4	Fair	Excellent	Poor	Poor - No correction, data rejected		
0.1	Excellent	Excellent	Excellent	n/a	n/a	n/a
	September Synoptic (9/24/12 - 9/28/12)					
25.2	Fair	Excellent	Fair	Fair	Bias	15.10%
20.4*	Excellent	Excellent	Excellent	n/a	n/a	n/a
16	Excellent	Excellent	Good	Good	Bias	7.78%
8.5	Excellent	Excellent	Excellent	n/a	n/a	n/a
6.2	Excellent	Excellent	Excellent	Excellent	Bias	-2.92%
4.9	Excellent	Excellent	Excellent	n/a	n/a	n/a
1.4	Excellent	Excellent	Excellent	n/a	n/a	n/a
0.1	Excellent	Excellent	Excellent	n/a	n/a	n/a
Boise Ck	Excellent	Excellent	Good	n/a	n/a	n/a
Buckley	Excellent	Excellent	Excellent	Excellent	Bias	3.43%
Enumclaw	Fair	Excellent	Excellent	n/a	n/a	n/a

Table G-53. pH continuous data quality results for synoptic surveys.

RM	Post-Check Rating	Fouling Check Rating	Field Check Rating	Data Correction Rating	Correction Type	Correction Amount
August Synoptic (8/19/12 - 8/24/12)						
28	Excellent	Excellent	Excellent	n/a	n/a	n/a
25.2	Good	Good	Good	Good	Fouling drift + Bias	0.23 to 0.37
20.4	Excellent	Excellent	Excellent	n/a	n/a	n/a
16	No data due to sonde failure					
6.2	Excellent	Excellent	Good	n/a	n/a	n/a
4.9	Excellent	Excellent	Excellent	n/a	n/a	n/a
1.4	Excellent	Excellent	Excellent	n/a	n/a	n/a
0.1	Excellent	Excellent	Excellent	n/a	n/a	n/a
September Synoptic (9/24/12 - 9/28/12)						
25.2	Excellent	Excellent	Good	Good	Bias	-0.22
20.4*	Excellent	Excellent	Excellent	n/a	n/a	n/a
16	Excellent	Excellent	Excellent	Excellent	Bias	-0.18
8.5	Excellent	Excellent	Excellent	n/a	n/a	n/a
6.2	Excellent	Excellent	Excellent	Excellent	Regression	-0.12 to 0.17
4.9	Fair	Excellent	Poor	Poor - No correction, data rejected		
1.4	Excellent	Excellent	Excellent	n/a	n/a	n/a
0.1	Excellent	Excellent	Excellent	n/a	n/a	n/a
Boise Ck	Excellent	Excellent	Excellent	n/a	n/a	n/a
Buckley	Excellent	Excellent	Excellent	n/a	n/a	n/a
Enumclaw	Excellent	Excellent	Excellent	n/a	n/a	n/a

Table G-54. DO continuous data quality results for synoptic surveys.

RM	Post-Check Rating	Fouling Check Rating	Field Check Rating	Data Correction Rating	Correction Type	Correction Amount
August Synoptic (8/19/12 - 8/24/12)						
28	Excellent	Excellent	Excellent	Excellent	Bias	-0.19
25.2	Excellent	Excellent	Excellent	n/a	n/a	n/a
20.4	Excellent	Excellent	Excellent	n/a	n/a	n/a
16	No data due to sonde failure					
6.2	Excellent	Excellent	Excellent	Excellent	Bias	-0.135
4.9	Excellent	Excellent	Excellent	n/a	n/a	n/a
1.4	Excellent	Excellent	Good	Good	Drift	0 to 0.38
0.1	Excellent	Excellent	Excellent	Excellent	Drift	0 to 0.13
September Synoptic (9/24/12 - 9/28/12)						
25.2	Excellent	Excellent	Excellent	n/a	n/a	n/a
20.4*	Excellent	Excellent	Excellent	Excellent	Bias	-0.1
16	Excellent	Excellent	Excellent	n/a	n/a	n/a
8.5	Excellent	Excellent	Excellent	Excellent	Bias	-0.11
6.2	Excellent	Excellent	Excellent	n/a	n/a	n/a
4.9	Excellent	Excellent	Good	Good	Bias	0.21
1.4	Excellent	Excellent	Good	n/a	n/a	n/a
0.1	Excellent	Excellent	Excellent	n/a	n/a	n/a
Boise Ck	Excellent	Excellent	Poor	Poor	Regression	-0.92 to -1.11
Buckley	Excellent	Excellent	Good	n/a	n/a	n/a
Enumclaw	Excellent	Excellent	Fair	n/a	n/a	n/a

For the continuous water quality stations at RM 28 (model boundary) and RM 3.7 (at the Sumner golf course): Rapidly dropping water levels and fine sediment accumulation lead to several data gaps in the continuous data collection, particularly at RM 3.7, a more depositional reach.

For RM 28, a complete record for the modeling period was constructed using a regression with the nearby USGS station at RM 24.2 to fill in data gaps. High quality pH data (no regression necessary) was collected during the most critical period (9/19/12 to 10/30/12).

For RM 3.7, the primary purpose of this station was to assist with calibration of the model and provide information about the extent of pH problems at the downstream end of the TMDL reach (Auburn to Lake Tapps tailrace return). High quality pH data was obtained during the critical period from 10/9/12 to 10/15/12.

USGS data quality

Stream flow records

USGS follows standardized protocols for stage and discharge measurement outlined in USGS Water-Supply Paper 2175 - MEASUREMENT AND COMPUTATION OF STREAMFLOW (Rantz et al, 1983). The methods include standard and well-documented quality control procedures. All stage and discharge data used in this TMDL received an accuracy rating of 'fair' or higher, meaning that at least 95 percent of the daily values fell within 8% of the true value (Table G-55).

Table G-55. USGS flow data quality rating criteria (https://help.waterdata.usgs.gov/codes-and-parameters/discharge-measurement-quality-code).

USGS Rating	Description
Excellent	The data is within 2% of the actual flow
Good	The data is within 5% of the actual flow
Fair	The data is within 8% of the actual flow
Poor	The data are >8% of the actual flow

Water quality records

USGS staff cleaned, calibrated, and redeployed sondes on a monthly basis during the course of the study following QA/QC procedures outlined in USGS protocols (Wagner et al., 2006).

Table G-56 provides a description of USGS accuracy rating codes for water quality records. In general, the USGS data used were rated as excellent or good, and these data meet the requirements of the Credible Data Policy and are acceptable for use (Table G-57). Table G-57 summarizes the data quality ratings for USGS data used in this TMDL.

Table G-56. USGS accuracy ratings of continuous water-quality records.

Parameter	Excellent	Good	Fair	Poor
Water Temperature	≤±0.2 °C	>±0.2–0.5 °C	>±0.5 – 0.8 °C	>±0.8 °C
Specific conductance	≤±3%	>±3–10%	>±10 – 15%	>±15 %
Dissolved Oxygen	≤±0.3 mg/L or ≤±5%, whichever is greater	>±0.3–0.5 mg/L or >±5–10%, whichever is greater	>±0.5 – 0.8 mg/L or >±10 – 15%, whichever is greater	>±0.8 mg/L or >±15%, whichever is greater
pH	≤±0.2 units	>±0.2–0.5 units	>±0.5 – 0.8 units	>±0.8 units
Turbidity	≤±0.5 turbidity units or ≤±5%, whichever is greater	>±0.5–1.0 turbidity units or >±5 –10%, whichever is greater	>±1.0 – 1.5 turbidity units or >±10–15%, whichever is greater	>±1.5 turbidity units or >±15%, whichever is greater

The Lake Tapps tailrace station (USGS #12101100) had some data quality ratings of fair and poor for temperature, DO, and turbidity. These downgraded ratings were primarily related to very low flows in the tailrace. The impact on the QUAL2Kw model is likely minimal, given that the flow is low, and the tailrace joins the river downstream of the TMDL reach. For the RM 24.2 station (#12098700), October 2012 was rated as fair/poor for pH. This data was not critical to the modeling effort, given that the nearby Ecology boundary station had good data quality during this period, and it is upstream of the critical area, so it was not the primary data used for calibration and will not be used to establish a TMDL.

Table G-57. USGS data quality ratings for continuous water quality data collected during the 2012 study.

RM	Station ID	SpCond	pH	Temp	DO	Turb
WY13 - October 2012						
RM7.6	12100490	excellent	excellent	Good	excellent	good
RM24.2	12098700	excellent	fair/poor[1]	excellent	excellent	excellent
LTD-tail	12101100	good	excellent	fair/good[2]	excellent/ fair/ poor	poor
WY12 - August & September 2012						
RM7.6	12100490	excellent	excellent	Good	excellent	good
RM24.1	12098700	excellent	good	excellent	excellent	excellent
LTD-tail	12101100	good	excellent/ good/ fair	Fair	fair	poor

[1] Fair Oct. 1-14, Poor Oct. 15-31

[2] Fair Oct. 1-12; Good Oct. 13-31

Muckleshoot Indian Tribe Fisheries Division (MITFD) data quality

Continuous Temperature

MITFD deployed continuous temperate data loggers at Pussyfoot (Trib15.6) and Second (Trib15.7) creeks during the 2012 study (see Table G-60 for location details).

MITFD staff performed a 5-point temperature verification on all data loggers using an NIST-traceable thermometer prior to and after deployment. MITFD used the same temperature instruments as Ecology (Onset Hobo Water Temp Pro V2). Installation, maintenance, and data quality assurance followed standardized protocols outlined in the Tribe's QAPP for Water Quality Monitoring of the White River (Rapin, 2010).

Continuous temperature data loggers met all MQOs outlined in the MITFD QAPP (Rapin, 2010) based on verifications completed before and after the deployment period. These data are of acceptable quality and meet the requirements of the Credible Data Policy.

Continuous water quality

MITFD staff followed USGS protocols (Wagner et al., 2006) for installation, maintenance, and QA/QC of the sonde. MITFD used a sonde that was the same or similar to those used by Ecology (Hydrolab DataSonde 5X). Further detail is included in the QAPP (Rapin, 2010).

For sonde water quality data collected at RM 10, MITFD used the same quality rating system as USGS (Table G-56) and all data were rated as either excellent or good (Table G-58). No data corrections were made for data rated as excellent. For data listed as good, small corrections were made according to the total correction factor calculated from post-deployment quality control data. Corrections were made by using a linear correction curve with a correction factor equal to zero applied to the first measurement of the deployment period and the total correction factor applied to the last measurement number of the deployment period. The total correction factor was relatively low for pH corrections (-0.26 for October 2012 deployment data).

Table G-58. MITFD sonde deployment Quality Assurance Ratings

Parameters	Quality Assurance Rating	
	Deployment periods	Deployment period
	8/17/2012 - 8/24/2012; 9/20/2012 - 9/28/2012	10/11/2012 - 10/12/2012
Water Temperature	Excellent	Excellent
Dissolved Oxygen	Excellent	Excellent
pH	Excellent	Good
Specific conductance	Excellent	Excellent

Data tables and plots

This appendix summarizes the data that were collected by Ecology specifically for the Lower White River pH TMDL, including continuous water quality deployments, the four synoptic surveys, and supplemental nutrient and flow monitoring.

Sample Locations

Tables G-59 and G-60 contain location details for the 2012 study.

Table G-59. Mainstem and point source location details for the 2012 study.

Location_ID	Study ID	Location Description	Latitude	Longitude
Mainstem				
10-WHT-28	W28	White River below Mud Mtn Dam	47.154860	-121.952060
WHI25.2	W25.2	White River at Rainier School	47.167059	-121.993199
WHI20.4	W20.4	White River below Buckley	47.186853	-122.065091
10-WHT-16.2	W16.2	White River above Muckleshoot Reservation	47.225674	-122.112891
10-WHT-10.3	W10.3	White River off Stuck River Dr	47.279810	-122.173510
10-WHT-8.5	W8.5	White River at east end of Game Farm Park	47.283494	-122.192876
10-WHT-7.5	W7.5	White River at R St SE	47.274820	-122.208580
WHI06.3	W6.3	White River above A Street	47.266334	-122.228909
10-WHT-4.8	W5	White River at 8th St	47.249870	-122.243830
10-WHT-4.0	W4	White River downstream of 16th St E	47.241370	-122.234450
WHI03.7	W3.7	White River above Lake Tapps tailrace	47.239405	-122.233673
10-WHT-1.4	W1.4	White River upstream of Fryar Ave	47.212660	-122.242220
WHI00.7	W0.5	White River at Pacific Ave	47.204127	-122.245761
10-WHT-0.1	W0.1	White River at mouth	47.200730	-122.253930
Point Sources				
MUCEFF	MFH	White River Hatchery	47.169860	-122.003620
10-MFH-BYPASS	MFH-Bypass	White River Hatchery bypass water	47.171390	-122.001150
10-EC-WWTP	EC	Enumclaw WWTP	47.188110	-122.005210
10-BK-WWTP	BK	Buckley WWTP	47.168070	-122.035170
SONOCO	SON	Sonoco Products Co.	47.213063	-122.241869

Table G-60. Tributary location details for the 2012 study.

Location_ID	Study ID	Location Description	Latitude	Longitude
Tributaries				
10-RED-0.1	TR27.6	Red Creek near mouth	47.156890	121.954590
10-RSSW-0.01	SW25.1	Old Rainier School WWTP outfall	47.166825	121.994012
10-LTD-DIV	LTD-DIV	Lake Tapps Canal at Diversion Dam	47.169790	122.006030
10-BOI-0.1	BOI	Boise Creek near mouth	47.176050	122.018600
10-LTD-FISH	LTD-FISH	Lake Tapps Canal fish return	47.169910	122.032930
10-UNW-TRIB20.6	TR20.6	Unnamed trib at ~RM 20.6	47.185080	122.062460
10-UNW-TRIB15.7	TR15.7	Second Creek downstream of SR164	47.223850	122.104680
10-UNW-0.1	TR15.6	Pussyfoot Creek at SR164	47.233450	122.105540
BOWMAN	TR8	Bowman Creek at mouth	47.274553	122.210295
10-BOW-0.3	TR8-up	Bowman Creek at Kersey Way	47.273073	122.207660
10-UNW-SW6.2	SW6.2	Stormwater outfall at ~RM 6.2	47.266780	122.228770
10-GOVT-0.3	TR5.3	Government Canal at Butte Ave	47.258500	122.245060
10-UNW-TRIB5.1	TR5.1	Wetlands outlet to White R. @ ~RM 5.1	47.253190	122.242710
10-UNW-TRIB4.3	TR4.3	Unnamed trib at Stewart Rd	47.250260	122.236950
10-UNW-SW3.3	TR3.3	Stormwater outfall at 24th St E bridge	47.235580	122.236310
10-UNW-TRIB2.9	TR2.9	Unnamed trib at E Valley Hwy & 29th St E	47.231190	122.225330
10-SAL-0.2	TR2.6	Salmon Creek at E Valley Hwy	47.217490	122.226140
10-UNW-SW0.9	TR0.9	Stormwater Outfall at ~RM 0.9	47.207470	122.243350
WTR01.3	TR1.3	Unnamed Trib @ White RM 1.3	47.212641	122.245921
LTD03.6	LTD-TAIL	Lake Tapps Power Flume Outlet	47.238076	122.231429

Sample (laboratory) data

Table G-61 contains parameter abbreviations used commonly in this report. Table G-62 contains laboratory sample results for the 2012 study. The dark grey cells represent a "U" qualifier in Environmental Information Management (EIM) database, which means the analyte was below the method reporting limit. The highlighted yellow cells represent a "J" qualifier in EIM, which means the associated result is an estimate.

Table G-61. Parameter abbreviations and units of measurements.

Abbreviation	Parameter	Unit of Measurement
Alk	Alkalinity, Total as CaCO3	mg/L
BOD	Biological Oxygen Demand	mg/L
Cl	Chloride	mg/L
NH3-N	Ammonia Nitrogen	ug/L
NO2-NO3	Nitrite-Nitrate Nitrogen	ug/L
TPN	Total Persulfate Nitrogen	ug/L
OP	Orthophosphate	ug/L
TP	Total Phosphorus	ug/L
DOC	Dissolved Organic Carbon	mg/L
TOC	Total Organic Carbon	mg/L
TSS	Total Suspended Solids	mg/L
TNVSS	Total Non-volatile Suspended Solids	mg/L
Turb	Turbidity	NTU
Chl a	Chlorophyll *a*	ug/L

Table G-62. Laboratory sample results for the 2012 study.

EIM Location ID	Study Location ID	Date	Time	ALK	BOD	Cl	Chl a	DOC	TOC	NH3-N	NO2-NO3	TPN	OP	TP	TNVSS	TSS	Turb
10-WHT-28	W28	8/21/2012	11:09					1	1	10	31	25	13.6	207			
10-WHT-28	W28	8/21/2012	11:09					1	1	10	27	26	13.4	204			
10-WHT-28	W28	8/21/2012	15:33	14.8		1.26	1	1	1	10	28	25	12.9	189	168	172	120
10-WHT-28	W28	8/23/2012	8:30	14.4						-	23	25	14.0	125			
10-WHT-28	W28	9/6/2012	12:30	15.7						-	18	25	14.8	127			
10-WHT-28	W28	9/20/2012	13:00	14.4						-	16	25	14.1	107			
10-WHT-28	W28	9/25/2012	9:35	15.3				1	1	10	16	25	13.5	102			
10-WHT-28	W28	9/25/2012	14:00	15.5		1.55	0.9	1	1	10	13	25	12.7	136	93	96	85
10-WHT-28	W28	10/11/2012	15:00	22.4		2.14	0.4	1	1	10	13	25	11.2	32.2	8	9	18
10-WHT-28	W28	10/18/2012	10:40	16						-	44	55	12.1	117			
10-WHT-28	W28	10/25/2012	8:45	21.7						-	60	77	7.9	21.7			
10-WHT-28	W28	10/25/2012	8:45	21.6		1.77	0.6	1	1	10	60	74	8.4	25.3	14	15	10
WHI25.2	W25.2	8/21/2012	10:15					1	1	10	30	25	13.5	201			
WHI25.2	W25.2	8/21/2012	14:00	14.8		1.3	1.1	1	1	10	30	25	13.2	173	162	167	120
WHI25.2	W25.2	9/25/2012	8:50	16.1				1	1	10	28	29	13.8	86.5			
WHI25.2	W25.2	9/25/2012	13:15	21	4	1.63	0.7	1	1	10	28	25	12.9	97.1	68	70	65
WHI20.4	W20.4	8/21/2012	9:26					1	1	10	38	35	14.6	201			
WHI20.4	W20.4	8/21/2012	15:00	14.9		1.41	1.1	1	1	11	45	48	14.8	194	162	167	120
WHI20.4	W20.4	9/25/2012	7:50	22.2				1	14.7	10	37	35	13.1	77.8			
WHI20.4	W20.4	9/25/2012	14:49	22.2		1.99	1.1	1	1	10	44	41	14.1	95.1	44	46	60
WHI20.4	W20.4	10/11/2012	16:15	25.7		2.31	1.1	1	1	10	34	54	17.1	37.0	5	6	15
WHI20.4	W20.4	10/25/2012	10:25	24.2		1.98	4.8	1	1	10	92	100	9.6	24.0	8	9	10
10-WHT-16.2	W16.2	8/21/2012	11:57					1	1	10	51	38	13.2	173			

EIM Location ID	Study Location ID	Date	Time	ALK	BOD	Cl	Chl a	DOC	TOC	NH3-N	NO2-NO3	TPN	OP	TP	TNVSS	TSS	Turb
10-WHT-16.2	W16.2	8/21/2012	16:49	16.4		1.45	1	1	1	10	53	66	14.6	185	146	150	120
10-WHT-16.2	W16.2	8/21/2012	16:49	15.4		1.37	1.1	1	1	10	55	58	14.9	176	141	145	120
10-WHT-16.2	W16.2	9/25/2012	11:05	22.8				1	1	10	50	58	12.6	73.8			
10-WHT-16.2	W16.2	9/25/2012	16:40	22.8		1.99	1.3	1	1	10	57	71	13.4	86.4	38	40	50
10-WHT-10.3	W10.3	8/21/2012	9:25					1	1	10	50	47	13.4	147			
10-WHT-10.3	W10.3	8/21/2012	16:05	17.5		1.45	1.2	1	1	10	56	53	14.5	151	130	134	120
10-WHT-10.3	W10.3	8/21/2012	16:05	16.4		1.48				10	51	55	15.5	151	128	132	110
10-WHT-10.3	W10.3	9/25/2012	8:47	24.1				1	1	10	50	49	11.8	69.8			
10-WHT-10.3	W10.3	9/25/2012	17:25	23.5		1.95	1.5	1	1	10	50	56	15.1	74.2	34	36	45
10-WHT-8.5	W9	8/21/2012	9:07					1	1	10	48	44	13.8	144			
10-WHT-8.5	W9	8/21/2012	18:20	16.5		1.46	1.2	1	1	10	47	56	14.0	169	124	126	110
10-WHT-8.5	W9	9/25/2012	8:15	23.9				1	1	10	51	44	11.9	69.4			
10-WHT-8.5	W9	9/25/2012	17:50	23.8		2	1.6	1	1	10	46	52	15.0	74.2	26	28	45
10-WHT-7.5	W8	8/15/2012	13:50	13.5						-	20	25	11.0	253			
10-WHT-7.5	W8	8/22/2012	9:25					1	1	10	53	55	13.2	125			
10-WHT-7.5	W8	8/22/2012	17:33	21.6		1.5	1	1	1	10	56	31	14.4	143	89	91	85
10-WHT-7.5	W8	9/26/2012	8:30	25				1	1	10	55	72	12.5	69.1			
10-WHT-7.5	W8	9/26/2012	13:40	24.9	2	1.89	1.3	1	1	10	33	40	12.3	64.4	22	23	33
10-WHT-7.5	W8	10/11/2012	11:45	27.9		2.23	1.8	1	1	10	29	43	10.7	26.0	6	7	13
10-WHT-7.5	W8	10/25/2012	13:03	25.8		2.03	1.1	1	1	10	89	112	9.5	21.8	7	8	8.7
WHI06.3	W6.2	8/22/2012	9:44					1	1	10	52	54	13.5	129			
WHI06.3	W6.2	8/22/2012	18:10	17.8		1.57	1	1	1	10	54	52	14.4	140	78	80	85
WHI06.3	W6.2	9/26/2012	8:05	24.7				1	1	10	58	84	12.3	70.7			
WHI06.3	W6.2	9/26/2012	14:05	25.2		1.9	1.3	1	1	105	38	149	12.3	59.6	23	23	34
WHI06.3	W6.2	10/25/2012	14:00	26.2		1.99		1	1	10	86	98	8.7	22.2	7	9	

EIM Location ID	Study Location ID	Date	Time	ALK	BOD	Cl	Chl a	DOC	TOC	NH3-N	NO2-NO3	TPN	OP	TP	TNVSS	TSS	Turb
10-WHT-4.8	W4.9	8/22/2012	8:30					1	1	10	56	57	13.2	127			
10-WHT-4.8	W4.9	8/22/2012	18:54	21.6		1.58	0.9	1	1	10	55	61	14.6	116	73	76	85
10-WHT-4.8	W4.9	9/26/2012	8:34	25.1				1	1	14	55	77	13.0	82.3			
10-WHT-4.8	W4.9	9/26/2012	13:15	24.8		1.91	1.4	1	1	14	33	60	12.1	59.1	24	25	35
10-WHT-4.8	W4.9	10/11/2012	17:50	28		2.28	1.6	1	1	11	15	47	12.6	29.6	6	7	12
10-WHT-4.8	W4.9	10/11/2012	17:50	28.3		2.3		1	1	11	34	46	13.4	28.2	6	7	
10-WHT-4.8	W4.9	10/25/2012	15:00	25.7		2.02	0.9	1	1	10	83	121	9.5	24.8	9	10	9
10-WHT-1.4	W1.4	8/22/2012	8:47					1	1	14	64	77	14.1	139			
10-WHT-1.4	W1.4	8/22/2012	17:29	22.7		1.61	0.9	1	1	14	57	64	14.2	120	75	77	80
10-WHT-1.4	W1.4	9/26/2012	7:46	26.3				1	1	21	71	106	12.9	87.3			
10-WHT-1.4	W1.4	9/26/2012	14:52	27.4	2	2.06	1.3	1	1	23	49	80	12.1	71.0	26	27	34
WHI00.7	W0.5	8/2/2012	13:00							-	-	-	-	-	45	51	33
WHI00.7	W0.5	8/2/2012	15:40							-	-	-	-	-	29	31	30
WHI00.7	W0.5	8/15/2012	11:25							-	-	-	-	-	57	62	58.9
WHI00.7	W0.5	8/23/2012	14:40							-	-	-	-	-	44	47	60
WHI00.7	W0.5	9/6/2012	14:40							-	-	-	-	-	26	28	55
WHI00.7	W0.5	9/20/2012	14:20							-	-	-	-	-	22	24	37
WHI00.7	W0.5	10/18/2012	14:30							-	-	-	-	-	53	55	75
WHI00.7	W0.5	10/25/2012	16:10							-	-	-	-	-	9	10	7.5
10-WHT-0.1	W0.1	8/22/2012	8:05					1	1	15	76	88	15.1	159			
10-WHT-0.1	W0.1	8/22/2012	16:13	23.9		1.7	1.2	1	1	13	65	75	15.1	124	71	73	70
10-WHT-0.1	W0.1	9/26/2012	7:52	28.5				1	1	27	75	114	13.3	98.8			
10-WHT-0.1	W0.1	9/26/2012	16:09	28.5		2.15	1.2	1	1	22	55	91	13.9	67.8	24	25	36
10-BK-WWTP	BK	8/22/2012		77.1		27		8.9	11	5,360	4,640	11,200	1,740	1,940	2	4	
10-BK-WWTP	BK	8/23/2012		67.7		26.8		9.4	10.6	3,740	4,800	9,620	1,950	2,060	4	4	

EIM Location ID	Study Location ID	Date	Time	ALK	BOD	Cl	Chl a	DOC	TOC	NH3-N	NO2-NO3	TPN	OP	TP	TNVSS	TSS	Turb
10-BK-WWTP	BK	9/25/2012		53.3		30.1		8.6	14.8	106	5,600	7,000	1,710	1,930	2	7	
10-BK-WWTP	BK	9/26/2012		53.6		30.2		8.3	9.7	124	4,540	5,640	1,990	2,270	2	5	
10-BK-WWTP	BK	10/11/2012		82.7		30.2		8.2	10.1	124	6,320	7,600	3,340	3,290	2	4	
10-BK-WWTP	BK	10/29/2012		39				4.8	6.2	125	3,250	3,870	143	261			
10-BK-WWTP	BK	10/30/2012		43				6.4	8	190	5,470	6,340	1,000	1,140			
10-EC-WWTP	EC	8/21/2012		118		32.2		8.2	9.7	197	3,690	4,760	186	301	1	3	
10-EC-WWTP	EC	8/22/2012		117		31.6		8	8.7	195	3,820	5,070	193	303	1	2	
10-EC-WWTP	EC	9/26/2012		112		34.9		8	8.8	42	4,320	5,440	108	238	2	9	
10-EC-WWTP	EC	10/11/2012		111		35.2		8.3	9.5	22	4,660	5,860	2,670	2,730	1	2	
10-EC-WWTP	EC	10/30/2012		55.6				4.7	5.4	211	2,120	2,890	168	272			
10-EC-WWTP	EC	10/31/2012		61.5				4.6	5.5	112	1,250	1,810	49.6	131			
10-EC-WWTP	EC	11/1/2012		59.6				4.6	5.4	89	1,520	2,090	415	505			
MUCEFF	MFH	8/21/2012	13:43	16.2		1.17		1	1	27	53	78	12.6	88.1	86	89	
MUCEFF	MFH	9/26/2012	15:20	24		2.31		1	1	63	75	195	19.2	58.3	23	25	
10-MFH-BYPASS	MFH-BYPASS	8/21/2012	14:04	15.1		1.31		1	1	10	27	27	12.4	245	231	240	
SONOCO	SON	8/23/2012	15:15	758		132		44.1	62	263	14,800	14,700	122	566	19	41	
SONOCO	SON	9/26/2012	9:50	760		133		49.2	67.6	1,720	1,610	7,410	21.5	466	20	41	
10-RED-0.1	TR27.6	8/21/2012	14:55	88.5		1.96	0.9			10	598	624	25.9	31.6	1	1	
10-RED-0.1	TR27.6	9/25/2012	14:20	87.8		1.87				11	608	602	27.0	29.7	1	1	
10-RSSW-0.01	SW25.1	8/21/2012	13:43	31.8		3.13				10	127	180	13.2	26.8	2	3	
10-LTD-DIV	LTD-DIV	8/21/2012	11:20	14.3		1.29				10	34	39	13.8	179	161	167	
10-LTD-DIV	LTD-DIV	9/25/2012	12:27	16.4		1.64				10	30	45	13.8	97.0	60	63	60
10-LTD-DIV	LTD-DIV	9/25/2012	12:27	20.9		1.69				10	29	41	13.7	108	60	64	65
10-BOI-0.1	BOI	8/21/2012	11:50					1	1.3	10	320	372	19.3	28.0			
10-BOI-0.1	BOI	8/21/2012	16:00	37		1.91	1.6	1.1	1.3	10	307	362	19.1	27.6	1	2	1.2

EIM Location ID	Study Location ID	Date	Time	ALK	BOD	Cl	Chl a	DOC	TOC	NH3-N	NO2-NO3	TPN	OP	TP	TNVSS	TSS	Turb
10-BOI-0.1	BOI	8/21/2012	16:00	38.8		2.03	1.4	1.4	1.3	10	280	366	18.6	28.0	1	2	1.5
10-BOI-0.1	BOI	9/25/2012	10:05	39.6				1.1	1.3	10	325	370	17.0	22.9			
10-BOI-0.1	BOI	9/25/2012	14:45	39.8		2.05	1.8	1	1	10	314	380	17.7	23.1	1	2	1
10-BOI-0.1	BOI	9/25/2012	14:45	39.8		2.08	1.7	1	1.1	10	320	352	18.1	23.3	1	2	0.9
10-BOI-0.1	BOI	10/11/2012	15:35	39.7		2.2		1.1	1.2	12	343	372	17.0	21.2	2	2	
10-BOI-0.1	BOI	10/25/2012	9:20	32		2.28		2	2.2	15	442	520	14.1	22.6	1	2	
10-LTD-FISH	LTD-FISH	8/21/2012	12:58	29.1		1.39				16	39	62	10.0	110	44	47	
10-LTD-FISH	LTD-FISH	9/25/2012	9:16	32		1.65				20	42	74	8.5	77.2	28	32	
10-UNW-TRIB20.6	TR20.6	9/25/2012	15:26	82.8		6.02				11	1,100	1,230	13.6	14.9	1	1	
10-UNW-TRIB15.7	TR15.7	8/21/2012	15:50	89.5		10.3				10	2,740	2,800	229	231	1	1	
10-UNW-TRIB15.7	TR15.7	9/25/2012	16:40	59.5		8.18				10	6,060	5,980	48.5	46.4	4	7	
10-UNW-0.1	TR15.6	8/21/2012	16:48	61.9		8.54				10	6,120	6,210	48.0	50.3	1	1	
BOWMAN	TR8	8/22/2012	10:30	37.1		2.71				24	52	194	9.6	41.9	5	8	
BOWMAN	TR8	8/22/2012	10:30	37.1		2.66				24	52	195	9.5	41.4	6	8	
BOWMAN	TR8	9/26/2012	8:25	34.8		2.56				22	44	166	7.2	31.2	5	7	
BOWMAN	TR8	10/11/2012	12:28	33.4		2.58		2.2	2.3	14	58	170	5.3	19.6	4	6	
BOWMAN	TR8	10/25/2012	13:30	35.8		2.83		2.3	2.6	11	48	162	6.4	23.4	4	8	
10-UNW-SW6.2	SW6.2	8/22/2012	11:50	35.1		1.9				27	166	335	12.2	27.8	1	1	
10-UNW-SW6.2	SW6.2	9/26/2012	9:00	41.2		1.65				26	75	142	5.9	38.4	8	9	
10-GOVT-0.3	TR5.3	8/22/2012	12:25	75		3.28				103	152	478	21.9	111	10	15	
10-GOVT-0.3	TR5.3	9/26/2012	9:20	73.3		3.15				59	145	345	14.0	125	43	54	
10-GOVT-0.3	TR5.3	9/26/2012	9:20	73.1		3.15				60	143	351	13.9	126	43	54	
10-UNW-TRIB5.1	TR5.1	9/26/2012	9:45	50		1.04				22	10	212	8.0	70.0	10	10	
10-UNW-TRIB4.3	TR4.3	9/26/2012	9:05	92.8		3.55				73	76	257	13.9	40.3	4	5	
LTD03.6	LTD-Tail	8/22/2012	13:10	30.8		2.24	0.6	1.8	1.8	28	94	195	6.9	23.6	1	2	2.6

EIM Location ID	Study Location ID	Date	Time	ALK	BOD	Cl	Chl a	DOC	TOC	NH3-N	NO2-NO3	TPN	OP	TP	TNVSS	TSS	Turb
LTD03.6	LTD-Tail	9/26/2012	9:45	33.2		2.19	1.1 🟨	1.6	1.7	48	70	184	6.4	27.2	2	3	
10-UNW-SW3.3	SW3.3	8/22/2012	16:35	370		24.9				5,760	26	5,760	3.0 ▨	1,090	38	52	
10-UNW-SW3.3	SW3.3	9/26/2012	13:00	359		26				6,280	18	5,970	21.3	991	25	38	
10-UNW-TRIB2.9	TR2.9	9/26/2012	10:28	68.6		2.47				10 ▨	300	291	37.1	58.0	12	23	
10-SAL-0.2	TR2.1	8/22/2012	14:05	90.9		4.72				23	896	1,050	27.1	249	51	71	
10-SAL-0.2	TR2.1	8/22/2012	14:05	90.3		4.88				23	382	1,070	27.9	245	50	70	
10-SAL-0.2	TR2.1	9/26/2012	11:05	86.5		4.69				27	1,030	1,200	34.7	77.5	3	5	
10-SAL-0.2	TR2.1	9/26/2012	11:05	87.2		4.7				30	1,090	1,130	32.8	75.1	3	5	
WTR01.3	TR1.3	8/22/2012	14:55	120		7.17				40	1,160	1,330	26.6	89.0	2	3	
WTR01.3	TR1.3	9/26/2012	13:45	113		7.17				30	1,130	1,330	28.5	68.7	3	4	
10-UNW-SW0.9	SW0.9	8/22/2012	16:00	164		7.25				498	96	582	392	683	2	3	
10-UNW-SW0.9	SW0.9	9/26/2012	15:26	156		6.64				429	116	597	436	717	2 ▨	3	
10-WHT-28	W28	8/21/2012	11:09					1	1	10	27	26	13.4	204	▨		

Qualifiers:

U = ▨

J = 🟨

Field water quality measurement data

Table G-63 contains parameters abbreviations commonly used in the appendix.

Table G-63. Measurement parameter abbreviations and units of measurements.

Abbreviation	Parameter	Unit of Measurement
Temp	Stream Temperature	°C
Cond	Specific Conductivity	uS/cm
pH	pH	S.U.
DO	Dissolved Oxygen (Hydrolab® probe)1	mg/L
Wink	Dissolved Oxygen (Winkler titration)	mg/L

Table G-64 contains field water quality measurement results for the 2012 study. Table G-65 contains flow measurement results for the 2012 study.

Table G-64. Field measurement results for the 2012 study.

EIM Location ID	Study Location ID	Date	Time	Temp	Cond	pH	DO	Wink
10-WHT-28	W28	8/19/2012	14:50	12.73	45.7	7.5	10.48	10.35
10-WHT-28	W28	8/21/2012	11:10	12.07	46.1	7.51	10.71	10.55
10-WHT-28	W28	8/21/2012	15:30	11.87	48	7.54	10.59	10.52
10-WHT-28	W28	8/23/2012	8:30	12.52	50.5	7.55		10.45
10-WHT-28	W28	10/11/2012	15:00	9.12	75.8	7.45	11.46	
10-WHT-28	W28	10/18/2012	10:56	7.00	32.4	7.51	12.13	
10-WHT-28	W28	10/25/2012	8:58	5.99	59	7.54	12.67	
WHI25.2	W25.2	8/19/2012	13:30	13.38	48	7.64		
WHI25.2	W25.2	8/21/2012	10:20	12.73	47.2	7.51	10.55	10.4
WHI25.2	W25.2	8/21/2012	14:00	12.40	48.3	7.6	10.5	10.45
WHI25.2	W25.2	8/23/2012	10:38	13.46	53.3	7.71		10.4
WHI25.2	W25.2	9/24/2012	10:20	10.26	64.9	7.55		10.8
WHI25.2	W25.2	9/25/2012	8:50	11.48	64.3	7.57	10.7	10.53
WHI25.2	W25.2	9/25/2012	13:10	11.80	62	7.38	10.6	10.6
WHI25.2	W25.2	9/27/2012	10:10	10.30	69.7	7.9		11.2
WHI25.2	W25.2	10/11/2012	14:00	9.52	81	7.68	11.88	

EIM Location ID	Study Location ID	Date	Time	Temp	Cond	pH	DO	Wink
WHI20.4	W20.4	7/18/2012	12:01	12.79	55	7.5	10.95	
WHI20.4	W20.4	8/19/2012	12:30	13.90	50.3	7.5	10.19	10.18
WHI20.4	W20.4	8/21/2012	9:20	13.70	45.1	7.53	10.22	10.2
WHI20.4	W20.4	8/22/2012	13:00	13.76	54.6	7.57		10.3
WHI20.4	W20.4	9/24/2012	11:00	10.67	69.2	7.6		11.15
WHI20.4	W20.4	9/25/2012	7:50	11.67	69.1	7.55	10.66	10.53
WHI20.4	W20.4	9/25/2012	14:50	12.50	70.5	7.2	10.69	10.65
WHI20.4	W20.4	9/26/2012	13:10	11.69	71	7.6		10.95
WHI20.4	W20.4	10/11/2012	16:15	9.94	84.5	7.77	11.4	11.2
WHI20.4	W20.4	10/25/2012	11:16	6.96	63	7.79	12.7	
10-WHT-16.2	W16.2	7/18/2012	14:21	13.99	60	7.5	10.54	
10-WHT-16.2	W16.2	9/24/2012	12:40	11.76	70.2	7.77		
10-WHT-16.2	W16.2	9/25/2012	11:00	12.31	72.9	7.67	10.73	10.85
10-WHT-16.2	W16.2	9/25/2012	16:40	12.98	71.7	7.5	10.58	10.5
10-WHT-16.2	W16.2	9/27/2012	11:40	11.25	73.7	7.74		11.25
10-WHT-8.5	W9	7/17/2012	16:43	16.23	63	7.64	10.36	
10-WHT-8.5	W9	9/24/2012	15:00	13.26	72.4	7.74		10.83
10-WHT-8.5	W9	9/25/2012	8:10	11.94	71.8	7.4		10.7
10-WHT-8.5	W9	9/25/2012	17:50	13.79	74.6	7.59	10.38	10.4
10-WHT-8.5	W9	9/27/2012	13:00	12.21	74.8	7.94		10.95
10-WHT-7.5	W8	9/26/2012	8:30	10.59	73.4	7.56	10.98	11.1
10-WHT-7.5	W8	9/26/2012	10:20	10.84	72.2	7.63		
10-WHT-7.5	W8	9/26/2012	13:40	12.89	74.6	7.94	10.73	10.92
10-WHT-7.5	W8	10/11/2012	12:04	10.75	86.7	8.16	11.86	11.9
10-WHT-7.5	W8	10/25/2012	13:03	7.96	67	7.9	12.7	
WHI06.3	W6.2	7/17/2012	14:22	15.73	62	7.88	10.85	
WHI06.3	W6.2	7/17/2012	14:59	15.32	62	7.75	10.63	
WHI06.3	W6.2	7/17/2012	15:03	15.26	62	7.66	10.62	
WHI06.3	W6.2	8/19/2012	11:30	15.69	54.9	7.59	9.94	9.95
WHI06.3	W6.2	8/21/2012	10:20	13.70	58.3	7.48	10.5	10.38

EIM Location ID	Study Location ID	Date	Time	Temp	Cond	pH	DO	Wink
WHI06.3	W6.2	8/21/2012	14:00	16.56	58.1	7.57	9.91	9.9
WHI06.3	W6.2	8/22/2012	19:40	15.98	59.4	7.71		9.75
WHI06.3	W6.2	9/24/2012	15:40	13.58	72.6	7.74		10.8
WHI06.3	W6.2	9/26/2012	8:10	10.65	73.5	7.52	10.93	11
WHI06.3	W6.2	9/26/2012	9:00	10.71	72.7	7.48		
WHI06.3	W6.2	9/26/2012	14:00	13.12	74.7	7.99	10.75	10.83
WHI06.3	W6.2	9/27/2012	16:03	13.99	75.8	8.03		10.52
WHI06.3	W6.2	10/11/2012	10:43	10.33	86.5	7.93	11.94	
10-WHT-4.8	W4.9	8/19/2012	10:30	15.55	56.1	7.52	9.89	9.8
10-WHT-4.8	W4.9	8/21/2012	9:20	13.37	58.3	7.51	10.44	10.4
10-WHT-4.8	W4.9	8/22/2012	18:53	16.40	59.2	7.68		9.75
10-WHT-4.8	W4.9	9/24/2012	16:10	13.60	72.7	7.76		10.75
10-WHT-4.8	W4.9	9/26/2012	8:30	10.71	75.3	7.4	10.89	10.85
10-WHT-4.8	W4.9	9/26/2012	13:10	12.10	68.5	7.91	11.16	11.2
10-WHT-4.8	W4.9	9/26/2012	14:00	12.64	75.2	7.97		
10-WHT-4.8	W4.9	9/27/2012	14:00	12.64	75.2	7.97		11
10-WHT-4.8	W4.9	10/11/2012	17:50	12.32	88.1	8.15	10.95	
10-WHT-4.0	W4	7/18/2012	19:02	15.39	64	7.51	10.38	
10-WHT-4.0	W4	10/11/2012	9:00	10.24	87.6	7.52	11.13	
WHI03.7	W3.7	7/19/2012	16:03	16.17	51	7.54	10.53	
WHI03.7	W3.7	10/11/2012	9:28	10.25	87.9	7.53	11.16	
WHI03.7	W3.7	10/18/2012	13:45	8.87	36.9	7.7	11.82	
10-WHT-1.4	W1.4	7/17/2012	11:27	14.25	73	7.17	10.45	
10-WHT-1.4	W1.4	8/19/2012	9:50	15.37	59.5	7.42	9.77	9.8
10-WHT-1.4	W1.4	8/22/2012	8:50	13.16	62.2	7.46		10.3
10-WHT-1.4	W1.4	8/22/2012	17:30	16.38	62.1	7.54		9.6
10-WHT-1.4	W1.4	9/24/2012	16:50	13.22	75.4	7.52		11.25
10-WHT-1.4	W1.4	9/26/2012	7:40	10.95	71.7	7.59		10.85
10-WHT-1.4	W1.4	9/26/2012	14:50	12.66	79.2	7.63	10.81	10.8
10-WHT-1.4	W1.4	9/27/2012	14:40	12.36	79.3	7.75		11.05

EIM Location ID	Study Location ID	Date	Time	Temp	Cond	pH	DO	Wink
10-WHT-1.4	W1.4	10/11/2012	8:37	10.27	92.2	7.5	10.97	
10-WHT-0.1	W0.1	7/17/2012	10:31	14.88	79	7.07	9.9	
10-WHT-0.1	W0.1	8/19/2012	8:44				9.68	9.7
10-WHT-0.1	W0.1	8/22/2012	8:20	12.97	65.5	7.38		10.25
10-WHT-0.1	W0.1	8/22/2012	16:20	15.95	66.7	7.4		9.95
10-WHT-0.1	W0.1	9/24/2012	17:20	13.04	78.4	7.39		10.75
10-WHT-0.1	W0.1	9/26/2012	7:50	11.14	81.8	7.24	10.51	10.55
10-WHT-0.1	W0.1	9/26/2012	16:10	12.82	82.9	7.4	10.63	
10-WHT-0.1	W0.1	9/27/2012	15:30	12.40	82.7	7.51		11.02
10-BK-WWTP	BK	9/25/2012	10:30	19.69	293.5	6.71		6.85
10-BK-WWTP	BK	9/26/2012	13:50	19.83	295	6.68		6.65
10-EC-WWTP	EC	9/25/2012	11:10	20.3	410.6	7.05		5.5
10-EC-WWTP	EC	9/26/2012	14:50	20.38	409	7.2		6.6
MUCEFF	MFH	8/21/2012	13:43	11.52	62.7	7.26		
SONOCO	SON	8/22/2012	11:00	19.28		7.21		
SONOCO	SON	9/25/2012	9:50	16.02		7.23		
SONOCO	SON	9/26/2012	12:25	16.22		7.16		
10-RED-0.1	TR27.6	8/21/2012	14:55	10.20	200	7.71	10.19	
10-RED-0.1	TR27.6	9/25/2012	14:20	9.86	209	7.52	10.35	
10-RSSW-0.01	SW25.1	8/21/2012	13:43	17.30	78.6	7.82	8.05	
10-BOI-0.1	BOI	8/21/2012	11:50	14.38	78.2	7.87	9.42	9.82
10-BOI-0.1	BOI	8/21/2012	16:00	17.36	90	7.12	7.86	
10-BOI-0.1	BOI	9/12/2012	16:13	12.92	84.6	7.42	10.61	
10-BOI-0.1	BOI	9/25/2012	10:30	12.49	95.2	7.91	9.99	10.35
10-BOI-0.1	BOI	9/25/2012	14:50	13.05	95.7	7.86	10.33	10.12
10-BOI-0.1	BOI	9/27/2012	10:41	10.71	89.5	7.84		10.7
10-BOI-0.1	BOI	10/11/2012	15:35	10.58	93.3	7.62	10.94	
10-BOI-0.1	BOI	10/25/2012	9:25	7.61	64	7.8	11.99	
10-LTD-DIV	LTD-Div	8/21/2012	11:20	12.62	48	7.44	10.15	10.4
10-LTD-DIV	LTD-DIV	9/25/2012	12:27	11.57	64.6	7.47	10.49	

EIM Location ID	Study Location ID	Date	Time	Temp	Cond	pH	DO	Wink
10-LTD-FISH	LTD-Fish	8/21/2012	12:58	14.2	68.9	7.08	9.42	9.33
10-LTD-FISH	LTD-FISH	9/25/2012	9:16	11.03	89.9	7.12	10.07	
10-WHT-SEEP16S	SCW16.2	7/18/2012	14:42	16.19	60	6.8	5.77	
10-UNW-TRIB15.7	TR15.7	8/21/2012	15:50	15.08	283.6	8.1		
10-UNW-0.1	TR15.6	8/21/2012	16:48	10.66	222.7	6.93		9.8
10-UNW-0.1	TR15.6	9/25/2012	16:40	10.39	205.7	6.8		
10-BOW-0.3	TR8-up	9/12/2012	14:48	13.68	82.1	6.51	6.28	
10-BOW-0.3	TR8-up	9/12/2012	15:00	13.72	82.7	6.46	6.26	
BOWMAN	TR8	8/22/2012	10:30	17.36	90	7.12	7.86	
BOWMAN	TR8	9/12/2012	15:15	13.82	82.5	6.8	8.66	
BOWMAN	TR8	9/26/2012	8:25	13.19	82.2	7.09	9	
BOWMAN	TR8	10/11/2012	12:28	10.56	85.5	7.23	9.94	
BOWMAN	TR8	10/25/2012	13:36	8.97	74	7.3	10.08	
10-WHT-SEEP6.3	W6.3seep	7/17/2012	14:24	13.65	162	6.61	4.42	
10-UNW-SW6.2	SW6.2	8/22/2012	11:50	12.77	85.2	6.77	9.22	
10-UNW-SW6.2	SW6.2	9/26/2012	9:00	11.89	87.9	6.75	8.88	
10-GOVT-0.3	TR5.3	8/22/2012	12:25	18.45	175.5	7.12	7.43	
10-GOVT-0.3	TR5.3	9/12/2012	14:05	17.31	177.2	7.01	10.18	
10-GOVT-0.3	TR5.3	9/12/2012	14:18	17.79	177.4	7.05	10.33	
10-GOVT-0.3	TR5.3	9/26/2012	9:20	12.5	187	7.04	6.87	
LTD03.6	LTD-Tail	8/22/2012	13:10	12.87	78	7.15	10.82	
LTD03.6	LTD-Tail	9/26/2012	9:45	11.11	81.4	6.89	7.5	
10-UNW-SW3.3	SW3.3	8/22/2012	16:35	13.58	736.5	6.81	5.51	
10-UNW-SW3.3	SW3.3	9/26/2012	13:00	14.2	822	6.91	5.36	
10-SAL-0.2	TR2.1	8/22/2012	14:05	13.07	196.6	7.47	9.28	
10-SAL-0.2	TR2.1	9/12/2012	12:15	11.56	189	7.54	10.72	
10-SAL-0.2	TR2.1	9/26/2012	11:05	11.23	208	7.58	9.98	
WTR01.3	TR1.3	7/3/2012	11:00	14.65	230	7.04	5.9	

EIM Location ID	Study Location ID	Date	Time	Temp	Cond	pH	DO	Wink
WTR01.3	TR1.3	8/22/2012	14:55	14.83	255.2	7.26	6.67	
WTR01.3	TR1.3	9/12/2012	10:50	11.1	251.3			
WTR01.3	TR1.3	9/26/2012	13:45	11.85	266	7.23	6.96	
10-UNW-SW0.9	SW0.9	8/22/2012	16:00	13.31	309.4	7.5	8.61	
10-UNW-SW0.9	SW0.9	9/26/2012	15:26	13.99	78.6	8.01	10.2	10

Table G-65. Flow measurement results for the 2012 study.

EIM Location ID	Study Location ID	Date	Time	Flow (Cfs)	Ave. Depth (ft)	Ave. Velocity (ft/s)	Wetted Width (ft)
10-WHT-28	W28	8/22/2012	9:00	876	1.7	4.05	129
10-WHT-28	W28	9/26/2012	14:00	497	1.5	2.87	119
WHI20.4	W20.4	8/22/2012	11:00	1040	2.9	4.11	86.8
WHI20.4	W20.4	9/26/2012	9:00	570	2.4	3.57	67.2
WHI03.7	W3.7	8/22/2012	13:00	885	3	2.94	101
WHI03.7	W3.7	9/26/2012	11:00	570	2.5	2.26	102
WHI00.7	W0.5	8/22/2012	14:00	947	5.1	1.35	138
WHI00.7	W0.5	9/26/2012	12:20	600	4.3	1.02	136
10-RED-0.1	TR27.6	8/21/2012	15:06	1.1	0.2	0.37	12.6
10-RED-0.1	TR27.6	9/26/2012	11:30	0.66	0.2	0.31	12.3
10-RED-0.1	TR27.6	10/18/2012	11:46	0.87			
10-RSSW-0.01	SW25.1	8/21/2012	13:43	0.01	0.1	0.05	1.9
10-LTD-FISH	LTD-FISH	8/21/2012	13:05	2.5	0.6	0.22	19.7
10-LTD-FISH	LTD-FISH	9/25/2012	9:26	2.46	0.5	0.71	7.4
10-UNW-TRIB15.7	TR15.7	8/21/2012	15:39	0.02	0.1	0.04	4.1
10-UNW-0.1	TR15.6	8/21/2012	16:29	0.45	0.4	0.12	8.6
10-UNW-0.1	TR15.6	9/25/2012	16:26	0.48	0.4	0.16	8.9
BOWMAN	TR8	8/22/2012	10:30	0.72	0.2	0.33	10
BOWMAN	TR8	9/12/2012	15:00	0.7			
BOWMAN	TR8	9/26/2012	11:25	0.91	0.2	0.41	10
BOWMAN	TR8	10/11/2012	12:30	0.71			
BOWMAN	TR8	10/25/2012	13:33	0.76			
10-UNW-SW6.2	SW6.2	8/22/2012	11:50	0.01	0.1	0.04	2.2
10-GOVT-0.3	TR5.3	8/22/2012	12:25	1.39			
10-GOVT-0.3	TR5.3	9/12/2012	14:20	0.73			
10-GOVT-0.3	TR5.3	9/26/2012	10:19	0.66			

EIM Location ID	Study Location ID	Date	Time	Flow (Cfs)	Ave. Depth (ft)	Ave. Velocity (ft/s)	Wetted Width (ft)
10-UNW-TRIB4.3	TR4.3	9/26/2012	9:16	0.74	0.2	1.38	2.7
10-UNW-SW3.3	SW3.3	8/22/2012	16:35	3.16			
10-UNW-SW3.3	SW3.3	9/26/2012	13:10	0.22			
10-UNW-TRIB2.9	TR2.9	9/26/2012	10:40	1.19			
10-SAL-0.2	TR2.1	8/22/2012	11:50	6.4	0.4	1.6	9.7
10-SAL-0.2	TR2.1	9/12/2012	13:00	6.1	0.4	1.69	8.2
10-SAL-0.2	TR2.1	9/26/2012	11:25	7.01	0.4	2.02	8.3
WTR01.3	TR1.3	8/22/2012	14:55	3.7	0.7	0.4	12.7
WTR01.3	TR1.3	9/20/2012	10:07	3.8	1.1	0.27	12.7
WTR01.3	TR1.3	9/26/2012	14:20	3.6	1.2	0.23	12.5
10-UNW-SW0.9	SW0.9	8/22/2012	16:00	0.97			
10-UNW-SW0.9	SW0.9	9/26/2012	15:37	0.83			

Continuous Water Quality Data Plots

Figures G-35 to G-37 contain continuous temperature plots for the White River mainstem and tributaries.

Figures G-38 to G-40 contain continuous water quality results from the synoptic survey 8/19/12 to 8/24/12.

Figures G-41 to G-43 contain continuous water quality results from the synoptic survey 9/24/12 to 9/28/12.

Figures G-44 to G-46 contain continuous water quality results from Ecology's long-term deployment at RM 28, the study upstream boundary, downstream of Mud Mountain Dam.

Figures G-47 to G-49 contain continuous water quality results from Ecology's long-term deployment at RM 3.7, at the downstream end of the Sumner golf course, immediately upstream of the Lake Tapps tailrace.

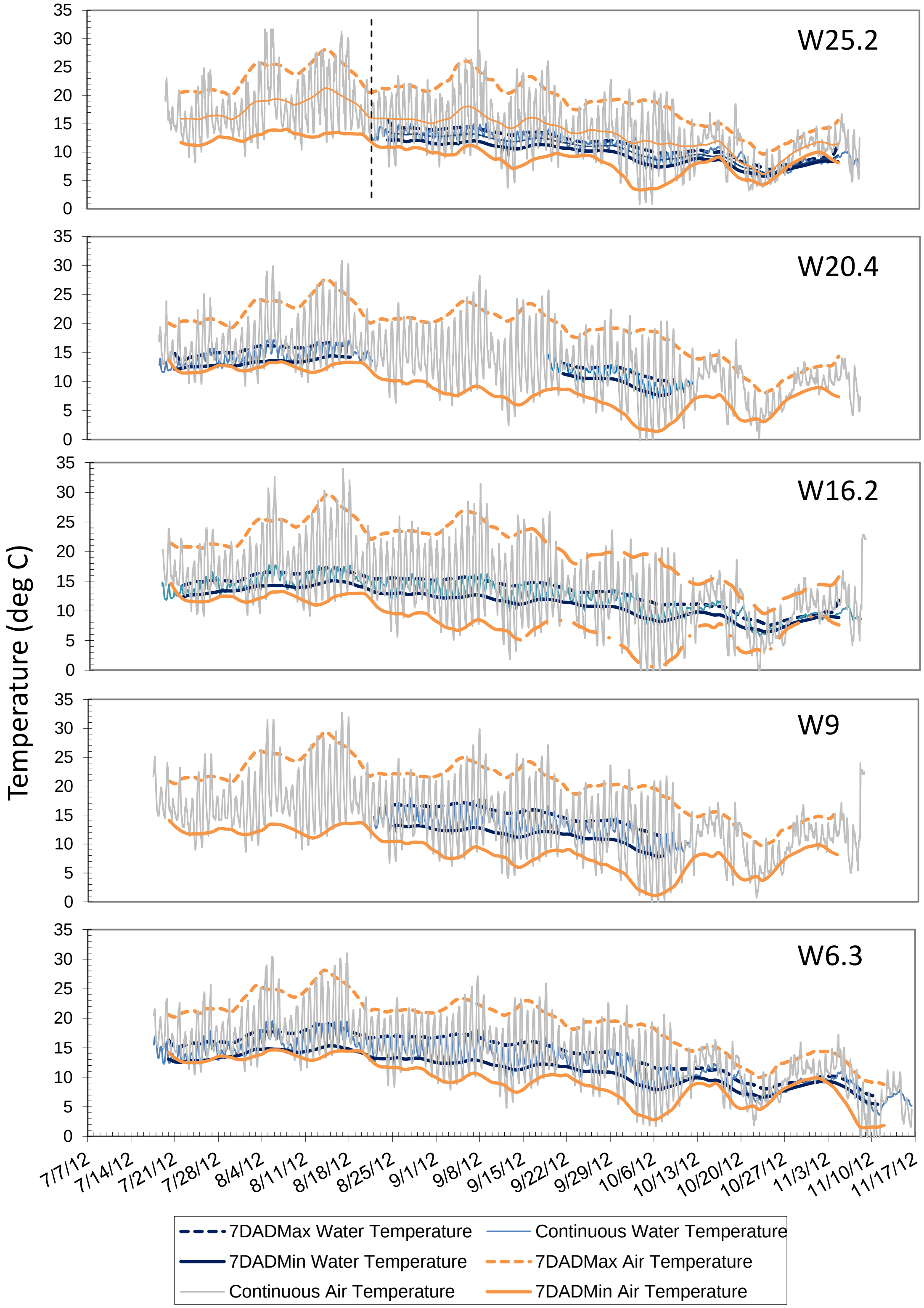

Figure G-35. 2012 continuous temperature data for the White River mainstem between RM 28 and RM 6.

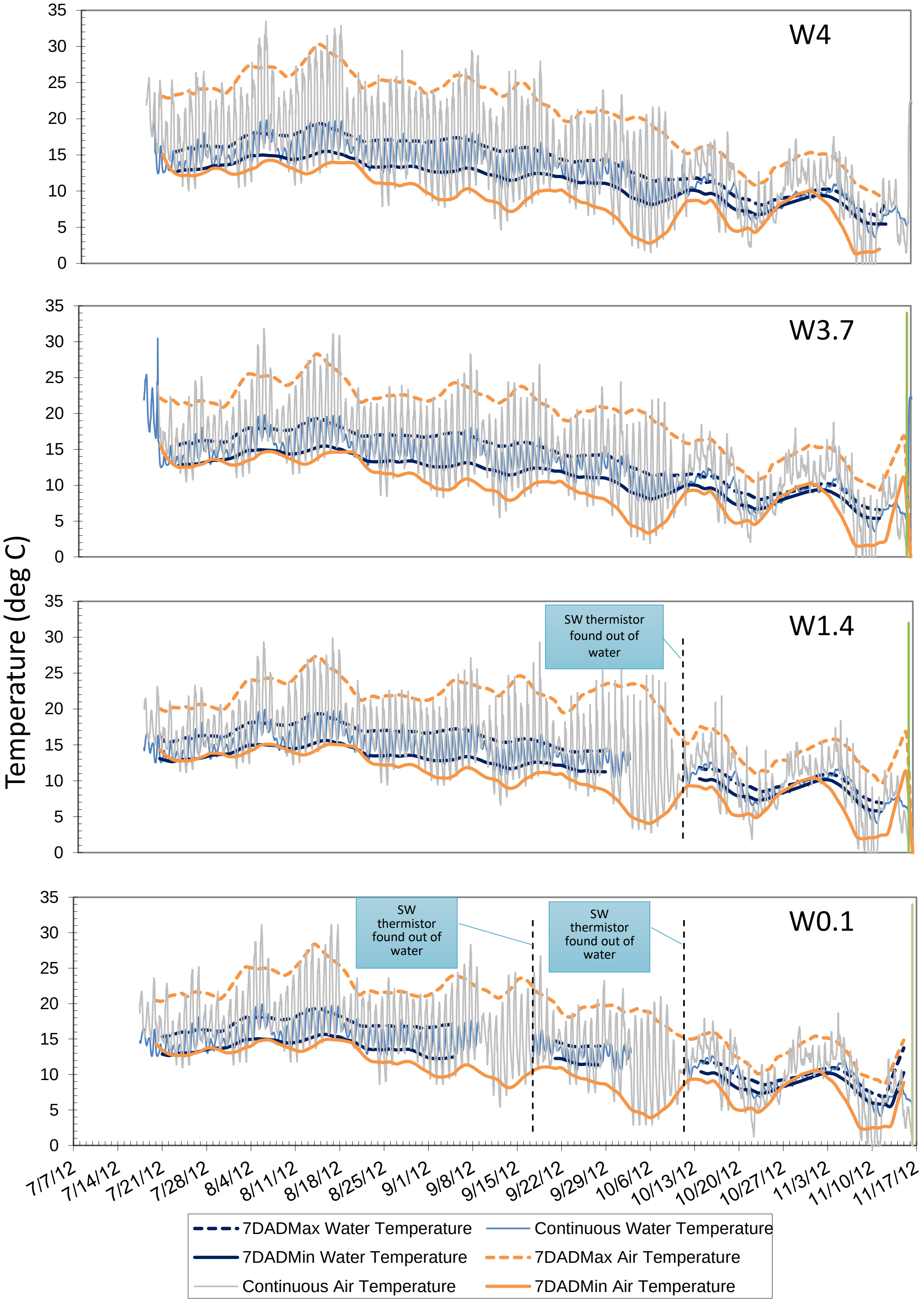

Figure G-36. 2012 continuous temperature data for the White River mainstem between RM 4 and RM 0.

