Tualatin Subbasin TMDL

Appendix 2-A
Tualatin River Total Maximum Daily Loads: Total Phosphorus and Dissolved Oxygen Analysis for the Upper River
Final Report

State of Oregon
Department of Environmental Quality

This Appendix describes the water quality models used to predict the impacts of summertime discharges from the Forest Grove and Hillsboro Waste Water Treatment Facilities (WWTF). The overall approach restricted all of the Clean Water Services WWTF discharges so that the existing allocations for total phosphorus would be maintained in the Lower River.

The document is organized as follows:

1. Executive Summary: Summarizes the modeling approach and major findings.
2. Introduction: Describes the Tualatin Basin in general, provides a relevant history of TMDLs in the Tualatin Basin, describes hydrology and water quality in the Tualatin mainstem river including the impacts and characteristics of the Clean Water Services WWTF discharges, describes the future operation proposal for the Clean Water Services WWTF and the need for additional waste load allocations in the TMDL amendment.
3. Phosphorus Analyses: Describes the critical assumptions and targets for the new allocations, summarizes the modeling approach, and provides key results.
4. Ammonia Analyses: Describes the existing ammonia TMDL, describes additional modeling information regarding ammonia, provides key results.
5. Requested Allocations: Presents Clean Water Services proposals for amendments to the total phosphorus and ammonia TMDL waste load allocations.
6. Appendices to the Analysis Report:
    a. Detailed description of the CE-Qual-W2 model used, and selected results
    b. Charts of model input parameters
    c. Charts of waste water treatment plant input parameters
    d. Model Calibration information
    e. Excel-spreadsheet used to define the mass balance model for total P
    f. Directions on use of the mass balance model
    g. Copy of the oxygen-demand trading language from the 2005 Watershed NPDES permit

Technical Report

Tualatin River Total Maximum Daily Load: Total Phosphorus and Dissolved Oxygen Analyses for the Upper River

Final Report

Submitted to

Clean Water Services

December 2009

Contents

Appendixes

Exhibits **Page**

Abbreviations and Acronyms

μg/L	micrograms per liter
AWWTF	advanced wastewater treatment facility
BOD	biochemical oxygen demand
$CBOD_5$	5-day carbonaceous BOD
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
District	Clean Water Services
DMR	Discharge Monitoring Report
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
JWC	Joint Water Commission
LA	load allocation
mg/L	milligrams per liter
mgd	million gallons per day
NPDES	National Pollutant Discharge Elimination System
NTS	natural treatment system
ODEQ	Oregon Department of Environmental Quality
OWRD	Oregon Water Resources Department
Project	Tualatin Basin Water Supply Project
RDOM	refractory dissolved organic matter
RM	river mile
RUSA	Roseburg Urban Sanitary Authority
SOD	sediment oxygen demand
TDS	total dissolved solids
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
TVID	Tualatin Valley Irrigation District
TVWD	Tualatin Valley Water District
USBR	U.S. Bureau of Reclamation

USGS	U.S. Geological Survey
WLA	waste load allocation
WWTF	wastewater treatment facility

Executive Summary

Background

In August 2001, the Oregon Department of Environmental Quality (ODEQ) finalized the Tualatin Subbasin total maximum daily loads (TMDLs) (ODEQ, 2001). These TMDLs addressed a number of different pollutants and related water quality concerns:

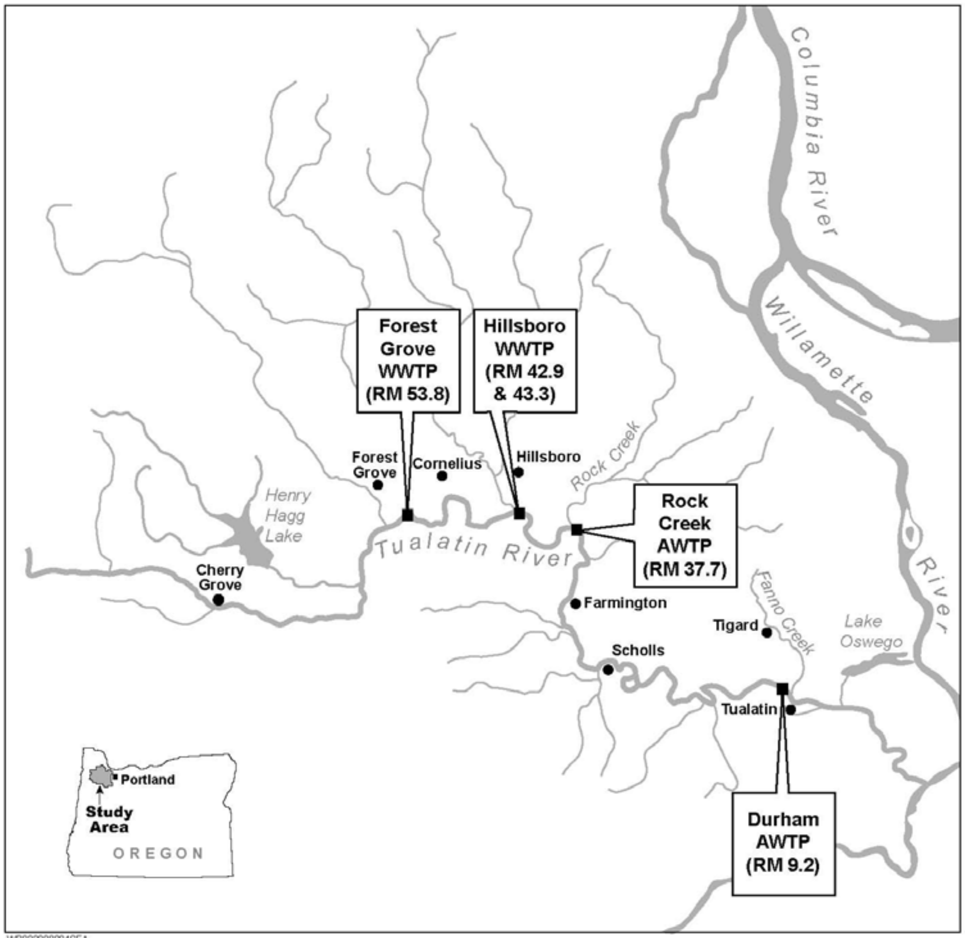
- The TMDL for total phosphorus (TP) was intended primarily to reduce algae blooms in the Lower River, although it was also expected to improve dissolved oxygen (DO) concentrations because algae settle to the bottom in the Lower River where they decay and contribute to oxygen demand exerted by the bottom sediments.
- The 2001 TMDL for ammonia was also intended to improve DO conditions in the Lower River. Ammonia can exert substantial oxygen demand, and the primary source in the subbasin that needed further regulation was that from the two municipal wastewater treatment facilities (WWTFs) on the Lower River owned and operated by Clean Water Services (the District) (see Exhibit ES-1).
- TMDLs for bacteria and temperature were also completed for the subbasin in 2001.

In the discussion above, the "Lower River" is considered that portion of the river downstream of Rood Road and the Rock Creek AWWTF. This portion of the river is flatter, deeper, and slower-moving than the Upper River, and is thus more prone to experience algae blooms and lower DO. In this regard, it functions more like a lake or reservoir than a free-flowing river. The mainstem Upper River, which is steeper, shallower and free-flowing has not historically had any significant water quality impairments related to algae and DO.

At the time of the 2001 TMDLs, only the Rock Creek and Durham Advanced Wastewater Treatment Facilities (AWWTFs) discharged to the river on a year-round basis. The District's two other WWTFs, located on the Upper River (Forest Grove and Hillsboro WWTFs), did not discharge during the summer season, but instead the raw wastewater coming to those WWTFs was and still is piped to the Rock Creek AWWTF for treatment and discharge to the Lower River.

The primary reason that the District is seeking updates of the 2001 TMDLs is to authorize summer discharges to the Upper River from the Forest Grove and Hillsboro WWTFs. This will most efficiently incorporate allocations for future growth and development in the basin by providing treatment and discharge more proximate to where future wastewater will be generated and yet also provide greatest operational flexibility. As part of this process, the District will upgrade the treatment capabilities at these two WWTFs, either via tertiary mechanical processes or via a framework that accommodates opportunities to include more sustainable wetland treatment and restoration strategies into plans for future growth and development.

EXHIBIT ES-1
Location of Clean Water Services Treatment Facilities in the Tualatin River Basin



Total Phosphorus TMDL

Previous TP TMDLs

The previous TMDL was an update of a 1988 TMDL, one of the first in the country. The 1988 TP TMDL established a goal of 0.07 mg/L for TP in the Lower River for the summer period. National Pollutant Discharge Elimination System (NPDES) permits issued by ODEQ to the District for the Rock Creek and Durham AWWTFs contained discharge limitations consistent with that goal. The District complied with these permit limits by installing advanced tertiary treatment processes, leading to substantial improvement in water quality in the Lower River.

Extensive monitoring by the District and others subsequently demonstrated that natural background concentrations actually exceeded the 1988 target throughout much of the subbasin, and especially in tributary streams and base flows to the Lower River. The 2001 update to the TP TMDL recognized this fact and established new goals based on background concentrations, which are shown for mainstem river locations in Exhibit ES-2. **It**

is very important to note that these targets were established by ODEQ as concentration-only TMDLs, and are applicable as summer median values.

EXHIBIT ES-2
Tualatin River Subbasin Estimated Total Phosphorus Background Concentrations During TMDL Season
Source: Table 43 of the 2001 TMDL

Stream Segment	Total Phosphorus Concentrations (Summer Median – mg/L)
Lower River	
Main stem Tualatin River @ Stafford Road (RM 5.5)	0.10
Main stem Tualatin River @ Highway 99W (RM 11.6)	0.11
Main stem Tualatin River @ Elsner (RM 16.2)	0.11
Main stem Tualatin River @ Farmington (RM 33.3)	0.10
Upper River	
Main stem Tualatin River @ Rood Road (RM 38.4)	0.09
Main stem Tualatin River @ Golf Course Road (RM 51.5)	0.04
Main stem Tualatin River above Dairy Creek	0.04

Because of the natural background approach that was used, there was no water quality modeling done to predict the changes in algae or DO concentrations in the Lower River that would result from successful implementation of the TP TMDL. The revised NPDES permit limitations for the Rock Creek and Durham AWWTFs were set at 0.10 and 0.11 mg/L as median monthly values, respectively, consistent with the background concentrations at their locations. The District has consistently been in compliance with these limitations, and the actual TP concentrations in the Lower River have been meeting the TMDL goals (see Exhibit ES-3).

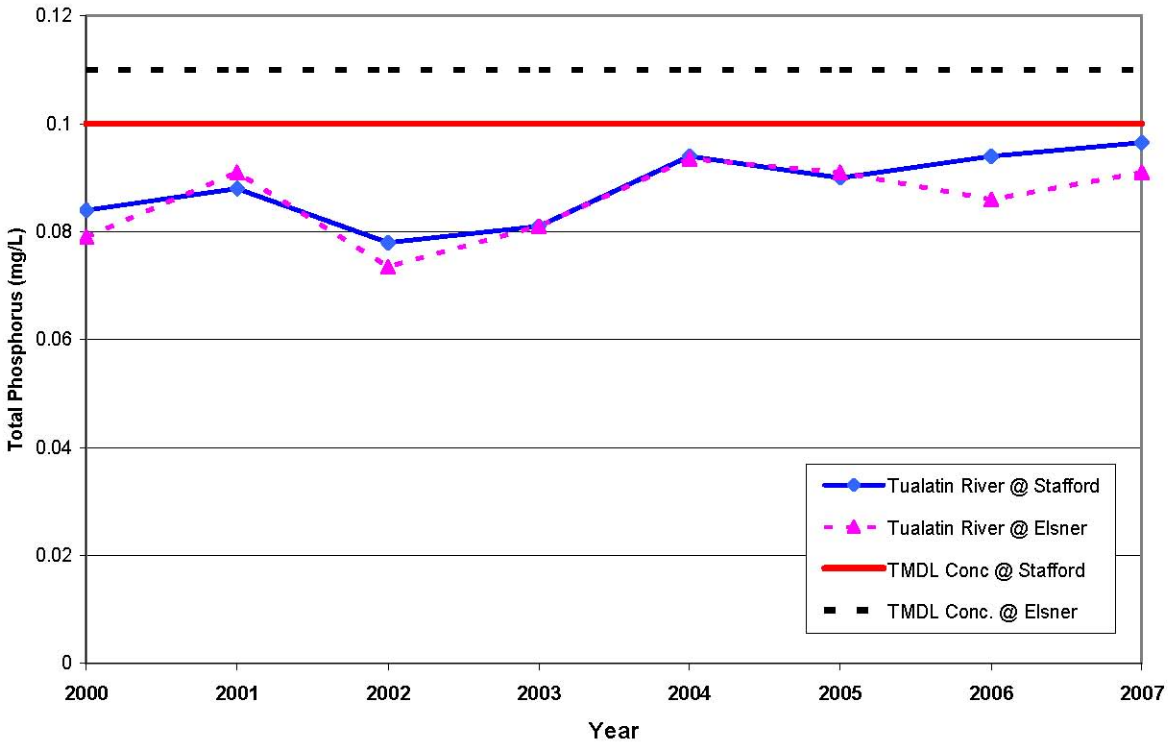
The District's Requested Update to the TP TMDL

The District's requests for this TP TMDL update are simple:

1. The Lower River is sensitive to TP, and thus the 2001 TMDL goal for the Lower River should remain unchanged at 0.10 mg/L downstream of the Rock Creek AWWTF. Discharges of TP can be allowed from the Forest Grove and Hillsboro WWTFs in the summer as long as the Lower River goals are met. This would be accomplished by shifting some of the TP capacity allocated to the Rock Creek AWWTF in the 2001 TMDL up-river to the Forest Grove and Hillsboro WWTFs.

2. The Upper River is not sensitive to TP, and thus TP concentrations there can be allowed to be somewhat higher than natural background conditions as long as defensible technical analyses show that algae and DO concentrations will not be substantially impacted in the Upper River or at the boundary with the Lower River.

EXHIBIT ES-3
Summer Median Total Phosphorus Concentrations in the Tualatin River, 2000 to 2007



What TP concentrations and loads from the Forest Grove, Hillsboro and Rock Creek WWTFs could be allowed and still meet the goal of 0.10 mg/L downstream of the Rock Creek AWWTF? As described in Chapter 3, the District developed a mass balance model for TP for the Upper River and extending to downstream of the Rock Creek AWWTF. This analysis shows that allowing a "bubble" allocation of 66.1 pounds per day (lb/day) shared by all three WWTFs would meet the Lower River goal. The Rock Creek AWWTF concentration-based permit limitation would remain unchanged, while the treatment performance for TP at the Forest Grove and Hillsboro WWTFs would be such that the 66.1 lb/day as a summer season median would not be exceeded, ensuring the summer season median goal of 0.10 mg/L.

What technical analysis has the District conducted to evaluate potential water quality effects in the Upper River? Since the 2001 TMDL, the United States Geological Survey (USGS) has developed a detailed water quality model of the Upper River. This CE-QUAL-W2 model uses well-established scientific theory and equations to predict a wide range of water quality conditions, including how algae and DO respond to TP. This model was rigorously calibrated by USGS based on actual field conditions and data for multiple years. The District ran this model to compare Upper River water quality with and without summer discharges from the Forest Grove and Hillsboro WWTFs. The with-discharge scenario included TP loads from these two WWTFs such that the bubble allocation of 66.1 lb/day would not be exceeded. Illustrative results for DO and algae are shown in Exhibits ES-4 and

ES-5, respectively. Not only are the predicted changes minimal, but the values readily meet water quality criteria applicable to the Upper River.

EXHIBIT ES-4
30-Day Average Dissolved Oxygen at Rood Road

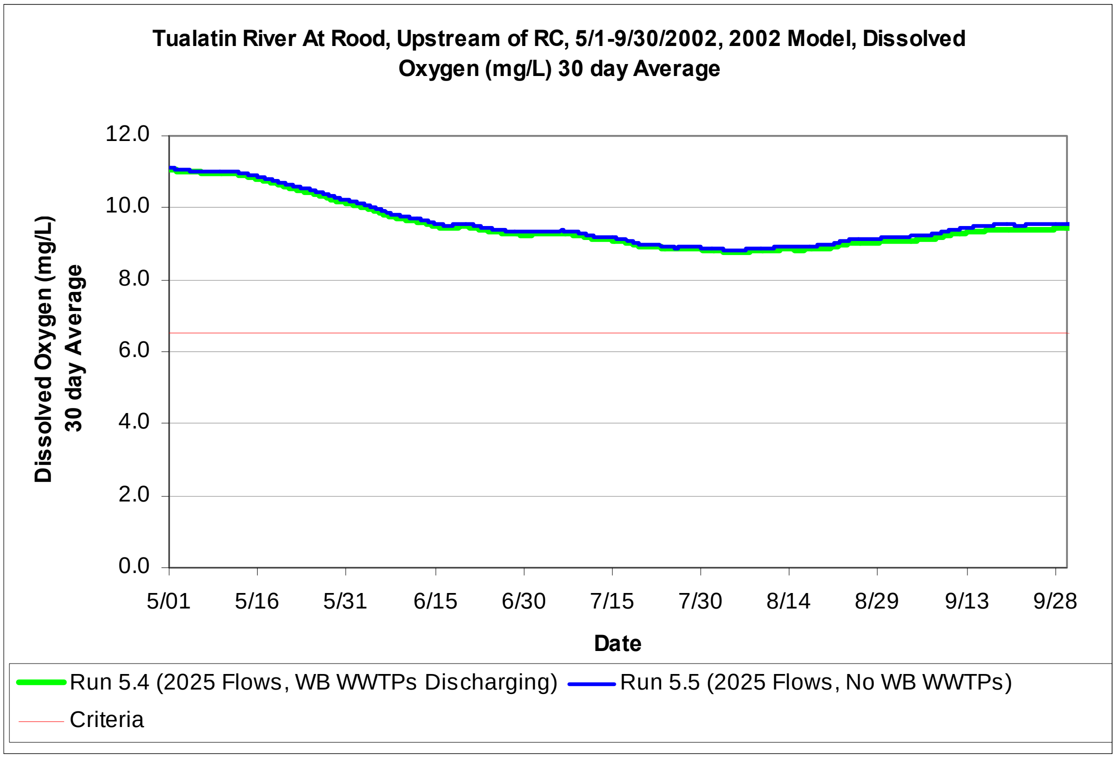
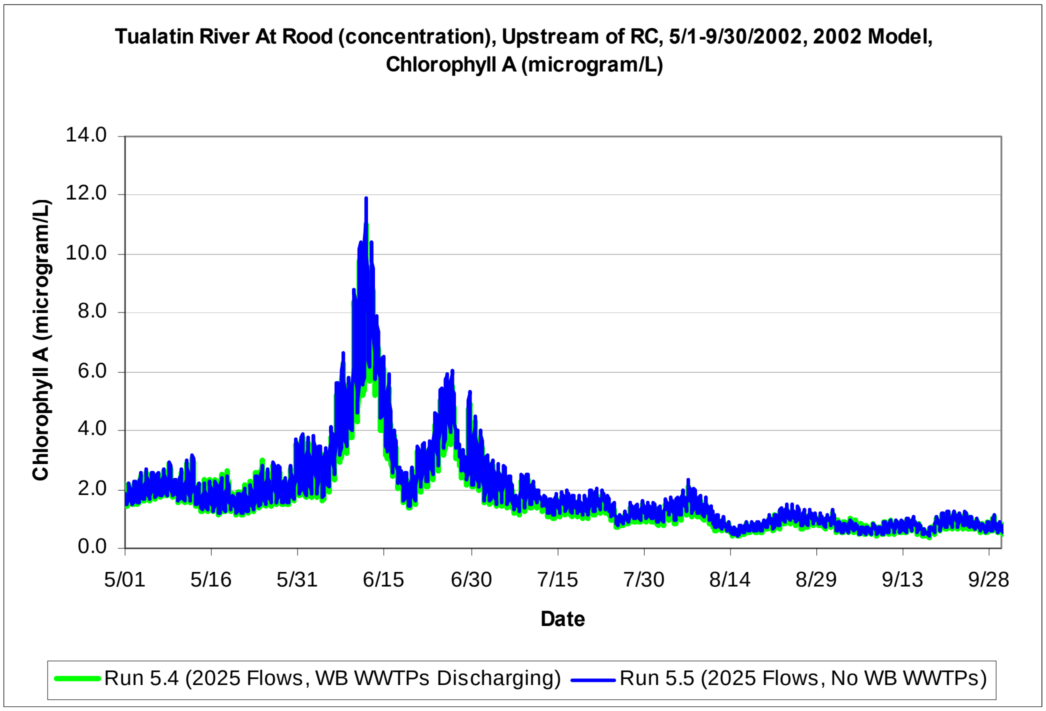


EXHIBIT ES-5
Chlorophyll *a* at Rood Road
This exhibit shows results for chlorophyll a *at Rood Road because that is the downstream-most location for the Upper River and therefore expected to show the maximum potential effect on algal growth by discharges to the Upper River.*



Ammonia TMDL

Previous Ammonia TMDLs

Ammonia from the two summer-discharging Lower River WWTFs also was addressed in the 1988 TMDL, leading to additional treatment upgrades for ammonia removal by the District at these WWTFs. Although this led to substantial improvement in DO in the Lower River, monitoring data indicated that DO problems still occurred in some years during the late summer and early fall. The USGS had already developed and calibrated a CE-QUAL-W2 model for the Lower River prior to the 2001 TMDL, and analyses with the model showed what additional ammonia removal would be needed during that critical period, and also that less ammonia removal than required by the 1988 TMDL would be needed at other times, such as spring and early summer. Extensive modeling by USGS was used by ODEQ to establish new ammonia allocations for the Rock Creek and Durham AWWTFs in the 2001 TMDL. The ammonia allocations were expressed as an equation that related allowable ammonia discharges to river flow, river DO, and month of the year. The TMDL allocation equation was then incorporated directly into the District's NPDES permit, as shown in Exhibit ES-6.

EXHIBIT ES-6
Current Ammonia (NH_3-N) Waste Discharge Limitations for Rock Creek and Durham AWWTFs

Weekly Median Maximum Load, lb/day	Concentration Variable (NH_3-N, mg/L):		Applicable Time Period
	Tier 1	Tier 2	
Weekly Median Maximum Ammonia Load = (Farmington Flow)(Concentration Variable)(5.39) lb/day, where: Farmington Flow is the previous calendar weekly consecutive-day median of the daily mean flow at the Farmington gauge in cfs, and Concentration Variable is NH_3-N in mg/L during the applicable period as in the next columns:	1.4	1.4	May and June
	1.4	0.8	July
	1.4	0.3	August
	0.8	0.21	September through November 15

Note: The applicable tier is based on the instream dissolved oxygen concentration (see Exhibit 3-1 for details).

Subsequent to the completion of the 2001 TMDL, ODEQ and the District developed a watershed permit that incorporated all four WWTFs and the District's stormwater management program into a single NPDES permit. This watershed permit framework provided the opportunity to develop a water quality credit trading process for oxygen-demanding parameters like ammonia. In the Lower River, the maximum effects of ammonia on DO from both AWWTFs are manifested in the vicinity of the Oswego Dam at about River Mile 3. The extensive monitoring and modeling work conducted by USGS has provided a sound scientific understanding of how ammonia decays and consumes oxygen in the Lower River. That understanding, in turn, provided the technical basis for inter-WWTF trading of ammonia in terms of equivalent DO effects at Oswego Dam.

Ammonia is not the only oxygen-demanding parameter in municipal wastewaters. The other commonly regulated parameter is carbonaceous biochemical oxygen demand (CBOD). CBOD was not explicitly addressed via allocations in the 2001 TMDL, but the existing CBOD concentrations and loads in the District's summer discharges to the Lower River were included in the USGS modeling scenarios that established the ammonia allocations. USGS represented CBOD in CE-QUAL-W2 via a model parameter called refractory dissolved organic matter (RDOM). Thus, CBOD was included in the TMDL modeling as an existing contributing parameter to DO demand in the river. That existing CBOD contribution was explicitly included in the watershed permit oxygen-demand trading algorithms. The oxygen-demand trading element of the watershed permit is essentially a "bubble" concept, with the size of the bubble variable based on river flow, DO, and month of the year.

The District's Requested Update to the Ammonia TMDL

As with TP, the District's request for the updated ammonia TMDL is simple. The overall ammonia allocations for the District's WWTFs from the 2001 TMDL would remain unchanged. The only difference is that some of that allocated load would be shifted from the Lower River AWWTFs upstream to the Forest Grove and Hillsboro WWTFs for summer discharge at those locations. The Upper River WWTFs would also be incorporated into the existing oxygen-demand trading "bubble" along with the Rock Creek and Durham AWWTFs.

Again, the river's DO status is most sensitive to ammonia in the Lower River, and the District's requested update would not change the combined allocated and permitted loads of ammonia and CBOD in the Lower River. Thus, new modeling for the Lower River is not needed for this TMDL update. As described above, the CE-QUAL-W2 model of the Upper River was run to confirm lack of adverse impacts in the Upper River as a result of summer season TP inputs from the Forest Grove and Hillsboro WWTFs. The scenario with these WWTFs discharging also included ammonia and CBOD in the discharges, with concentrations set to the high end of what might be allowed by the oxygen-demand trading program. As shown in Exhibit ES-4, these loads to the Upper River did not adversely impact DO concentrations in the Upper River.

1.0 Introduction

1.1 Background

In August 2001, the Oregon Department of Environmental Quality (ODEQ) finalized the Tualatin Basin total maximum daily loads (TMDLs) (ODEQ, 2001). TMDLs establish goals for water quality improvements. In this case, TMDLs were developed for several water quality parameters, including total phosphorus (TP) and ammonia. The TP TMDL was established primarily to control algae blooms in the Lower River, but it was also expected to improve dissolved oxygen (DO) concentrations. The ammonia TMDL was directly focused on DO improvement. The river water quality conditions that might be attained with such actions as wastewater treatment for TP and oxygen-demanding pollutants (ammonia and biochemical oxygen demand, or BOD) or increased river flows are predicted using computer models. A "natural background" approach was used for the TP TMDL, and thus water quality modeling was not conducted for TP. The TP and ammonia goals were translated by the TMDL into waste load allocations (WLAs) that have been incorporated into a National Pollutant Discharge Elimination System (NPDES) discharge permit for Clean Water Services' (the District's) wastewater treatment facilities (WWTFs).

The 2001 TMDL document stated ODEQ's adaptive management policy to revise loading capacity and allocations to accommodate changed needs or new information. One reason for modification is the availability of new scientific information. The TMDL notes that, subject to resource availability, TMDLs will be reviewed once every 5 years or possibly sooner. It is now past this 5-year period.

In addition, ODEQ reiterated its commitment to watershed permitting, adaptive management, and modification of the TMDL as appropriate in its October 29, 2001, letter entitled *Guidance for Interpretation of the Tualatin Subbasin TMDL in Renewal of Permits*. The letter also establishes ODEQ's commitment to work closely with the District and others to address any concerns regarding calculations and assumptions in the TMDL models through the adaptive implementation process. Finally, the letter affirms ODEQ's commitment to make such refinements in the TMDL or models on a timely basis if new information becomes available.

The analyses in this report focus primarily on the Upper River (operationally defined either as where the Rock Creek Advanced WWTF, or AWWTF discharges, or approximately as upstream of near Rood Road). This is because the District does not desire any substantive modifications to the previous 2001 TMDLs related to TP and DO for the Lower River. The analyses do extend to just downstream of the Rock Creek AWWTF in order to demonstrate that the modifications for the Upper River will comply with existing Lower River TMDLs. The rationale and methodologies for this are described in more detail in subsequent sections of this report.

1.2 Justification for TMDL Revision

The primary considerations that warrant review and revision of the DO and TP TMDLs applicable to the Upper River at this time are as follows:

- To provide WLAs for ammonia and TP for dry season discharges from the Forest Grove and Hillsboro WWTFs;
- To take advantage of a new water quality modeling capability for the Upper Tualatin River from Gaston to Rood Road;
- To most efficiently incorporate allocations for future growth and development in the basin by providing treatment and discharge more proximate to where future wastewater will be generated and yet also provide greatest operational flexibility by utilizing the oxygen-demand trading framework in the existing NPDES watershed permit;
- To develop a framework that accommodates opportunities to include more sustainable wetland treatment and restoration strategies into plans for future growth and development.

The analyses contained herein were designed to be compatible with current regulatory practice and scientific methodology.

1.3 Approach to Updating the TP and DO TMDLs

The District has several ongoing studies, including facilities plans for the Rock and Durham AWWTFs, the Reclaimed Water Master Plan, West Basin Facilities Plan, Tualatin Basin Water Supply Project (Project), and various separate feasibility and pre-design studies for natural treatment systems (NTS) associated with the Forest Grove and Hillsboro sites. The work associated with these studies is complete or nearing completion. Thus, they provide timely input into modeling approaches and potential operational scenarios that may affect TP and DO conditions in the basin and influence the revised TMDLs.

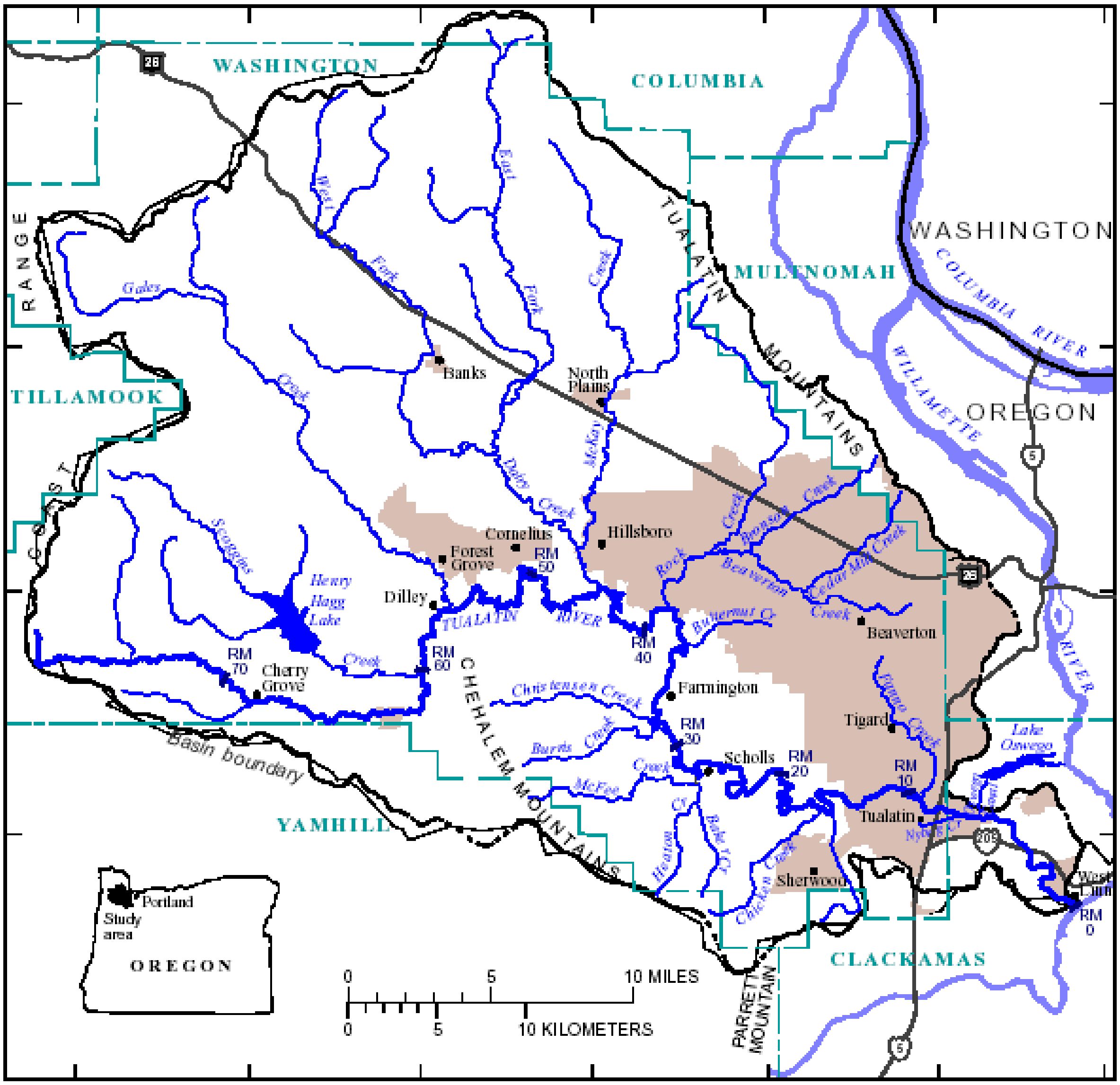
The District and ODEQ have agreed that the District would be responsible for developing updated water quality models for TP and DO for the mainstem river, and for conducting modeling scenarios needed for the TMDL updates. The modeling effort is documented in this technical report.

1.4 Description of Tualatin Basin: Existing Hydrology

The Tualatin River is the most northern tributary within the Willamette River watershed (Exhibit 1-1). The Tualatin River is about 80 miles long. The drainage basin is approximately 43 miles long and 29 miles wide, and covers an area of 712 square miles. The boundary between the Upper and Lower Rivers is generally demarcated by the Rood Road Bridge at River Mile (RM) 38.4, just upstream of the Rock Creek AWWTF. As noted above, this analysis extends to downstream of the Rock Creek AWWTF in order to demonstrate that the modifications for the Upper River will comply with existing Lower River TMDLs. Thus, the mass loads entering the Lower River are the Upper River loads, the tributary Rock Creek, and Rock Creek AWWTF that enter the Tualatin just below Rood Road.

Land uses in the Tualatin River watershed range from forests in the Coast Range, Tualatin Mountains, and Chehalem Mountains, to agricultural areas near Forest Grove, Scholls, Gaston, and North Plains, to densely populated areas such as Hillsboro, Tigard, and Beaverton. Finally, the river flows through the southwestern edge of the Portland metropolitan area before discharging to the Willamette River at West Linn.

EXHIBIT 1-1
Location Map



Tualatin River flows during the dry season are strongly influenced by the various management actions that occur during this season. Flows in the watershed are managed for flood control, irrigation, water supply, and water quality uses. This management is provided in part by two reservoirs.

Barney Reservoir is located in the Trask River basin and stored water is transferred to the upper Tualatin River through a pipeline. Barney Reservoir has active storage capacity of

17,000 acre-feet allocated to several cities and the Tualatin Valley Water District (TVWD), and Clean Water Services (the District).

Henry Hagg Lake is located on Scoggins Creek in the Tualatin basin and provides active water storage capacity of about 53,000 acre-feet. The dam (Scoggins Dam) and reservoir are owned by the U.S. Bureau of Reclamation (USBR). Storage water in the reservoir is contracted to Tualatin Valley Irrigation District (TVID) and other irrigation water users, various municipal and industrial water suppliers such as the Joint Water Commission, and the District. The District contracts 12,618 acre-feet from the reservoir for use in maintaining water quality in the Tualatin River. Hagg Lake storage water is conveyed to the mainstem Tualatin River via Scoggins Creek. Much of the irrigation and municipal/industrial water released from Hagg Lake is withdrawn at the Spring Hill Pump Station at RM 56.1.

1.5 Clean Water Services Treatment Facilities

The District is a special service district that serves more than 500,000 customers in the urban portion of Washington County. The District has 12 member cities and owns and operates four wastewater treatment facilities in the Tualatin River basin at sites in Forest Grove, Hillsboro, and Tigard, as shown in Exhibit 1-2. The four the District facilities and outfalls are the Forest Grove WWTF (RM 53.8), the Hillsboro WWTF (RM 42.9 and 43.3), the Rock Creek AWWTF (RM 37.7), and the Durham AWWTF (RM 9.2). All four facilities discharge to the Tualatin River between Forest Grove and the confluence with the Willamette River. The Forest Grove and Hillsboro WWTFs are located in the Upper River (i.e., above the Rood Road Bridge which is used to demarcate the upper and lower sections of the Tualatin River). All the District plants and discharges are permitted by ODEQ, under the consolidated watershed NPDES permit (covering Permits 101141, 101142, 101143, and 101144).

1.5.1 Current Operations of the District's WWTFs

The Rock Creek and Durham AWWTFs currently discharge year-round, while the Forest Grove and Hillsboro WWTFs currently only discharge during the wet season (defined in the current NPDES permit in relation to specific river flows at the Farmington gage and the calendar date). Exhibit 1-3 summarizes the existing permitted flows and Exhibit 1-4 summarizes current treatment technologies applicable to oxygen-demanding parameters and phosphorus. Because they do not discharge during the dry season, the critical season for river DO and TP, they were not considered for the 2001 Tualatin Subbasin TMDL.

The District anticipates, however, that it is appropriate for these two facilities to commence dry season discharges in the future, as summarized below. Thus, a primary reason to update the TMDLs is to account for future growth and development and planning for the District's WWTFs, including providing WLAs for the two WWTFs. Note that two 24-inch pipelines connect the Forest Grove, Hillsboro, and Rock Creek WWTFs. These pipelines allow transfer of treated or untreated wastewater and biosolids between the three plants, greatly enhancing the District's operational and maintenance flexibility.

Although wastewater point sources other than the four WWTFs exist in the Tualatin basin, they are primarily small industrial noncontact cooling water discharges and thus their contributions of flow, ammonia and TP to the river are negligible and therefore not considered in these analyses. It is not necessary to change how the TMDLs account for other point sources.