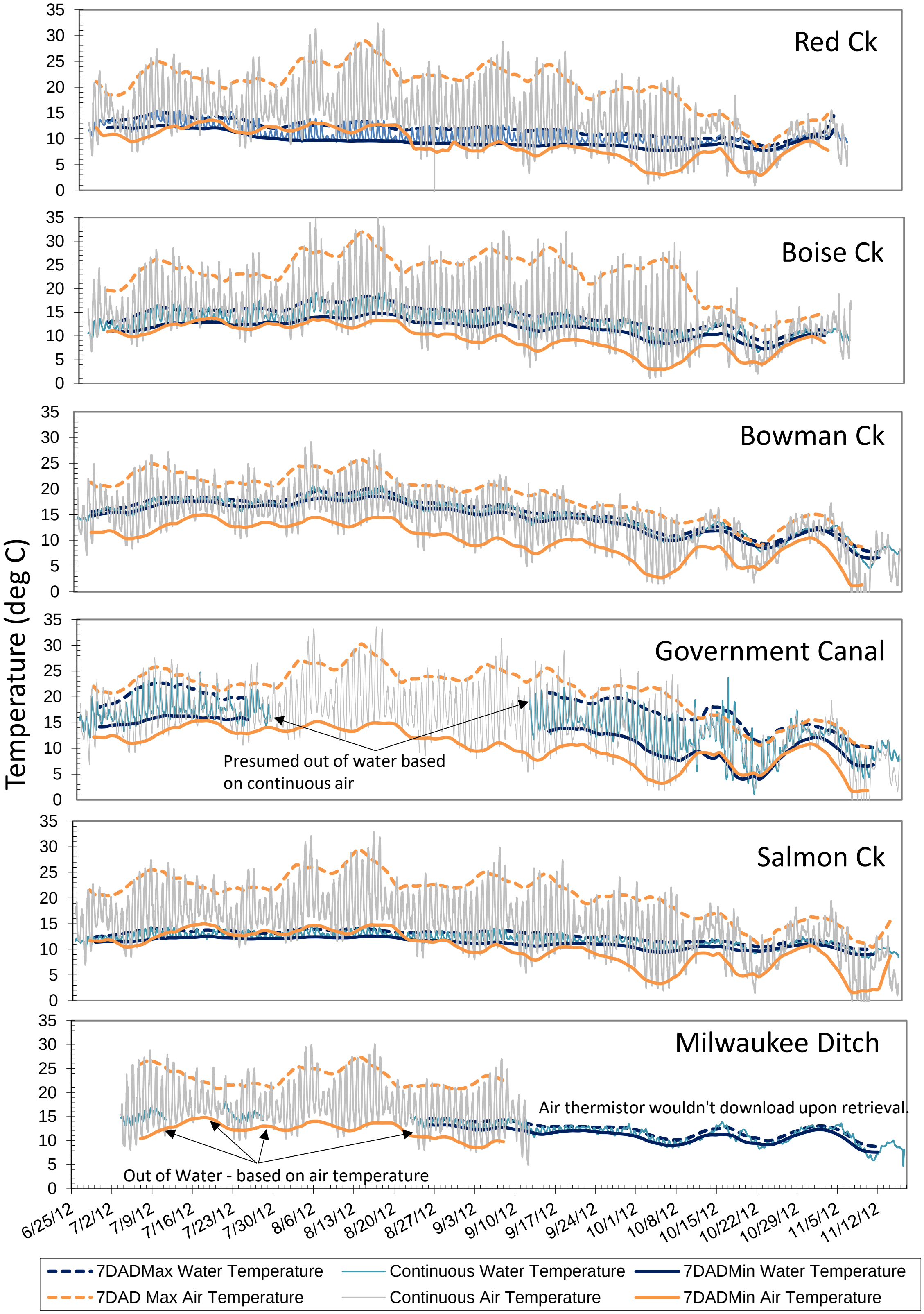

Figure G-37. 2012 continuous temperature data for tributaries to the White River.

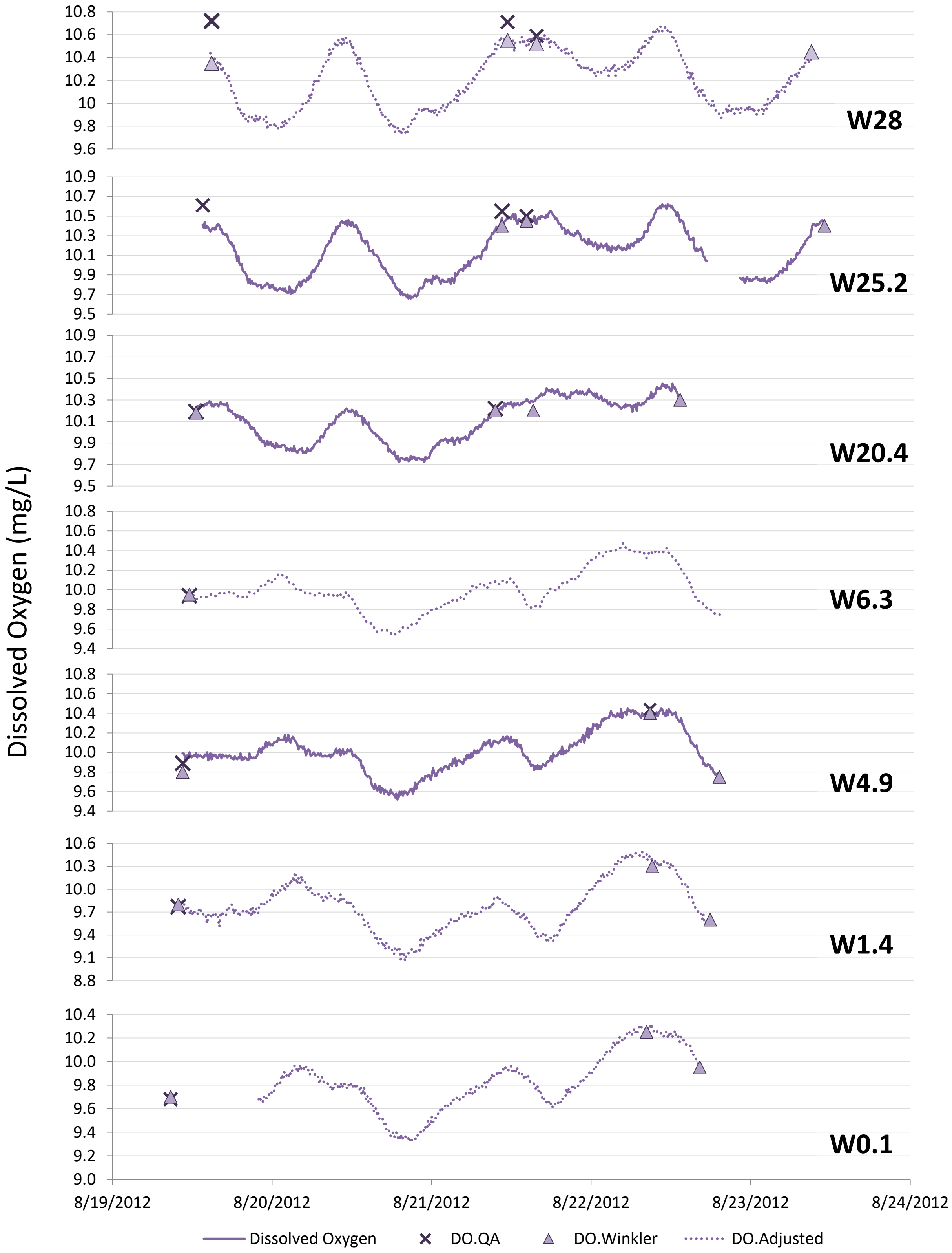

Figure G-38. August 2012 synoptic survey dissolved oxygen deployment data.

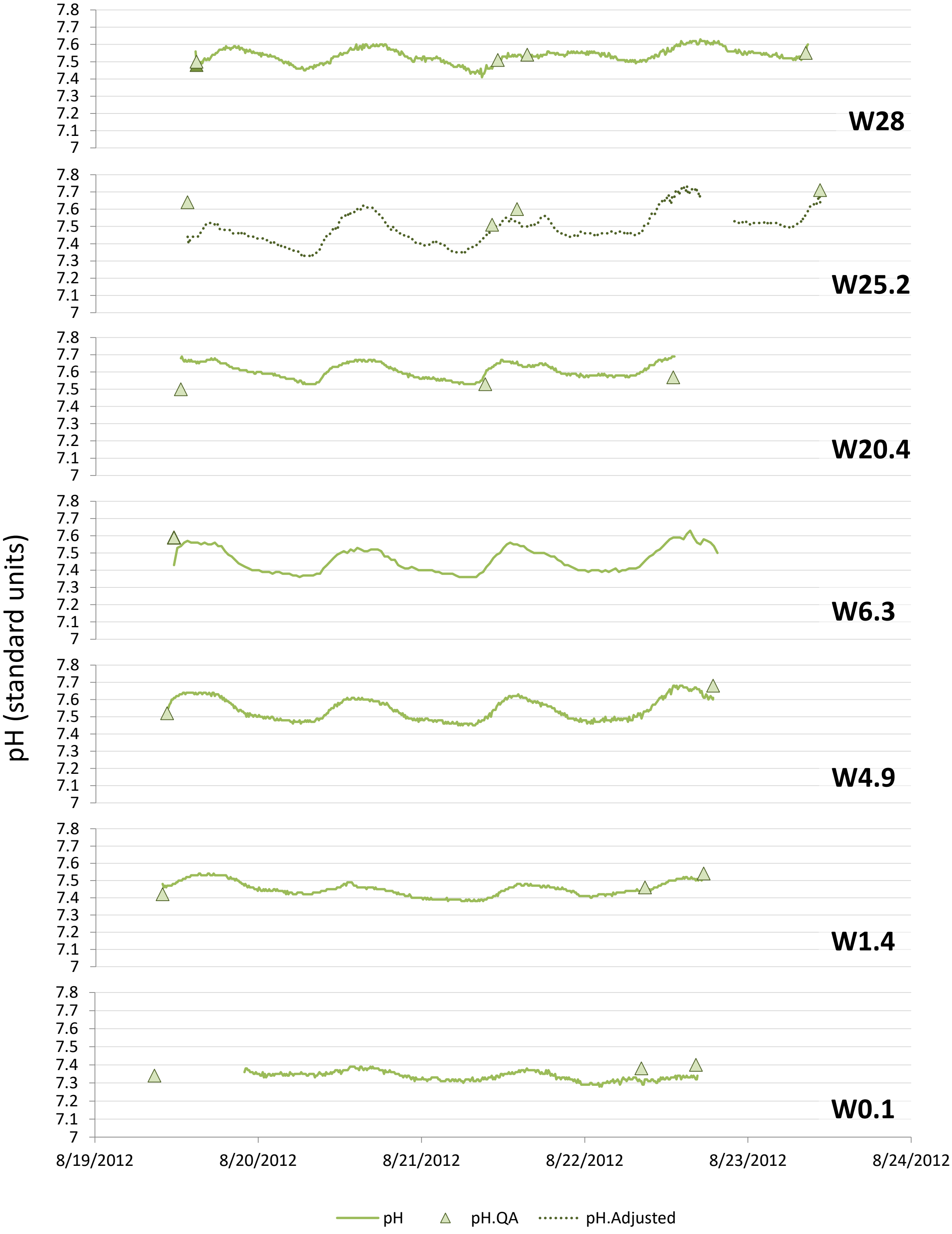

Figure G-39. August 2012 synoptic survey pH deployment data.

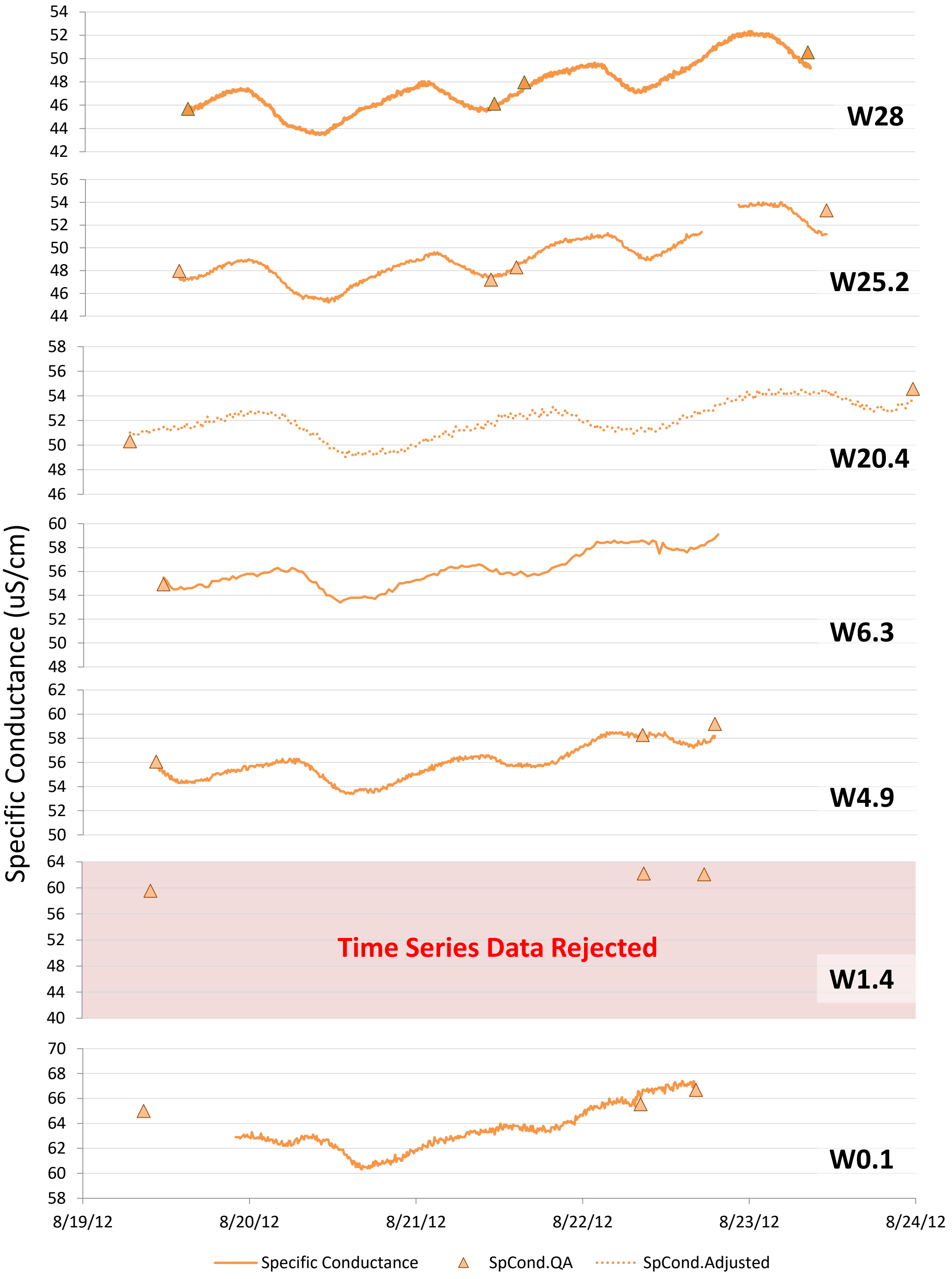

Figure G-40. August 2012 synoptic survey specific conductance deployment data.

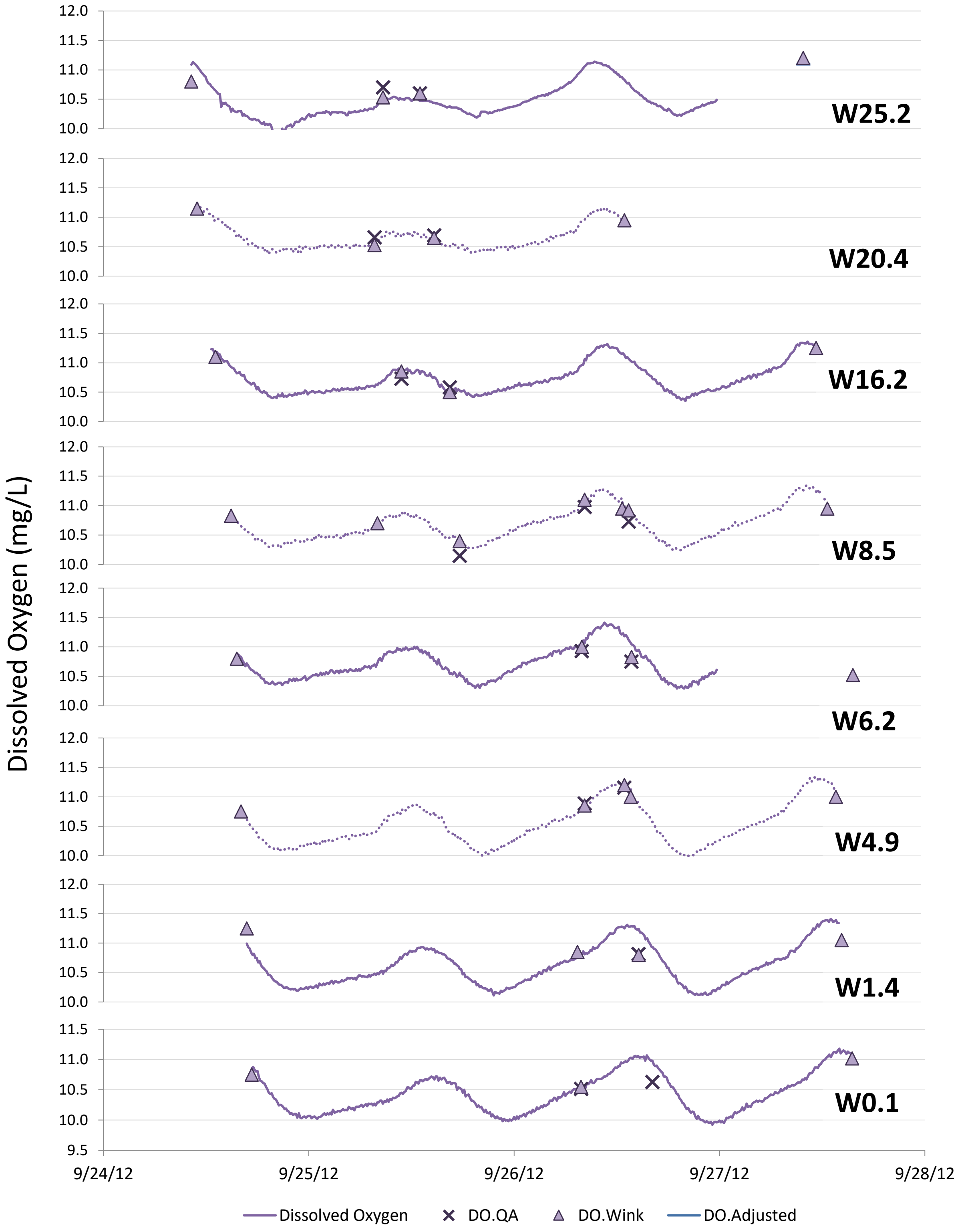

Figure G-41. September 2012 synoptic survey dissolved oxygen deployment data.

Figure G-42. September 2012 synoptic survey pH deployment data.

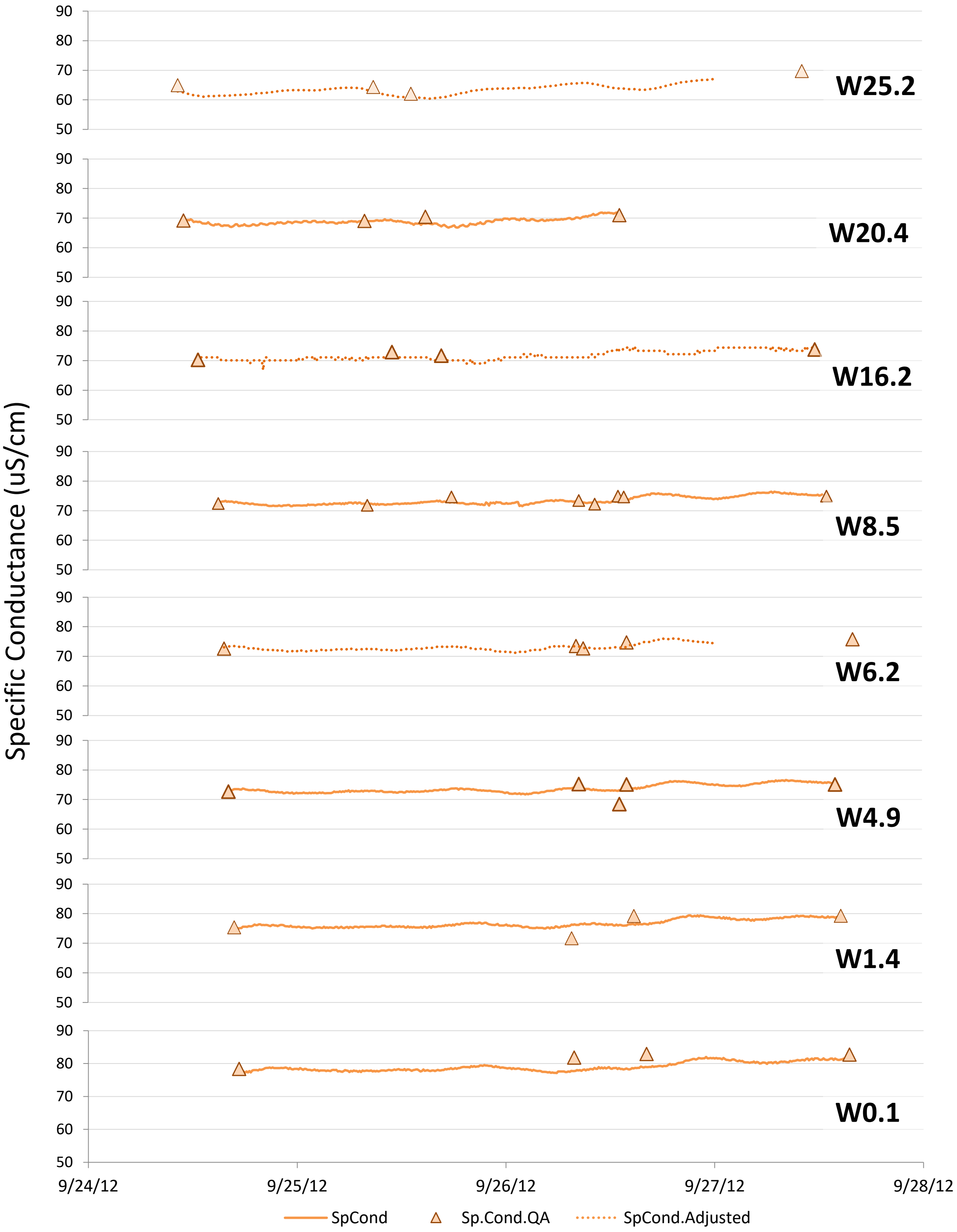

Figure G-43. September 2012 synoptic survey specific conductance deployment data.

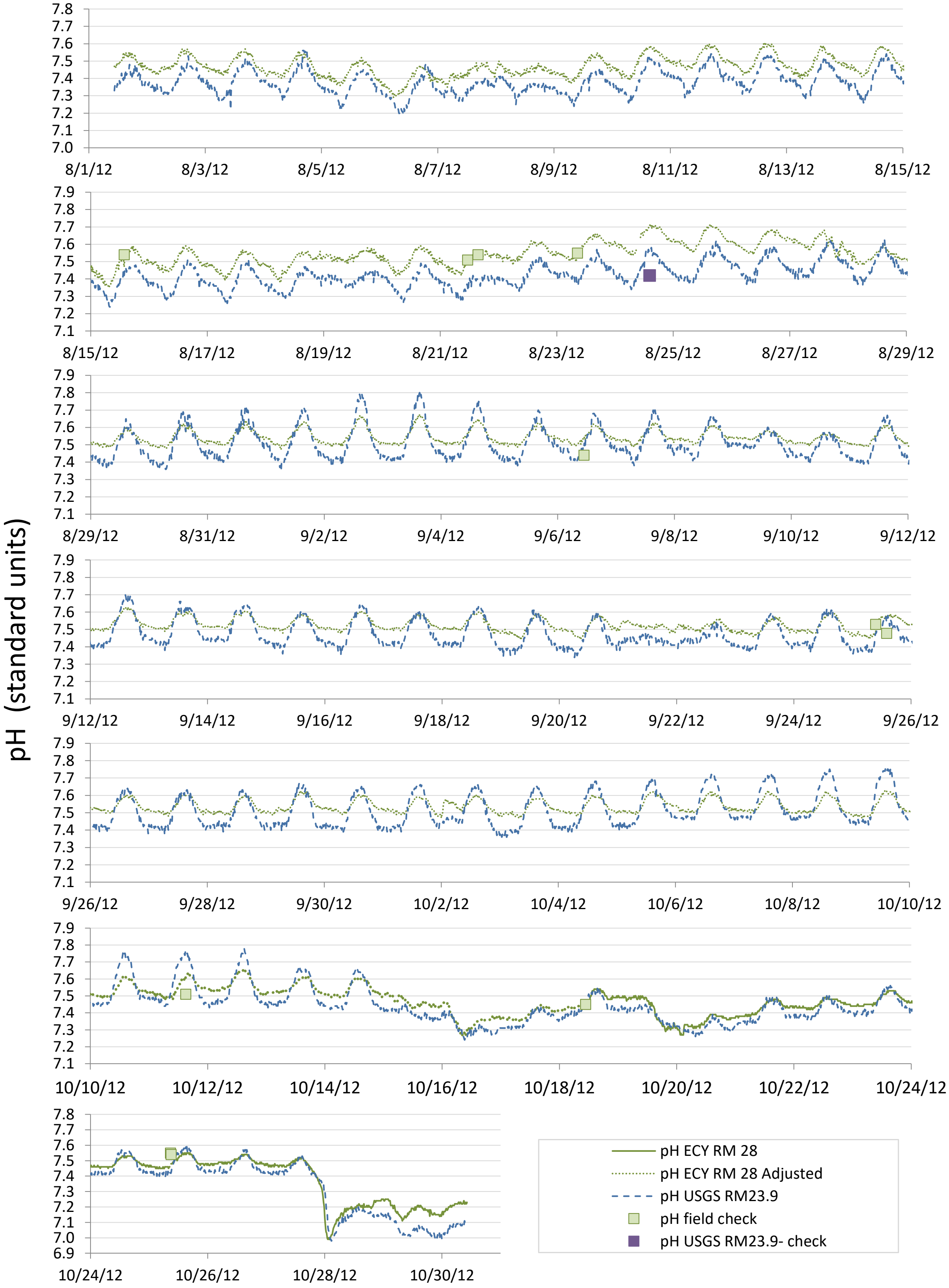

Figure G-44. Continuous pH data from August through October 2012 at RM 28.

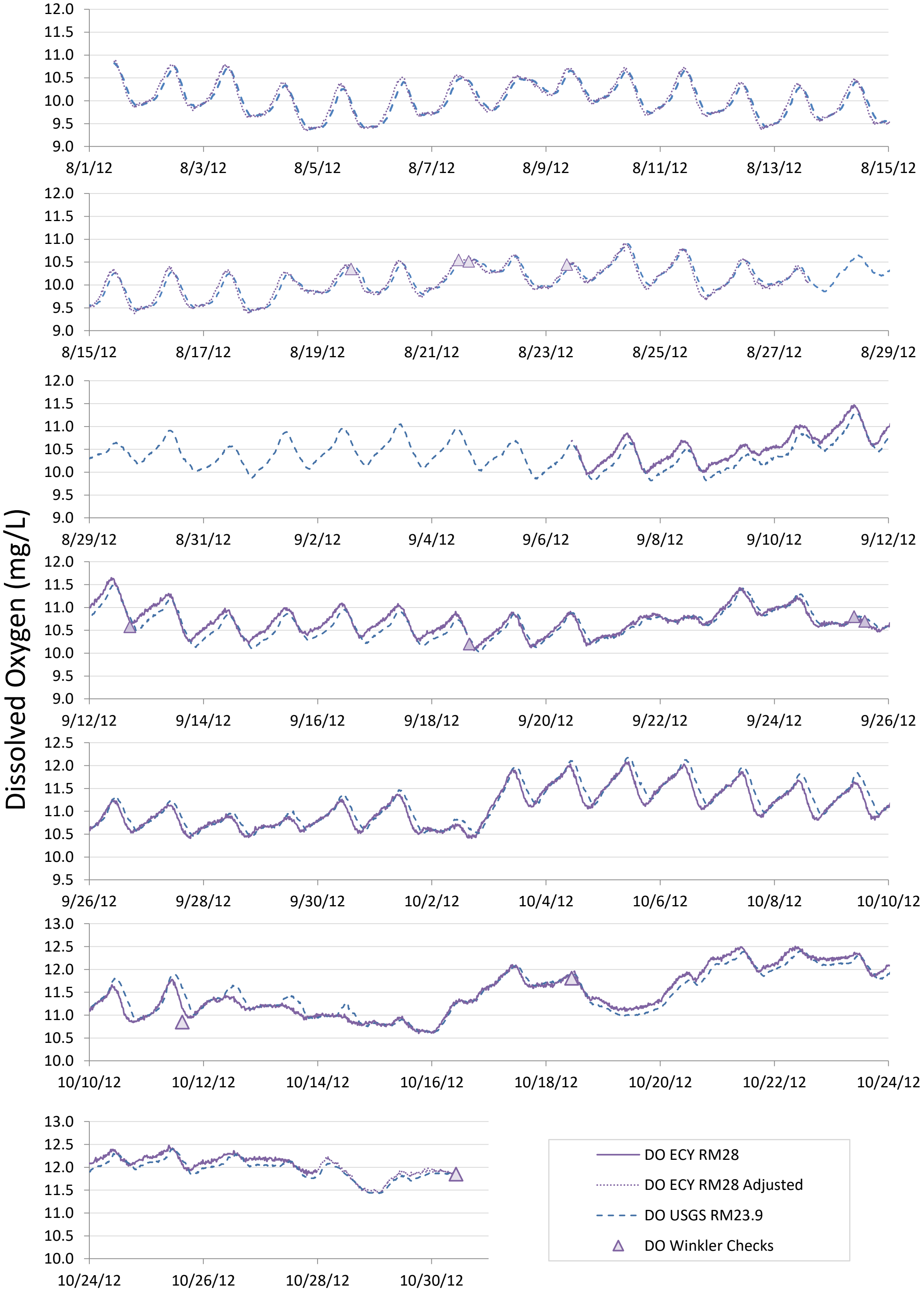

Figure G-45. Continuous dissolved oxygen data from August through October 2012 at RM 28.

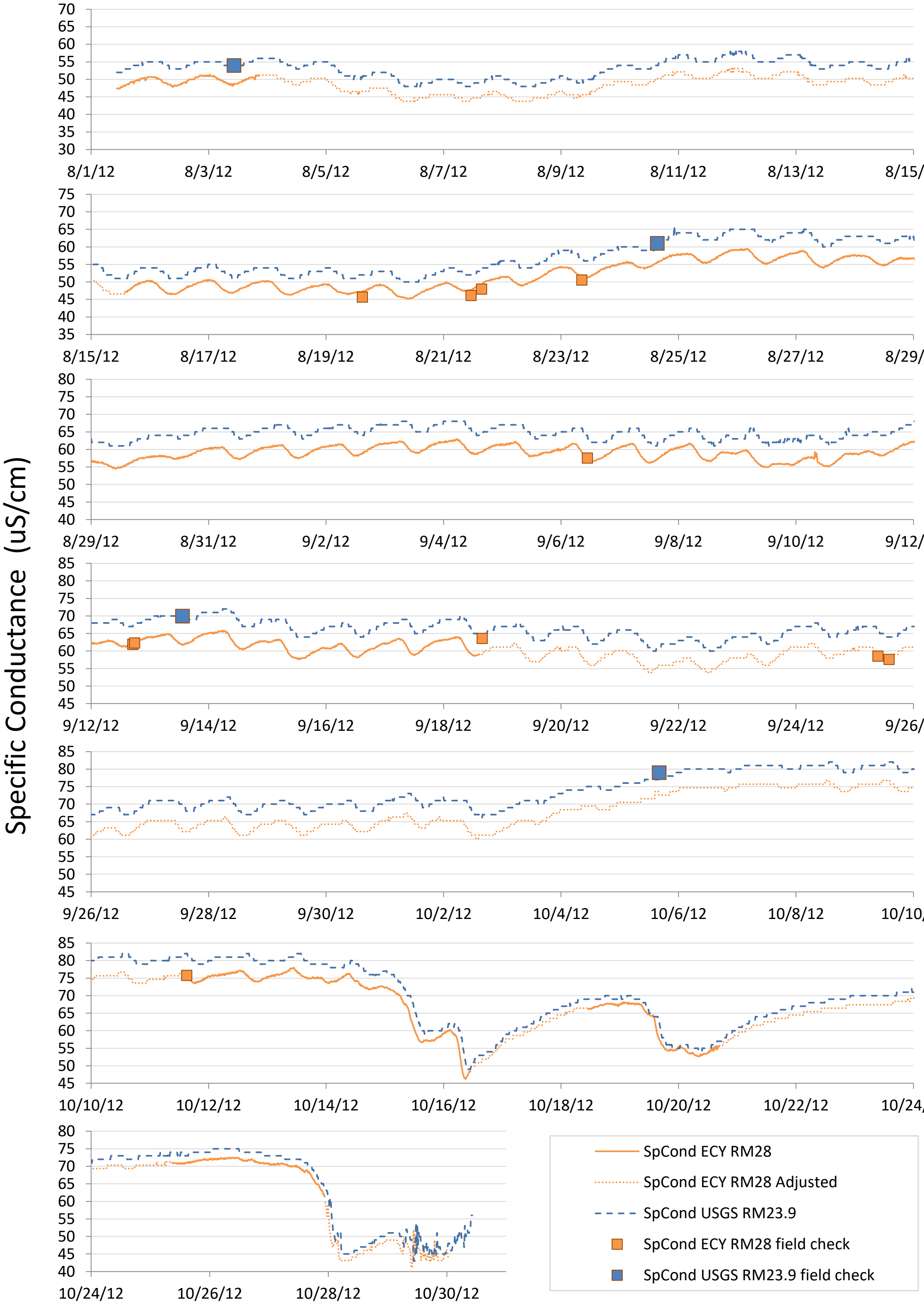

Figure G-46. Continuous specific conductance data from August through October 2012 at RM 28.

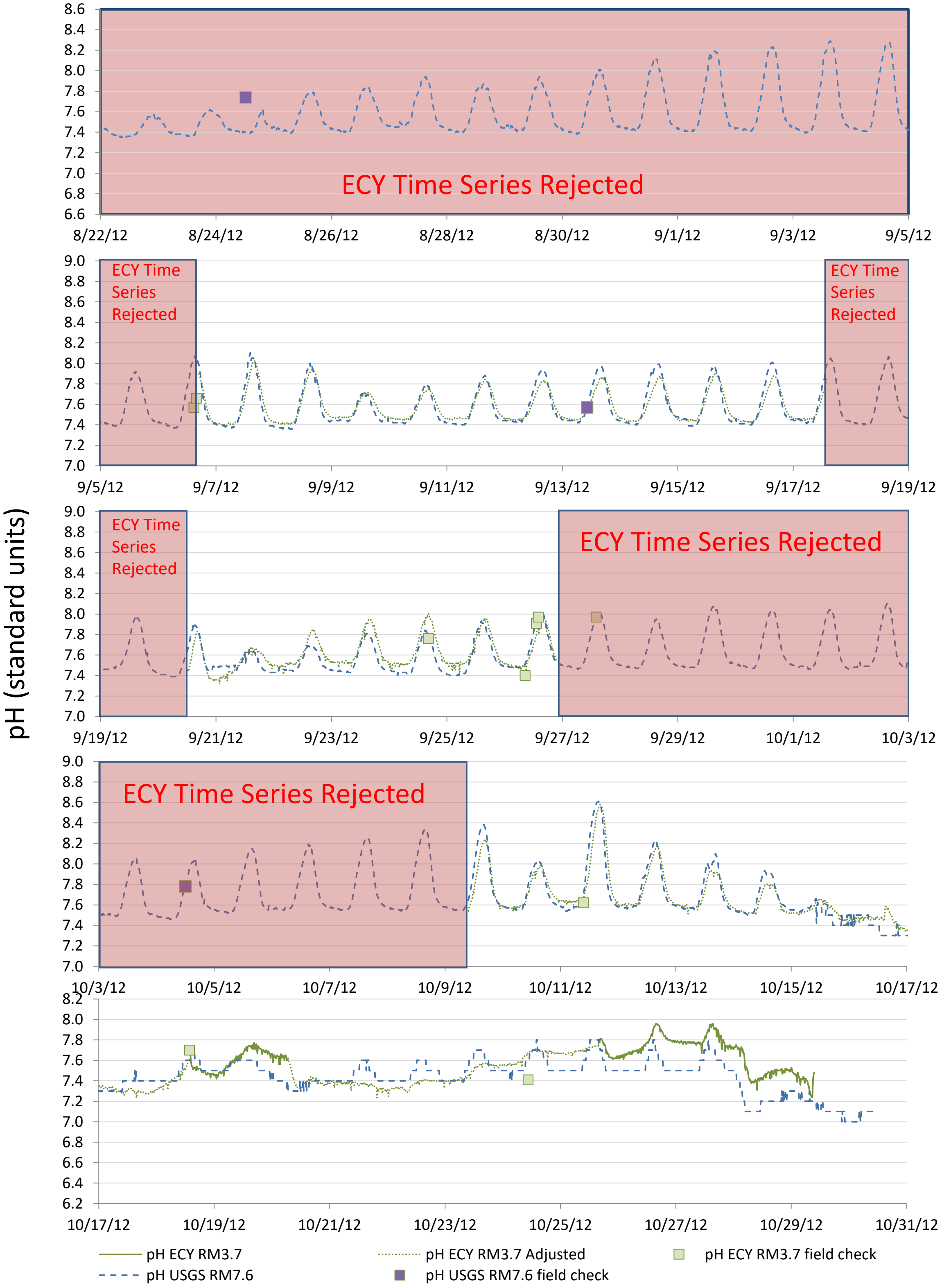

Figure G-47. Continuous pH data from August through October 2012 at RM 3.7.

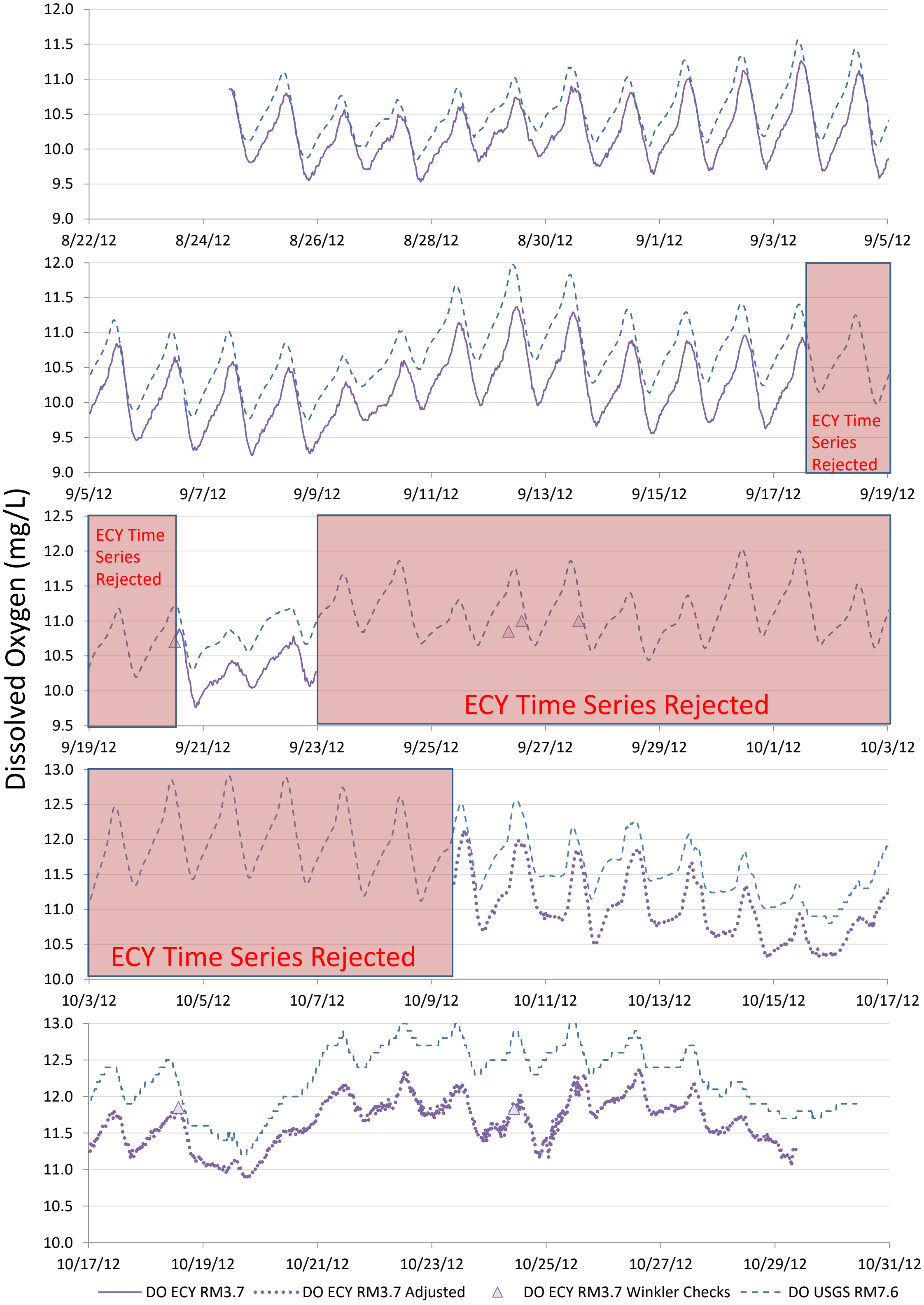

Figure G-48. Continuous dissolved oxygen data from August through October 2012 at RM 3.7.

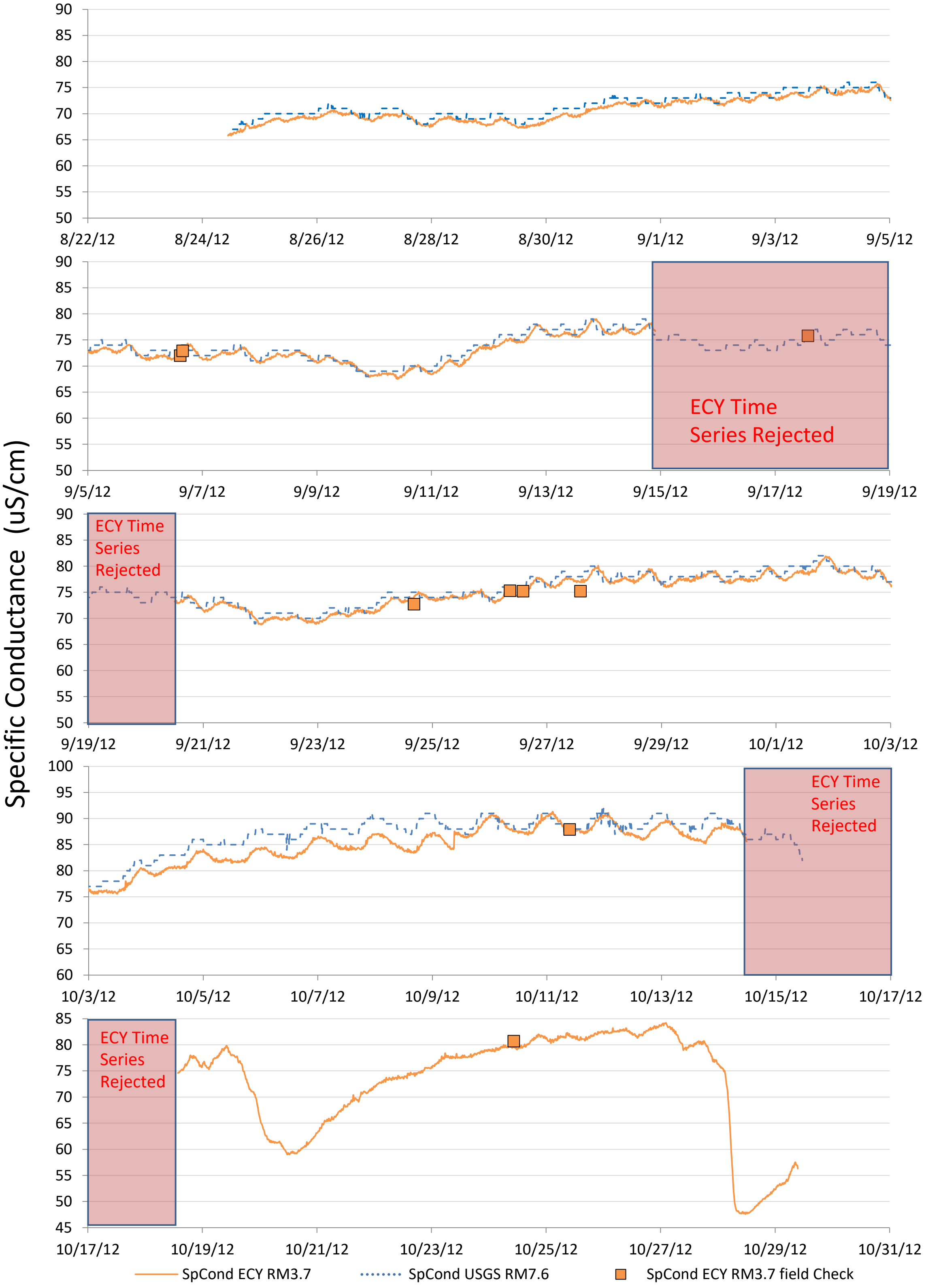

Figure G-49. Continuous specific conductance data from August through October 2012 at RM 3.7.

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Appendix H. Surface-water/groundwater interactions and near-stream groundwater quality in the Lower White River

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Introduction

Ecology conducted a groundwater assessment of the Lower White River mainstem during the summer and fall of 2012. This study was part of the larger Lower White River TMDL study also conducted at the same time. It was undertaken to gain a better understanding of groundwater's influence on area streamflows and surface water quality.

Groundwater was specifically targeted for evaluation since nutrient-rich discharges of groundwater can contribute to problematic instream aquatic plant growth and biomass production (Angier and McCarty, 2008; Dahm et al., 1998). Left unchecked, such growth can contribute to increased biological and chemical oxygen demand and ultimately to a reduction in the amount of oxygen available to support fish and other aquatic organisms.

The primary goals of this investigation were to:

1. Evaluate and quantify groundwater discharge volumes to the Lower White River mainstem during the modeling period (August through October 2012).
2. Characterize local and regional groundwater quality just prior to its discharge into area streams.
3. Use the results of groundwater discharge estimates and water quality samples to estimate continuous groundwater inputs to the QUAL2Kw model.

Numerous field techniques were employed to achieve these goals. In the summer of 2012, instream piezometers were installed at selected points along the river to monitor streambed thermal profiles and vertical hydraulic gradients between the river and near-surface groundwater. Synoptic streamflow and surface-water quality surveys were conducted in August, September, and October 2012 to develop seepage balances for the White River. During these surveys selected piezometers, two local springs, and two off-stream wells were also sampled to characterize groundwater quality. This appendix documents the results of these investigations. The TMDL report contains further description of how these results were applied, including in the Study Results (Appendix F), TMDL Analysis (Appendix E), and Model Documentation (Appendix I) sections.

Hydrogeologic setting

A recent USGS publication provides an excellent description of the hydrogeologic setting within the study area (Welch et al, 2015). This report uses the USGS nomenclature for confining and aquifer units (Table H-66; Figure H-50).

Table H-66. Hydrogeologic units and descriptions within the study area; adapted from Welch et al (2015).

Unit	Layer Type	Description	Aliases or sub-units
AL1	aquifer	alluvial silt, sand, and gravel deposits that closely follow Holocene river valleys	Qal; Qa; Hyporheic zone
MFL	confining	unsorted layer of pebble/cobbles/boulders mixed with clay/silt/sand originating from lahars most notably Osceola and Electron mudflows	Qvl(o); Qvl(e); Qme/Qmo; Qlh
AL2	aquifer	older Holocene alluvium and ancient deltaic deposits that accumulated along the estuarine margins of the ancestral Puyallup River and Duwamish River valleys during the early to middle Holocene time.	Qu(d); Ancient Auburn Delta
A1	aquifer	stratified silt, sand, and gravel deposited by large meltwater streams	Qvr; Qvrg; Vashon recessional outwash
A2	confining	various proportions of clay, silt, sand, and gravel	Qvt; Qgm; Vashon till
A3	aquifer	well-sorted sand or sand and gravel, with lenses of silt and clay	Qva; Qpfc; Vashon Advance Outwash
B	confining	fine-grained silts and clays deposited during the Olympia interglacial and glaciolacustrine clays deposited during early Vashon time.	Olympia beds–Qob; Lawton clay–Qvlc
C	aquifer	pre-Olympia glacial drift deposits; consists of sand and gravel, with minor lenses of silt, clay, and till	Qpf; Salmon Springs Drift
D	confining	alluvial and lacustrine sand, silt, and clay deposits, and occasional deposits of volcanic ash; no surficial exposure in Lower White River study area	Puyallup interglacial deposits
E	aquifer	silt, sand, and gravel, with discontinuous till and lacustrine deposits; no surficial exposure in Lower White River study area	Stuck Drift
F	confining	silt and clay, with minor lenses of sand and gravel; no surficial exposure in Lower White River study area	Alderton Formation deposits

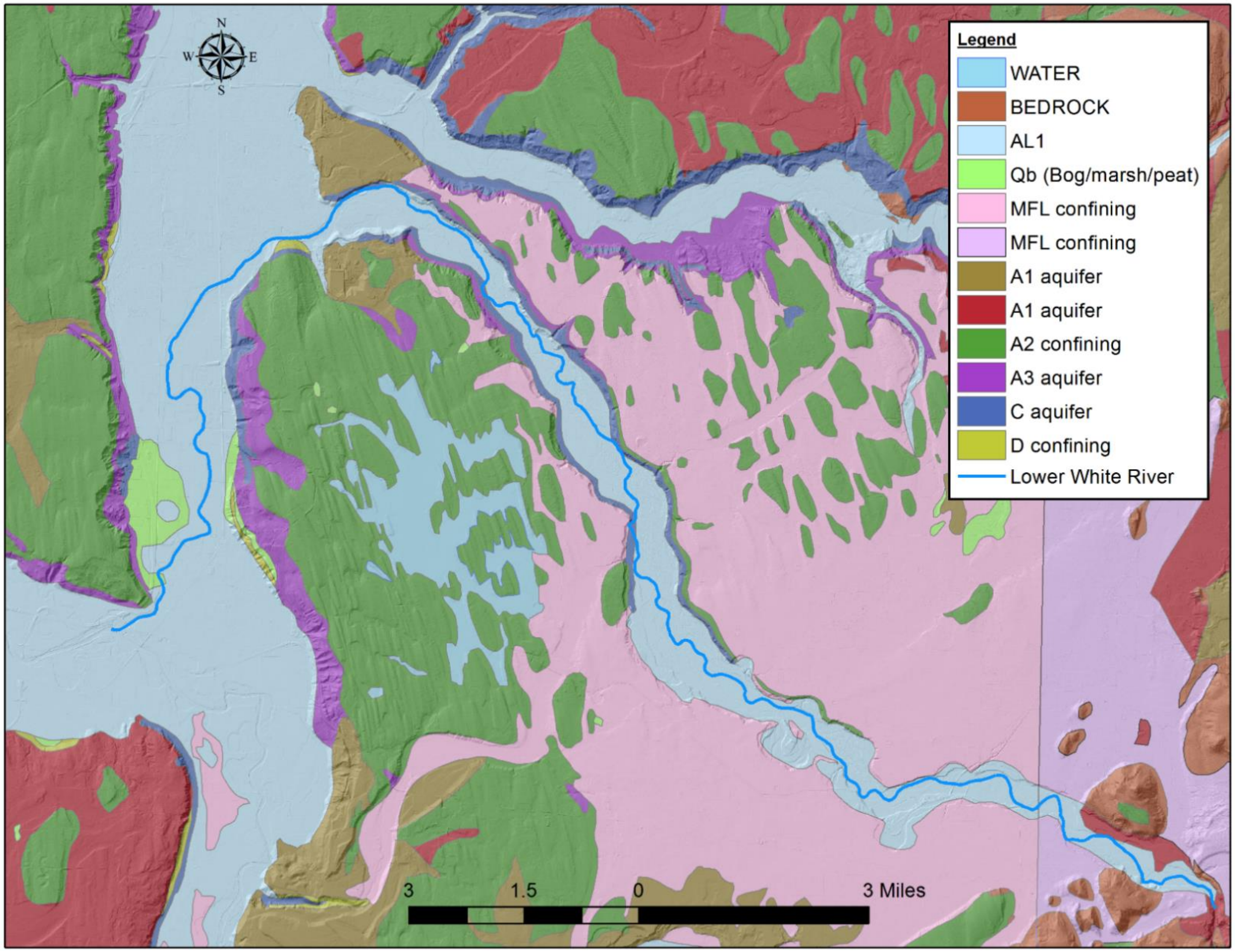

Figure H-50. Hydrogeologic setting of study area.

During the Fraser glaciation, approximately 15,000 years ago, the advance of the Cordilleran ice sheet from British Columbia reached its maximum extent into Puget Sound. The Puget ice lobe that formed Puget Sound had several smaller advances and retreats. The Fraser glaciation ended approximately 10,000 years ago.

With the retreat of the glaciers the Puyallup and White Valleys were initially formed as subglacial meltwater channels that eroded the glacial deposits. These deposits commonly known as Vashon recessional outwash, comprise the A1 aquifer which is present within the study area. There is surficial exposure of the A1 aquifer at points along the White River, particularly in the upper portion of the study area. At the time these deposits were formed, Puget Sound included the Puyallup and White River valley areas to Commencement Bay and north through Sumner and Auburn to Seattle. An area of higher elevation from Edgewood to West Seattle was an island in Puget Sound (Waldron, 1962; Luzier, 1969; Dragovich et al, 1994).

The arm of Puget Sound that covered Sumner and Auburn eventually filled with sediment transported by rivers and from lahars originating from Mt. Rainier. The lahars deposited layers of volcanic sediment interspersed with the alluvial deposits from the rivers. This process formed a series of layers that gradually filled this arm of the sound with semi-consolidated material consisting of clay, silt, sand, and gravel. This process continued for approximately 6,000 years when the largest recorded lahar from Mt. Rainier, the Osceola Mudflow, flowed through the White River valley.

The Osceola Mudflow began as a water-saturated avalanche or series of avalanches during possible eruptions or magma flow at the summit of Mt. Rainier. The mudflow filled valleys of the White River system to depths of 250 to 450 feet, flowed northward and westward more than 75 miles, covered more than 60,000 acres of the Puget Sound lowland, covered another 40,000 acres under the water of Puget Sound, and extended as much as 12 miles under water. The communities of Buckley, Enumclaw, Auburn, Sumner, and Puyallup are wholly or partly located upon Osceola Mudflow deposits (Dragovich et al, 1994).

The mudflow was composed of clay-rich gravel, cobbles, and boulders that were also deposited on the drift plains surrounding the Lower White River and the slopes of the river valley between present day Auburn and Mud Mountain Dam. The mudflow deposits created a poorly drained confining layer, referred to as the MFL layer, which limits downward movement of groundwater.

Tooley (1997) speculated that the MFL confining layer forced lateral movement of groundwater and nutrients to tributary streams, based on poor recharge rates measured by Dinicola (1990) within the mudflow deposits and observation of seeps along the White River bluffs.

The Lake Tapps Reservoir Uplands can provide baseflow to the White River depending on the reach and seasonal conditions (CWA, 2010; PGG, 1999). In general, groundwater flows radially outward from the reservoir/uplands through the two primary aquifer layers surrounding the reservoir: the A3 aquifer composed of Vashon Advance Outwash and the C aquifer primarily composed of glacial drift, locally referred to as Salmon Springs Drift.

Groundwater from these units can discharge to the White River, the Puyallup River, and several large springs within study area including Coal Creek Springs, West Hill Spring, Salmon Springs, Sumner Springs, Crystal/County Springs, and Elhi Springs. These springs are located near the base of the downslope for the Lake Tapps Uplands, along the north and west flanks of the plateau, and are used by the cities of Auburn, Sumner, and Puyallup for municipal water supply (CWA, 2010).

Piezometer Methods and Location

In July 2012, Ecology installed nine shallow instream piezometers along the White River between RM 26 and the mouth (Figure H-52) using methods described by Sinclair and Pitz (2009).

The piezometers consisted of an upper removable pipe section (or extension) and a lower five-foot section of 1.5-inch diameter galvanized pipe (Figure H-51). The piezometers were used to monitor surface water/groundwater head relationships, streambed water temperatures, and near-stream groundwater quality at discrete points along the river (see Figure H-30 and Table H-67 for site locations). Piezometers were manually installed into the streambed to a maximum depth of about five feet. Where possible, they were located in quiet water away from riffles, point bars, or other streambed features that might induce local-scale hyporheic exchanges.

The piezometers were developed after installation with a manual bladder-type bilge pump to ensure a good hydraulic connection with the streambed sediments. Piezometers were accessed monthly, when flows permitted, to make comparative river and groundwater hydraulic head measurements. The river stage (hydraulic head) was measured by aligning an engineer’s tape parallel to the piezometer pipe and measuring the distance from the river water surface to the top of the piezometer casing. The groundwater level inside the piezometer was measured from the same reference point, using a calibrated low-displacement E-tape or steel hand tape (Marti, 2009). For angled (off-vertical) piezometers these “raw” values were corrected using simple trigonometric relationships to obtain true (angle normalized) depth to water measurements.

The water level difference (represented by the inside and outside of pipe measurements) indicates the direction and magnitude of the local hydraulic potential between the river and underlying groundwater. When the piezometer head exceeds (is higher than) the river stage, groundwater flow into the river can be inferred. Similarly, when the river stage is higher than the groundwater level in the piezometer, loss of water from the river to groundwater can be inferred.