EXHIBIT 1-2
Location of Clean Water Services Treatment Facilities in the Tualatin River Basin

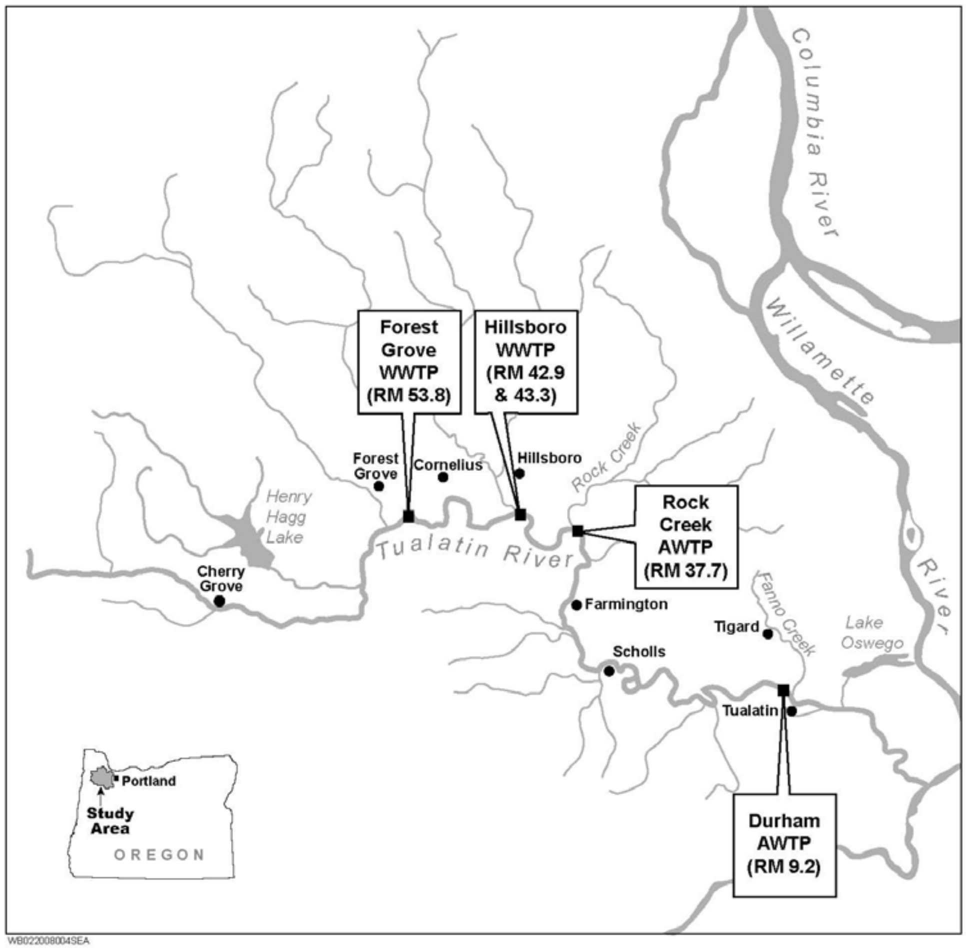


EXHIBIT 1-3
Current Design Average Dry Weather Flow for the District's Four Facilities

Facility	Outfall Number	Design Average Dry Weather Flow (mgd)
Durham AWWTF	D001 & D003	22.6
Rock Creek AWWTF	R001 & R003	39.0
Forest Grove WWTF	F001	5.0*
Hillsboro WWTF	H001 & H002	3.7*

*No dry season discharge, these design flows are applicable only as mass limits triggers during high flow periods; see also Exhibit 1-5 for updated estimates of dry weather flows.

EXHIBIT 1-4
Summary of Current Treatment Technologies Relevant to Oxygen-Demanding Parameters and Phosphorus

Facility	Technologies for Meeting Oxygen-Demand Limits	Additional Tertiary Technologies for Meeting Phosphorus Limits	Additional Comments
Durham AWWTF	Primary and enhanced secondary treatment (activated sludge and nitrification)	Enhanced biological phosphorus removal, chemical addition, clarification and filtration	
Rock Creek AWWTF	Primary and enhanced secondary treatment (activated sludge and nitrification)	Chemical addition, clarification and filtration	Biosolids from Forest Grove and Hillsboro are transferred via pipeline to Rock Creek AWWTF for processing
Forest Grove WWTF	Secondary treatment (activated sludge)	Not applicable	No summer discharge
Hillsboro WWTF	Secondary treatment (activated sludge)	Not applicable	No summer discharge

1.5.2 Future Operations of the District's WWTFs

As discussed in more detail later in this report, the District is proposing to enhance the treatment capabilities at Forest Grove and Hillsboro for year-round discharge. Under this operational change, wastewater flows to the two WWTFs during the low flow period would no longer be diverted to Rock Creek, but would be directly discharged to the upper Tualatin River. If permitted, Forest Grove and/or Hillsboro are projected to begin year-round discharge, potentially within the next permit cycle. The specific treatment alternatives that are being considered for the two WWTFs are described in Section 2.5.4.3.

Within the context of this operational change, the service area also is experiencing population growth, which will result in increased influent flows. As such the Durham and Rock Creek AWWTFs are projected to have increasing flows over the next 20 to 30 years. Increased flows will necessitate upgrades for capacity expansion.

The specific additional treatment technologies for the two AWWTFs necessary for compliance with ammonia and phosphorus WLAs will depend in part on the acceptance of the allocations and trading program proposed in this report, as well as the revised TMDLs and WLAs for other parameters such as temperature.

Exhibit 1-5 summarizes the future flow estimates under the operational change described above. Flow ranges are shown for Forest Grove and Rock Creek WWTFs because of current uncertainties about how much wastewater would be best handled at each WWTF, which will depend not only on service area growth conditions but also treatment capacity at Forest Grove.

EXHIBIT 1-5
Summary of Future Operations of the District's Four Facilities with Respect to Flow (mgd)

Facility	Current Permitted Dry Season Design Flow	Existing Dry Season Discharge	Estimated 2025 Dry Season Design Flow	Estimated 2025 Dry Season Discharge
Durham AWWTF	22.6	~ 18	25.7	25.7
Rock Creek AWWTF	39.0[a]	~ 31[a]	54.6[a]	43.8 to 54.6[b]
Forest Grove WWTF	5.0[c]	2.4[d]	3.7 to 7.2[b]	< 3.2 to < 6.7[b]
Hillsboro WWTF	3.7[c]	4.1[d]	4.6[b]	4.1[b]

[a]Without dry season discharges from Forest Grove or Hillsboro WWTFs.

[b]Depends on final design of NTS for Forest Grove and Hillsboro WWTFs.

[c]No dry season discharge, these design flows are applicable only as mass limits triggers during high effluent flow periods.

[d]No actual dry season discharge, these flows are currently conveyed to Rock Creek AWWTF for treatment and discharge are actually part of Rock Creek AWWTF's existing discharge of ~31 mgd.

Note that the above flow balances for 2025 in this exhibit account for 0.5 mgd of wastewater needed to convey biosolids from both the Forest Grove and Hillsboro WWTFs to the Rock Creek AWWTF.

1.6 Tualatin River Mainstem Water Quality

1.6.1 Applicable Water Quality Standards

1.6.1.1 Designated Uses

Designated beneficial uses in the Tualatin River Subbasin include fisheries, aquatic life, drinking water, recreation, and irrigation (ODEQ, 2003).

1.6.1.2 Applicable TP Criteria

Although ODEQ does not have a numeric criterion for TP, it does have a narrative criterion to avoid nuisance aquatic plant growth, and the standards also establish an "action level" of 15 micrograms per liter (µg/L) phytoplankton (water column) chlorophyll-*a* that is applicable to reservoirs and rivers. This action level is not a formal numeric criterion for which an exceedance indicates a standards violation; however, exceedances do trigger the requirement that ODEQ undertake a study to determine if designated beneficial uses are impaired. If impairment is identified in the study, ODEQ then is to establish a control strategy where technically and economically practicable (ODEQ, 2001).

1.6.1.3 Applicable DO Criteria

The applicable DO criteria for the mainstem Tualatin River downstream of Gaston were defined by ODEQ in the TMDL as 6.5 milligrams per liter (mg/L) as a 30-day mean minimum, 5.0 mg/L as a 7-day minimum mean, and 4.0 mg/L as an absolute minimum (ODEQ, 2001). Oregon's water quality standards also establish a numeric criterion for pH of no less than 6.5 and no greater than 8.5 units.

1.6.2 Historical Water Quality Concerns

Water quality in the Tualatin River varies seasonally. Most water quality concerns for the Tualatin River mainstem are manifested during the warm and relatively dry summer, and, if the flows remain low, into the fall. In the reservoir-like reach of the river, from RM 3.4 to 30, long travel times, when combined with available nutrients (phosphorus and nitrogen) and sunny summer weather, produce blooms of phytoplankton. These blooms at times have exceeded ODEQ's action level for chlorophyll-*a*, but also provide substantial DO via algal production during long summer daylight hours.

The long travel times in this reach of the river, however, also provide time for organic sediments on the bottom of the river to exert a demand on DO in the water column (sediment oxygen demand [SOD]). Algal settling and decay contribute to SOD. In the fall, when algal productivity is inhibited by shorter days, the SOD can lead to substantial DO sags in this reach.

Consequently, algae, pH and DO concentrations have been of concern historically and led ODEQ to list the Tualatin River as an impaired water body in the 1980s and 1990s. Specifically, the Tualatin River Subbasin had stream segments listed on the 1998 Oregon 303(d) list for: temperature, bacteria, DO, chlorophyll-*a*, toxics (arsenic, iron, and manganese), biological criteria and pH. Since development and ongoing implementation of TMDLs, all parameters applicable to the mainstem river (other than iron and manganese) have been removed from the most recent 2004/2006 303(d) list.

More detail regarding past and current water quality concerns relative to TP and DO is provided in Section 1.6.3 below, as well as in Section 2.4.

1.6.3 Summary of Previous TMDLs for Tualatin Subbasin and Resulting Water Quality Improvements

TMDLs were established in 1988 for ammonia and phosphorus to address low DO and elevated pH and chlorophyll *a* in the mainstem. Since 1988, substantial progress has been made in protecting and improving water quality in the Tualatin River and its tributaries. Studies by the United States Geological Survey (USGS) show the Tualatin River is healthier today than it has been in generations. The health of Tualatin River basin urban streams is improving even though the population of Washington County has increased by nearly 100,000 people in the last decade.

These accomplishments have been made possible through a collaborative process involving ODEQ, U.S. Environmental Protection Agency (EPA), the District, and other impacted watershed partners including agencies, organizations, and industries. The successes that have been achieved are due to a number of factors including those listed below.

- Investment by the District's ratepayers of more than $325 million in advanced wastewater treatment facilities.
- Creation and operation of comprehensive surface water management utilities by the District and Clackamas County, which have greatly advanced the control of urban surface water pollution.

- Voluntary actions by the District involving the commitment of millions of dollars, such as acquisition of stored water by the District to restore river flows. In depth scientific investigation and analysis by the USGS, Oregon Graduate Institute, the District and others yielding critical insights into factors influencing the river and its tributaries enabling refinement of water quality improvement strategies.
- Improvements in agricultural and forestry practices within the watershed.
- An adaptive management strategy that has allowed the District and other management agencies the flexibility to build upon new scientific information as it emerges to create the strategies that are needed to improve the health of the Tualatin and its tributaries.

ODEQ recognized these improvements, concluding in 2001 that the DO and pH standards in the mainstem were met most of the time. This quality reflected reduced ammonia and phosphorus loadings from WWTFs, management of releases from Hagg Lake for water quality purposes, and implementation of nonpoint controls of agricultural, forestry, and urban runoff (ODEQ, 2001). However, ODEQ also determined that an updated TMDL was needed for the mainstem river for ammonia and phosphorus (chlorophyll-*a*, pH, and DO were related parameters addressed), and that temperature and bacteria should be included as well.

This latest TMDL, completed in August 2001, addressed temperature, phosphorus, bacteria, and DO (via settleable volatile solids) for the major tributary streams in the subbasin (ODEQ, 2001). The TMDL is currently being implemented by the various designated management agencies.

In a parallel process to revising the TP and DO TMDLs, the District and ODEQ are currently initiating a process to revise the TMDL for temperature for the tributaries and mainstem river. This is being done in large part because ODEQ has substantially revised its standards (designated fish uses and temperature criteria) (ODEQ, 2003) since the completion of the TMDL in 2001. A separate report has been prepared by the District for the temperature TMDL (CH2M HILL, 2008).

The existing (2001) TMDLs for TP and DO are discussed in more detail in Sections 2 and 3, respectively.

1.7 Objectives for the Updated TP and DO TMDLs

The modeling described in Sections 2 and 3 of this report achieves three primary objectives, which are aligned with the TMDL revision justifications outlined in Section 1.2:

- Establish a Technically Defensible, Up-to-Date Modeling Framework; and
- Provide basis for waste load allocations for TP and ammonia for upriver discharges during the summer season at Forest Grove and /or Hillsboro.

1.7.1 Establish a Technically Defensible, Up-to-Date Modeling Framework

Dry season discharges from the Forest Grove and Hillsboro WWTFs were not anticipated in the previous TMDLs for DO and TP. As a result, the mainstem modeling done for these previous TMDLs did not include the upper segments of the river upstream of Rood Bridge at RM 38.4. This updated TMDL used a new Upper River water quality model, as described in Sections 2.2 and 2.3.

1.7.2 Provide Updated and New Waste Load Allocations to Accommodate Future Increased Design Flows and Dry Season Discharges

Updated effluent design flows for the four District WWTFs have been established via recently completed facilities plans. These include design flows applicable to the upcoming NPDES permit cycle, as well as for future growth out to the year 2025. In addition, the District anticipates dry season discharges from the Forest Grove and Hillsboro WWTFs in the near future (see Section 1.7.3 below). Without new WLAs for Forest Grove and Hillsboro, their dry season flows would continue to be diverted to Rock Creek AWWTF.

For DO, new allocations for these facilities will improve operational flexibility and efficiency by having treatment and discharge more proximate to future growth areas and by utilizing the existing oxygen-demand trading framework.

For TP, the TMDL revisions will establish a new “bubble” WLA for dry season TP discharges including Rock Creek, Forest Grove, and Hillsboro WWTFs. The bubble allocation would be set such that the existing TMDL target for the Lower River (i.e., 0.10 mg/L as a seasonal median at Farmington, as shown in Exhibit 1-11) would still be met. This bubble will support TP credit trading among the three facilities.

The TP bubble allocation also will facilitate use of treatment options such as Natural Treatment Systems (NTS) at the Forest Grove and/or the Hillsboro WWTFs. The NTS at both sites would include further “polishing” of the secondary treatment effluent at each site, and the water would be further used to restore existing but degraded natural wetland areas. Thus, use of NTS provides for a more sustainable strategy than mechanical and chemical processes that otherwise would have to be included to a greater extent at the Rock Creek AWWTF.

2.0 Phosphorus Analyses for Updated TMDL

2.1 Overview of Previous Phosphorus TMDLs

The first total phosphorus (TP) TMDL, one of the first in the country, was completed in 1988. The 1988 TP TMDL established a goal of 0.07 mg/L for TP in the Lower River for the summer period. National Pollutant Discharge Elimination System (NPDES) permits issued by ODEQ to the District for the Rock Creek and Durham AWWTFs contained discharge limitations consistent with that goal. The District complied with these permit limits by installing advanced tertiary treatment processes, leading to substantial improvement in water quality in the Lower River.

Extensive monitoring by the District and others subsequently demonstrated that natural background concentrations actually exceeded the 1988 target throughout much of the subbasin, and especially in tributary streams and base flows to the Lower River. The 2001 update to the TP TMDL recognized this fact and established new goals based on background concentrations.

Because of the natural background approach that was used, there was no water quality modeling done to predict the changes in algae or DO concentrations in the Lower River that would result from successful implementation of the TP TMDL. The revised NPDES permit limitations for the Rock Creek and Durham AWWTFs were set at 0.10 and 0.11 mg/L as median monthly values, respectively, consistent with the background concentrations at their locations. The District has consistently been in compliance with these limitations and the actual TP concentrations in the Lower River have been meeting the TMDL goals.

2.2 2001 TP TMDL: Critical Assumptions and Targets

The following bulleted list provides a summary of critical assumptions and methods used in the 2001 TMDL that are relevant to this updated TMDL (excerpts from the 2001 TMDL are indicated by *italics*, with page references to the 2001 document).

- The primary goal was to control total phosphorus levels in the lower Tualatin River:

    As explained in Section 4.4.6.2, the loading capacities – and therefore the allocations – contained in this portion of the TMDL were developed to address water quality issues specific to the lower mainstem Tualatin River. As such, the aggregate loading from all sources to the lower mainstem is the critical factor. [page 143]

    …phosphorus loading capacities on the tributaries are not necessary to meet water quality standards on the tributaries themselves. However, since the tributaries loads of phosphorus impact the mainstem Tualatin River, tributary loading capacities are necessary to achieve standards on the mainstem. [page 137]

- This is a concentration-based TMDL, with capacities based on "background" levels:

  Since the applicable water quality standards are dependent on the instream phosphorus concentrations (along with other factors), loading capacities in the form of concentrations are considered more appropriate than mass loads. [page 137]

- "Background" levels are based on dry season base flow conditions:

  In order to approximate the impacts of groundwater on tributary phosphorus concentrations, DEQ has examined instream concentrations during non-runoff periods. During non-runoff periods (periods when there is not enough rainfall to generate surface run-off) the sources of phosphorus in the tributaries are considered to be primarily from groundwater. [page 135]

- Dry season base flow total phosphorus concentrations were established as the summer (i.e., May–October) seasonal median TMDL concentrations for the Tualatin River and its tributaries:

  The concentrations of phosphorus contributed by groundwater are expected to fluctuate throughout the season as different geologic strata, with different phosphorus concentrations, contribute flows to the tributary streams. For this reason, the seasonal median values, as opposed to the minimum values, have been chosen to represent the seasonal background concentrations. For this same reason, the background concentrations are expected to fluctuate from year to year. [page 135, Table 46]

- The resulting TP targets for the tributaries and mainstem established by the 2001 TMDL per the above assumptions are summarized in Exhibits 2-1 and 2-2. The TP TMDL season encompasses May through September. Thus, the targets represent median values over this season.

EXHIBIT 2-1
Estimated Tributary Background Concentrations of Phosphorus During TMDL Season
Source: Table 42 of the 2001 TMDL

Tributary	Total Phosphorus Median Concentration Range (mg/L)
Bronson Creek	0.13
Burns Cr./Baker Cr./McFee Cr./Christensen Cr.	0.12
Cedar Creek/Chicken Creek/Rook Creek (South)/ Nyberg Creek/Hedges Creek/Saum Creek	0.14
Dairy Creek	0.09
Fanno Creek	0.13
Gales Creek	0.04
Rock Creek	0.19

EXHIBIT 2-2
Tualatin River Subbasin Estimated Total Phosphorus Background Concentrations During TMDL Season
Source: Table 43 of the 2001 TMDL

Stream Segment	Total Phosphorus Concentrations (Summer Median – mg/L)
Lower River	
Main stem Tualatin River @ Stafford Road (RM 5.5)	0.10
Main stem Tualatin River @ Highway 99W (RM 11.6)	0.11
Main stem Tualatin River @ Elsner (RM 16.2)	0.11
Main stem Tualatin River @ Farmington (RM 33.3)	0.10
Upper River	
Main stem Tualatin River @ Rood Road (RM 38.4)	0.09
Main stem Tualatin River @ Golf Course Road (RM 51.5)	0.04
Main stem Tualatin River above Dairy Creek	0.04

- Water quality modeling was not conducted in establishing the 2001 TP TMDL.
- The TMDL WLAs for treatment plants were: Rock Creek AWWTF: 0.08 mg/L, monthly median (this was an error that was later corrected, see below); Durham AWWTF: 0.11 mg/L, monthly median.
- The TMDL also established mass-based TP WLAs and load allocations (LAs) for stormwater sources in the watershed, including the District's Municipal Separate Storm Sewer System (MS4).

2.3 Current Permitted TP Waste Discharge Limitations

Subsequent to the 2001 TMDL, in the 2004–2005 timeframe, the District and ODEQ developed the watershed-based NPDES permit for the four WWTFs and stormwater discharges currently in effect. Exhibit 2-3 presents the District's current TP waste discharge limitations for the two AWWTFs. These TP WLAs, expressed as monthly median concentration limits, are consistent with the TP targets identified in the 2001 TMDL, as seen in Exhibit 2-2.

Additionally, a note on page 31 of the Watershed Permit Evaluation Report corrected the 2001 TMDL WLA error for Rock Creek (noted in section 2.2): *The TMDL contains an error in Table 50 for the Rock Creek WWTP waste load allocation. The value was erroneously given as 0.08 mg/L. The actual value, following the assumptions, methodologies and data given in the TMDL (including Appendix C-5) is 0.10 mg/L.*

EXHIBIT 2-3
Current Phosphorus Waste Discharge Limitations
Since Forest Grove and Hillsboro do not currently discharge during the phosphorus reduction period, which begins May 1 and ends October 31, they do not have phosphorus effluent limits.

Outfall	Monthly Median Phosphorus Effluent Concentration
D001	0.11 mg/L
R001	0.10 mg/L

2.4 2001 TP TMDL Implementation Results

Examples of the progress that has been made since the original 1988 TMDL are shown in Exhibits 2-4, and 2-5. Exhibit 2-4 shows that the TMDL targets for total phosphorus in the lower mainstem river were consistently met over the 2000-2007 period, even in a very dry low-flow year such as 2001 (the second lowest flow year in the period from 1928 through 2001 [Montgomery Watson Harza, 2006]). Exhibit 2-5 shows that in addition to the improvement in TP in the lower river, the pH criteria were also met routinely over the 1996-2007 period as compared to earlier years).

EXHIBIT 2-4
Summer Median Total Phosphorus Concentrations in the Tualatin River, 2000 to 2007

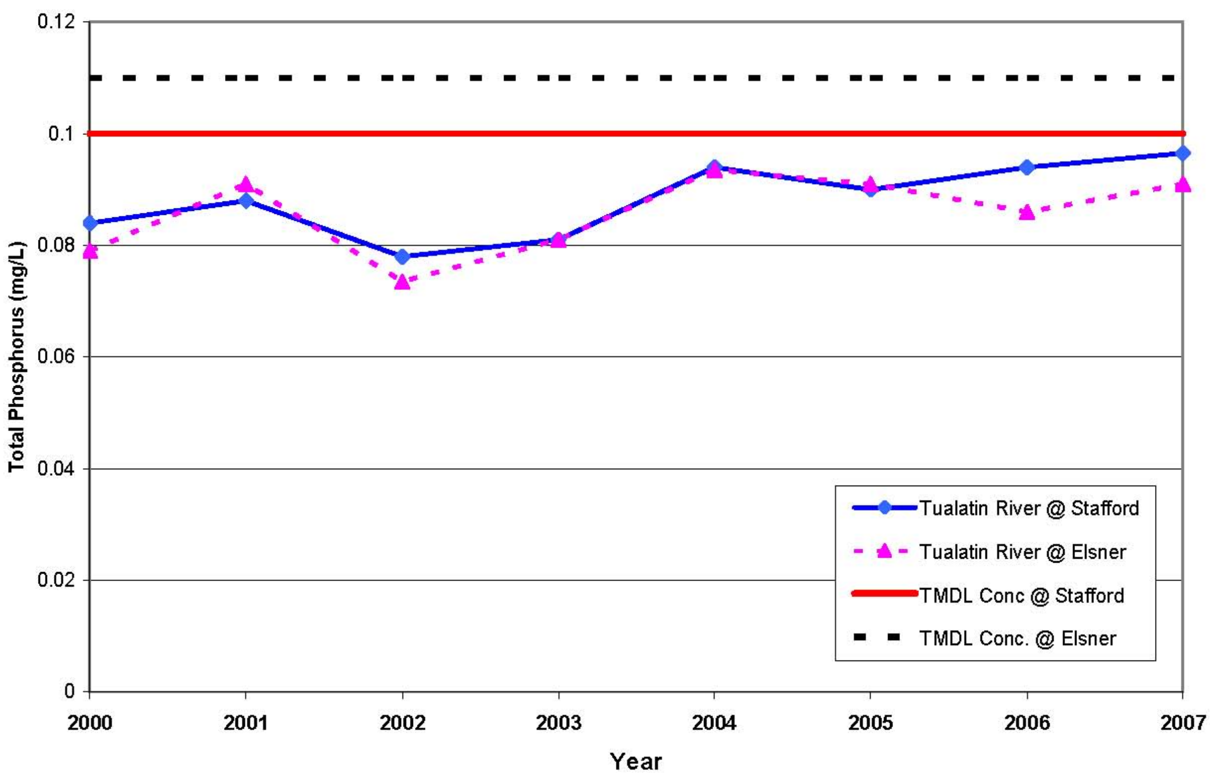
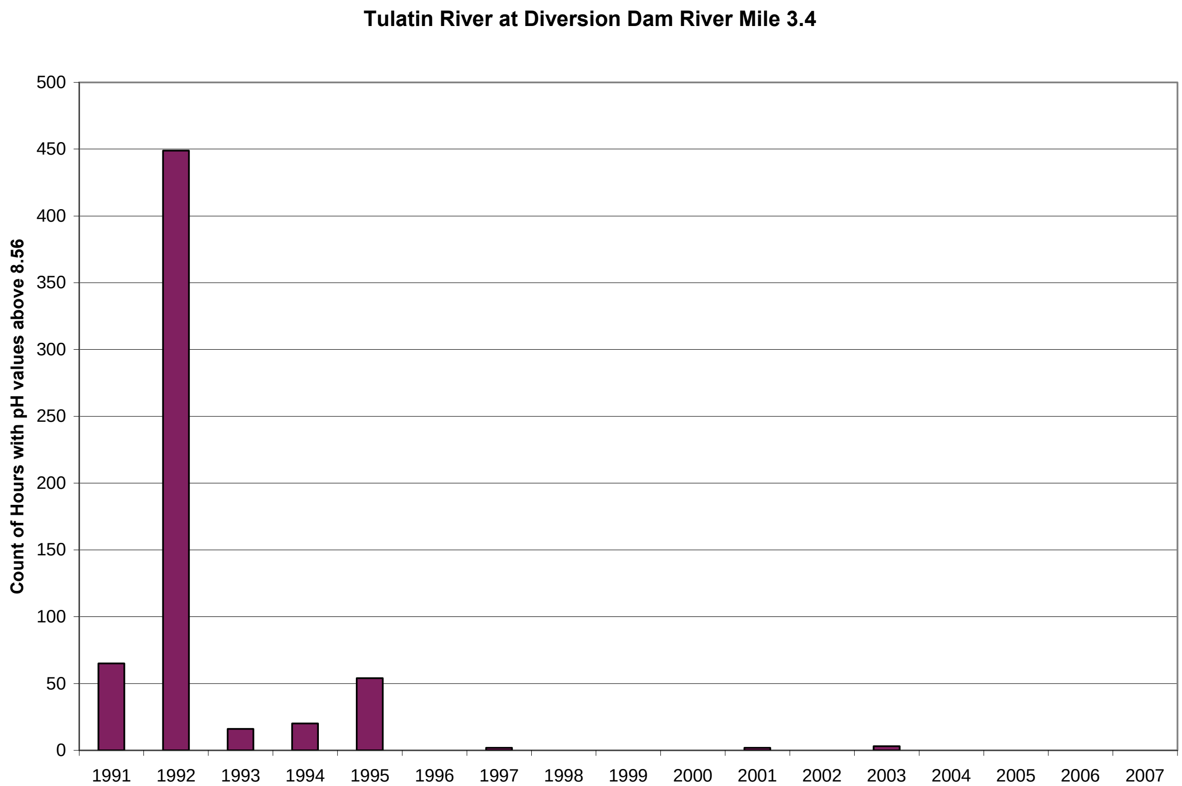


EXHIBIT 2-5
pH by Year at Oswego Diversion Dam, 1991 to 2007



2.5 2009 TP Model Development and Validation

2.5.1 Overall Modeling Methods

This revision of the TP TMDL followed the steps described below.

1. An initial, simple mass balance for TP for the Upper River for July–August 2002 was developed to provide a rough approximation of how much TP could be discharged collectively from the Forest Grove, Hillsboro, and Rock Creek WWTFs during the dry season and not exceed the previous TMDL targets for TP for the lower river downstream of the Rock Creek AWWTF. This target was 0.10 mg/L as a seasonal median value. See Section 2.5.2.1 for the basis for the 66.1 pounds per day (lb/day). A more detailed mass balance for TP was also later developed, allowing scenario analyses for the years 2002 through 2007, either for individual years or the entire 6-year period.

2. Conservatively representative estimates of effluent quality for dry season discharges from Forest Grove and Hillsboro WWTFs were then developed, including TP values constrained such that the 66.1 lb/day downstream of the Rock Creek AWWTF would not be exceeded. These estimates would be used as inputs to a deterministic (i.e., process-based) water quality model for the Upper River. CE-QUAL-W2 was the model used. See Appendix A for the basis for effluent quality inputs, Appendix B for charts of

model inputs for tributaries, and Appendix C for charts of model inputs for Rock Creek AWWTF effluent quality.

3. The next step was to run the CE-QUAL-W2 model for the Upper River to validate that conservatively representative discharges from Forest Grove and Hillsboro WWTFs do not cause water quality problems in the Upper River. This model terminates at the Rood Road Bridge just upstream of Rock Creek and the Rock Creek AWWTF. See Section 2.5.2.2 for a description of the model and Appendix A for the basis for the inputs for tributary streams to the Upper River. See Section 2.6 for a description of predicted water quality conditions in the Upper River.

4. Finally, the outputs from the Upper River CE-QUAL-W2 model were tabulated and a spreadsheet model was constructed to calculate parameter concentrations, including TP, downstream of the Rock Creek AWWTF. This spreadsheet accounted for the measured inputs from Rock Creek and the Rock Creek AWWTF. This was done to ensure that parameter concentrations downstream of the Rock Creek AWWTF were consistent with the existing TMDL targets, including TP of 0.10 mg/L on seasonal median basis. See Section 2.6.1.1 for a summary of water quality parameter values downstream of Rock Creek AWWTF.

2.5.2 Description of Models for the TP TMDL Analyses

2.5.2.1 Simple Mass Balance Model for Establishing a TP Bubble WLA

A simple mass balance model was constructed in an Excel workbook to estimate a collective, or “bubble” WLA for Forest Grove, Hillsboro and Rock Creek that would meet the goal of maintaining a TP concentration of 0.10 mg/L downstream of the Rock Creek AWWTF. Adverse impacts of TP in the Tualatin River are manifested in the lower, reservoir-like portion of the river, and thus maintaining the existing target is important for that segment. The model was based on data for July–August 2002. The results of this simple mass balance were then used to establish the basis for some of the inputs to the CE-QUAL-W2 model run for May–September 2002. Subsequently, a more detailed mass balance model was also developed.

Exhibit 2-6 presents the summary results of the simple mass balance model and shows that a bubble WLA of 66.1 lb/day TP complies with the specified instream concentration target.

EXHIBIT 2-6
Upper Tualatin River TP Mass Balance Summary and Bubble WLA Calculation, Representative of July–August 2002
Key: TR = Tualatin River mainstem location; and u/s and d/s = upstream and downstream

River Location or Input/Withdrawal	Flow, mgd	TP, mg/L	TP, lb per day	Basis
TR u/s of Forest Grove WWTF	47.3	0.04	15.8	TMDL goal
- Forest Grove WWTF	4.1	0.40	13.7	Iterated TP
TR d/s of Forest Grove WWTF	51.4	0.07	29.5	Mass balance
- Irrigation withdrawals (2)	-10.8	0.07	-6.2	Actual
TR d/s of withdrawals	40.6	0.07	23.2	Mass balance
- Dairy Creek	14.3	0.09	10.7	TMDL goal
TR d/s Dairy Creek	54.9	0.07	34.0	Mass balance
- Hillsboro WWTF	4.1	0.40	13.7	Iterated TP
TR d/s of Hillsboro WWTF	59	0.10	47.7	Mass balance
- Irrigation withdrawal	-8.5	0.10	-6.9	Actual
TR at Rood Road	50.4	0.10	40.8	Mass balance
- Rock Creek	8.0	0.19	12.7	TMDL goal
- Rock Creek AWWTF	46.5	0.10	38.8	Current limit
TR d/s of Rock Creek AWWTF	104.9	0.10	92.2	Mass balance
Total WWTF Load = Bubble WLA	**54.7**		**66.1**	

2.5.2.2 CE-QUAL-W2 Model

Potential Tualatin River water quality effects were assessed using a model that was developed by the USGS (Sullivan and Rounds, 2005; USGS, 2005). The latest model for the Tualatin River basin is a USGS-modified version of CE-QUAL-W2 version 3.12, a two-dimensional, laterally averaged model originally developed by the U.S. Army Corps of Engineers (Corps) and more recently updated by the Corps and Portland State University (Cole and Wells, 2002). This model simulates hydrodynamics, water temperature, and water quality.

The original Tualatin River model from Oswego Dam to Rood Bridge (RM 3.5 to 38.4) was developed by USGS to better understand and quantify the processes controlling nutrient transport, algal communities, and DO. This original model was developed using an earlier version of the Corps CE-QUAL-W2 model version 2.0. This Tualatin River model was originally calibrated using data from May–October of 1991, 1992, and 1993 as documented by Rounds et al. (1999). This model was later recalibrated by USGS to include the summers of 1991 through 1997 (Rounds and Wood, 2001). USGS and Portland State researchers made a number of modifications to the base model, as documented in those same reports. This version of the model was used for the 2001 TMDL for establishing the WLAs for ammonia for the Rock Creek and Durham AWWTFs.

Most recently, the model was upgraded by USGS to version 3.12 and calibrated with year-round data from 2000 to 2003, hereafter referred to as the Lower Tualatin River model. A second model was developed by USGS for the river from Rood Bridge to Gaston (RM 38.4

to 62.3), referred to hereafter as the Upper Tualatin River Model (also version 3.12). Details of these river models are documented in Appendix D. Both models include the previous USGS modifications to the Corps base model and some additional modifications for this latest application. River hydrodynamics, water temperature, orthophosphate, total phosphorus, ammonia, algae (two algal groups that do not represent a specific type of algae such as diatoms, green or blue-green algae), chlorophyll-*a*, zooplankton, and DO were modeled, calibrated and tested with measured river data. Other modeled constituents included dissolved and particulate organic matter, nitrate, dissolved solids, and suspended sediment.

Complex water quality models such as CE-QUAL-W2 require many types of boundary data, calibration data, and meteorological data as well as rate data such as the rates of algal growth and settling. The data used for this modeling were collected by a variety of organizations for many purposes. The types and sources of most of the data used by the models are listed in Exhibit 2-7.

EXHIBIT 2-7
Sources of Data

Data Type	Tualatin River Model Sources
Bathymetry data	USGS, the District
Meteorological data	USBR, USGS
Hydrological data	OWRD, USGS, TVID, JWC, the District
Water temperature and water quality data	OWRD, USGS, the District
Vegetation and shading data	USGS, ODEQ

Key:
District = Clean Water Services
JWC = Joint Water Commission
ODEQ = Oregon Department of Environmental Quality
OWRD = Oregon Water Resources Department
TVID = Tualatin Valley Irrigation District
USBR = U.S. Bureau of Reclamation
USGS = U.S. Geological Survey

2.5.2.3 Detailed TP Mass Balance Model

Model Setup

The detailed mass balance model is included on a CD in Appendix E. Instructions for using the mass balance model are included in Appendix F. The model is based on a simple mass balance framework that assumes TP is conservative. That is:

TP Concentration Downstream =

$$((\text{Discharge}_1 * \text{TP}_1) + (\text{Discharge}_2 * \text{TP}_2)) \,/\, (\text{Discharge}_1 + \text{Discharge}_2)$$

The model extends from the Gaston gage (RM 62.3) to the Farmington gage (RM 33.3), with major inputs and outputs between the two stations as shown in Exhibit 2-8 below.

EXHIBIT 2-8
Setup of Detailed Mass Balance TP Model

Location			
Name	RM	Code	+ / -
GASTON	62.3	GASO	
Irrigation - Wapato Canal	62.0	WAPO	-
Scoggins Creek	60.0	SCOO	+
Irrigation		-	-
Correction			
SPRINGHILL / DILLEY	58.8	DLLO	
Gales Ck.	56.8	GALES	+
JWC / Springhill Pump Plant	56.1	SHPP	-
Unnamed Tributaries		-	+
Forest Grove WWTP	55.2	CWSFG	+
Irrigation		-	-
Correction			
GOLF COURSE	51.5	TRGC	
Irrigation		-	-
Unnamed Tributaries		-	+
Dairy Ck.	44.7	DAIRY	+
Correction			
HIGHWAY 219	44.4	TRJB	
Unnamed Tributaries			+
Hillsboro WWTP	43.9	CWSHB	+
Unnamed Tributaries		-	+
Irrigation		-	-
Correction			
ROOD BRIDGE	39.1	ROOD	
Rock Ck.	38.1	RCTV	+
Rock Creek WWTP	38.1	CWSRC	+
Gordon Ck.	37.4	-	+
Butternut Ck.	35.7	-	+
Irrigation		-	-
Correction			
FARMINGTON	33.3	FRMO	

Input Data Sources for the TP Mass Balance Model

Discharge and concentration data collected from 2002 to 2007 were used to populate the model. This information was obtained from three sources: USGS monitoring, Tualatin River Flow Management Technical Committee Annual Reports, and the District's databases. Median TP values for May through October were calculated by the mass balance to be consistent with the existing TP TMDL target statistic and period. For consistency, median discharge (effluent and river flow) data were also used. Data sources for each model node are noted within the model itself on node-specific worksheets.

The data input values with the largest uncertainty are the flows associated with unnamed tributaries and irrigation withdrawals. These values were iteratively estimated as part of the model calibration step, described in Section 2.5.3.2 below.

2.5.3 Model Validation

2.5.3.1 CE-QUAL-W2 Model

The USGS is preparing a full technical report on development and validation of the upper and lower river models. In the interim USGS has prepared a letter which explains the upgrades, expansion and calibration of the model (included as Appendix D).

2.5.3.2 Detailed TP Mass Balance Model

The model was calibrated using the full 2002-2007 data set for the May-October period. At each major river node (Springhill/Dilley, Gold Course, Highway 219, Rood Bridge, and Farmington), predicted flows were matched as closely as possible to observed flows by adjusting unnamed tributary inputs and irrigation withdrawals. Once flow values were resolved, TP concentrations did not need to be adjusted by more than 0.001 mg/L to match observed values. These adjustment values are preserved in the "MassBalanceModel-Calibration" worksheet (on the CD in Appendix E) for documentation.

2.5.4 Specific Modeling Approaches and Inputs

The overall modeling methods were described in Section 2.5.1. The subsections below provide more details on the technical basis, methods and model inputs.

2.5.4.1 Selection of Hydrologic Year for Modeling

Historical river hydrologic conditions have been statistically evaluated (see the temperature TMDL modeling report [CH2M HILL, 2008]). This evaluation has shown that using hydrologic conditions for 2001 and 2002 provides a conservative analysis (both were very low-flow years during the critical summer and early fall time periods). These two hydrologic years also were used by ODEQ for the recently completed Willamette Basin temperature TMDL for calibration and developing allocations.

For this updated TP and DO TMDL, 2002 was used for the CE-QUAL-W2 upper model analyses because 2002 was a very low flow year during critical summer and early fall time periods, thus providing modeling results that are conservative.

In addition, the more detailed mass balance model for TP includes the years 2002 through 2007, and allows analysis of the individual years or the entire 6 year period.