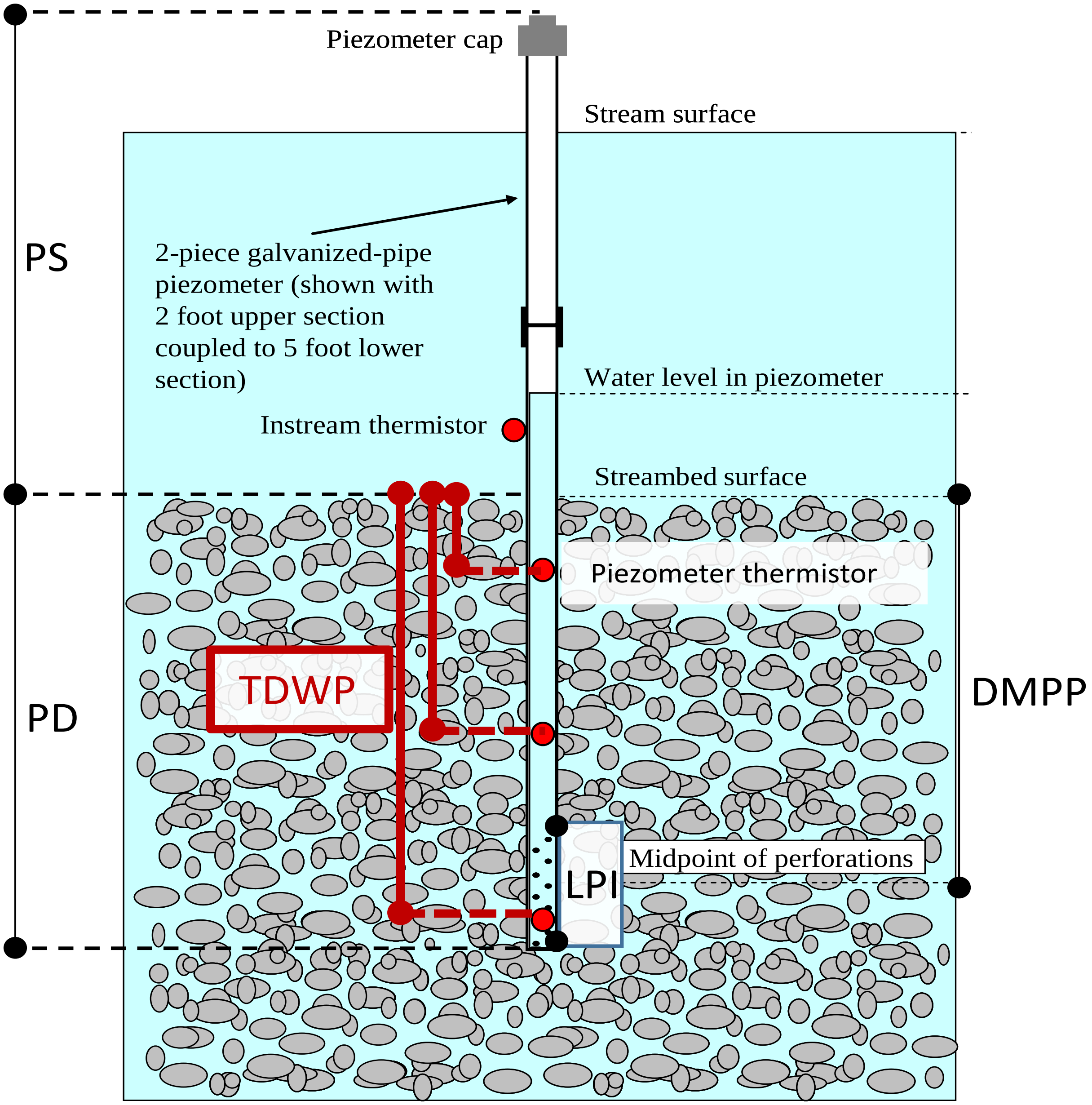

Figure H-51. Schematic of a typical instream piezometer and thermistor array.

PS = piezometer stickup above streambed; PD = piezometer depth below streambed; LPI = length of perforated interval; DMPP = depth (below streambed) to mid-point of piezometer perforations; TDWP = thermistor deployment depths (below streambed) within piezometer.

Table H-67 provides details of piezometer construction, location, and thermistor deployments.

Table H-67. Physical Description and Location of Instream Piezometers.

Map ID [1]	Well tag ID #	Location name	RM (mile)	Well location (TRS)	Latitude (decimal degrees)	Longitude (decimal degrees)	Site elevation (feet)	PS (feet)[1]	PD (feet)[1]	LPI (feet)	DMPP (feet)[1]	TDWP (feet)[1]
P1	AHT056	10-WHT-0.2	0.2	20N/04E-23 SE SE	47.2005187	-122.25374	47	2.5	4.37	0.5	4.19	1.09 2.42 3.96
P2	AHT057	10-WHT-1.4	1.4	20N/04E-49 NE NE	47.21292	-122.24205	36	2.34	4.46	0.3	4.30	-0.21 1.96 4.12
P3	AKY467	10-WHT-3.7	3.7	20N/04E-12 NE	47.23932	-122.23358	48	4.9	6.27	0.3	6.14	2.33 3.92 5.91
P4	AHT062	10-WHT-4.0	4	20N/04E-12 NE NE	47.24137	-122.23446	50	2.05	3.49	0.5	3.23	1.22 2.18 3.24
P5	AHT058	10-WHT-6.3	6.3	21N/05E-31 SW NW	47.26664	-122.22710	86	2.32	4.05	0.3	3.92	0.89 2.36 3.78
P6	AHT059	10-WHT-9.0	9	21N/05E-29 NE	47.28344	-122.19269	144	2.4	3.67	0.4	3.50	0.99 2.17 3.28
P7	AHT061	10-WHT-16.0	16	20N/05E-13 NE NW	47.22655	-122.11397	352	2.71	3.89	0.5	3.66	1.18 2.23 3.41
P8	AHT060	10-WHT-20.4	20.4	20N/06E-29 SW SE	47.18668	-122.06517	509	2.5	3.42	0.3	3.28	0.71 1.76 2.78
												1.06

Map ID [1]	Well tag ID #	Location name	RM (mile)	Well location (TRS)	Latitude (decimal degrees)	Longitude (decimal degrees)	Site elevation (feet)	PS (feet)[1]	PD (feet)[1]	LPI (feet)	DMPP (feet)[1]	TDWP (feet)[1]
P9	AHT063	10-WHT-25.5	25.5	19N/06E-01 SW NW	47.16579	-121.99319	702	3.25	3.26	0.5	3.01	1.98 2.90

PS = piezometer stickup above streambed; PD = piezometer depth below streambed; LPI = length of perforated interval; DMPP = depth (below streambed) to mid-point of piezometer perforations; TDWP = thermistor deployment depths (below streambed) within piezometer.

[1] PS, PD, DMPP, and TDWP are based on measurements made at the start of the project.

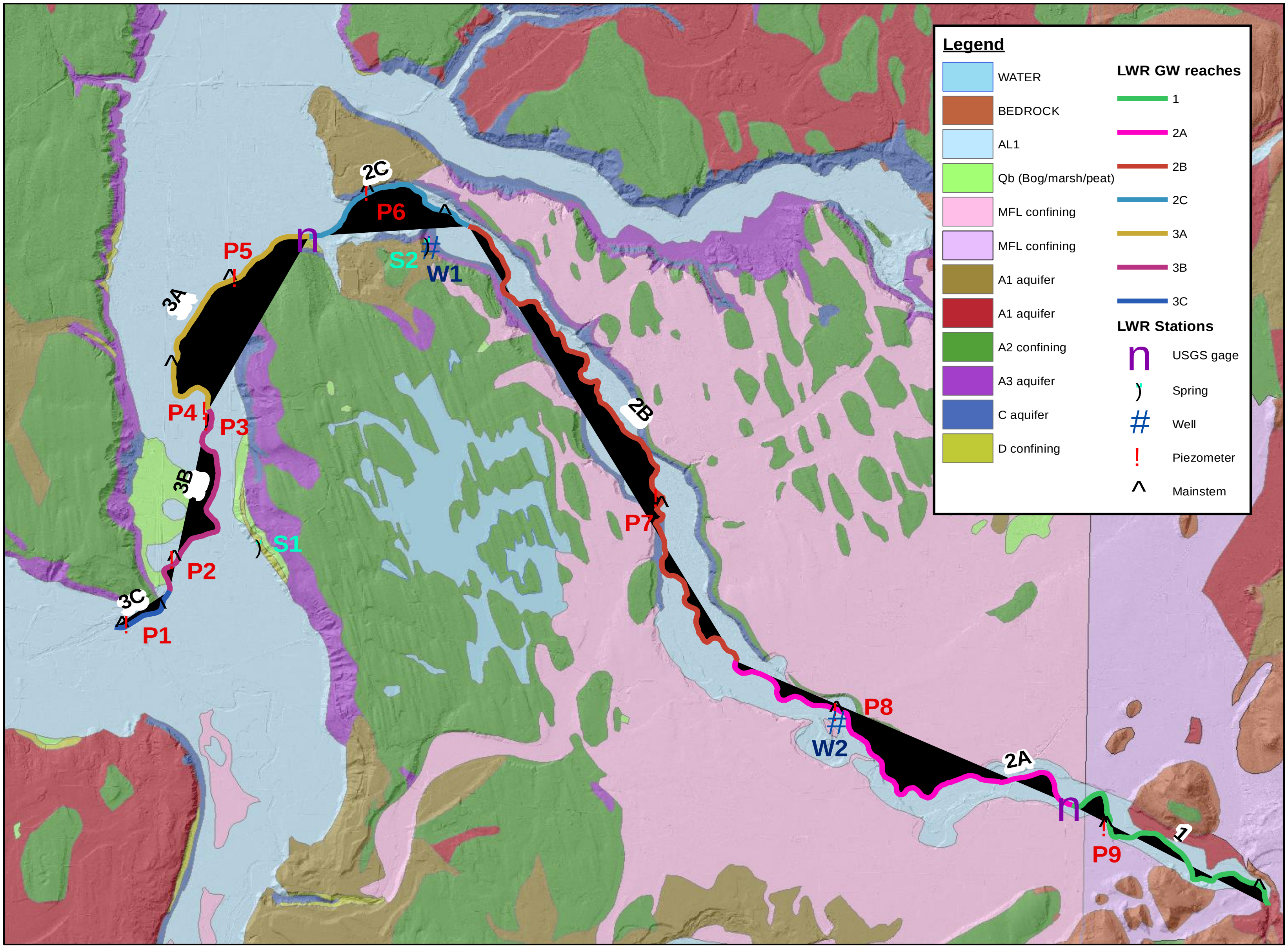

Figure H-52. Study area surficial geology and location of streamflow gages and instream piezometers.

Equation 1 was used to derive vertical hydraulic gradients for each piezometer, from the paired groundwater level and river stage measurements. Converting the field-measured water levels to hydraulic gradients normalizes for differences in piezometer depth and screen interval between sites, thereby enabling direct comparisons to be drawn between piezometers.

$$i_v = \frac{dh}{dl} \quad (1)$$

Where:

i_v is vertical hydraulic gradient (dimensionless),

dh is the difference in head between the river stage and instream piezometer water level (in units of “L”),

dl is the distance from the streambed surface to the mid-point of the piezometer perforations (in units of “L”),

where “L” represents a unit of length that is consistent for both *dh* and *dl*.

By convention, negative hydraulic gradient values indicate potential loss of water from the river to groundwater, while positive values indicate potential groundwater discharge into the river.

Thermal profiling of streambed sediments

Streams and rivers commonly experience pronounced (several degree) daily fluctuations in water temperature due to variations in atmospheric and solar heating over the course of a day. In contrast, groundwater generally shows little if any diurnal temperature variability since it is typically insulated from the sun and atmosphere by overlying rock or sediment. These differences in daily temperature pattern, between a river and near-surface groundwater, can be monitored to provide secondary confirmation of the surface water/groundwater interactions inferred from periodic hydraulic gradient measurements.

For this project we instrumented each instream piezometer with three recording thermistors to monitor groundwater temperatures within the upper 3 to 6 feet of the streambed sediments. One thermistor was located near the piezometer bottom within the perforated interval of the pipe, one approximately 0.5 to 1 ft below the streambed, and one roughly equidistant between the upper and lower thermistors. A fourth thermistor was mounted to the outside of the piezometer to monitor the stream temperature (Figure H-51) (Mathieu and Pelletier, 2012).

At piezometer sites where streambed water temperatures are highly dampened, relative to instream temperatures, one can infer that groundwater is moving upward through the streambed and discharging to the river (a gaining river reach) (Figure H-53). Conversely, at sites where streambed water temperatures closely mimic those of the river, one can infer that water is leaving the river and moving down into the streambed at that location (a connected losing reach) (Stonestrom and Constantz, 2003) (Figure H-53).

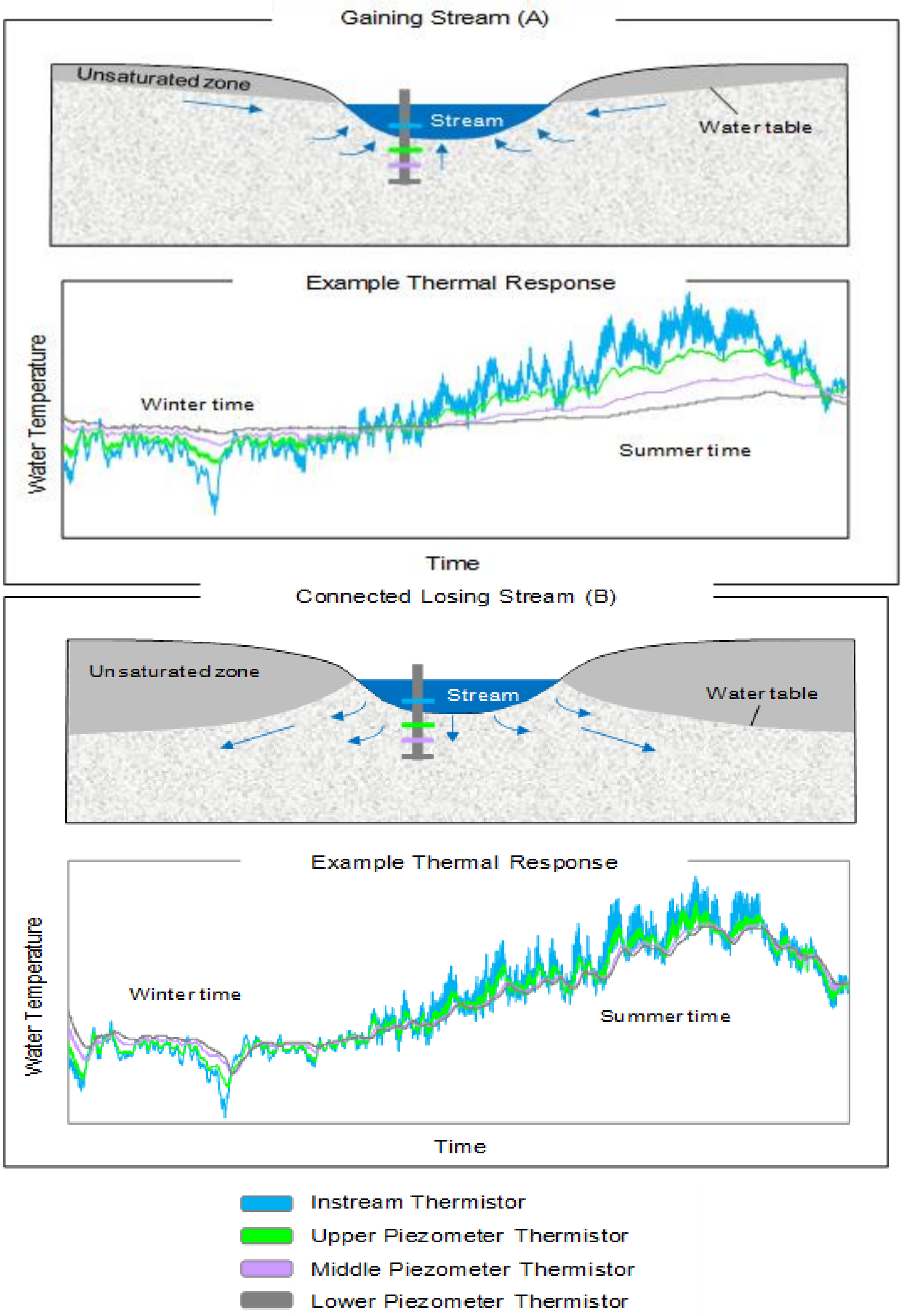

Figure H-53. Example streambed thermal response for a perennial gaining (A) and losing (B) stream.

Sample and measurement methods

To assess the concentration of phosphorous and nitrogen-based nutrients that groundwater potentially contributes to local streams we sampled 5 instream piezometers, where groundwater discharge was indicated. Ecology also sampled two off-stream wells and two springs in the study area (Table H-68). Water samples were collected during the July and August 2011 synoptic surveys and were evaluated for field parameters and a small suite of laboratory-analyzed constituents (Table H-69) (Mathieu and Pelletier, 2012).

Table H-68. Physical Description and Location of off-stream wells and springs.

Map ID [1]	Well tag ID #	Location name	RM (mile)	Well location (TRS)	Latitude (decimal degrees)	Longitude (decimal degrees)	Site elevation (feet)
S1	n/a	Sumner Springs	0.2	20N/04E-23 SE SE	47.20052	-122.25374	47
S2	n/a	Coal Creek Springs	1.4	20N/04E-49 NE NE	47.21292	-122.24205	36
W1		Well at Coal Creek Springs	3.7	20N/04E-12 NE	47.23932	-122.23358	48
W2		Well at private residence	4	20N/04E-12 NE NE	47.24137	-122.23446	50

Table H-69. Target analytes, test methods, and method detection limits.

Parameter	Test method	Reporting limit
Field Measurements		
Water level	Calibrated E-tape	0.1 foot
Temperature	Alcohol Thermometer	0.1°C
Specific Conductance	Hydrolab MS-5	1 µS/cm
pH	Hydrolab MS-5	0.1 SU
Dissolved Oxygen	Hydrolab MS-5	0.1 mg/L
Laboratory Parameters		
Alkalinity[1]	SM2320B	5 mg/L
Chloride[1]	EPA300.0	0.1 mg/L
Orthophosphate[1]	SM4500PG	0.003 mg/L
Total phosphorus[1]	SM4500PF	0.001 mg/L
Nitrate+nitrite-N[1]	SM4500NO3I	0.01 mg/L
Ammonia[1]	SM4500NH3H	0.01 mg/L
Total persulfate nitrogen-N[1]	SM4500NB	0.025 mg/L
Dissolved organic carbon[1]	SM5310B	1 mg/L
Iron[1]	EPA200.7	0.05 mg/L

[1] Dissolved fraction

MF: Membrane filter method; SU: Standard units

All sites were sampled using a length of new ¼ inch high density polyethylene (HDPE) tubing. When sampling a piezometer, the installed thermistor string was first removed and set aside. One end of the HDPE tubing was then inserted into the piezometer until it abutted the casing perforations. The other end of the tubing was then connected to a peristaltic pump via a short length of clean silastic tubing. The pump discharge was routed through a closed-atmosphere flow cell connected to a Hydrolab® model MS-5 multimeter to enable field parameters to be evaluated. Piezometers were purged at a maximum rate of 0.25 to 0.5 L/min. Where possible, purging continued until the difference in measured field parameter values for 2 successive 3-minute measurement periods differed by less than 5 percent. Equivalent methods were used to sample the springs and off-stream wells.

At the completion of purging, laboratory bound samples were collected by disconnecting the pump discharge line from the flow cell. All analytes (with the exception of chloride and alkalinity) were filtered in the field using a 0.45 micron in-line-capsule filter.

Samples for DOC, nitrate+nitrite-N, total persulfate nitrogen (TPN), ammonia, and dissolved total phosphorus (DTP) were collected in pre-acidified bottles containing sulfuric acid. Samples for iron analysis were collected in bottles pre-acidified with nitric acid. Filled sample bottles were tagged and stored on ice pending their arrival at the laboratory.

Quality assurance results

Field meter calibration

Water quality field meters were calibrated in accordance with the manufacturer's instructions at the start of each sampling day (Swanson, 2007). Fresh commercially prepared buffer solutions and reference standards were used for all pH and specific conductance calibrations respectively. The dissolved oxygen sensor was calibrated against theoretical water-saturated air using the manufacturer-supplied calibration chamber. The initial pH and specific conductance calibrations were checked by placing the probes in pH buffer solutions and reference standards, respectively, and evaluating the difference between the standard and the meter values (Table H-70). The pH calibration was accepted if the metered values differed by less than ± 0.05 pH units from the buffer value. The specific conductance calibration was accepted if the meter values deviated by no more than ± 5% from the specific conductance check standards.

Following each sampling event, the meters were rechecked against reference standards to confirm they had not drifted unacceptably since the initial calibration. Using the post-use acceptance criteria listed in Table H-70 the results were either accepted, qualified as estimates, or rejected as unusable.

Based on this evaluation, the specific conductance results for the August 2012 sampling event were rejected due to an exceedance of both pre- and post-use calibration criterion. The remaining field results were acceptable and are reported here without further qualification.

Table H-70. Field meter calibration records for the 2012 synoptic groundwater quality survey.

		pH				Specific conductance				Dissolved oxygen		
Date	**Status**	**Buffer (pH)**	**Meter reading (pH)**	**Diff. from buffer (s.u.)**	**Accept or reject[a]**	**Buffer (µS/cm)**	**Meter reading (µS/cm)**	**Diff. from buffer (%)**	**Accept or reject[1]**	**Meter reading (mg/L**	**Saturation (percent)**	**Accept or reject[b]**
8/20/12	Pre-use	4	4.01	0.01	Accept	99	99.1	0%	**Reject**	8.6	100	Accept
		7.01	7.04	0.03		1413	943.8	-33%				
8/23/12	Post-use	4	4.1	0.1	Accept	99	66.8	-33%	**Reject**	8.77	102.2	Accept
		7.01	7.11	0.1		1413	933.7	-34%				
10/22/12	Pre-use	4.01	4.07	0.06	Accept	99			Accept	8.6	99.8	Accept
		7.01	7.07	0.06		1412	1413	0%				
10/25/12	Post-use	4.01	4.03	0.02	Accept	99	103.8	5%	Accept	8.85	102.9	Accept
		7.01	7.02	0.01		1412	1411	0%				

[a] Calibration acceptance criteria by parameter

pH
≤ ± 0.05 pH[1] = accept calibration
> ± 0.05 pH[2] = reject calibration

Specific conductance
≤ ±5%[1] = accept calibration
> ±5%[2] = reject calibration

Dissolved Oxygen (saturation percent)
≥ 99.7 and ≤ 100.3 = accept calibration
< 99.6 or > 100.4 = reject calibration

[b] Post-use acceptance criteria - deviations from check standards

pH
≤ ±0.15 pH[1] = accept results
> ±0.15 and ≤ ±0.5 pH[2] = qualify results as estimates ("J" code)
> ±0.5 pH[2] = reject results

Specific conductance
≤ ±5%[1] = accept results
> ±5% and ≤ ±10%[2] = qualify results as estimates ("J" code)
> ±10%[2] deviation from any standard = reject results

Dissolved oxygen (saturation percent)
≥ 99.5 and ≤ 100.5 = accept calibration
< 99.4 or > 100.6 = qualify results as estimates ("J" code)

[1] deviation from all standards; [2] deviation from any standards

All wells and piezometers were sampled using properly calibrated field meters, dedicated sample tubing, and new in-line-cartridge or syringe filters, where appropriate. Samples were collected in clean bottles supplied by MEL. Pre-acidified bottles were used for preserved samples. Filled sample bottles were labeled, bagged, and then stored in clean, ice-filled coolers pending their arrival at the laboratory. Sample chain-of-custody procedures were followed throughout the project.

Laboratory quality assurance

MEL follows strict protocols to both ensure and later evaluate the quality of their analytical results (WA State Department of Ecology, 2008). Where appropriate, instrument calibration was performed by laboratory staff before each analytical run and checked against initial verification standards and blanks. Calibration standards and blanks were analyzed at a frequency of approximately 10 percent during each analytical run and then again at the end of each run. The laboratory also evaluates procedural blanks, spiked samples, and laboratory control samples as additional checks of data quality. The results of these analyses were summarized in a case narrative and submitted to the Ecology project manager along with each analytical data package.

Table H-71. Field parameter and laboratory analysis measurement quality objectives.

Parameter	Check standards (% recovery limits)	Field duplicate sample (%RSD)	Matrix spikes (% recovery limits)	Matrix spike duplicates (RPD)
Field Parameters				
pH	± 0.2 SU	± 0.1 SU	NA	NA
Specific conductance	± 10 µS/cm	± 10 %	NA	NA
Temperature	± 0.1 C	± 5 %	NA	NA
Dissolved oxygen	± 0.2 mg/L	NA	NA	NA
Laboratory Analyses				
Alkalinity	80-120 %	± 10 %	75-125 %	± 10 %
Chloride	90-110 %	± 5 %	75-125 %	± 5 %
Orthophosphate	80-120 %	± 10 %	75-125 %	± 10 %
Total phosphorus	85-115 %	± 10 %	75-125 %	± 10 %
Nitrate+Nitrite-N	80-120 %	± 10 %	75-125 %	± 10 %
Ammonia	80-120 %	± 10 %	75-125 %	± 10 %
TPN-N	80-120 %	± 10 %	75-125 %	± 10 %
Dissolved organic carbon	80-120 %	± 10 %	75-125 %	± 10 %
Iron	85-115%	± 10 %	75-125 %	± 10 %

The laboratory's quality assurance narratives and supporting data for this project indicate that all samples arrived at the laboratory in good condition. Except as discussed below, all samples were processed and analyzed within accepted EPA holding times. Constituent concentrations for laboratory blank samples consistently fell below the analytical detection limit for target analytes. In addition, matrix spike samples, laboratory replicate samples, and laboratory control sample analyses all met applicable acceptance criteria (Table H71). Data quality exceptions included:

- Total phosphorus – Three samples were qualified as estimates ("J" code) due to a contaminated lab method blank. One field blank had a very small concentration of phosphorus in the result (5 ug/L).
- Total persulfate nitrogen – One laboratory duplicate sample had a slightly high RSD of 13.56%, which met the laboratory quality objective for individual duplicates (20%) but exceeded the measurement quality objective for field replicates (10%). One sample was "J" qualified because the lab exceeded the holding time.
- Nitrate-Nitrite - One sample was "J" qualified because the lab exceeded the holding time.

Table H-72. Field and laboratory QC sample results for the 2012 study.

Sample date	Metric	ALK (mg/L)	Cl (mg/L)	Dissolved						
				DOC (mg/L)	OP (ug/L)	TP (ug/L)	NO3 + NO2-N (ug/L)	NH4 (ug/L)	TPN-N (ug/L)	Iron (mg/L)
Field Duplicate Samples and Filter Blanks										
Aug 21-22, 2012	Sample	133	16.4	2.6	14.6	39.1	10 U	315	327	5.71
	Rep/Dupe	134	16.6	2.5	13.3	42	10 U	313	323	5.79
	%RSD	0.53	0.86	2.77	6.59	5.06	0.00	0.45	0.87	0.98
	Blank	5 U	0.10 U	1 U	3 U	5 U	10 U	10 U	25 U	0.05 U
Oct. 23-24, 2012	Sample	24.8	1.79	1 U	12.2	11	11	10 U	108	0.05 U
	Rep/Dupe	24.7	1.77	1 U	11.8	10.6	11.1	10 U	114	0.05 U
	%RSD	0.29	0.79	0.00	2.36	2.62	0.64	0.00	3.82	0.00
	Blank	5 U	0.10 U	1 U	3 U	5 U	10 U	10 U	25 U	0.05 U
Mean % RSD		0.41	0.83	1.39	4.47	3.84	0.32	0.23	2.35	0.49
Laboratory Replicates and Blanks										
Aug 21-22, 2012	Sample	120	7.23	5.02	14 J	44	10 U	10 U	25 U	10
	Rep/Dupe	118	7.25	4.89	14.6	42 J	10 U	11	25 U	10.1
	%RSD	1.19	0.20	1.86	2.97	3.29	-	6.73	-	0.70
	Blank	5 U	0.10 U	1 U	3 U	**5**	10 U	10 U	25 U	0.05U
Oct. 23-24, 2012	Sample	113	13.4	4.9	5.1	10	0.09	10 U	1000	9.81
	Rep/Dupe	113	13.5	4.97	4.9	10.6	0.093	10 U	825	9.62
	%RSD	0.00	0.53	1.00	2.83	4.12	2.32	-	**13.56**	1.38
	Blank	5 U	0.10 U	1 U	3 U	5 U	10 U	10 U	25 U	0.05U

U -analyte not detected at or above the reported value.
J -analyte positively identified, the numeric result is an estimate.
Bold values indicate an exceedance of the project quality assurance criteria.

Field quality assurance

To assess sampling bias and overall analytical precision, field equipment blanks and replicate samples were collected and submitted "blind"[14] to the laboratory during each sample event. Equipment blanks were prepared using laboratory grade de-ionized water and were handled and filtered in the same manner as other samples. Precision for each of the field replicate and laboratory duplicate analyses was quantified by evaluating the percent relative standard deviation[15] (%RSD) for each duplicate sample pair. The resulting values were then tabulated and compared to the project data quality objectives (Table H-72).

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[14] The term "blind" refers to "identical" samples that were submitted to the laboratory under different sample numbers, in order to maintain sample anonymity during laboratory analysis.

[15] Calculated for a pair of results, x_1 and x_2, as 100 * (S/Average of x_1 and x_2) where S is the standard deviation of the sample pair.

Field data

Most of the field and laboratory data (Table H-73) presented in this report are available in digital format from Ecology's Environmental Information Management (EIM) database. Readers can use the EIM Search (wa.gov)[16] webpage to access the data.

The data for this study are archived in EIM under the following study name and user study ID:

- EIM study name: Lower White River pH TMDL
- EIM user study ID: GPEL0010

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[16] https://apps.ecology.wa.gov/eim/search/default.aspx

Table H-73. Field measurement and laboratory sample results from the 2012 study.

Location ID	Well Tag ID Number	Sample Date	Groundwater Field Parameters[a]					Laboratory Analyses[bc]								
			VHG[d] (Ft)	WT[e] (deg C)	pH (s.u.)	Cond (uS/cm)	DO (mg/L)	ALK (mg/L)	CL (mg/L)	OP (ug/L)	TP (ug/L)	NO2-N03 (ug/L)	NH3 (ug/L)	TPN (ug/L)	DOC (mg/L)	Iron (mg/L)
10-WHT-0.2	AHT056	07/17/2012	0.062	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/22/2012	0.050	12.83	6.06	-	0.37	133	16.4	14.6	39.1	10 U	315	327	2.6	5.71
		09/17/2012	0.047	-	-	-	-	-	-	-	-	-	-	-	-	-
		10/24/2012	0.049	12.51	6.35	301.6	0.42	123	13.4	11.8	38.7	10 U	274	289	2.2	5.02
		11/16/2012	0.055	-	-	-	-	-	-	-	-	-	-	-	-	-
10-WHT-1.4	AHT057	07/17/2012	-0.016	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/22/2012	-0.111	-	-	-	-	-	-	-	-	-	-	-	-	-
		09/17/2012	0.054	-	-	-	-	-	-	-	-	-	-	-	-	-
		10/24/2012	-0.092	-	-	-	-	-	-	-	-	-	-	-	-	-
10-WHT-3.7	AKY467	07/19/2012	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/22/2012	0.003	14.08	6.82	-	8.42	117	1.81	30.8	247	40	416	356	2.9	6.04
		09/17/2012	-0.002	-	-	-	-	-	-	-	-	-	-	-	-	-

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[a] Low producing wells were pre-purged dry the day before sampling. The field parameters for these wells are reported as estimates (J-coded) since they may not be indicative of true in situ groundwater conditions

[b] Data qualifier codes: U = analyte was not detected at or above the reported value; J = the analyte was positively identified, the reported numeric result is an estimate

[c] All laboratory analysis parameters were field filtered and represent the dissolved sample fraction.

[d] VHG = Vertical hydraulic gradient

[e] WT = Water temperature

			Groundwater Field Parameters[a]					Laboratory Analyses[bc]								
Location ID	Well Tag ID Number	Sample Date	VHG[d] (Ft)	WT[e] (deg C)	pH (s.u.)	Cond (uS/cm)	DO (mg/L)	ALK (mg/L)	CL (mg/L)	OP (ug/L)	TP (ug/L)	NO2-N03 (ug/L)	NH3 (ug/L)	TPN (ug/L)	DOC (mg/L)	Iron (mg/L)
		10/24/2012	0.002	10.26	6.99	239.3	1.76	285	2.39	427	1280	18	3850	3840	11.8	21.9
		11/16/2012	0.003	-	-	-	-	-	-	-	-	-	-	-	-	-
10-WHT-4.0	AHT062	07/18/2012	-0.030	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/22/2012	-0.010	-	-	-	-	-	-	-	-	-	-	-	-	-
		09/17/2012	-0.012	-	-	-	-	-	-	-	-	-	-	-	-	-
		10/23/2012	-0.010	-	-	-	-	-	-	-	-	-	-	-	-	-
10-WHT-6.3	AHT058	07/17/2012	0.018	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/21/2012	-0.012	-	-	-	-	-	-	-	-	-	-	-	-	-
		09/17/2012	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		10/24/2012	-0.013	-	-	-	-	-	-	-	-	-	-	-	-	-
10-WHT-9.0	AHT059	07/17/2012	0.011	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/21/2012	-0.011	-	-	-	-	-	-	-	-	-	-	-	-	-
		09/17/2012	-0.336	-	-	-	-	-	-	-	-	-	-	-	-	-
		10/23/2012	-0.032	-	-	-	-	-	-	-	-	-	-	-	-	-
10-WHT-16.0	AHT061	07/18/2012	0.013	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/21/2012	0.016	13.29	6.17	-	2.53	25.6	1.58	9.9	11	82	10 U	78	1	0.025
		09/18/2012	0.013	-	-	-	-	-	-	-	-	-	-	-	-	-
		10/24/2012	0.016	11.54	6.68	100.2	3.21	33.3	2.41	10.1	7.7	105	10 U	119	1 U	0.025
10-WHT-20.4	AHT060	07/18/2012	0.008	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/21/2012	0.011	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/22/2012	0.013	11.25	7.03	-	0.77	104	6.55	19.1	19.8	24	10 U	48	1 U	0.025
		09/18/2012	0.011	-	-	-	-	-	-	-	-	-	-	-	-	-

Location ID	Well Tag ID Number	Sample Date	Groundwater Field Parameters[a]					Laboratory Analyses[bc]								
			VHG[d] (Ft)	WT[e] (deg C)	pH (s.u.)	Cond (uS/cm)	DO (mg/L)	ALK (mg/L)	CL (mg/L)	OP (ug/L)	TP (ug/L)	NO2-N03 (ug/L)	NH3 (ug/L)	TPN (ug/L)	DOC (mg/L)	Iron (mg/L)
		10/23/2012	0.013	9.94	7.34	266.5	0.75	95.9	6.2	17.3	19.7	32	10 U	47	1 U	0.025
10-WHT-25.5	AHT063	07/19/2012	0.000	-	-	-	-	-	-	-	-	-	-	-	-	-
		08/21/2012	0.008	13.57	6.12	-	0.28	13.6	1.35	3.6	5 U	67	10 U	73 J	1 U	0.445
		09/18/2012	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-
		10/23/2012	0.008	10.11	6.28	105	0.45	13.6	1.79	3 U	5 U	63	10 U	61	1 U	0.583
Well at Coal Ck springs	ACQ739	08/22/2012	-	11.76	6.28	-	5.79	52.9	3.7	10.9	19.2 J	947	10 U	1000	1 U	0.441
		10/23/2012	-	10.99	6.32	127.5	5.78	49.9	3.69	11.7	10.8	1050 J	10 U	1070	1 U	0.124
Coal Ck springs		08/22/2012	-	10.76	6.43	-	7.77	56.4	3.71	17.8	18.8 J	1050	10 U	1120	1 U	0.025
		10/23/2012	-	10.01	6.56	135.3	7.44	54.6	3.59	15.6	15.3	1140	10 U	1150	1 U	0.025
Sumner springs		08/22/2012	-	10.34	6.79	-	9.34	113	5.44	18.7	23.1 J	2210	10 U	2290	1 U	0.025
		10/24/2012	-	9.99	7.08	249.8	9.11	108	5.4	21.2	18.1	2220	10 U	2200	1 U	0.025
Private well near Buckley		10/24/2012	-	11.22	6.52	81.9	1.85	24.8	1.79	12.2	11	110	10 U	108	1 U	0.025

Surface-water/groundwater interactions

The general characterization of gaining and losing stream reaches presented here is a highly simplified view of the complex physical processes that control surface-water and groundwater interactions along a stream. These interactions are highly variable, both spatially and temporally, due to the interplay of local, intermediate, and regional scale exchange processes (Stonestrom and Constantz, 2003). There is currently no single field technique or analysis method that adequately characterizes these subtleties.

Accordingly, for this study we used three common field methods to characterize surface-water/groundwater interactions along the White River. Streamflow seepage assessments (synoptic surveys) were conducted on August 21-22 and September 25-26, 2012, to quantify net streamflow gains and losses along the river. The seepage surveys were supplemented with periodic measurements of streambed vertical hydraulic gradient and continuous monitoring of streambed thermal profiles at a small network of instream piezometers installed along the river. These latter measurements provide further insights into both the timing and direction of water exchanges at discrete points along the river.

The collective results of these evaluations are presented below. For the purposes of this discussion, we've subdivided the White River into three reaches based on the locations of continuous streamflow gages, and further divided reaches 2 and 3 into sub-reaches based on piezometer locations and surficial hydrogeology.

Reach 1: RM 28 (boundary) to RM 23.9 (USGS gage)

The 8/22/12 flow balance indicates ~5 cfs streamflow loss across this reach; however, streamflow was not steady during this survey, with ~20% variability at the RM23.9 gage. The 9/26/12 flow balance indicates ~47 cfs gain. Flows were more stable during this survey, with less than 10% variability at the RM23.9 gage.

In order to develop a continuous flow balance for the entire modeling period Ecology used input flow from the USGS at RM 33 (station 12097850). A 5-day running average of the residual flow balance was calculated using daily flow values for the upstream and downstream USGS stations and inputs measured during the September synoptic. This average daily residual balance assumes negligible input between RM 33 and RM 28. On 9/26/12 flow at USGS gage at RM 33 was 501 cfs and measured Ecology flow at RM 28 was 497 cfs. Only a few short watercourses with small drainage areas are mapped within this stretch. The average daily flow balance measured between gages at RM33, and RM 23.9 (Figure H-54c) indicates Reach 1 was:

- losing during the first week of August,
- relatively neutral (no consistent gain or loss) up until the August synoptic,
- gaining during low flow period from late August to mid-October,
- and highly variable during late Oct storms.

Gains ranged from 23 to 51 cfs during the steady gain period (late August to mid-October, with a median gain of 41.3 cfs). Wetzel et al (2015) estimated similar gains between RM 33 and 23.9 of 41 cfs in October 2011 and 46 cfs in October 2012.

An uncertainty analysis was performed on the 9/26/12 seepage flow balance (Figure H-54b). Ecology's ADCP flow measurement at RM 28 was rated as excellent quality with less than 1% standard error. Ecology tributary flows (magnetic meter used) were rated as good. The USGS gage at RM 23.0 was rated as fair quality. Based on the combined standard error in this reach the calculated seepage gain is greater than the 95% confidence interval of the measurement error. The results of the flow balance and uncertainty analysis provide strong evidence that reach 1 is a gaining reach.

An instream piezometer installed at the lower end of reach 1 (Figure H-54a; site P9), just upstream of the Lake Tapps diversion dam, exhibited a neutral vertical hydraulic gradient (VHG) during July and small positive VHG measurements in August, September, and October (+0.006 to 0.008). Although the gradients are subtle, the general pattern matches that of the continuous residual flow balance and provides further evidence of groundwater (GW) discharge to the river.

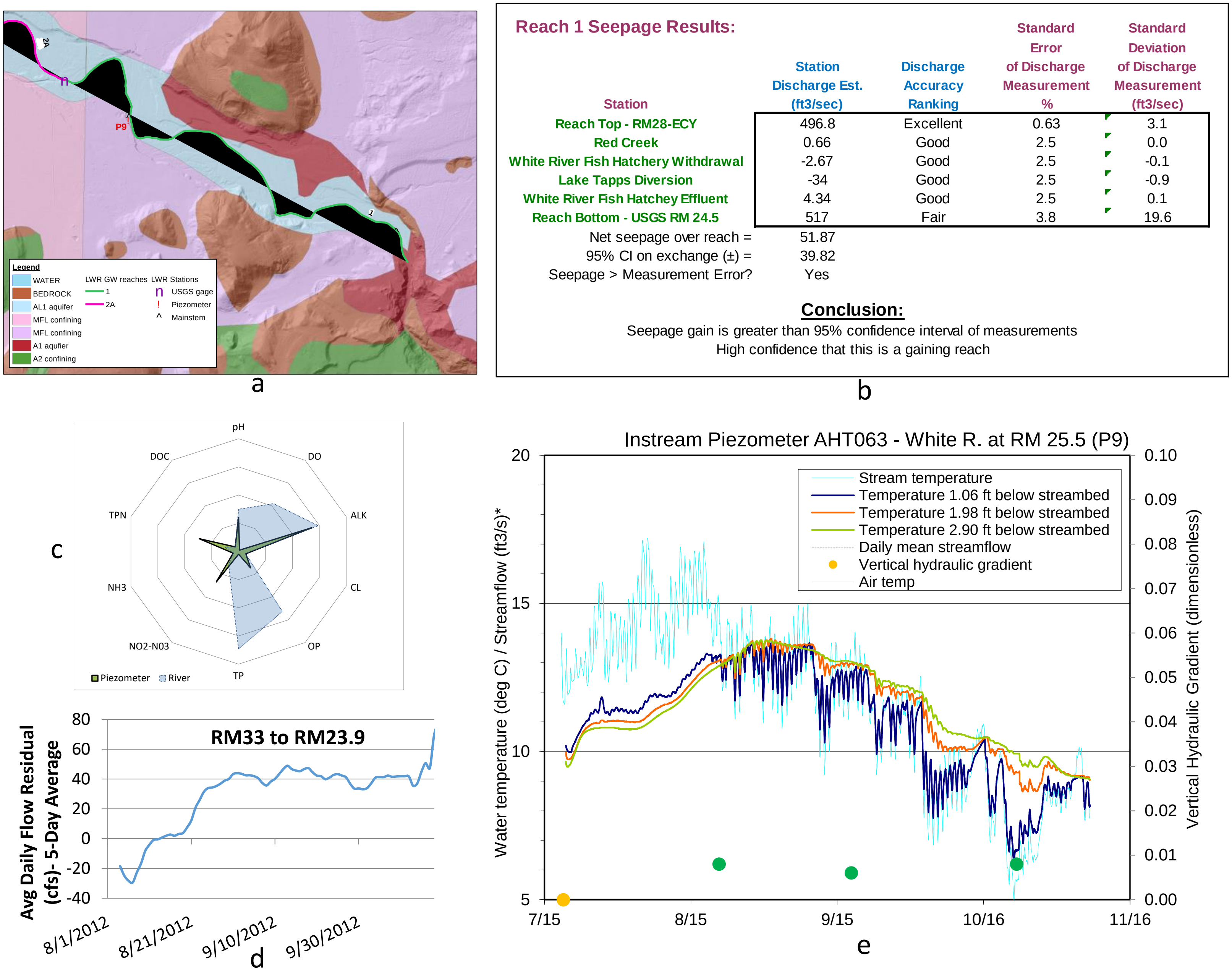
The piezometer at RM 25.2 (P9) exhibited a relatively stable thermal signature in the lowest thermistor throughout the period of record. From 7/19/12 to ~8/21/12 stream temperatures were significantly warmer than those in the piezometer with strong thermal separation and little fluctuation in the lower thermistor. This pattern is consistent with piezometers installed along a gaining stream reach (i.e., where groundwater discharge is occurring) (Figures H-54e and H-52).

The strong thermal separation between the river and lower thermistor was still evident on 9/26/12 (~2.5 °C), but with the warmest temperatures occurring at the lowest thermistor and coolest temperatures in the river (inverse relationship). This inverse of the river/piezometer thermal relationship started on 8/21/12 and is consistent with the seasonal thermal transitions commonly observed in piezometers installed along gaining stream reaches (Figure H-52).

Surficial exposure of the coarse A1 aquifer could result in lateral discharge of groundwater along the right (north) bank of river (Figure H-54a). Bedrock hills on either side of the river (north and south bank) may also constrict regional groundwater flow toward the river.

Based on water quality sample results, the chemical composition of piezometer and river water were noticeably different (Figure H-54c). Low DO, low pH, and high nitrates (compared to river) in piezometer are generally indicative of groundwater influence.

The collective weight of evidence gathered during this study suggests Reach 1 is a gaining reach where groundwater discharges to the river are occurring. The QUAL2Kw model used a 5-day running average of the daily flow residual as the groundwater model input, equally dispersed within the reach.



Reach 1 Seepage Results:

Station	Station Discharge Est. (ft3/sec)	Discharge Accuracy Ranking	Standard Error of Discharge Measurement %	Standard Deviation of Discharge Measurement (ft3/sec)
Reach Top - RM28-ECY	496.8	Excellent	0.63	3.1
Red Creek	0.66	Good	2.5	0.0
White River Fish Hatchery Withdrawal	-2.67	Good	2.5	-0.1
Lake Tapps Diversion	-34	Good	2.5	-0.9
White River Fish Hatchey Effluent	4.34	Good	2.5	0.1
Reach Bottom - USGS RM 24.5	517	Fair	3.8	19.6
Net seepage over reach =	51.87			
95% CI on exchange (±) =	39.82			
Seepage > Measurement Error?	Yes			

Conclusion:

Seepage gain is greater than 95% confidence interval of measurements
High confidence that this is a gaining reach

Figure H-54. Reach 1 groundwater assessment – a) surficial hydrogeology and sampling locations; b) flow balance and uncertainty; c) instream piezometer vs surface water quality at RM 25.5; d) 5-day running average of continuous flow residual between RM 33 and 23.9; e) instream piezometer temperatures at RM 25.5.

Reach 2: RM 23.9 (USGS gage:) to RM 7.6 (USGS gage:)

Ecology subdivided Reach 2 into three sub-reaches:

- SubReach2A (RM 23.9 to 18.2): The downstream end of SubReach2A was delineated based on distance to piezometers P8 and P9 (Figure H-55a), as well as a slight change in the surficial hydrogeology, with some exposure of the C aquifer starting at the bottom of SubReach2A.
- SubReach2B (RM 18.2 to 10): The downstream end of SubReach2B was delineated based on distance to piezometers P7 and P8 (Figure H-55a), as well as a change in the surficial hydrogeology. Subreach2B marks the approximate end of the MFL layer as the surficial confining layer.
- SubReach2C (RM 10 to 7.6): The upstream end of SubReach2C was delineated based on distance to piezometers P6 and P7 (Figure H-55a), as well as a change in the surficial hydrogeology. Subreach2C marks the widening of the White River valley and the approximate beginning of connectivity to the ancient Auburn delta AL2 aquifer unit and the deeper E aquifer unit.

For Reach 2, the 8/22/12 streamflow balance indicates a ~77 cfs gain; however, streamflow was not steady during this survey, with ~20% variability at the RM 23.9 gage. The 9/26/12 flow balance indicates ~25 cfs gain. Flows were more stable during this survey, with less than 10% variability at the RM 23.9 gage.

The average daily continuous flow balance (Figure H-55c) measured between gages at RM 23.9 and RM 7.6 (Figure H-55a) indicates Reach 2 was:

- gaining significantly, up to 160 cfs, during the first week of August,
- gaining but steadily decreasing in gain from early August to early October,
- gaining at steady base flow of ~20 cfs by the second week of October,
- and highly variable during late Oct storms.

For the seepage survey dates, the estimated gain was ~120 cfs on 8/22/12 and ~36 cfs on 9/26/12. Wetzel et al (2015) estimated similar gains between RM 23.9 and 7.6 of 28 cfs in October 2011 and 26 cfs in October 2012.

An uncertainty analysis was performed on the 9/26/12 seepage flow balance (Figure H-55d). Ecology tributary flows (magnetic meter used) were rated as good. The USGS gage at RM 23.0 was rated as fair quality and the USGS gage at RM 7.6 was rated as good quality. Based on the combined standard error in this reach the seepage gain is not greater than the 95% confidence interval of the measurement error. The seepage gain is greater than the 66% confidence interval of the measurement error. The results of the flow balance and uncertainty analysis provide only weak evidence that reach 2, overall, is a gaining reach.

An instream piezometer installed near the middle of SubReach2A (Figure H-56a; site P8), downstream of Buckley, exhibited positive VHG measurements throughout the study period (+0.011 to +0.013). The piezometer installed near the middle of SubReach2B (Figure H-57a; site P7), downstream of Buckley, also exhibited positive VHG measurements throughout the study period (+0.013 to +0.016). However, the piezometer installed near the middle of SubReach2C (Figure H-58; site P6), in Auburn, exhibited negative VHG measurements throughout the study period (-0.011 to -0.336).

The piezometer at RM 20.4 (P8) exhibited a relatively stable thermal signature in lowest thermistor throughout the period of record. From 7/19/12 to ~10/2/12 stream temperatures were significantly warmer than piezometer temperatures, with strong thermal separation and little fluctuation in the lower thermistor. This pattern suggests a gaining thermal piezometer signature. On 10/2/12, stream temperatures decreased below groundwater temperatures (lowest thermistor). At this point the upper and middle thermistors started tracking stream temperatures more closely with little separation (Figure H-56c).

The piezometer at RM 16.2 (P7) exhibited a relatively stable thermal signature in the lowest thermistor throughout the period of record. Abnormal data was collected from 7/19/12 to ~8/3/12. This could possibly be due to a bad seal following installation, with the sediment eventually equilibrating/sealing. From 8/3/12 to ~8/22/12 stream temperatures were significantly warmer than piezometer temperatures, with strong thermal separation and little fluctuation in the lower thermistor. This pattern suggests a gaining thermal piezometer signature. From 8/22/12 to ~10/2/12 the lower thermistor temperatures remained relatively stable, with slight tracking of stream temperature lows (that fall below groundwater temperatures at night). Air temperatures frequently are very low in this time frame (around 5-7 °C). From 10/2/12 to 10/13/12 the lower thermistor is tracking stream diel temp most of the day and only returns to groundwater background at peak stream temperatures (Figure H-57c).

The piezometer at RM 9 (P6) showed less thermal separation between thermistors than the other piezometers in reach 2. From 7/19/12 to 10/2/12 moderate thermal separation was observed between thermistors, with the lower thermistor tracking stream temperature trends to some degree. From 10/2/12 to 10/13/12 there was even less thermal separation and stream temperatures were similar to groundwater temperatures, with the lower thermistor tracking the stream closely (Figure H-59)

Within SubReach2A and Subreach2B the White River valley cuts continually deeper and a relatively steep bluff face exposes several aquifer layers and likely results in lateral discharge of groundwater during most if not all of the year (Figure H-55a). This exposure increases moving downstream, with some surficial exposure of the C aquifer starting in SubReach2B, as well as exposure of the A3 aquifer unit.

In SubReach2C, the underlying AL1 alluvial aquifer unit and ancient Auburn delta AL2 aquifer and a deeper aquifer unit likely have a primary flowpath/gradient which directs groundwater north toward the Green river along the historic path of the White River through Auburn, although some portion of flow is likely directed south (Welch et al., 2015).

Based on water quality sample results, the chemical composition of piezometers P7 and P8 were noticeably different from their corresponding river water samples. At RM 20.4 (SubReach 2A; P8), low DO, high alkalinity, and high chlorides (compared to the river) in the piezometer, could be indicative of groundwater influence (Figures H-56b). At RM 16.2 (SubReach2B; P7), low DO, low pH, and high alkalinity (compared to the river) in the piezometer, could be indicative of groundwater influence (Figures H-57b). The piezometer at RM 9: (P6) was not sampled because of consistently negative VHG measurements.

The magnitude of the estimated gain in Reach 2 is similar to an earlier estimate of groundwater gain for this stretch of the river.

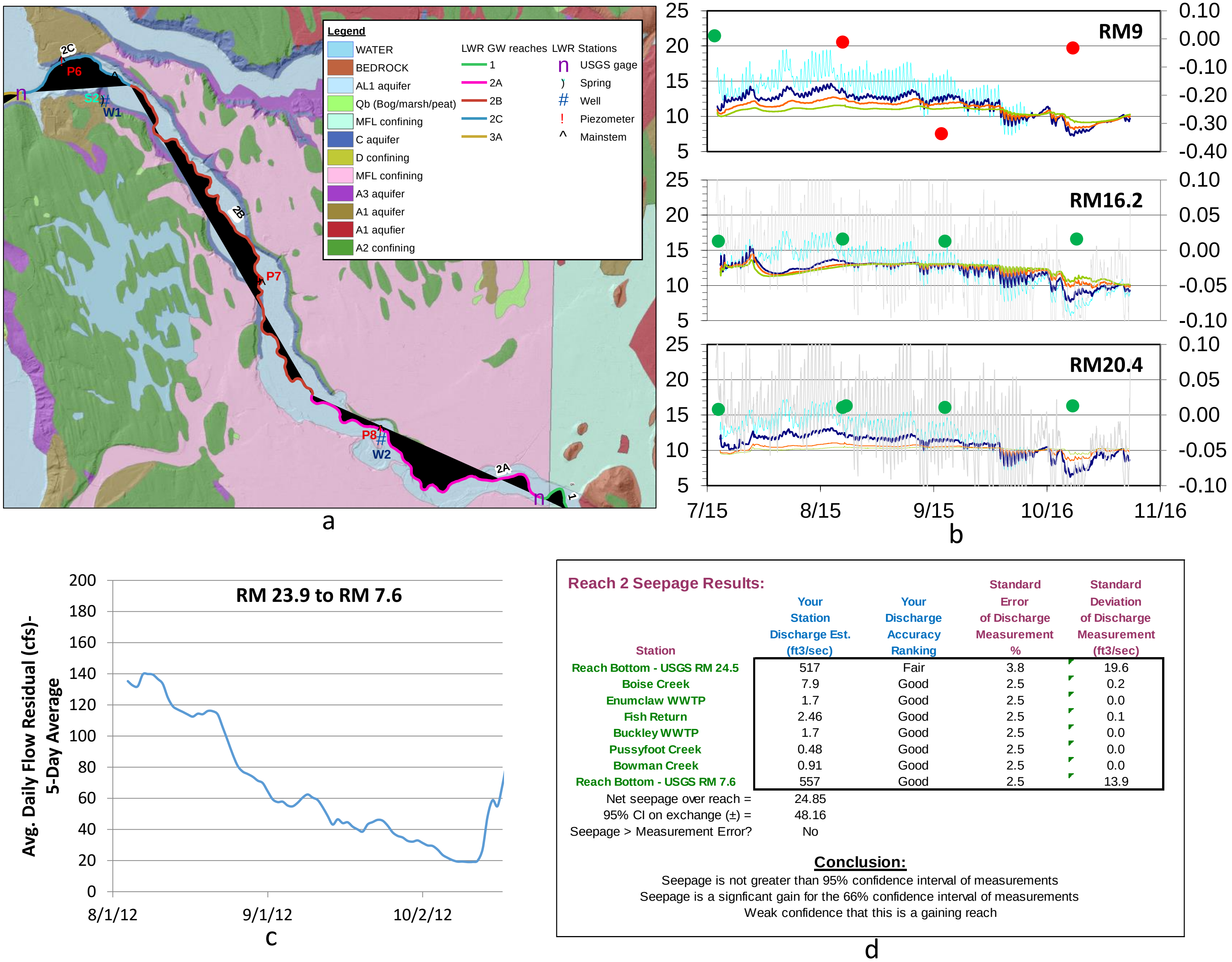
Based on the PGG 1999 study, the WR-1 well (~RM9) location was determined to be gaining during winter and losing during summer. The WR-2 well (RM7.6) location was determined to be losing year-round. These results are consistent with the 2012 results which suggest SubReach2C is losing.

During a float of the river on 8/20/12, Ecology observed seeps along bluffs within SubReaches 2A and 2B. There was also a seep visible along the exposed face of bluff at RM 20.4 in SubReach 2A during routine site visits.

The weight of evidence suggests Reach 2 is likely a gaining reach overall with discharge of groundwater to the river occurring. Evidence is slightly weaker than for Reach 1 and there is some evidence that SubReach2C is a losing reach.

Within the QUAL2Kw model, Ecology used the 5-day running average and with gains distributed to 2A and 2B, and with losses distributed to 2C. Distribution of gains and losses was based on the sub-reach lengths, for example if the total reach 2 net groundwater gain is 25 cfs on a given day, then:

- Subreach2C represents 16% of the total length of Reach 2, so
- Subreaches 2A & 2B receive 116% of total net gain (29 cfs), equally dispersed,
- and Subreach2C loses 16% of total net gain (4 cfs).



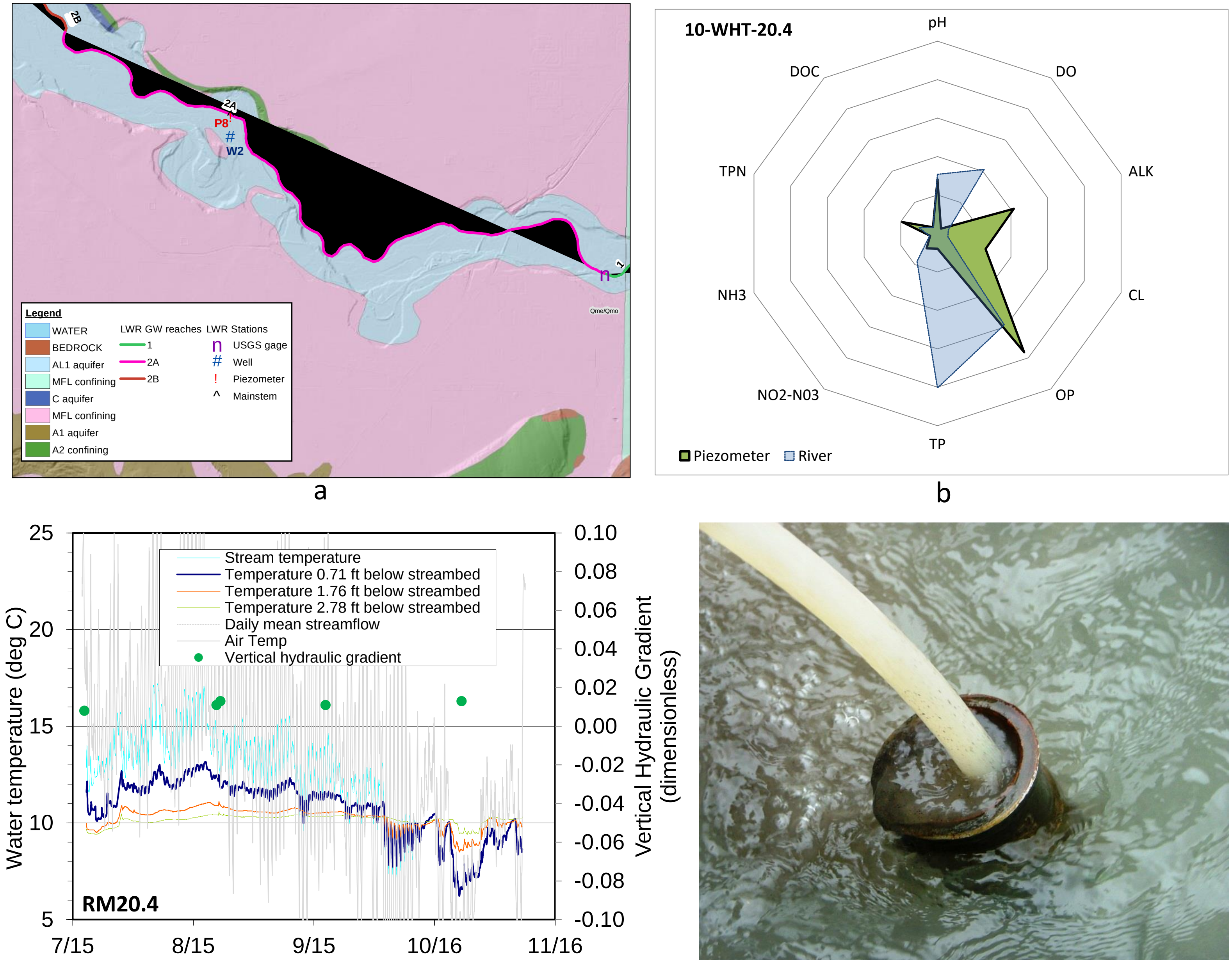
Reach 2 Seepage Results:

Station	Your Station Discharge Est. (ft3/sec)	Your Discharge Accuracy Ranking	Standard Error of Discharge Measurement %	Standard Deviation of Discharge Measurement (ft3/sec)
Reach Bottom - USGS RM 24.5	517	Fair	3.8	19.6
Boise Creek	7.9	Good	2.5	0.2
Enumclaw WWTP	1.7	Good	2.5	0.0
Fish Return	2.46	Good	2.5	0.1
Buckley WWTP	1.7	Good	2.5	0.0
Pussyfoot Creek	0.48	Good	2.5	0.0
Bowman Creek	0.91	Good	2.5	0.0
Reach Bottom - USGS RM 7.6	557	Good	2.5	13.9
Net seepage over reach =	24.85			
95% CI on exchange (±) =	48.16			
Seepage > Measurement Error?	No			

Conclusion:

Seepage is not greater than 95% confidence interval of measurements
Seepage is a signficant gain for the 66% confidence interval of measurements
Weak confidence that this is a gaining reach

Figure H-55. Reach 2 groundwater assessment – a) surficial hydrogeology and sampling locations; b) instream piezometer temperatures/VHG at RM 20.4, RM 16.2, and RM 9; c) 5-day running average of continuous flow residual between RM 23.9 and 7.6; d) flow balance and uncertainty.