2.5.4.2 Basis for Evaluation

The CE-QUAL-W2 model developed by USGS for the Upper River was used to simulate river water quality from the point of discharge of the Hillsboro and Forest Grove WWTFs downstream to Rood Road, which is the terminus of the Upper Model and just upstream of the Rock Creek AWWTF. This modeling provided assessment of temperature, dissolved oxygen, and phytoplanktonic algae (as chlorophyll-*a*) in addition to phosphorus, ammonia, and 5-day carbonaceous BOD ($CBOD_5$). This modeling accounts for the Dairy Creek input in the Upper Model between Forest Grove and Hillsboro, plus any decay or attenuation of loads between the Forest Grove and Hillsboro facilities and Rood Road. Thus, the modeled load remaining at Rood Road plus the Rock Creek and Rock Creek AWWTF loads represent those that would be discharged to the lower 39 miles of the river (these later loads were based on measured values and were added onto the CE-QUAL-W2 output from the Upper Model via a spreadsheet mass balance analysis).

The existing TP/DO and temperature TMDLs will need to be modified to provide WLAs for the Forest Grove and Hillsboro WWTFs to discharge during the dry season.

This basis for evaluation is further defined as detailed below.

- The existing TP TMDL establishes a target background TP concentration of 0.10 mg/L at Farmington. Thus, as long as the Forest Grove and Hillsboro discharges during the critical season do not increase the TP downstream of the Rock Creek AWWTF above a summer median value of 0.10 mg/L TP, then water quality in the lower river will be in conformance with TMDL goal. A simple mass balance spreadsheet was initially constructed to estimate TP concentrations from Forest Grove, Hillsboro and Rock Creek WWTFs that would meet the TMDL goal (see Exhibit 2-6). This mass balance indicated a “bubble” allocation to the three WWTFs of 66.1 lb/day of TP would be protective of the goal. The detailed mass balance model produced similar results (see Section 2.6.1.2).
- DO and algae levels should be substantively similar in the upper river, specifically DO should remain well above the applicable DO criteria and chlorophyll-*a* should remain relatively unaffected.

2.5.4.3 Future Operations for Forest Grove, Hillsboro, and Rock Creek

As discussed in Section 1, Forest Grove and Hillsboro do not currently discharge during the summer dry season; instead, they send their flows to Rock Creek for treatment. The District anticipates that dry season discharges from the Forest Grove and Hillsboro WWTFs to the Tualatin River could include the scenarios described below.

- **Forest Grove WWTF**:
  - Advanced tertiary treatment, to the levels currently being provided by the Rock Creek AWWTF during the dry season to meet all NPDES permit requirements for the AWWTF, or
  - Advanced secondary treatment, including nitrification, followed by wetlands polishing and restoration (also referred to as a Natural Treatment System, NTS).
- **Hillsboro WWTF**: Advanced secondary treatment, including nitrification, followed by a NTS.
- **Rock Creek AWWTF**: As allowed by current permit but with flows and parameter loads shifted to Forest Grove and Hillsboro WWTFs, and accounting for estimated 2025 design and actual flows which are not reflected in the current permit.

The dry season discharges from the Forest Grove and Hillsboro WWTFs will be subject to appropriate monitoring and reporting requirements, which will be addressed in the District’s new watershed permit currently under development.

2.6 Technical Results of Updated TP TMDL Analyses

2.6.1 Median Summer Season Concentrations of TP

2.6.1.1 CE-QUAL-W2 Results

Consistent with the previous TP TMDL, the calculated median summer season TP concentration downstream of the Rock Creek AWWTF with the Forest Grove and Hillsboro WWTFs discharging is 0.098 mg/L, which remains below the previous TP TMDL's summer season target of 0.10 mg/L (see Exhibit 2-9). The combined TP WLA for the Forest Grove, Hillsboro and Rock Creek WWTFs that achieves the summer season target is 66.1 lb/day. These downstream values were calculated by adding the measured flows and loads from Rock Creek and the Rock Creek AWWTF to the flows and loads at the downstream boundary of the Upper Model (i.e., at Rood Road).

EXHIBIT 2-9
Constituent Concentrations Downstream of Rock Creek AWWTF with and without Forest Grove and Hillsboro WWTF Discharges
The highlighted value of 0.098 is less than the target 0.10 mgL TP for the river below Rock Creek.

		Monthly Average					Median May-Sept
		May	**June**	**July**	**August**	**September**	
No Discharge from Forest Grove and Hillsboro WWTFs (Run 5.5), below RC AWWTF							
Flow	(cfs)	390.8	240.4	177.0	160.6	208.3	199.8*
Temp.	(degrees C)	13.6	17.6	19.7	19.4	17.6	18.3
DO	(mg/L)	9.693	8.773	8.212	8.300	8.754	8.572
Phosphate	(mg/L)	0.038	0.057	0.068	0.066	0.036	0.051
TP	(mg/L)	0.070	0.087	0.093	0.086	0.068	0.083
Forest Grove and Hillsboro WWTFs Discharging (Run 5.4), below RC AWWTF							
Flow	(cfs)	390.8	240.4	176.9	160.6	208.3	199.9*
Temp.	(degrees C)	13.6	17.5	19.6	19.2	17.5	18.1
DO	(mg/L)	9.686	8.778	8.254	8.352	8.778	8.622
DO (tributary RDOM unconstrained; Run 5.6, see Appendix A)	(mg/L)	9.685	8.777	8.247	8.347	8.771	8.614
Phosphate	(mg/L)	0.043	0.064	0.075	0.073	0.045	0.059
TP	(mg/L)	0.080	0.101	0.105	0.101	0.082	**0.098**

* No change in flow because the Forest Grove and Hillsboro flows are otherwise discharged at the Rock Creek AWWTF.

2.6.1.2 Detailed TP Mass Balance Results

Primary Results

The model indicates that TP concentrations at Farmington would remain at or below 0.10 mg/L during the May-October period under the following three primary assumptions:

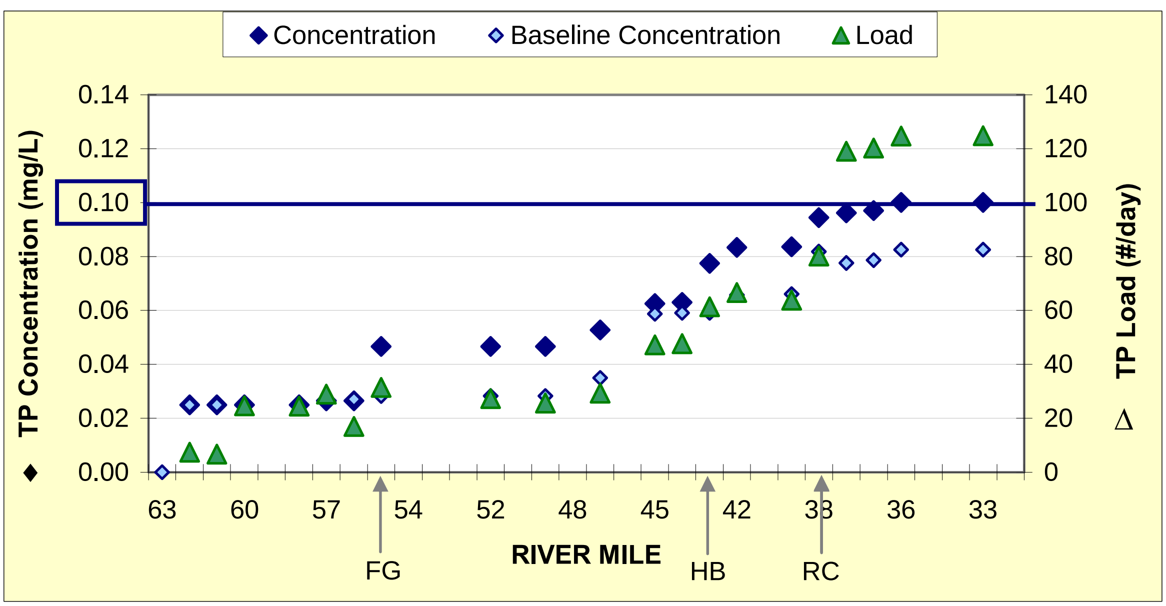
1. The combined TP mass load of Rock Creek, Forest Grove, and Hillsboro does not exceed 66.1 lb/day (see also Exhibit 2-11);
2. The District's future flow augmentation levels will be the same as current flow augmentation levels; and
3. Water quality standards are being met in the tributaries upstream of the facilities (i.e., the TP mg/L in each tributary is equal to its TMDL allocation, see also Exhibit 2-12.

Exhibit 2-10 (see also Appendix E) graphically presents the mass balance results that demonstrate the modeled compliance with the 0.10 mg/L TP target under the three assumptions above.

EXHIBIT 2-10
Primary TP Mass Balance Results (Median TP Concentration, May through October, 2002-2007)
Assumes TP Mass Load ≤ 66.1 lb/day, current flow augmentation levels, and tributaries meeting water quality standards.

FARMINGTON TP

0.100	mg/L



Basis for WWTF Loading Assumptions

It is assumed the three WWTFs—Rock Creek, Forest Grove WWTF, and Hillsboro—discharge at the flows and TP concentrations listed in Exhibit 2-11. Because the mass balance is conservative, any combination that meets the same total loading for all three facilities combined will produce the same result at Farmington. Note that the 4.1 mgd for the Hillsboro WWTF is consistent with Exhibit 1-5, while 4.1 mgd for the Forest Grove WWTF falls within the range of anticipated flows in Exhibit 1-5. Future flows for Forest Grove may vary depending on treatment technologies selected (e.g., advanced mechanical versus NTS) and development patterns in the service area.

EXHIBIT 2-11
Basis for WWTF TP Discharge Assumptions in Detailed Mass Balance Model: Primary Run

WWTF	Max Q (mgd)	Max TP mg/L	Max TP lb/day
Rock Creek	46.5	0.10	38.8
Forest Grove	4.1	0.40	13.7
Hillsboro	4.1	0.40	13.7
Total TP lb/day			*66.1*

Basis for Flow Augmentation Assumptions

“Current” flow augmentation levels from the two reservoirs from which the District may make supply calls are assumed as follows:

- Barney Reservoir: generally 14 cfs in September and October; and
- Scoggins Dam (Hagg Lake): generally an average of 30 – 40 cfs for summer and early fall months.

Basis for Tributary Water Quality Assumptions

The three tributaries—Gales Creek, Dairy Creek, and Rock Creek—are assumed to meet their TMDL load allocations with the flow and TP in-stream concentrations listed in Exhibit 2-12.

EXHIBIT 2-12
Basis for WWTF TP Discharge Assumptions in Detailed Mass Balance Model: Primary Run

Tributary Creek	Q (mgd)	TP (mg/L)
Gales	13.5	0.04
Dairy	23.8	0.09
Rock	10.3	0.19

Additional Modeling Demonstrates Benefits of the District’s Flow Augmentation

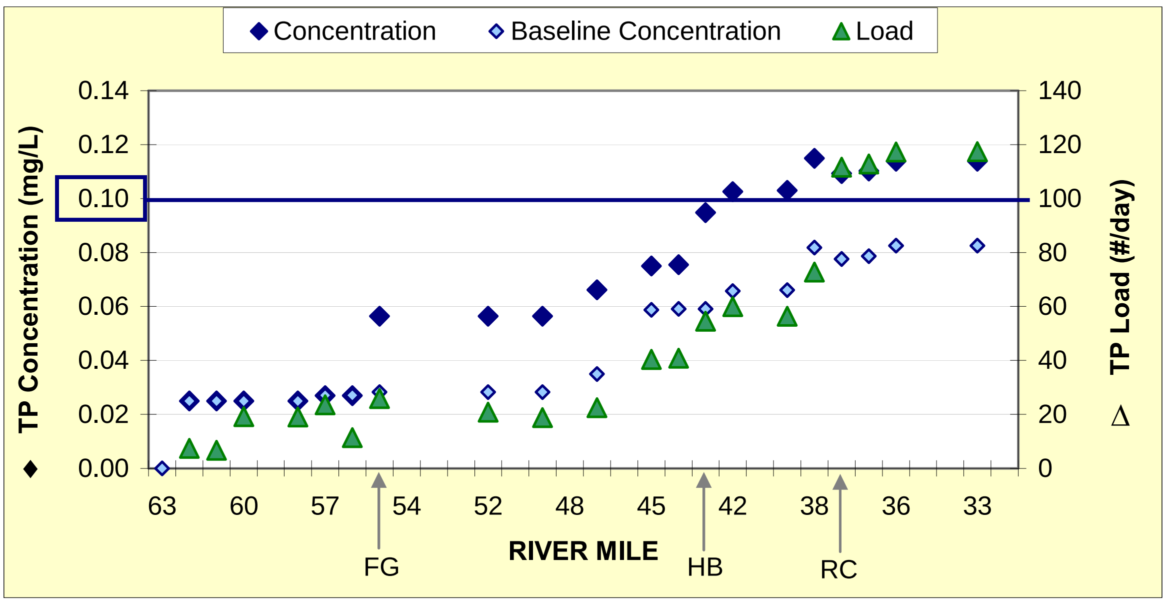
The model specifically incorporates benefits from District’s flow augmentation. The results shown in Exhibit 2-10 above assume that future flow augmentation levels will be the same as current flow augmentation levels. However, if the releases from Scoggins Dam are instead assumed to be zero, then modeled TP concentrations at Farmington are 0.014 mg/L higher, as shown in Exhibit 2-13 below. This analysis conservatively reflects only the benefit from Scoggins Dam releases, as Barney Reservoir releases are still assumed at current levels.

This analysis demonstrates that the District’s augmentation water provides a measurable benefit to the TMDL target at Farmington by keeping TP concentrations 0.014 mg/L lower than they are predicted to be without the augmentation, and helping to ensure that the Lower River target can continue to be met.

EXHIBIT 2-13
Supplementary TP Mass Balance Results #1 (Median TP Concentration, May through October, 2002–2007)
Assumes TP Mass Load ≤ 66.1 lb/day, reduced flow augmentation levels, and tributaries meeting water quality standards.

FARMINGTON TP

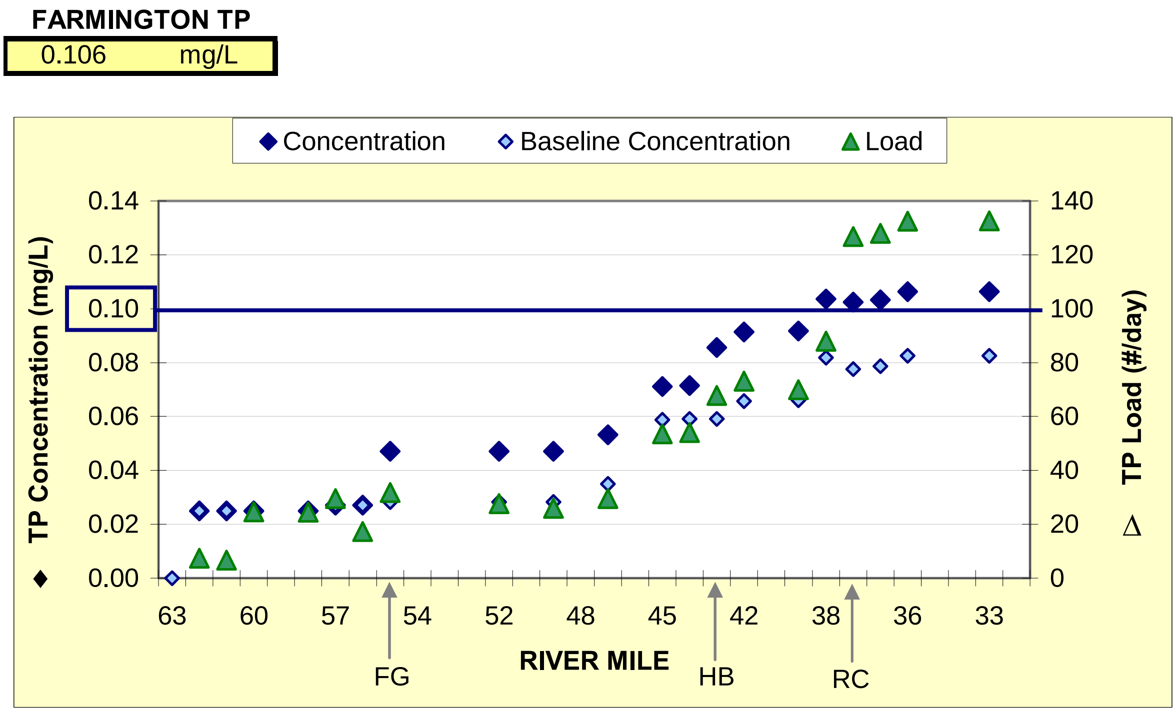
0.114	mg/L



Additional Modeling Demonstrates Importance of Compliance in the Tributaries

The model also provides insight into what would happen if the major tributaries were unable to meet their 2001 TMDL load allocations. Instead of the assumed tributary concentration values shown in Exhibit 2-12, the following observed TP concentrations can be modeled (keeping the flow assumptions in Exhibit 2-12 constant): Gales Creek, 0.045 mg/L; Dairy Creek, 0.121 mg/L; and Rock Creek, 0.209 mg/L. This scenario reflects assuming no improvements in tributary inputs to the mainstem Tualatin River, and results in a predicted TP concentration at Farmington of 0.106 mg/L (an increase of 0.006 mg/L compared to the primary assumption results shown in Exhibit 2-12), as shown in Exhibit 2-14.

EXHIBIT 2-14
Supplementary TP Mass Balance Results #2 (Median TP Concentration, May through October, 2002-2007)
Assumes TP Mass Load ≤ 66.1 lb/day, current flow augmentation levels, and tributaries at observed concentrations.



Summary Results of Detailed TP Mass Balance Modeling

The detailed mass balance model confirms that the 2001 TMDL target for TP for the Lower River (0.10 mg/L at Farmington) will continue to be met under the "bubble allocation" scenario (66.1 lb/day for Rock Creek, Forest Grove, and Hillsboro combined discharges). The supplementary modeling also shows that the benefits provided by the District's flow augmentation (0.014 mg/L lower at Farmington) more than offsets uncertainty associated with whether tributary improvements will occur (0.006 mg/L higher at Farmington). Exhibit 2-15 summarizes the alternative assumptions for the model results presented in Exhibits 2-10, 2-13, and 2-14 above.

EXHIBIT 2-15
Summary of Assumptions and Modeling Results for the Detailed TP Mass Balance Analysis
The orange shading highlights the change in key assumptions for each scenario versus the primary set of assumptions.

Scenario	Bubble WLA TP lb/day	Tributary Flow Augmentation from Reservoirs[1]		Tributary TP mg/L	Modeled TP mg/L at Farmington	TP mg/L Benefit of Flow or Quality v. Base Case	Reference Exhibit
		Barney	***Scoggins***				
1	66.1	Current	Current	TMDL WLA	0.100	N/A	Ex. 2-10
2	66.1	Current	NONE	TMDL WLA	0.114	-.014	Ex. 2-13
3	66.1	Current	Current	Observed	0.106	-.006	Ex. 2-14

2.6.2 DO and Chlorophyll a Concentrations

The CE-QUAL-W2 model predicts that DO concentrations at Rood Road (the downstream boundary of the upper model, just upstream of Rock Creek) are not substantially different with Forest Grove and Hillsboro WWTFs discharging (i.e., less than 0.10 mg/L lower on average), and remain well above the applicable DO criteria for the dry season (see Exhibits 2-16 and 2-17). Additional time-series charts for DO for other locations (e.g., between the Forest Grove and Hillsboro WWTFs) are provided in Appendix G.

In addition, the DO concentration at the upstream boundary of the lower (reservoir-like) river is slightly higher with the Forest Grove and Hillsboro WWTFs discharging in the dry season (see Exhibit 2-9). The DO concentration at this latter boundary is influenced by the inputs from Rock Creek and the Rock Creek AWWTF.

Chlorophyll *a* concentrations at Rood Road are slightly lower with Forest Grove and Hillsboro WWTFs discharging in the dry season (see Exhibit 2-18). Again, additional time-series plots for chlorophyll *a* at other locations are provided in Appendix G.

Exhibits 2-19 and 2-20 are longitudinal plots of DO and chlorophyll *a* for the month of August. This month is representative of warm summer conditions (charts for other months are provided in Appendix G).

Exhibit 2-19 shows a slight dip in DO at the point of the Forest Grove WWTF discharge which is because the DO in the effluent (assumed to have the same DO as the Rock Creek AWWTF) is slightly lower than the river DO at that river location.

Exhibit 2-20 shows that greater chlorophyll *a* spikes do not occur upstream of Rood Road, and similar plots for the other months are provided in Appendix G.

Note that the river bottom and water surface elevation (WSE) profiles are quite different for the upper and lower rivers. The higher gradient and shallower water depths in the Upper River, compared to the lower gradient and deeper reservoir-like lower river, explain why the Upper River is not very sensitive to loadings of TP. Higher gradient promotes higher river velocities, shorter residence times, and therefore less opportunity for water quality

[1] As noted in the November 2009 report: This analysis conservatively reflects only the benefit from Scoggins Dam releases because Barney Reservoir releases do not occur throughout the dry season.

effects. Appendix H provides plots of river bottom and WSE profiles for the Upper and Lower rivers. The change in gradient at about river mile 47 is evident, and the backwater effects in the Lower River are also well-illustrated. The backwater effects in the Lower River would occur regardless of the presence of the Oswego Dam (note the high elevation of the rock outcrop that occurs at about river mile 10 in Cook Park).

EXHIBIT 2-16
Instantaneous Dissolved Oxygen at Rood Road

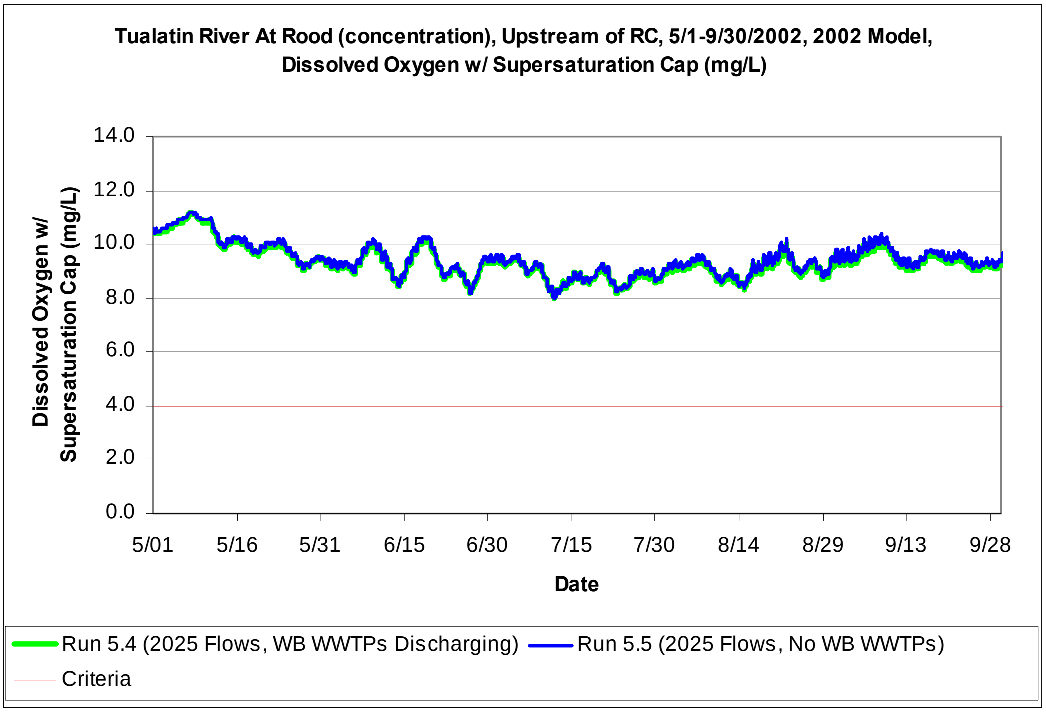


EXHIBIT 2-17
30-Day Average Dissolved Oxygen at Rood Road

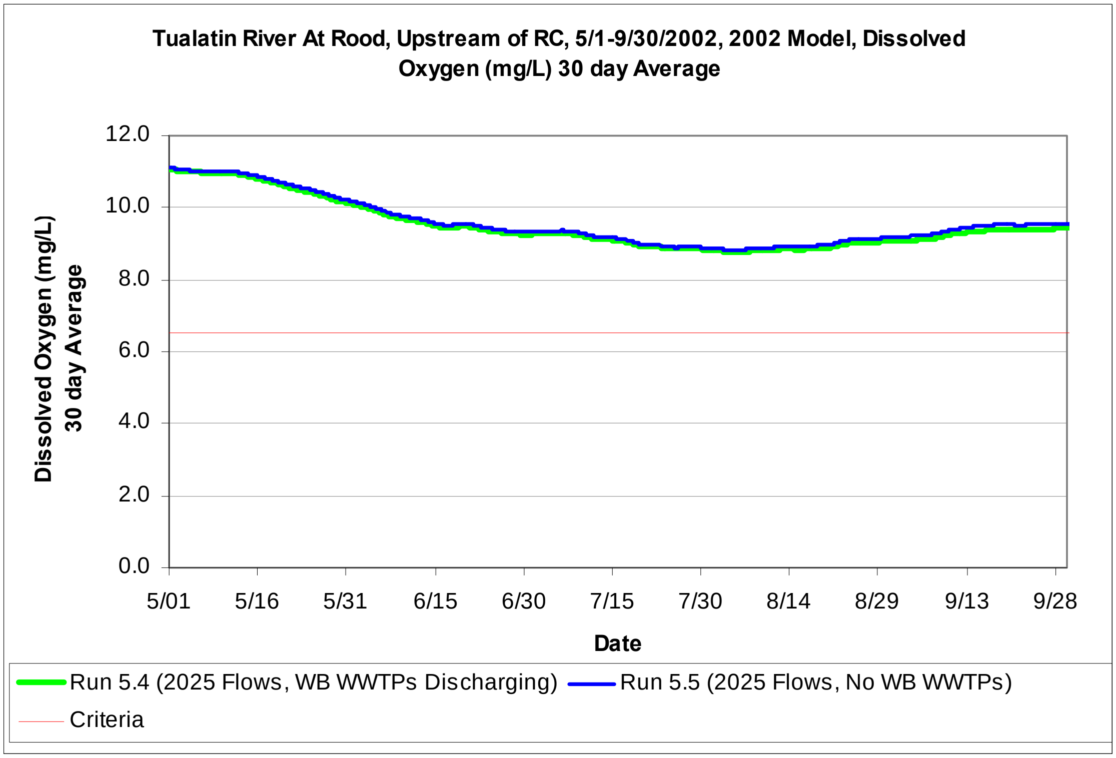


EXHIBIT 2-18
Chlorophyll *a* at Rood Road
Exhibit 3-3 shows results for chlorophyll a *at Rood Road because that is the downstream-most location for the Upper River and therefore expected to show the maximum potential effect on algal growth by discharges to the Upper River.*

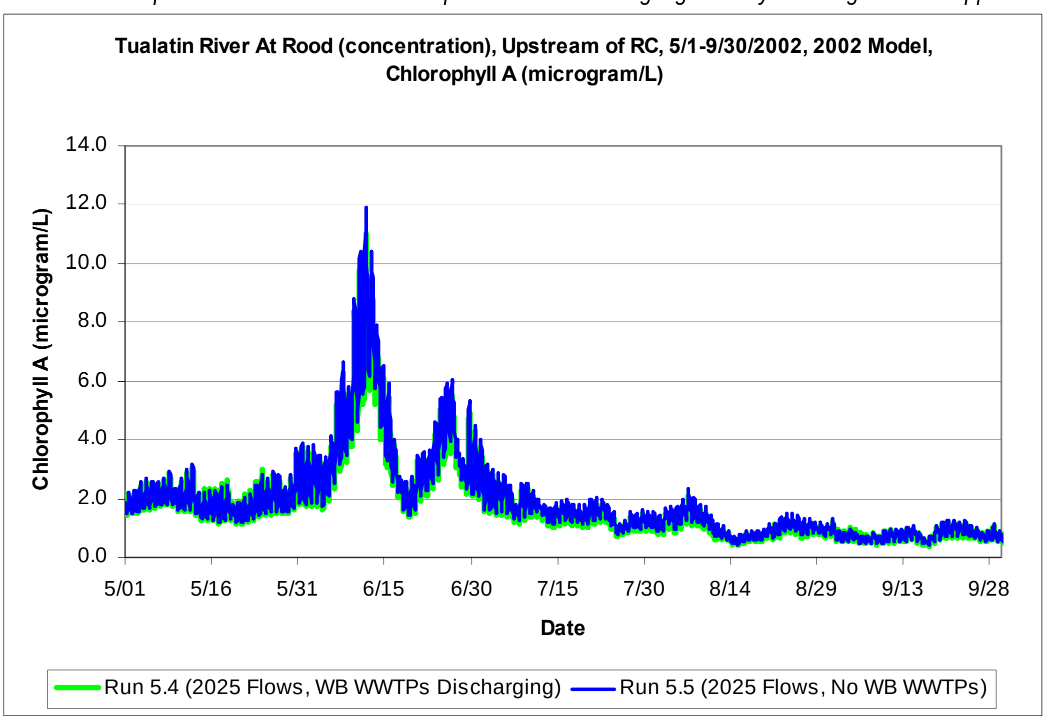


EXHIBIT 2-19
Longitudinal Profile of DO in the Upper River for August

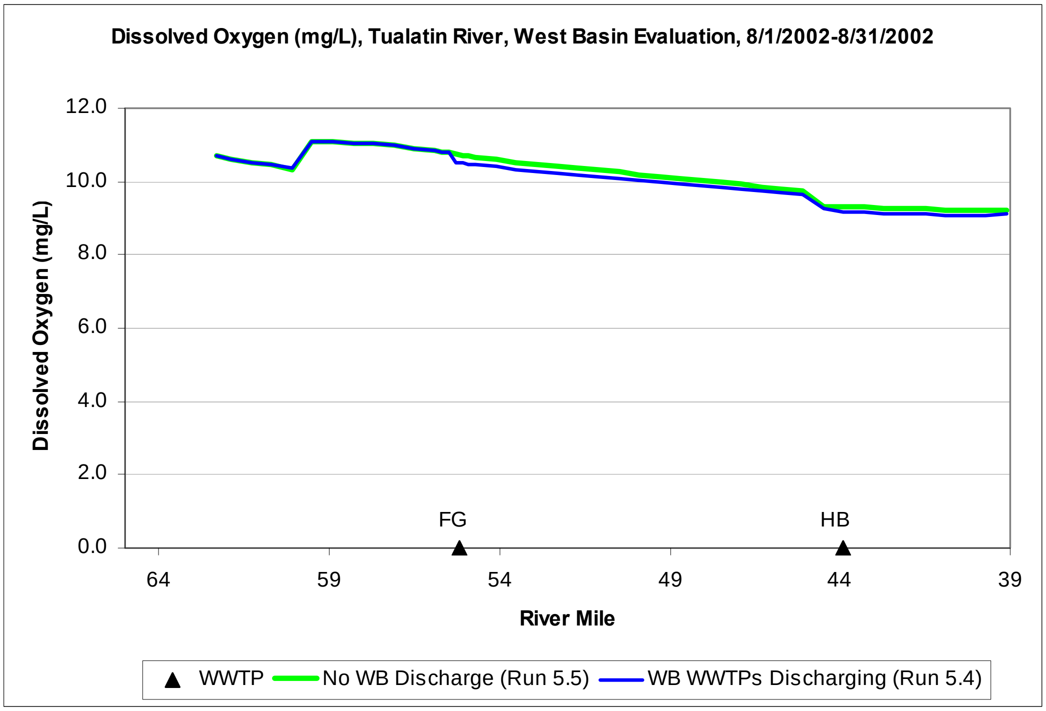
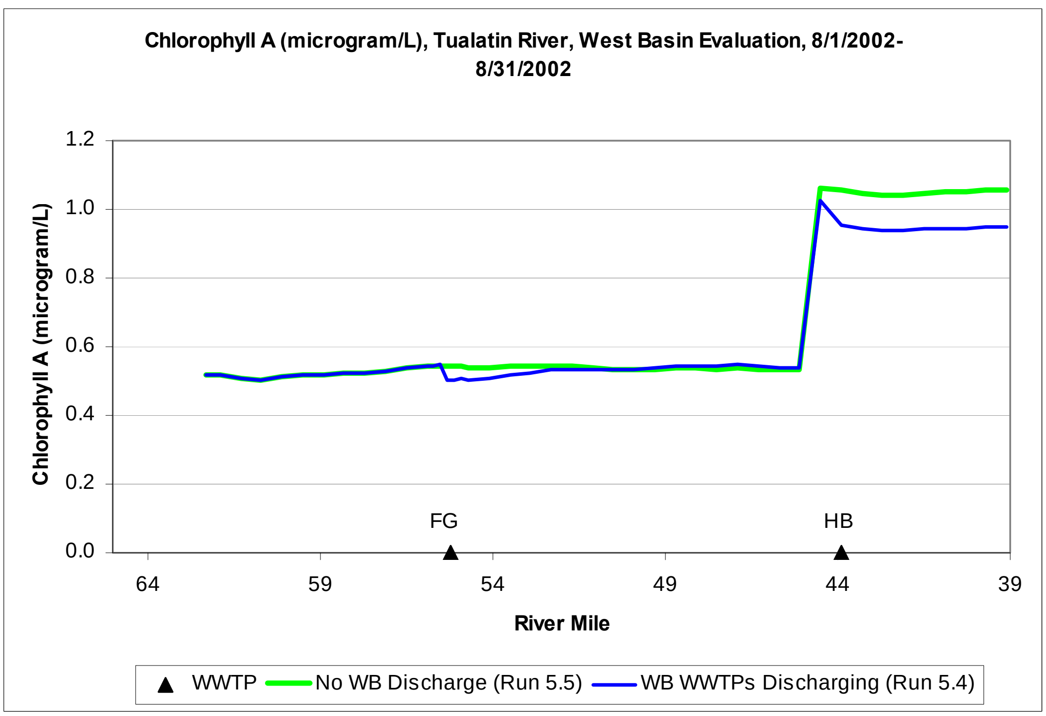


EXHIBIT 2-20
Longitudinal Profile of Chlorophyll *a* in the Upper River for August

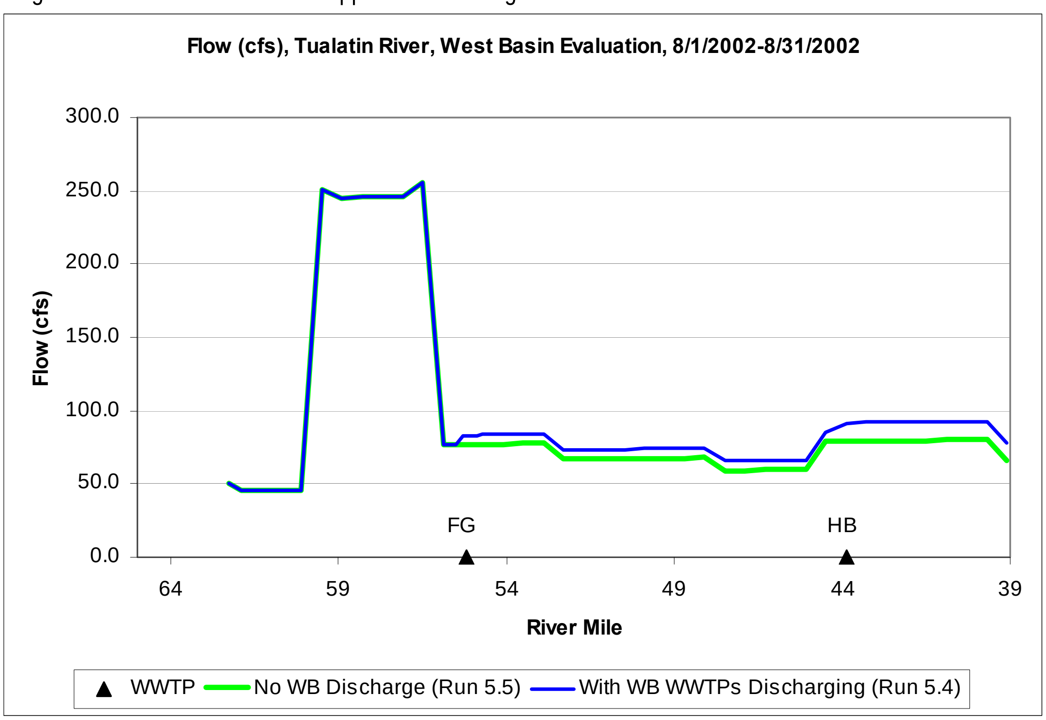


2.6.3 Tualatin River Flow Considerations

Maintaining suitable flows in the Tualatin River is a concern for various stakeholders in the watershed. For perspective on this issue, Exhibit 2-21 shows a longitudinal chart of average mainstem river flows in August for the Upper River from the CE-QUAL-W2 model. Additional charts for each month for May through September are included in Appendix G. For the driest months (July through September), the large increase in flow near river mile (RM) 60 is attributed to the releases from Hagg Lake through Scoggins Creek, most of which (with the exception of the Districts water quality augmentation releases) is then withdrawn from the river at the Springhill Pump Plant just upstream of the Forest Grove WWTF.

As would be expected, there is only a slight increase in river flow in the Upper River downstream of Forest Grove and Hillsboro WWTFs for the model run in which the WWTFs are discharging, as compared to no dry season discharge. The river flow downstream of the Rock Creek AWWTF is essentially the same for these two scenarios because the Forest Grove and Hillsboro flows would otherwise be discharged at Rock Creek, and because it was assumed for the model run that all of the Forest Grove and Hillsboro WWTF effluent would go directly to the river rather than NTS. For the NTS options, some of the effluent will infiltrate and some will be lost to evapotranspiration, thus making the river flows in the Upper River closer to the no-discharge scenario. In any case, flows in both the upper and lower rivers will be similar because the volume of water at Forest Grove and Hillsboro WWTFs is relatively small compared to total river flow.