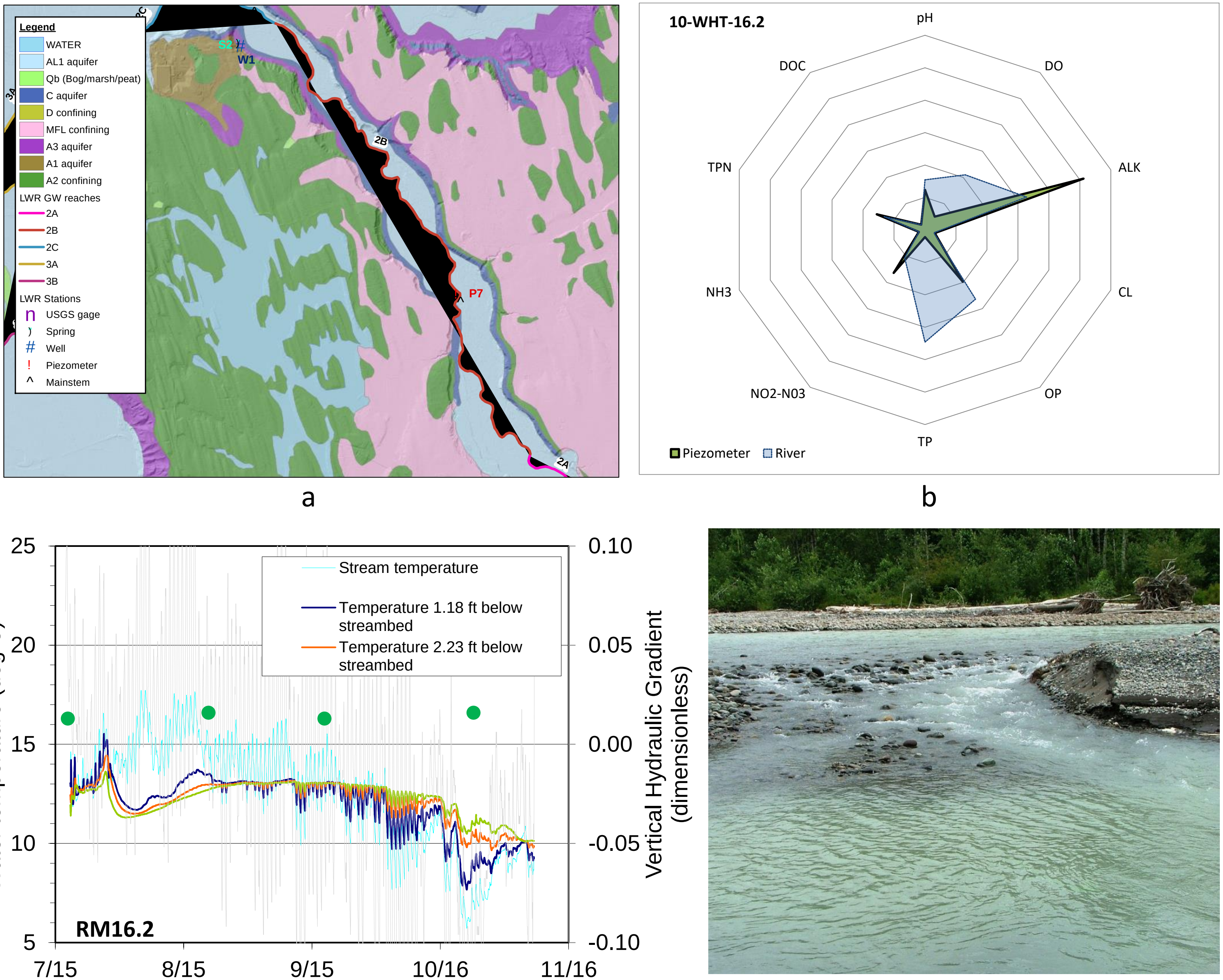
a

b

c

d

Figure H-56. Reach 2a groundwater assessment – a) surficial hydrogeology and sampling locations; b) instream piezometer P8 vs surface water quality at RM 20.4; c) instream piezometer temperatures/VHG at RM 20.4; d) photograph of instream piezometer being developed at RM 20.4.



a

b

c

d

Figure H-57. Reach 2b groundwater assessment – a) surficial hydrogeology and sampling locations; b) instream piezometer vs surface water quality at RM 16.2; c) instream piezometer temperatures/VHG at RM 16.2; d) photo of White River near piezometer at RM 16.2.

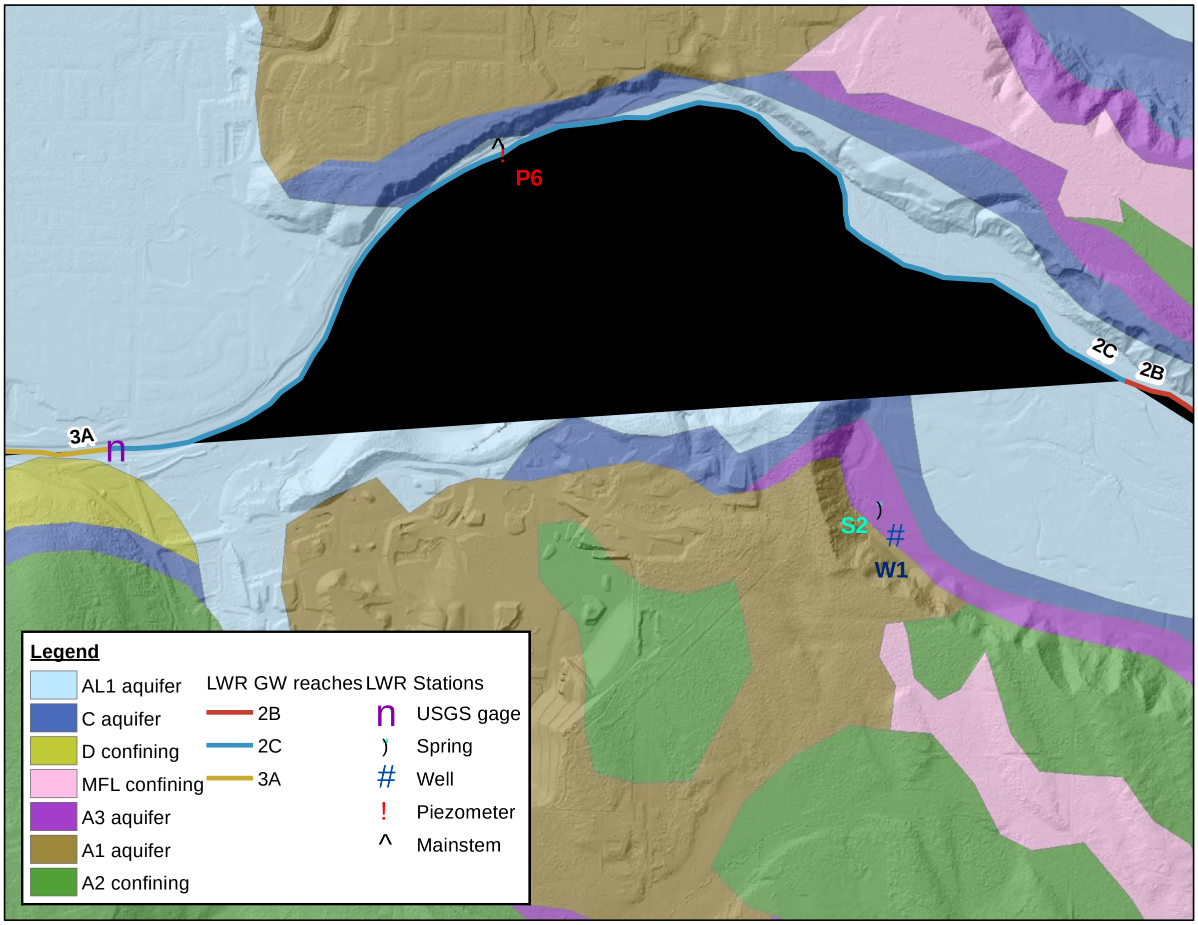


Figure H-58. Surficial hydrogeology and sampling locations at RM 9 (Subreach 2C).

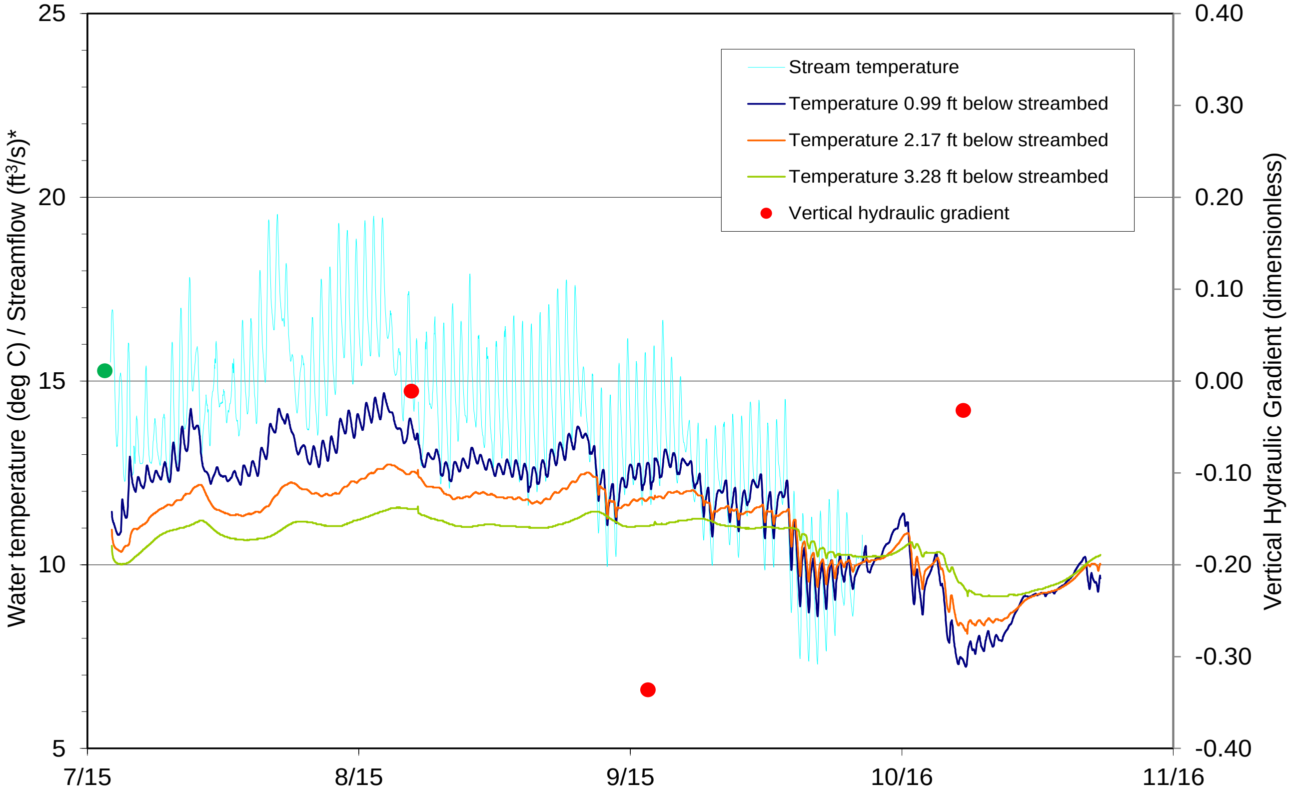


Figure H-59. Instream piezometer temperatures/VHG at RM 9 (Subreach 2C).

Reach 3: RM 7.6 (USGS gage:) to mouth

Ecology subdivided Reach 3 into three sub-reaches:

- SubReach3A (RM 7.6 to 4): The downstream end of SubReach3A was delineated based on piezometer P4 (Figure H-60a), as well as a continuation of hydrogeology similar to SubReach2C.
- SubReach3B (RM 4 to 0.9): The downstream end of SubReach3B was delineated based on distance to piezometers P1 and P2 (Figure H-61a) and the end of model reach 32.
- SubReach3C (RM 0.9 to 0): Consists solely of QUAL2Kw model reach 33. It was separated from SubReach3B due to the significant difference in piezometer and VHG sample and measurement results between piezometers P1 and P2.

The 8/22/12 flow balance indicates ~38 cfs loss in Subreach3A and ~42 cfs gain in subreaches 3B and 3C combined; however, flow was not steady during this survey, with ~20% variability at the RM 23.9 gage. The 9/26/12 flow balance indicates ~19 cfs loss in Subreach3A and ~12 cfs gain in sub-reaches 3B and 3C combined. Flows were more stable during this survey, with less than 10% variability at the RM 23.9 gage.

Continuous average daily flow residuals could not be calculated for Reach 3 because there is no gage on the White River below RM 7.6.

An uncertainty analysis was performed on the 9/26/12 seepage flow balance for SubReach3A (Figure H-60c). The USGS gage at RM 7.6 was rated as good quality. Ecology tributary flows (magnetic meter used) were rated as good. Ecology's ADCP flow measurement at RM 3.7 was rated as excellent quality with less than 1% standard error. Based on the combined standard error in this reach the seepage loss is not greater than the 95% confidence interval of the measurement error. The seepage loss is greater than the 75% confidence interval of the measurement error. The results of the flow balance and uncertainty analysis provide only weak evidence that reach 3A is a gaining reach.

An uncertainty analysis was performed on the 9/26/12 seepage flow balance for SubReach3B and 3C (Figure H-61c). Ecology's ADCP flow measurements at RM 3.7 and RM 0.5 were rated as excellent quality with less than 1% standard error. Ecology tributary flows (magnetic meter used) were rated as good. Based on the combined standard error in this reach the seepage gain is not greater than the 95% confidence interval of the measurement error. The seepage gain is greater than the 80% confidence interval of the measurement error. The results of the flow balance and uncertainty analysis provide moderate evidence that Subreaches 3B and 3C are gaining reaches.

An instream piezometer installed near the middle of SubReach3A (Figure H-60a; site P5) exhibited one positive VHG measurements and two negative VHG measurements (-0.012 to -0.013). The piezometer installed at the downstream end of SubReach3A (Figure H-60a; site P4) exhibited negative VHG measurements throughout the study period (-0.010 to -0.012).

An instream piezometer installed at the upstream end of SubReach3B (Figure H-61a; site P3) exhibited relatively neutral VHG measurements (-0.002 to +0.003). Of note, this well made very little water during field visits, which indicates gradient values might be suspect. The piezometer further downstream in SubReach3B (Figure H-61a; site P2) exhibited both negative and positive VHG measurements (-0.111 to +0.054). The piezometer in SubReach3C (Figure H-61a; site P1) exhibited positive VHG measurements throughout the study period (+0.047 to +0.055).

The piezometer at RM6.3 (P5) exhibited a relatively large thermal signature from 7/19/12 to ~8/19/12 which would indicate a potential gaining signal. This agrees with early VHG measurement of +0.018 on 7/17/12. This piezometer showed less thermal separation from ~8/20/12 to 10/13/12 with the lower thermistor tracking stream temperature to some degree (Figure H-60b).

The piezometer at RM 4 (P4) showed little thermal separation and piezometer thermistors tracked stream temperatures. This thermal signal is indicative of a losing reach (Figure H-60b).

The piezometers within SubReach3B at RM 3.7 (P3) and RM 1.4 (P2), as well as the piezometer in SubReach3C at RM 0.2 (P1), all showed large thermal separation and stable temperatures in the lower piezometer thermistor. The thermal signature at all three piezometers is indicative of a gaining reach (Figure H-61b).

The hydrogeology of Subreach3A is a transition area between that of Subreach2C (seasonally losing) and the river valley downstream (recharge from uplands and exposure of shallower A3 and C aquifer units).

The hydrogeology of Subreaches 3B and 3C contains potential sources of recharge from both the Lake Tapps uplands to the east and Federal Way uplands to the west. The Lake Tapps uplands are particularly productive due to recharge from Lake Tapps and exposure of both the Vashon advance outwash A3 aquifer and the Salmon Springs Drift C aquifer. This area contains several productive springs (Salmon, Sumner, Crystal, and Elhi Springs) and groundwater fed tributaries, most notably Salmon Creek.

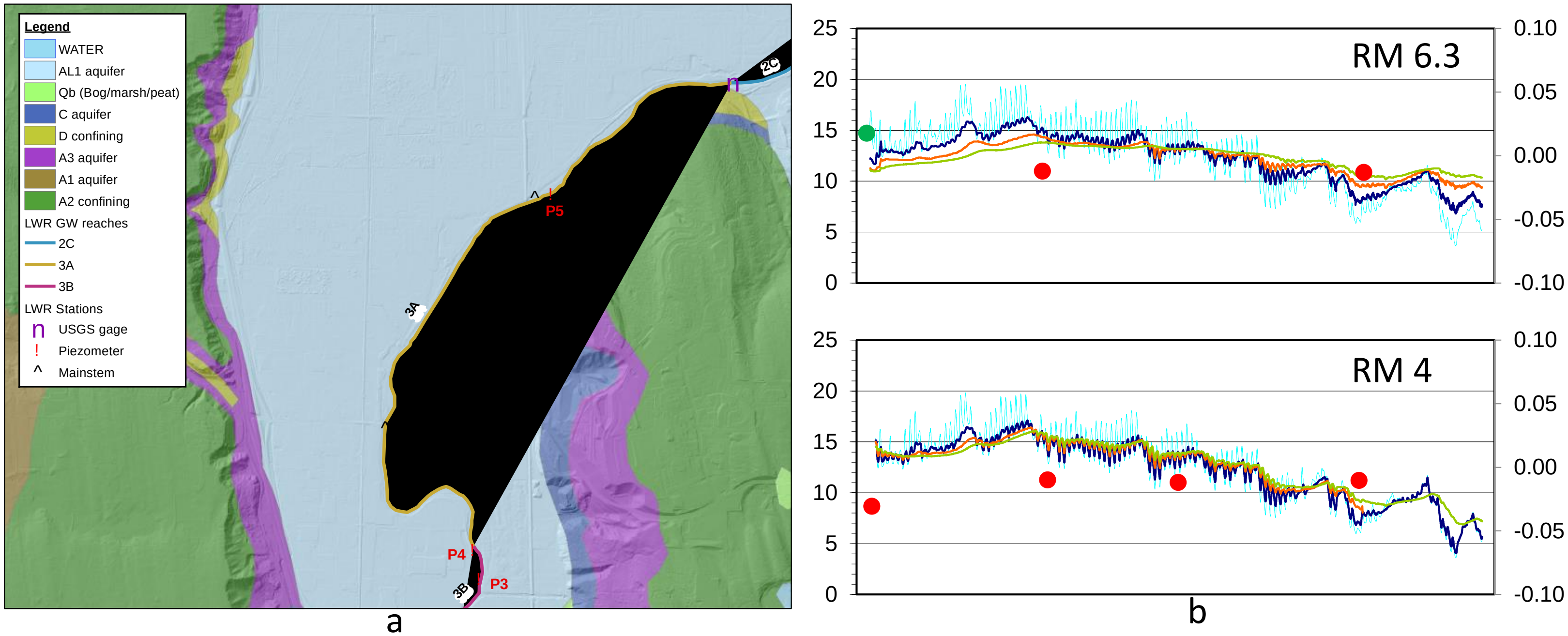
Based on water quality sample results, the chemical composition of piezometer P1 was noticeably different from the corresponding river water samples (Figure H-61d). At RM 0.2 (SubReach 3C; P1), low DO, low pH, and very high alkalinity (compared to river) in piezometer, could be indicative of groundwater influence. Also, chloride and ammonia concentrations were very high in the piezometer indicating significant anthropogenic influence on localized groundwater chemistry.

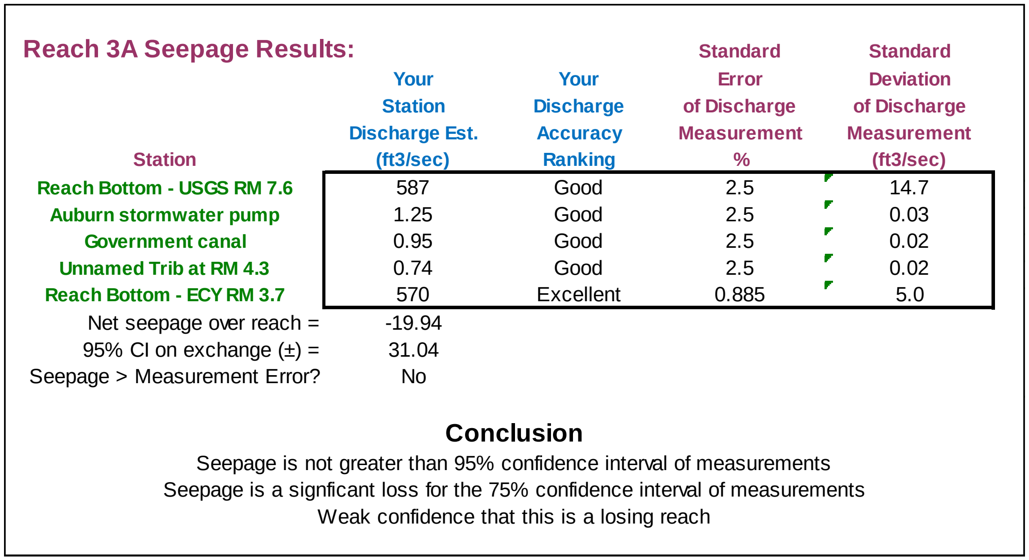
All other piezometers within Reach 3 were not sampled for water quality due to negative VHG measurements. In the case of RM 3.7, there was some groundwater chemistry data, but no surface water chemistry data.

PGG 1999 study data from Well WR-3 (~RM6.3) indicates this location is likely gaining for most of the year but may be losing during low-flow conditions.

The weight of evidence suggests Reach 3A is likely a losing reach overall with discharge from the river to the hyporheic zone occurring. The QUAL2Kw model assumes a constant equally dispersed abstraction of 19 cfs within reach 3A for the entire model period, given that there is no continuous flow data at the mouth.

The evidence is inconclusive for SubReach3B, with some evidence indicating streamflow gains and some losses. The weight of evidence suggests SubReach3C is likely a gaining reach overall with discharge of groundwater to river occurring. The gaining evidence is modest, because the estimated flow gain is relatively small (~12 cfs) compared to potential error and the amount of flow in the river. However, piezometer temperatures, VHG, and water quality strongly suggest Subreach3C is gaining. The QUAL2Kw model assumes a constant 12 cfs gain in Subreach reaches3B and 3C.





Reach 3A Seepage Results:

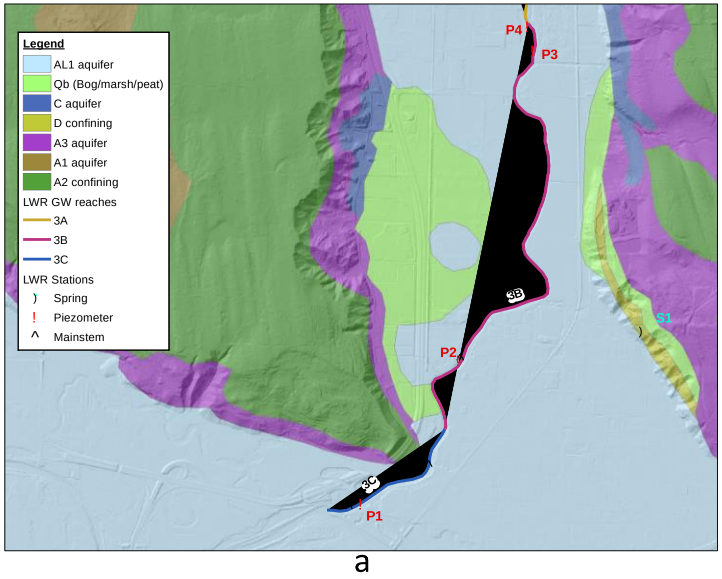
Station	Your Station Discharge Est. (ft3/sec)	Your Discharge Accuracy Ranking	Standard Error of Discharge Measurement %	Standard Deviation of Discharge Measurement (ft3/sec)
Reach Bottom - USGS RM 7.6	587	Good	2.5	14.7
Auburn stormwater pump	1.25	Good	2.5	0.03
Government canal	0.95	Good	2.5	0.02
Unnamed Trib at RM 4.3	0.74	Good	2.5	0.02
Reach Bottom - ECY RM 3.7	570	Excellent	0.885	5.0
Net seepage over reach =	-19.94			
95% CI on exchange (±) =	31.04			
Seepage > Measurement Error?	No			

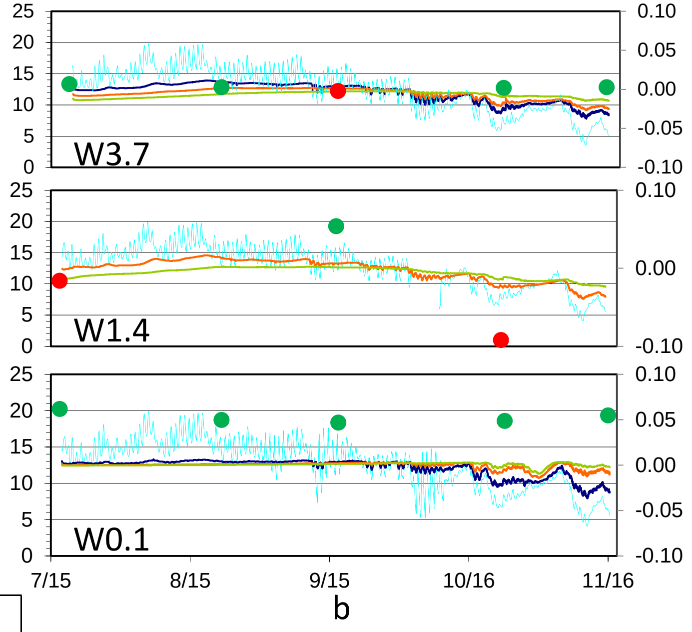
Conclusion

Seepage is not greater than 95% confidence interval of measurements
Seepage is a signficant loss for the 75% confidence interval of measurements
Weak confidence that this is a losing reach

c

Figure H-60. Reach 3A groundwater assessment – a) surficial hydrogeology and sampling locations; b) instream piezometer temperature/VHG at RM 6.3 and RM 4; c) flow balance and uncertainty.





Reach 3B/3C Seepage Results:

Station	Your Station Discharge Est. (ft3/sec)	Your Discharge Accuracy Ranking	Standard Error of Discharge Measurement %	Standard Deviation of Discharge Measurement (ft3/sec)
Reach Bottom - ECY RM 3.7	570	Excellent	0.885	5.0
Lake Tapps tailrace	5	Good	2.5	0.1
Sumner storm outfall RM 3.3	0.22	Good	2.5	0.0
Unnamed Trib at RM 2.6	1.19	Good	2.5	0.0
Salmon Creek	7.01	Good	2.5	0.2
Milwaukee Ditch	3.8	Good	2.5	0.1
Sumner storm outfall RM 0.9	0.83	Good	2.5	0.0
Reach Bottom - ECY RM 0.5	600	Excellent	1	6.0
Net seepage over reach =	11.95			
95% CI on exchange (±) =	15.68			
Seepage > Measurement Error?	No			

Conclusion

Seepage is not greater than 95% confidence interval of measurements
Seepage is a signficant gain for the 80% confidence interval of measurements
Moderate confidence that this is a gaining reach

c

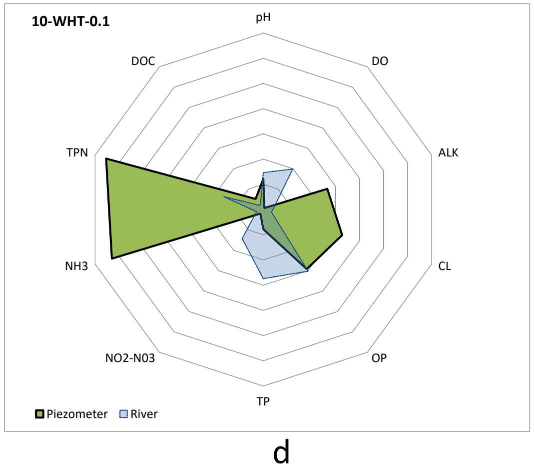


Figure H-61. Reach 3B/3C groundwater assessment – a) surficial hydrogeology and sampling locations; b) instream piezometer temperatures/VHG at RM 3.7 (P3), RM 1.4 (P2), and RM 0.1 (P1); c) flow balance and uncertainty; d) instream piezometer P1 vs surface water quality at RM 0.1.

Discussion

Orthophosphate concentrations are particularly important to the Lower White River pH TMDL, as this parameter is used to set wasteload and load allocations for point and nonpoint sources. This groundwater assessment identified two broader areas of dry season groundwater discharge, and thus phosphorus loading, to the White River:

- From RM 28 to RM 10 (Reach 1, 2a, and 2b):
    - The lowest concentrations of orthophosphate (<3 and 3.6 ug/L) were found in Reach 1 at RM 25.2.
        - Paired surface water samples were high in comparison (12.9 to 13.8 ug/L).
    - Concentrations were also relatively low (9.9 and 10.1 ug/L) in Reach 2b at RM 16.2.
        - Paired surface water samples were high in comparison (12.6 to 14.8 ug/L).
    - Concentrations were comparatively high (17.2 and 19.3 ug/L) in Reach 2a at RM 20.4.
        - Paired surface water samples were low in comparison (13.1 to 14.8 ug/L).
        - The RM 20.4 piezometer may possibly be influenced by phosphorus loading from a housing subdivision immediately adjacent to the river at this site. There are no other housing developments in close proximity to the river in Reach 2a (RM 18.1 to 23.7), so this value could potentially be biased high and not representative of the reach as a whole; particularly given that the nearest upstream and downstream piezometers had lower concentrations.
- From RM 3.7 to RM 0 (Reach 3b and 3c):
    - High concentrations (30.8 and 427 ug/L) of orthophosphate were observed in Reach 3b at RM 3.7.
        - This piezometer was located on the east bank of the river at the downstream end of what was the Sumner Golf Course, at the time of sample collection. This site is no longer being operated as a golf course and is currently listed as vacant industrial land.
        - No paired surface water samples were collected at this piezometer.
    - Moderate concentrations (11.8 and 14.6 ug/L) of orthophosphate were observed in Reach 3c at RM 0.2.
        - Paired surface water samples were slightly high in comparison (13.3 to 15.1 ug/L).
    - The chemical composition of the groundwater discharge in the lower river was much different compared to the upper river. The lower river piezometers both had higher levels of phosphorus, ammonia, dissolved organic carbon, and iron.

  - While phosphorus concentrations were higher in the lower river, these piezometers were below RM 3.6 and the critical, peak algal growth reach of the river (~RM10 to 3.6) and are not predicted to contribute to pH WQS exceedances in the Lower White River.

Further discussion of how groundwater impacts and input values are applied in the White River model and TMDL analysis are included in other appendices of the TMDL report.

Summary and conclusions

This study was undertaken to support a TMDL investigation of the Lower White River. The primary study goals were to:

- Assess the magnitude and direction of surface water/groundwater interactions along the river.
- Characterize groundwater quality along gaining stream reaches.

Multiple field and analytical techniques were used to achieve these objectives. Stream seepage studies were conducted in August and September 2012 to quantify net streamflow gains and losses along selected stream reaches. These reach-based evaluations were supplemented with information from a small network of instream piezometers that were monitored to evaluate surface water/groundwater head relationships, streambed temperatures, and near-stream groundwater quality.

Collectively, these evaluations reveal that the White River (from RM 28 to the mouth) is likely comprised of alternating gaining and losing stream reaches. During the September seepage evaluation, the river showed net overall gains from groundwater of approximately +69 cfs between the upper end of reach 1 and the lower end of reach 3.

Measurable concentrations of dissolved orthophosphate and dissolved total phosphorus were found in all sampled piezometers at values ranging from 3 U to 427 ug/L and 3 U to 1,280 ug/L respectively. Concentrations of dissolved nitrate+nitrite-N and ammonia ranged from 10 U to 2,220 ug/L and 10 U to 3,850 ug/L respectively.

The water quality values reported here do not account for biological or geochemical transformations that can potentially reduce phosphorous and nitrogen-based nutrient concentrations in groundwater as it passes through the final few feet of the streambed. Accordingly, these values probably represent the upper-bound range of nutrient concentrations that groundwater contributes to the river locally. If future TMDL modeling efforts indicate a need to further constrain the nutrient concentrations reported here, it may be possible to quantify the potential influence of these processes where field conditions allow.

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[22] https://apps.ecology.wa.gov/publications/publications/0003001.pdf

Appendix I. Model documentation

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Introduction

Washington State Department of Ecology developed a dynamic one-dimensional QUAL2Kw (Version 6.0) model of the White River to simulate biological productivity and diel pH swings. Ecology developed and calibrated the model using data collected in the summer and fall of 2012. Details of the data collection, study area, and project goals and objectives are available in the QAPP (Mathieu and Pelletier, 2012) and Appendix F.

This appendix documents the development, calibration, and model quality analysis of the 2012 White River QUAL2Kw model. This documentation is intended for technical staff looking for detailed information on how the model was developed and how the model predictions fit with observed data. A more concise overview of the modeling and analysis framework is provided in Appendix D (Analytical Framework).

QUAL2Kw 6.0 modeling framework

The QUAL2Kw 6.0 modeling framework (Pelletier and Chapra, 2008) was used to develop the loading capacity for nutrients and to make predictions about water quality under various scenarios. The QUAL2Kw model framework and complete documentation are available at Models & tools for TMDLs - Washington State Department of Ecology[23]

The QUAL2Kw 6.0 modeling framework has the following characteristics:

- One dimensional. The channel is well-mixed vertically and laterally. Also includes up to two optional transient storage zones connected to each main channel reach (surface and hyporheic transient storage zones).
- Non-steady, non-uniform flow using kinematic wave flow routing. Continuous simulation with time-varying boundary conditions for periods of up to one year.
- Dynamic heat budget. The heat budget and temperature are simulated as a function of meteorology on a continuously varying or repeating diel time scale.
- Dynamic water-quality kinetics. All water quality state variables are simulated on a continuously varying or repeating diel time scale for biogeochemical processes.
- Heat and mass inputs. Point and nonpoint loads and abstractions are simulated.
- Phytoplankton and bottom algae in the water column, as well as sediment diagenesis, and heterotrophic metabolism in the hyporheic zone are simulated.

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[23] https://ecology.wa.gov/Research-Data/Data-resources/Models-spreadsheets/Modeling-the-environment/Models-tools-for-TMDLs

- Variable stoichiometry. Luxury uptake of nutrients by the bottom algae (periphyton) is simulated with variable stoichiometry of N and P.

The previous versions of Ecology's QUAL2Kw modeling framework assume flows are constant, and other boundary conditions are represented by a repeating diel pattern. Ecology recently updated QUAL2Kw to include use of the kinematic wave (KW) method of flow routing (Chapra, 1997) for simulation of continuously changing channel velocity and depth in response to changing flows. In addition, the updated QUAL2Kw framework allows input of continuous changes in other boundary conditions (e.g., tributary loading and meteorology). Incorporation of KW transport and continuous boundary forcing now allows QUAL2Kw to be used to simulate continuous changes in water quality for up to a year.

QUAL2Kw V6 was selected for determining the nutrient loading capacity for the TMDL for multiple reasons including that the model is:

- Capable of simulating advanced periphyton/bottom algae dynamics including growth, respiration, scouring, nutrient/light/temperature limitation, and (importantly) internal cell nutrient concentrations and quotas.
- Capable of simulating dynamic conditions for a full periphyton growth season, including flow, temperature, and (importantly) solar radiation/shade. An hourly time series input may be used for each reach of the model.
- Well documented and routinely used for nutrient TMDL development in EPA region 10.
- Actively enhanced and maintained by Greg Pelletier, a senior engineer and modeler at Ecology.

Within QUAL2Kw, hydrodynamics for each reach is simulated based on channel characteristics, user supplied flow parameters, and the one-dimensional KW method. The KW equation is used to drive advective transport through free-flowing segments and to calculate flows, volumes, depths, and velocities resulting from variable upstream inflow.

Ecology also used the U.S. Army Corps of Engineers computer model, the Hydrologic Engineering Centers River Analysis System (HEC-RAS), to develop the channel geometry for the QUAL2Kw model. HEC-RAS is designed to perform one-dimensional hydraulic calculations for a network of natural or constructed channels and is often used for flooding risk analysis. Ecology used steady flow surface water profiles from existing HEC-RAS models of the White River to generate power curves for the QUAL2Kw channel geometry.

Ecology used two additional tools to develop the shade inputs for the model: TTools, and the Shade model.

- 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.
    - Ecology updated TTools in 2015 with more modern python code and some additional improved features. This new version was used for inputs to the White River QUAL2Kw model.

- Ecology’s Shade.xlsm model (version 40b04a06; Ecology, 2014) was used to estimate effective shade along the mainstem of the White River.
    - Effective shade was calculated at 10-meter intervals along the streams and then averaged within each model segment 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).
    - Ecology recently updated the Shade model to simulate shade over a 365-day period (previously only 1 day simulation).

Model assumptions

The model makes several assumptions about the system and its inputs including, but not limited to:

General

- The channel is generally well mixed vertically and laterally and can be represented in a one-dimensional model.
- Photosynthesis and respiration from attached benthic algae, or periphyton, are primarily responsible for diel swings in pH in the White River.
- During periods of low flow and turbidity, periphyton is primarily limited by a single limiting nutrient at any given time, either phosphorus or nitrogen, depending on whichever nutrient is currently in the shortest supply relative to the cellular needs of the periphyton.
- Periphyton growth rates, in relation to nutrients, are controlled by intracellular concentrations, not external concentrations in the water column; and internal concentrations can differ from external because periphyton are capable of variable stoichiometry or storing nutrients in excess of needs during periods of increased supply.
- Chronic and acute scour is a significant source of periphyton loss, particularly during rapid and large increases in flow (i.e., runoff events, dam releases).
- Hyporheic flow occurs in all the model reaches.
- Periphyton growth kinetics represented within the calibrated model would be similar under environmental conditions different from the 2012 modeling period (e.g., at lower flows or reduced nutrient loading).

Inputs

- Gaining and losing groundwater reaches could be inferred from the results of flow balances, piezometer temperatures/water levels, and the results of previous studies.
- Water quality samples collected from gaining piezometers are representative of water quality in groundwater discharging to the river.

- Continuous time series of nutrient concentrations for boundary conditions and sources, developed through interpolation between data points or regression with another time series record, are reasonably representative of nutrient loading during periods with no observed data.

Model setup

Ecology set-up the QUAL2Kw model as a continuous model simulating hydraulics, water quality, and periphyton growth for the period of 8/2/2012 to 10/29/12 (89 days) (Table I-74).

Table I-74. QUAL2Kw setup options for the 2012 White River Model.

System ID:		
Month	8	
Day	2	
Year	2012	
Local standard time zone relative to UTC	-8	hours
Daylight savings time	No	
Simulation and output options:		
Calculation step	1.40625	Minutes
Number of days for the simulation period	89	days
Simulation mode	Continuous	
Solution method (integration)	Euler	
Solution method (pH)	Newton-Raphson	
Simulate hyporheic transient storage zone (HTS)	Level 1	
Simulate surface transient storage zone (STS)	No	
Option for conduction to deep sediments in heat budget	Lumped	
State variables for simulation	All	
Simulate sediment diagenesis	No	
Simulate alkalinity change due to nutrient change	Yes	

The model divides the White River into 33 segments of non-uniform length over the course of 28 river miles (~44 km) (Table I-75). Model segments vary in length from 0.9 to 1.7 kilometers, which was dictated by transect locations within the HEC-RAS model. HEC-RAS segments were combined to achieve QUAL2Kw segments with a minimum travel time of ~11 minutes at the model's highest flow. The size of model segments and minimum travel time were optimized to achieve a balance between computational considerations (model run time, numerical stability, etc.) and predictive capabilities (ability to predict important processes, goodness of fit to observed data, etc.).

Ecology combined transect geometry and calibrated roughness coefficients from three separate HEC-RAS models into a HEC-RAS model which covered the extent of the study area and contained the most up to date channel geometry. Outputs from the HEC-RAS model were used to segment the river in the QUAL2Kw model (described below) and develop power rating curves to define the geometry in the QUAL2Kw model (Table I-76).

Table I-75. Model segment lengths, channel slopes, and elevations for the QUAL2Kw model.

Reach Label	Reach Number	Reach length (km)	Channel Slope (m/m)	D/S location (km)	Elevation U/S (m)	Elevation D/S (m)
Headwater	0			44.1		245.1
RS 27.429 - RS 26.677	1	1.6	0.0073	42.6	245.1	233.5
RS 26.443 - RS 25.746	2	1.6	0.0077	41.0	233.5	221.5
RS 25.475 - RS 25.241	3	1.3	0.0067	39.7	221.5	212.8
RS 24.668 - RS 24.247	4	1.5	0.0062	38.2	212.8	203.6
RS 23.742 - RS 22.973	5	1.6	0.0078	36.6	203.6	190.8
RS 22.723 - RS 21.874	6	1.7	0.0078	34.9	190.8	177.4
RS 21.656 - RS 21.025	7	1.3	0.0071	33.6	177.4	168.3
RS 20.864 - RS 20.006	8	1.7	0.0073	31.9	168.3	155.8
RS 19.792 - RS 19.045	9	1.6	0.0073	30.2	155.8	143.9
RS 18.784 - RS 18.069	10	1.5	0.0075	28.7	143.9	132.6
RS 17.85 - RS 17.298	11	1.3	0.0068	27.5	132.6	123.9
RS 17.06 - RS 16.488	12	1.3	0.0064	26.1	123.9	115.3
RS 16.228 - RS 15.61	13	1.4	0.0050	24.7	115.3	108.4
RS 15.361 - RS 14.773	14	1.3	0.0078	23.4	108.4	98.3
RS 14.563 - RS 13.954	15	1.4	0.0045	22.1	98.3	92.1
RS 13.72 - RS 13.408	16	1.3	0.0061	20.7	92.1	84.0
RS 12.891 - RS 12.372	17	1.1	0.0046	19.7	84.0	79.1
RS 12.233 - RS 11.805	18	1.1	0.0056	18.6	79.1	73.2
RS 11.573 - RS 10.725	19	1.6	0.0061	17.1	73.2	62.7
RS 10.596 - RS 10.343	20	0.9	0.0055	16.2	62.7	58.0
RS 10.065 - RS 9.477	21	0.9	0.0047	15.3	58.0	52.3
RS 9.311 - RS 8.269	22	1.9	0.0056	13.3	52.3	41.5
RS 8.111 - RS 7.252	23	1.5	0.0066	11.8	41.5	31.6
RS 7.17 - RS 6.569	24	1.1	0.0015	10.7	31.6	30.0
RS 6.482 - RS 5.92	25	1.3	0.0069	9.4	30.0	22.8
RS 5.822 - RS 5.197	26	1.1	0.0030	8.3	22.8	19.5
RS 5.1420* - RS 4.531(W64)	27	1.2	0.0031	7.1	19.5	15.9
RS 4.406(W63) - RS 3.806(W60B)	28	1.3	0.0005	5.8	15.9	15.3
RS 3.612(W60A) - RS 3.017(W57)	29	1.3	0.0006	4.5	15.3	14.5
RS 2.800(W56) - RS 2.275(W53)	30	1.2	0.0013	3.4	14.5	13.0
RS 2.084(W52) - RS 1.36 (SON)	31	1.2	0.0003	2.2	13.0	12.7
RS 1.34 - RS 0.90 (W45)	32	1.0	0.0009	1.1	12.7	11.8
RS 0.70 (W44) - RS 0.00 (W39A)	33	1.1	0.0025	0.0	11.8	9.0

Table I-76. Power rating curves for velocity and depth developed from combined HEC-RAS transect outputs.

Source	D/S location (km)	HEC-RAS transects included	Length (km)	Min Travel Time (mins)	Velocity		Depth		Vel. R^2	Depth R^2
					b	a	b	a		
NHC	42.6	RS 27.429 - RS 26.677	1.59	15	0.2	0.447	0.458	0.117	0.986	0.997
NHC	41.0	RS 26.443 - RS 25.746	1.56	12	0.2	0.539	0.503	0.104	0.998	0.996
NHC	39.7	RS 25.475 - RS 25.241	1.30	14	0.3	0.311	0.393	0.167	0.999	0.994
NHC	38.2	RS 24.668 - RS 24.247	1.49	17	0.2	0.425	0.506	0.101	0.942	0.996
NHC	36.6	RS 23.742 - RS 22.973	1.64	15	0.2	0.474	0.475	0.103	0.999	0.999
NHC	34.9	RS 22.723 - RS 21.874	1.72	14	0.3	0.449	0.497	0.105	1.000	1.000
NHC	33.6	RS 21.656 - RS 21.025	1.28	12	0.2	0.591	0.378	0.164	0.993	0.995
NHC	31.9	RS 20.864 - RS 20.006	1.73	15	0.2	0.489	0.457	0.123	0.998	0.999
NHC	30.2	RS 19.792 - RS 19.045	1.62	15	0.2	0.699	0.338	0.170	0.988	0.997
NHC	28.7	RS 18.784 - RS 18.069	1.50	13	0.2	0.576	0.413	0.148	0.996	0.997
NHC	27.5	RS 17.85 - RS 17.298	1.27	13	0.2	0.554	0.386	0.138	0.996	0.995
NHC	26.1	RS 17.06 - RS 16.488	1.34	12	0.2	0.667	0.356	0.174	0.994	0.993
NHC	24.7	RS 16.228 - RS 15.61	1.40	13	0.2	0.533	0.443	0.114	0.999	0.995
NHC	23.4	RS 15.361 - RS 14.773	1.28	14	0.2	0.582	0.281	0.212	0.981	0.967
NHC	22.1	RS 14.563 - RS 13.954	1.36	14	0.2	0.421	0.423	0.109	0.994	0.993
NHC	20.7	RS 13.72 - RS 13.408	1.33	16	0.3	0.336	0.371	0.120	0.998	0.998
NHC	19.7	RS 12.891 - RS 12.372	1.06	11	0.3	0.361	0.480	0.095	0.995	0.995
NHC	18.6	RS 12.233 - RS 11.805	1.06	12	0.2	0.552	0.346	0.204	0.990	0.994
NHC	17.1	RS 11.573 - RS 10.725	1.73	17	0.2	0.622	0.338	0.150	0.968	0.977
King	16.2	RS 10.596 - RS 10.343	0.85	12	0.4	0.232	0.296	0.222	0.975	0.895
King	15.3	RS 10.065 - RS 9.477	1.21	15	0.3	0.271	0.125	0.398	0.984	0.992
King	13.3	RS 9.311 - RS 8.269	1.93	14	0.5	0.307	0.124	0.471	1.000	0.999
King	11.8	RS 8.111 - RS 7.252	1.49	13	0.5	0.290	0.162	0.407	0.998	0.998
King	10.7	RS 7.17 - RS 6.569	1.11	12	0.4	0.272	0.216	0.328	0.981	0.996
King	9.4	RS 6.482 - RS 5.92	1.04	13	0.4	0.267	0.243	0.330	0.981	0.973
King	8.3	RS 5.822 - RS 5.197	1.10	14	0.3	0.297	0.351	0.213	0.971	0.897
USGS	7.1	RS 5.1420* - RS 4.531(W64)	1.17	13	0.2	0.365	0.151	0.452	0.990	0.999
USGS	5.8	RS 4.406(W63)- RS	1.28	14	0.4	0.276	0.162	0.504	0.997	0.997
USGS	4.5	RS 3.612(W60A) - RS	1.31	14	0.3	0.315	0.164	0.494	0.997	0.990
USGS	3.4	RS 2.800(W56) - RS	1.15	12	0.3	0.302	0.159	0.538	0.998	0.998
USGS	2.2	RS 2.084(W52) - RS 1.36	1.12	13	0.1	0.467	0.395	0.341	0.981	0.916
USGS	1.1	RS 1.34 - RS 0.90 (W45)	1.03	15	0.0	0.578	0.546	0.339	0.996	0.993
USGS	0.0	RS 0.70 (W44) - RS 0.00	1.08	15	0.0	0.593	0.521	0.310	0.999	0.987

The headwater boundary condition was derived from time series and discrete data collected by Ecology (see Appendix F – 2012 Study Results) and USGS at RM 23.9, downstream of Mud Mountain Dam (Figures I-62 and I-63; Table I-77).

Table I-77. Description of headwater data sources and methods used to generate hourly inputs to model.

Variable	Source	Manipulation	Comments
Flow	USGS	Estimated	USGS flows at RM 23.9 and Lake Tapps diversion canal added together; then 1.5-hour offset applied to estimate RM 28 continuous flow
Temperature	Ecology (ECY)	none	
Conductivity	ECY	Adjusted	Some corrections made based on QC data; Regression with USGS station during data gaps; See Appendix G for further detail.
Inorganic Solids	ECY/ USGS	Regression	ECY TSS = [USGS Turbidity @ RM23.9]^2*0.0087+[USGS Turbidity @ RM23.9]*0.3+7.995; $R^2=0.96$ $p<0.01$; ECY ISS = [ECY TSS]*0.9792-1.0194; $R^2=0.99$ $p<0.01$
Dissolved Oxygen	ECY	Adjusted	Some corrections made based on QC data; Regression with USGS station during data gaps; See Appendix G for further detail.
CBOD slow	ECY	Interpolation	Constant value of 0.5
CBOD fast	ECY	Interpolation	Constant value of 0.5
Organic Nitrogen	ECY	Interpolation	NH3-N (1 ug/L constant) and NO3-N interpolation with diel signal (see below) were subtracted from linear interpolation between Total Persulfate Nitrogen (TPN) data points. Organic N = TPN - NH3N – NO3N
NH3-Nitrogen	ECY	Interpolation	Constant value of 1 ug/L
NO3-Nitrogen	ECY	Interpolation	Daily linear interpolation between afternoon data points; added + 3 ug/L diel signal based on typical diel variation during synoptic surveys.
Organic Phosphorus	ECY	Regression	ECY TP = =3.1547*[USGS Turbidity @ RM23.9)^0.8603; $R^2=0.97$ $p<0.01$ Organic P = TP - SRP
Inorganic Phosphorus (SRP)	ECY	Interpolation	Daily linear interpolation between afternoon data points; added + 0.75 ug/L diel signal based on typical diel variation during synoptic surveys.
Phytoplankton (Chl a)	ECY	Interpolation	Linear interpolation between data points
Detritus (POM)	ECY	Interpolation	Linear interpolation between data points
Alkalinity	ECY	Interpolation	Linear interpolation between data points

Variable	Source	Manipulation	Comments
pH	ECY	Adjusted	Some corrections made based on QC data; Regression with USGS station during data gaps; See Appendix G for further detail.

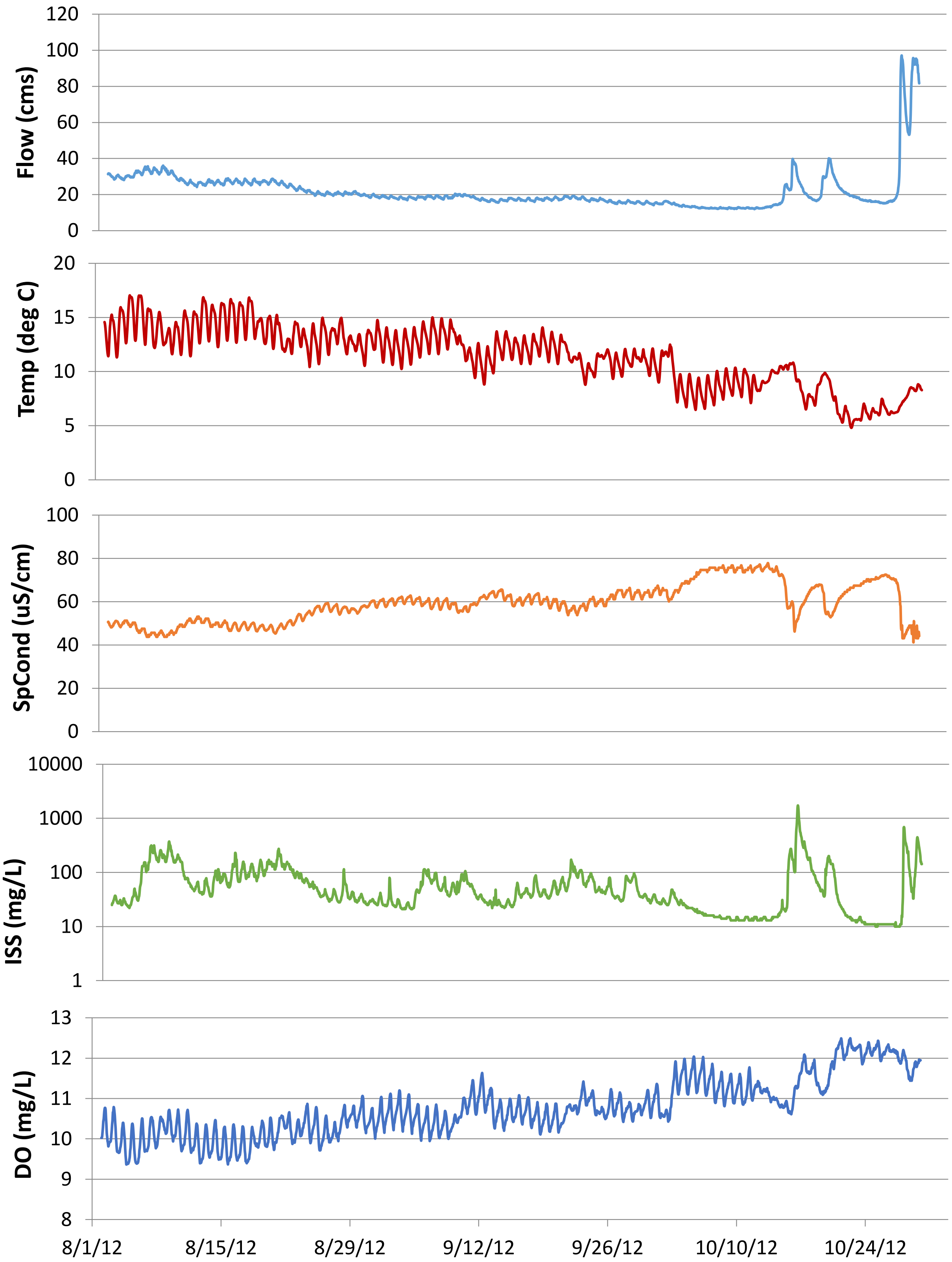

Figure I-62. Flow, temperature, specific conductance, ISS, and DO headwater inputs to the model.

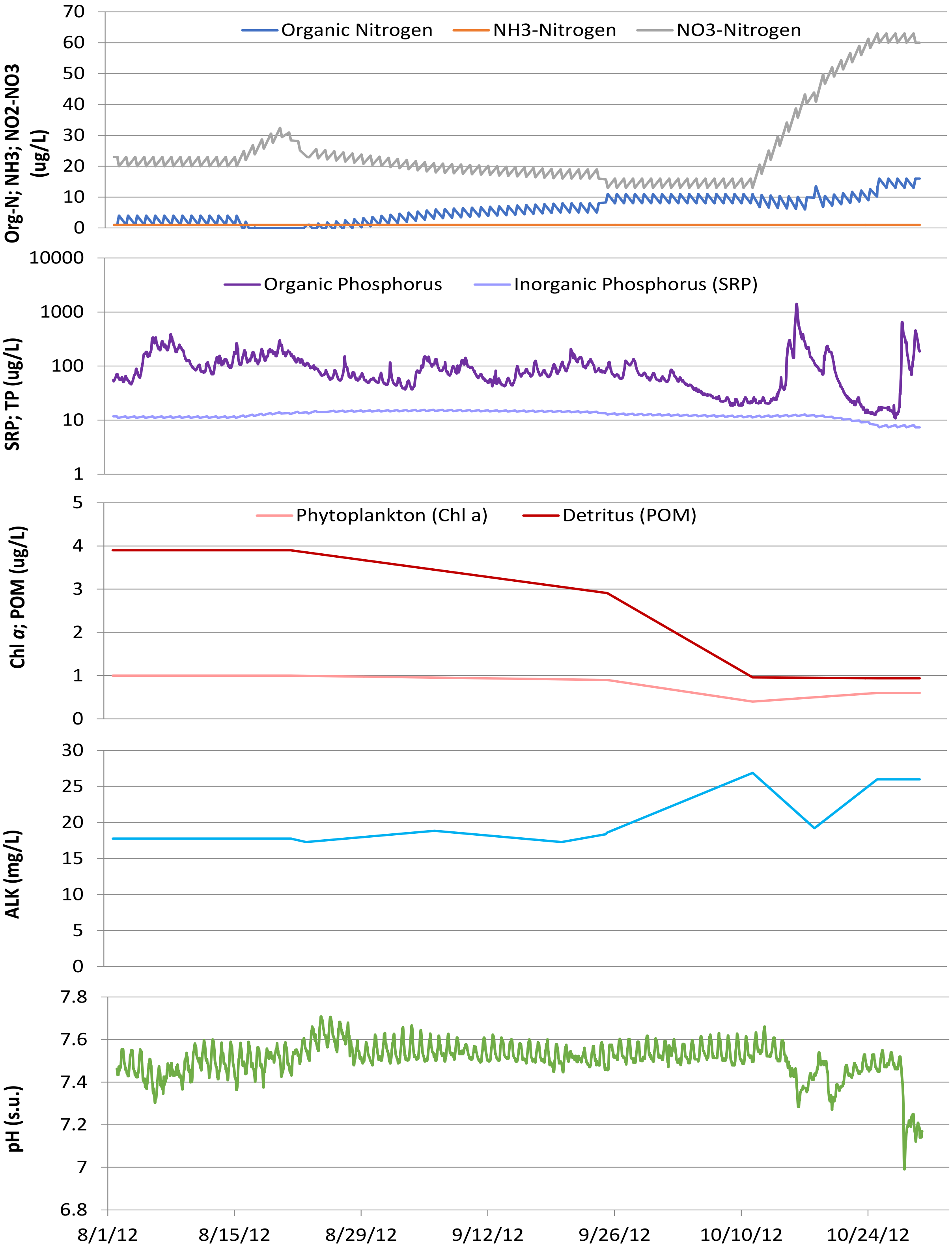

Figure I-63. Nitrogen, phosphorus, chlorophyll *a*, POM, alkalinity, and pH headwater inputs to the model.

Significant inputs and abstractions (Table I-78) within the model were represented in the continuous sources worksheet and included:

- Gaining groundwater input in 24 model segments (Reach 1-3, 5-20, 29-33). Appendix C describes the methodology for developing groundwater inputs in detail.
- Losing to groundwater in 8 segments (Reach 21-28).
- Tributary (surface water) inputs in 11 segments (Reach 1, 3, 5, 6, 13, 14, 23, 26, 28, 30, and 32).
- Abstraction (withdrawal) in one segment (Reach 4), which is the combined effect of the Lake Tapps diversion canal/dam and the White River Fish Hatchery withdrawal.
- Municipal wastewater treatment facilities for the cities of Enumclaw and Buckley (Reach 5 and 6).
- An industrial recycled paper processing facility with treated wastewater, Sonoco Products (Reach 31).
- The White River Hatchery; owned and operated by the Muckleshoot Indian Tribe (Reach 5).

Where possible, continuous inputs represented actual time series data collected during the study. For parameters or locations where only limited discrete data were collected, a continuous time series record was created based on one of three methods of estimation: 1) linear regression with another location or parameter with continuous data available, 2) linear interpolation between data points, 3) the average value of the discrete data.

Table I-78. Inflows and abstractions in the 2012 White River QUAL2Kw model.

Reach Number	Inflow Source#1	Inflow Source#2	Inflow Source#3	Inflow Source#4	Inflow Source #5	Abstraction
1	GW	Red Ck.				
2	GW					
3	GW			SW25.1		
4						Hatchery pump + Lake Tapps Diversion
5	GW	Boise Ck.	ECWWTP	MFH		
6	GW	LTD-Fish	BKWWTP			
7	GW					
8	GW					
9	GW					
10	GW					
11	GW					
12	GW					
13	GW	TR15.7				
14	GW	TR15.6				
15	GW					
16	GW					
17	GW					
18	GW					
19	GW					
20	GW					
21						Losing GW
22						Losing GW
23		Bowman				Losing GW
24						Losing GW
25				SW6.2		Losing GW
26		Government Canal				Losing GW
27						Losing GW
28		TR4.3			LTD-Tail	Losing GW
29	GW			SW3.3		
30	GW	Salmon Ck.			TR2.6	
31	GW		Sonoco			
32	GW	Milwaukee Ditch		SW0.9		
33	GW					

GW = groundwater; WWTP = wastewater treatment plant; SW= stormwater; MFH = Muckleshoot Fish Hatchery; LTD = Lake Tapps Diversion; TR =Tributary

Ecology used meteorology time series data from various external sources, as described in Table I-79. In general, air and dew point temperature data were interpolated for each model reach using continuous data from the primary locations in Ecology's network of loggers deployed during the 2012 study. For Wind Speed, Cloud Cover, and Solar Radiation the continuous data from a primary source was used for all model reaches, with the exception of solar radiation (see discussion of temperature calibration).

Supplementary data sources were primarily used to verify the general accuracy of the primary data and were occasionally used to fill or regress small data gaps.

Table I-79. Meteorological Data Sources Used to Develop Inputs to the QUAL2Kw model.

Station ID	Location	~Latitude	~Longitude	~Elevation (m)	Network	Air Temperature	Dew Point	Wind Speed	Cloud Cover	Solar Radiation
ENCW1	Enumclaw	47.22	-121.96	230	RAWS	S	S	S		S
KTCM	McChord Air Base	47.15	-122.48	98	NWS/FAA	S	S	S	P	
WSU-Puyallup	Puyallup	47.19	-122.33	10	AgWeatherNet	S	S	P		P
10-WHT-28	Below MM Dam	47.15	-121.95	245	ECY/TMDL	P	P			
WHI25.2	Above Diversion	47.17	-121.99	215	ECY/TMDL	S				
WHI20.4	Below Buckley	47.19	-122.07	160	ECY/TMDL	P	P			
10-WHT-16.2	Above MIT	47.23	-122.11	110	ECY/TMDL	P	P			
10-WHT-8.5	Game Farm Park	47.28	-122.19	45	ECY/TMDL	P	P			
WHI06.3	Auburn River HS	47.27	-122.23	25	ECY/TMDL	P	P			
10-WHT-4.0	Below of 16th St E	47.24	-122.23	16	ECY/TMDL	P				
WHI03.7	Above Tailrace	47.24	-122.23	15	ECY/TMDL	P				
10-WHT-1.4	Above Fryar Ave	47.21	-122.24	13	ECY/TMDL	P				
10-WHT-0.1	Just above mouth	47.20	-122.25	10	ECY/TMDL	P	P			

P= Primary Data Source; S= Supplementary Data Source; NWS/FAA = National Weather Service/Federal Aviation Administration; RAWS= Interagency Remote Automatic Weather Stations (Bureau of Land Management and WA Department of Natural Resources).

Shade input data was derived using the ArcGIS extension “TTools” and Ecology’s Shade.xlsm model. Near-stream vegetation cover, along with channel morphology and stream hydrology, represent the most important factors that influence stream temperature. To obtain a detailed description of existing riparian conditions in the White River basin, a combination of GIS analysis, interpretation of aerial photography, and hemispherical photography was used.

A GIS coverage of riparian vegetation in the study area (Figure I-64) was created from:

- Field notes and measured tree heights collected during riparian surveys Ecology conducted as part of the 2012 study.
- Analysis of the color digital aerial ortho-photos from 2011 and 2012.
- Analysis of LIDAR (first return minus bare earth) data collected by King County.

Polygons representing different vegetation types were mapped within a 300-foot buffer on either side of the river at a 1:2000 scale using GIS. Riparian vegetation was classified into vegetation categories (Table I-80). Each vegetation category was assigned three characteristic attributes: maximum height, average canopy density, and streambank overhang. The process for developing these attributes was:

1. Start with the values used for these categories in other western Washington temperature TMDLs.
2. Compare side-by-side LIDAR tree heights with field measurements of tree heights from the 2012 study to establish general comparability.
3. Adjusted tree heights for each category, based on typical heights obtained from sampling the LIDAR tree heights of visible tree crowns within polygons assigned to that category.
4. Adjusted overhang values based on typical overhangs measured in aerial photography.
5. Kept generic density values from other studies as these are bins to classify vegetative polygons into based on visual assessment of stand density in aerial photos.

After the vegetation polygons were delineated, a longitudinal profile of the White River was created by sampling information along the right and left banks of the stream at 10-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 10-meter interval using a digital elevation model (DEM).

The output from TTools was then used as an input into Ecology's Shade model (Ecology, 2008) to estimate effective shade along the White 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 from 10m intervals was then averaged within each model reach for input into the QUAL2Kw model.

The updated version of the Shade model is capable of simulating effective shade for a period of up to one year; however, it only allows for one fixed set of wetted widths. Given that the flow and wetted width are fairly variable over the modeling period, Ecology broke the modeling period down into eight periods with similar flow and created a shade model with flow specific wetted width for each of the eight periods (Table I-81).

Table I-80. Vegetation codes, heights, densities, and overhang values.

Numeric Code in Shade Model	Description	Height (m)	Density (%)	Overhang (m)	Frequency of Occurrence
112	coniferous, small, dense	15.0	75%	1.5	0.1%
122	coniferous, medium, dense	45.0	75%	4.5	0.1%
210	deciduous, small, moderate	15.0	50%	3.0	0.5%
211	deciduous, small, sparse	18.0	25%	2.7	0.2%
212	deciduous, small, dense	21.0	75%	3.2	7.8%
221	deciduous, medium, sparse	37.0	25%	5.6	0.4%
222	deciduous, medium, dense	37.0	75%	5.6	2.8%
223	deciduous, medium, dense (alder)	30.0	75%	4.5	1.0%
312	mixed, small, dense	21.0	75%	1.9	3.0%
321	mixed, medium, sparse	23.0	25%	2.0	16.5%
322	mixed, medium-large, dense	37.0	75%	4.6	1.5%
323	mixed, medium, dense	28.0	75%	3.5	18.3%
332	mixed, large, dense	45.0	75%	5.6	0.4%

Numeric Code in Shade Model	Description	Height (m)	Density (%)	Overhang (m)	Frequency of Occurrence
400	riparian scrub/shrub	2.0	75%	0.2	6.6%
401	scrub/shrub upland	2.0	25%	0.2	3.1%
402	riparian tall shrub/small trees	4.5	75%	0.4	16.6%
500	grass/rush/sedge riparian	0.5	75%	0.1	2.8%
600	barren/lawn	0.0	100%	0.0	15.4%
700	Impervious/open water	0.0	100%	0.0	3.1%

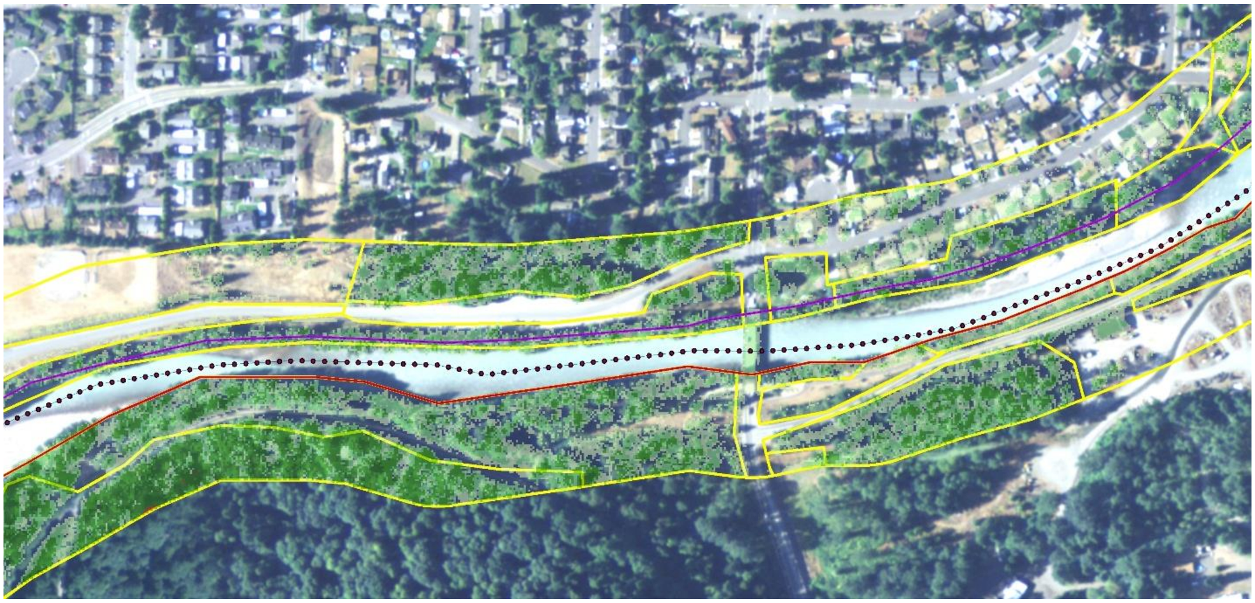

Figure I-64. Example of digitized riparian vegetation polygons with LIDAR data.

Table I-81. Shade model date ranges and associated streamflow values.

Date Range	Days	Average Flow (cfs)	Median Flow (cfs)
Aug 2 -23	22	912	878
Aug 24 - Sept 25	33	590	585
Sept 26 - Oct 14	19	462	450
Oct 15 -17	3	875	754
Oct 18	1	590	590
Oct 19 - 21	3	944	851
Oct 22 - 27	6	598	580
Oct 28 - 29	2	2780	2780

In general, Ecology used default rates, constants, kinetics and options for the initial model setup and systematically adjusted these variables during model calibration. In a few cases, Ecology made alterations prior to calibration including:

- The hyporheic transient storage zone was turned on to simulate potential effects of the hyporheic zone. The results of previous studies, coarse nature of the alluvial substrate, and field observations suggested that hyporheic flow was likely present throughout the study reach, particularly in the middle reaches of the study area. Table I-82 contains parameters used for the hyporheic zone.

- The background (ke_b) and ISS (k_i) light extinction rates (Table I-83) were altered based on rates calculated from the light extinction surveys. These parameters were determined based on the linear regression (r^2=0.98) between light extinction coefficients and ISS sample results collected in the fall (late September to late October). Using all results (including summer) the regression was much weaker (r^2=0.55) and resulted in a relatively high value of ke_b (1.8/m), compared to the default value. Figure I-65 depicts the regression used. ke_b was increased to the whole number of 1/m in the model, based on the higher value from summer surveys and discussion with other Ecology modelers about background extinction in other water bodies.
- Initial periphyton biomass was set to levels observed in the August synoptic survey.

Table I-82. Thermal and hyporheic properties for the hyporheic transient storage zone for the QUAL2Kw model.

Reach Number	Sediment and hyporheic transient storage (HTS) zones					
	Sediment thermal conductivity (W/m/ degC)	Sediment thermal diffusivity (cm^2 /sec)	Sediment/ hyporheic zone thickness (cm)	Hyporheic Flow fraction (unitless)*	Hyporheic sediment porosity (fraction of volume)	Deep sediment temperature below sediment/HTS (deg C)
1 – 4	1.6	0.0064	25	0.05	0.4	10
5 – 22	1.6	0.0064	50	0.15	0.4	10
23 - 33	1.6	0.0064	25	0.05	0.4	10

* Parameter for diffusive exchange

Table I-83. Non-default light extinction rates for the QUAL2Kw model.

Parameter	Term	Value	Unit
Background light extinction	ke_b	1	*/m*
ISS light extinction	k_i	0.065	*1/m-(mg ISS/L)*

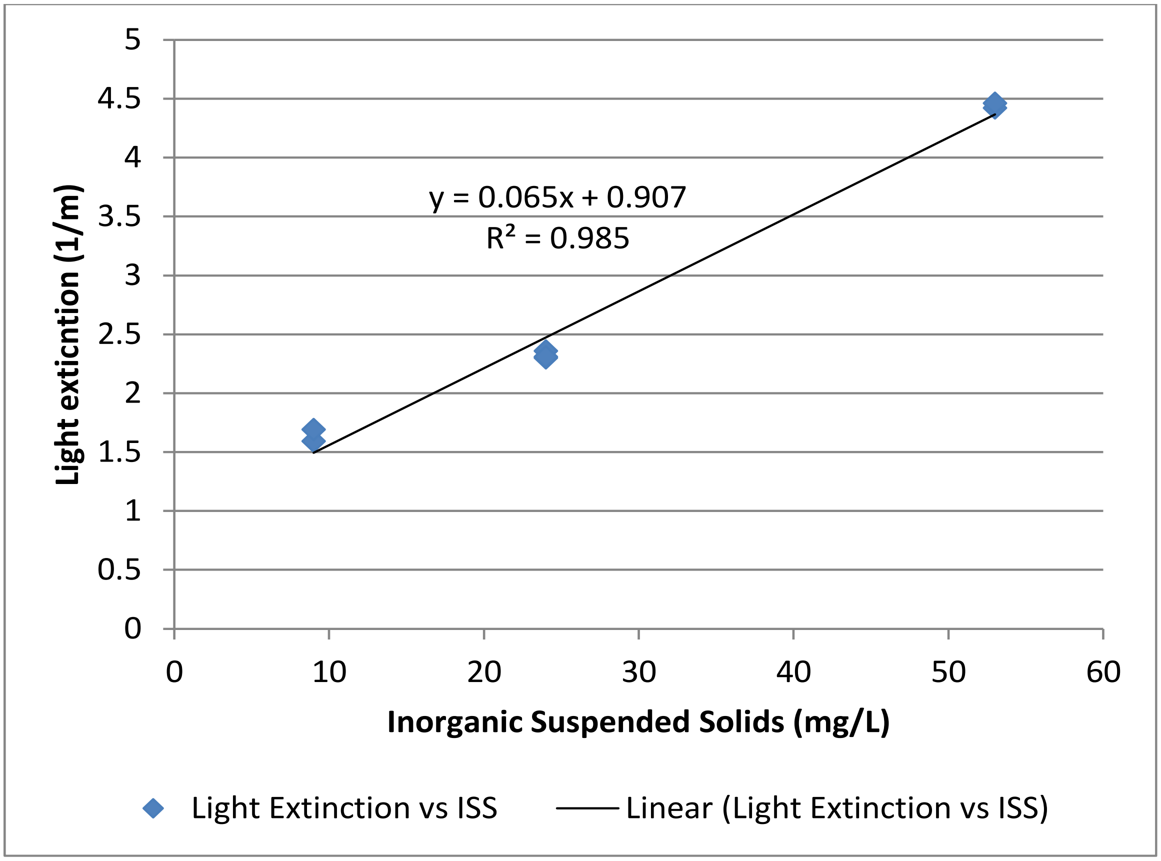

Figure I-65. Linear regression of light extinction and ISS for fall samples collected from 9/27/12 to 10/25/12.

Model calibration

Hydraulics calibration

Given that each of the three HEC-RAS models had undergone a thorough calibration process, additional calibration of the combined model did not prove necessary. Ecology evaluated the performance of the combined model to confirm that further calibration was not necessary by comparing model predicted water surface elevations to observed USGS gage water surface elevations.

Although the HEC-RAS models were calibrated for flood conditions, the low-flow channel roughness coefficients appear to be well calibrated (less than 10% of depth at low flows), based on the relatively small absolute differences between measured and predicted water levels. Table I-84 presents the modeled water elevations in comparison to water surface measurements collected from three USGS stations in the critical stretch of the river from Auburn to Sumner. USGS measurements were collected in the NGVD 1929 vertical datum. Ecology converted to NGVD 1988 datum for comparison with HEC-RAS predictions using a datum shift of ~3.5 feet calculated using NOAA's National Geodetic Survey (NGS) Orthometric height conversion tool[24].

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[24] http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl

Table I-84. Comparison of modeled HEC-RAS water elevations to measured USGS elevations.

Date & Time	Station	Flow (ft^3/s)	NGVD29 gage (ft)	NGVD88 gage (ft)	HEC-RAS elev. (ft)	ABS Diff elev. (ft)
08/06/2012 07:00 PDT	W7.6	1,300	111.1	114.6	114.6	0.05
08/10/2012 18:15 PDT	W7.6	1,000	110.7	114.3	114.3	0.07
08/25/2012 22:45 PDT	W7.6	700	110.3	113.8	114	0.125
10/03/2012 22:15 PDT	W7.6	499	110	113.5	113.5	0.01
10/28/2012 02:00 PDT	W7.6	1,600	111.3	114.8	114.9	0.08
10/28/2012 05:30 PDT	W7.6	3,500	112.4	115.9	116.4	0.425
10/28/2012 21:45 PDT	W7.6	2,200	111.7	115.2	115.4	0.18
	W7.6	300		112.9	113	0.087
Median =						**0.083**
08/06/2012 07:00 PDT	W6.2	1,300	79.79	83.31	84.09	0.78
08/10/2012 18:15 PDT	W6.2	1,000	79.44	82.96	83.46	0.5
08/25/2012 22:45 PDT	W6.2	700	79.07	82.59	82.77	0.18
10/03/2012 22:15 PDT	W6.2	499	78.66	82.18	82.22	0.04
10/20/2012 09:00 PDT	W6.2	1,490	80.03	83.55	84.47	0.92
10/30/2012 23:00 PDT	W6.2	3,510	82.96	86.48	87.32	0.84
	W6.2	300		81.64	81.53	0.109
Median =						**0.5**
10/20/12 15:30	W4.9	1,300	59.53	63.04	62.89	0.15
10/17/12 4:00	W4.9	1,000	59.16	62.67	62.43	0.24
10/18/12 3:30	W4.9	700	58.69	62.2	61.91	0.285
10/03/2012 22:15 PDT	W4.9	499	58.27	61.78	61.49	0.29
10/28/2012 02:00 PDT	W4.9	1,600	59.57	63.08	63.3	0.22
10/28/2012 05:30 PDT	W4.9	3,500	61.6	65.11	65.34	0.23
10/28/2012 21:45 PDT	W4.9	2,200	60.62	64.13	64.06	0.07
	W4.9	300		61.16	60.97	0.185
Median =						**0.225**

Ecology next compared predicted time of travel data in QUAL2Kw with observed time of travel data from the two dye studies, to assess the quality of the geometry obtained from the HEC-RAS model. Originally, the QUAL2Kw geometry was calibrated by applying a set of multipliers to velocity and depth coefficients, in order to optimize the fit with the observed time of travel data. During temperature calibration, an issue with some of the depth rating curves from HEC-RAS was discovered and fixed. The coefficient multipliers were adjusted (QUALK2w geometry was recalibrated) using the updated depth curves.

For the August 2012 survey (1,030 to 1,280 cfs flow range), the average absolute difference between the calibrated, predicted time of travel and the observed time of travel in the model was 10 minutes (~3% of observed), with a range of 4 to 12 minutes (Figure I-66). For the October 2013 survey (540 to 615 cfs flow range), the average absolute difference of predicted vs observed time of travel in the model was 17 minutes (~4% of observed), with a range of 3 to 47 minutes (Figure I-67). Within the model, the October 2013 dye release was simulated on 9/18/12 to 9/19/12 (517 to 612 cfs flow range).

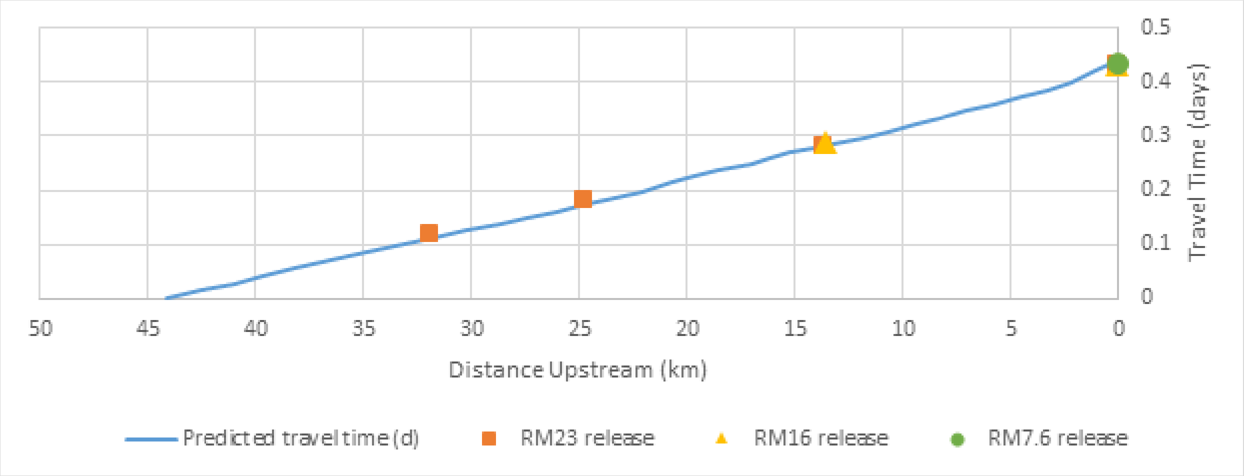

Figure I-66. August 8th, 2012, dye release.

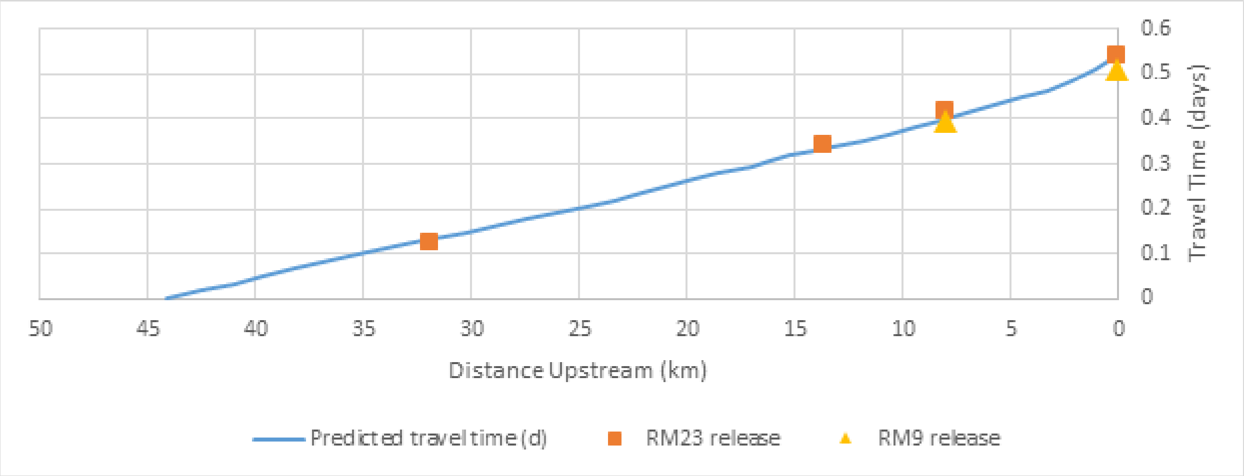

Figure I-67. October 28th, 2013, dye release, simulated in the model on September 18th, 2012.

Temperature calibration

After Ecology completed calibration of the hydraulics and channel geometry, the initial goodness of fit for temperature was calculated using the root mean squared error (RMSE), as a measure of unbiased overall error, and the average difference between predicted and observed values, as a measure of the bias (hereafter referred to as just bias) (Table I-85). Error statistics were calculated on an hourly basis throughout the 89-day modeling period and represent a comprehensive goodness of fit for the diel cycle and multiple temperature regimes within the model period, rather than an evaluation of daily max/min/mean during critical conditions. In some reaches this represented the entire modeling window, while others had some data gaps.

The initial average RMSE for all evaluated reaches, prior to temperature calibration, was 0.74°C and the average bias was -0.56°C. Results of other modeling efforts suggest this would generally be considered an acceptable level of model skill for this type of application (Sanderson and Pickett, 2014). This initial level of fitness suggests relatively high quality for both the channel geometry obtained from the HEC-RAS model and the input data used in the QUAL2Kw model.

Table I-85. Pre-calibration error statistics for temperature in the QUAL2Kw model.

Reach	~RM	RMSE	BIAS	Reach	~RM	RMSE	BIAS
3	25	0.15	-0.02	23	8	0.80	-0.70
8	20	0.37	-0.30	25	6	0.83	-0.64
13	16	0.66	-0.57	28	4	0.97	-0.67
21	10	n/a	n/a	31	1.5	1.09	-0.85
22	9	0.88	-0.69	33	0	0.87	-0.61
					Average =	**0.74**	**-0.56**

Additional parameters were adjusted, and evaluations made to improve the temperature fitness. These measures included:

- Adjusting groundwater temperatures:
    - Ecology originally used groundwater temperatures from the lowest thermistor of the closest piezometer to a given model reach; however, during periods with very cold stream temperatures, piezometer temperatures were mimicking the stream temperatures and dropping below the typical groundwater temperatures;
    - During periods where the stream was colder than the piezometer, Ecology used a minimum groundwater input temperature of 11°C (based on regional groundwater monitoring) to address this issue.
- Recalculating depth rating curves:
    - While investigating the channel depth as a possible source of error/bias, Ecology noticed the coarser model geometry was biased deeper than the finer scale geometry from HEC-RAS, particularly from ~RM 10 to 28.
    - Ecology discovered that the original method used for calculating depths for combined segments resulted in an overall increase in average depth. The original method was to divide the sum of the segment volumes by the sum of the segment surface areas. It is unclear, but the bias may have been caused by the method by which HEC-RAS calculates volume and surface area.
    - To fix the problem, Ecology recalculated depths by weighting an average depth for a combined segment based on the length of each segment. For example, if two segments (A & B) were combined and Segment A was 400 meters long with a depth of 0.6 meters and Segment B was 600 meters long with a depth of 0.4 meters, the weighted depth of the combined segment was calculated as (0.6*(400/1000)) + (0.4*(600/1000)) = 0.48 meters.
    - The new depth rating curves had, in general, much smaller residuals and larger R-squared values. They also resulted in a significant improvement in both RMSE and Bias.

- Switching to Brutsaert longwave radiation:
    - Ecology switched from the Brunt (default) to the Brutsaert model for longwave emissivity using the default coefficient of 1.24. The Brutsaert model is recommended in systems with a wide range of atmospheric conditions, which is appropriate for the Lower White River during the modeling period, which had a large range in air and stream temperatures, cloud cover, and solar radiation (Table I-86).
- Adjusting hyporheic flow parameters:
    - Ecology increased hyporheic zone thickness from 10 to 50 cm and flow fraction from 0.05 to 0.15 in the middle-braided section of the river from ~RM 20 to 9. Predictably, increasing hyporheic flow improved RMSE (narrowed diel ranges), but displayed little effect on bias.
- Increasing K_{brut} (emissivity parameter):
    - Ecology increased the emissivity coefficient from 1.24 (default) to 1.31 (recommended for dry season based on Sridhar and Elliot (2002) and Culf and Gash (1993)).

Table I-87 contains the progressive model skill results throughout the temperature calibration process. Model skill improved significantly during calibration with a final average RMSE of 0.38°C and average bias of -0.02°C.

Table I-86. Selected (non-default) terms in 'Light and Heat'

Category	Model parameter	Setting
Solar shortwave radiation	Atmospheric attenuation model for solar	Observed
Downwelling atmospheric longwave IR radiation	Atmospheric longwave emissivity model	Brutsaert
Downwelling atmospheric longwave IR radiation	Brutsaert longwave emissivity parameter (k_{brut}) (only used if Brutsaert longwave model is selected)	1.31

Table I-87. Progressive model skill results throughout the temperature calibration of the 2012 QUAL2Kw model.

		V5_4b (increased groundwater temps)		V5_4d updated depth curves		V5_4e switched to Brutsaert longwave		V5_4f + Hyporheic; recalibrate geometry		V5_4g + k_{brut} to 1.31 (final calibration)	
Reach	**~RM**	**RMSE**	**BIAS**	**RMSE**	**BIAS**	**RMSE**	**BIAS**	**RMSE**	**BIAS**	**RMSE**	**BIAS**
3	25	0.17	-0.01	0.21	-0.01	0.2	0.02	0.2	0.02	0.19	0.04
8	20	0.34	-0.24	0.42	-0.21	0.38	-0.1	0.26	-0.09	0.24	-0.04
13	16	0.59	-0.5	0.6	-0.42	0.5	-0.28	0.4	-0.25	0.36	-0.19
21	10	NC	NC	NC	NC	NC	NC	0.49	-0.05	0.50	-0.08
22	9	0.76	-0.6	0.77	-0.43	0.63	-0.17	0.46	-0.10	0.46	-0.03
23	8	0.7	-0.62	0.7	-0.43	0.57	-0.2	0.41	-0.14	0.39	-0.03
25	6	0.7	-0.55	0.68	-0.36	0.55	-0.13	0.39	-0.06	0.39	-0.05
28	4	0.83	-0.58	0.78	-0.4	0.62	-0.15	0.44	-0.08	0.41	0.04
31	1.5	0.93	-0.7	0.82	-0.5	0.63	-0.19	0.41	-0.11	0.37	0.03
33	0	0.76	-0.52	0.69	-0.33	0.58	-0.08	0.46	-0.02	0.49	0.09
Average =		**0.64**	**-0.48**	**0.63**	**-0.34**	**0.52**	**-0.14**	**0.39**	**-0.09**	**0.38**	**-0.02**

NC = not calculated; temperature data from MIT was finalized and incorporated into model calibration between V5_4e and V5_4f model versions.

Figure I-68 depicts visual goodness of fit to observed data for longitudinal temperature for 8/20/12, during the warmest period of the summer.

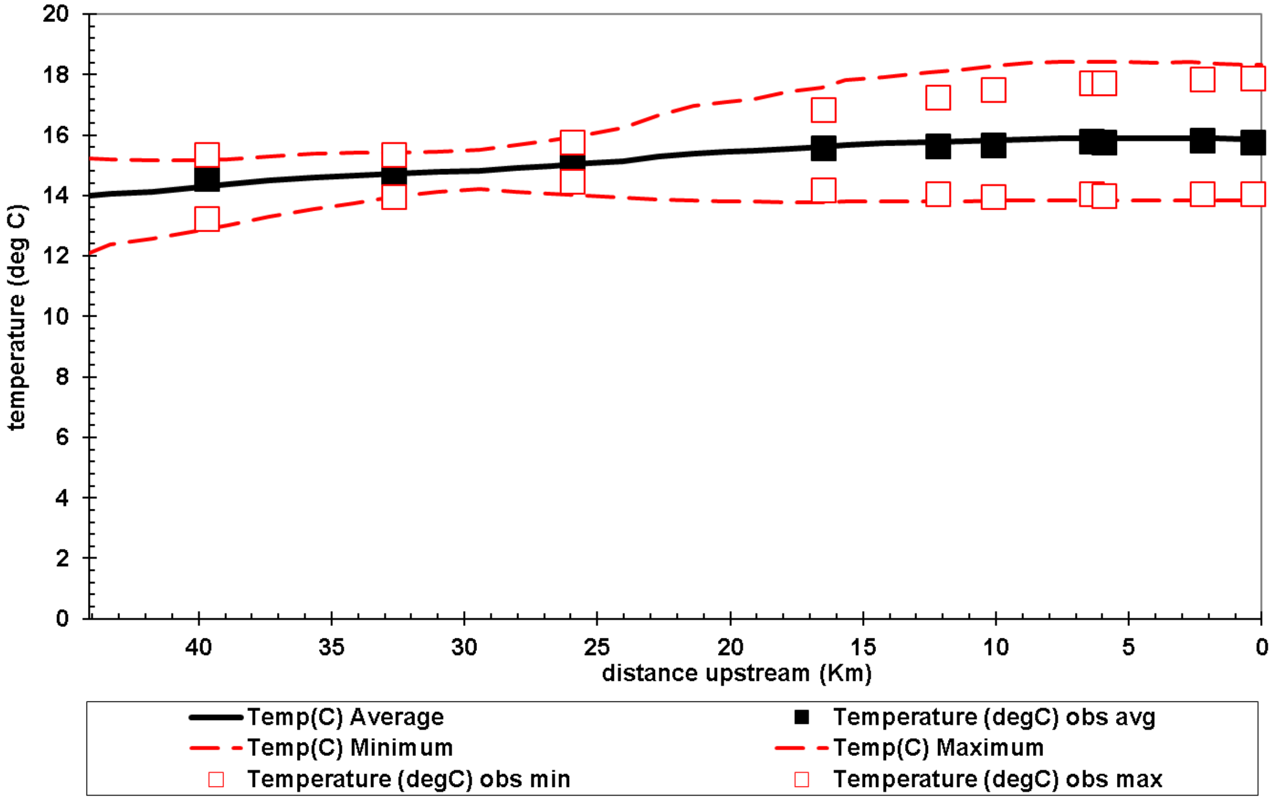

Figure I-68. Longitudinal temperature profile for 8/20/12 in the calibrated 2012 QUAL2Kw model.

Visual evaluation of initial temperature predictions revealed a significant negative bias in the model predictions compared to observed data during the early October survey (Figures I-69 and I-70). Further investigation revealed there was a discrepancy between weather data and observations collected in Tacoma/SeaTac/Puyallup (west end of study area and closer to Puget Sound) and Enumclaw/Buckley (east side of study area). The model was using cloud cover and solar radiation from the western stations, which had cloudy/foggy conditions with little solar input in early October, particularly during the mornings. Solar radiation and observational data collected in Enumclaw showed that the eastern watershed was much clearer/sunnier during this time frame, particularly in the morning.

The model was adjusted by using separate solar inputs for the eastern and western portions of the watershed. The result was significant improvement in the goodness of fit for temperature in early October (Figures I-71 and I-72).

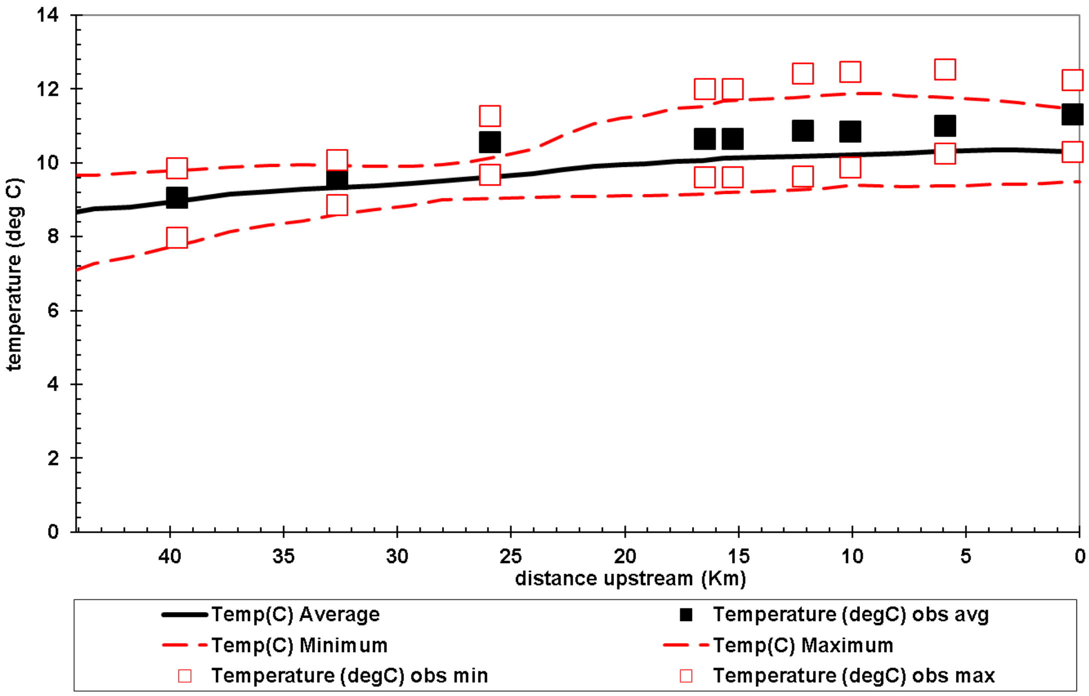

Figure I-69. Longitudinal temperature profile for 10/11/12, prior to observed solar radiation adjustment.

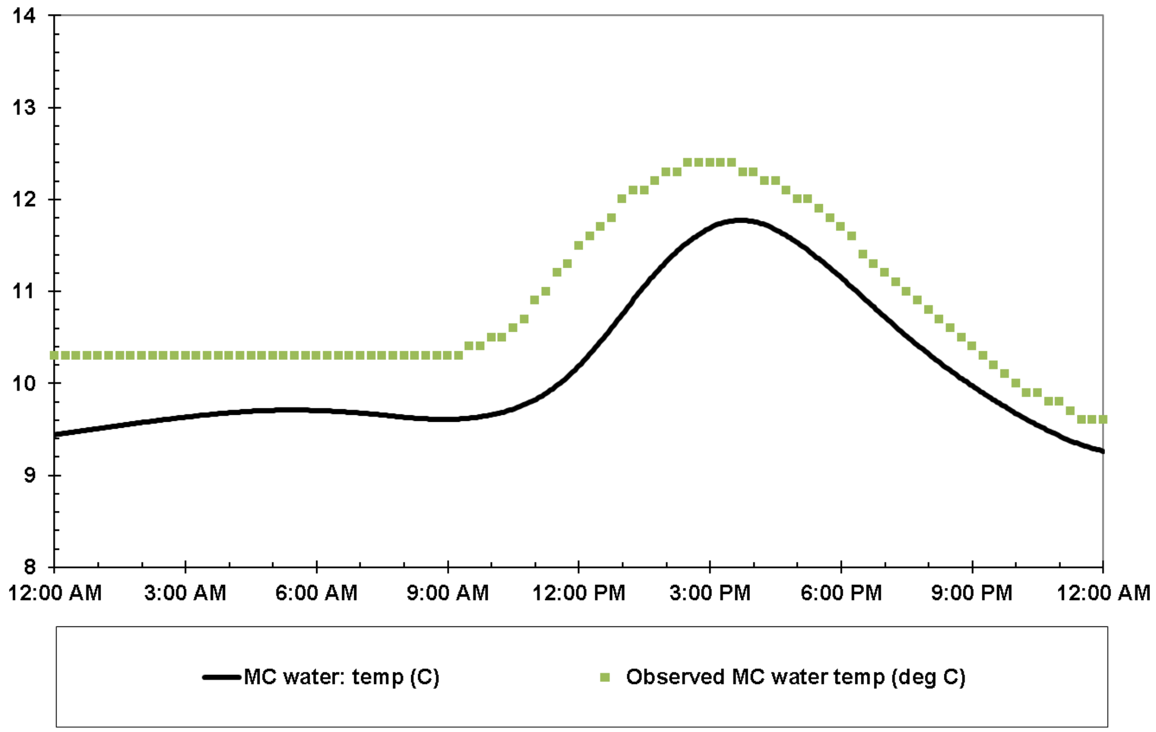

Figure I-70. Diel temperature for 10/11/12, prior to observed solar radiation adjustment.

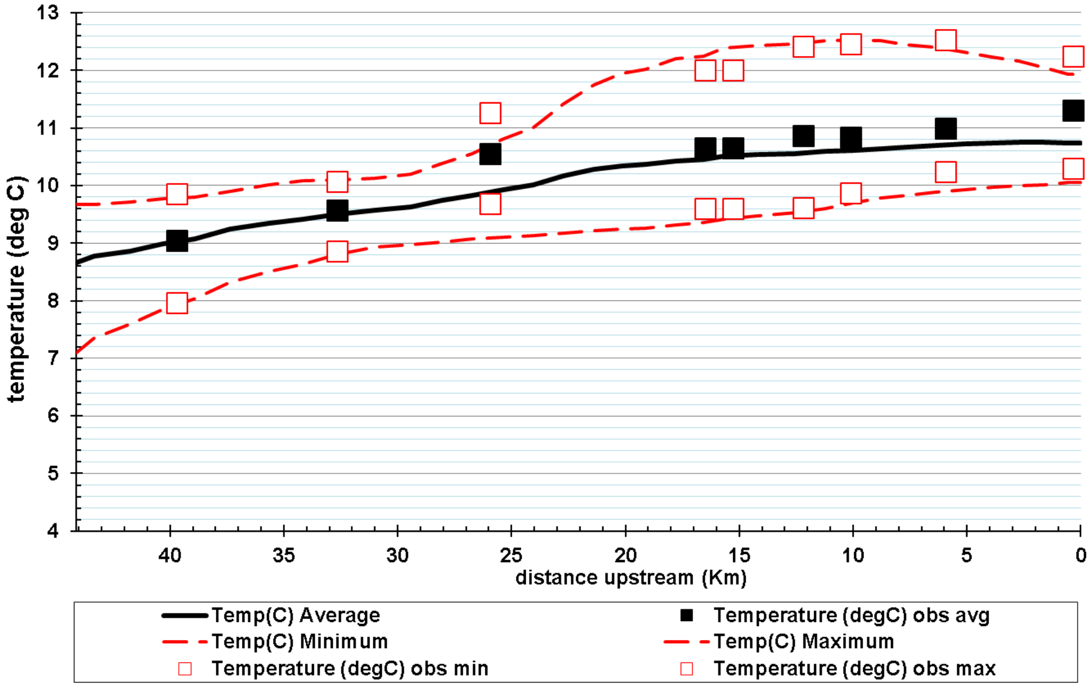

Figure I-71. Longitudinal temperature profile for 10/11/12, after observed solar radiation adjustment.

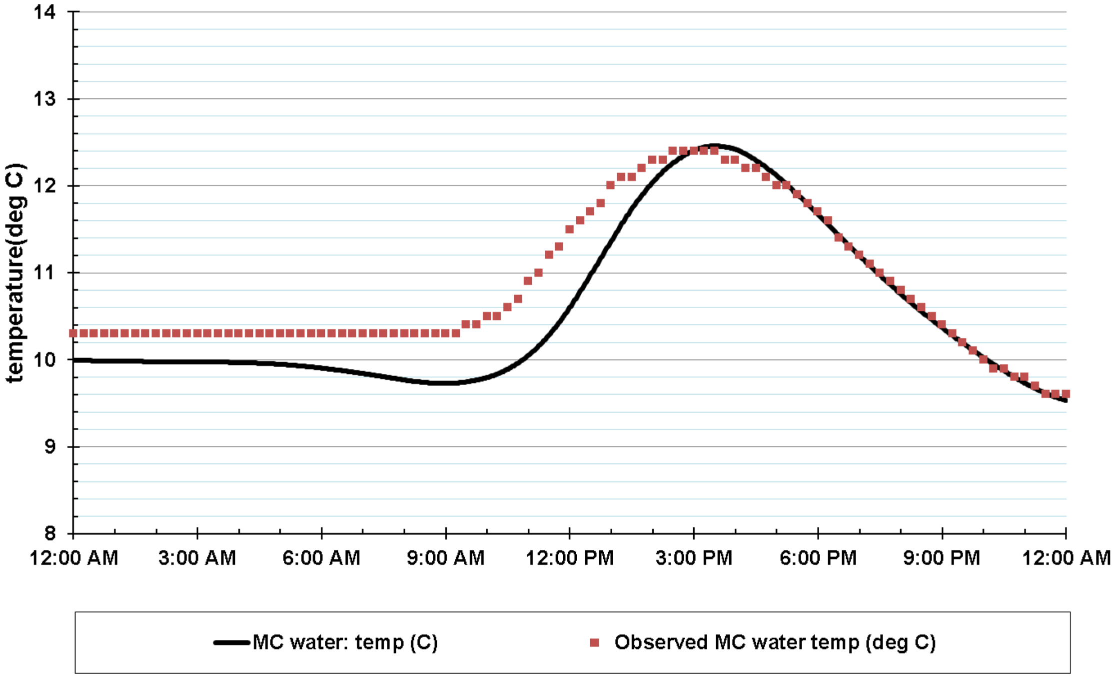

Figure I-72. Diel temperature for 10/11/12, after observed solar radiation adjustment.

Overall, the model describes the temperature regime of the Lower White River well, including diel fluctuations and periods of erratic temperature change (Figure I-73).

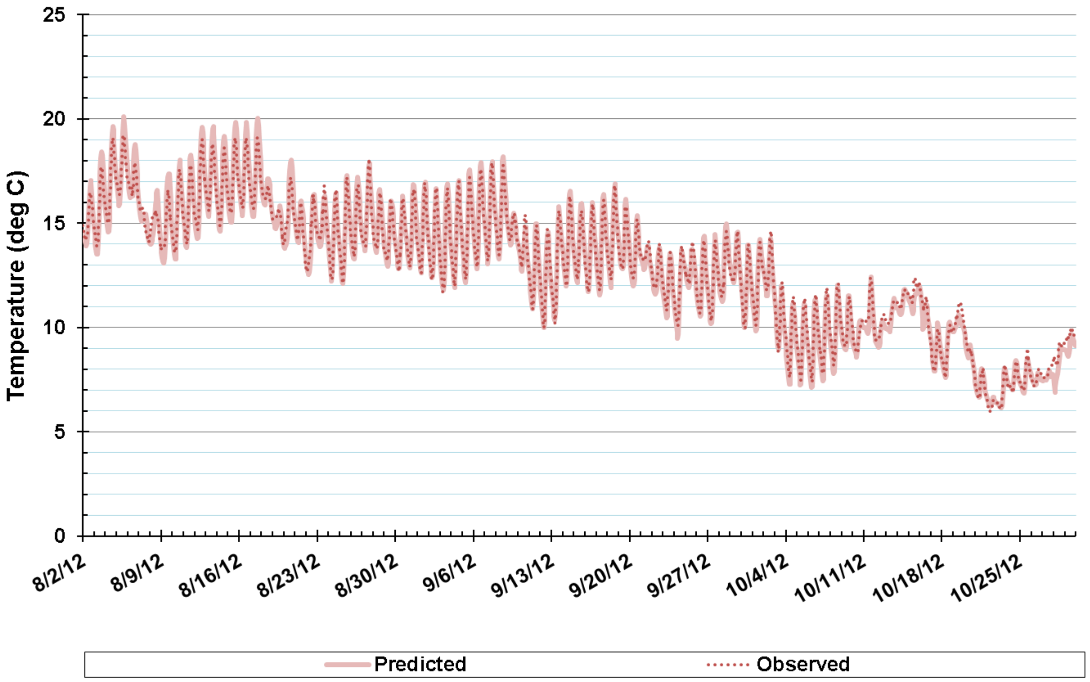

Figure I-73. Dynamic temperature goodness of fit for the calibrated model at Reach 23 (observed data from RM 7.6).

Calibration of pH, nutrient, bottom algae, and other water quality parameters

Ecology began calibration of water quality parameters by adjusting the ISS settling velocity, within the range of literature values, to optimize goodness of fit to observed ISS data. Given the wide range and dynamic nature of the ISS data, it was difficult to match both high and low ISS data with one settling range. Ecology optimized the settling rate for goodness of fit with the low ISS condition, as this represents a more critical condition for algal growth and pH in the river. The RMSE for all observed vs. predicted TNVSS (ISS) data collected during the study was 13.9 ug/L with a bias of -3.1 ug/L. For low ISS conditions (<20 ug/L), the RMSE was 2.9 ug/L with a bias of 0.2 ug/L. Figures I-74 and I-75 depict goodness of fit for dynamic TSS and ISS predictions in Reach 23 compared to data from RM 7.6.

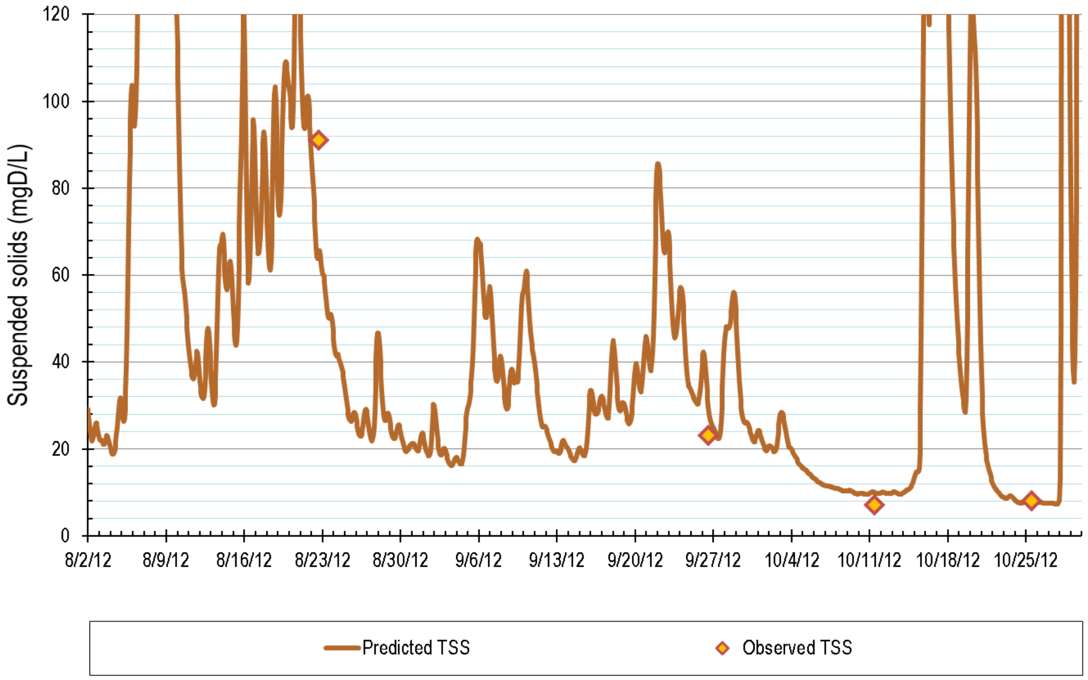

Figure I-74. Dynamic model predicted total suspended solids for Reach 23 vs. observed data from RM 7.6.

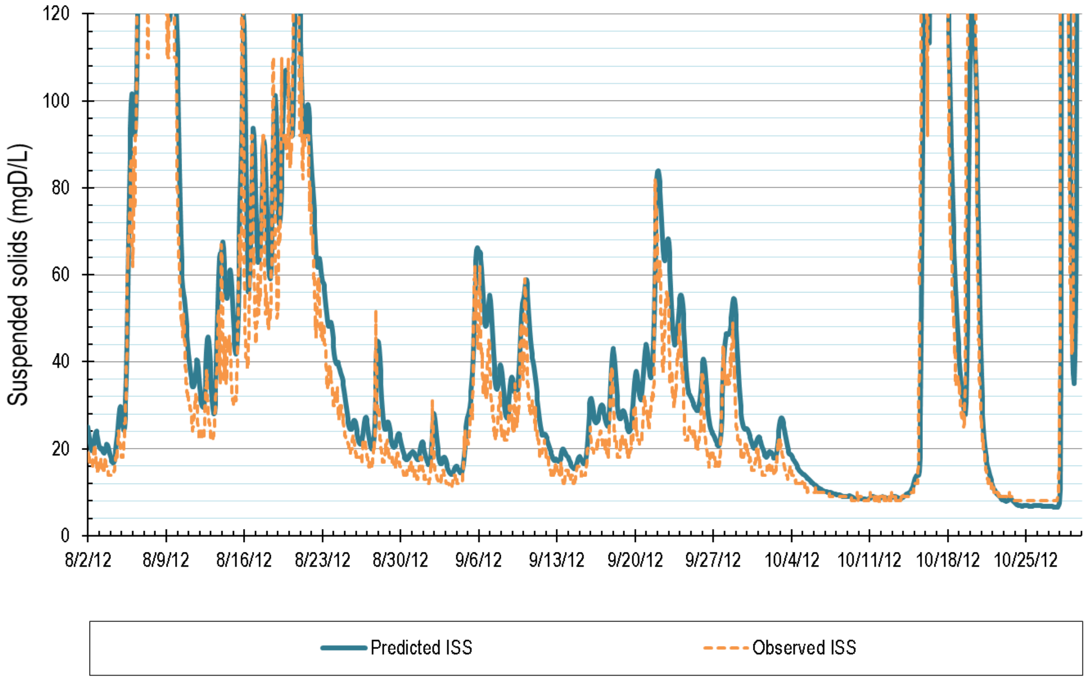

Figure I-75. Dynamic model predicted inorganic suspended solids for Reach 23 compared an “observed” time series from RM 7.6. The “observed” time series was constructed using the USGS turbidity time series at RM7.6 and a regression (R^2=0.96) between USGS turbidity and Ecology’s ISS sample results.

After calibrating to observed solids data, Ecology began calibrating the model for pH, DO, nutrients, and bottom algae. Before calibration, Ecology performed some research to refine the calibration ranges for parameters on the ‘Rates’ sheet of the QUAL2Kw model. Ecology compiled rate sets from 29 calibrated QUAL2Kw models developed throughout the Western U.S (Tables I-88 and I-89). These models were all developed for TMDLs by, or for, state agencies including:

- Washington State Department of Ecology (Carroll et al, 2006; Mohamedali and Lee 2008; Sargeant et al, 2006; Snouwaert and Stuart, 2015).
- Oregon Department of Environmental Quality (DEQ) (Turner et al, 2006).
- Utah DEQ (Neilson et al, 2014).
- Montana DEQ (Flynn and Suplee, 2011).
- California Regional Water Quality Board (Butkus, 2011; Tetra Tech, 2009).

Table I-88. Statistics for select parameters from calibrated QUAL2Kw models in the Western U.S.

Parameter	n	Min	25th Percentile	Median	75th Percentile	Max
Stoichiometry:						
Carbon	20	28.5	40	40	40	70
Nitrogen	20	2.8	7.2	7.2	7.2	10
Phosphorus	20	0.4	1	1	1	1
Dry weight	20	100	100	100	100	107
Chlorophyll	20	0.3	0.5	1	1	3
Inorganic suspended solids:						
Settling velocity	28	0.000001	0.2	0.59344	1.01974	2
Slow CBOD:						
Hydrolysis rate	26	0	0.1	0.365	1.10032	3.9988
Oxidation rate	11	0	0.065	0.2	0.549855	3.57425
Fast CBOD:						
Oxidation rate	20	0	0.35	2.7121	4	6
e						
Hydrolysis	29	0.001	0.1	0.25	0.6	3.8998
Settling velocity	20	0	0.09271	0.16743	0.2225	1.8312
Ammonium:						
Nitrification	29	0.01	0.93	2.5	4	10
Nitrate:						
Denitrification	29	0	0.44	1	1.01	1.94
Sed denitrification transfer	29	0	0	0.1	0.6	0.99
Organic P:						
Hydrolysis	29	0.001	0.11	0.25	1.5	4.21255
Settling velocity	21	0	0.08	0.11	0.5	1.84958
Inorganic P:						
Settling velocity	21	0	0.08802	1.26	1.80012	2
Sed P oxygen attenuation	22	0	0.202685	1.01094	1.40852	2
Detritus (POM):						
Dissolution rate	29	0.001	0.5	1.58	3	5

Parameter	n	Min	25th Percentile	Median	75th Percentile	Max
Settling velocity	27	0	0.108375	0.42	0.860875	1.95865

Table I-89. Statistics for select bottom algae parameters from calibrated QUAL2Kw models in the Western U.S.

Parameter	n	Min	25th Percentile	Median	75th Percentile	Max
Bottom Algae:						
Max Growth rate	26	8.6	12.1	25.6	49.7	161.1
Basal respiration rate	26	0.0068	0.1	0.2	0.4651	1.2
Photo-respiration rate parameter	9	0.01	0.01	0.01	0.01	0.39
Excretion rate	25	0	0.07	0.2037	0.3439	0.4816
Death rate	26	0.001	0.0775	0.2582	0.5	4.46
External N half sat constant	26	15	185.5	300	342.5	493.2
External P half sat constant	26	10	52.9	67.5	100	178
Inorganic C half sat constant	25	0	1.30E-05	0.000031	9.00E-05	0.00013
Light constant	26	1.69	50	56	70.3	100
Ammonia preference	26	1.2	15.25	22.75	25	80.96
Subsistence quota for N	25	0.7	1	7.2	24.1	72
Subsistence quota for P	25	0.1	0.1285	1	4.66	10
Maximum uptake rate for N	25	28	360	500	750	1405
Maximum uptake rate for P	25	4	50	100	145	232
Internal N half sat ratio	25	0.9	1.2	2.04	3.68	9
Internal P half sat ratio	25	0.13	1.3	1.4	3.42	5

Ecology inserted the 25th and 75th percentile values into the Lower White River QUAL2Kw model as ranges for auto-calibration using the genetic algorithm. This provided an initial calibration, which resulted in reasonable parameterizations for nutrient and oxygen related kinetics in the water column. An optimal fit for pH, nutrient concentrations, and bottom algae biomass was difficult to obtain with auto-calibration, most likely because an ideal weighting scheme was not found. Further manual calibration of bottom algae rates was necessary to optimize these variables. Ecology performed the manual calibration by iteratively adjusting one rate and comparing improvements in fit mathematically and visually. The calibrated rate results from the auto-calibration runs were also useful in guiding the manual calibration of bottom algae rates. Table I-90 contains the final calibrated parameters in the 'Rates' worksheet in the QUAL2Kw model.

Figure I-76 through Figure I-79 contain select results for nitrogen and phosphorus from the calibrated model. Dynamic results are depicted in the critical stretch of the river at RM 7.6.

Longitudinal profiles are shown for 10/11/12, when productivity was highest during the study period.

Ecology primarily relied on the USGS pH data collected at RM 7.6 (R St Bridge) for visual evaluation during calibration of pH (Figure I-80). This USGS deployment was suspended from the bridge and provided the best quality pH data, with no data gaps, during the modeling period. Longitudinal profiles and diel curves also factored into manual calibration (Figures I-81 and I-82).

Table I-90. Calibrated (non-default) parameters in the 'Rates' worksheet for the QUAL2Kw model.

Parameter	Value	Units	Symbol
Stoichiometry:			
Carbon	40	gC	gC
Nitrogen	7.2	gN	gN
Phosphorus	1	gP	gP
Dry weight	100	gD	gD
Chlorophyll	0.5*	gA	gA
Inorganic suspended solids:			
Settling velocity	0.6	m/d	v_i
Oxygen:			
Reaeration model	User model		
User reaeration model parameter A	3.25374		
User reaeration model parameter B	0.535525		
User reaeration model parameter C	-1.525284		
Slow CBOD:			
Hydrolysis rate	0.69742	/d	k_{hc}
Oxidation rate	0.149185	/d	k_{dcs}
Fast CBOD:			
Oxidation rate	0.5	/d	k_{dc}
Organic N:			
Hydrolysis	0.256524	/d	k_{hn}
Settling velocity	0.2722072	m/d	v_{on}
Ammonium:			
Nitrification	1.6411962	/d	k_{na}
Nitrate:			
Denitrification	1.0016267	/d	k_{dn}
Sediment denitrification transfer coefficient	0.019626	m/d	v_{di}
Organic P:			

Parameter	Value	Units	Symbol
Hydrolysis	0.1212034	/d	k_{hp}
Settling velocity	0.2841788	m/d	v_{op}
Inorganic P:			
Settling velocity	0.5	m/d	v_{ip}
Sediment P oxygen attenuation half sat constant	1.57202	mgO$_2$/L	k_{spi}

*Based on observed ratio from periphyton tissue samples.