EXHIBIT 2-21
Longitudinal Profile of Flow in the Upper River for August



2.7 Conclusions of the 2009 TP TMDL Modeling

- Dry season waste load allocations (WLAs) for TP should be provided in the updated TMDL for the Forest Grove and Hillsboro WWTFs because:
  - TP concentrations in the river downstream of the Rock Creek AWWTF will meet the existing TP TMDL goal for the Lower River, which is the portion of the river most sensitive to TP's effects on algal growth and DO; and
  - Dissolved oxygen (DO) and algae (as chlorophyll *a*) are not adversely impacted in the Upper River.
- A new "bubble" WLA for TP of 66.1 lb/day for the Forest Grove, Hillsboro and Rock Creek WWTFs will achieve the existing TP TMDL goal for the Lower River. Whatever treatment technology is employed for the Forest Grove WWTF (e.g., advanced tertiary or NTS) and Hillsboro (i.e., NTS) will be designed to ensure that the bubble WLA will be met.
- The simple and detailed mass balance spreadsheet models both demonstrate the District's ability to meet the 0.10 mg/L TP target in the Lower River.

3.0 Ammonia Analyses for Updated TMDL

3.1 Overview of Previous Ammonia TMDLs

Ammonia from the two summer-discharging Lower River WWTFs also was addressed in the 1988 TMDL, leading to additional treatment upgrades for ammonia removal by the District at these WWTFs. Although this led to substantial improvement in DO in the Lower River, monitoring data indicated that DO problems still occurred in some years during the late summer and early fall. The USGS had already developed and calibrated a CE-QUAL-W2 model for the Lower River prior to the 2001 TMDL, and analyses with the model showed what additional ammonia removal would be needed during that critical period, and also that less ammonia removal than required by the 1988 TMDL would be needed at other times, such as spring and early summer. Extensive modeling by USGS was used by ODEQ to establish new ammonia allocations for the Rock Creek and Durham AWWTFs in the 2001 TMDL. The ammonia allocations were expressed as an equation that related allowable ammonia discharges to river flow, river DO, and month of the year.

Subsequent to the completion of the 2001 TMDL, ODEQ and the District developed a watershed permit that incorporated all four WWTFs and the District's stormwater management program into a single NPDES permit. This watershed permit framework provided the opportunity to develop a water quality credit trading process for oxygen-demanding parameters like ammonia. In the Lower River, the maximum effects of ammonia on DO from both AWWTFs are manifested in the vicinity of the Oswego Dam at about River Mile 3. The extensive monitoring and modeling work conducted by USGS has provided a sound scientific understanding of how ammonia decays and consumes oxygen in the Lower River. That understanding, in turn, provided the technical basis for inter-WWTF trading of ammonia in terms of equivalent DO effects at Oswego Dam.

Ammonia is not the only oxygen-demanding parameter in municipal wastewaters. The other commonly regulated parameter is carbonaceous biochemical oxygen demand (CBOD). CBOD was not explicitly addressed via allocations in the 2001 TMDL, but the existing CBOD concentrations and loads in the District's summer discharges to the Lower River were included in the USGS modeling scenarios that established the ammonia allocations. USGS represented CBOD in CE-QUAL-W2 via a model parameter called refractory dissolved organic matter (RDOM). Thus, CBOD was included in the TMDL modeling as an existing contributing parameter to DO demand in the river. That existing CBOD contribution was explicitly included in the watershed permit oxygen-demand trading algorithms. The oxygen-demand trading element of the watershed permit is essentially a "bubble" concept, with the size of the bubble variable based on river flow, DO and month of the year.

3.2 Current Ammonia WLAs and Effluent Limits

The 2001 TMDL established WLAs for ammonia for the Rock Creek and Durham AWWTFs. The WLAs were established as load limits dependent on river flow, month of the year, and in-river DO concentration (see Exhibit 3-1). The watershed permit implemented these WLAs along with oxygen-demand trading provisions. The permit authorizes trading of ammonia and CBOD within each AWWTF and between the two AWWTFs based on oxygen-demand equivalency at Oswego Dam, the most sensitive location on the lower river for DO sags (see pages 6 to 9 of the NPDES permit, included here as Appendix I).

EXHIBIT 3-1
Current Ammonia (NH_3-N) Waste Discharge Limitations for Durham and Rock Creek AWWTFs

Weekly Median Maximum Load, lb/day	**Concentration Variable (NH_3-N, mg/L):** *THE APPLICABLE TIER IS BASED ON THE INSTREAM DISSOLVED OXYGEN CONCENTRATION AS DESCRIBED IN THE NOTES SECTION OF THIS TABLE.*		**Applicable Time Period**
Weekly Median Maximum Ammonia Load = (Farmington Flow)(Concentration Variable)(5.39) lb/day, where: Farmington Flow is the previous calendar weekly consecutive-day median of the daily mean flow at the Farmington gauge in cfs, and Concentration Variable is NH_3-N in mg/L during the applicable period as in the next columns:	**Tier 1**	**Tier 2**	
	1.4	1.4	May and June
	1.4	0.8	July
	1.4	0.3	August
	0.8	0.21	September through November 15

Notes:
(a) The ammonia reduction period is May 1 through November 15, except as noted above.
(b) Between September 1 and November 15 when the seven-consecutive-day median of daily mean flow at the Farmington gauge is at least 350 cfs, ammonia reduction does not apply.
(c) The ammonia loadings as ammonia-nitrogen shall not exceed the Weekly Median Maximum Ammonia Load limitation, calculated using the formula and variables given above.
(d) The Tier 1 concentration variable is in effect for any week when ammonia reduction is required unless the following conditions occur, in which case the Tier 2 concentration variable is in effect:

(i) For Rock Creek AWWTF: Either the weekly mean of the daily mean DO concentrations, with no credit for supersaturation, at RM 24.5 (Neals), for the ***previous*** *week is less than 6.7 mg/L or the weekly mean of the daily mean DO concentrations, with no credit for supersaturation, at RM 3.4 (Oswego Dam), for the* ***previous*** *week is less than 6.7 mg/L.*
(ii) For Durham AWWTF: The weekly mean of the daily mean DO concentrations at RM 3.4 (Oswego Dam), with no credit for supersaturation, for the ***previous*** *week is less than 6.7 mg/L.*

3.3 Methods Applicable to Updated Ammonia TMDL

The District's request for the updated ammonia TMDL is simple. The overall ammonia allocations for the District's WWTFs from the 2001 TMDL would remain unchanged. The only difference is that some of that allocated load would be shifted from the Lower River AWWTFs upstream to the Forest Grove and Hillsboro WWTFs for summer discharge at those locations. The Upper River WWTFs would also be incorporated into the existing oxygen-demand trading "bubble" along with the Rock Creek and Durham AWWTFs.

The river's DO status is most sensitive to ammonia in the Lower River, and the District's requested update would not change the combined allocated and permitted loads of ammonia and CBOD in the Lower River. Thus, new water quality modeling for the Lower River is not needed for this update.

As described in Section 2, the CE-QUAL-W2 model of the Upper River was run to confirm lack of adverse impacts in the Upper River as a result of summer season TP inputs from the Forest Grove and Hillsboro WWTFs. The scenario with these WWTFs discharging also included ammonia and CBOD in the discharges, with concentrations set to the high end of what might be allowed by the oxygen-demand trading program.

3.4 Results and Conclusions of the Updated Ammonia TMDL Analyses

As shown in Exhibit 2-9 and exhibits in Section 2.6.2, ammonia and CBOD loads to the Upper River associated with summer season discharges from the Forest Grove and Hillsboro WWTFs did not adversely impact DO concentrations in the Upper River, based on the results of the Upper River CE-QUAL-W2 model.

For that modeling scenario, the ammonia concentrations were based on the District's plans to provide effluent nitrification at both WWTFs. The WWTF flows input assumed no loss through natural treatment systems or other restored wetlands. These assumptions provide the greatest load that may apply for the likely range of treatment scenarios for the Forest Grove and Hillsboro WWTFs. Such loads would have to be balanced with Rock Creek and/or Durham AWWTFs in order to meet the existing overall DO bubble allocation. Using ammonia and $CBOD_5$ loads for the Forest Grove and Hillsboro WWTFs that are skewed to the high end provides opportunity to conservatively evaluate DO effects in the upper river and the fraction of these parameters that might decay in the upper river prior to reaching the Rock Creek AWWTF location. The results showed that some CBOD would decay between Forest Grove and Rood Road, although ammonia decay was not evident from the modeling results (see Appendix A for greater detail on parameter decay results).

Ammonia and $CBOD_5$ loads will ultimately be constrained by the existing Lower River allocations for these parameters as implemented in the NPDES permit via the oxygen-demand trading program, an oxygen-demand trading bubble that would be modified to include summer dry season discharges from Forest Grove and Hillsboro WWTFs, but without modifying the previous TMDL allocations. The trading provisions implemented via an updated watershed permit should also incorporate the decay of CBOD that occurs between Forest Grove WWTF and Rood Road.

4.0 District Requested Allocations

4.1 Total Phosphorus TMDL Update

The District requests that the existing TMDL targets (i.e., load capacities) expressed as summer median concentrations downstream of the Rock Creek AWWTF be retained in this updated TMDL for TP. In addition, the TP targets for the Upper River (where TP does not cause adverse water quality effects) would be removed, as summarized in Exhibit 4-1.

EXHIBIT 4-1
Tualatin River Subbasin Total Phosphorus Load Capacity (Target) Concentrations During TMDL Season
Source: Modified from Table 45 of the 2001 TMDL

Stream Segment	Total Phosphorus Concentrations (Summer Median – mg/L)
Lower River	
Main stem Tualatin River @ Stafford Road (RM 5.5)	0.10
Main stem Tualatin River @ Highway 99W (RM 11.6)	0.11
Main stem Tualatin River @ Elsner (RM 16.2)	0.11
Main stem Tualatin River @ Farmington (RM 33.3)	0.10
Upper River	
Main stem Tualatin River @ Rood Road (RM 38.4)	Not applicable
Main stem Tualatin River @ Golf Course Road (RM 51.5)	Not applicable

The District does not request any changes to the tributary load capacity (target) concentrations as shown in Table 45 of the 2001 TMDL.

The District also requests that a TP WLA of 66.1 lb/day be established as a "bubble" allocation and implemented by retaining the summer median TP concentration target of 0.10 mg/L TP for the river downstream of the Rock Creek AWWTF. Then, the trading of the total TP load among the Forest Grove, Hillsboro, and Rock Creek WWTFs would be implemented via the reissued watershed permit. Exhibit 4-2 summarizes the District's requested TP allocations.

EXHIBIT 4-2
District Requested Waste Load Allocations for TP for Each WWTF

WWTF	WLA Value	Waste Load Allocation Period
Bubble for Forest Grove, Hillsboro and Rock Creek	66.1 pounds per day	May through October Median
Rock Creek	0.10 mg/L	Monthly Median
Forest Grove	See Bubble WLA	May through October Median
Hillsboro	See Bubble WLA	May through October Median
Durham	0.11 mg/L	Monthly Median

4.2 Ammonia (Dissolved Oxygen) TMDL Update

The existing ammonia WLAs for Durham and Rock Creek would remain in place, as shown in Exhibit 4-3, which replicates the current permit limits in Schedule A at Section 1.a.(3). The only differences from the current WLAs are shown in yellow highlight.

EXHIBIT 4-3
Ammonia Waste Load Allocations for Durham, Rock Creek, Forest Grove and Hillsboro WWTFs

(a) The ammonia reduction period is May 1 through November 15, except as noted below;
(b) Between September 1 and November 15 when the seven-consecutive-day median of daily mean flow at the Farmington gauge is at least 350 cfs, ammonia reduction does not apply; and
(c) The ammonia loadings as ammonia-nitrogen shall not exceed the Weekly Median Maximum Ammonia Load limitation, calculated using the formula and variables given below.

Outfall Number	Parameter	Weekly Median Maximum Load, lb/day
D001, R001, F001, H001	Ammonia – N	Weekly Median Maximum Ammonia Load = (Farmington Flow)(Concentration Variable) (5.39) lb/day, where: Farmington Flow is the previous calendar weekly consecutive-day median of the daily mean flow at the Farmington gauge in cfs, and Concentration Variable is NH_3-N in mg/L during the applicable period as follows:

Concentration Variable (NH_3-N, mg/L) (The applicable tier is based on the instream dissolved oxygen concentration as described below)		Applicable Time Period
Tier 1	Tier 2	
1.4	1.4	May and June
1.4	0.8	July
1.4	0.3	August
0.8	0.21	September through November 15

(d) The Tier 1 concentration variable is in effect for any week when ammonia reduction is required unless the following conditions occur, in which case the Tier 2 concentration variable is in effect.
  (i) For Rock Creek AWTF: Either the weekly mean of the daily mean DO concentrations, with no credit for supersaturation, at RM 24.5 (Neals), for the ***previous*** week is less than 6.7 mg/L or the weekly mean of the daily mean DO concentrations, with no credit for supersaturation, at RM 3.4 (Oswego Dam), for the ***previous*** week is less than 6.7 mg/L. (See Note 2.)

  (ii) For Durham AWTF: The weekly mean of the daily mean DO concentrations at RM 3.4 (Oswego Dam), with no credit for supersaturation, for the ***previous*** week is less than 6.7 mg/L. (See Note 2.)

(e) Waste load allocations for Durham, Rock Creek, Forest Grove and Hillsboro WWTFs will be implemented via the oxygen-demand trading program as authorized and defined in the watershed NPDES permit.

Schedule A Note 2 reads as follows: In-stream monitoring for dissolved oxygen is currently following the USGS QA/QC procedures described in Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting, 2000: U.S. Geological Survey Water Resources Investigations Report 00-4252, 53 p. http://water.usgs.gov/pubs/wri/wri004252/

As with TP, the District requests a bubble allocation for ammonia consistent with the oxygen-demand trading approach in the current NPDES permit (see Appendix I), but modified to include dry season discharges from the Forest Grove and Hillsboro WWTFs.

The first part of implementing the oxygen-demand bubble allocation leaves the ammonia allocations in the 2001 TMDL essentially unchanged. The new bubble allocation for ammonia for the four facilities would then be established using the same approach as currently in place to calculate the combined oxygen demand load limitation for the Durham and Rock Creek AWWTFs as would be amended to include the Forest Grove and Hillsboro WWTFs. As discussed in Section 3, the primary revision to the formulas necessary to calculate this bubble WLA involves accounting for the decay of CBOD between the Forest Grove WWTF and Rood Road. The specific details and modified equations are included in a separate trading white paper prepared by the District.

5.0 References

CH2M HILL. 2008. *Tualatin River Total Maximum Daily Load Temperature Modeling*. Final Technical Report.

Clean Water Services. 2008. *NPDES Permit Renewal Issues, Final Report*. August.

Cole, T. M. and Wells. S. A. 2002. *CE-QUAL-W2; A Two-Dimensional, Laterally Averaged, Hydrodynamics and Water Quality Model, Version 3*: U.S. Army Corps of Engineers, Instruction Report EL-02-1 [variously paged].

Montgomery Watson Harza. 2006. *Tualatin River basin Water Supply Project: Surface Water Hydrology Technical Report*.

Oregon Department of Environmental Quality (ODEQ). 2001. *Tualatin Subbasin Total Maximum Daily Load (TMDL)*.

Oregon Department of Environmental Quality (ODEQ). 2003. Oregon Administrative Rules—Chapter 340, Division 041. Water Quality Standards: Beneficial Uses, Policies, and Criteria for Oregon.

Rounds, S.A. and T.M. Wood. 2001. *Modeling Water Quality in the Tualatin River, Oregon, 1991- 1997*. US Geological Survey Scientific Report 01-4041.

Rounds, S.A., T.M. Wood, and D.D. Lynch. 1999. *Modeling Discharge, Temperature, and Water Quality in the Tualatin River, Oregon*. U.S. Geological Survey Water Supply Paper 2465-B.

Sullivan, A.B., S.A. Rounds. 2005. *Modeling Hydrodynamics, Temperature and Water Quality in Henry Hagg Lake, Oregon, 2000-2003.* U.S. Geological Survey Scientific Investigations Report 2004-5261, 38 p.

United States Geological Survey (USGS). 1972. *Appraisal of Streamflow in the Tualatin River Basin, Oregon.* Open-File Report.

Appendix A

Detailed Description of CE-QUAL-W2 Inputs and Selected Results

APPENDIX A

Detailed Description of CE-QUAL-W2 Inputs and Selected Results

Operational and System-Related Model Assumptions

The basic approach to evaluate dry season discharges for Forest Grove and Hillsboro WWTF discharges of oxygen-demanding parameters (ammonia and $CBOD_5$) and TP is to run the CE-QUAL-W2 Upper River model with the assumptions listed below.

- NTSs (wetlands) do not reduce effluent flows to the river via evapotranspiration (ET) and infiltration. In reality, however, ET and infiltration will be significant components of the water balance. In the absence of finalized NTS sizing data, this conservative assumption is used instead.
- TP loads for Forest Grove and Hillsboro will be a bubble load (estimated initially via simple mass balance and then confirmed with CE-QUAL-W2 run) that keeps median TP downstream of Rock Creek AWWTF at existing TMDL target of 0.10 mg/L TP measured as seasonal median.
- Tributary TP loads were also set at their respective TMDL targets for this model run to be consistent.

This basic approach to defining model input parameters becomes more complicated when a further goal is to also evaluate potential effects of Forest Grove and Hillsboro WWTF discharges on DO in the Upper River, and considering that $CBOD_5$ and TP are interrelated in the CE-QUAL-W2 model via the refractory dissolved organic matter (RDOM) parameter.

Effluent Flow Inputs

The parameters for effluent flow are summarized in Exhibit A-1. This model run is intended to provide a reasonably conservative representation of dry weather discharges from the Forest Grove and Hillsboro WWTFs. Actual flows and loads will be further established by ongoing engineering evaluations of NTS at these facilities, and will ultimately be governed by the new bubble allocation for TP and the oxygen-demand trading constraints in the existing NPDES permit.

EXHIBIT A-1
Summary of Effluent Flows for the CE-QUAL-W2 Upper River Model for the Tualatin River

Effluent Flows	Forest Grove WWTF	Hillsboro WWTF	Rock Creek AWWTF[d]
2025 Dry Season Design Flow	4.6 mgd[a]	4.9 mgd (includes 0.3 mgd to be sent to Rock Creek)[b]	54.6 mgd (no Forest Grove or Hillsboro discharges)
Flow for Biosolids Treatment	0.5 mgd sent to Rock Creek AWWTF	0.5 mgd sent to Rock Creek AWWTF	1.0 mgd received in total from Forest Grove and Hillsboro WWTFs
2025 Dry Season Design Flow to the Tualatin River[c]	4.1 mgd	4.1 mgd	46.4

[a]The Council Creek Pump Station is scheduled to be completed before 2025. This may lead to Forest Grove dry season design flow of 4.6 mgd. The difference between this and 2.9 mgd (original 2025 projection) will be considered reduced flow to Rock Creek AWWTF.

[b]The total Hillsboro WWTF 2025 flow is projected to be 4.9 mgd, but because of nitrification constraints, 0.3 mgd of this will be sent to the Rock Creek AWWTF.

[c]Flat line flows were used, not ratios applied to actual flows. Forest Grove = 4.6 - 0.5. Hillsboro = 4.9 - 0.3 - 0.5. Rock Creek = 54.6 – 4.9 - 4.6 + 0.3 + 0.5 + 0.5

[d] Rock Creek AWWTF is not located in the Upper Model, instead this AWWTF discharge was included in the mass balance to calculate parameter concentrations in the Tualatin River downstream of the AWWTF

Effluent Water Quality Parameter Inputs

Input parameters for WWTF water quality are summarized in Exhibit A-2. The CE-QUAL-W2 model does not directly simulate BOD, but instead simulates various components of organic matter. For the Tualatin model, USGS used the Refractory Dissolved Organic Matter (RDOM) component as the means to simulate BOD. The model also assumes that RDOM contains a certain amount of phosphorus (i.e., 1.1 percent of the RDOM is phosphorus). Thus, RDOM and phosphorus inputs are interrelated. Given these interrelationships, the approach to be used for determining the basis for inputs related to BOD, TP, and RDOM shown in Exhibit A-2 (see also Charts in Appendix C), is as follows:

- **Forest Grove** — PO_4 = 0.20, RDOM = 17.2, $CBOD_5$ = 4.9, TP = 0.40, NH4 = 0.40;
- **Hillsboro** — PO_4 = 0.20, RDOM = 17.2, $CBOD_5$ = 4.9, TP = 0.40, NH4 = 0.07; and
- **Rock Creek** — PO_4 = actual (except when TP > 0.10, in these cases set PO_4 = 0.05, RDOM = 4.55, $CBOD_5$ = 1.3, TP = 0.10), NH4 = as allowed by permit, and RDOM and $CBOD_5$ as allowed by oxygen-demand trading in permit but constrained so TP not greater than 0.10.

The rationale for this approach is that it keeps TP at target levels downstream of Rock Creek and uses $CBOD_5$ numbers that are consistent and "reasonable" relative to what Hillsboro is predicted to achieve without wetlands and what Forest Grove likely would be able to achieve when accounting for wetlands. This approach will set the total $CBOD_5$ and ammonia discharged from the Forest Grove and Hillsboro WWTFs at higher levels than likely allowed when bubbled with the Rock Creek AWWTF's oxygen-demanding WLA in the existing permit. Thus, the approach is conservative in that it will allow evaluation of effects on DO and algae, and potential decay of $CBOD_5$ and ammonia, in the Upper River, while recognizing that the current WLA will protect DO in the Lower River in any case.

EXHIBIT A-2
Summary of Water Quality Input Parameters for the CE-QUAL-W2 Upper River Model Run for the Tualatin River

Parameter	Forest Grove WWTF	Hillsboro WWTF	Rock Creek AWWTF
Ammonia	0.4 mg/L[a]	0.07 mg/L[b]	Permitted (existing TMDL and permit constrained)
$CBOD_5$ *When considered independent of RDOM*	4.9 mg/L[c]	4.9 mg/L[b]	Permitted (1.4 mg/L, as in permit to be used in combined oxygen demand at Oswego Dam calculation, but constrained so that TP not > 0.10 mg/L)
Effluent dissolved oxygen	Same as Rock Creek	Same as Rock Creek	Actual (aerated)
Total Phosphorus: Bubble TP load for 3 WWTFs = 66.1 lb/day. *When considered independent of RDOM*	0.40 mg/L[d]	0.40 mg/L[d]	Permitted (0.10 mg/L)
RDOM	17.2 mg/L	17.2 mg/L	Permitted (but constrained so that TP not > 0.10 mg/L)
Phosphate	0.20 mg/L	0.20 mg/L	Actual[f]
Total Suspended Solids	Permitted	Permitted	Permitted
Nitrate	Rock Creek Actual	Rock Creek Actual	Using empirical relationship between NH4 and NO3): $NH_4 < 6$ mg/L → $NO_3 = NO_3$ $NH_4 \leq 6$ mg/L → $NO_3 = 5.0 - 0.074(NH_4)$
TDS, conductivity, bacteria, chloride, DO, and total organic carbon	Same as Rock Creek	Same as Rock Creek	Actual

[a] Per West Basin Facilities Plan and final design. Wetlands will very effectively remove ammonia, so this is certainly a conservative approach.

[b] Based on Pro2D modeling.

[c] This would be 8.0 mg/L per West Basin Facilities Plan and final design, however, CH2M HILL believes that NTS will remove BOD to 3 to 5 mg/L.

[d] Iterated from simple TP mass balance for Upper River.

[e] RDOM is related to both $CBOD_5$ and TP: RDOM = (4.9/1.4)* $CBOD_5$; TP = PO_4 + (0.011)*RDOM; and Organic particulate P (PP) = 0.011*RDOM.

[f] Except when > 0.10, set to 0.05.

Tributary Water Quality Parameter Inputs

The parameters for tributary water quality are summarized in Exhibit A-3. See Tables and charts in Appendix B for effects of the assumptions in Exhibit A-3 on tributary water quality parameters. Note the decrease at times in actual RDOM to avoid exceeding TP target. A second model run was also made keeping tributary RDOM at actual concentrations to evaluate effects of higher RDOM (i.e., not capped to meet TP targets) on upper river DO levels. The results of that second model run are presented later in this Appendix.

EXHIBIT A-3
Summary of Tributary Water Quality Parameters for the CE-QUAL-W2 Upper River Model for the Tualatin River

Parameter	Tualatin River at Gaston	Scoggins Creek	Gales Creek	Dairy Creek	Rock Creek*
Total Phosphorus	Not changed	Not changed	0.04 mg/L (background)	0.09 mg/L (background)	0.19 mg/L (background)
Phosphate	Not changed	Not changed	Actual (unless > 0.04 mg/L, then set to 0.04 mg/L)	Actual (unless > 0.04 mg/L, then set to 0.04 mg/L)	Actual (unless > 0.04 mg/L, then set to 0.04 mg/L)
RDOM	Not changed	Not changed	Actual (unless TP > 0.04 mg/L, then set RDOM so TP = 0.04 mg/L)	Actual (unless TP > 0.04 mg/L, then set RDOM so TP = 0.04 mg/L)	Actual (unless TP > 0.04 mg/L, then set RDOM so TP = 0.04 mg/L)

*Rock Creek is not located in the Upper Model, instead inputs from this creek were included in the mass balance analysis to calculate parameter values for the Tualatin River downstream of the Rock Creek AWWTF.

$CBOD_5$ and Ammonia Decay Modeling Results

$CBOD_5$ and ammonia concentrations in the effluent from Forest Grove and Hillsboro were set at levels more indicative of what would be discharged to the NTS rather than what would be discharged from the NTS sites to the Tualatin River. This was done to conservatively evaluate potential effects on DO in the upper river and also to evaluate if substantial decay of $CBOD_5$ and ammonia would occur in the upper river.

It is anticipated that WLAs for $CBOD_5$ and ammonia would be determined as bubble allocations for the Forest Grove, Hillsboro, and Rock Creek WWTFs. These allocations would be derived from the existing WLAs for oxygen-demanding materials from the previous TMDL as contained in the existing NPDES watershed permit, including continued ability to trade within this three-plant bubble and with the Durham AWWTF. The only additional provision would be accounting for decay of $CBOD_5$ between the Forest Grove and Hillsboro WWTFs and Rood Road.

$CBOD_5$ from the Forest Grove and Hillsboro WWTFs' effluent, modeled as RDOM by the upper river model, does decay to some extent between the point of discharge and Rood Road (see RDOM charts in Appendix G), with the fraction decayed values summarized by month in Exhibit A-4.

The model does not directly reveal the extent of ammonia decay in the Upper River because any decay that may be occurring is masked by slightly increasing ammonia concentrations in the upper model even when the Forest Grove and Hillsboro WWTFs are not discharging (see ammonia charts in Appendix G). This is likely due to natural oxidation of background sources of organic nitrogen in organic matter.

EXHIBIT A-4
Fraction RDOM Decayed upon Reaching Rood

	RDOM Originating at FG			RDOM Originating at HB		
Time Period	**RDOM @ FG** (mg/L)	**RDOM @ Rood** (mg/L)	**Fraction Decayed**	**RDOM @ HB** (mg/L)	**RDOM @ Rood** (mg/L)	**Fraction Decayed**
May	2.03	1.90	0.064	3.05	3.01	0.013
June	1.85	1.61	0.130	3.16	3.08	0.025
July	2.05	1.73	0.156	3.44	3.31	0.038
August	1.91	1.70	0.110	3.41	3.30	0.032
September	1.53	1.47	0.042	2.63	2.60	0.011

Finally, the longitudinal charts for ammonia concentrations in Appendix G show that instream concentrations increase in the Upper River as a result of the dry season discharges from Forest Gove and Hillsboro WWTFs, but the concentrations remain very low (less than 0.05 mg/L) relative to ammonia toxicity thresholds.

To account for decay of $CBOD_5$ between the Forest Grove and Hillsboro WWTFs and Rood Road, and to support implementation of a bubble allocation, Forest Grove $CBOD_5$ loads would use the fraction decayed values in Exhibit A-4 (converted to fraction left) to make them equivalent to loads discharged from the Rock Creek AWWTF. The sum of the equivalent ultimate oxygen demand at Oswego Dam would be determined as dictated in the existing permit, including oxygen-demand trading within and between all four of the District's WWTFs. There is insufficient decay of $CBOD_5$ between Hillsboro and Rood Road to consider including the decay in the trading; and similarly, the decay of ammonia between Forest Grove and Hillsboro and Rood Road could not be effectively determined and is also not included in trading. The trading aspects of the bubble allocation will be provided in a separate report for the renewal of the District's Watershed-based NDPES permit.

DO Effects with RDOM in Tributaries Not Constrained

Run 5.4 represents the scenario with summer discharges from Forest Grove and Hillsboro WWTFs. In that scenario, Upper River tributaries (Gales Creek and Dairy Creek) feature TP concentrations (combination of phosphate and a fraction of organic matter [RDOM]) that are limited to the background levels identified in the TMDL. Another discharge scenario, Run 5.6, was modeled with the WWTFs discharging but without constraining RDOM. Exhibits A-5 and A-6 show that the constrained RDOM condition used in Run 5.4 had very little effect on DO (the median May to September DO concentration was less than 0.01 mg/L higher in Run 5.4). Additional charts comparing Runs 5.4 and 5.6 can be found in Appendix G.

EXHIBIT A-5
Longitudinal DO Comparison in the Upper River during August for Different RDOM Conditions

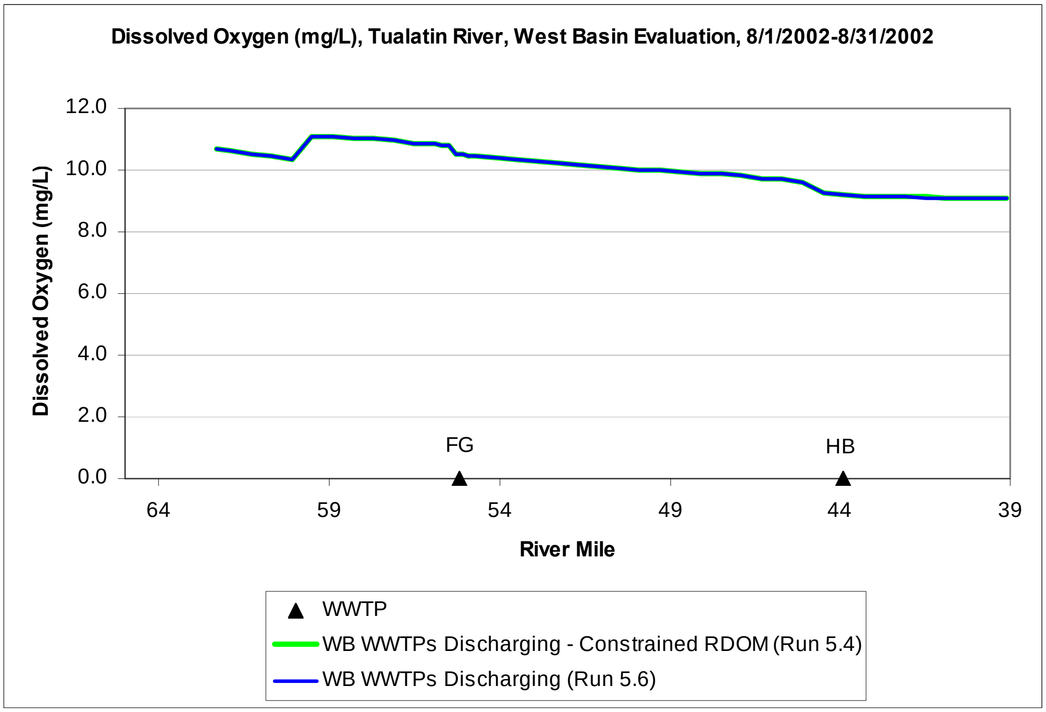
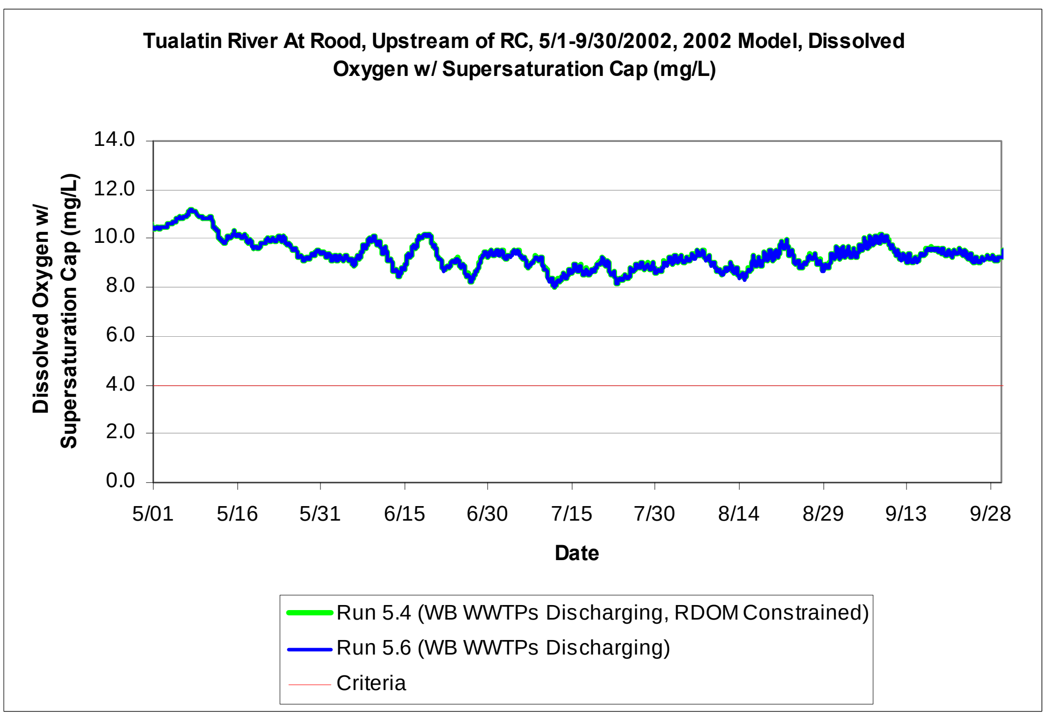


EXHIBIT A-6
Comparison of Instantaneous DO at Rood Road for Different RDOM Conditions

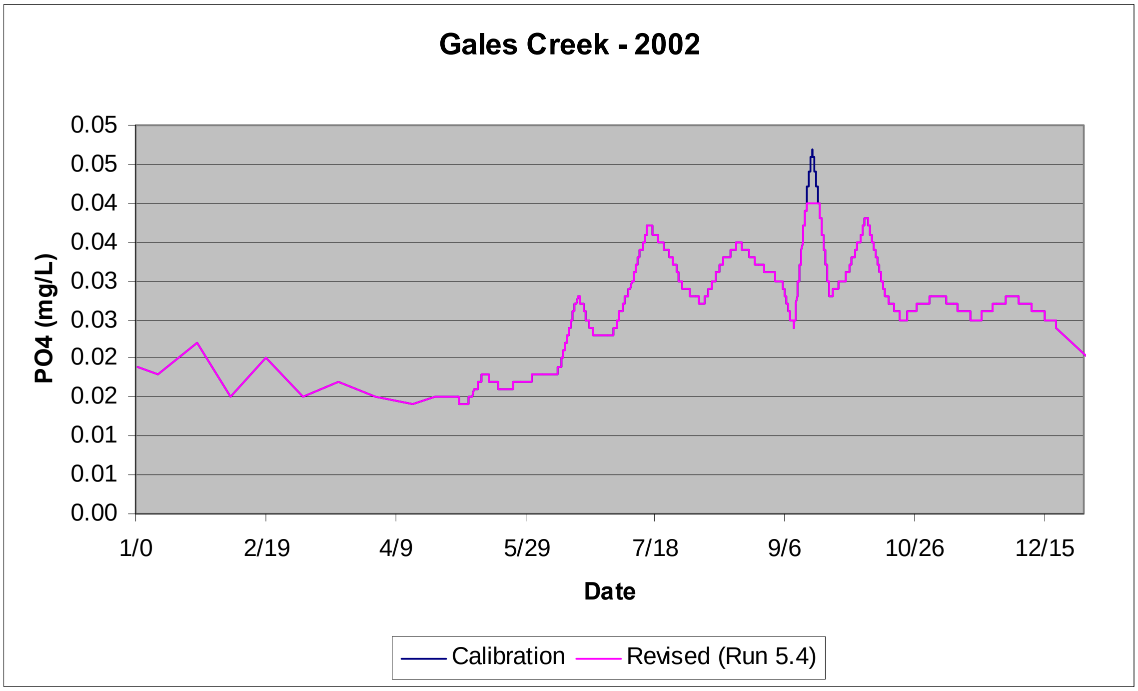


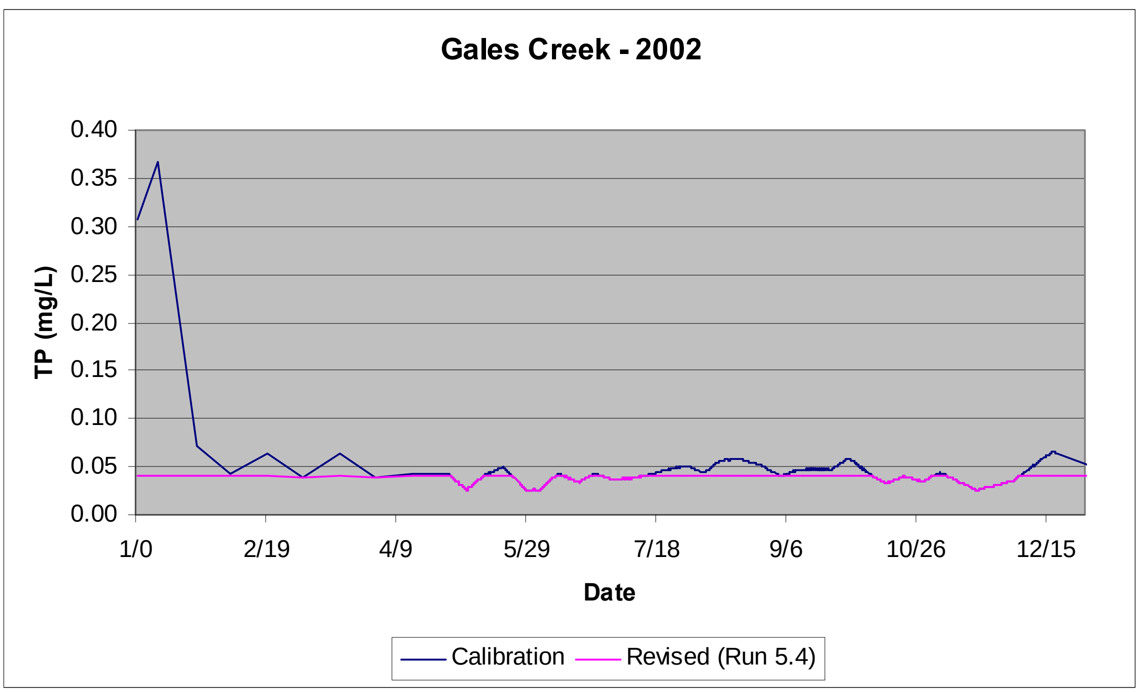
Appendix B

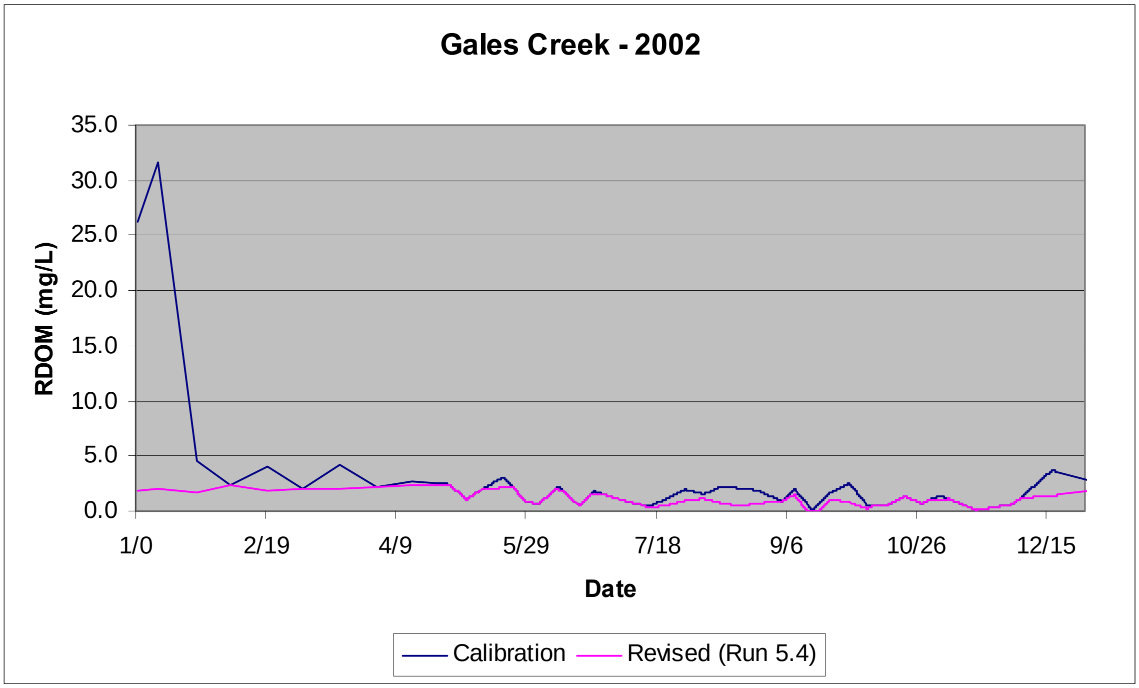
Charts of Model Inputs for Tributaries

Gales Creek

		Monthly Average					Median
		May	June	July	August	Sept	May-Sept
TP	(mg/L)	0.03	0.04	0.04	0.04	0.04	0.04
PO4	(mg/L)	0.02	0.02	0.03	0.03	0.03	0.03
RDOM	(mg/L)	1.68	1.30	0.73	0.78	0.73	0.94
Particulate-P, from RDOM (1.1%)	(mg/L)	0.02	0.01	0.01	0.01	0.01	0.01