Parameter	Value	Units	Symbol
Bottom Plants:			
Growth model	Zero-order		
Max Growth rate	18	gD/m^2/d or /d	C_{gb}
Temp correction	1.025		q_{gb}
First-order model carrying capacity	100	gD/m^2	$a_{b,max}$
Basal respiration rate	0.08	/d	k_{r1b}
Photo-respiration rate parameter	0.33	unitless	k_{r2b}
Temp correction	1.04		q_{rb}
Excretion rate	0.35	/d	k_{eb}
Temp correction	1.07		q_{db}
Death rate	0.08	/d	k_{db}
Temp correction	1		q_{db}
Scour function	Flow		
Coefficient of scour function	0.1	/d/cms or /d/mps	*cdet*
Exponent of scour function	0.1		*ddet*
Minimal biomass after scour event	1.2	gD/m^2	*X0*
Catastrophic scour rate during flood event	20	/d	*Kcat*
Critical flow or vel for catastrophic scour	36	cms or m/s	*Qcrit*
External nitrogen half sat constant	500	ugN/L	k_{sNb}
External phosphorus half sat constant	50	ugP/L	k_{sPb}
Inorganic carbon half sat constant	5.96E-05	moles/L	k_{sCb}
Bottom algae use HCO3- as substrate	Yes		
Light model	Smith		
Light constant	57	langleys/d	K_{Lb}
Ammonia preference	20.57	ugN/L	k_{hnxb}
Nutrient limitation model for N and P	Minimum		
Subsistence quota for nitrogen	2.95	mgN/gD	q_{0N}
Subsistence quota for phosphorus	1	mgP/gD	q_{0P}
Maximum uptake rate for nitrogen	60	mgN/gD/d	r_{mN}
Maximum uptake rate for phosphorus	8	mgP/gD/d	r_{mP}
Internal nitrogen half sat ratio	1.12		$K_{qN,ratio}$
Internal phosphorus half sat ratio	1.3		$K_{qP,ratio}$
Nitrogen uptake water column fraction	1		$N_{UpWCfrac}$
Phosphorus uptake water column fraction	1		$P_{UpWCfrac}$

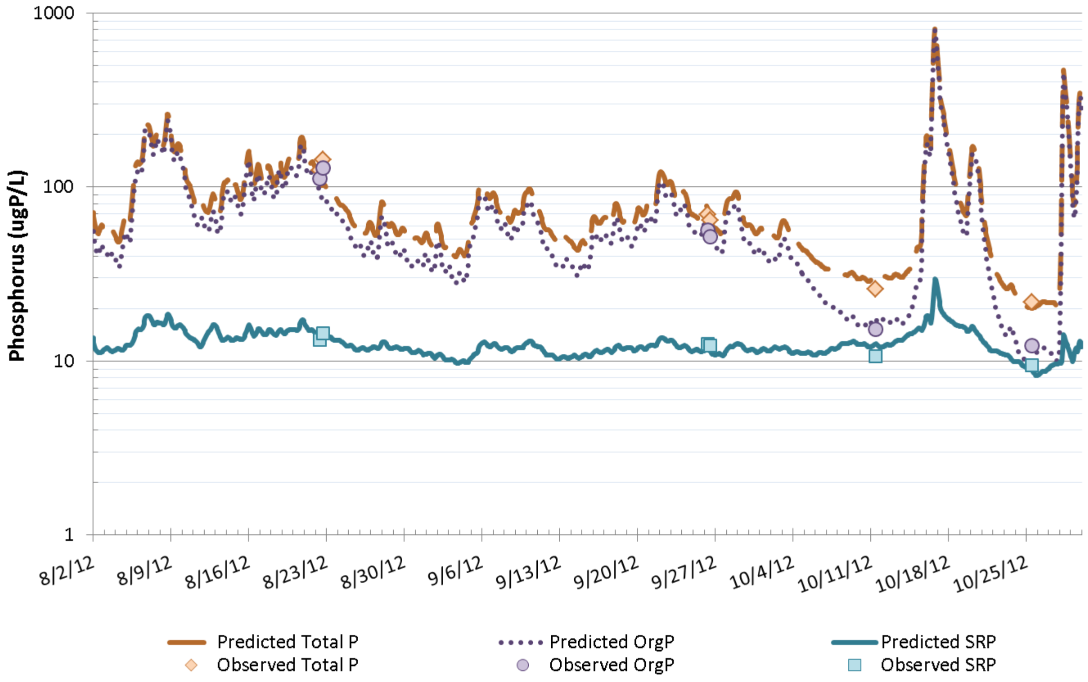

Figure I-76. Dynamic model predicted phosphorus for Reach 23 compared to observed data from RM 7.6.

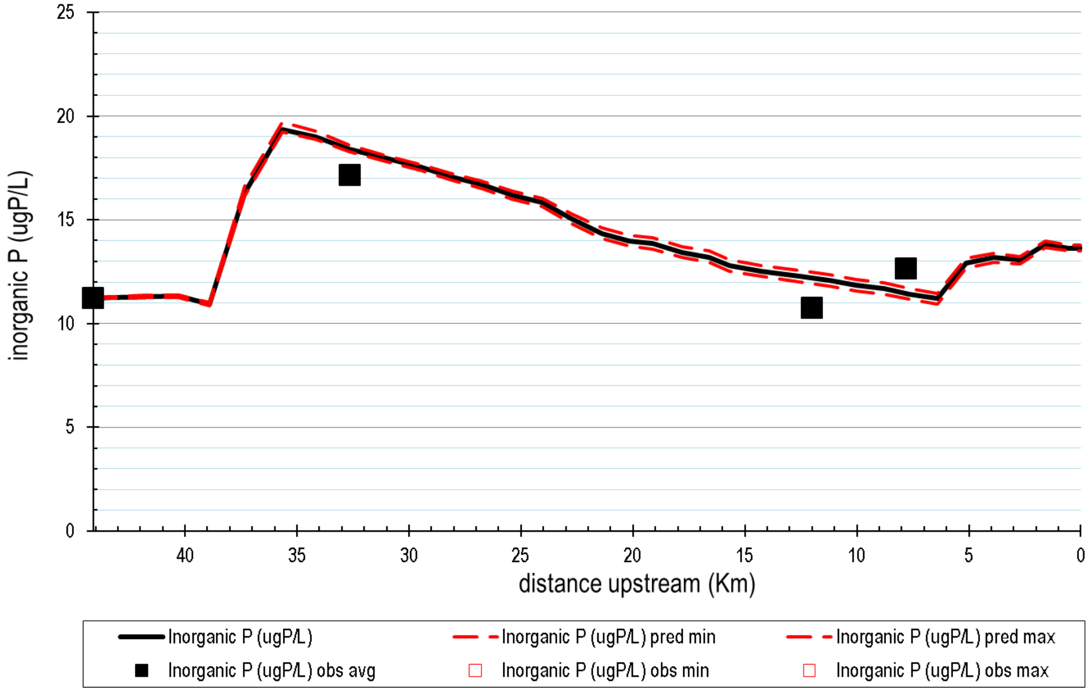

Figure I-77. Longitudinal inorganic phosphorus predictions for 10/11/12 compared to observed data.

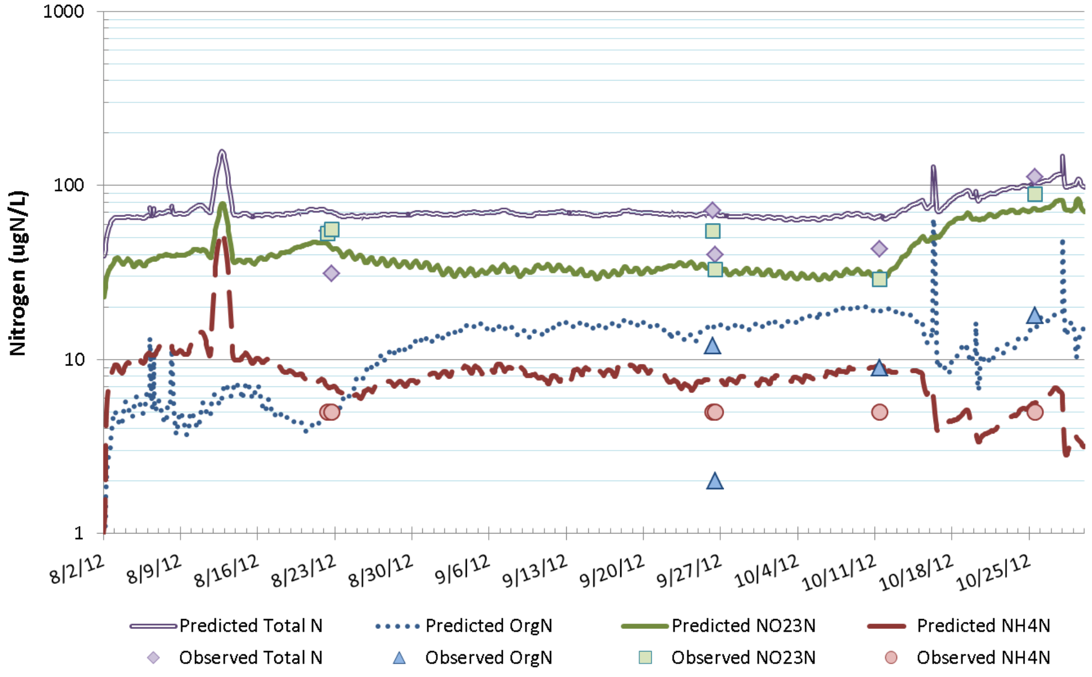

Figure I-78. Dynamic model predicted phosphorus for Reach 23 compared to observed data from RM 7.6.[25]

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[25] *"Observed" NH3N were below the reporting limit (10 ug/L) and are represented as half the reporting limit (5 ug/L) in the plot. "Observed" Organic Nitrogen values are based on unknown NH4 and thus subject to additional error.*

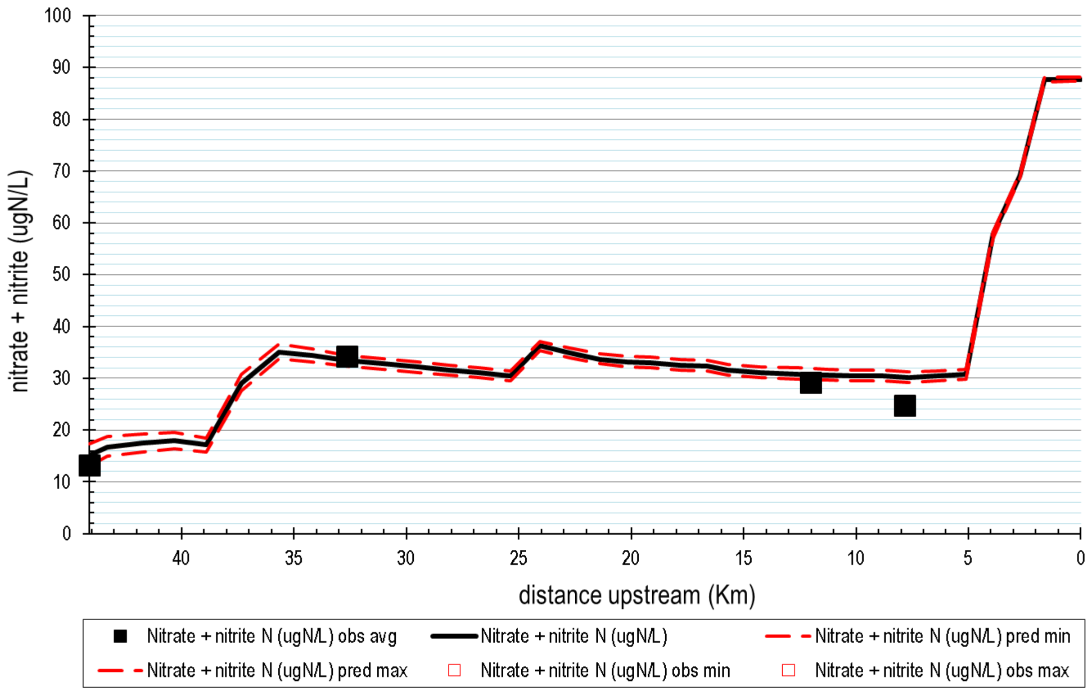

Figure I-79. Longitudinal nitrate/nitrite predictions for 10/11/12 compared to observed data.

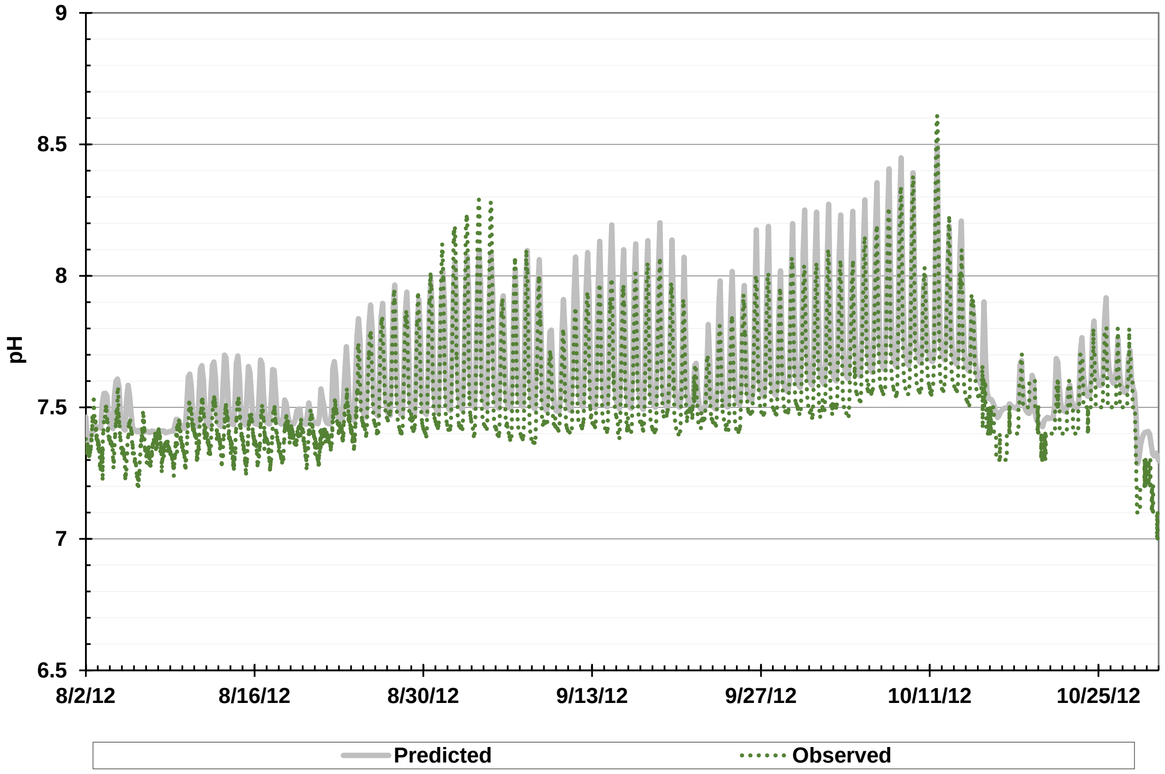

Figure I-80. Dynamic model predicted pH for Reach 23 compared to observed data from RM 7.6.

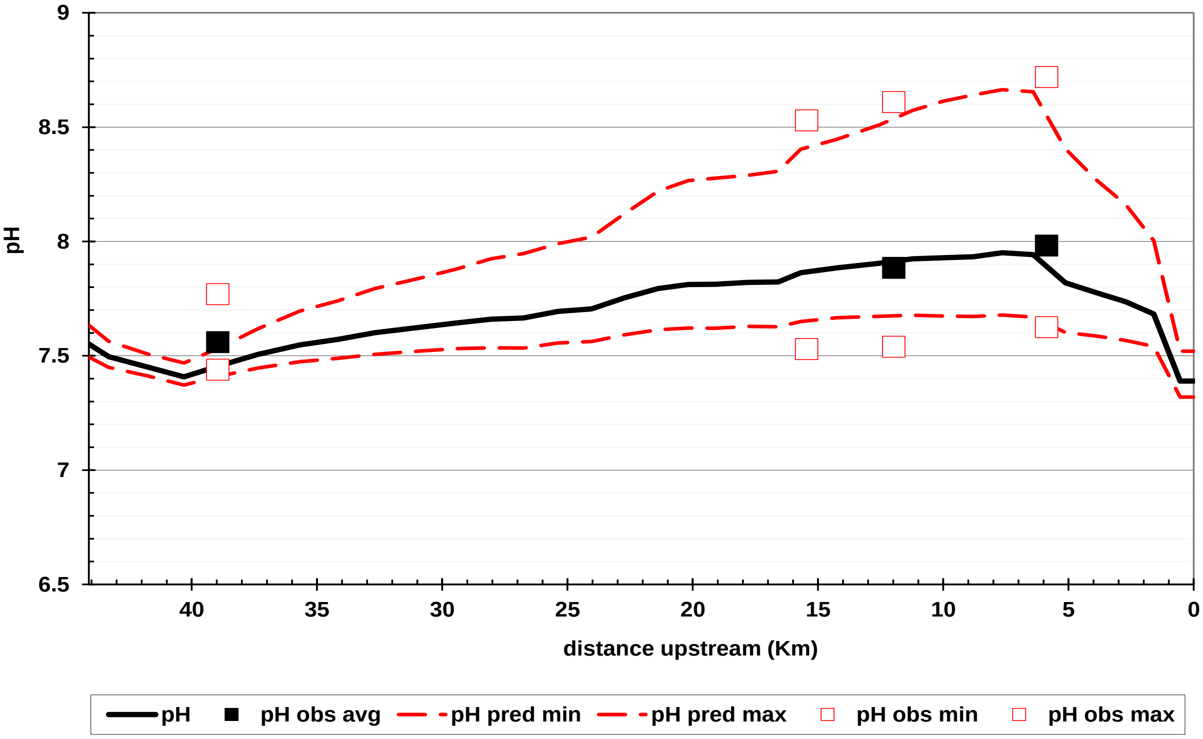

Figure I-81. Longitudinal pH predictions for 10/11/12 compared to observed data.

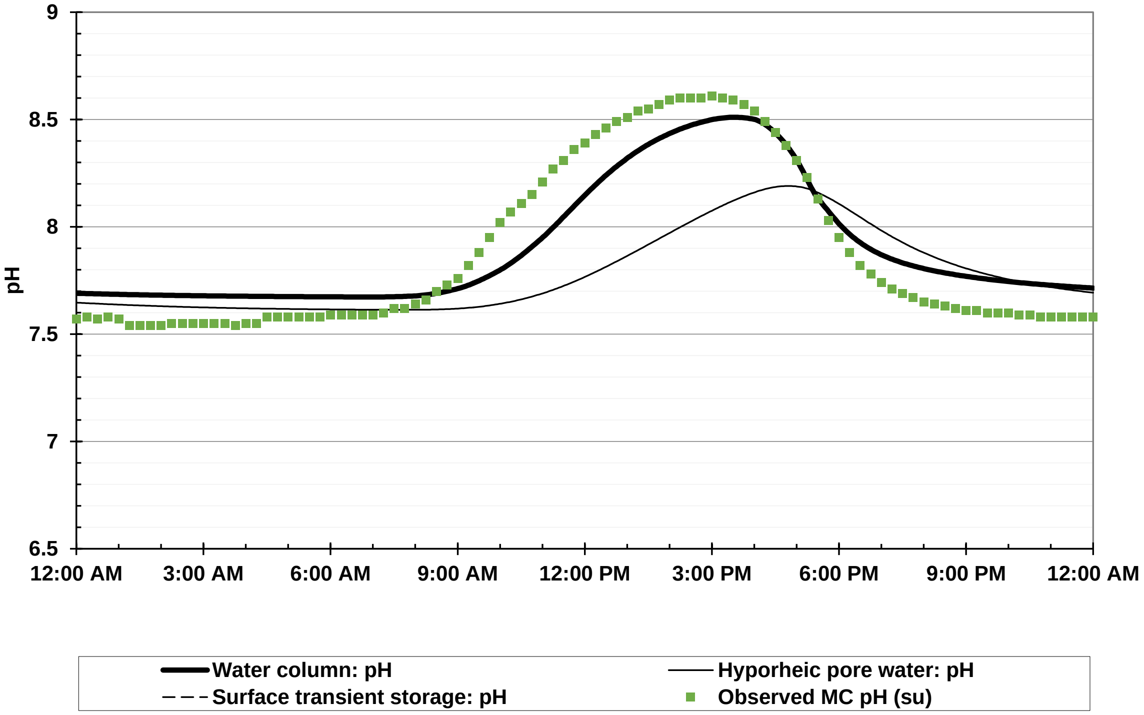

Figure I-82. Diel pH predictions for 10/11/12 in Reach 23 compared to observed data from RM7.6. Note: Surface transient storage was not simulated, so there is no line on the plot.

Nutrient Limitation

Ecology calibrated the Lower White River model in a manner that provided an optimal goodness of fit with observed data and in which the predicted nutrient limitation reflected the ambiguity of nutrient limitation in the river (see Appendix F: 2012 Study Results and Appendix D: Analytical Framework for further discussion) and allowed for the likely possibility of co-limitation under critical conditions. The calibrated model suggests a system that is near the threshold for either nitrogen or phosphorus being the single limiting nutrient (Figure I-83).

The vertical axis of Figure I-83 represents the growth limitation coefficient for each nutrient. In the model only the lowest coefficient of the three nutrients is used. The maximum bottom algae growth rate is multiplied by the nutrient limitation coefficient, the temperature limitation coefficient, and the light limitation coefficient to derive the dynamic periphyton growth rate. The intersecting lines for the N and P coefficients show that the calibrated model is slightly phosphorus limited most of the time and slightly nitrogen limited at other times (most notably under critical conditions in early October).

Ecology attempted to calibrate the model using the nutrient co-limitation functions (multiplicative and harmonic mean), however a satisfactory level of fitness could not be obtained. These co-limitation functions have not actually been used in a published QUAL2Kw model, to Ecology's knowledge, and may need further development before being useful for representing limitation dynamics. Ultimately, Ecology used the single limiting nutrient function (minimum). Further justification of this approach is explained in Appendix D.

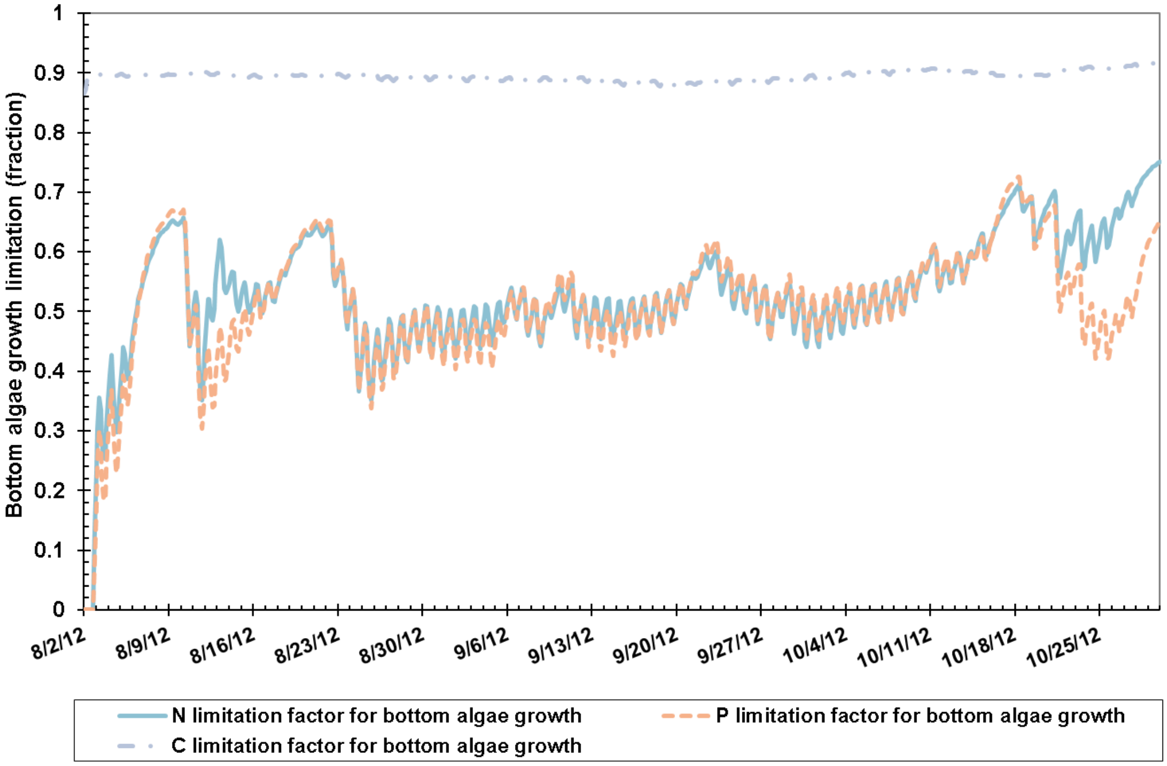

Figure I-83. Nutrient limitation in Reach 23 of the calibrated 2012 model for the Lower White River.

Periphyton scour

Ecology also found that using QUAL2Kw's scour function improved the calibration for bottom algae and pH, particularly after the large storm events in mid-October (see Figure I-84 and discussion in Appendix F- Study Results). A flow-based scour function was implemented with a catastrophic flow threshold and rate which triggered during the October storms. A minimum biomass after scour event was included which prevents the biomass from being completely wiped out during a large storm.

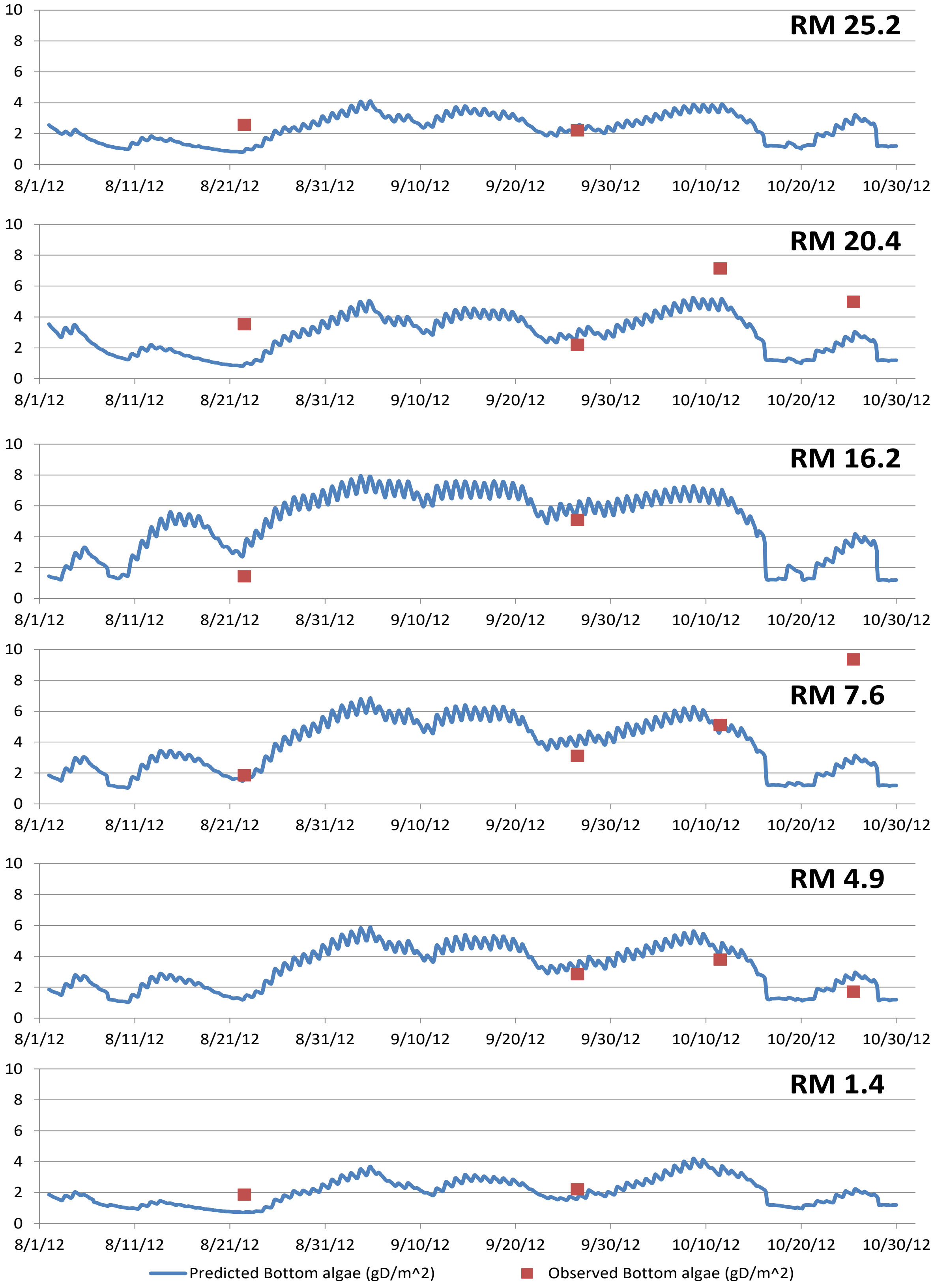

Figure I-84. Bottom algae predicted vs observed biomass results for the 2012 study.

Model evaluation - error and sensitivity analysis

Ecology evaluated the quality of the model through both quantitative and qualitative methods, including:

- Quantitative:
    - Assessing goodness of fit to observed data using RMSE.
    - Assessing the bias of the model compared to the observed data.
    - Performing sensitivity analysis on key rate parameters and inputs.
- Qualitative:
    - Visual comparison of observed vs predicted spatial and temporal patterns in the data (see model calibration section).
    - "Under-the-hood" technical review of the model by:
        - A water quality modeler from Ecology's Environmental Assessment Program, who was not a member of the TMDL workgroup.
        - Review by TMDL workgroup member: Joel Massmann, Ph.D., P.E., Principal Engineer of Keta Waters, LLC.

Error Analysis

The Lower White River QUAL2Kw model goodness of fit to observed data is summarized in Tables I-91 and I-92. Four statistics were used to evaluate model error (Figure I-85). The Root Mean Squared Error (RMSE) statistic expresses the magnitude of typical model error for a variable in the same units as that variable. The Root Mean Squared Error Coefficient of Variation (RMSE CV) expresses the proportion of typical model error to the typical value of the variable. The overall bias statistic expresses the tendency of the model to over- or under-predict the value of a given variable. Bias% expresses this tendency as a proportion of the typical value of the variable. The average observed values from this study for most variables are given for reference.

$$RMSE = \sqrt{\frac{\Sigma(T_{modeled} - T_{observed})^2}{n}}$$

$$RMSE\ \ CV = \frac{RMSE}{Avg\ obs\ value}$$

$$Bias = \frac{\sum(T_{modeled} - T_{observed})}{n}$$

$$Bias\ \% = \frac{Bias}{Avg\ obs\ value}$$

Figure I-85. Equations for statistics used in error assessment.

For most variables, RMSE and bias are calculated by comparing modeled daily average values to observed daily average or grab sample values. For variables that display a marked diel swing, such as temperature, dissolved oxygen, and pH, the RMSE and bias are calculated for daily maximums and minimums as well. RMSE CV and Bias%, which express error as a proportion of typical variable values, are given for those variables that express a quantity or concentration of something. These statistics are not appropriate for temperature or pH.

The results of the error analysis suggest the QUAL2Kw model simulates pH in the Lower White River in relatively close agreement with the pH values observed in the 2012 study. In particular, the daily maximum pH value had a minimal amount of error (RMSE = 0.17 S.U.) and low bias (overall bias = +0.04 S.U.). The model also provides a good simulation of nutrient concentrations, with minimal error for SRP (RMSE = 1.3 ug/L) and low bias (+0.09 ug/L).

Table I-91. Summary statistics for goodness-of-fit of the QUAL2Kw model to observed continuous data.

Statistic	Temp-Min (degC)	Temp-Max	Temp-Mean	SpCond - Mean (uS/cm)	DO – Min (mgO2/L)	DO – Max	DO – Mean	pH-Min	pH-Max	pH-Mean
Mean	11.54	14.40	12.88	71.64	10.10	10.96	10.50	7.41	7.78	7.55
RMSE	0.26	0.33	0.21	4.57	0.27	0.30	0.22	0.11	0.17	0.11
RMSCV = RMSE/Mean				0.06	0.03	0.03	0.02			
Bias	-0.07	0.06	0.02	1.89	0.04	0.08	0.02	0.08	0.04	0.05
Bias % = Bias/Mean				2.6%	0.4%	0.7%	0.2%			

Table I-92. Summary statistics for goodness-of-fit of the QUAL2Kw model to observed discrete data.

Statistic	ISS (mgD/L)	Nitrate + nitrite N (ugN/L)	SRP (ugP/L)	Alk (mg/L)	Total N (ug/L)	Total P (ugP/L)	TSS (mgD/L)	Bottom algae (gD/m^2)
Mean	40.86	51.91	13.15	23.31	62.87	99.69	45.95	3.59
RMSE	17.04	10.78	1.3	2.89	27.67	14.14	18.41	1.33
RMSCV = RMSE/Mean	0.42	0.21	0.10	0.12	0.44	0.14	0.40	0.37
Bias	-10.12	-2.83	0.09	0.56	16.10	-7.44	-10.77	-0.34
Bias % = Bias/Mean	-24.8%	-5.5%	0.7%	2.4%	25.6%	-7.5%	-23.4%	-9.5%

Note: No error statistics for NH3-N because greater than 70% of observed values were below the reporting limit.

Sensitivity analysis

In order to analyze the sensitivity of individual parameter estimates, particularly those on the 'Rates' worksheet, Ecology re-ran the calibrated model with one parameter at a time, first set to the 25th percentile of the auto-calibration range (low) and then set to the 75th percentile (high). Ecology evaluated the sensitivity of the goodness of fit for pH, inorganic phosphorus, nitrate-nitrite, and bottom algae biomass based on the low and high variations (Figure I-86 to I-89). The vertical axis in these figures represents the decrease in the goodness of fit to the observed data (increase in error/RMSE) based on altering a given parameter in the specified direction.

With respect to pH, the model was most sensitive to increased maximum growth rate for bottom algae (Figure I-86). This result agrees with evidence that the Lower White River is not a highly productive stream, which is evident from the relatively low algal biomass levels and predominance of diatoms over green algae. However, pH was also sensitive to a low max growth rate, which highlights the importance of this parameter in the model. The Lower White River calibrated growth rate (18 gD/m^2/d) was similar to the median growth rate of the 27 QUAL2Kw models (25 gD/m^2/d) with zero-order growth rates.

Goodness of fit for inorganic phosphorus was most sensitive to the hydrolysis rate for organic phosphorus and the inorganic P settling velocity (Figure I-87). Nitrate was most sensitive to the high end of the range for both the bottom algae maximum uptake rate for nitrogen and sediment denitrification transfer coefficient (Figure I-88). Bottom algae biomass was most sensitive to a high minimal biomass after catastrophic scour event (Figure I-89), suggesting the importance of the scour function to fitness, and was also moderately sensitive to a larger number of rates (compared to the other variables examined).

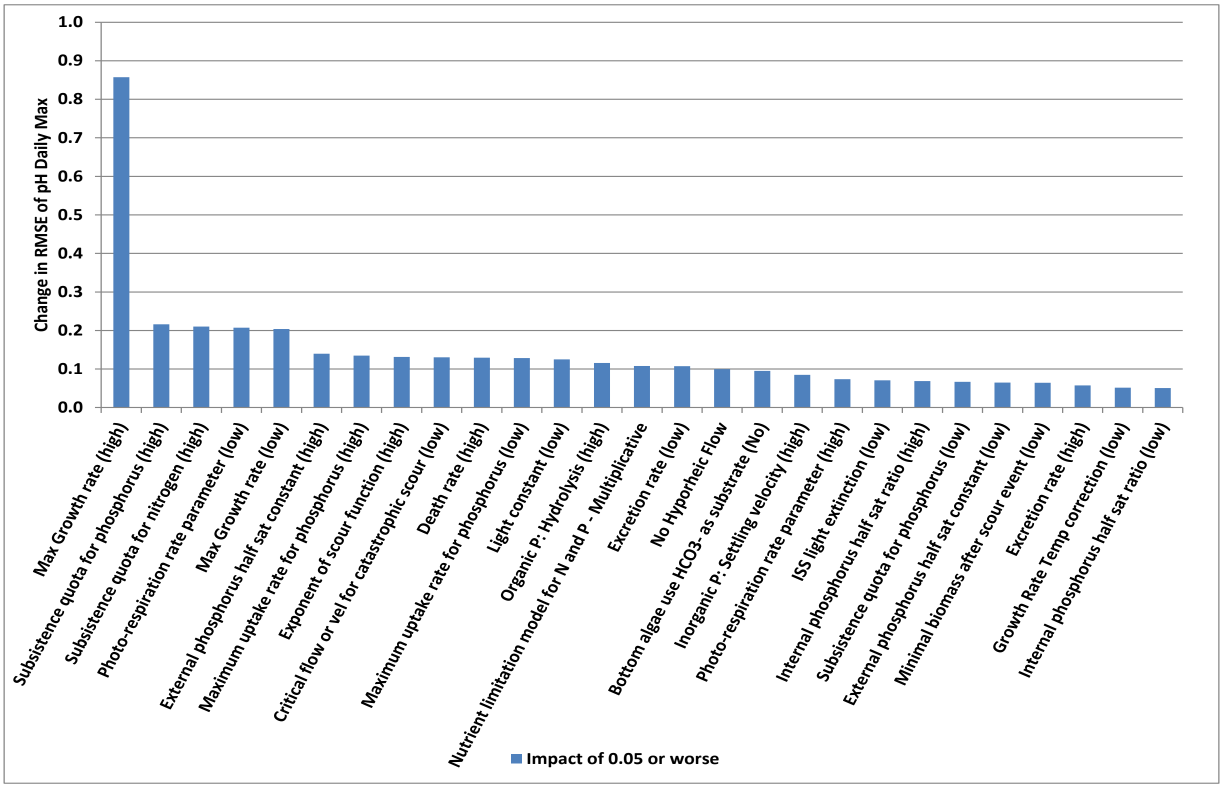

Figure I-86. Sensitivity of pH goodness of fit to variations in model parameters.

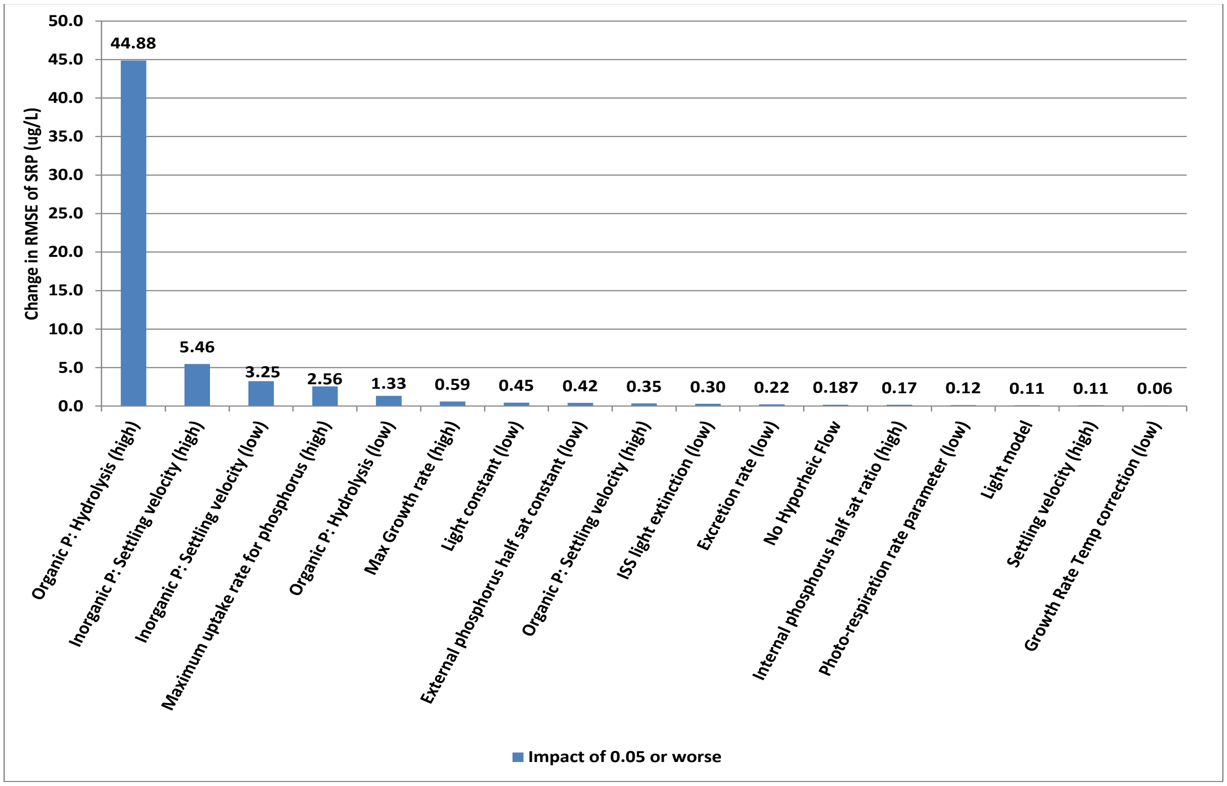

Figure I-87. Sensitivity of inorganic phosphorus goodness of fit to variations in model parameters.

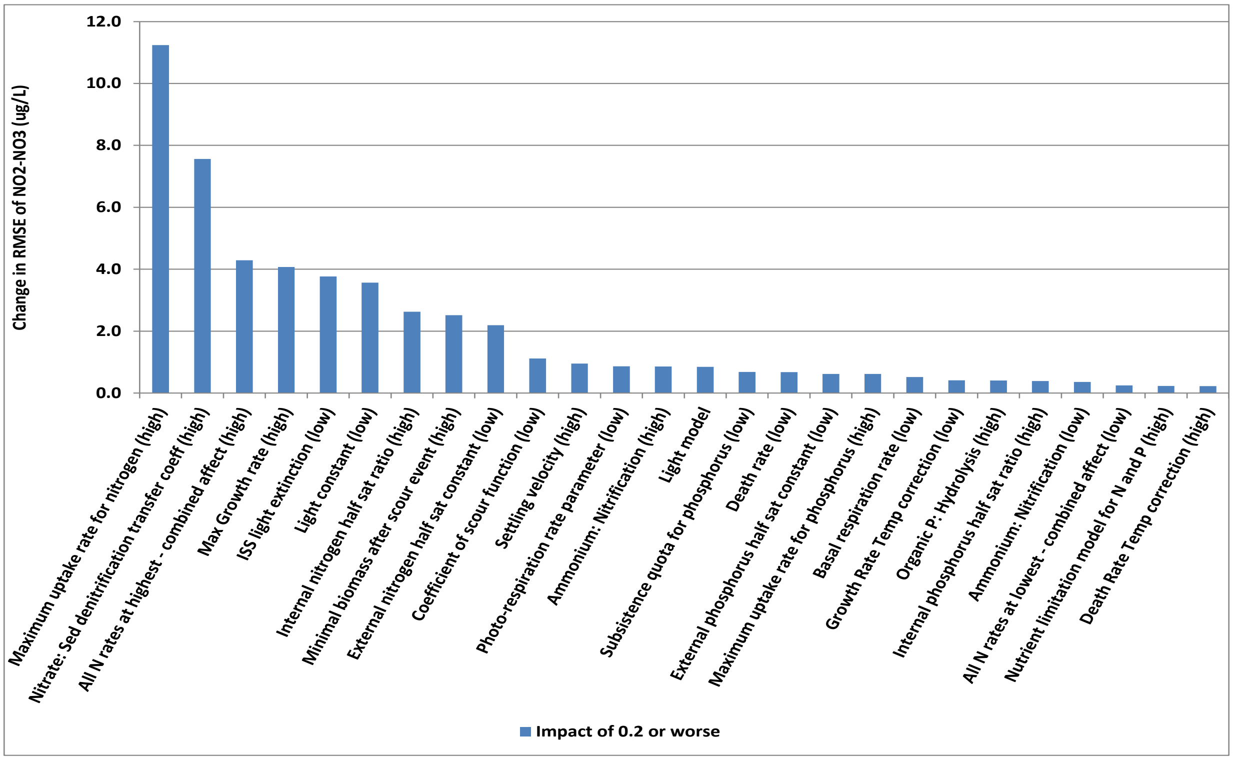

Figure I-88. Sensitivity of nitrate-nitrite goodness of fit to variations in model parameters.

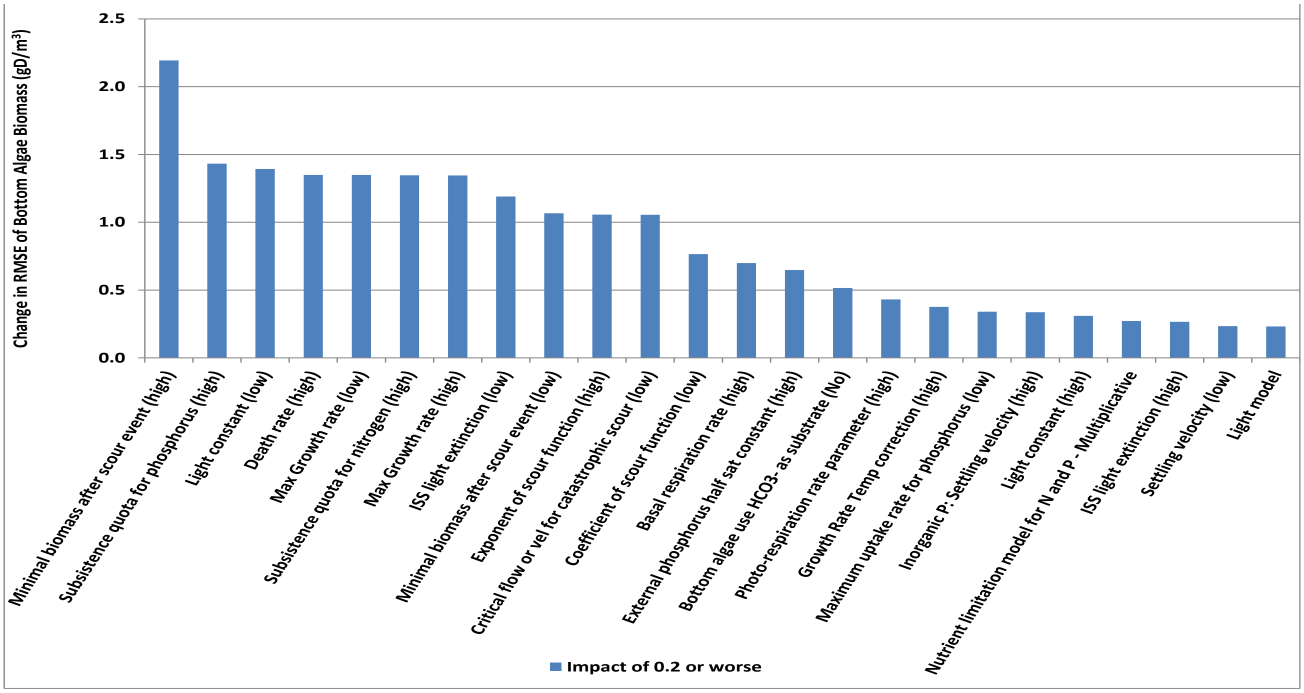

Figure I-89. Sensitivity of bottom algae biomass goodness of fit to variations in model parameters.

Ecology also tested the sensitivity of the model to three major influences that are often considered in TMDLs: effective shade, phosphorus loading from nonpoint sources, and phosphorus loading from point sources (Figure I-90). Figure I-90 depicts longitudinal pH profiles for these sensitivity scenarios on 10/11/12 in the model. Each influence was tested independently of the other two.

To evaluate the influence of effective shade, Ecology replaced the existing condition shade input with the system potential shade estimates. The system potential shade estimates are effective shade calculations for the Lower White River derived using estimates of the potential tree heights and canopy densities under pre-development conditions (see system potential pH model discussion for details).

The addition of system potential shade reduced peak pH values by less than 0.1 within the portion of the model where criteria are exceeded for existing conditions. Both parts of the water quality standard were still exceeded under this scenario. The lack of significant reduction in pH is likely due to the wide channel disturbance zone and wetted widths in the river, particularly in the system potential model where RM 4 to 9 has a wider disturbance zone (and reduced shade) under pre-levee conditions.

To evaluate the influence of nonpoint phosphorus sources, Ecology reduced groundwater and surface water tributary phosphorus concentrations to those used in the system potential model. The impact of removing nonpoint sources (-0.12 pH at RM 4.4) was greater than for removing effective shade, but both parts of the standards were still exceeded.

To evaluate the influence of point phosphorus sources. Ecology removed point sources flows and loads completely from the model. The impact of removing point sources (-0.26 pH at RM 4.4) was the greatest of the three influences tested and resulted in pH below water quality standards.

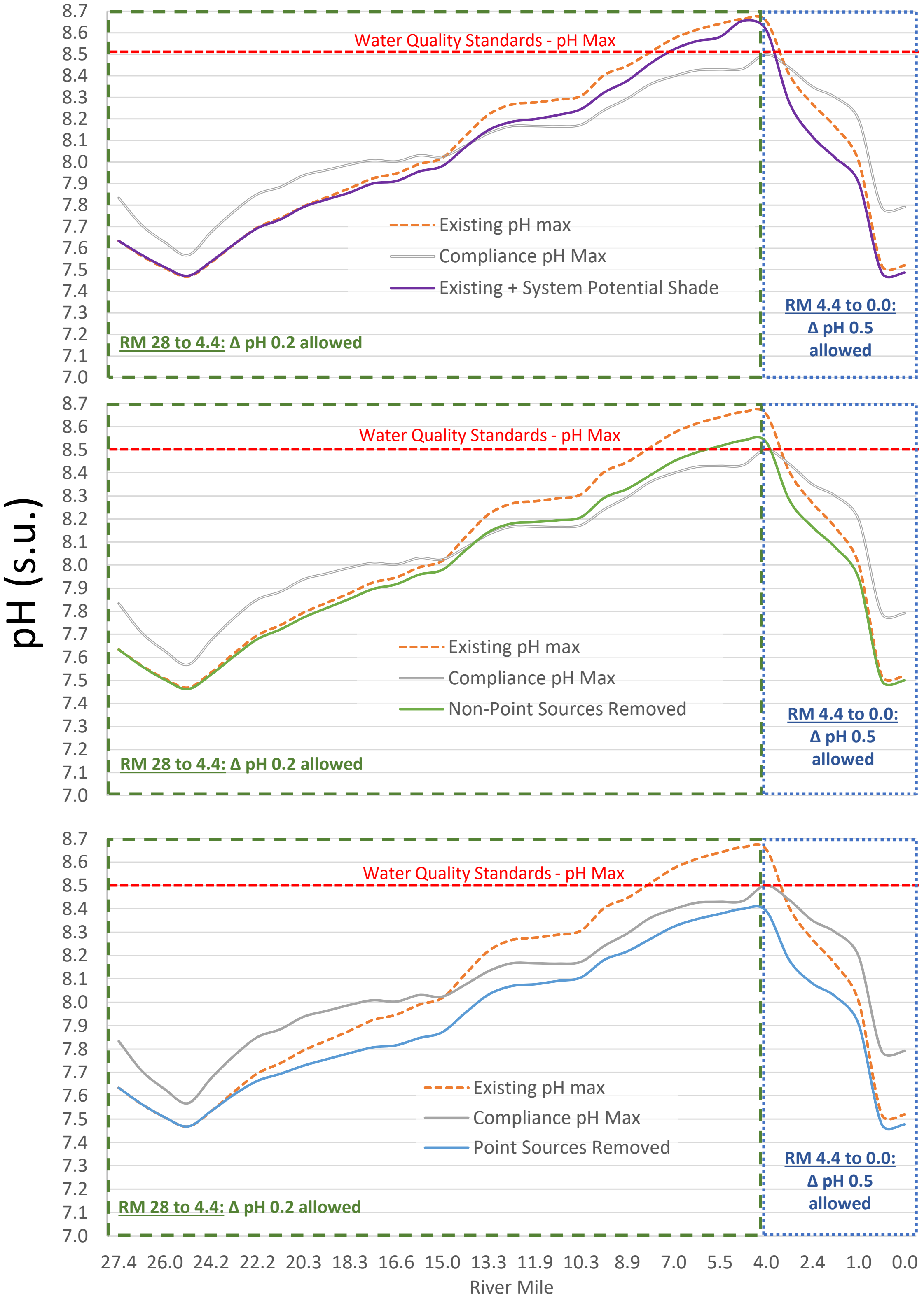

Figure I-90. Sensitivity of the calibrated 2012 model to effective shade, nonpoint sources, and point sources.

Nutrient limitation sensitivity

Ecology also explored the sensitivity of the 2012 model to a more strongly nitrogen limited system.

Table I-93 depicts changes to the parameters on the 'Rates' worksheet between the final model calibration (which fluctuates between being slight N and slightly P-limited, aka "co-limitation") and the nitrogen limited sensitivity scenario. The sensitivity scenario contains subsistence quotas and maximum uptake rates that are at the stoichiometric ratio for mass between N and P (7.2:1). In order to retain a good fit to observed data, it was very important to adjust the excretion rate to a lower number.

Table I-93. Changes to parameterization of current model in alternate model.

Parameter	Current "Co-limited" Model	N-limited sensitivity scenario
Excretion rate	0.35	0.12
External nitrogen half sat constant	490	300
Subsistence quota for nitrogen	3.1	7.2
Subsistence quota for phosphorus	1	1
Maximum uptake rate for nitrogen	60	72
Maximum uptake rate for phosphorus	8	10

Overall, the goodness of fit appears comparable between the model calibration and nitrogen limited sensitivity scenario, particularly amongst key variables including pH (dynamic/ longitudinal/diel) (Figure I-91) and dissolved nutrients (Figure I-92). However, the evaluation of fitness was not as complete as for the model calibration, given this was only an exploration of the model's sensitivity to nutrient limitation.

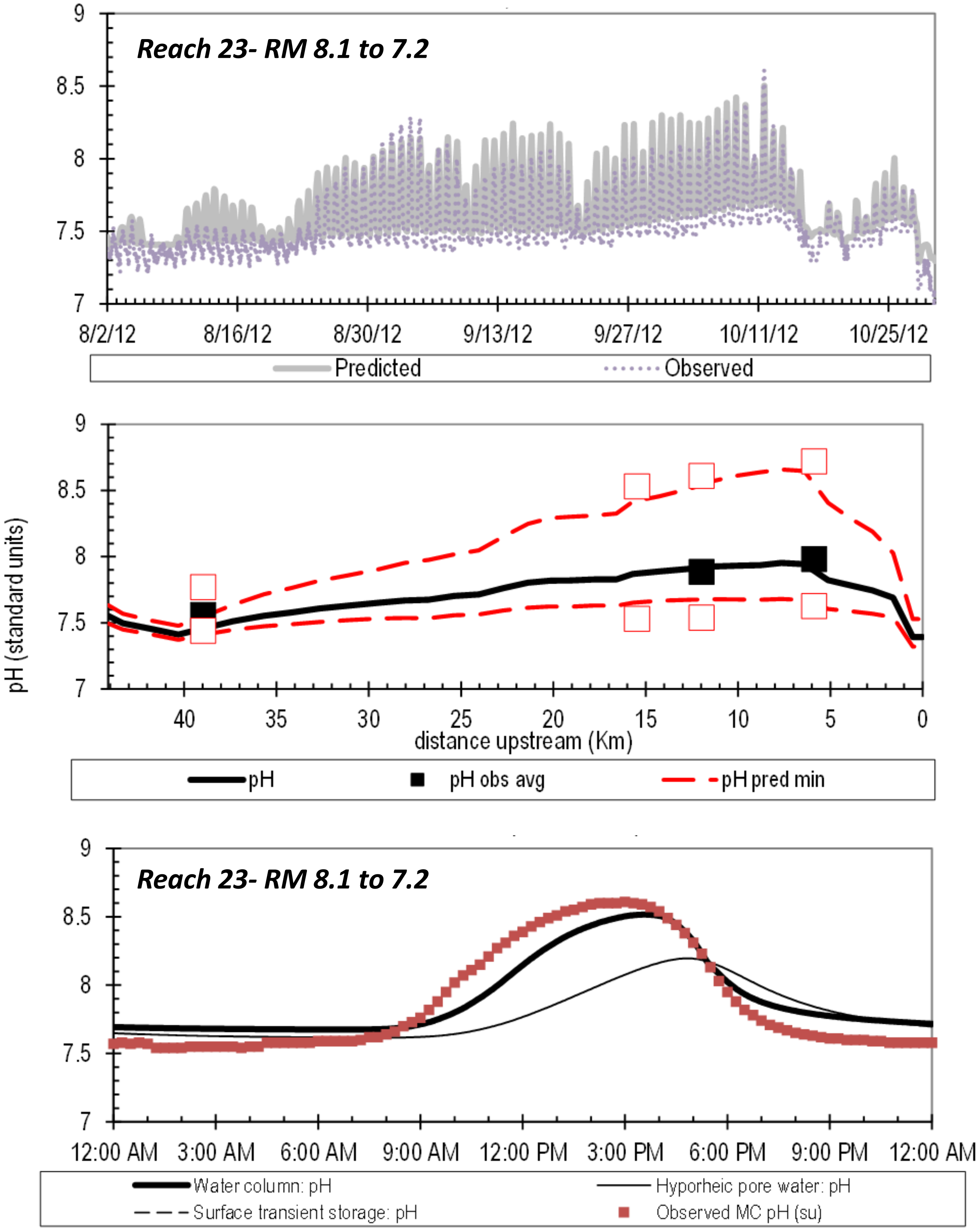

Figure I-91. Predicted vs observed pH results for the nitrogen-limited sensitivity scenario.

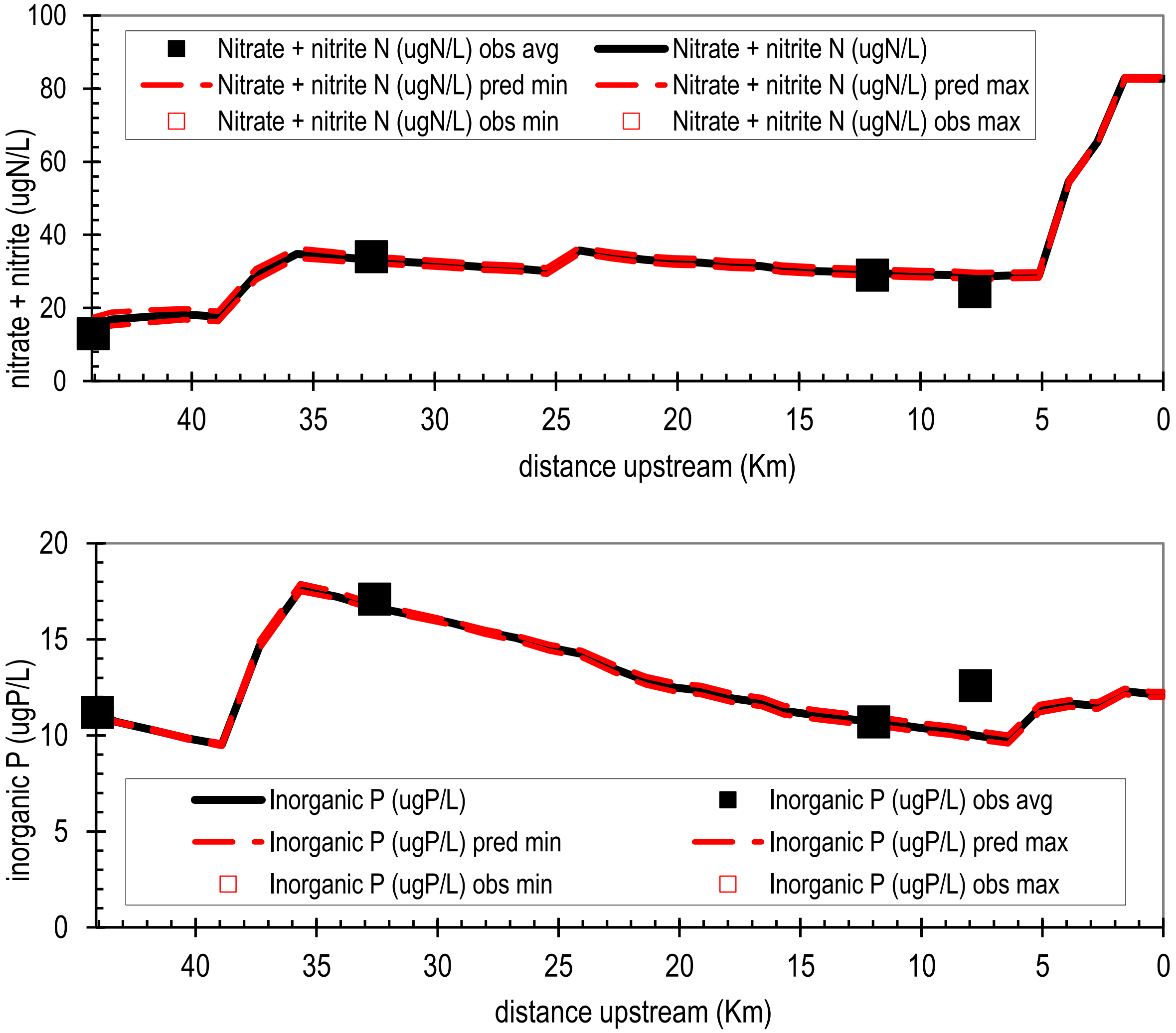

Figure I-92. Predicted vs observed nutrient results for the nitrogen-limited sensitivity scenario.