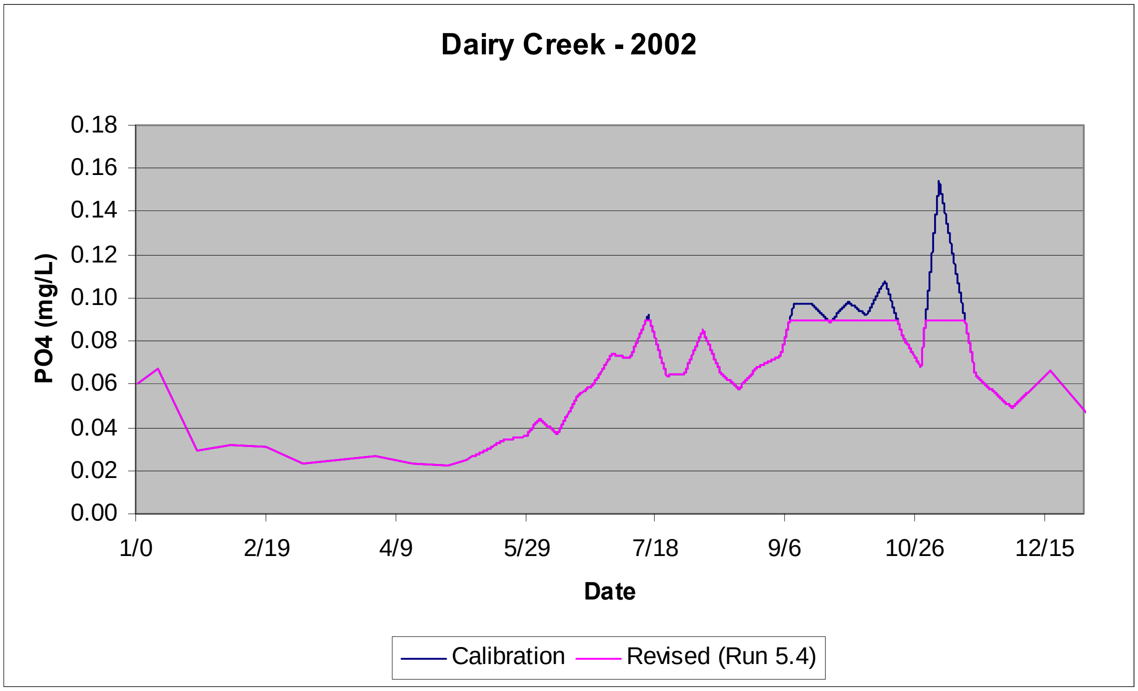


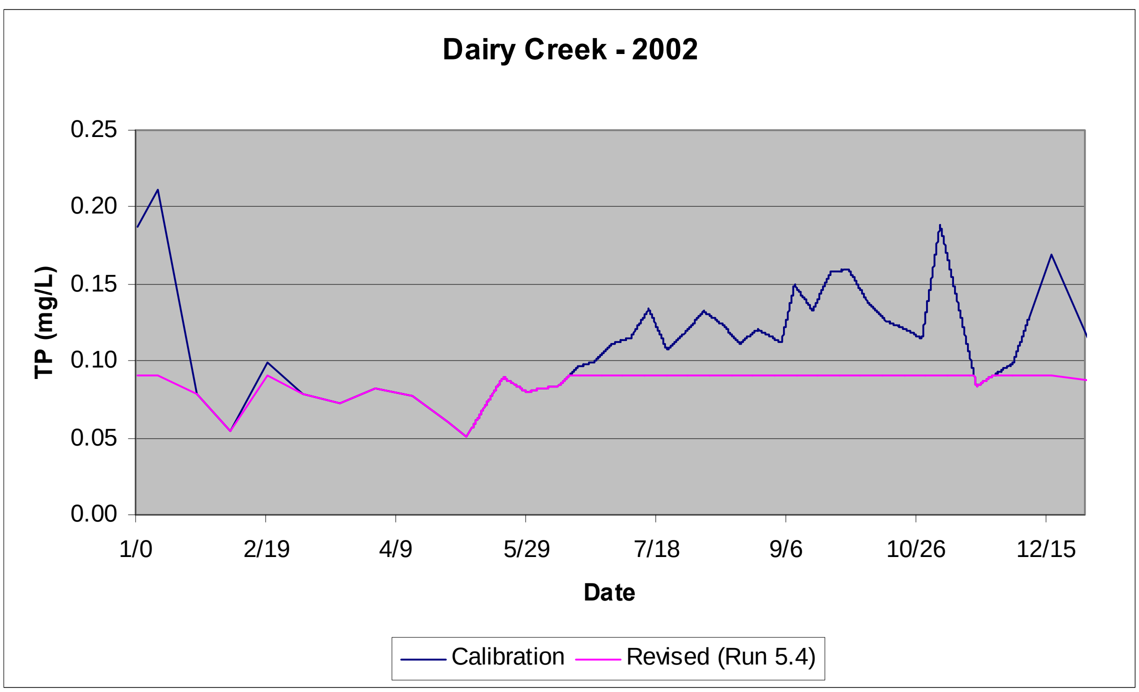


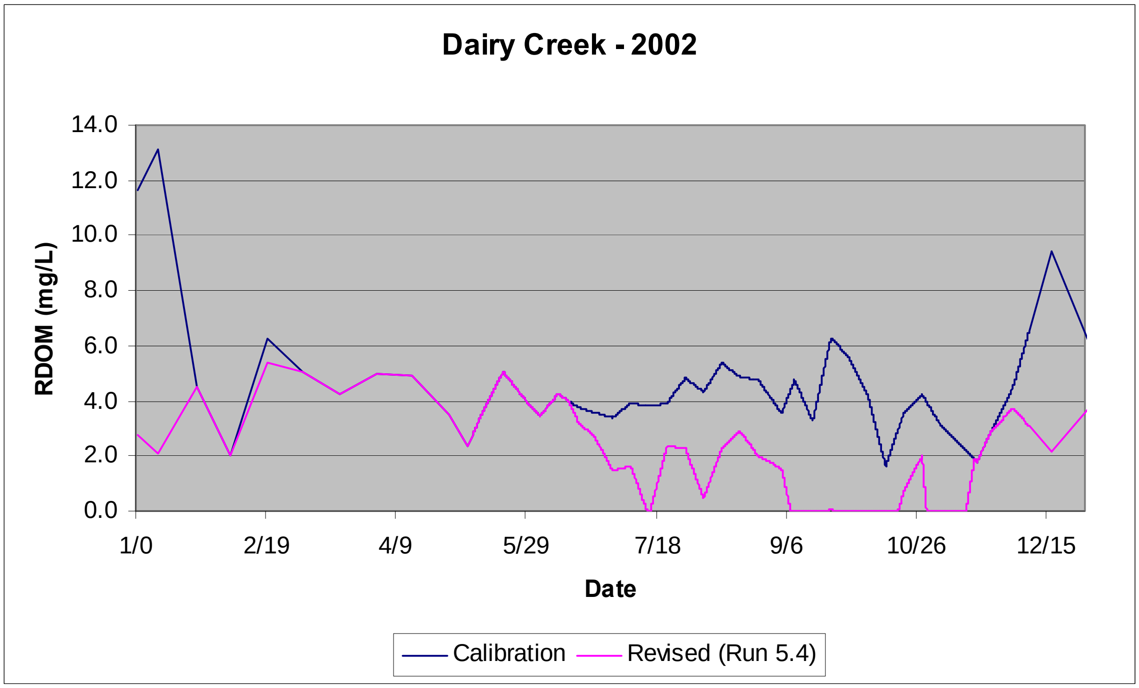

Gales Creek - 2002
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
RDOM (mg/L)
1/0
2/19
4/9
5/29
7/18
9/6
10/26
12/15
Date
Calibration
Revised (Run 5.4)

Dairy Creek

		Monthly Average					Median
		May	June	July	August	Sept	May-Sept
TP	(mg/L)	0.08	0.09	0.09	0.09	0.09	0.09
PO4	(mg/L)	0.03	0.05	0.07	0.07	0.09	0.07
RDOM	(mg/L)	4.15	3.26	1.47	1.93	0.27	2.09
Particulate-P, from RDOM (1.1%)	(mg/L)	0.05	0.04	0.02	0.02	0.00	0.02



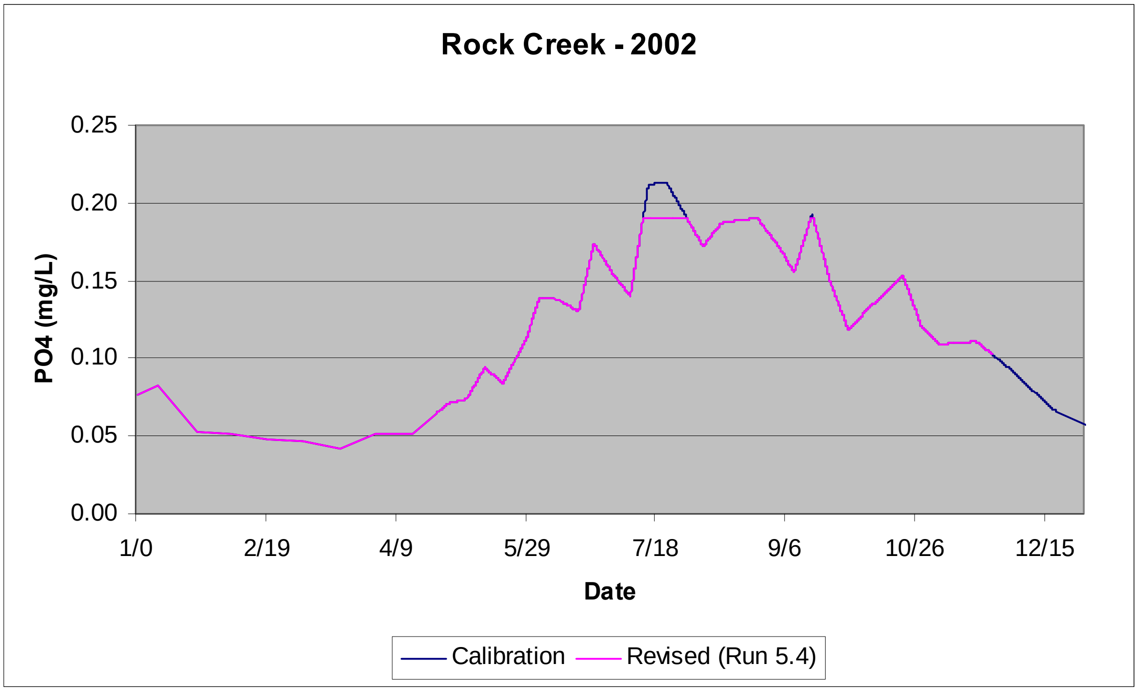


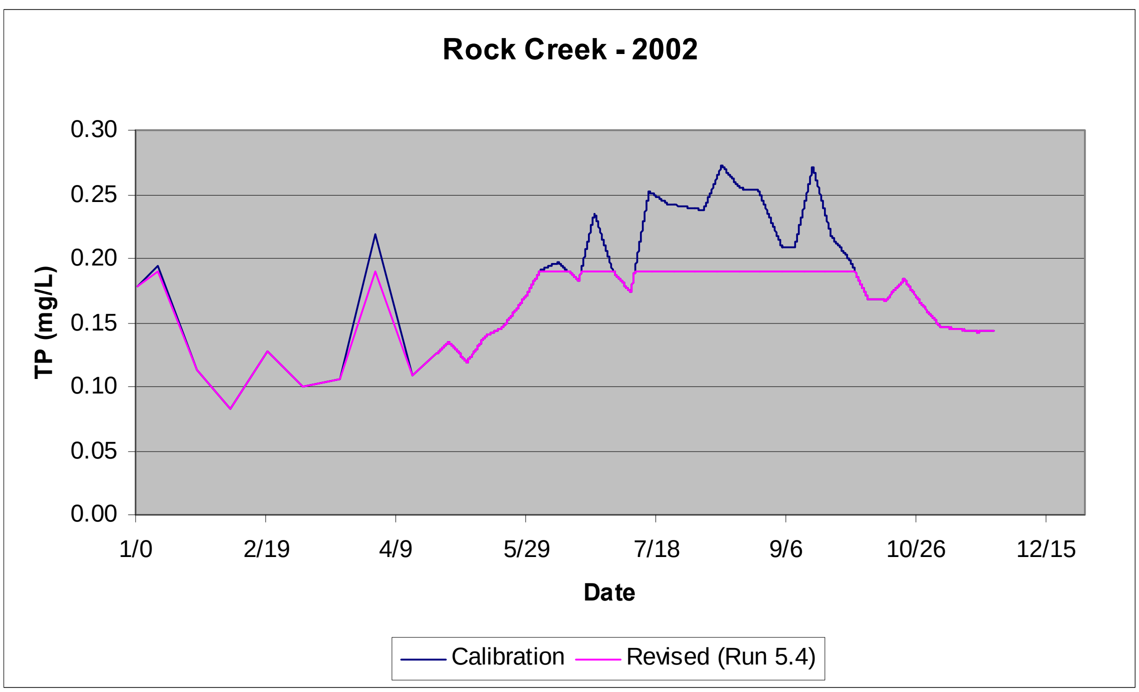


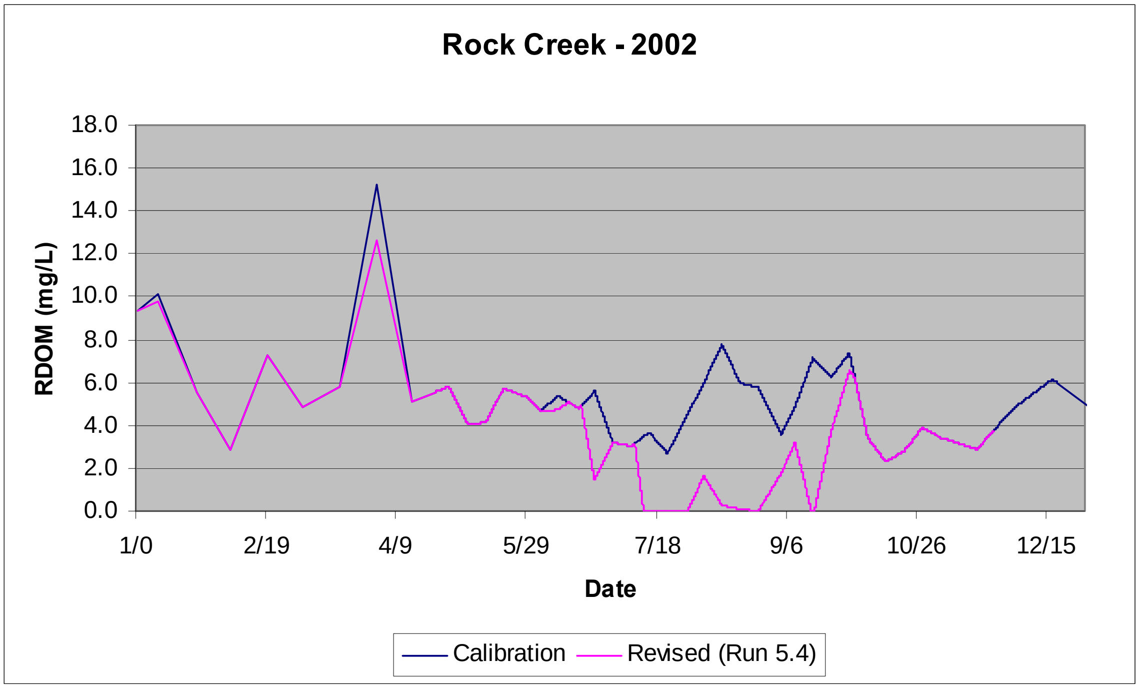
Dairy Creek - 2002
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
RDOM (mg/L)
1/0
2/19
4/9
5/29
7/18
9/6
10/26
12/15
Date
Calibration
Revised (Run 5.4)

Rock Creek

		Monthly Average					Median
		May	June	July	August	Sept	May-Sept
TP	(mg/L)	0.14	0.19	0.19	0.19	0.19	0.19
PO4	(mg/L)	0.09	0.15	0.18	0.18	0.16	0.16
RDOM	(mg/L)	4.90	3.97	1.08	0.52	2.68	2.64
Particulate-P, from RDOM (1.1%)	(mg/L)	0.05	0.04	0.01	0.01	0.03	0.03





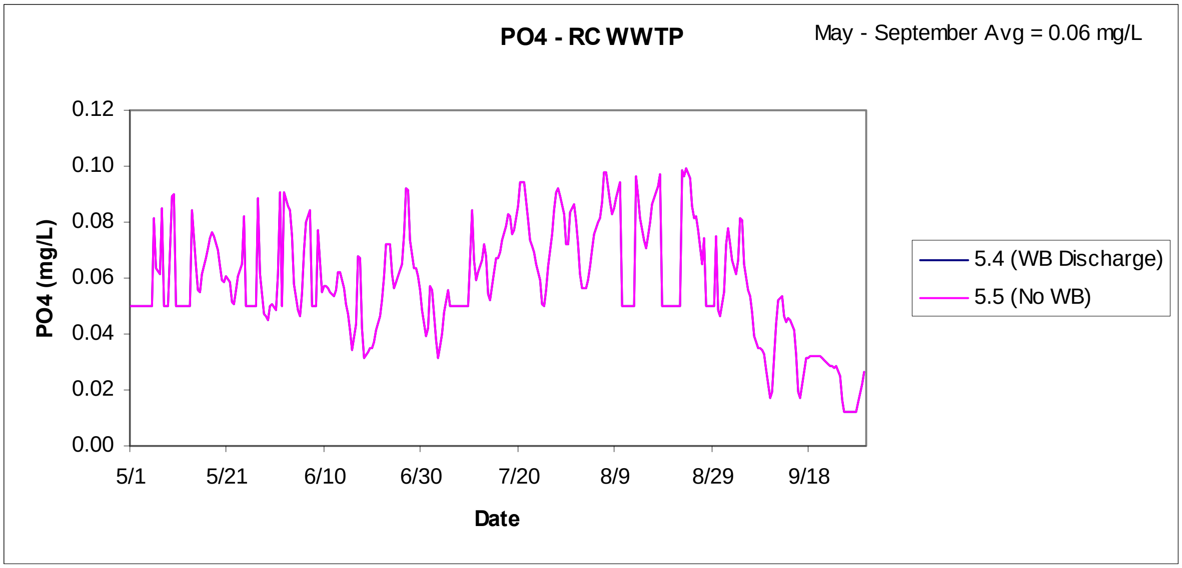

Rock Creek - 2002
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
RDOM (mg/L)
1/0
2/19
4/9
5/29
7/18
9/6
10/26
12/15
Date
Calibration
Revised (Run 5.4)

Appendix C

Charts of Model Inputs for Rock Creek AWWTF Effluent Quality

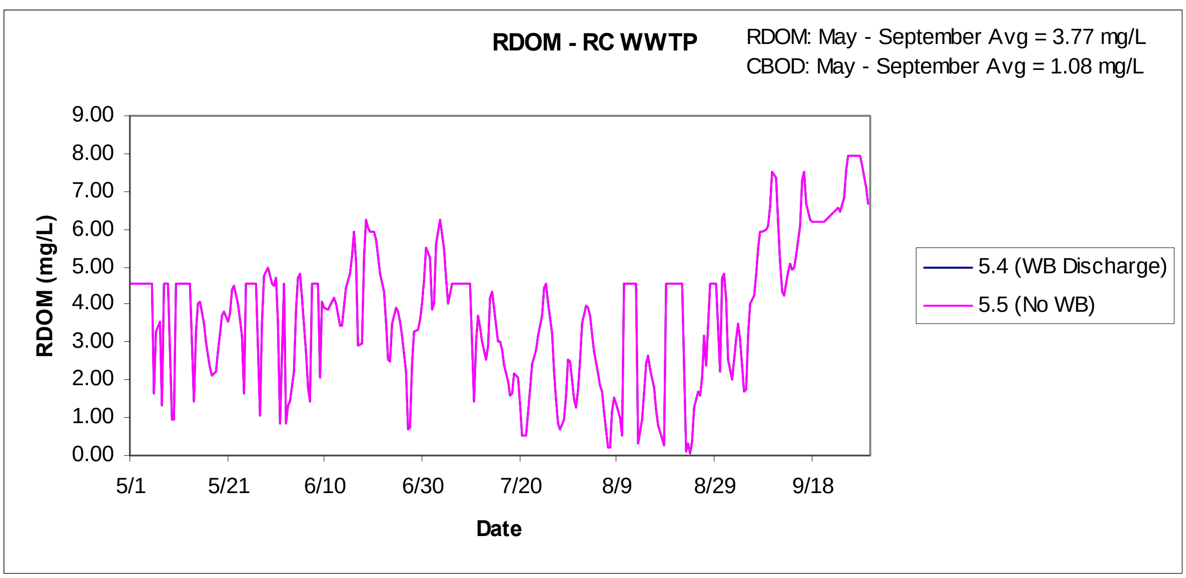
2002 ROCK CREEK EFFLUENT PHOSPHATE (AS P)

Run 5.4 has dry season discharges from Forest Grove and Hillsboro, Run 5.5 has no discharges from these WWTFs



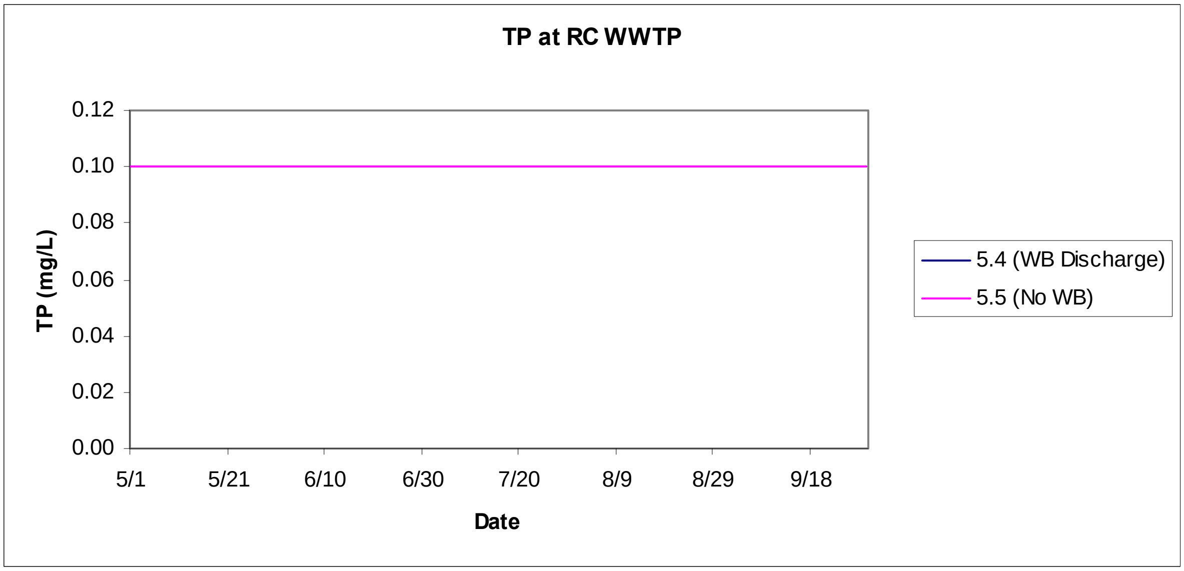
2002 ROCK CREEK EFFLUENT RDOM

Run 5.4 has dry season discharges from Forest Grove and Hillsboro, Run 5.5 has no discharges from these WWTFs



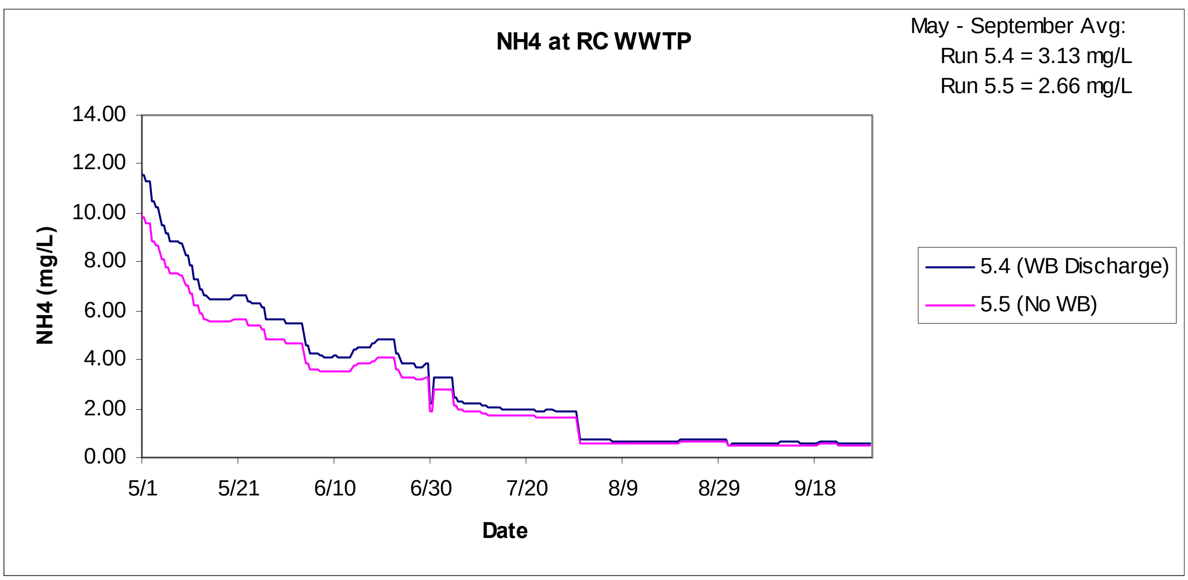
2002 ROCK CREEK EFFLUENT TOTAL PHOSPHORUS

Run 5.4 has dry season discharges from Forest Grove and Hillsboro, Run 5.5 has no discharges from these WWTFs



2002 ROCK CREEK EFFLUENT AMMONIA (AS N)

Run 5.4 has dry season discharges from Forest Grove and Hillsboro, Run 5.5 has no discharges from these WWTFs



Appendix D

USGS Calibration Letter

Appendix E

Detailed Mass Balance Model for TP (CD)

Appendix F

Running the TP Mass Balance Model

APPENDIX F

Running the TP Mass Balance Model

These directions are also included in the “ReadMe” worksheet (see CD in Appendix E).

The “Mass Balance Model” worksheet contains a control panel that is the only location requiring user input. Green cells in the control panel give the user a dropdown list of options from which to select. Yellow cells in the control panel are pre-programmed with formulas to either display observed values or prompt the user to provide defined values. Blue cells in the control panel allow the user to enter a specific flow or TP concentration to represent future scenarios. The user is required to provide the input described below.

- Year and Season - The user may select any single year from the dataset (2002 to 2007) or the entire 6 year range. As of October 2009, the annual data set has not been calibrated so the only option is to run the model to estimate the May through October TMDL season.
- Wastewater Treatment Plants - The user specifies the type of data they want to use for the three WWTPs (Forest Grove, Hillsboro, and Rock Creek). If the user selects "Observed" as the data type, the observed (measured) values will display. If the user selects "Defined," they will be prompted to enter the desired effluent flow and TP concentration for that WWTP.
- Tributaries - The user specifies the type of data they want to use for the three largest tributaries (Gales Creek, Dairy Creek, and Rock Creek). If the user selects "Observed" as the data type, the observed (measured) values will display. If the user selects "TMDL LA," the TP load allocations from the Tualatin Subbasin Total Maximum Daily Load (ODEQ, 2001) will be displayed and entered into the mass balance.
- Reservoir Augmentation Flows - The user specifies if District augmentation flows are being released from each reservoir (“On”), and the flows will be listed in the cell to the right. The user may also determine the downstream benefits from these flows by electing to stop the release of these flows (“Off”), or by adding more flows to the existing augmentation flows (“On” and input into “Additional Flow” column). Note that these flows only represent District augmentation flows and do not represent requests from other constituencies for water (which are already accounted for in the model).

When the user completes the required inputs in the control panel, an orange cell near the top of the page presents the modeled TP concentration at Farmington. The chart below the Farmington result displays TP concentration and load in the Tualatin River from Gaston to Farmington.

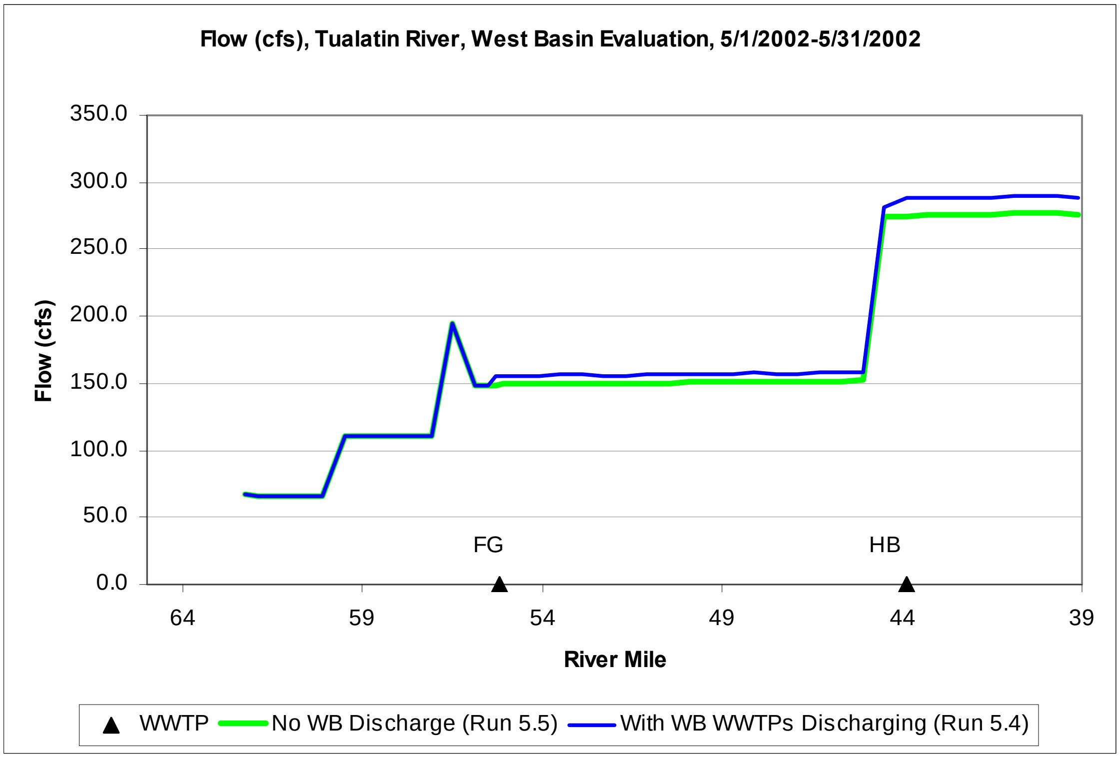
Other unnumbered worksheets in the model contain data from the Tualatin River inflows (Scoggins Creek, Gales Creek, Forest Grove WWTP, Dairy Creek, Hillsboro WWTP, Rock Creek, Rock Creek WWTP, Gordon Creek, Butternut Creek, and smaller unnamed tributaries), withdrawals (Wapato Canal, JWC/Springhill Pump Plant, and smaller unnamed irrigation withdrawals), and river gages (Gaston, Springhill/Dilley, Golf Course, Highway 219, Rood Bridge, and Farmington). These worksheets are programmed to respond to user-provided conditions in control panel and should not be adjusted.

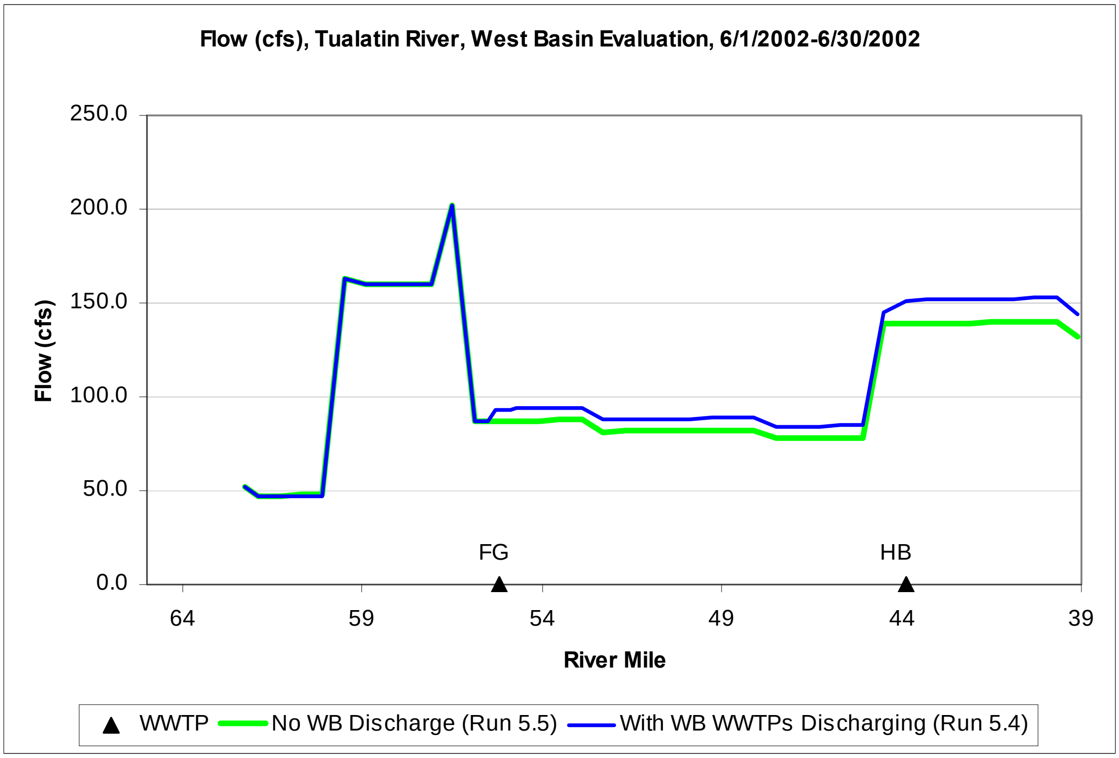
Appendix G

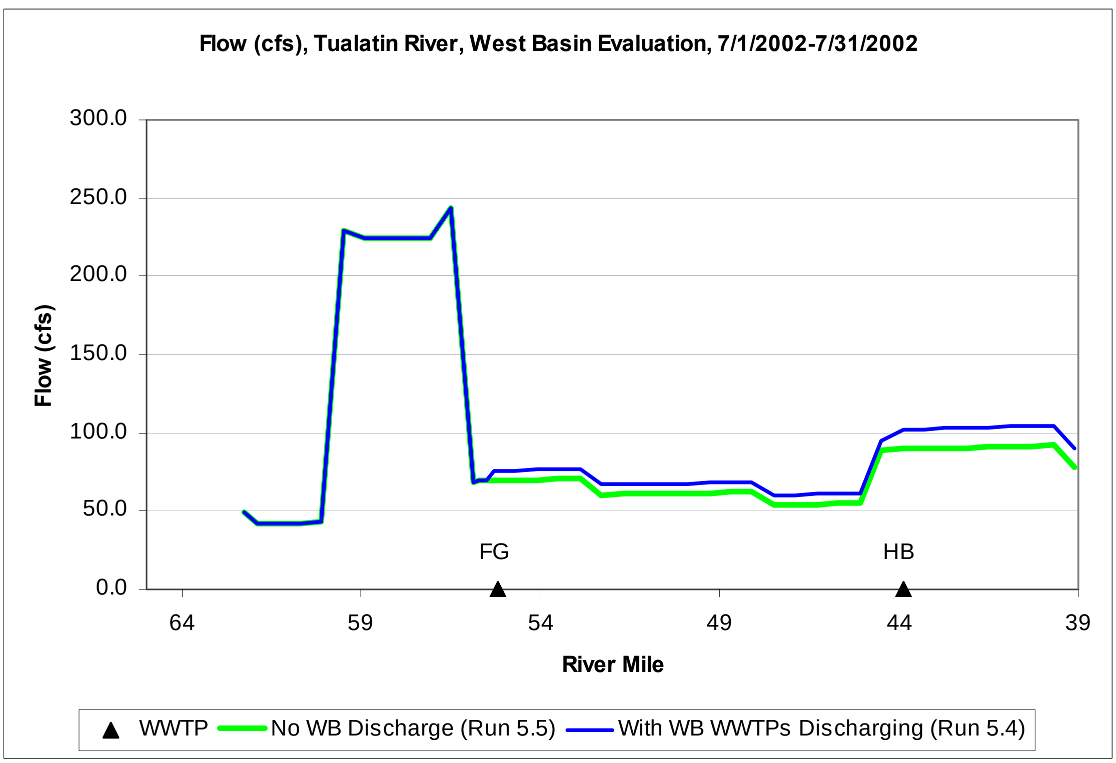
Charts of CE-QUAL-W2 Modeling Results

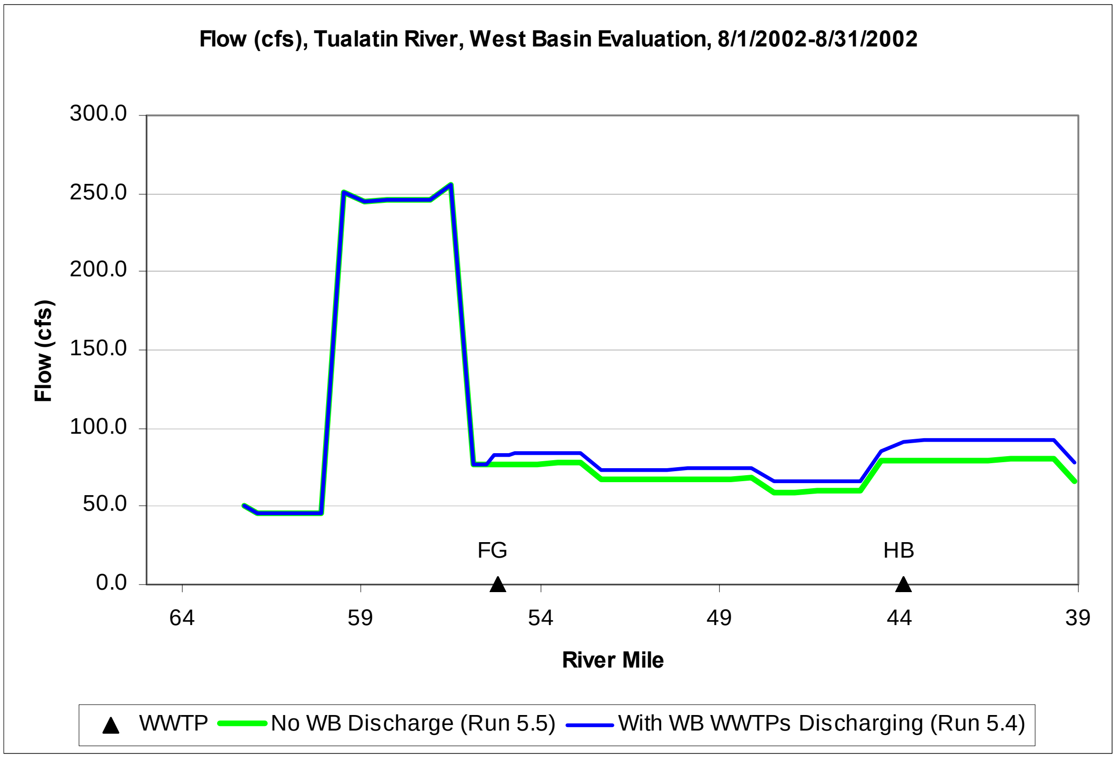
West Basin Discharge (Run 5.4) vs. No Discharge (Run 5.5) Comparison

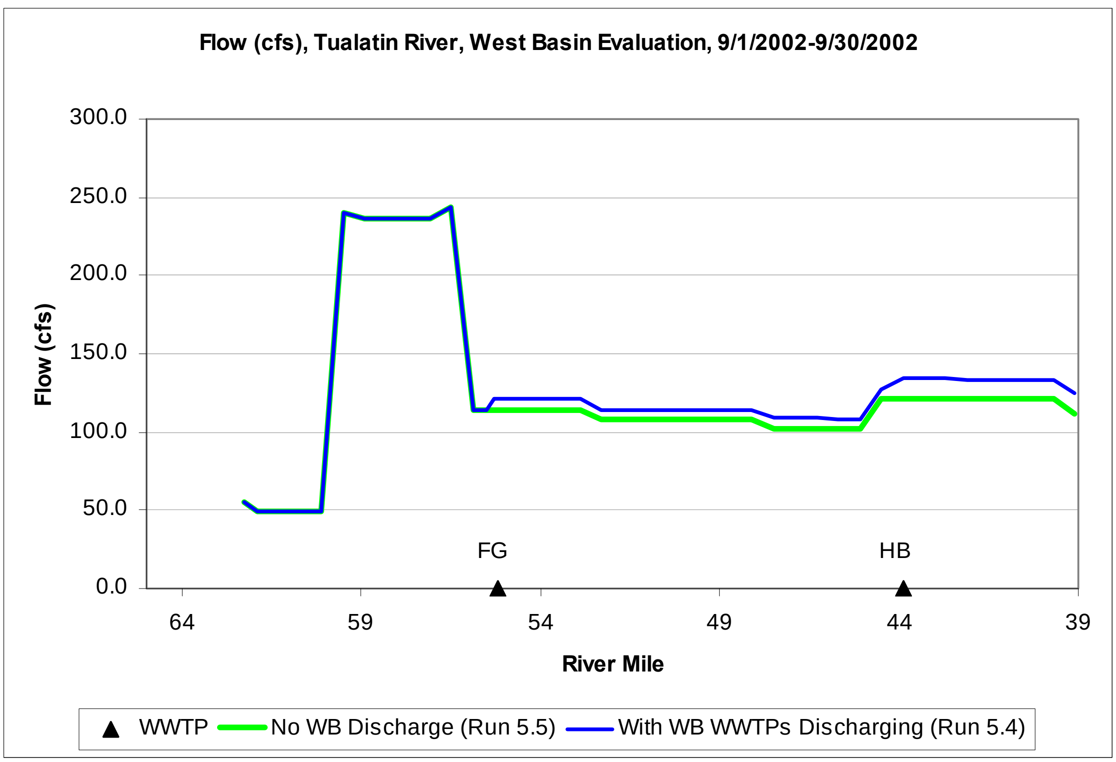
Longitudinal – Flow



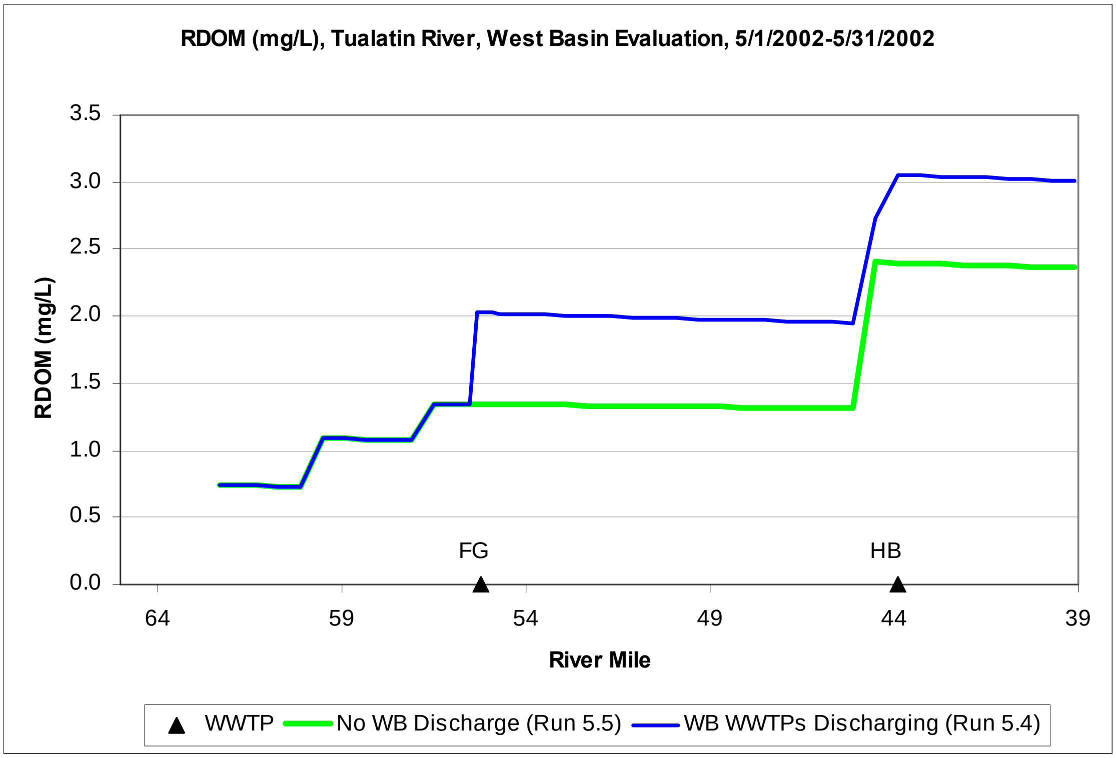

Flow (cfs), Tualatin River, West Basin Evaluation, 6/1/2002-6/30/2002
Flow (cfs)
250.0
200.0
150.0
100.0
50.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
With WB WWTPs Discharging (Run 5.4)

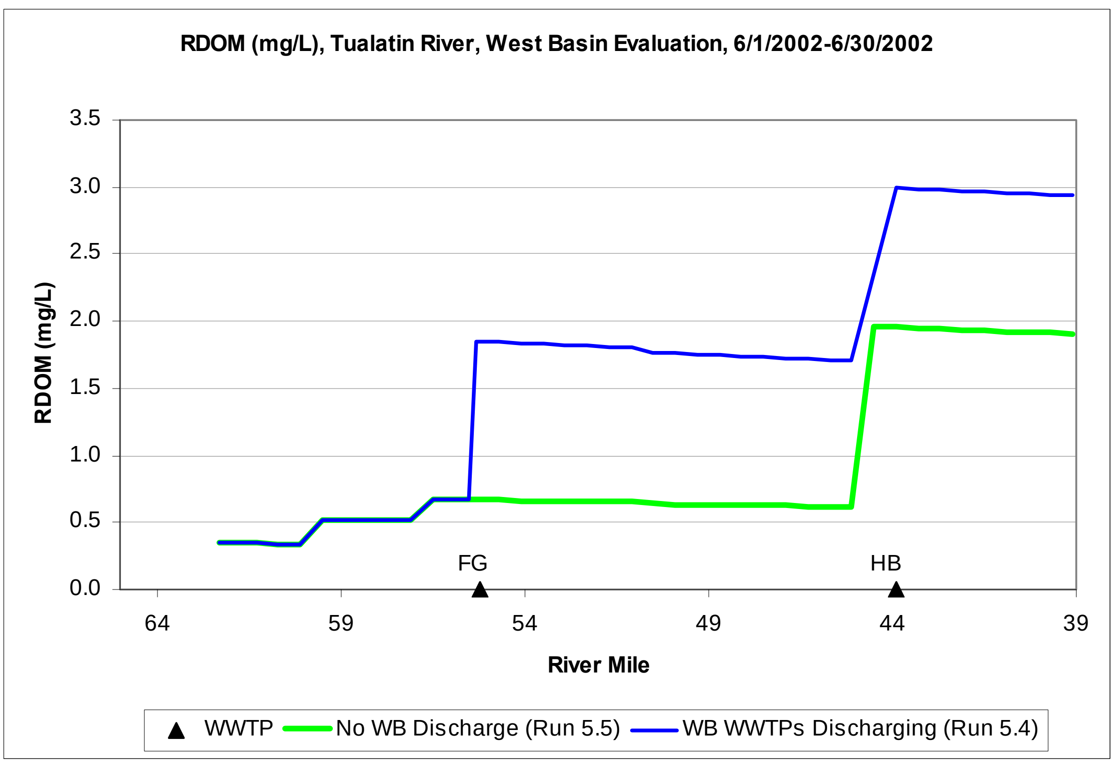

Flow (cfs), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Flow (cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
With WB WWTPs Discharging (Run 5.4)

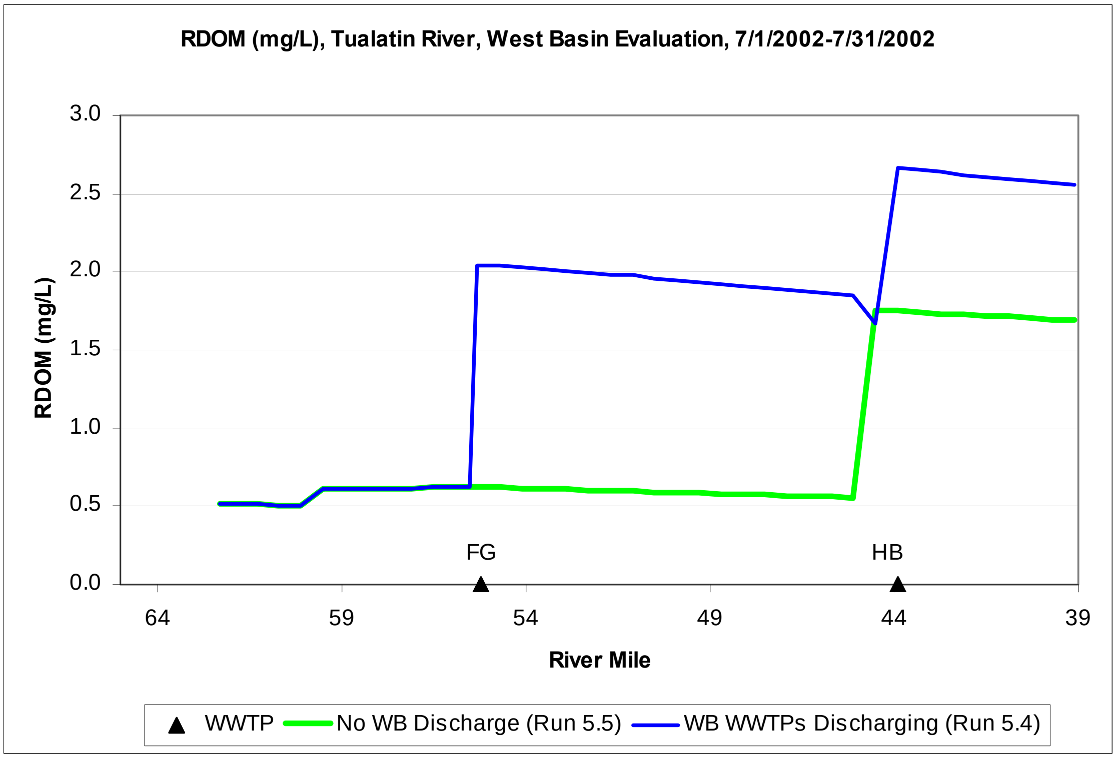

Flow (cfs), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Flow (cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
With WB WWTPs Discharging (Run 5.4)

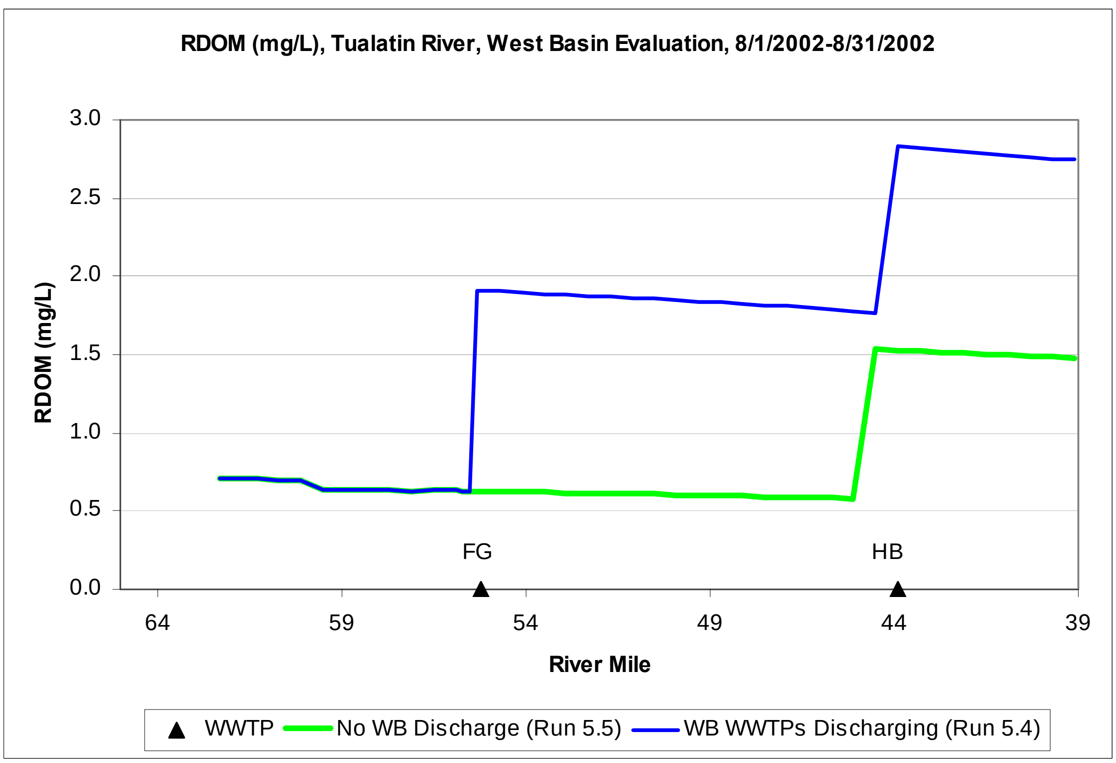

Flow (cfs), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Flow (cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
With WB WWTPs Discharging (Run 5.4)

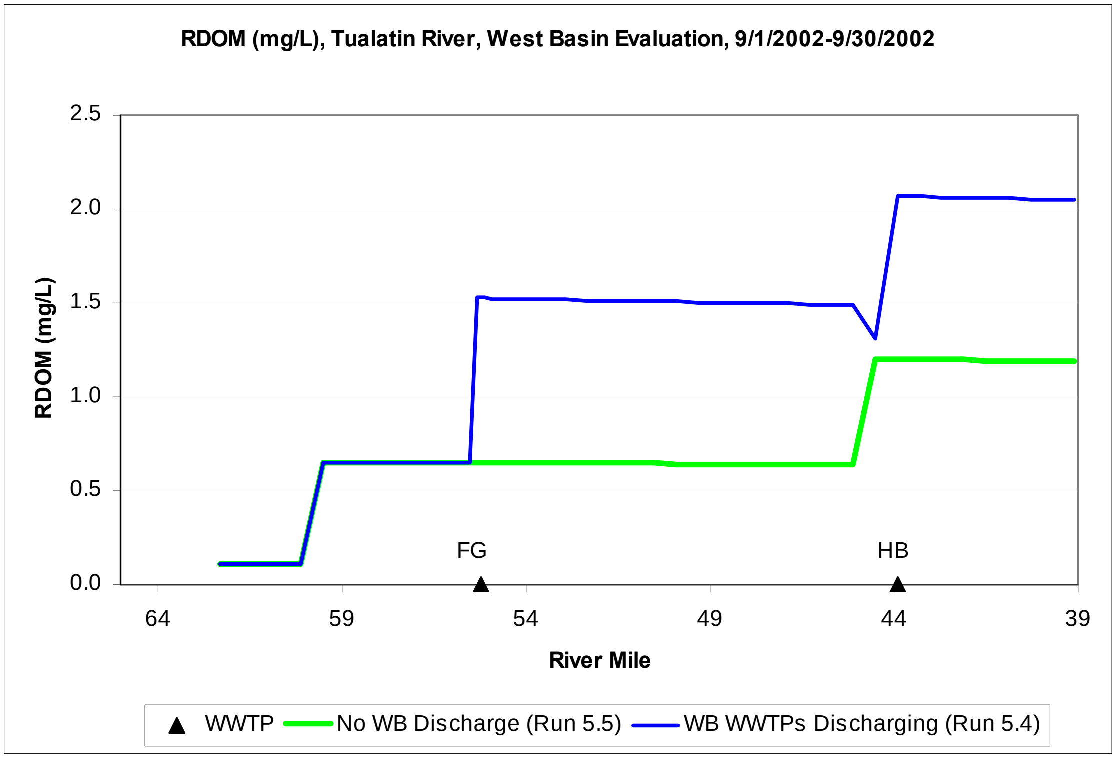
Longitudinal – RDOM



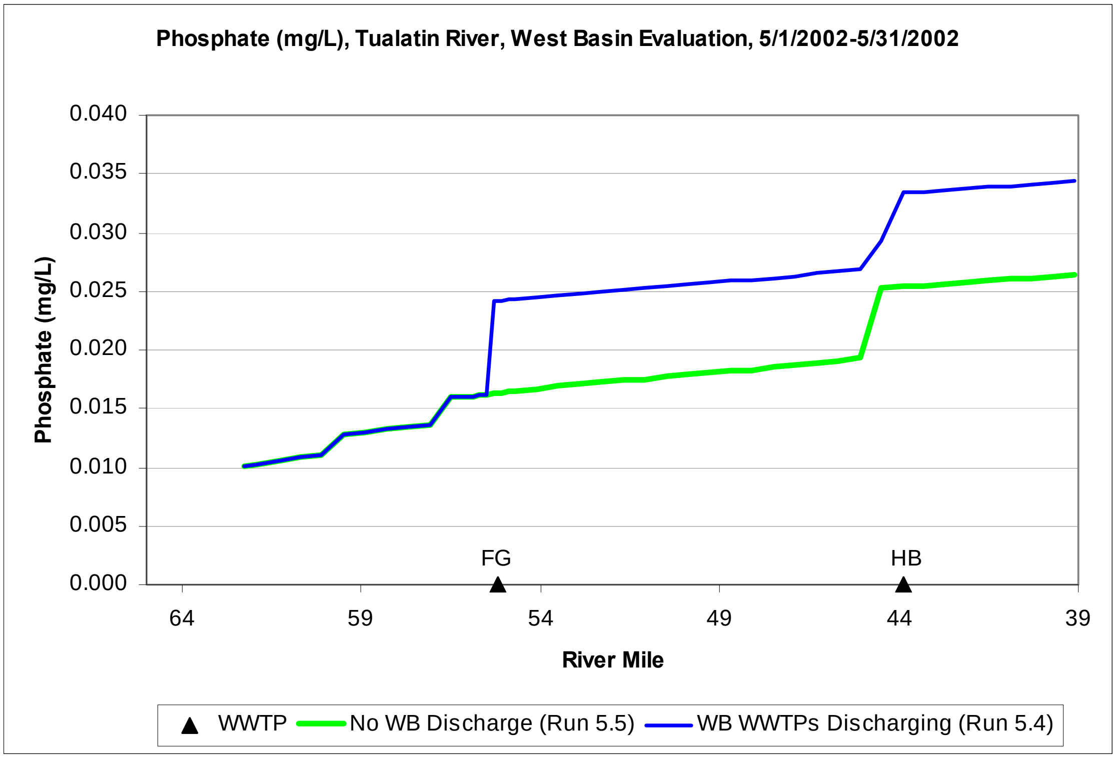


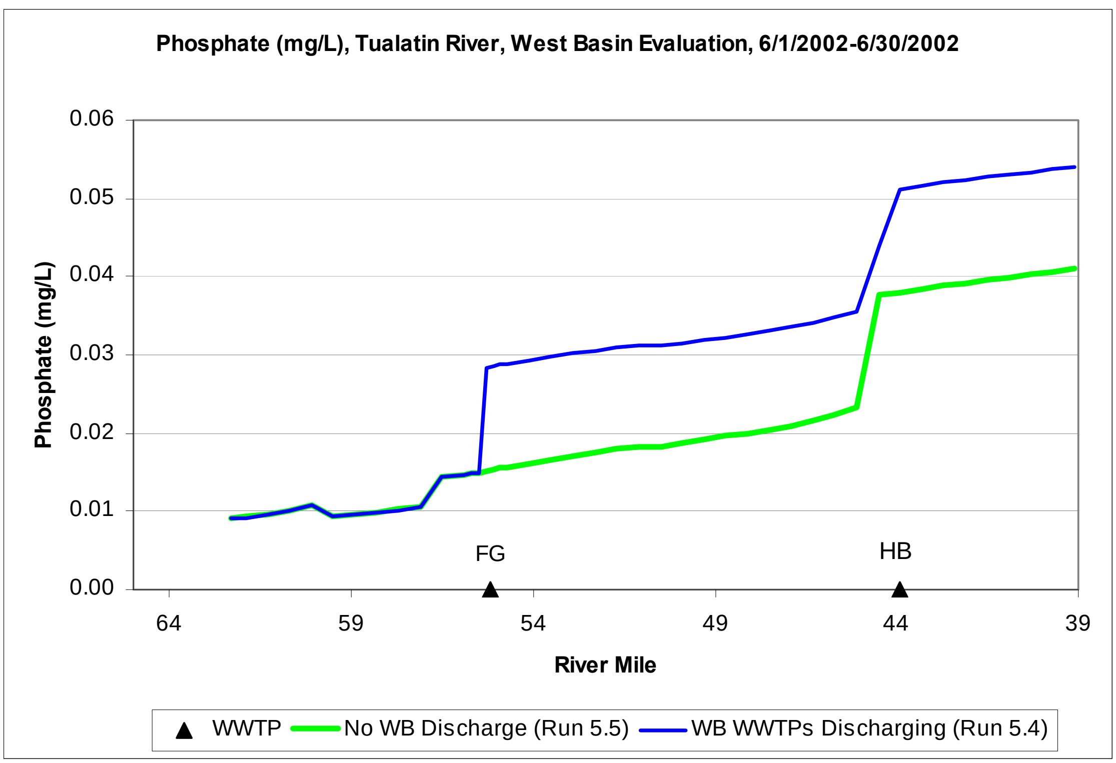

RDOM (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
RDOM (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

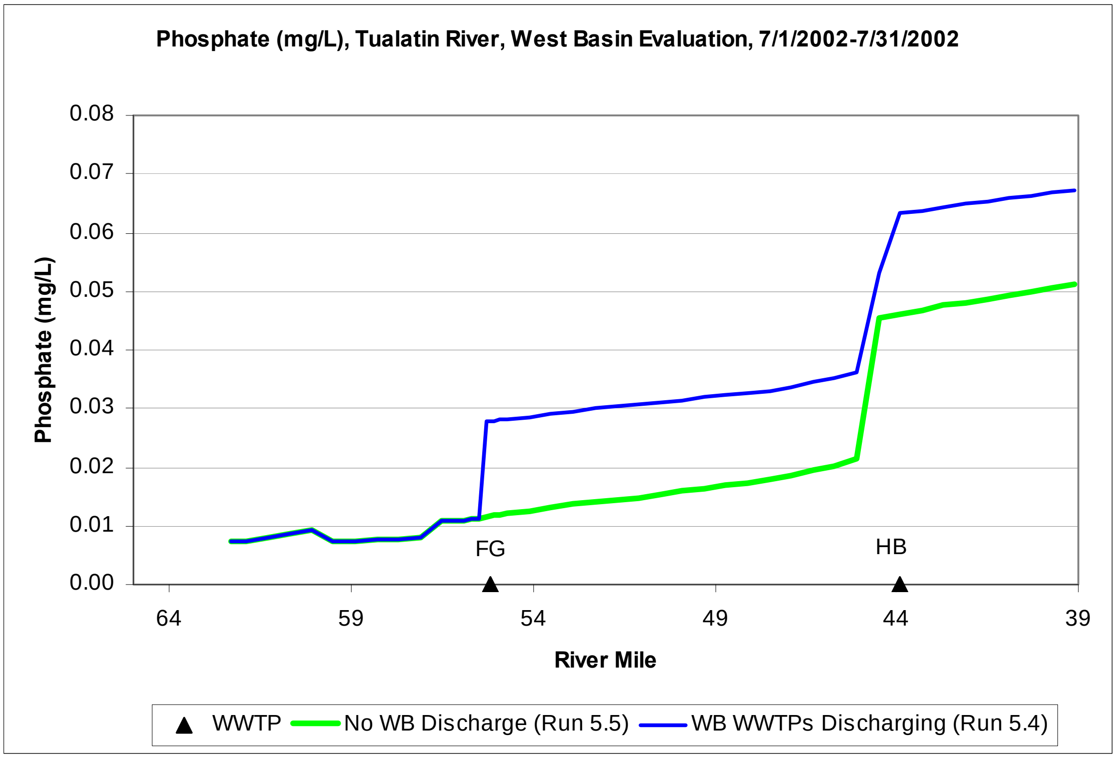

RDOM (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
RDOM (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

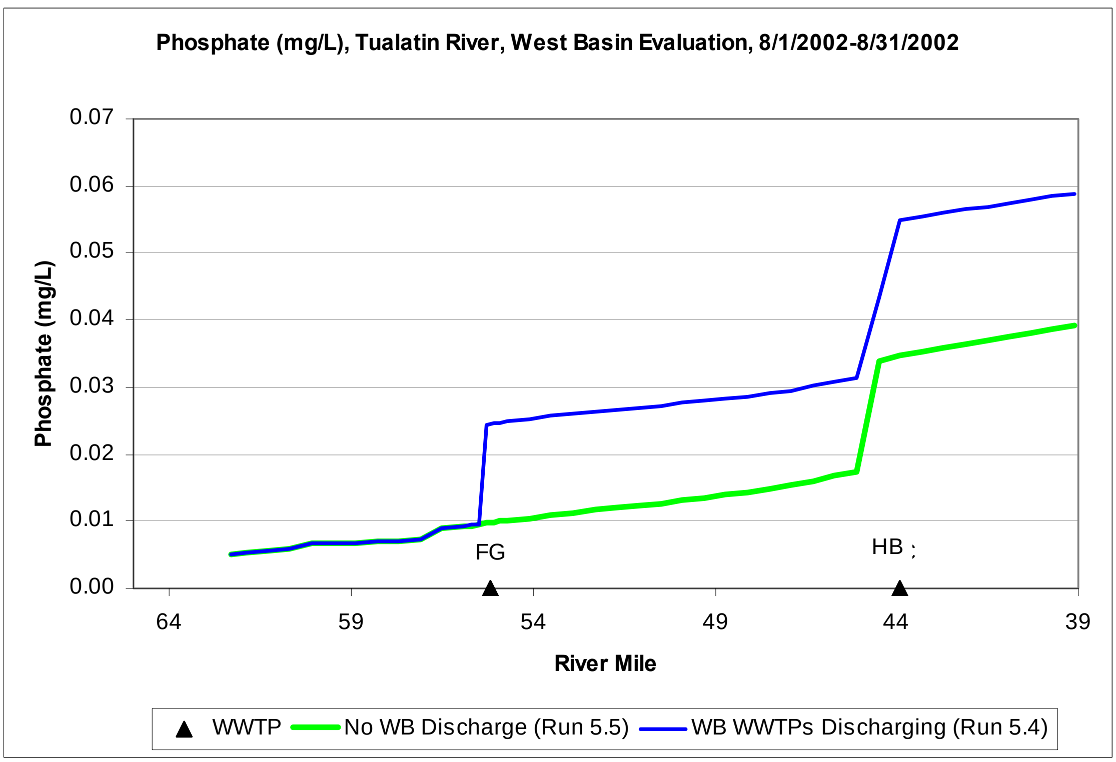

RDOM (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
RDOM (mg/L)
2.5
2.0
1.5
1.0
0.5
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

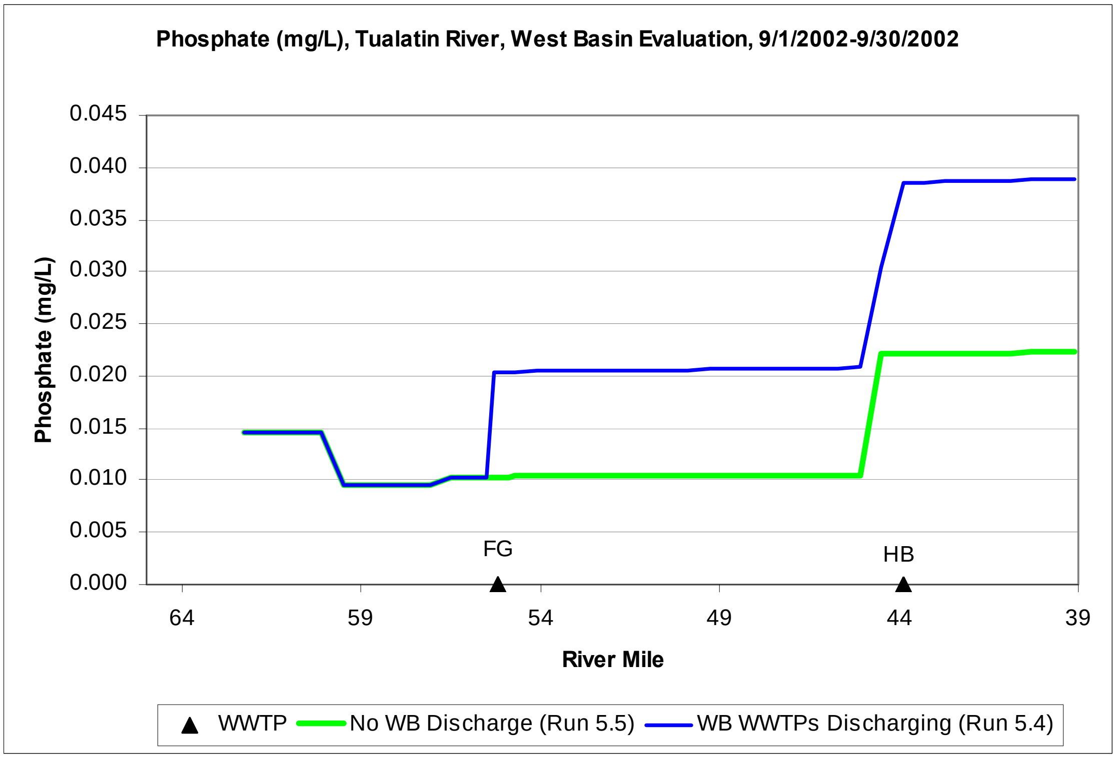
Longitudinal – Phosphate (PO_4 as P)



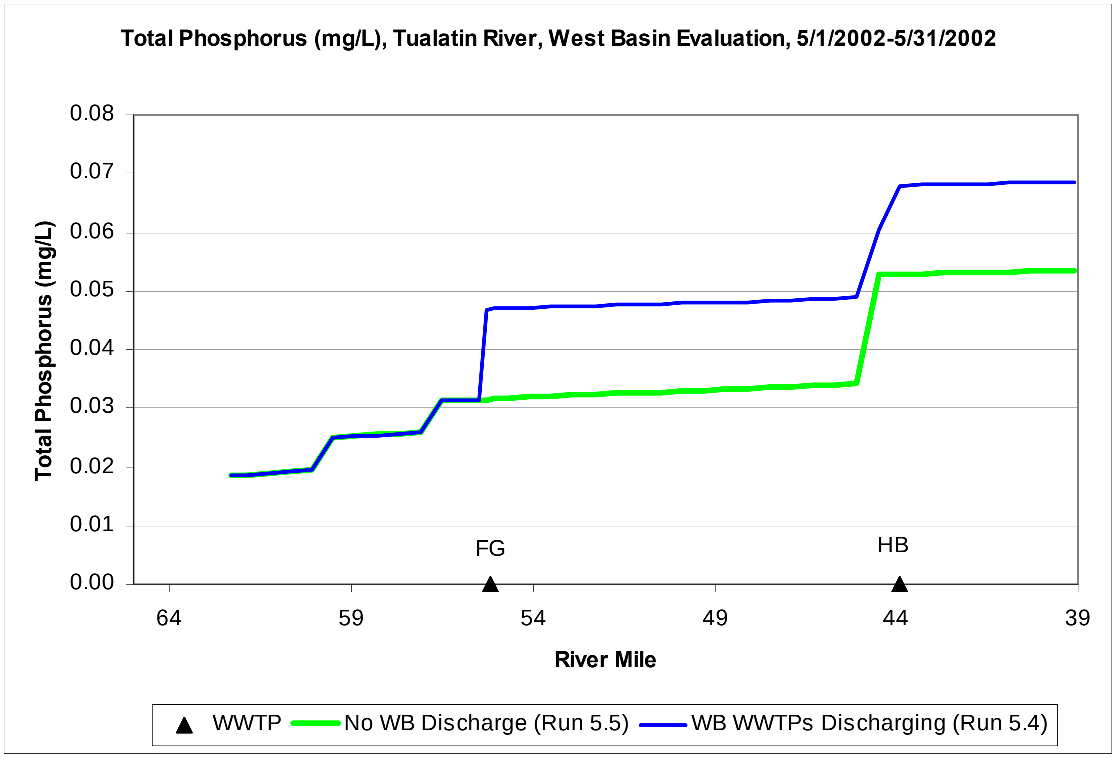


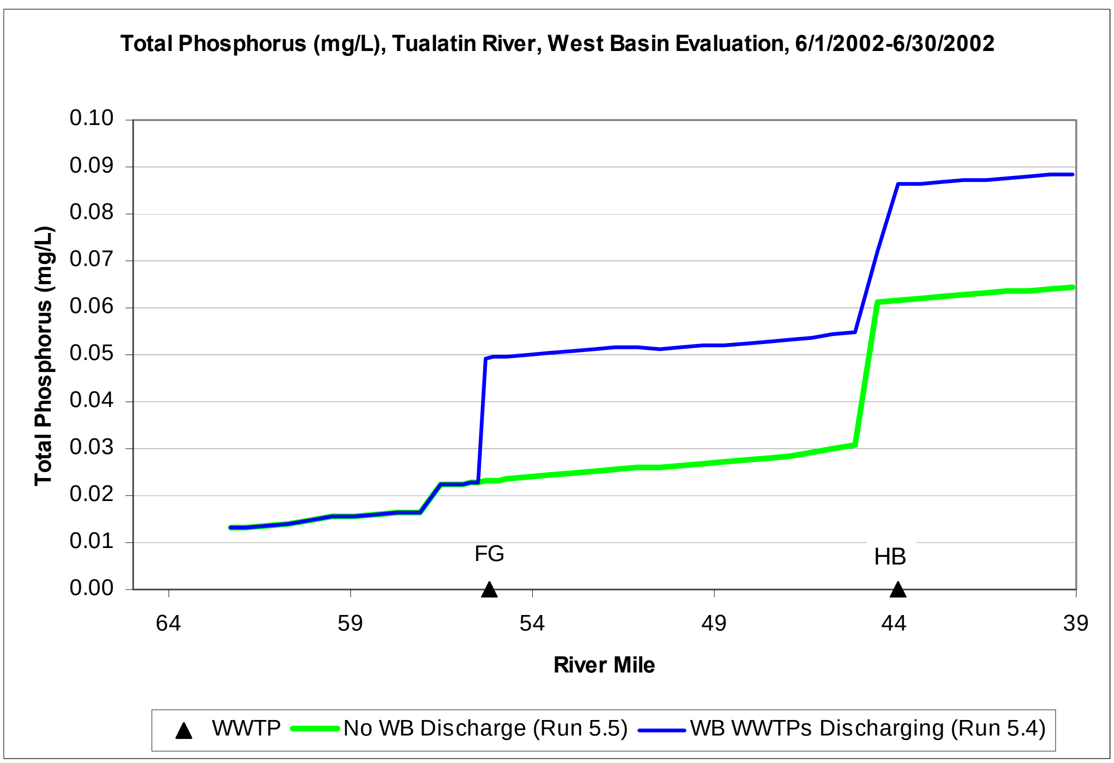

Phosphate (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Phosphate (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