In order to provide a general perspective of management implications of a more N-limited system, Ecology tested the sensitivity of the nitrogen limited scenario to the removal of phosphorus from point source inputs. Figure I-93 depicts the longitudinal pH results for existing conditions and removal of phosphorus from point sources under the nitrogen limited scenario. The results show that pH does not change significantly in response to phosphorus reductions. Figure I-94 shows dynamic nutrient limitation results for the scenario where phosphorus point sources are removed; the results show that the system remains “N-limited” even with substantial reductions in phosphorus inputs. Further discussion of nutrient limitation is included in Appendix D.

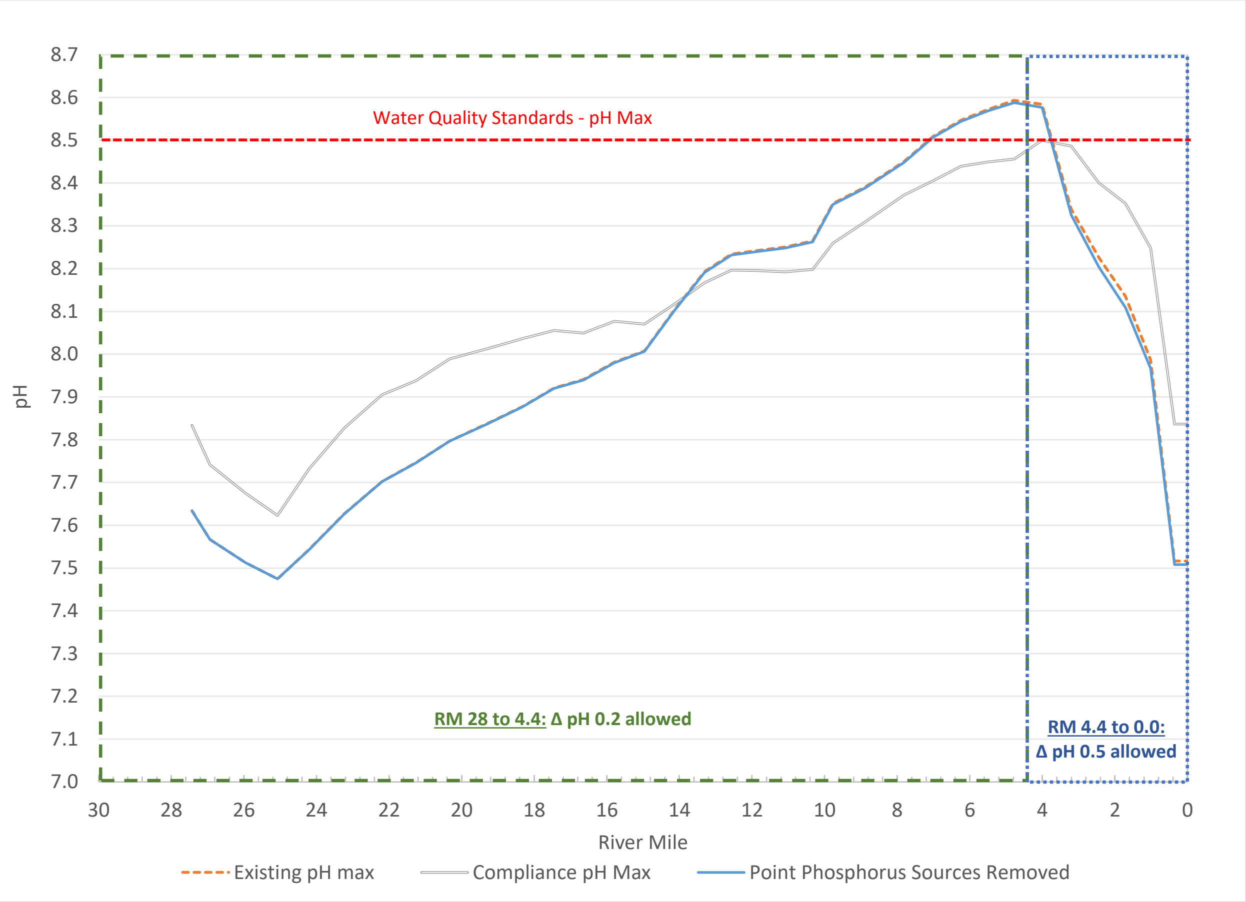

Figure I-93. Longitudinal pH in nitrogen sensitivity scenario for existing vs point sources of phosphorus removed.

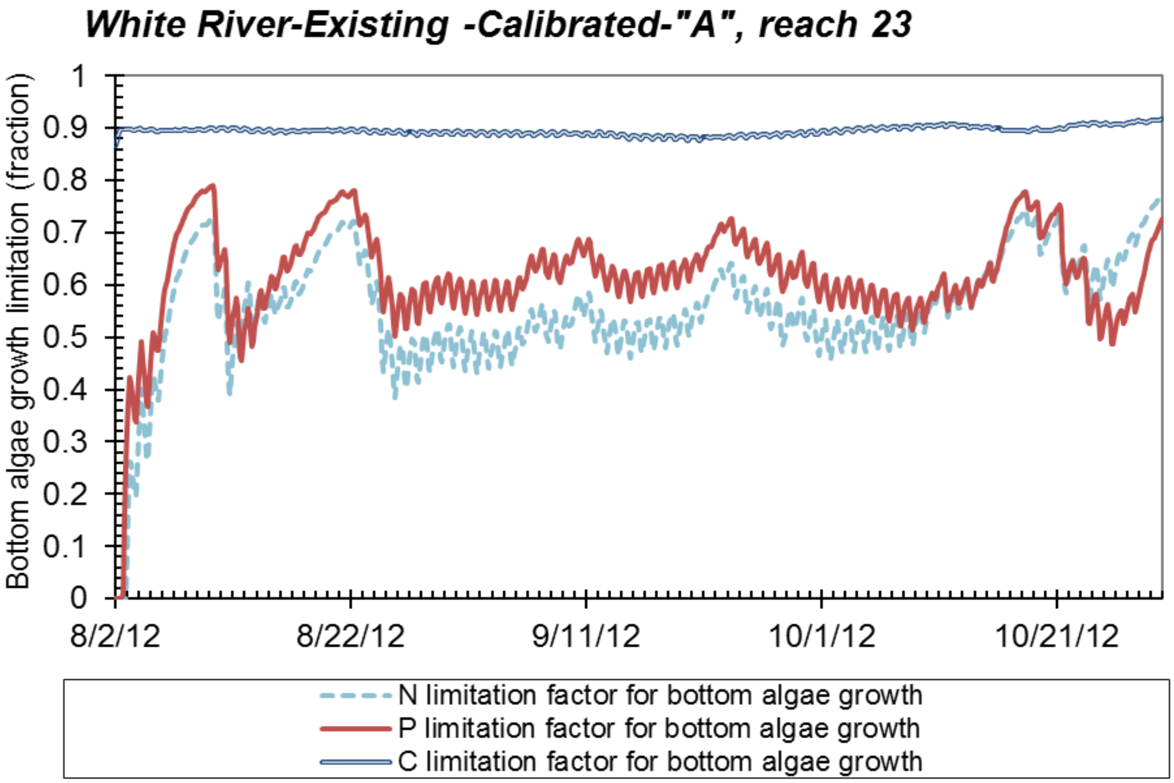

Figure I-94. Nutrient limitation in nitrogen limited sensitivity scenario, after point sources of phosphorus were removed.

System potential pH model

In order to evaluate the "less than 0.2 anthropogenic change" criteria, the 2012 calibrated model was used as a starting point to develop a model simulation of "natural" or system potential pH conditions. Several changes were made to the 2012 model in order to simulate system potential pH. The anthropogenic changes that are addressed in the system potential model are limited to impacts that have been historically documented (pre-western settlement vegetation), measurable (large water diversions), or can be reasonably estimated given reference conditions or local/regional data distributions (nutrient concentrations). Complex or speculative changes are generally avoided due to lack of available supporting information.

Headwater boundary flows

The headwater flows were reduced from 2012 values (7-day low flow of 412 cfs) to values from the year 1994 (7-day flow of 250 cfs) to represent 7Q10 flow conditions. A 7Q10 low flow was used in the system potential model so that the model could be compared to the critical conditions TMDL allocation scenario. Values from 1994 were determined to be representative of system potential based on the following analysis.

Ecology plotted the 7-day flows from the four lowest 7-day flow years from the 7Q10 analysis for USGS station 12098500, for the period of 1977-2002. These were 1983, 1987, 1994, and 2002. Of these years, 1983 is the outlier. It has a 27-year recurrence interval (lowest 7-day flow on record). It also has an atypical pattern with higher flows than other years in August and September and then a very steep decline and short baseflow period.

Ecology explored scaling the 2012 flow record down to get to a 7Q10 flow (Figure I-95; black dotted line); however, this method produced historically low (unrealistic) flows in the months of August and September.

Of the remaining years, 1987 and 1994 appeared to be the most similar to 2012 and displayed a more typical flow pattern for this time of year. Ultimately, 1994 was selected because it mirrored the 2012 pattern well and had lower flows in early October, when conditions were critical in the 2012 model.

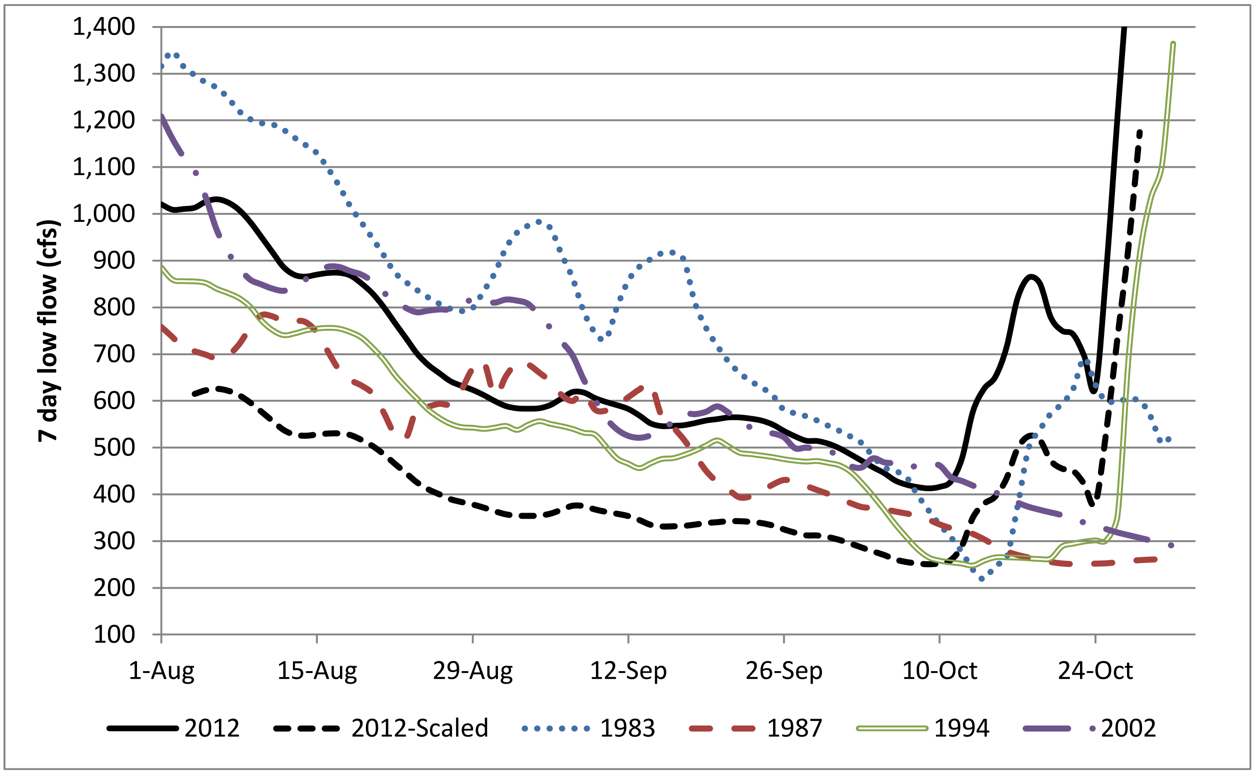

Figure I-95. Comparison of 7Q10 flow years for USGS station 12098500.

Nutrient concentrations

The 2012 nutrient concentrations for the headwater boundary at RM 28 were reduced by 5% in the natural conditions model. This approach reflects the fact that existing headwater nutrients are already relatively low, but that there are some potential anthropogenic nutrient sources upstream, most notably potential increased sediment/phosphorus delivery due to forest harvest practices.

Nutrient concentrations for surface water inputs (tributaries) were set as the 25th percentile from the historical dataset of samples collected from tributaries in the study area between August 1st and October 31st. Figures I-96 and I-97 depict the cumulative frequency and 25th percentile results for SRP and NO2-NO3 in White River tributaries, respectively.

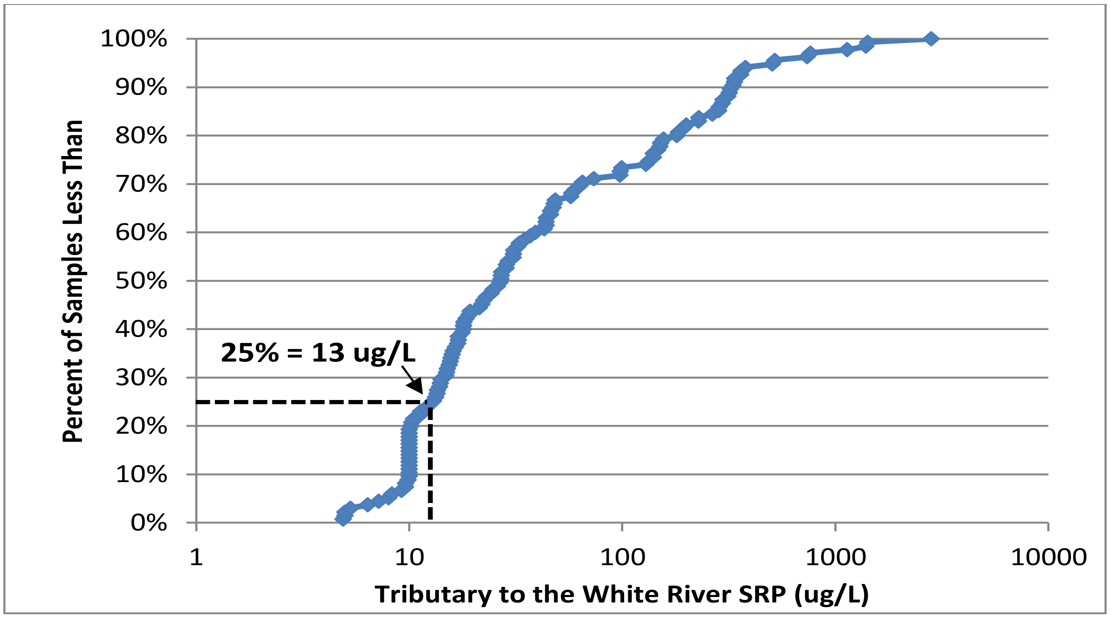

Figure I-96. Cumulative frequency of SRP concentrations from historical data and the 2012 study.

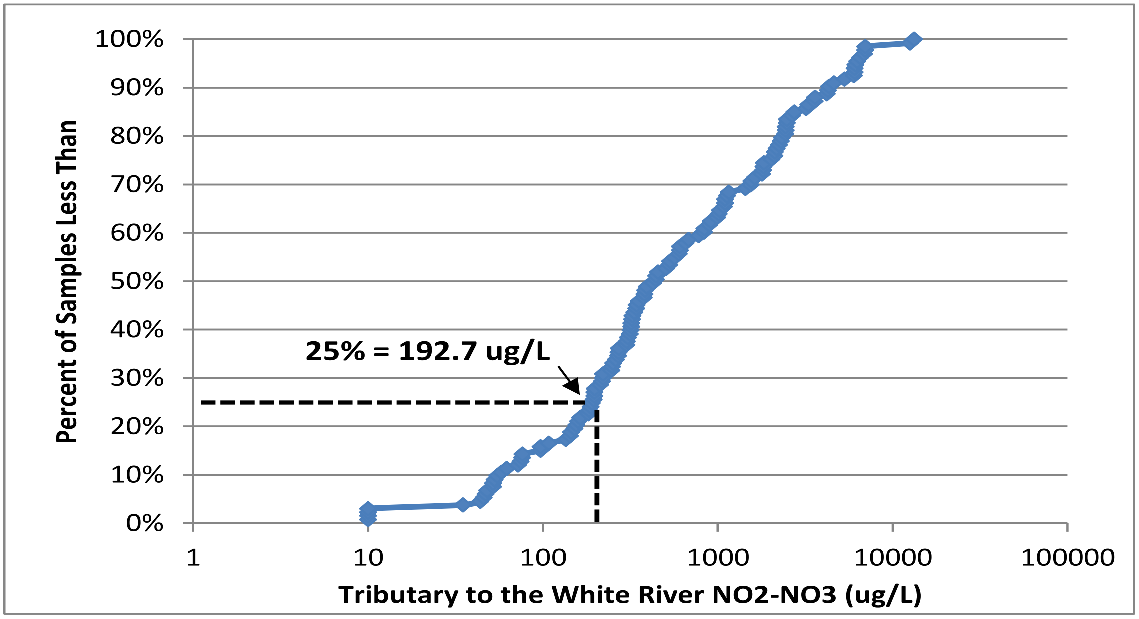

Figure I-97. Cumulative frequency of NO2-NO3 concentrations from historical data and the 2012 study.

Nutrient concentrations for groundwater inputs were set as the 25th percentile from the 2012 samples collected from piezometers, springs, and off-stream wells in the study area. Figures I-98 and I-99 depict the cumulative frequency and 25th percentile results for SRP and NO2-NO3 in groundwater, respectively.

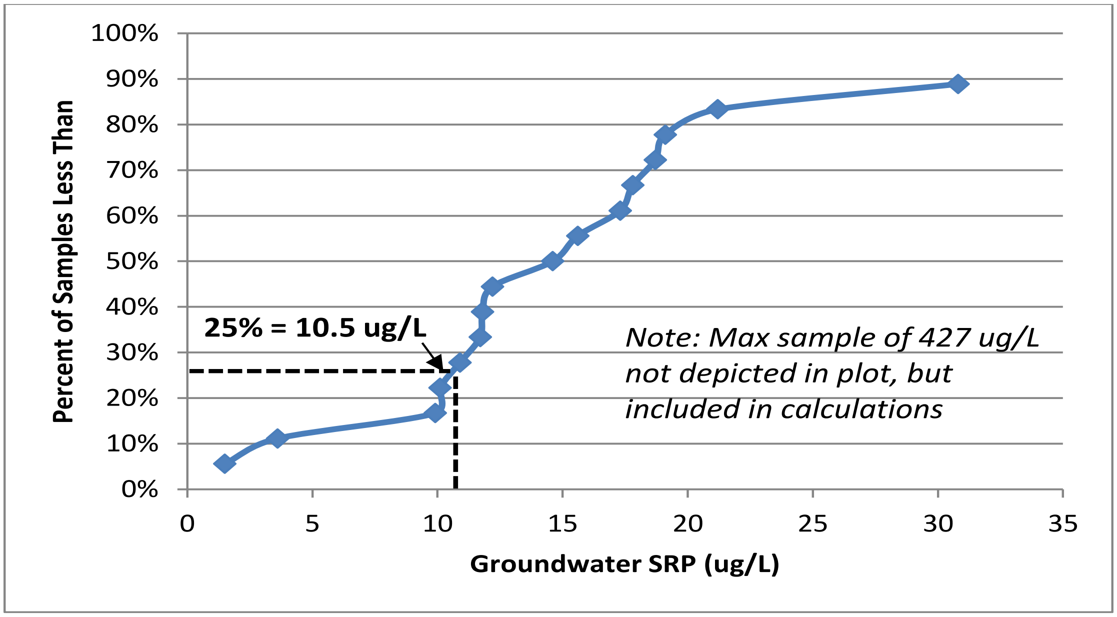

Figure I-98. Cumulative frequency of groundwater SRP concentrations from the 2012 study.

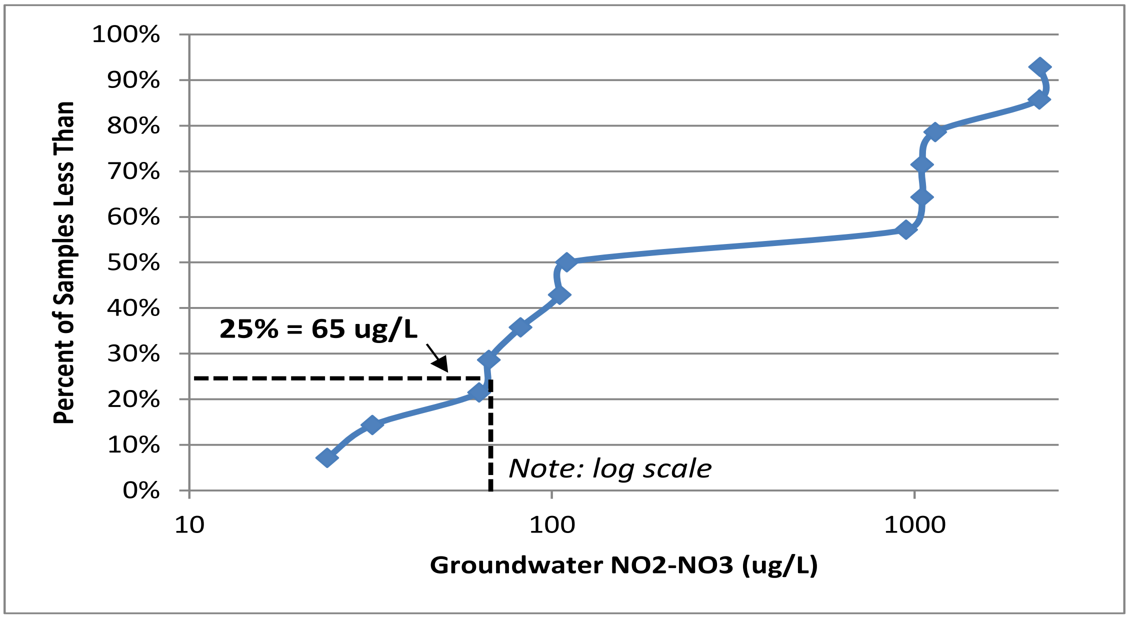

Figure I-99. Cumulative frequency of groundwater SRP concentrations from the 2012 study.

Removed point source inputs and abstractions/withdrawals

Ecology removed the flow and water quality inputs from the Buckley and Enumclaw WWTPs, White River Hatchery, Sonoco, and stormwater sources. Ecology also removed the abstractions for the White River diversion and the White River Hatchery.

System potential shade

Ecology estimated historic system potential shade by mapping three riparian zones and assigning mature tree heights and densities to each zone (Figure I-100). The tree heights and categories were estimated based on:

- Descriptions of historic riparian tree species and estimates of diameters in the Lower White River valley (Collins and Sheikh, 2005). Hardwoods were found to dominate the lower valley riparian area, particularly black cottonwoods (*populous trichocarpa*).
- Consultation with Martin Fox, Ph.D., a forest hydrology expert and fisheries biologist for the Muckleshoot Indian Tribe, who has been researching historic riparian vegetation on the White River to understand large wood debris recruitment and fish habitat potential on the river.
- Descriptions of historic riparian tree species and estimates of diameters taken directly from General Land Office (GLO) field survey maps and notes of the area circa 1860-1880. The GLO notes are one of the primary data sources utilized by Collins and Shiekh (2005). Ecology extended the analysis beyond the lower river valley to the upper reaches of the study area.
- Diameter at breast height (DBH) measurements from Collins and Sheikh (2005) and the GLO field notes were converted from DBH to tree height using species specific height/DBH models developed for coastal areas of the Pacific Northwest (Hanus et al, 1999; Keyser, 2015).
- The three riparian zones were manually digitized in GIS:
    - The disturbance zone boundaries were digitized primarily from historical 1907 survey maps for the lower river and aerial photographs for the upper river.
    - The flood terrace and uplands were delineated using a combination of current digital elevation models, the historic GLO/survey maps, and aerial photography.

Table I-94 contains median tree diameter and height estimates. For the flood terrace zone, a system potential tree height of 30 meters was used, based on the median height of 29 meters for cottonwoods estimated by Collins and Sheikh (2005). For the upland zones, Ecology estimates were used for conifers, because Collins and Sheikh focused on the lower river valley, whereas Ecology research extended to the upper valley. A height of 40 meters was used based on the estimates for western cedar (*Thuja plicata*) and Douglas fir (*Pseudotsuga menziesii*), 37 and 43 meters respectively. The upland zone was more frequently applied in the upper river (~RM 12 to 28) and very rarely applied below RM 12).

Table I-94. System potential median tree diameter and height estimates

Study-Tree Species	Median DBH (in)	Max DBH (in)	Median Height (m)	Max Height (m)
ECY-Cedar	22	70	37	70
C&S-Cedar	20	100	34	83
ECY-Fir	25	70	43	78
C&S-Fir	11	60	25	72
ECY-Alder	8	24	23	26
C&S-Alder	8	34	23	26
C&S-Cottonwood	20	80	29	46

ECY= Ecology estimates from GLO notes; C&S= Collins and Sheikh, 2005.

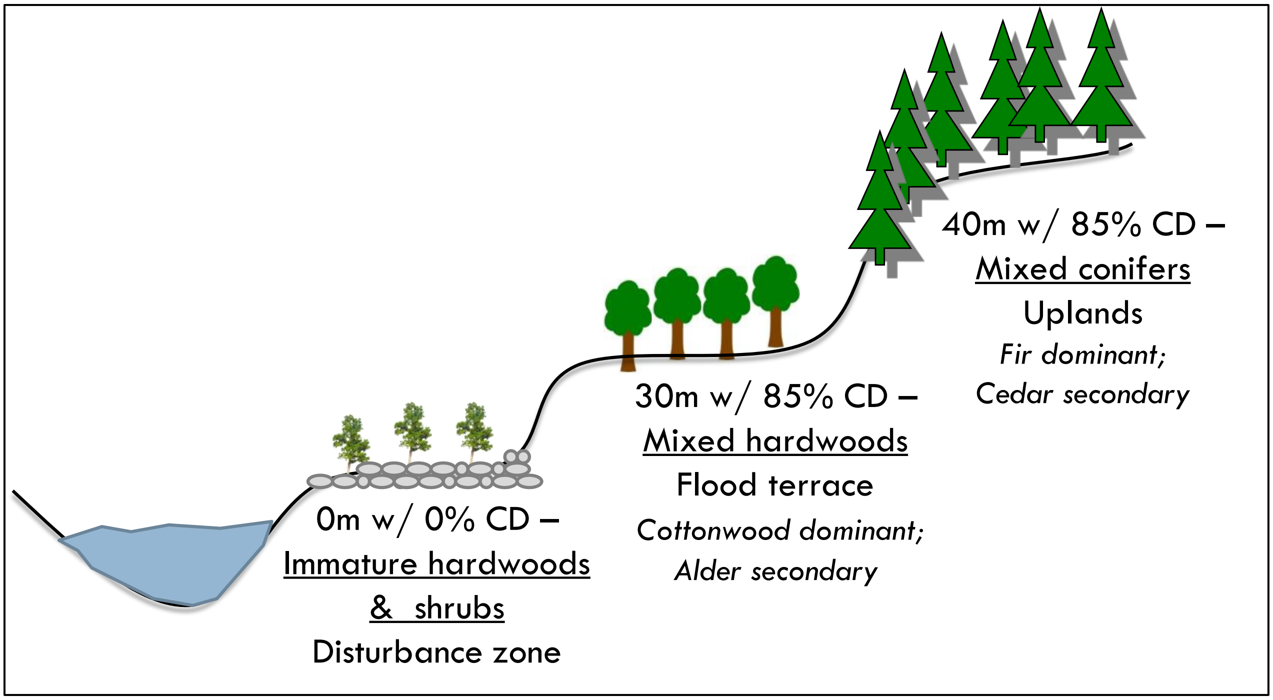

Figure I-100. System potential riparian shade zones.

Channel geometry and shade in Auburn/Pacific/Sumner

Ecology digitized the historic, pre-levee channel and disturbance zone from 1907 survey maps (Figures I-101 and I-102). The pre-levee channel was used in the system potential shade model and the resulting shade outputs were used in the system potential pH model. Ecology also replaced the channel geometry coefficients within the levee reach with coefficients from immediately upstream of levee area to reflect the wider and shallower channel geometry most likely present in this stretch of the river, prior to levees.

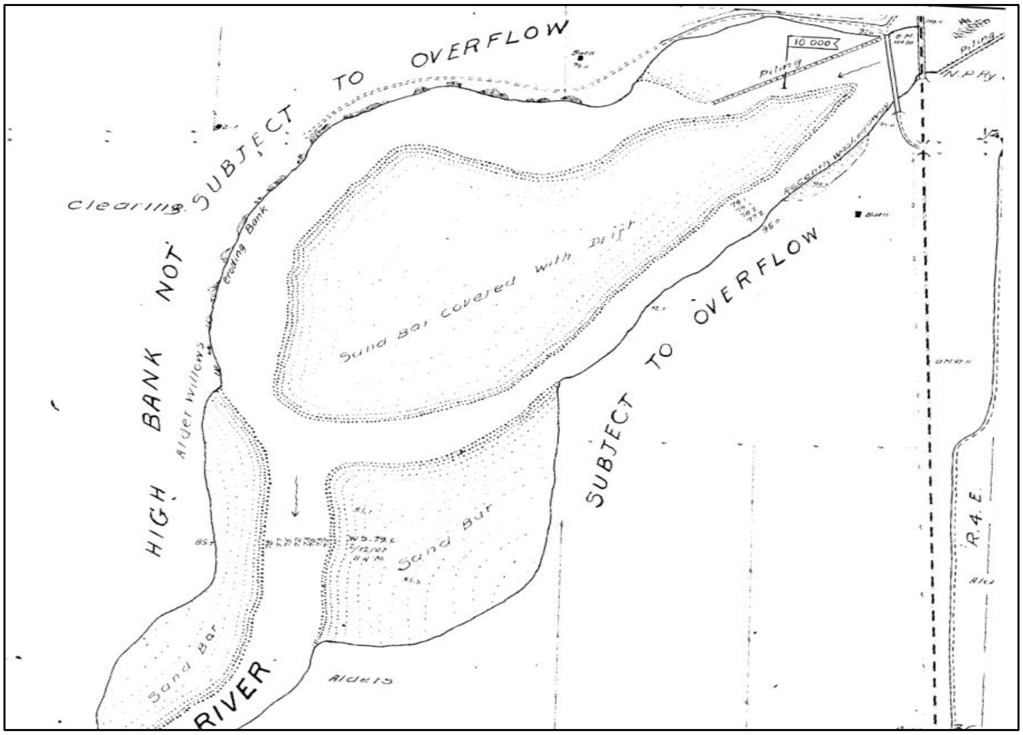

Figure I-101. Example section of 1907 survey map for the Lower White River in Auburn, downstream of present day A St Bridge.

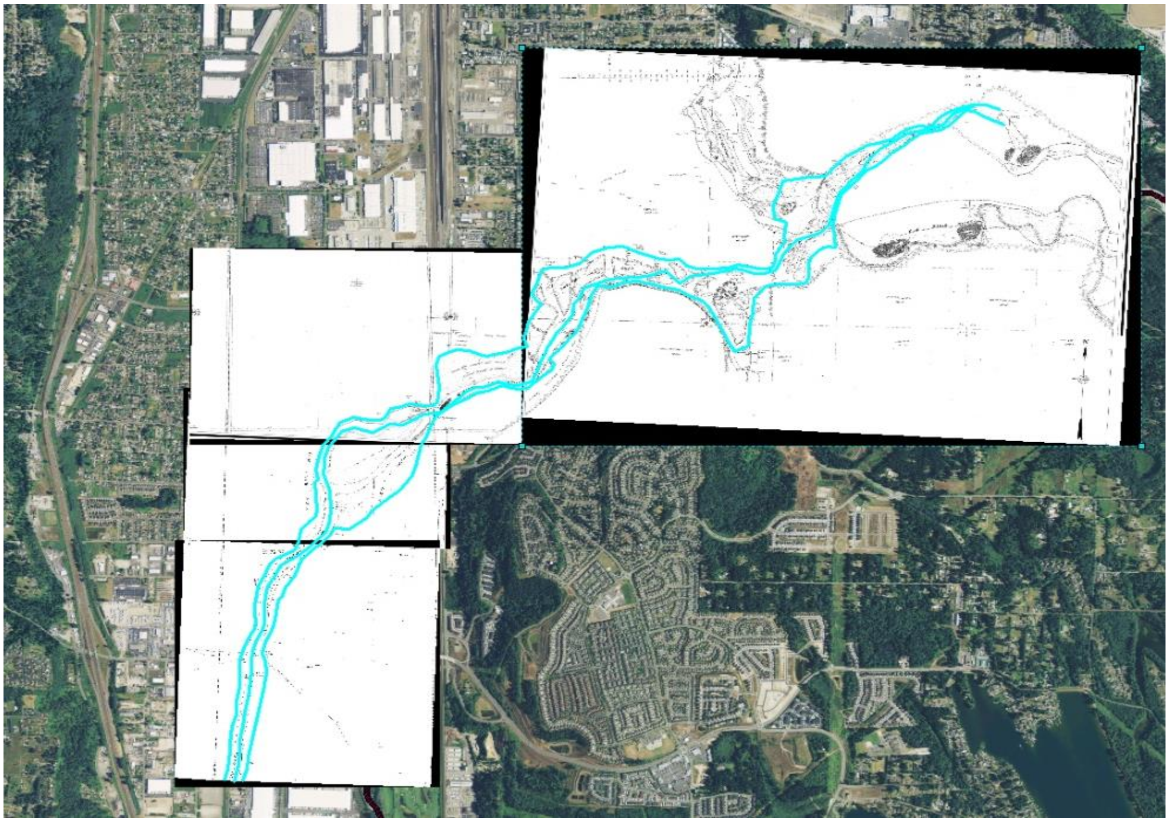

Figure I-102. Digitized channel and disturbance zone from the 1907 survey map.

System Potential Model Assumptions

- The technical approach for estimating nutrients is an adequate representation of "natural" concentrations.
- Historical survey maps of the Lower White River channel and disturbance zone, before the river was leveed (1907), represent the "natural" channel.
- The present-day channel geometry of the Lower White River upstream of all levees is a reasonable approximation of the historical channel geometry in the leveed reach, prior to levees.
- Mature system potential riparian shade is adequately represented by three zones: 1) Near-stream disturbance zone: sparse or no vegetation (0m) height; 2) Floodplain: Cottonwood/Alders (30m); 3) Uplands: Firs/Cedars (40m).
- Historical groundwater flows were similar to levels estimated from the 2012 study. Similarly, the percent of river flow exchanging with the hyporheic zone, and the thickness of this zone were similar to those estimated in the 2012 study.

System potential results

The QUAL2Kw model was run with system potential modifications to estimate the system potential pH, for comparison to the water quality standards. Figure I-103 depicts continuous pH in Reach 27 (RM 4.4), where pH is at its greatest. Figure I-104 depicts longitudinal pH results for the system potential model. The magnitude of the pH diel swings was significantly reduced in the system potential model; however, the diel and season long patterns in pH were very similar to the existing conditions model, just muted.

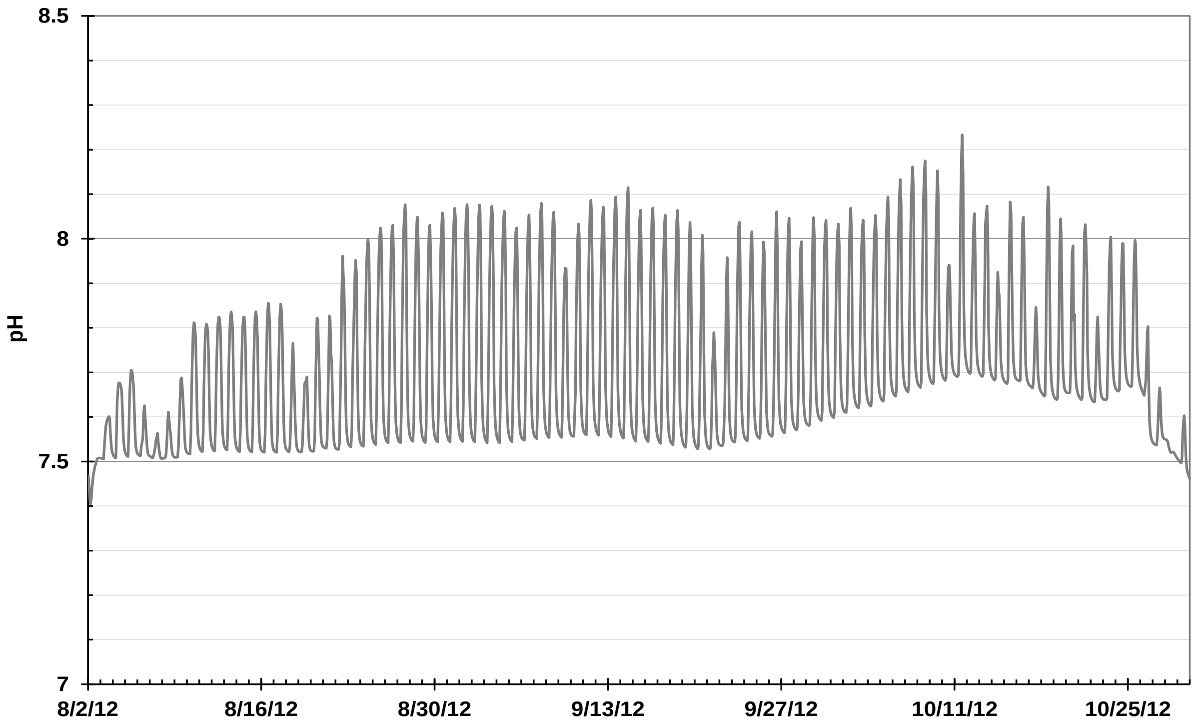

Figure I-103. Dynamic system potential pH in Reach 27 (RM 4).

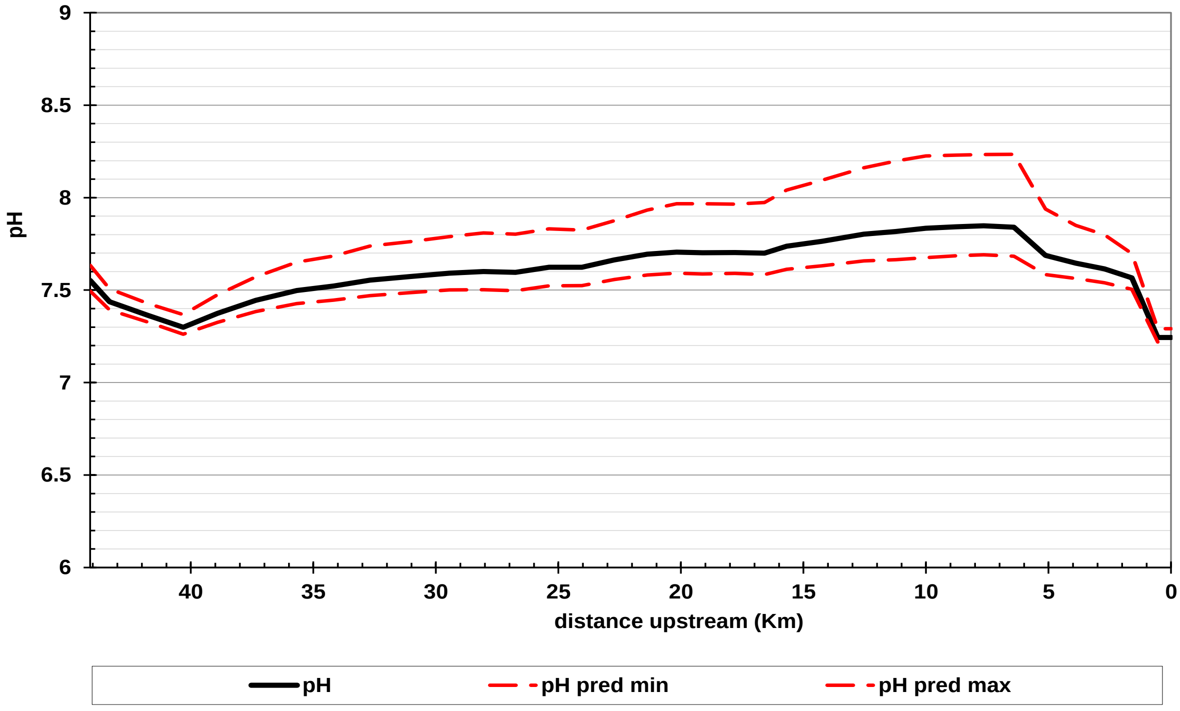

Figure I-104. Longitudinal system potential pH for 10/11/12 (most critical day).

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Appendix J. Overview and summary of data from previous studies

This appendix provides an overview and summary of data from studies that were conducted prior to the 2012 study that is described in Appendix F. While the 2012 data were used to calibrate the water quality model that was used to simulate dynamic changes in pH in the Lower White River, data collected during earlier studies were used to develop and support the conceptual model for describing effects of nutrients on pH levels in the Lower White River.

Background related to previous data collection

This section presents data that describe the relationships among phosphorus, periphyton, and pH in the Lower White River collected during previous studies. Most of the data that are described in this section were collected by the University of Washington, between September 2000 and September 2001, as part of a study funded by the Department of Ecology. The study included the following activities:

- Seven river locations were sampled for periphyton, nutrients, pH, turbidity, temperature, and other parameters at approximately two-week intervals;
- pH was continuously monitored at several locations over multi-day periods; and
- Three synoptic surveys were completed in which flows and nutrient concentrations were measured at all significant mainstem and tributary sources.

The data that resulted from this study are fully described in Stuart (2002). The sampling and monitoring locations used in the University of Washington study are shown in Figure J-105**.**

Although much of the analysis described in this section is based on data from the 2000-2001 University of Washington study, data collected as part of other studies are also referenced in the sections that follow. The data collected in these other studies are generally consistent with the 2000-2001 data collected by the University of Washington, in that they show 1) high pH values occurring from July through October 2) pH values increasing in the lower reaches of the river, and 3) diurnal fluctuations in pH with peak values occurring in daylight hours.

The historic data included in this section was used to develop and support the conceptual model for effects of nutrients on pH levels in the Lower White River. The earlier data describe the river under different flow and nutrient loading conditions. While data collected in 2012 were used to develop and calibrate the QUAL2KW model for the TMDL, the earlier data add further insights into the river dynamics, including the effects of scour and phosphorus uptake on periphyton growth. Important findings from this earlier work that contributed to the conceptual model for the TMDL include the following:

The amount of flow in the White River affects algae and pH. Flows affect nutrient concentration, nutrient travel distances, water temperatures, algae scour from riverbed sediments, and carbon dioxide exchange with the atmosphere.

Periphyton growth can be limited by light during summer months because of naturally occurring turbidity in the river. This turbidity comes from sediment released from glaciers. During colder periods during late summer and early fall, the river runs clear and more light reaches algae on the underlying riverbed, spurring growth.

The Lower White River is naturally sensitive to changes in pH because it has low alkalinity and little buffering capacity.

Low-flow, low-turbidity, and high-nutrient conditions in the Lower White River lead to large daily fluctuations in pH and daily maximum pH above the 8.5 criterion.

Periphyton growth response times, at critical low flows, can be fairly rapid (7-10 days) to reach levels that result in pH values above 8.5.

There is evidence of periphyton biomass decrease due to scour following abrupt changes in flow.

The data show that the periphyton biomass increases downstream from RM 25.2 reaching a peak in the vicinity of RMs 20.3 and 16.4. Data downstream of this point suggests that periphyton biomass decreases with river miles.

The phosphorus loads from the wastewater treatment plants cause significant increases in SRP concentration in the White River, particularly during periods of low flow. Phosphorus concentrations decrease between RM 20.3 and RM 8.0 in part because of phosphorus uptake by periphyton. This uptake can drive the system toward phosphorus-limited conditions.

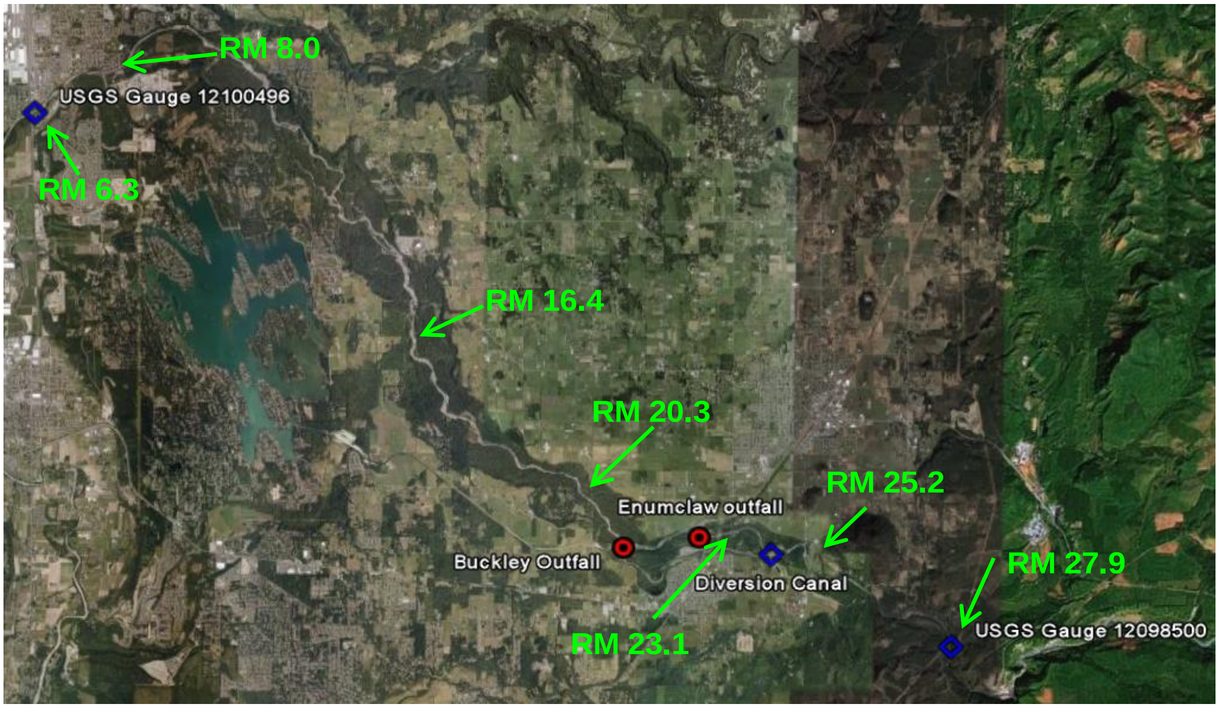

Figure J-105. Data collection locations during the 2000-2001 University of Washington study.

General river conditions: flow and turbidity

The White River originates at glaciers in Mt. Rainier National Park and flows 68 miles to its confluence with the Puyallup River. Data collected in previous studies describe river conditions between river mile (RM) 25.4, near the city of Buckley, and RM 5.2, near the City of Pacific. The river elevations in this section of the river range from approximately 730 feet at RM 25.4 to approximately 60 feet at RM 5.2.

This section of the river includes the diversion dam that is used to divert water into Lake Tapps and the tailrace channel that is used to release water from Lake Tapps. The portion of the river between the diversion dam and the tailrace channel is often referred to as the "diversion reach."

This part of the river is also referred to as the "reservation reach" because the river flows though the Muckleshoot Indian Tribe reservation, between approximately river mile 16 and river mile 8.

Flow data for the 2000-2001 study period are available from several USGS gages located along this section of the White River. These gages are listed in Table J-95. Figure J-106 shows flows during the 2000-2001 study period for the three high-lighted gages listed in Table J-95. The *White River near Buckley* gage (Gage 12098500) provides flow values at a location upstream of the diversion canal. The *White River at Buckley* gage (Gage 12100000) provides flow values downstream of the diversion canal. This location is above the outfalls for the Enumclaw and Buckley WWTP's. The *White River near Auburn* gage (Gage 12100496) provides flow values at the lower end of the study area and is used in a water-balance approach to estimate groundwater inflow into the river.

Figure J-106 shows that White River flow during the 2000-2001 study period followed a seasonal pattern typical of glacier-fed rivers in the Pacific Northwest. River flows above the diversion dam are below the annual average in the fall and winter and are above the annual average during the spring and early summer. This pattern is also described in the data included in Table J-96. Average and median flows for the full 2000-2001 study period (9/15/2000 to 9/15/2001) are compared with flows during the fall and early winter (9/20/2000 to 1/4/2001) in Table J-96.

The diversion dam historically diverted a much larger amount of the flow to Lake Tapps, resulting in much lower flow in the White River below the diversion, compared to the 2012 data collection period and current conditions. For example, the mean monthly diversion during January was 905 cubic feet per second (cfs) between 1982 and 2004 and was 20 cfs between 2011 and 2018. These earlier diversions caused artificially low flows in the river and increased periphyton growth rates under critical low-flow conditions.

The turbidity of the White River also varies seasonally, as shown in Figure J-107. The amount of suspended solids increases significantly during the spring and summer, as temperatures rise, and the amount of glacial melt-water in the river increases.

The sediment load from glacial melt-water affects periphyton growth and pH values. During warmer summer months, sediment is released from snow and glacial ice in the upper watershed. During autumn and winter, cooler weather reduces the sediment release from glaciers. As a result, the river becomes clear and more light reaches the river bed to increase periphyton growth during the fall months. The change in river clarity and its impact on periphyton and pH values can be dramatic during the fall period.

The combined effects of lower flows and lower turbidity result in higher rates of periphyton growth during the fall and early winter months. Based on observed periphyton concentrations that are presented in sections that follow, a defined periphyton "growing season" was evident during the 2000-2001 data collection period. Flow during this growing season is shown in Figure J-108. Average and median values for the growing season are included in Table J-96. The average flow observed during the 2000-2001 growing season below the diversion dam is 130 cfs (USGS gage 12099100).

As a point of reference, the natural 7Q10 flow for the White River above the diversion dam (USGS gage 12098500) is 260 cfs, based on data collected from 1977 to 2003, and is 302 cfs based on data collected from 1928 to 2003. These 7Q10 values are also shown in Figure J-108.

The flow data included in Figures J-106 and J-108 indicate that the White River is a gaining stream over the section from River Mile 23.3 to River Mile 6.3. The average flow at the **White River near Auburn** gage (RM 6.3) is approximately 60 cfs greater than the average flow at *the* **White River at Buckley** gage (RM 23.3). This corresponds to an increase of approximately 3.5 cfs per river mile. The increase is derived from both small tributaries and groundwater inflow. The relative magnitude of these inflows is described in more detail in later sections of this appendix.

Table J-95. USGS White River gaging stations

Gage name	Number	River mile	Comments
White River near Buckley	12098500	27.9	Above diversion canal
White River Canal at Buckley	12099000	0.8	Located at White RM 24.3
White River above Boise Creek	12099100	24.2	Replaced gage 12100000
Boise Creek	12099600	0.1	Located at White at RM 24.0
White River at Buckley	12100000	23.3	Below diversion canal
White River near Auburn	12100496	6.3	Near lower end of study area

Table J-96. Average and median flows for the full 2000-2001 study period (9/15/2000 to 9/15/2001) compared with flows during the fall and early winter (9/20/2000 to 1/4/2001).

	USGS Gage Number				
	12098500	**12099100**	**12099600**	**12100000**	**12100496**
Average flows					
9/15/00 to 9/15/01	1005	244	21	274	334
9/20/00 to 1/4/01	678	130	17	150	210
Median flows					
9/15/00 to 9/15/01	794	270	16	293	340
9/20/00 to 1/4/01	593	119	14	134	192

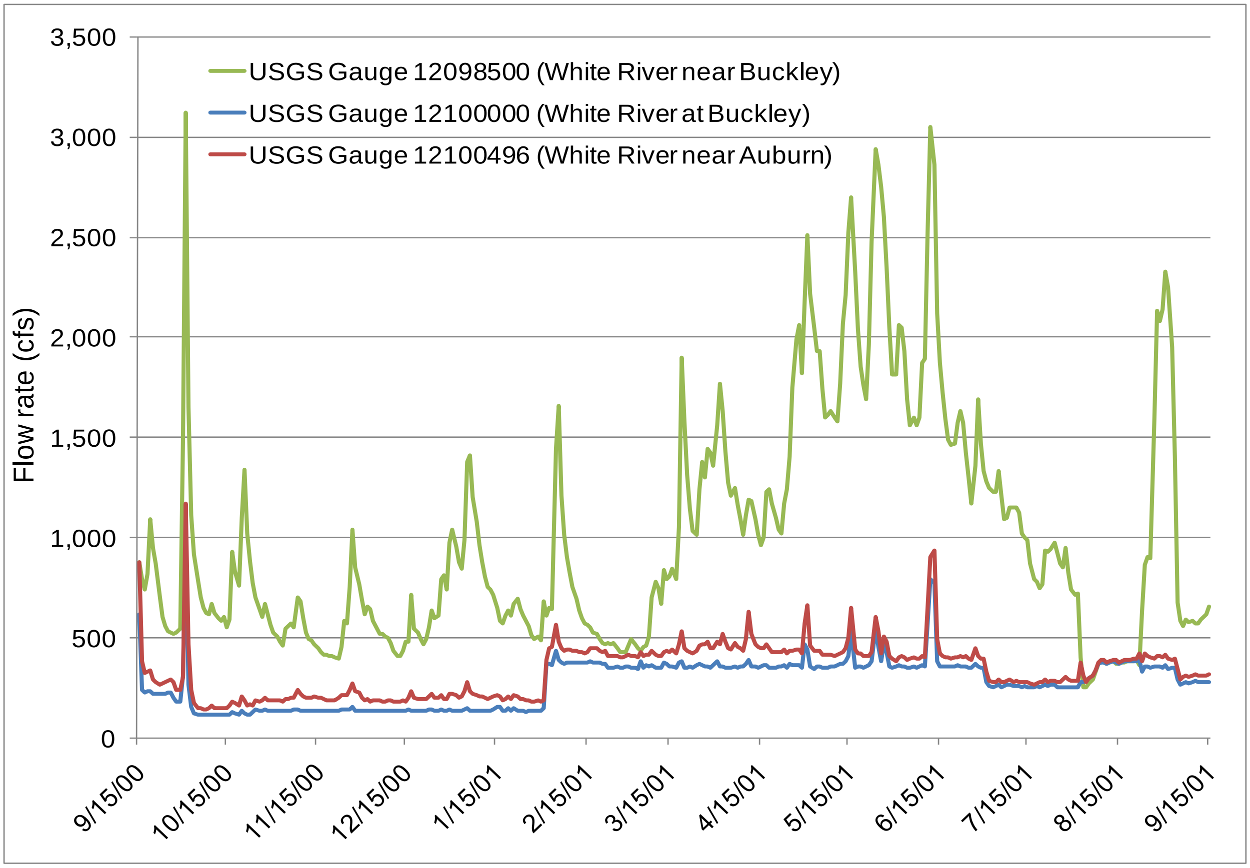

Figure J-106. Flows during the 2000-2001 study period for the three high-lighted gages listed in Table J-95.

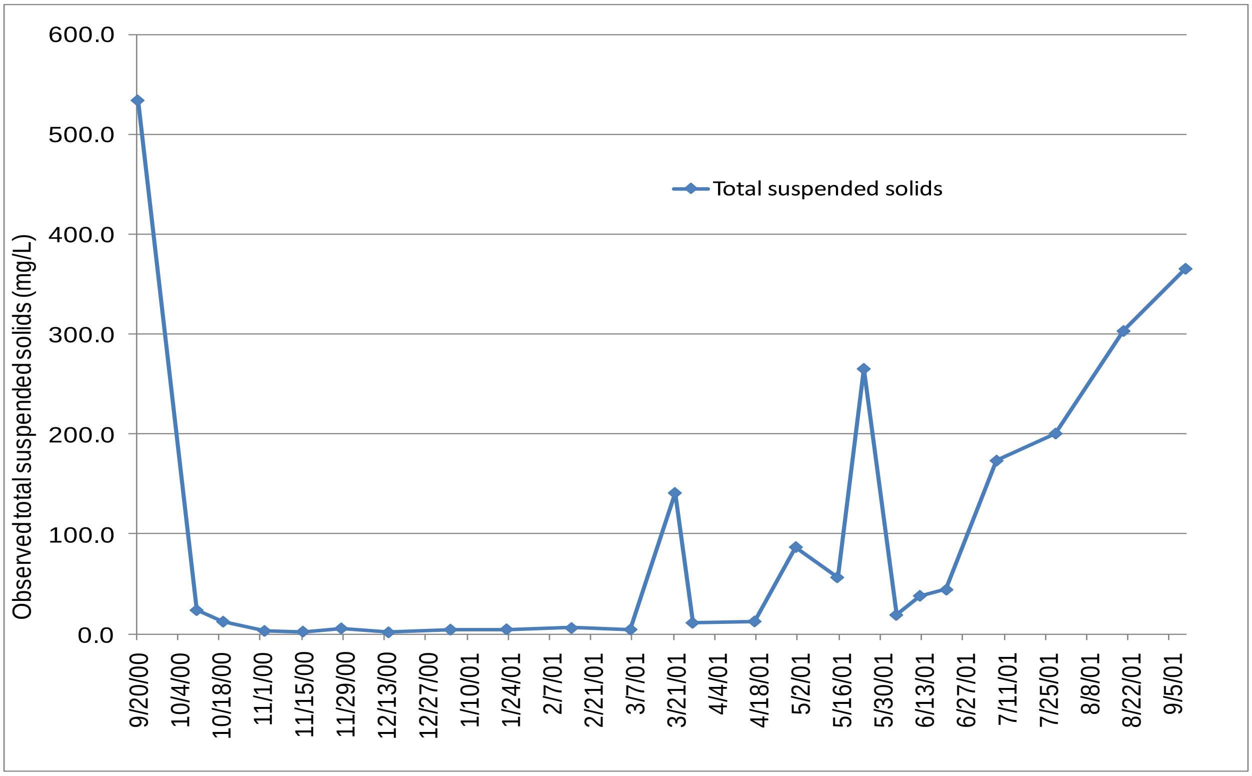

Figure J-107. Average total suspended solids during the 2000-2001 data collection period. Averages were calculated from samples collected at six stations between RM6.3 and RM26.