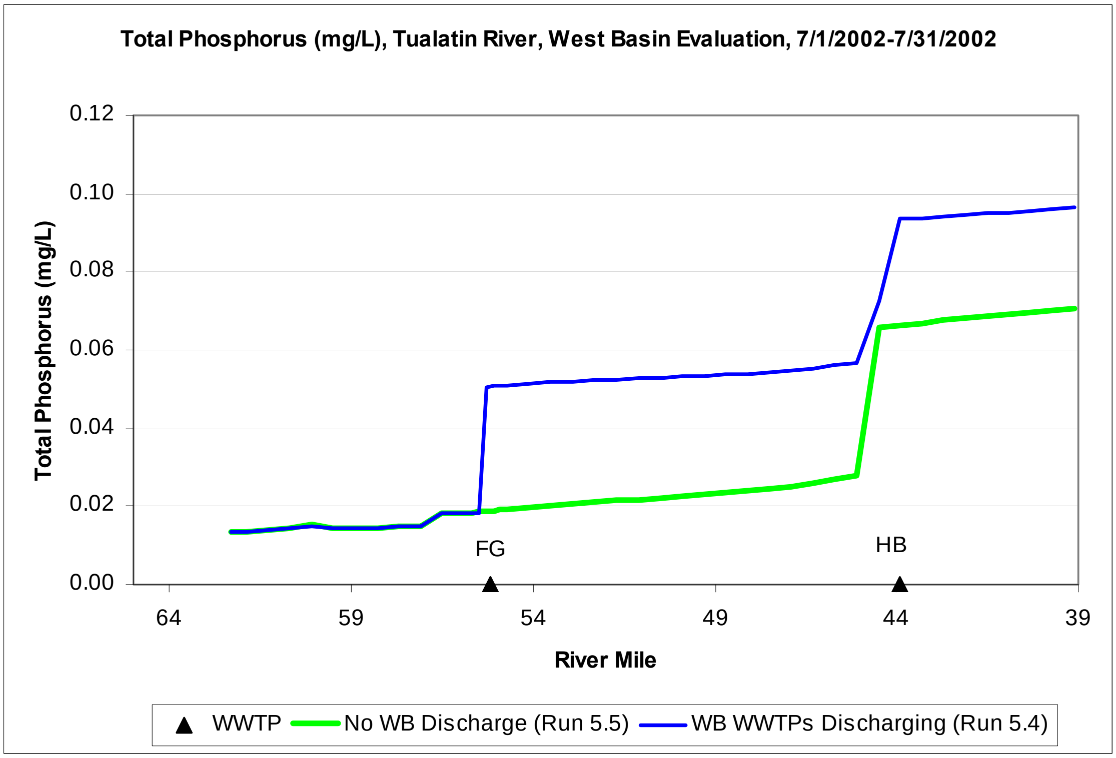

Phosphate (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Phosphate (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

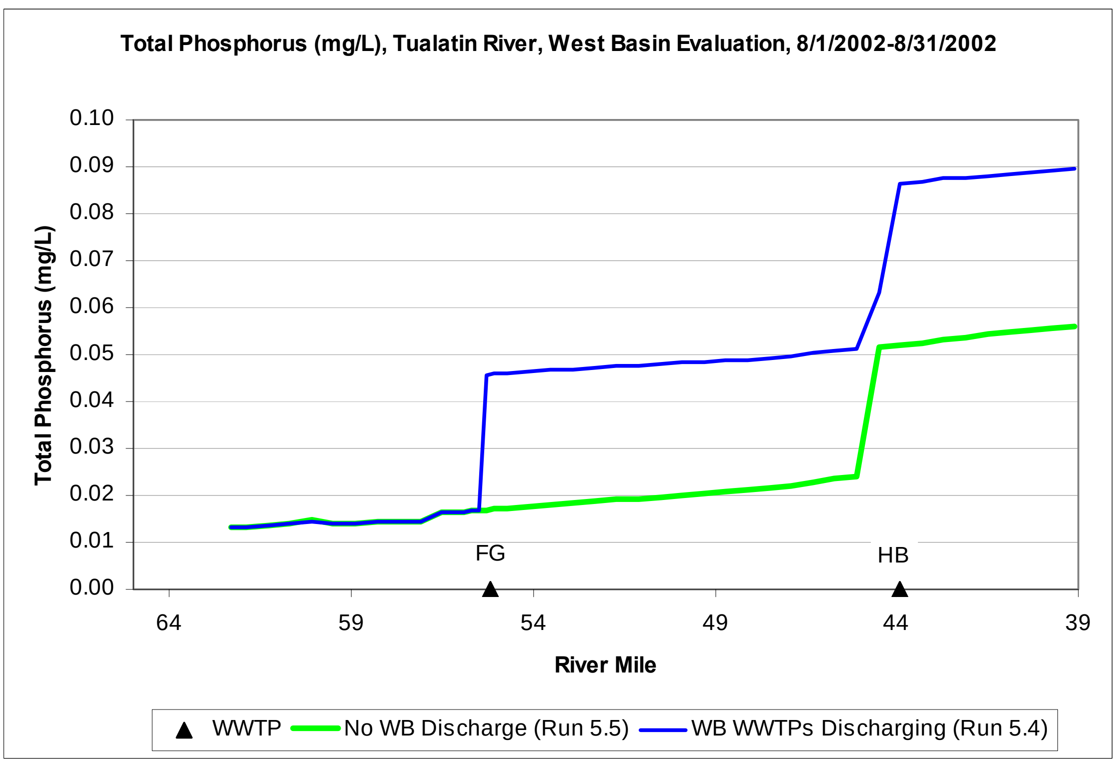

Phosphate (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Phosphate (mg/L)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

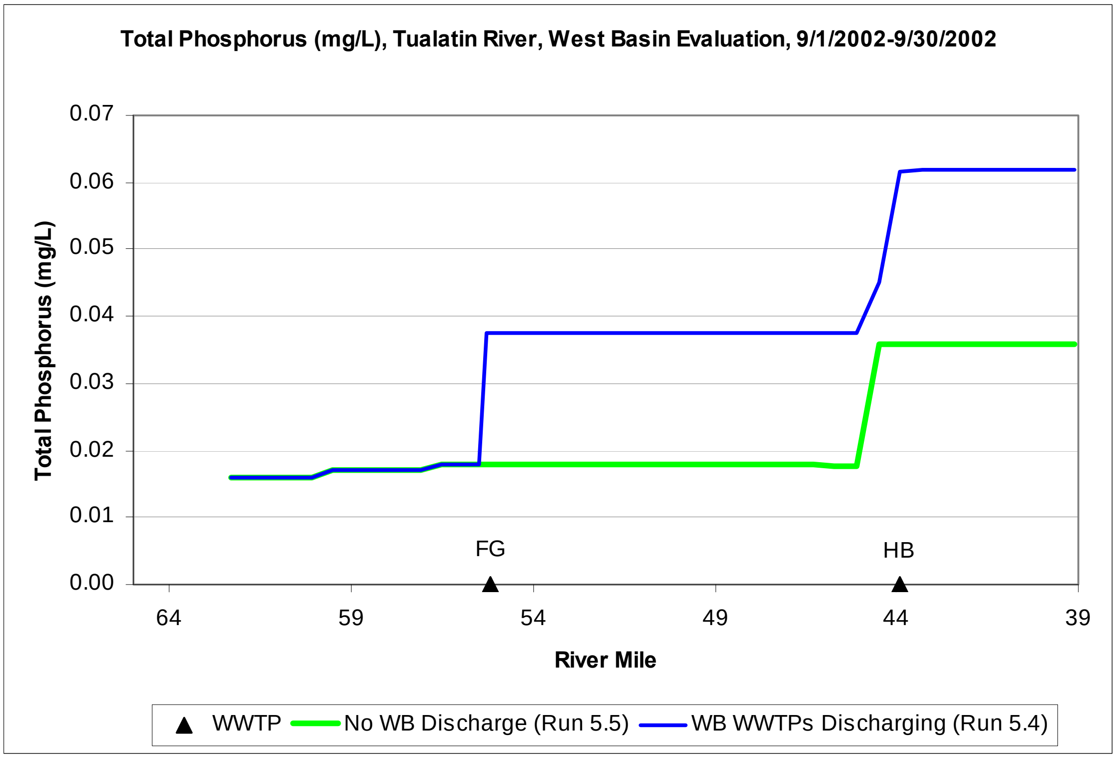
Longitudinal – Total Phosphorus





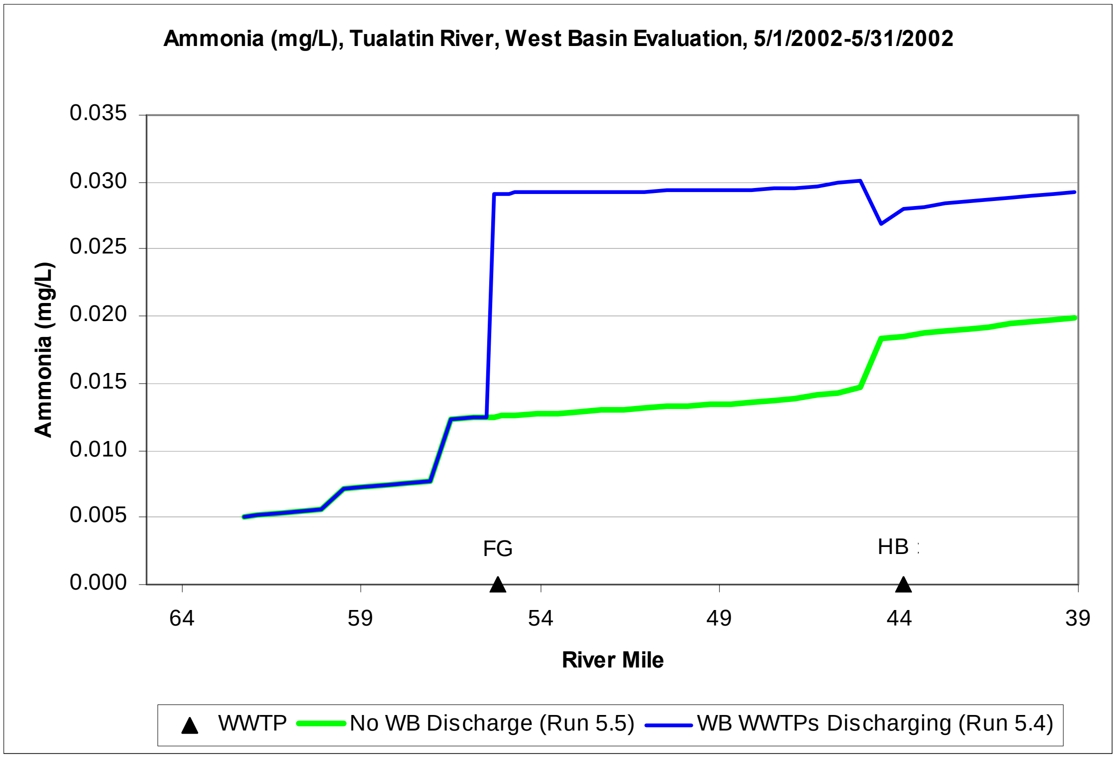

Total Phosphorus (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Total Phosphorus (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

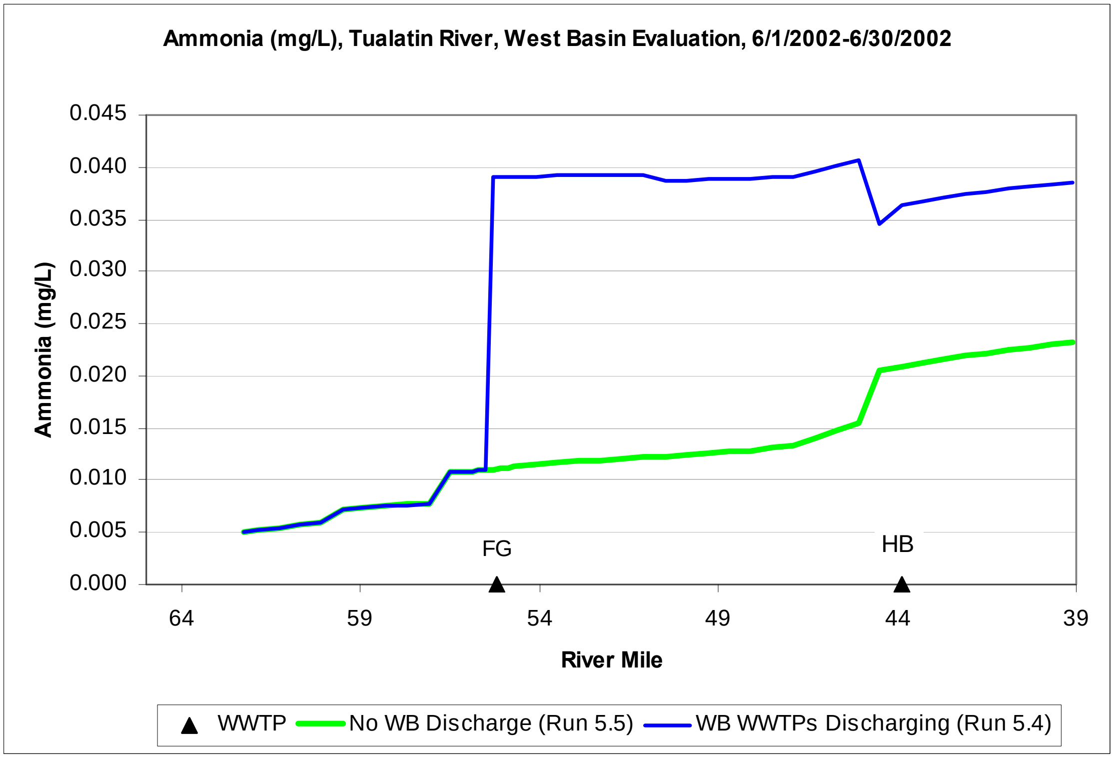

Total Phosphorus (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Total Phosphorus (mg/L)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

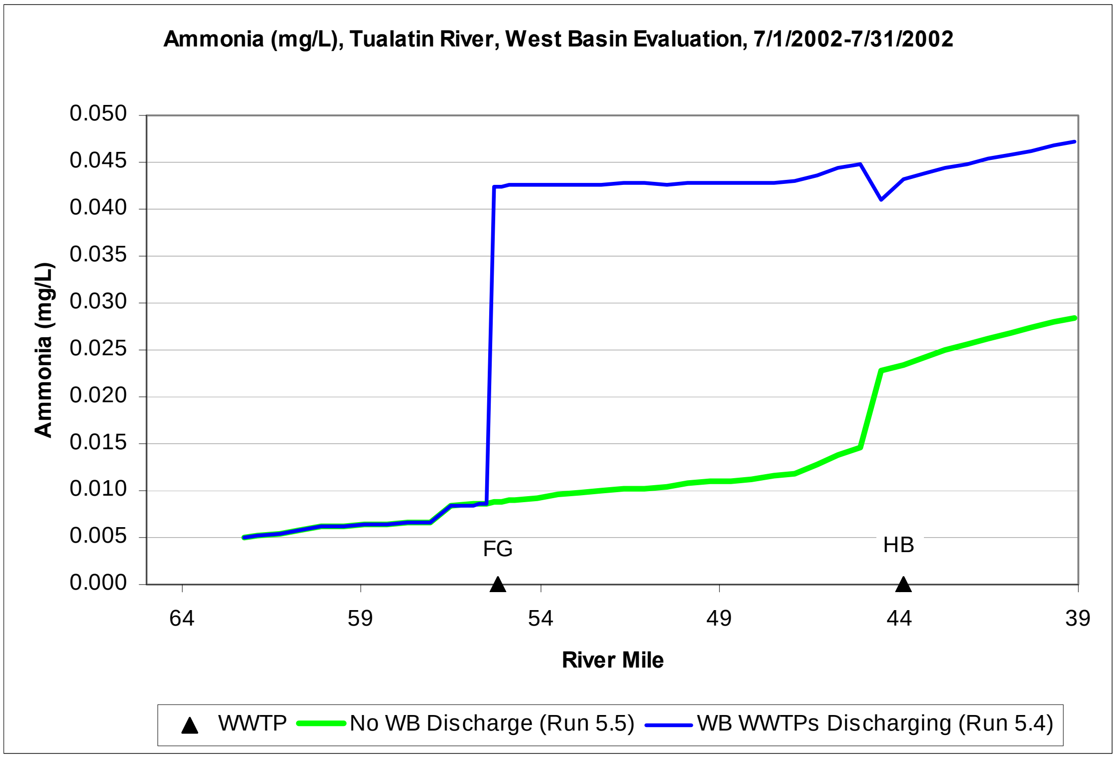


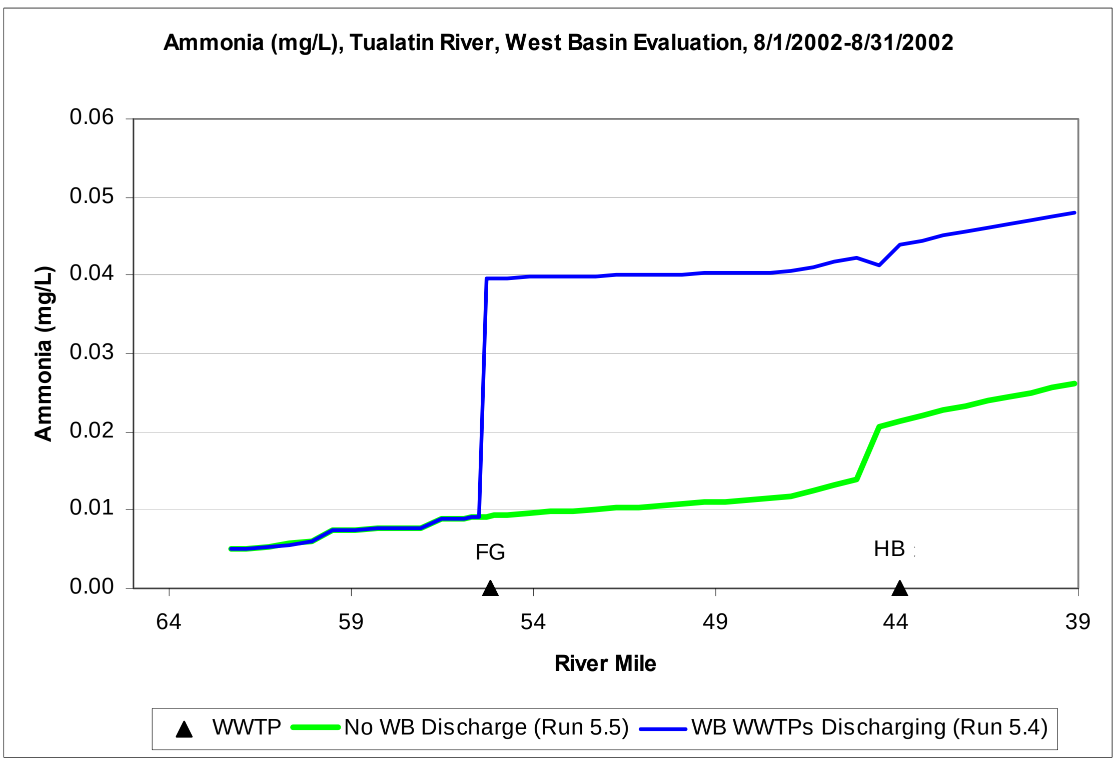
Total Phosphorus (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Total Phosphorus (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

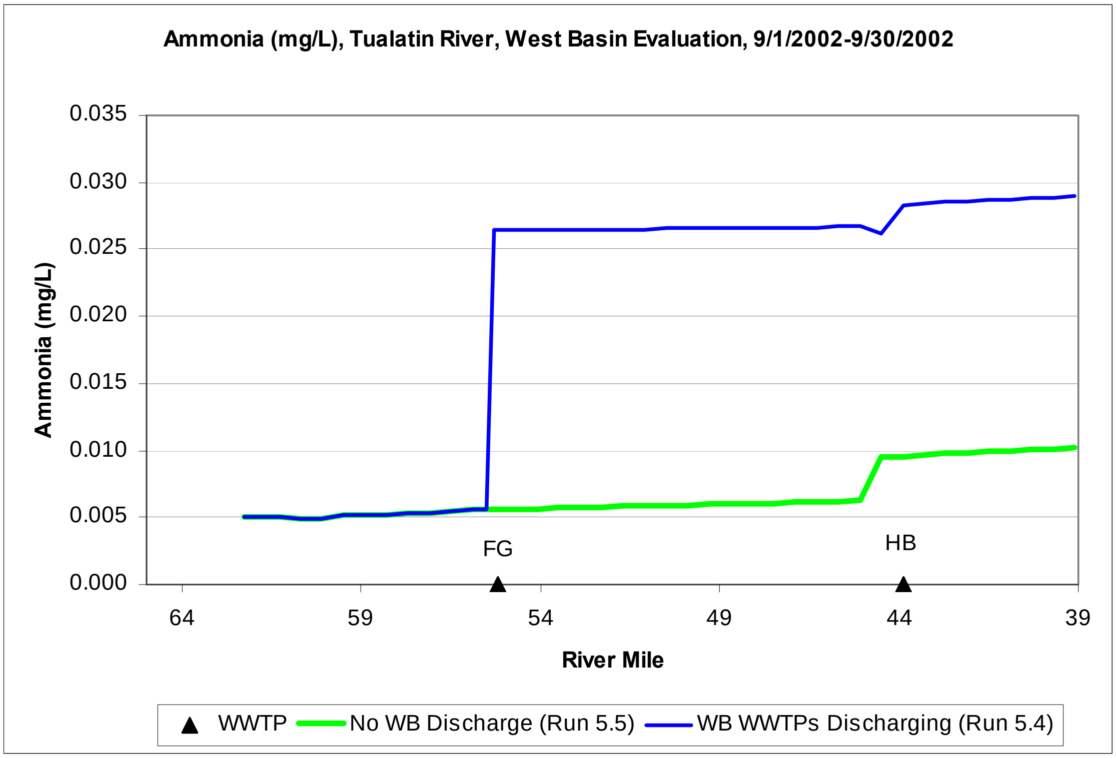
Longitudinal – Ammonia (NH_4 as N)



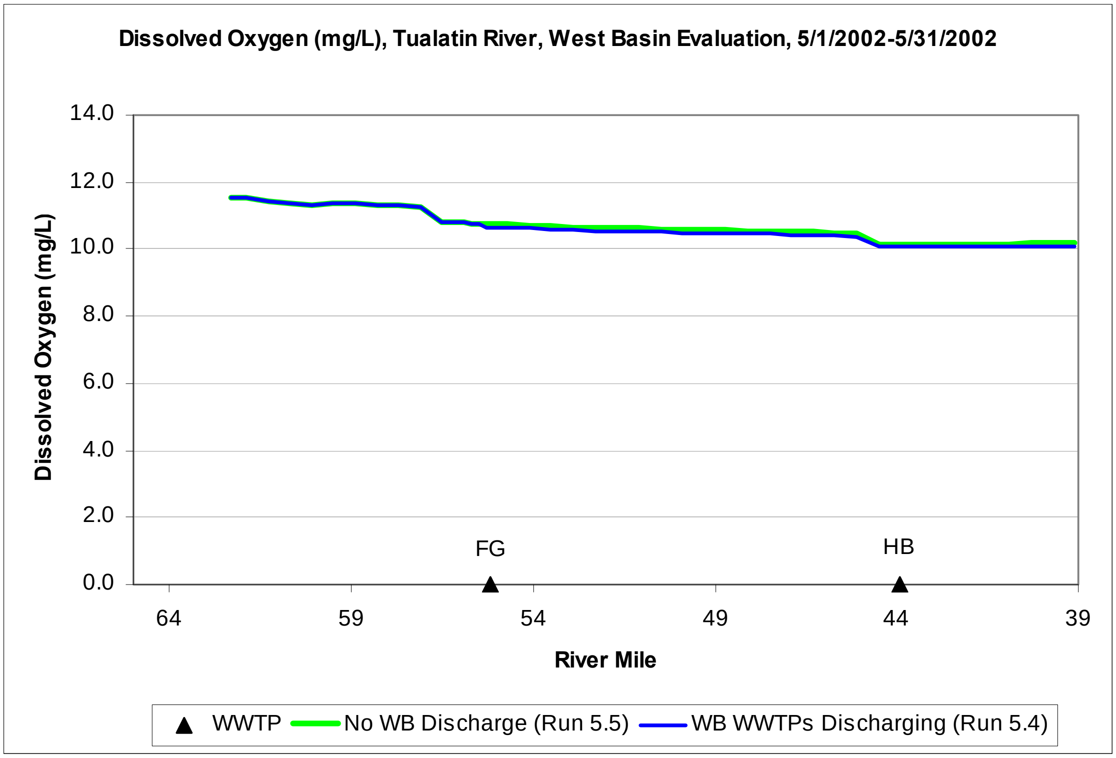


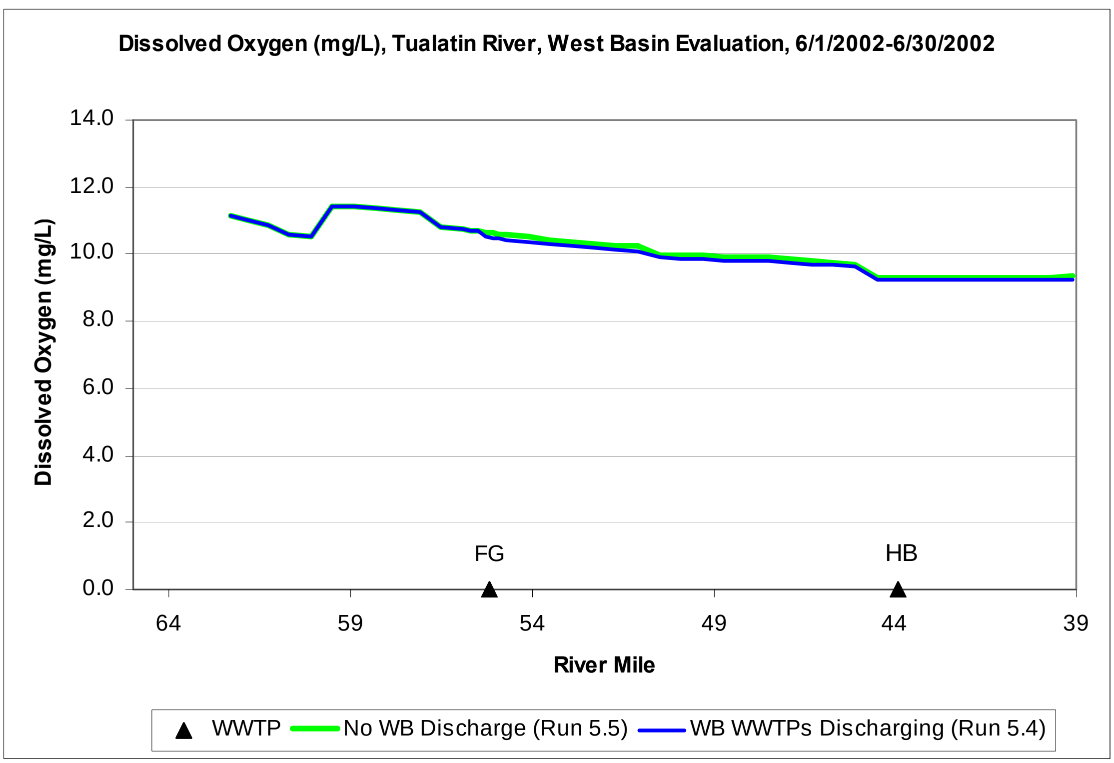

Ammonia (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Ammonia (mg/L)
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

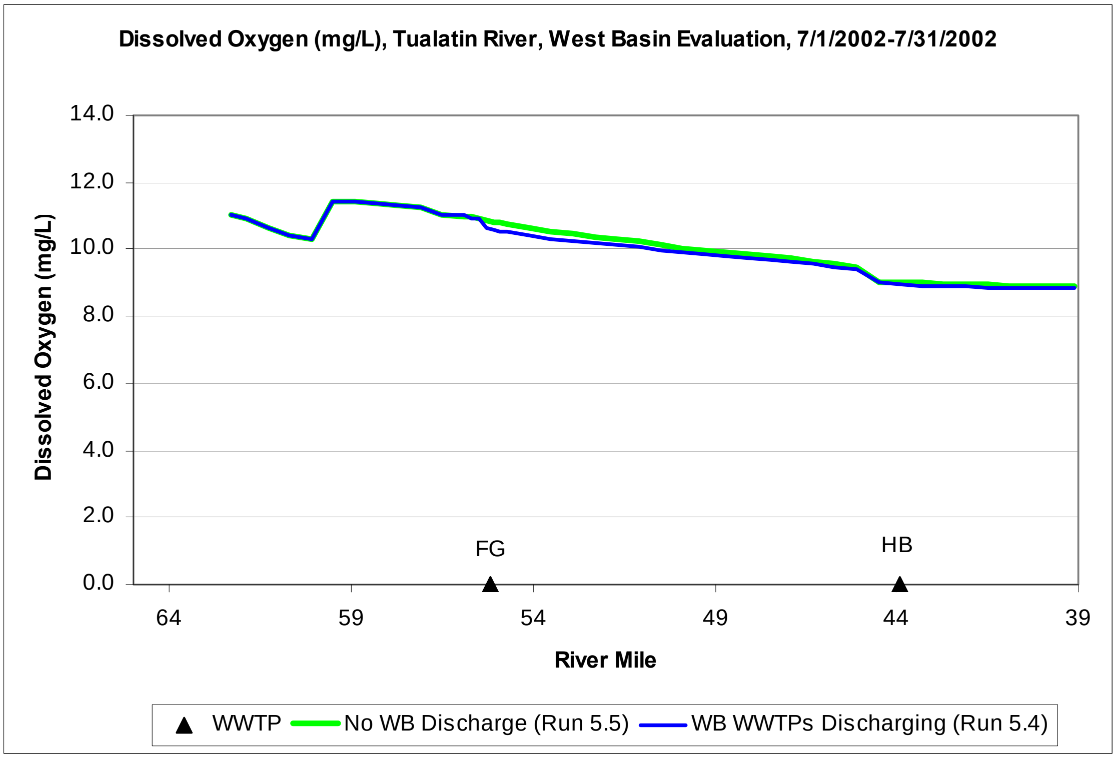

Ammonia (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Ammonia (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)


Ammonia (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Ammonia (mg/L)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

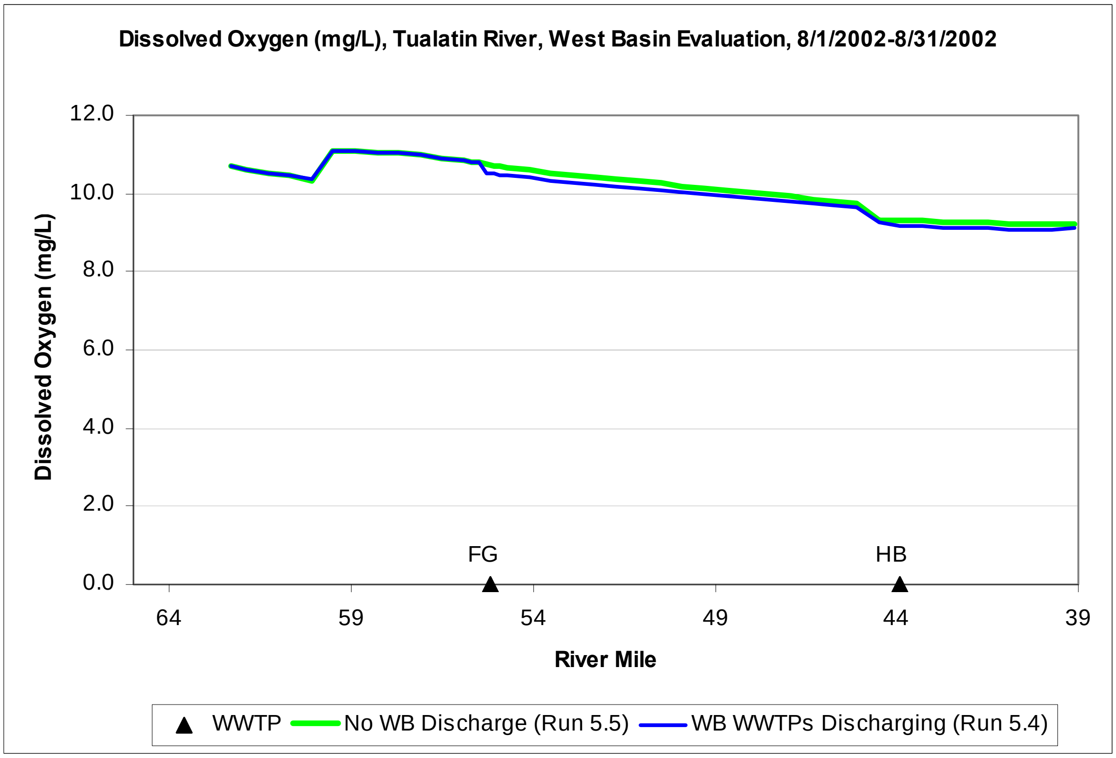
Longitudinal – Dissolved Oxygen



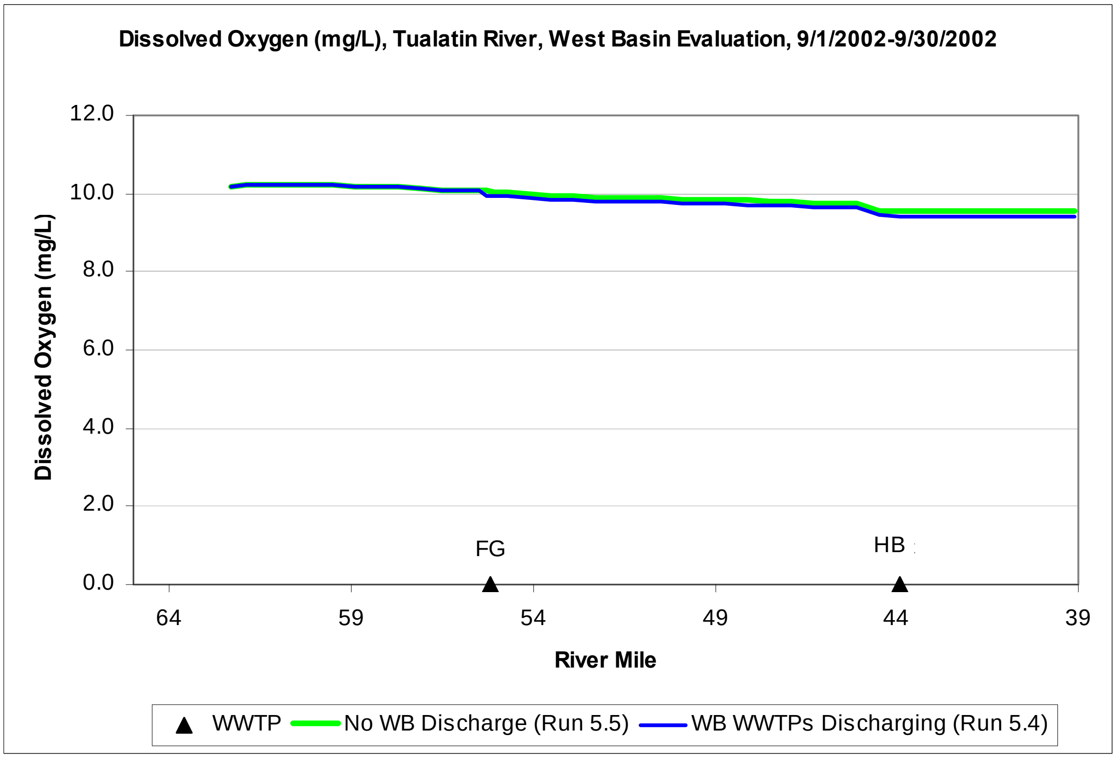




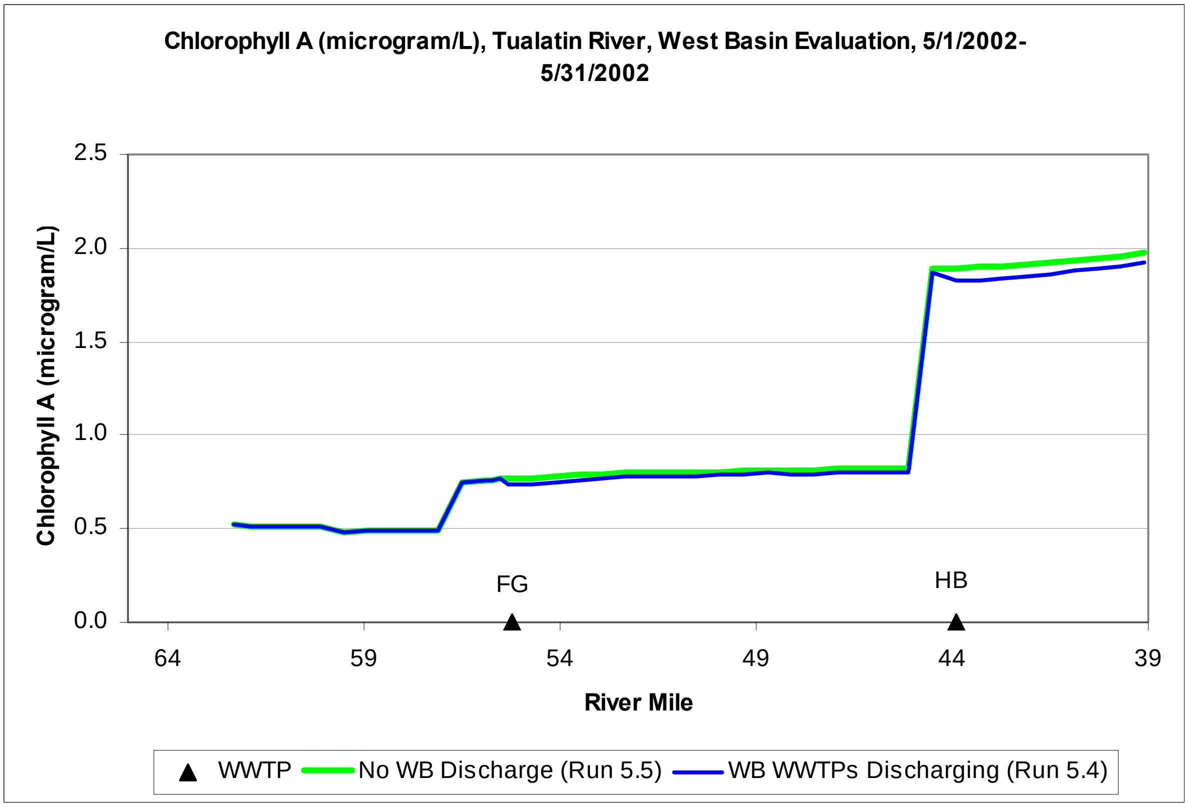
Dissolved Oxygen (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Dissolved Oxygen (mg/L)
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