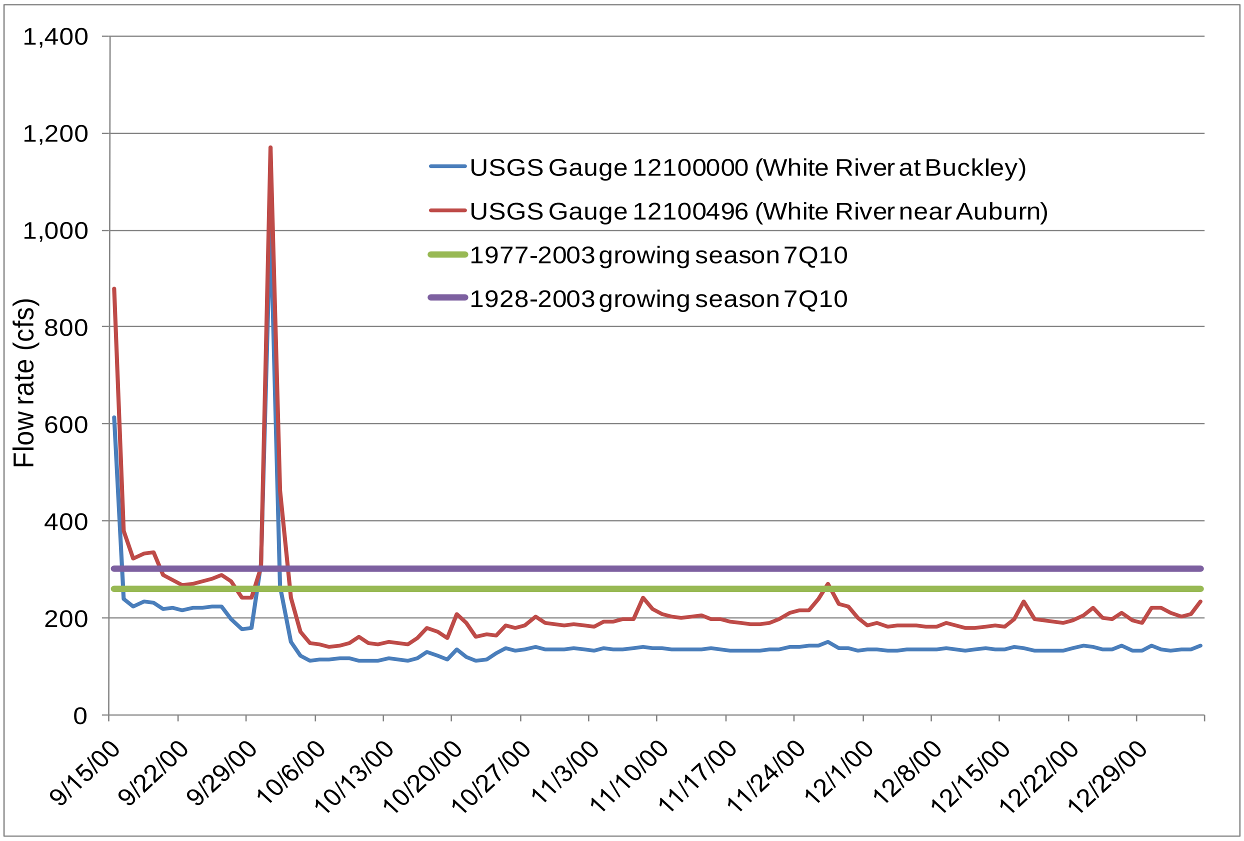

Figure J-108. Observed flows during 2000-2001 periphyton growing season.

Observed pH levels

Prior to the 2012 study used to develop the TMDL model, exceedances of the Washington State surface water quality pH standard (6.5 – 8.5) in the Lower White River had been observed beginning in July 1971, with values exceeding the upper range of the standard. These exceedances were observed in all months except February, have been observed at monitoring points from RM 4.9 to RM 19.8, and have been observed under both low-flow (less than 200 cfs) and moderate-flow (greater than 500 cfs) conditions. No exceedances were observed above the discharge points for the wastewater treatment plants.

Previously-collected data that describe pH in the Lower White River can be categorized into two groups: 1) discrete “grab” samples, and 2) continuous monitoring data. Tables J-97 to J-99 summarizes previous data that were collected as discrete grab samples. Table J-97 identifies grab samples collected in the Lower White River as part of Ecology’s Environmental Assessment Program’s long-term monitoring program between 1961 and 2006. Ecology does not currently have any active long-term monitoring stations in the Whiter River watershed.

Water quality data were also collected from several monitoring stations on the White River on approximately monthly intervals beginning in October of 1961 as part of this assessment program. Parameters measured include temperature, pH, dissolved oxygen, nutrients, turbidity, and stream flow, although not all parameters are available for all dates and sites.

Quality assurance protocols associated with this long-term monitoring program have become increasingly sophisticated over time (Erickson, 1999). As noted above, data collected during earlier studies were used to develop and support the general conceptual model for describing effects of nutrients on pH levels in the White River. The earlier data that were collected with less stringent quality assurance protocols were not used in model calibration and were not quantitatively compared with more recent data.

Grab samples have also been collected by the Department of Ecology as part of data collection programs related to specific TMDL projects. Table J-98 describes data that were collected on the Lower White River as part of the Puyallup River dissolved oxygen TMDL (Pelletier, 1993) and Table J-99 describes data that were collected as part of the Assimilative Capacity Study for the Lower White River (Erickson, 1999).

Grab samples do not provide a reliable measure of peak pH values. The pH values in rivers and streams exhibit diurnal variations due to the effects of photosynthesis and respiration. Peak values typically occur in mid- to late afternoon. Streams and rivers that exhibit pH values less than 8.0 during the morning hours may have afternoon values that exceed 9.0. Most of the grab samples that are identified in Tables J-97 to J-99 were collected before 2:00 pm and do not represent daily peak values. Higher-frequency or continuous pH monitoring is required to reliably estimate these daily peaks.

Table J-100 identifies previously-collected datasets that describe high frequency or continuous variation in pH in the Lower White River. These datasets include pH measurements that are made at intervals ranging from 10 to 30 minutes for durations from one or two days to one or two months. Column D in Table J-100 gives the number of daily peaks that are included in each dataset and Column E gives the number of these daily peaks that exceed the 8.5 pH standard. Approximately 30% (64 out of 219) of the daily peaks below RM 24 exceed the pH standard. None of the peaks above RM 24 exceed the standard.

Figure J-109 gives examples of the daily pH fluctuations that have been observed at river miles 4.9, 8.0, and 16.4. These data have been collected by the USGS (Ebbert, 2003), Puget Sound Energy and Cascade Water Alliance (HDR Engineering, 2001), and by the University of Washington (Stuart, 2002). The data exhibit diurnal variations indicative of algae photosynthesis and respiration. While most of the pH exceedances that have been observed with the continuous monitoring efforts occur during the fall, exceedances have also been observed during January and March (Stuart, 2002).

The highest pH values observed by the University of Washington during their 2000-2001 study period were measured in November of 2000 at RM 16.4. These data are shown in Figure J-110. The pH data were collected over a six-day period between 11/22 and 11/28/2000. These data bracket periphyton and nutrient data that were collected on 11/28/2000. The peak pH observation occurred on 11/24/2000 and was equal to 9.3. Data collected at RM 27.9 upstream of the outfalls for the wastewater treatment plant are also shown in Figure J-110. The data shown in Figure J-110 illustrate that the diurnal fluctuations at RM 27.9 are relatively small. The pH at this location ranged from 7.61 to 7.84 during the six days of data collection. The diurnal fluctuations at RM 16.4 are much larger, with pH ranging from a minimum of 7.62 to a maximum of 9.3. The minimum pH values are similar (7.61 versus 7.62) while the peak pH values are much different (7.84 versus 9.3). These data provide additional evidence of pH fluctuations caused by periphyton growth.

Data collected by the USGS during the summer of 2002 suggest that algae growth occurs relatively rapidly in response to increased nutrient concentrations caused by reduced flows in the White River. Figure J-111 shows flow rates in the White River measured at USGS gage 12100000 (**White River at Buckley**) and pH values measured at RM 4.9 during the period August 8 through October 15, 2002 (Ebbert, 2003). Flows dropped from approximately 800 cfs to approximately 300 cfs on August 26, 2002 as a result of changes in diversion rates at the diversion canal. Because of the hydraulic characteristics of the White River, this change in flow is accompanied by relatively small changes in water depth and light availability. The flows remained at the lower levels throughout September and October. The pH values at RM 4.9, which were at approximately 7.6 during the week preceding the change in flows, began increasing approximately one week after the flows had been reduced. The pH values began exceeding the standard of 8.5 on September 10, 2002, 15 days after the change in flows. The pH values eventually reached levels above 9.0 during early October. These data suggest response times for algae growth and pH changes that are on the order of 7 to 10 days.

The amplitude of the pH fluctuations in the White River are due in part to the relatively low alkalinity of the river water. Table J-101 lists alkalinity data collected by the University of Washington during the 2000-2001 growing season.

Table J-97. Observed pH values from discrete "grab" samples at White River sites. Long-term Monitoring Data from Department of Ecology's Environmental Assessment Program.[29]

River Mile	First date	Last date	Data points	# of Exceedances	Peak pH	Months with pH exceedances
4.9	12/2/68	9/18/96	45	0	8.2	None
6.3	10/18/61	9/18/73	92	7	9.1	July, August, October, November
8.0	10/21/98	9/25/06	96	7	9.4	March, April, May, July, September, October
19.8	10/26/72	9/17/73	24	3	9.0	June, August, September
23.1	10/27/92	9/28/91	11	0	8.0	None

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[29] https://ecology.wa.gov/Research-Data/Monitoring-assessment/River-stream-monitoring/Water-quality-monitoring

Table J-98. Observed pH values from discrete "grab" samples at White River sites from the Puyallup River TMDL (Pelletier, 1993).

		River Mile Location							
Date	**Flow**	**25.2**	**23.1**	**20.4**	**14.9**	**10.3**	**8**	**6.3**	**4.9**
18-Sep-90	566	7.8	7.9	7.9		8.7	9.1	9.2	9.2
19-Sep-90	570	7.8	7.8	7.9		8.6	9.1	9.1	9.2
02-Oct-90	165	7.7	7.8	7.8	8.6	9.5	9.6	9.6	9.7
03-Oct-90	166	7.7	7.7	7.6	7.8	9.1	9.2	9.1	9.2

Table J-99. Observed pH values from discrete "grab" samples at White River sites from the Ecology Draft Assimilative Capacity Study (Erickson, 1999).

Date	RM25.2	RM23.1	RM20.4	RM14.9	RM10.3	RM8	RM6.3	RM4.9
26-Jun-96	7.5	7.7	8	8.8	8.1	8.1	8	7.8
31-Jul-96	7.4	7.5	7.6	7.8	7.7	7.9	7.8	7.9
22-Aug-96	7.6	7.6	7.7	8.2	8	8.2	8.5	8
12-Sep-96	7.7	7.6	7.7	8.1	8.2	8.4	8.6	8.5
24-Sep-96	7.7	7.4	7.7	7.9	7.8	7.9	8.1	8
9-Oct-96	7.4	7.1	7.5	8.1	7.8	8.7	9	8.8
1-Aug-97	7.8					8.7	7.3	9
8-Aug-97	7.6					7.7	7.7	7.7
15-Aug-97	7.6					8	8.1	7.9
21-Aug-97	7.7					8.2	8.2	8
28-Aug-97	7.8					8	7.9	7.7
4-Sep-97	7.2					7.5	7.7	7.6
18-Sep-97	8.1					7.9	7.7	7.5
24-Sep-97	7.9					8.6	8.7	8.4
2-Oct-97	7.4					7.7	8.1	7.7
9-Oct-97	7.5					8	8	8.1
16-Oct-97	8					8.5	8.7	8.4
23-Oct-97							9.5	9.1

Date	RM25.2	RM23.1	RM20.4	RM14.9	RM10.3	RM8	RM6.3	RM4.9
30-Oct-97	7.5					7.7	7.3	7.6
6-Nov-97						7.4	7.3	7.2
13-Nov-97	8					7.7	7.8	7.8

Table J-100. Summary of Continuous pH measurements at White River Sites.

Start Date/Time	End Date/Time	RM	Number of daily peaks	Days with exceedances	Maximum pH	Reference
A	B	C	D	E	F	G
e	10/16/2001 13:30	4.9	54	15	9.33	PSE/CWA
8/2/2002 11:30	10/16/2002 9:30	4.9	74	32	9.2	USGS
6/25/1996	6/27/1996	8.0	2	0	7.65	Erickson
7/30/1996	8/1/1996	8.0	2	0	7.65	Erickson
8/21/1996	8/23/1996	8.0	1	0	7.9	Erickson
9/11/1996	9/13/1996	8.0	2	0	8.3	Erickson
9/23/1996	9/25/1996	8.0	2	0	7.9	Erickson
10/8/1996	10/10/1996	8.0	3	3	8.8	Erickson
10/27/2000 10:10	10/30/2000 18:30	8.0	4	4	8.77	Stuart
12/14/2000 14:00	12/15/2000 14:00	8.0	1	1	8.79	Stuart
1/15/2001 14:15	1/18/2001 0:30	8.0	3	1	8.70	Stuart
3/4/2001 16:23	3/6/2001 15:53	8.0	3	2	8.67	Stuart
7/3/2001 14:00	7/8/2001 11:15	8.0	5	0	8.23	Stuart
7/12/2001 0:00	7/15/2001 5:45	8.0	3	0	8.14	Stuart
7/20/2001 14:30	7/30/2001 17:45	8.0	11	0	8.31	Stuart
8/14/2001 13:15	8/20/2001 16:15	8.0	7	0	7.72	Stuart
9/2/2001 18:45	9/10/2001 17:00	8.0	8	0	7.94	Stuart
9/11/1996	9/13/1996	14.9		0		Erickson
11/22/2000 12:00	11/28/2000 17:15	16.4	7	6	9.30	Stuart
7/3/2001 15:45	7/7/2001 0:00	16.4	3	0	8.10	Stuart

Start Date/Time	End Date/Time	RM	Number of daily peaks	Days with exceedances	Maximum pH	Reference
7/16/2001 10:30	7/18/2001 14:30	16.4	3	0	8.07	Stuart
7/20/2001 15:45	7/30/2001 18:00	16.4	11	0	8.21	Stuart
8/14/2001 11:45	8/20/2001 16:30	16.4	7	0	7.66	Stuart
9/4/2001 7:30	9/6/2001 23:15	16.4	3	0	7.50	Stuart
8/2/1996	8/23/1996	25.2	2	0	7.4	Erickson
9/11/1996	9/13/1996	25.2	2	0	7.6	Erickson
9/23/1996	9/25/1996	25.2	2	0	7.3	Erickson
10/8/1996	10/10/1996	25.2	3	0	7.4	Erickson
11/22/2000 11:00	11/28/2000 14:45	27.9	6	0	7.84	Stuart
12/14/2000 9:45	12/15/2000 15:00	27.9	2	0	7.13	Stuart

Table J-101. Observed alkalinity in the White River during the 2000-2001 growing season. Values are in mg/L as CaCO3. From University of Washington study (Stuart, 2002).

Location	9/20 2000	10/9 2000	10/19 2000	10/27/2000	11/2 2000	11/15 2000	11/28 2000	12/14 2000	1/4/2001
RM 6.3	21	31							
RM 8.0	20		29	31	31	33	30.5		33
RM 16.4					28.5	28.5	25		27
RM 20.3	19	19	24	23	27	27	25	25	24
RM 23.1	18	22	20.5	23	26	14.5	22	23.5	21
RM 25.2	25	25	17	20	23	23	19	21.5	
RM 27.9							18		
Averages:	**19**	**21**	**25**	**26**	**28**	**26**	**26**	**24**	**26**

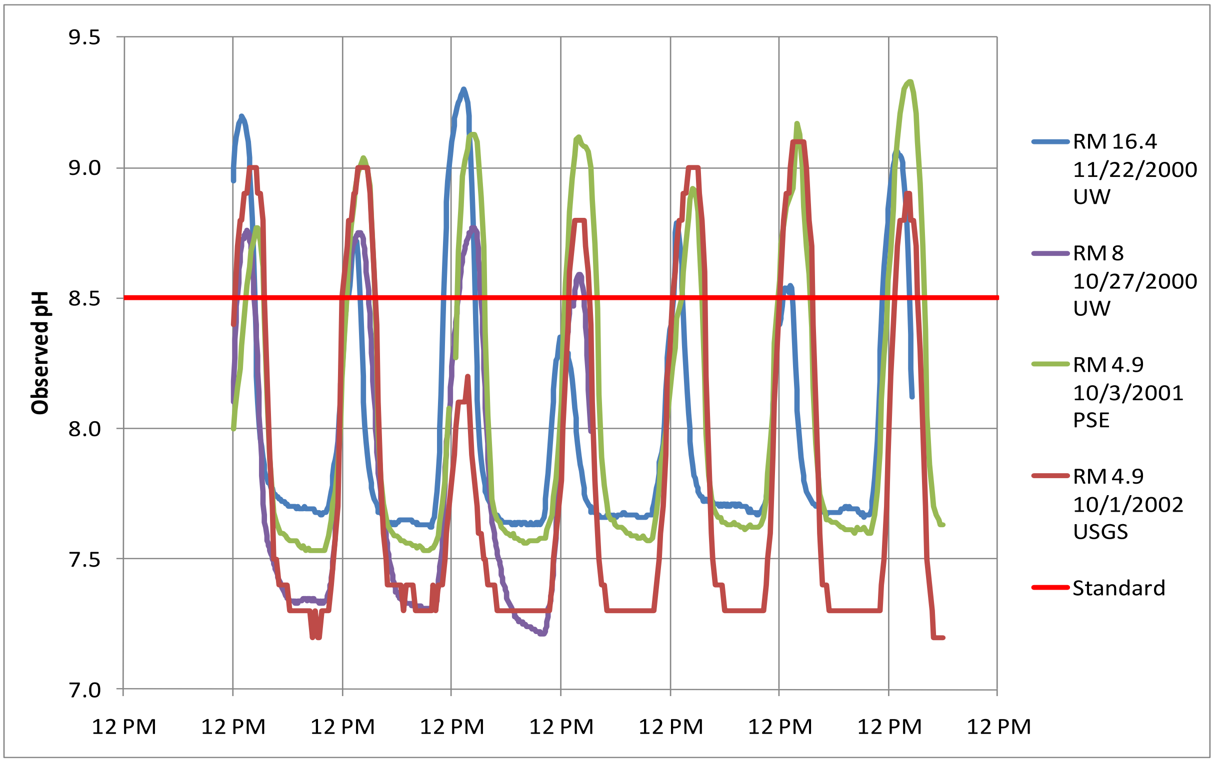

Figure J-109. Examples of the daily pH fluctuations that have been observed at river miles 4.9, 8.0, and 16.4. Dates in legend refer to the beginning point for each example.

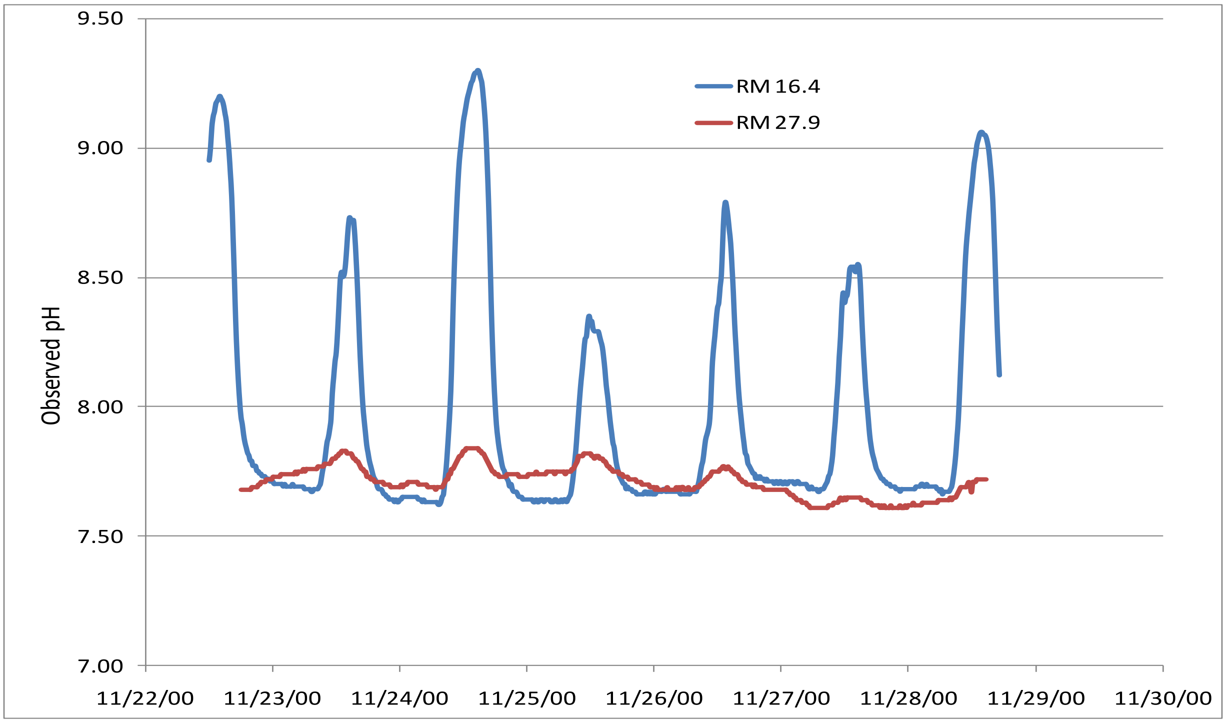

Figure J-110. Comparison of pH above and below wastewater treatment plant outfalls. RM 16.4 is below the outfalls and RM 27.9 is above the outfalls.

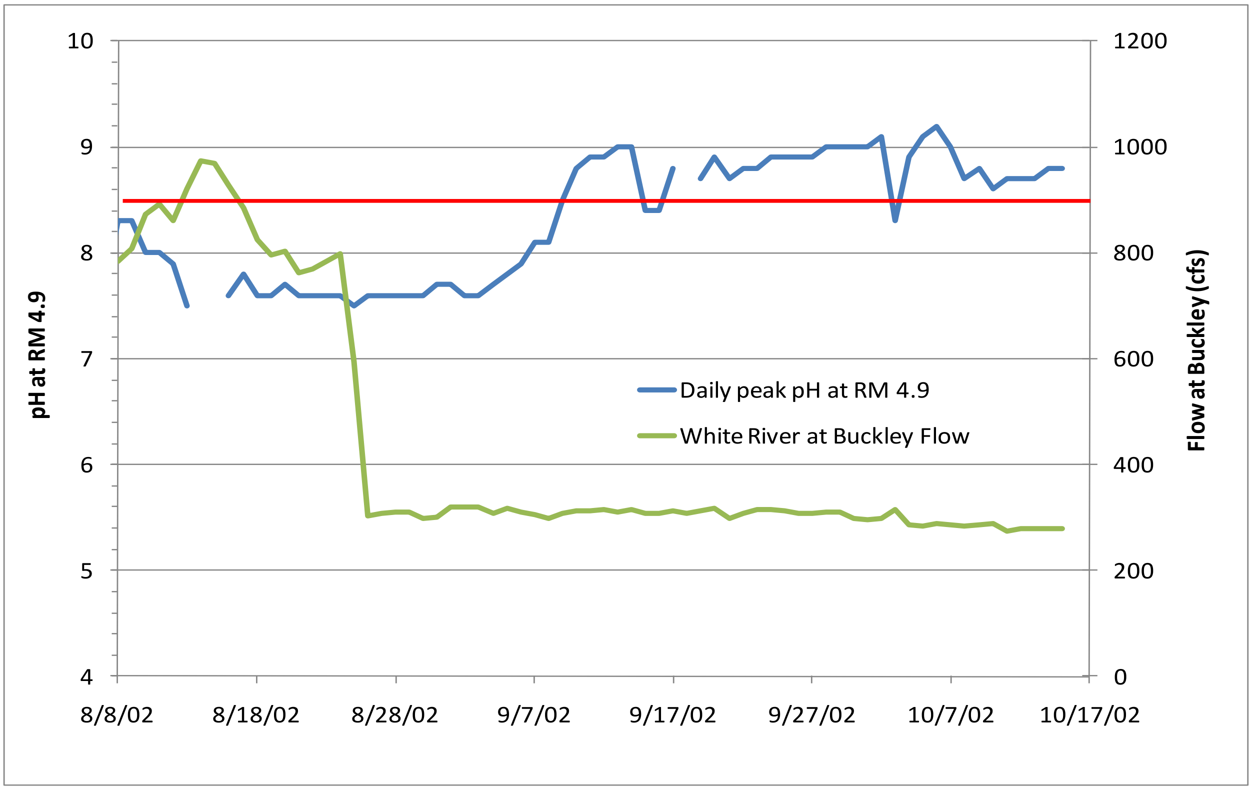

Figure J-111. Relationship between flow and pH based on USGS data from 2002.

Observed periphyton levels

Periphyton concentrations in the White River have been quantified using measurements of chlorophyll *a*. These data were collected by the Department of Ecology in 1996-1997 (Erickson, 1999) and by the University of Washington in 2000-2001 (Stuart, 2002). The data collected by the University of Washington during 2000-2001 provide a more comprehensive description of algae conditions in the river.[30]

Chlorophyll *a* data collected during the period from September 2000 through September 2001 are listed in Table J-102. The bottom two rows in Table J-102 give average values for the growing season (defined as September 20, 2000 to January 4, 2001) and for the post-growing season (January 23 to September 10, 2001). The two right-most columns in Table J-102 give average concentrations for monitoring stations above (RM's 23.1, 25.2) and below (RM's 20.3, 16.4, 8.0 and 6.3) the wastewater outfalls for the cities of Enumclaw and Buckley.

The average monthly concentrations for monitoring stations above and below the wastewater discharge locations for the Cities of Enumclaw and Buckley are summarized in Figure J-112. These data show that periphyton levels increased between September 2000 and January 2001 at locations both above and below the outfalls. This growth is consistent with the conceptual

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[30] Periphyton studies were conducted during three dates (September 11, September 24, and October 9) and at three sites each (RM 25.2, 14.9, and 8.0) for a total of 9 data points during Ecology's 1996-97 study. Data were collected at 7 locations (RM 27.9, 25.2, 23.1, 20.3, 16.4, 8.0 and 6.3) over 24 dates for a total of 116 data points during the University of Washington study.

model described above in which periphyton growth is caused by the combined effects of lower flows and lower turbidity during the fall and early winter months. The data presented in Table J-102 and Figure J-112 also show that the growth rate below the outfalls was much higher than the rate above the outfalls. For example, the average periphyton concentration below the outfalls increased by a factor of approximately nine between September 20 and December 14 (from 41.6 to 380.2 mg/m^2). During this same period, the average concentration above the outfalls increased by a factor of approximately two (from 36.6 to 80.6 mg/m^2).

Figure J-113 shows average concentrations above and below the WWTP outfalls both during and after the 2000-2001 growing season. These data show that the highest average concentrations during the growing season occur at RM 16.4.

The data included in Table J-102 show that the average chlorophyll *a* concentration below the WWTPs reached a maximum value on January 4, 2001. The decline in periphyton after this date may have been the result of sloughing that results with high concentrations of periphyton. River flow and turbidity both increased in winter and could also be factors. However, the flow and turbidity data shown in Figures J-106 and J-107 suggest that flows increased on approximately February 1, 2001, and turbidity began to increase after approximately March 1, 2001. These increases occurred after periphyton levels had begun to decline at most sites. However, the average periphyton concentration dropped from approximately 184 mg/m^2 on January 23 to approximately 56 mg/m^2 on February 13. This relatively rapid drop may be associated with sloughing caused by the increase in flows on February 1.

Table J-102. Chlorophyll *a* concentrations measured during the 2000-2001 study period. All values are in units of mg/m2.

Date	RM 6.3	RM 8.0	RM 16.4	RM 20.3	RM 23.1	RM 25.2	Ave.	Ave. Above[1]	Ave. Below[1]
9/20/00	73.6	31.7		19.5	36.2	36.9	39.6	36.6	41.6
10/10/00	71.5			72.4	64.9	13.8	55.7	39.4	72.0
10/19/00		177.3		275.8	98.9	10.9	140.7	54.9	226.5
11/2/00		239.9	160.1	184.1	55.7	77.7	143.5	66.7	194.7
11/15/00		209.6		260.4	13.8	104.2	147.0	59.0	235.0
11/28/00		248.6	306.3	343.9	17.8	53.6	194.1	35.7	299.6
12/14/00		121.1	447.2	572.3	23.7	137.5	260.3	80.6	380.2
1/4/01		247.4	585.2	470.2	228.0		382.7	228.0	434.3
1/23/01		31.9	316.5	477.1	30.8	62.0	183.7	46.4	275.2
2/13/01		21.9	124.3	114.0	3.4	16.9	56.1	10.2	86.7
3/6/01	115.0	100.3	192.1	220.5	2.4	8.3	106.5	5.4	157.0
3/21/01		219.4		11.8			115.6	n.a.	115.6
3/23/01			29.3				n.a.3	n.a.	n.a.
3/27/01		92.9	18.1	15.6	16.7	6.2	29.9	11.4	42.2
4/17/01		32.8	38.8	25.5	11.3	6.9	23.1	9.1	32.4
5/1/01		88.0	69.8	29.0	19.1	5.5	42.3	12.3	62.2

Date	RM 6.3	RM 8.0	RM 16.4	RM 20.3	RM 23.1	RM 25.2	Ave.	Ave. Above[1]	Ave. Below[1]
5/15/01		185.5	178.1	63.3	73.0	4.3	**100.8**	**38.7**	**142.3**
5/24/01		101.2	97.3	12.8	19.5	2.5	**46.6**	**11.0**	**70.4**
6/12/01		95.8	86.4	18.8	30.1	3.5	**46.9**	**16.8**	**67.0**
6/21/01	111.7	100.8	50.8	22.5	19.4	18.5	**54.0**	**19.0**	**71.5**
7/8/01	53.7	40.0	46.2	21.2	15.3	12.6	**31.5**	**13.9**	**40.3**
7/30/01		6.6	17.5	1.4	46.6	20.3	**18.5**	**33.4**	**8.5**
8/20/01	10.8	19.5	16.8	7.2	17.1	2.1	**12.3**	**9.6**	**13.6**
9/10/01	47.4	68.5	98.0	10.7	4.9	0.3	**38.3**	**2.6**	**56.1**
Growing Season average[2]	**72.5**	**182.2**	**374.7**	**274.8**	**67.4**	**62.1**	**172.3**	**75.1**	**235.5**
Post-Growing Season average[2]	**67.7**	**80.3**	**92.0**	**70.1**	**22.1**	**12.1**	**58.5**	**17.1**	**82.7**

[1] Averages above wastewater treatment plants are based on data from river miles 23.1 and 25.2. Averages below plants are based on data from river miles 6.3, 8, 16.4, and 20.3.

[2] The growing season is defined as September 20, 2000 to January 4, 2001 and the post-growing season is defined as January 23 to September 10, 2001.

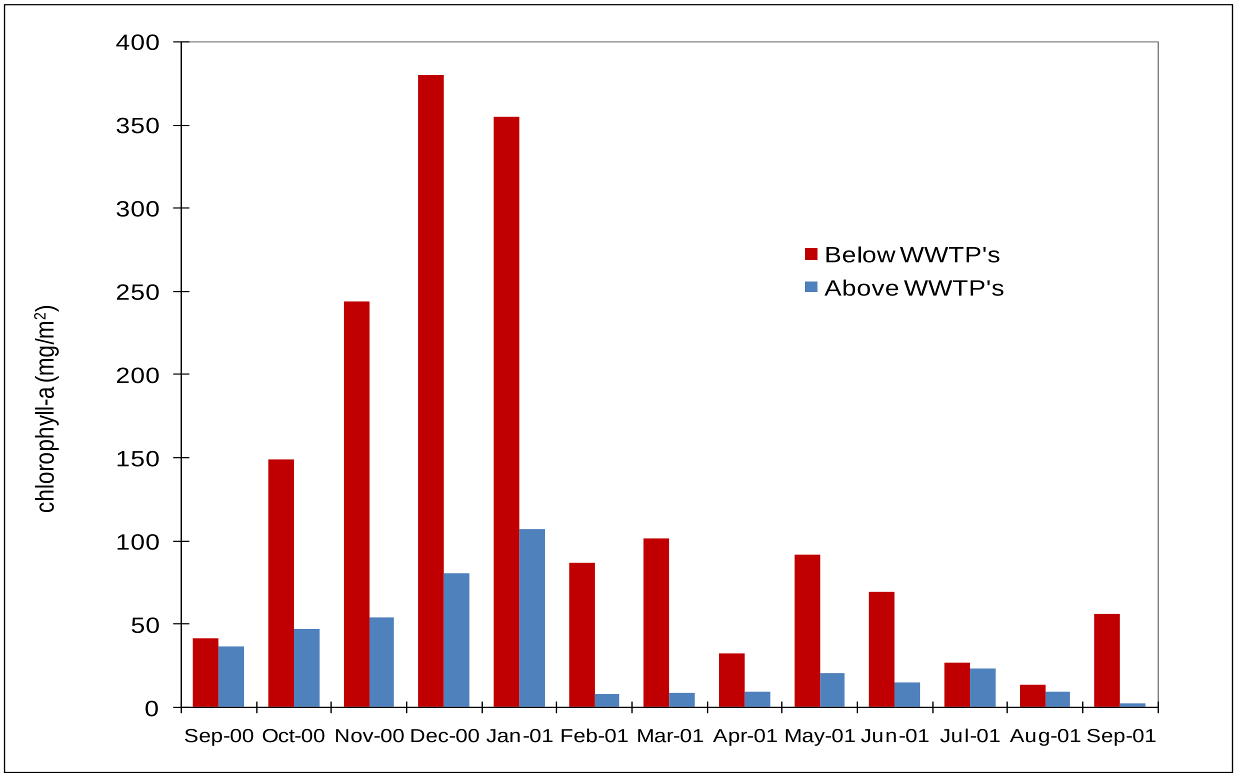

Figure J-112. Average monthly chlorophyll *a* concentrations for monitoring stations above (RM's 25.2, 23.1) and below (RM's 20.3, 16.4, 8.0 and 6.3) the wastewater outfalls.

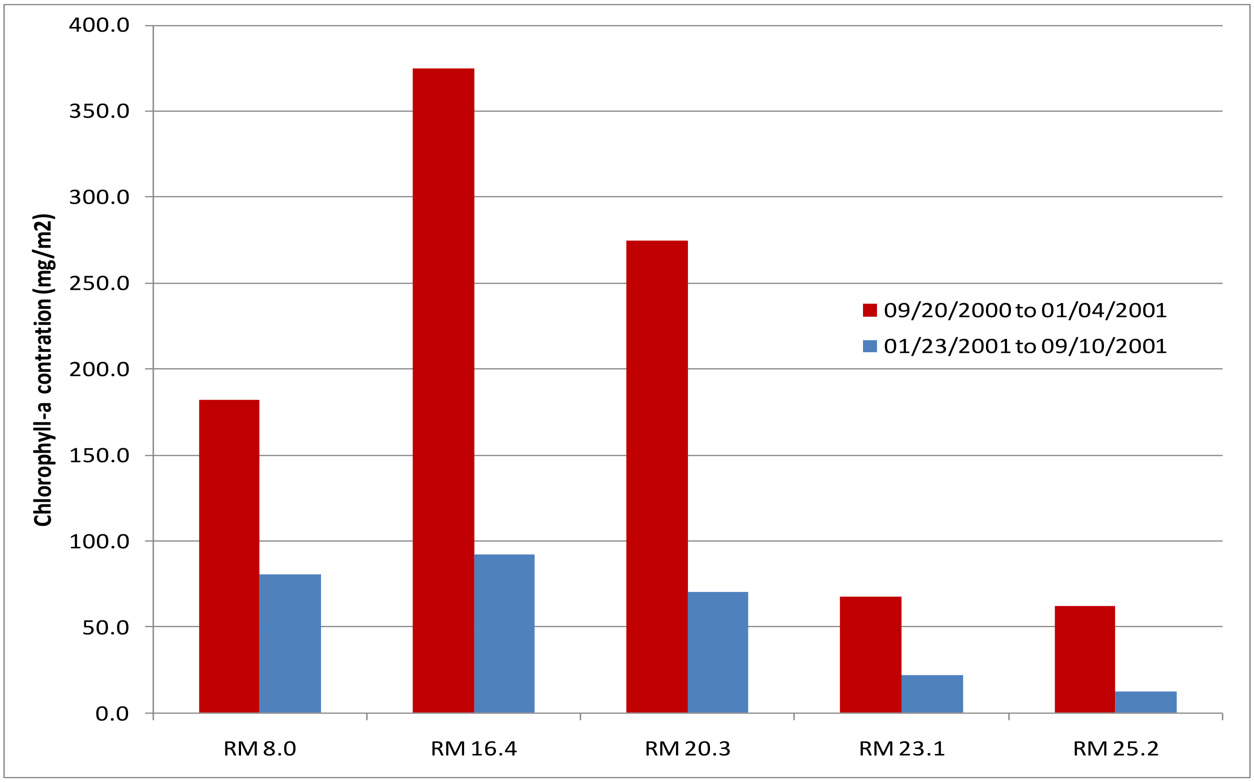

Figure J-113. Average chlorophyll *a* concentration during and after the 2001 growing season

Observed nutrient levels and nutrient limitations

Nutrient concentrations observed in the White River from data collected by the University of Washington during the 2000-2001 growing season are summarized in Table J-103 and in Figure J-114. The data include measurements of soluble reactive phosphorus (SRP), total phosphorus (TP), ammonia (NH3-N), and nitrate (NO3). Figure J-114 shows average SRP and dissolved inorganic nitrogen (DIN) concentrations. The DIN concentrations are derived by summing the NH3 and NO3 concentrations. The locations in Figure J-114 where the bars representing DIN are higher than the bars representing SRP identify locations where the ratio of DIN:SRP exceeds 7.

The average DIN concentrations during the 2000-2001 growing season increased in a downstream direction, with the largest increase occurring between RM 23.1 and RM 20.3 at the location of the Buckley and Enumclaw WWTP's. The average DIN concentration was highest at the most down-stream data collection point (RM 8). The average SRP concentrations were highest immediately downstream of the WWTP's at RM 20.3. The SRP concentrations then decreased downstream of RM 20.3, presumably because of phosphorus uptake by periphyton. This phosphorus uptake will tend to drive the limiting nutrient for the system toward phosphorus. It should be noted that the nutrient concentrations observed in 2000-2001 represent different treatment and nutrient loading levels from the WWTPs, compared to current conditions and practices.

Table J-103. Observed nutrient concentrations during the 2000-2001 growing season. From Stuart (2002).

Location	SRP (ug/L)	TP (ug/L)	NH4 (ug/L)	NO3 (ug/L)	DIN:SRP ratio
9/20/2000 (Day 1)					
RM 8.0	31.2	861.7	21.9	162.2	5.90
RM 16.4	n.a.	n.a.	n.a.	n.a.	
RM 20.3	45.5	794.2	12.6	158.4	3.76
RM 23.1	15.7	1449.3	9.4	60.5	4.45
RM 25.2	18.4	800.3	5.7	48.4	2.94
10/19/2000 (Day 29)					
RM 8.0	50.3	70.3	0.5	249.4	4.97
RM 16.4	n.a.	n.a.	n.a.	n.a.	
RM 20.3	112.9	154.3	7.2	257.1	2.34
RM 23.1	26.7	47.3	0.8	60.4	2.29
RM 25.2	19.6	55.9	U	37.2	1.90
11/2/2000 (Day 43)					
RM 8.0	25.9	50.8	1.1	201.8	7.83
RM 16.4	86.9	123.9	10.9	242.7	2.92
RM 20.3	77.4	103.7	U	229.5	2.97
RM 23.1	14.8	33.2	2.7	62.6	4.41
RM 25.2	16.8	28.4	2.7	36.1	2.31
11/15/2000 (Day 56)					
RM 8.0	33.2	69.7	6.9	837.1	25.42
RM 16.4	63.2	84.9	U	304.6	4.82
RM 20.3	64.4	98.0	36.3	284.7	4.98

Location	SRP (ug/L)	TP (ug/L)	NH4 (ug/L)	NO3 (ug/L)	DIN:SRP ratio
RM 23.1	10.4	49.8	3.7	93.6	9.36
RM 25.2	16.7	19.3	U	53.8	3.22
11/28/2000 (Day 69)					
RM 8.0	55.3	119.6	32.3	332.2	6.59
RM 16.4	48.9	69.2	6.8	525.4	10.88
RM 20.3	58.4	96	5.8	527.8	9.14
RM 23.1	14.1	45.1	6.2	423.9	30.50
RM 25.2	13.1	28.4	U	141.1	10.77
12/14/2000 (Day 85)					
RM 8.0	35.9	66.8	1.8	1312.6	36.61
RM 16.4	31.7	68.8	U	280.3	8.84
RM 20.3	53.3	69.1	4.6	292.4	5.57
RM 23.1	10.5	32	4.6	144.4	14.19
RM 25.2	11.1	36.5	U	82.5	7.43
1/4/2001 (Day 106)					
RM 8.0	94.5	133.4	19.3	362	4.03
RM 16.4	55.2	103.2	5.5	478.1	8.76
RM 20.3	59.7	111.7	13.7	625	10.70
RM 23.1	14.9	41.5	10.8	497.9	34.14
RM 25.2	n.a.	n.a.	n.a.	n.a.	
1/23/2001 (Day 127)					
RM 8.0	55.8	72.5	9.2	900.1	16.30
RM 16.4	69.3	91.8	5.8	577.5	8.42
RM 20.3	60	74.9	U	489.1	8.15
RM 23.1	23.1	47.7	12.4	348.8	15.64
RM 25.2	18.3	32.7	4.4	127.8	7.22

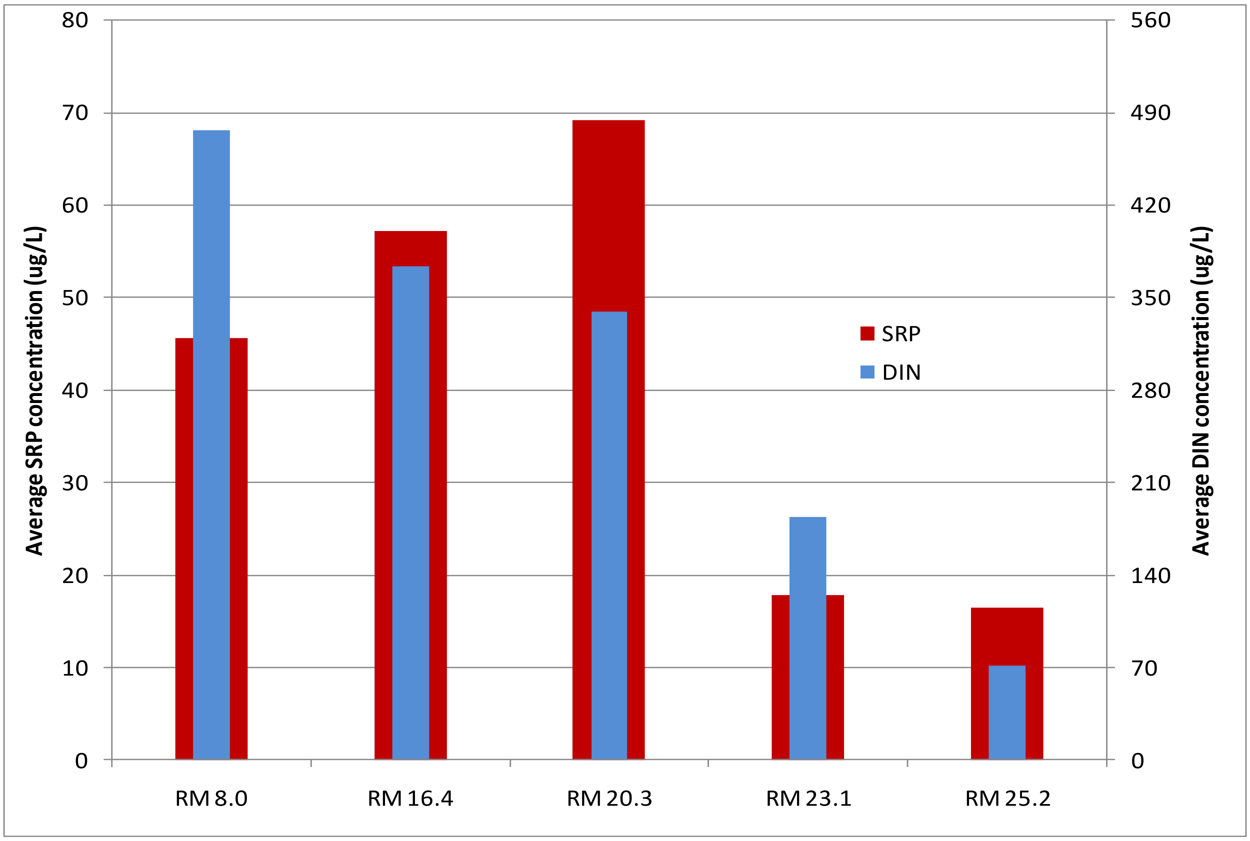

Figure J-114. Average SRP and DIN concentrations for the period 9/20/2000 through 1/04/2001.

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Appendix K. Letters of TMDL Support and MOA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 155
Seattle, WA 98101

WATER
DIVISION

August 24, 2022

Mr. Vince McGowan
Water Quality Program Manager
Washington Department of Ecology
PO Box 47600
Olympia, Washington 98504-7600
vmcg461@ecy.wa.gov

Re: EPA support for the Muckleshoot Indian Tribe reservation capacity in the Lower White River pH Total Maximum Daily Load

Dear Mr. McGowan:

The purpose of this letter is to express the U.S. Environmental Protection Agency's (EPA) support for the Lower White River pH Total Maximum Daily Load (TMDL), developed as a joint effort between the Washington Department of Ecology (Ecology), the Muckleshoot Indian Tribe (MIT), and EPA. This multi-agency workgroup is developing the Lower White River pH TMDL under a Memorandum of Agreement established in 2001. Ultimately, Ecology will establish the TMDL, with approval by EPA.

As a member of this workgroup, EPA has provided input on the technical modeling aspects of the TMDL and the allocation strategy for the TMDL. In particular, EPA has worked closely with MIT to protect the Tribe's use of the Lower White River. Because part of the river in the TMDL study area flows through the MIT's reservation, the TMDL must ensure the loading capacity for that portion of the river is accounted for in the calculations and allocations. This provides assurance that the remainder of the river flowing through State lands will meet water quality standards. Since Ecology does not have jurisdictional authority to establish loads for the MIT's reservation, the TMDL makes boundary assumptions about future loading that may occur as the river flows through MIT's reservation. This capacity is set aside as a separate 'MIT reservation capacity' for soluble reactive phosphorus (SRP) discharges, which may be used by the Tribe as needed. It accounts for growth that may occur on the reservation in the next 20 years and could be used for future municipal, industrial, aquaculture, or other potential discharges. These uses are summarized in the next paragraphs and are explained more fully in the TMDL.

The TMDL is developed based on the assumption that the MIT reservation capacity will only be used by sources discharging to Tribal waters (with the exception of the White River Hatchery, which is located further upstream on Tribal trust land and discussed later in this document). EPA supports the MIT reservation capacity and the TMDL's intention to provide assurances that the overall water quality goals for the Lower White River will be met, by allowing for additional loading capacity in the part of the river that is not under State or Federal jurisdiction. The current EPA-approved water quality standards for pH for the State of Washington are the appropriate measure for calculating the amount of soluable reactive phosphorus (SRP) that the Lower White River can receive daily. If, in the future, EPA promulgates federal water quality standards or approves water quality standards developed by the MIT under the CWA, this TMDL agreement may be revisited.

The reservation capacity amount was determined by addressing two important goals: 1) an equitable distribution of the load is allocated between existing point sources discharging SRP outside of Tribal waters and future point sources that may discharge within the Tribal water boundaries; and 2) future fish production capacity to support salmon recovery and Tribal fishing rights. The TMDL uses the same methods to determine the wasteload allocations for municipal WWTPs and stormwater permittees upstream of the MIT reservation, including future growth, as it does for the assumed loading to be contributed by potential future Tribal facilities within the MIT reservation.

EPA issues National Pollutant Discharge Elimination System (NPDES) permits on tribally owned land and plans to issue any future NPDES permits located in Indian Country, including on the MIT reservation. While the White River Hatchery is located upstream of the reservation boundary and discharges to the State of Washington's waters, MIT owns and operates the hatchery. The hatchery is located on Tribal trust land and falls under the jurisdiction of EPA's upland finfish general permit (WAG130000). Since the hatchery discharges to the State's waters, the facility is given a wasteload allocation from the TMDL loading capacity (not the MIT reservation capacity). If MIT wishes to use the wasteload allocation for the hatchery interchangeably with the reservation capacity or otherwise discharge at an alternate location than what is modeled in the TMDL, MIT will conduct an additional reasonable potential analysis to ensure the changes to locations of discharge points do not cause or contribute to exceedances of the water quality standards.

Since EPA plans to issue permits for any future NPDES coverage MIT may seek, EPA intends to work with the Tribe to ensure the overall MIT reservation capacity is not exceeded. Should any new permits be needed in the future, EPA and MIT will follow the usual requirements and communication procedures and coordinate closely and early in the permitting process. In issuing permits for the Tribe, EPA will ensure the MIT reservation capacity is adhered to, and it will consider the assumptions and requirements outlined in the TMDL. Upon use of the reservation capacity, MIT and/or EPA will notify Ecology to ensure consistency with the TMDL for State waters upstream and downstream of the MIT reservation. MIT and EPA will track assigned permit limits to ensure the sum of total discharges assigned to Tribal waters does not exceed the MIT reservation capacity.

TMDLs must plan for future growth, as well as distribute loading capacity equitably among existing and potential future sources. TMDLs that do this, like the Lower White River pH TMDL, will be more sustainable in the long-term and successfully ensure water quality goals are achieved. EPA is supportive of the approaches taken in the TMDL and commits to working closely with MIT to ensure the reservation capacity is carried out in the way it was intended. Further, EPA recognizes that the success of the TMDL in restoring water quality relies not only on the intended use of the reservation capacity, but also on implementation of point and nonpoint source allocations of phosphorus loading under State jurisdiction. In particular, the implementation of nonpoint source controls on phosphorus, while not required by a permit, will be critical to achieving water quality goals in the Lower White River. The Implementation Plan developed by Ecology outlines many critical steps needed to address nonpoint sources of phosphorus loading in the watershed and serves as a roadmap for meeting water quality standards.

EPA appreciates the solid working relationships we have built with MIT and Ecology through the course of helping to develop this TMDL as part of a multi-agency workgroup. I want to take this opportunity to thank the many staff and managers who have supported the development of this TMDL over the years. EPA looks forward to continuing to work together while implementing this important TMDL. If you have any questions, or need any additional information, you may contact me at (206) 553-1855 or have your staff contact Gunnar Johnson at (206) 553-2114 or by email at *Johnson.Gunnar@epa.gov*.

Sincerely,

ANGELA CHUNG

Digitally signed by ANGELA CHUNG
Date: 2022.08.31 14:21:20 -07'00'

Daniel Opalski
Director

cc: Andrew Kolosseus, Southwest Regional Office Section Manager, Washington Department of Ecology (*akol416@ecy.wa.gov*)
Donovan Gray, TMDL Lead, Washington Department of Ecology (*dogr461@ecy.wa.gov*)
Jaison Elkins, Chair, Muckleshoot Indian Tribe (jaison.elkins@muckleshoot.nsn.us)
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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WATER
DIVISION

August 24, 2022

The Honorable Jaison Elkins, Chair
Muckleshoot Indian Tribe
39015 172nd SE
Auburn, Washington 98092-9763
jaison.elkins@muckleshoot.nsn.us

Re: EPA support for the Muckleshoot Indian Tribe reservation capacity in the Lower White River pH Total Maximum Daily Load

Dear Chairman Elkins:

The purpose of this letter is to express the U.S. Environmental Protection Agency's (EPA) support for the Lower White River pH Total Maximum Daily Load (TMDL), developed as a joint effort between the Washington Department of Ecology (Ecology), the Muckleshoot Indian Tribe (MIT), and EPA. This multi-agency workgroup is developing the Lower White River pH TMDL under a Memorandum of Agreement established in 2001. Ultimately, Ecology will establish the TMDL, with approval by EPA.

As a member of this workgroup, EPA has provided input on the technical modeling aspects of the TMDL and the allocation strategy for the TMDL. In particular, EPA has worked closely with MIT to protect the Tribe's use of the Lower White River. Because part of the river in the TMDL study area flows through the MIT's reservation, the TMDL must ensure the loading capacity for that portion of the river is accounted for in the calculations and allocations. This provides assurance that the remainder of the river flowing through State lands will meet water quality standards. Since Ecology does not have jurisdictional authority to establish loads for the MIT's reservation, the TMDL makes boundary assumptions about future loading that may occur as the river flows through MIT's reservation. This capacity is set aside as a separate 'MIT reservation capacity' for soluble reactive phosphorus (SRP) discharges, which may be used by the Tribe as needed. It accounts for growth that may occur on the reservation in the next 20 years and could be used for future municipal, industrial, aquaculture, or other potential discharges. These uses are summarized in the next paragraphs and are explained more fully in the TMDL.

The TMDL is developed based on the assumption that the MIT reservation capacity will only be used by sources discharging to Tribal waters (with the exception of the White River Hatchery, which is located further upstream on Tribal trust land and discussed later in this document). EPA supports the MIT reservation capacity and the TMDL's intention to provide assurances that the overall water quality goals for the Lower White River will be met, by allowing for additional loading capacity in the part of the river that is not under State or Federal jurisdiction. The current EPA-approved water quality standards for pH for the State of Washington are the appropriate measure for calculating the amount of soluable reactive phosphorus (SRP) that the Lower White River can receive daily. If, in the future, EPA promulgates federal water quality standards or approves water quality standards developed by the MIT under the CWA, this TMDL agreement may be revisited.

The reservation capacity amount was determined by addressing two important goals: 1) an equitable distribution of the load is allocated between existing point sources discharging SRP outside of Tribal waters and future point sources that may discharge within the Tribal water boundaries; and 2) future fish production capacity to support salmon recovery and Tribal fishing rights. The TMDL uses the same methods to determine the wasteload allocations for municipal WWTPs and stormwater permittees upstream of the MIT reservation, including future growth, as it does for the assumed loading to be contributed by potential future Tribal facilities within the MIT reservation.

EPA issues National Pollutant Discharge Elimination System (NPDES) permits on tribally owned land and plans to issue any future NPDES permits located in Indian Country, including on the MIT reservation. While the White River Hatchery is located upstream of the reservation boundary and discharges to the State of Washington's waters, MIT owns and operates the hatchery. The hatchery is located on Tribal trust land and falls under the jurisdiction of EPA's upland finfish general permit (WAG130000). Since the hatchery discharges to the State's waters, the facility is given a wasteload allocation from the TMDL loading capacity (not the MIT reservation capacity). If MIT wishes to use the wasteload allocation for the hatchery interchangeably with the reservation capacity or otherwise discharge at an alternate location than what is modeled in the TMDL, MIT will conduct an additional reasonable potential analysis to ensure the changes to locations of discharge points do not cause or contribute to exceedances of the water quality standards.

Since EPA plans to issue permits for any future NPDES coverage MIT may seek, EPA intends to work with the Tribe to ensure the overall MIT reservation capacity is not exceeded. Should any new permits be needed in the future, EPA and MIT will follow the usual requirements and communication procedures and coordinate closely and early in the permitting process. In issuing permits for the Tribe, EPA will ensure the MIT reservation capacity is adhered to, and it will consider the assumptions and requirements outlined in the TMDL. Upon use of the reservation capacity, MIT and/or EPA will notify Ecology to ensure consistency with the TMDL for State waters upstream and downstream of the MIT reservation. MIT and EPA will track assigned permit limits to ensure the sum of total discharges assigned to Tribal waters does not exceed the MIT reservation capacity.

TMDLs must plan for future growth, as well as distribute loading capacity equitably among existing and potential future sources. TMDLs that do this, like the Lower White River pH TMDL, will be more sustainable in the long-term and successfully ensure water quality goals are achieved. EPA is supportive of the approaches taken in the TMDL and commits to working closely with MIT to ensure the reservation capacity is carried out in the way it was intended. Further, EPA recognizes that the success of the TMDL in restoring water quality relies not only on the intended use of the reservation capacity, but also on implementation of point and nonpoint source allocations of phosphorus loading under State jurisdiction. In particular, the implementation of nonpoint source controls on phosphorus, while not required by a permit, will be critical to achieving water quality goals in the Lower White River. The Implementation Plan developed by Ecology outlines many critical steps needed to address nonpoint sources of phosphorus loading in the watershed and serves as a roadmap for meeting water quality standards.

EPA appreciates the solid working relationships we have built with MIT and Ecology through the course of helping to develop this TMDL as part of a multi-agency workgroup. I want to take this opportunity to thank the many staff and managers who have supported the development of this TMDL over the years. EPA looks forward to continuing to work together while implementing this important TMDL.

If you have any questions, or need any additional information, you may contact me at (206) 553-1855 or have your staff contact Gunnar Johnson at (206) 553-2114 or by email at *Johnson.Gunnar@epa.gov*.

Sincerely,

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CHUNG

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ANGELA CHUNG
Date: 2022.08.31
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Daniel Opalski
Director

cc: Isabel Tinoco, Fisheries Director, Muckleshoot Indian Tribe (*isabel.tinoco@muckleshoot.nsn.us*)
Glen St. Amant, Fisheries Habitat Protection Assistant Director, Muckleshoot Indian Tribe (*glen@muckleshoot.nsn.us*)
Nancy Rapin, Water Team Leader, Muckleshoot Indian Tribe (*nrapin@muckleshoot.nsn.us*)
Vince McGowan, Water Quality Program Manager, Washington Department of Ecology (*vmcg461@ecy.wa.gov*)
Andrew Kolosseus, Southwest Regional Office Section Manager, Washington Department of Ecology (*akol416@ecy.wa.gov*)
Donovan Gray, TMDL Lead, Washington Department of Ecology (*dogr461@ecy.wa.gov*)

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December 19, 2022

Daniel Opalski
Director, Water Division
United States Environmental Protection Agency
Region 10
1200 Sixth Avenue, Suite 155
Seattle, WA 98101
opalski.dan@epa.gov

Re: Support for the Lower White River pH Total Maximum Daily Load

Dear Director Opalski:

The White River is a large tributary to one of the largest basins draining to southern Puget Sound, the Puyallup River Basin. The aquatic life present in the river, particularly salmonids, is an especially important resource for local communities. Water quality monitoring shows that pH levels in parts of the Lower White River (LWR), below Mud Mountain Dam, exceed Washington State water quality standards, which is harmful to aquatic life.

In response, the Washington State Department of Ecology (Ecology) has developed a water cleanup plan, also known as a Total Maximum Daily Load (TMDL) report, to restore healthy pH conditions. Due to the importance of the watershed, the LWR pH TMDL project has been a priority for Ecology since the 1990s. Ecology has remained committed to completion of this TMDL throughout the long development process and is heavily invested and motivated in seeing these efforts reach fruition through transition to successful implementation, and eventual TMDL compliance and attainment of water quality standards.

This TMDL protects an important recreational, cultural, and economic resource in a highly populated and growing area. The Lower White River provides important habitat for lower Puget Sound salmonids, which the TMDL will help protect. The TMDL will also help implementation of TMDLs for other pollution problems in the Puyallup River. For example, the Puyallup Fecal Coliform TMDL found that water quality improvements in the LWR, especially the tributaries to the LWR in the vicinity of the Enumclaw Plateau (e.g., Boise Creek), to be critical to its success.

In response, Ecology has prioritized this subbasin as one of its top regional priorities for technical assistance, and since 2017 we have focused compliance and monitoring resources in this area. Ecology continues to invest considerable effort identifying pollution sources and working with landowners, local stakeholders, and others to implement on-the-ground solutions to water quality problems and we recently began a 10-year effectiveness monitoring project to support these implementation efforts.

Ecology is committed to continued active work on implementation of the LWR pH TMDL, especially in the Enumclaw Plateau, for a minimum of 10 years following TMDL approval. Ecology looks forward to many years of collaborative work with sister agencies and local stakeholders in pursuit of its LWR recovery goals.

Sincerely,

Vincent McGowan, PE
Water Quality Program Manager
Department of Ecology

cc: Andrew Kolosseus, Southwest Region Office Section Manager, Washington Department of Ecology (akol416@ecy.wa.gov)
Donovan Gray, TMDL Lead, Washington Department of Ecology (dogr461@ecy.wa.gov)
Gunnar Johnson, Life Scientist, Water Division, EPA Region 10 (johnson.gunnar@epa.gov)
Jaison Elkins, Chair, Muckleshoot Indian Tribe (jaison.elkins@muckleshoot.nsn.us)
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