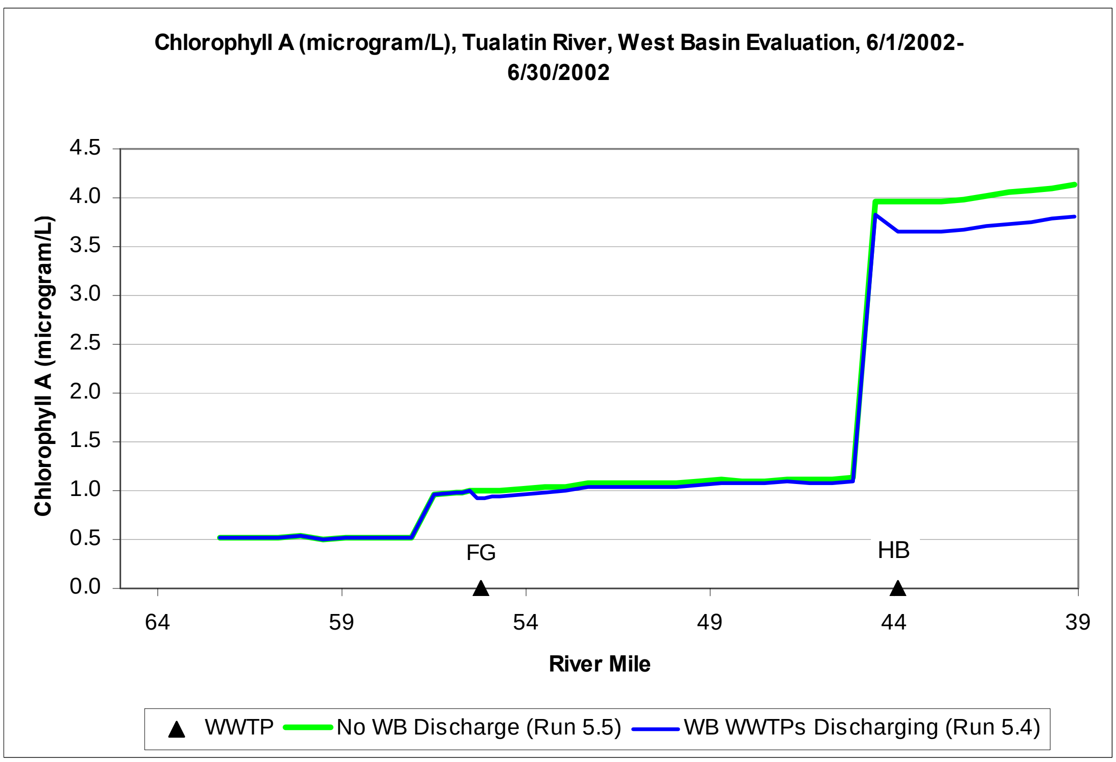


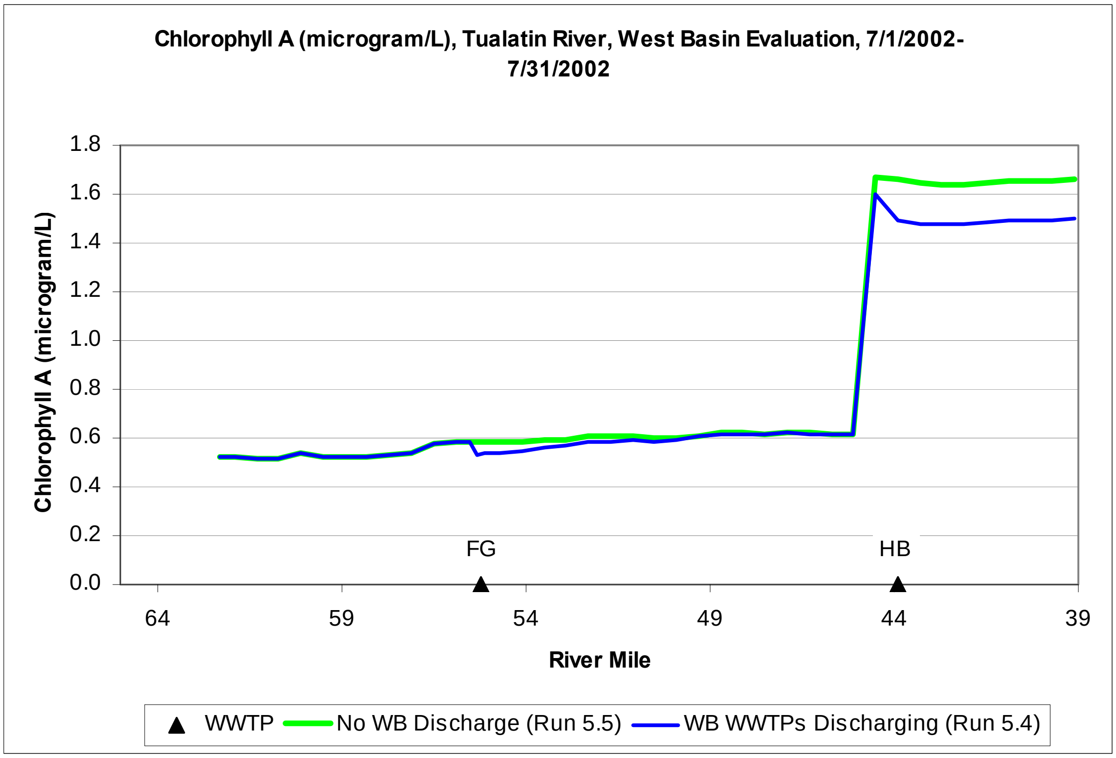
Dissolved Oxygen (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Dissolved Oxygen (mg/L)
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

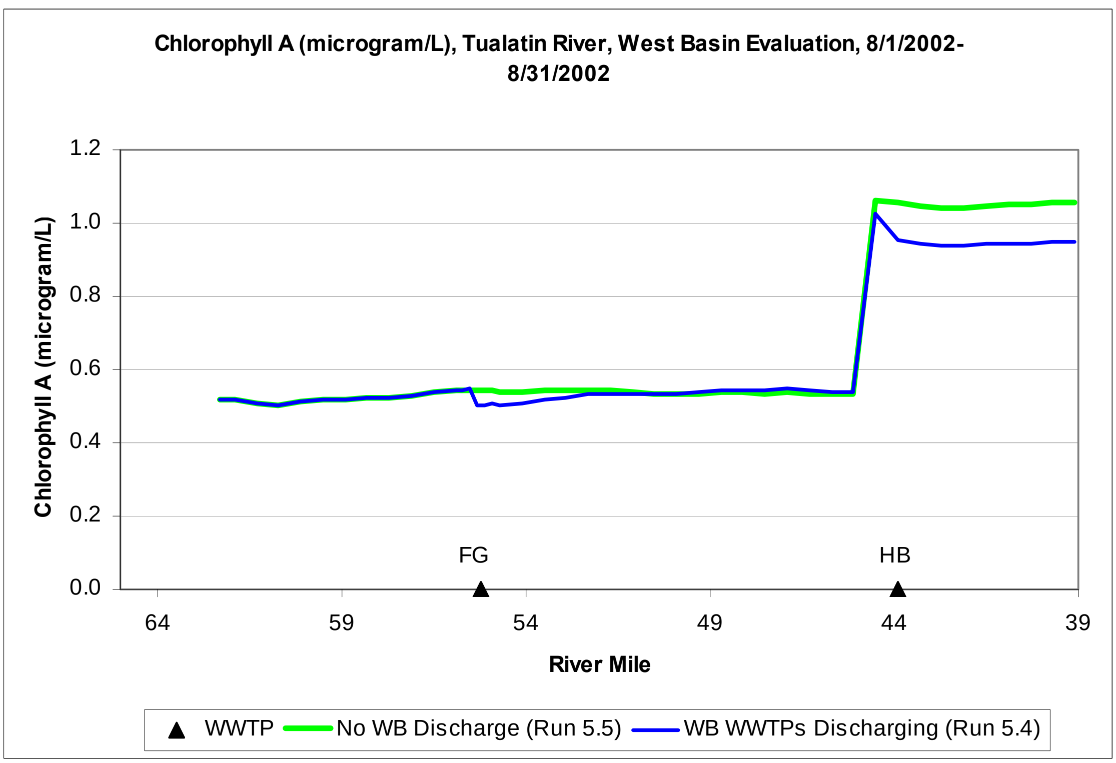

Dissolved Oxygen (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Dissolved Oxygen (mg/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

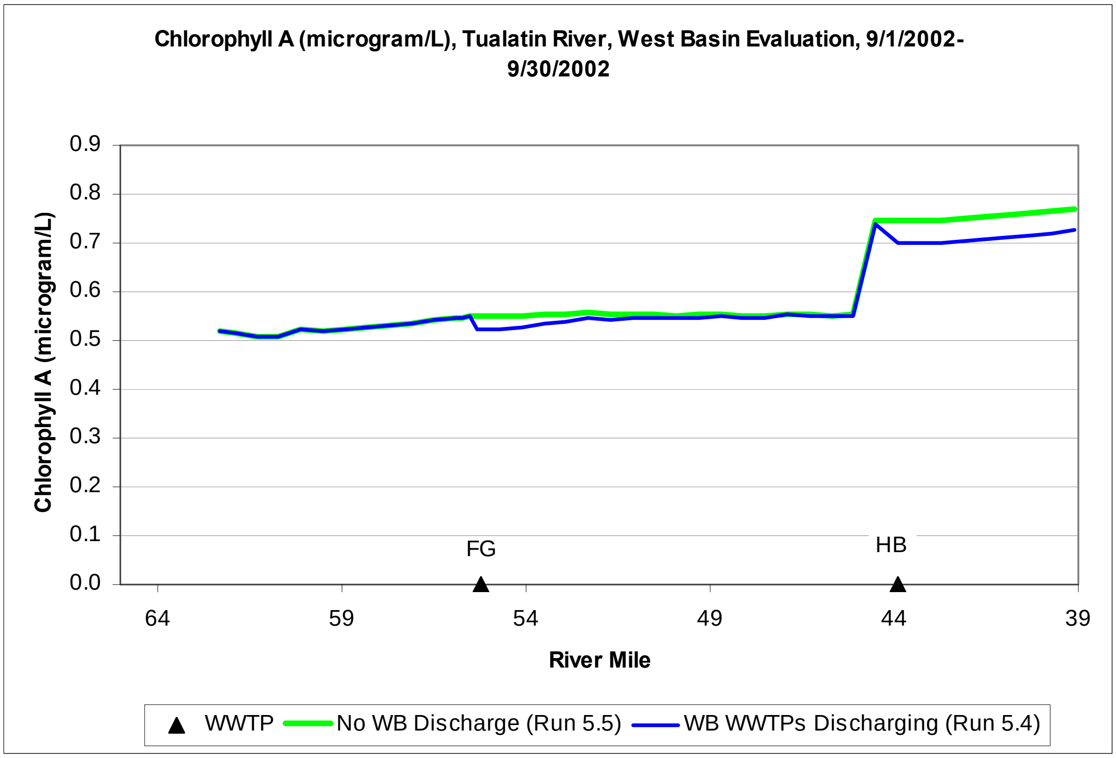
Longitudinal – Chlorophyll A



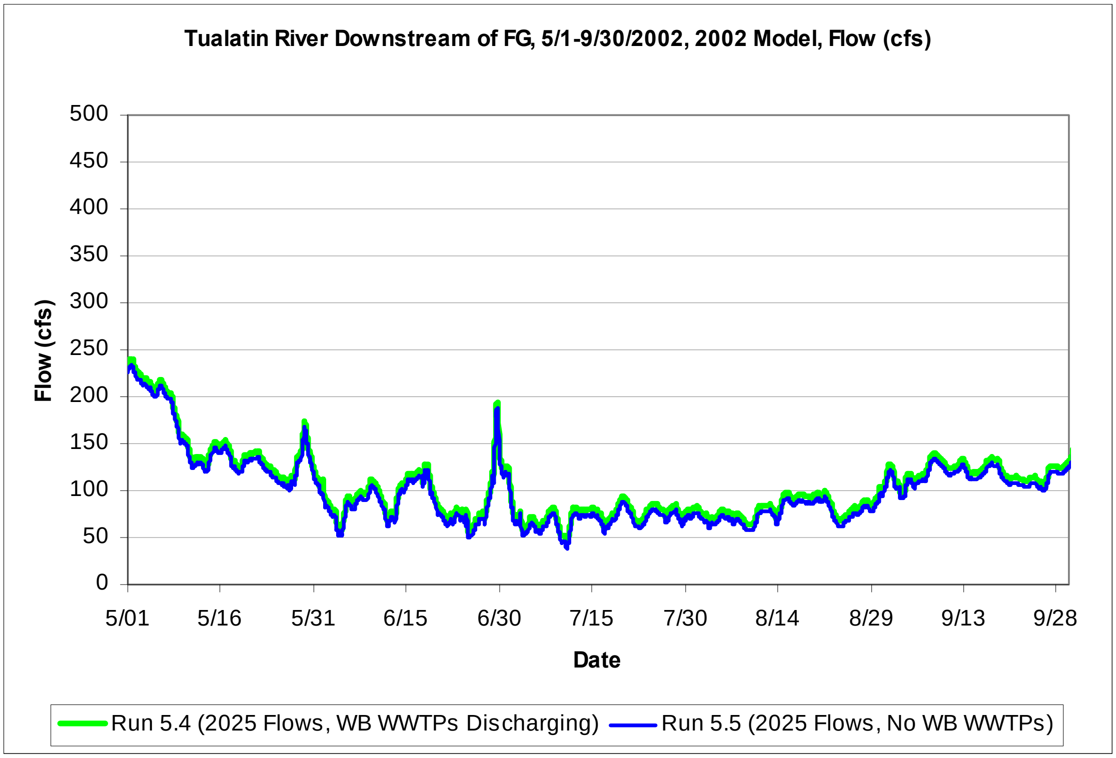


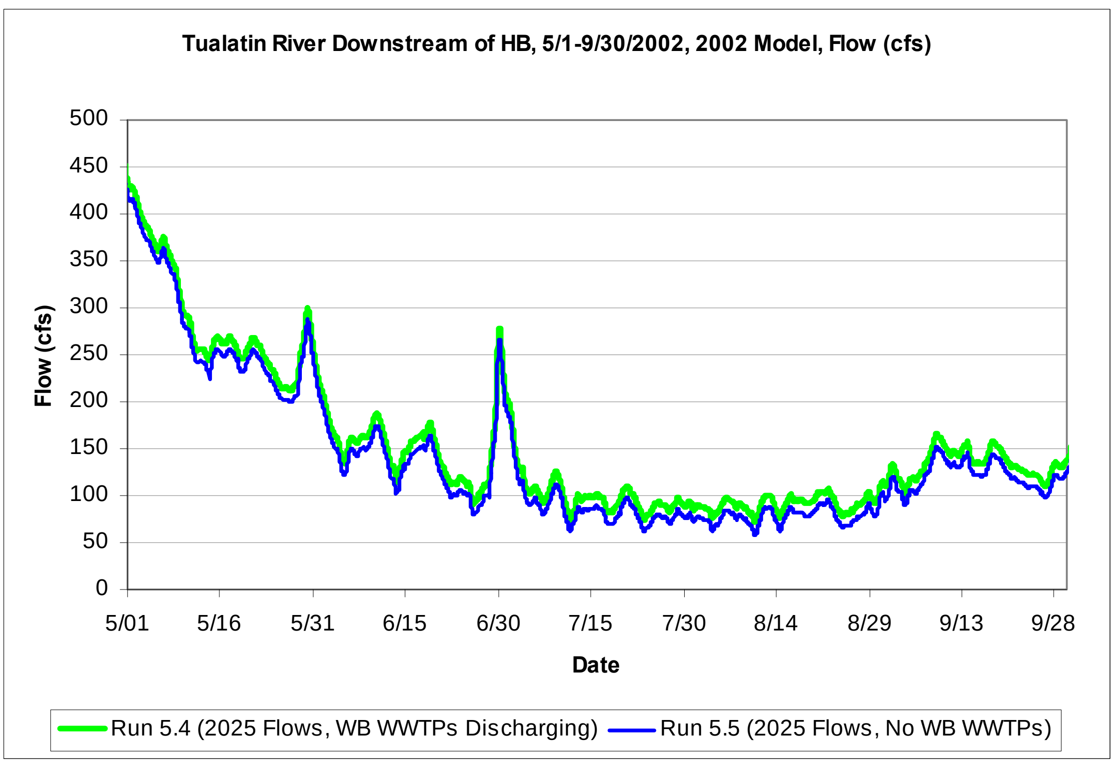

Chlorophyll A (microgram/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Chlorophyll A (microgram/L)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

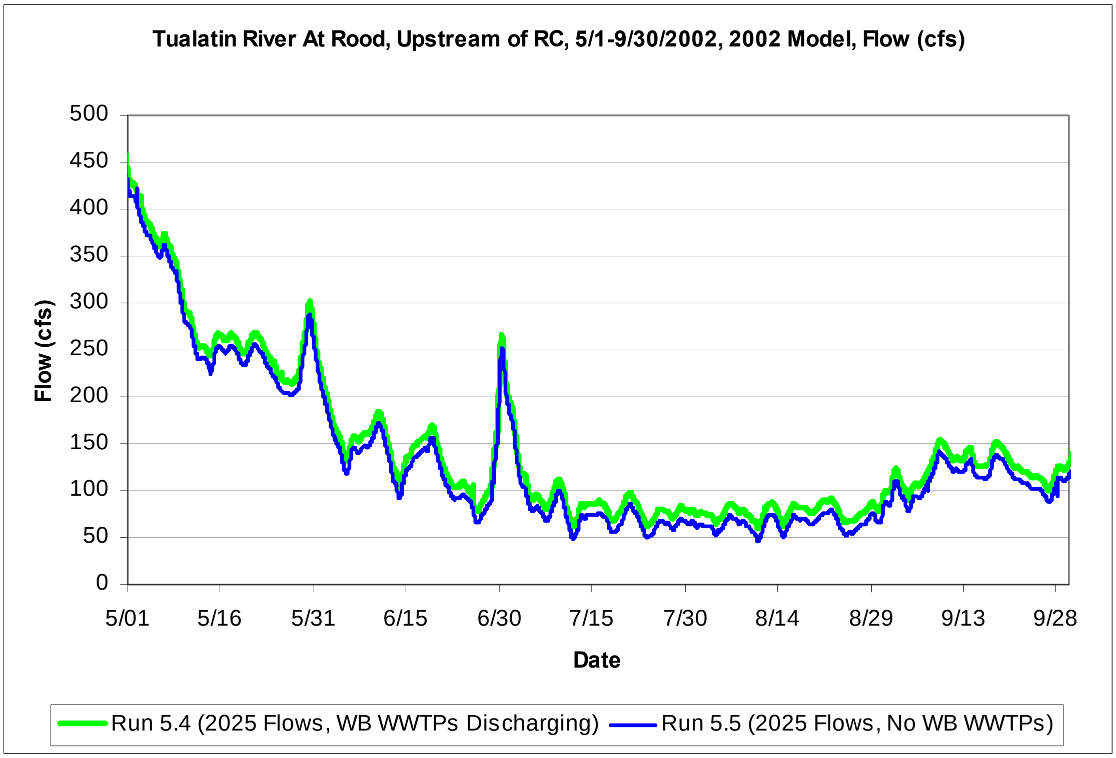

Chlorophyll A (microgram/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Chlorophyll A (microgram/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)


Chlorophyll A (microgram/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Chlorophyll A (microgram/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
No WB Discharge (Run 5.5)
WB WWTPs Discharging (Run 5.4)

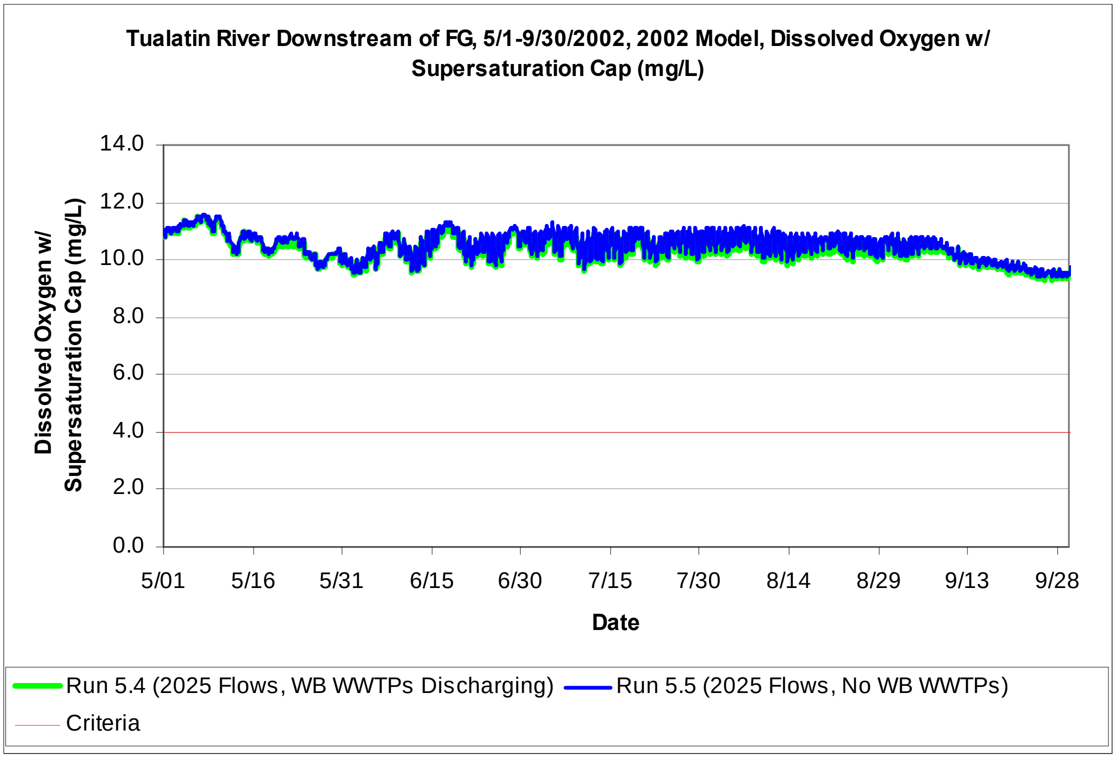
Time Series – Flow

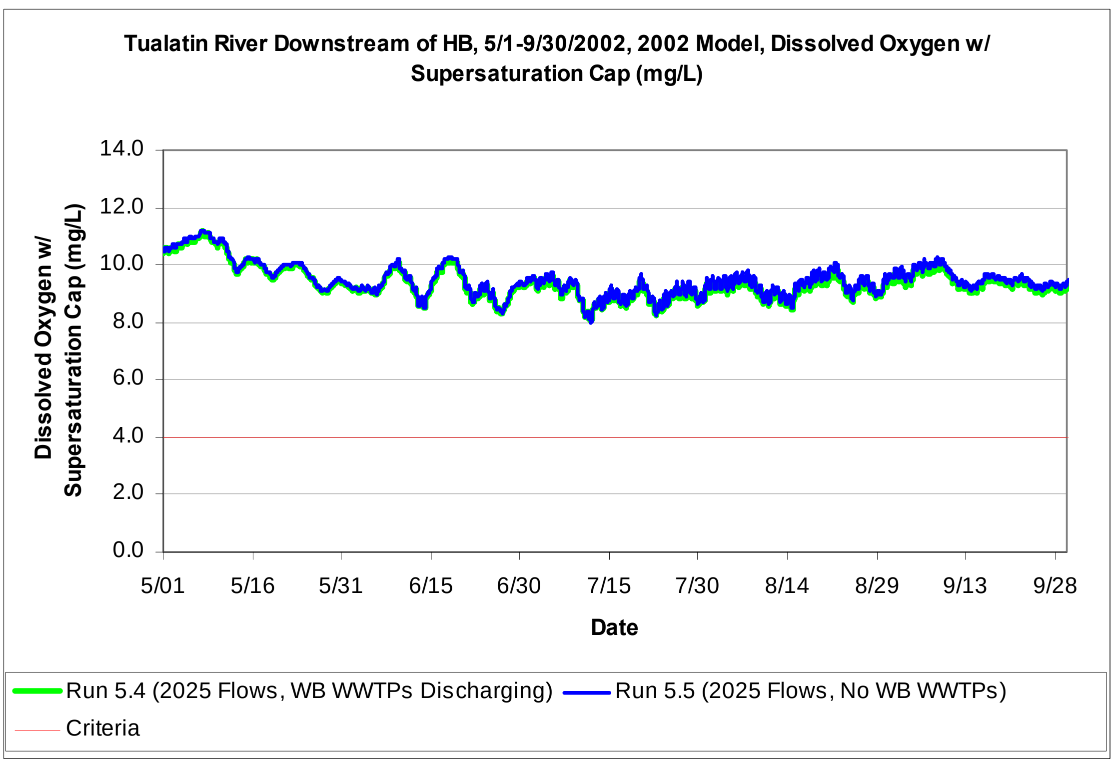


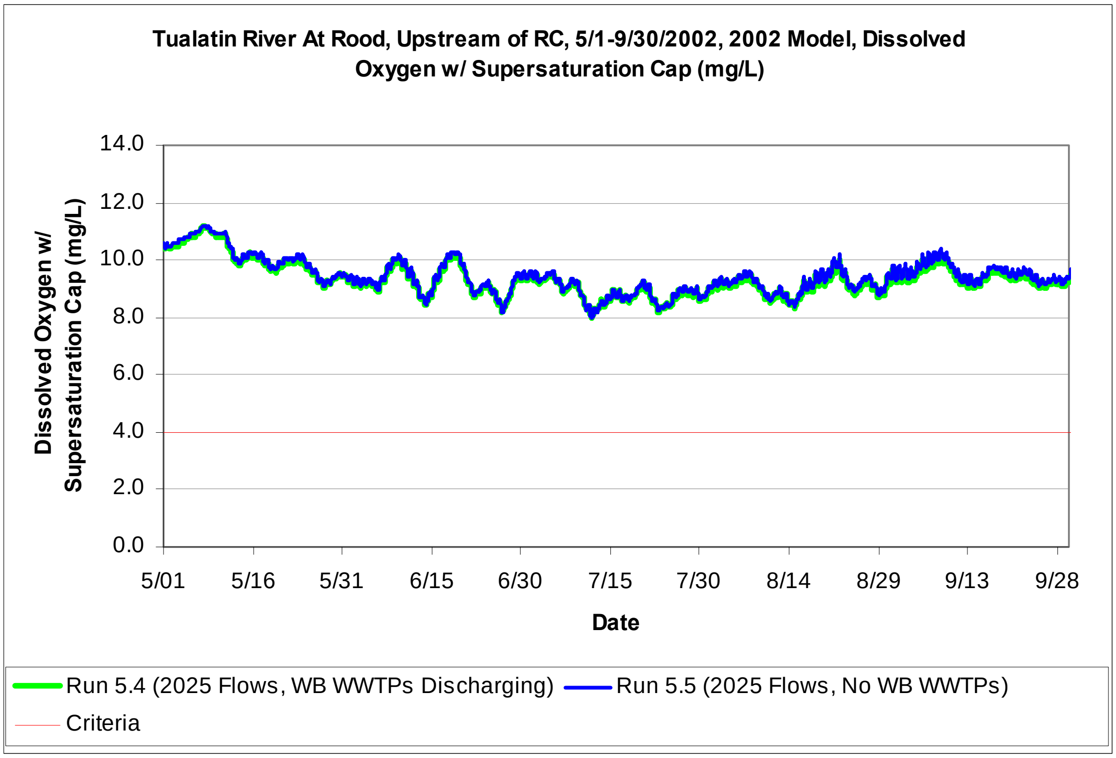



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Flow (cfs)
Flow (cfs)
500
450
400
350
300
250
200
150
100
50
0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (2025 Flows, WB WWTPs Discharging)
Run 5.5 (2025 Flows, No WB WWTPs)

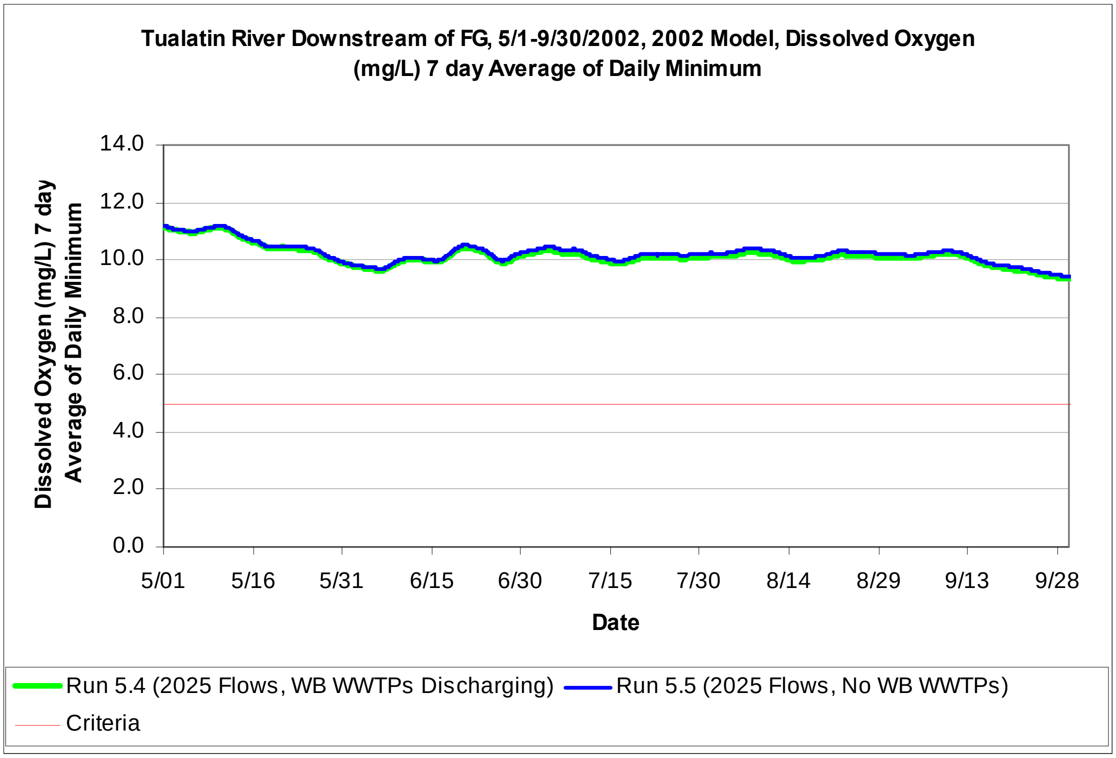
Time Series – Dissolved Oxygen (Instantaneous with Supersaturation Cap)

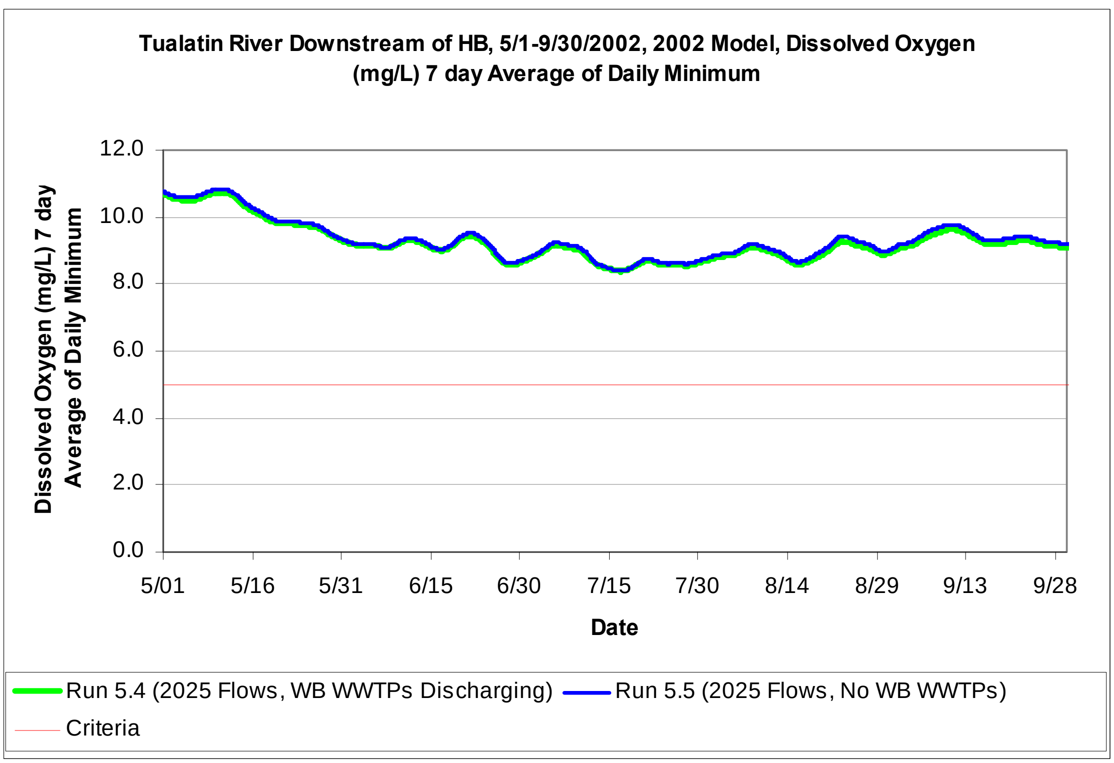


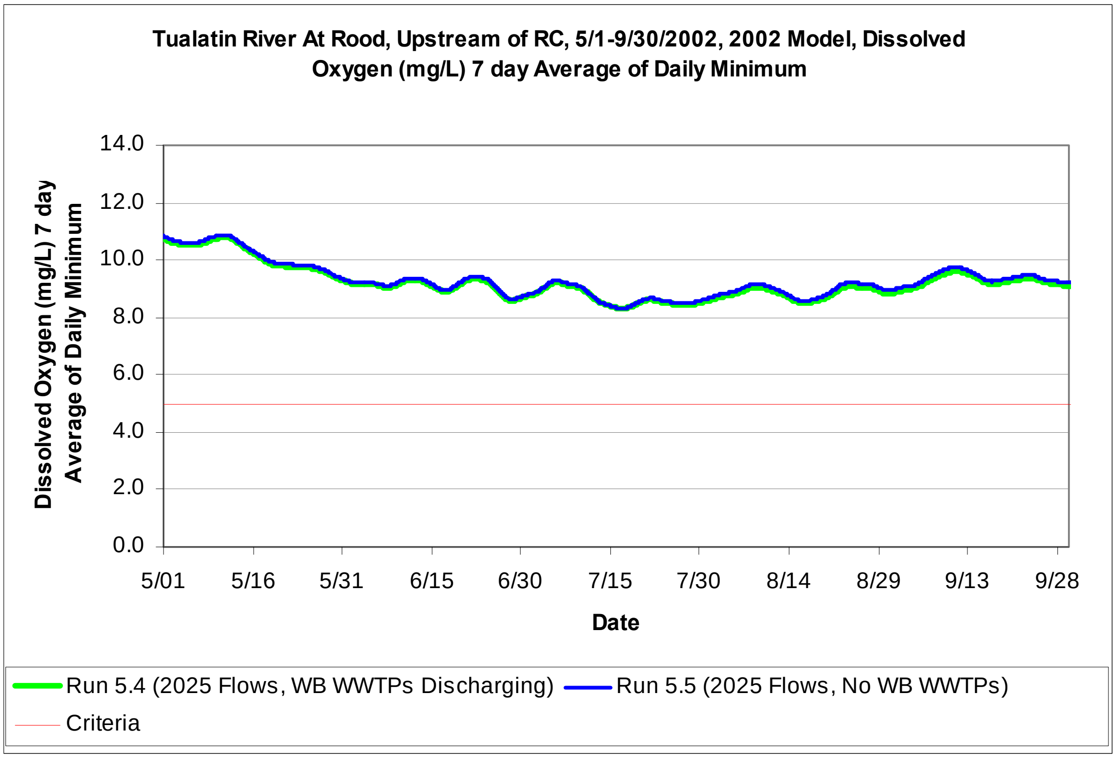



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Dissolved Oxygen w/ Supersaturation Cap (mg/L)
Dissolved Oxygen w/ Supersaturation Cap (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (2025 Flows, WB WWTPs Discharging)
Run 5.5 (2025 Flows, No WB WWTPs)
Criteria

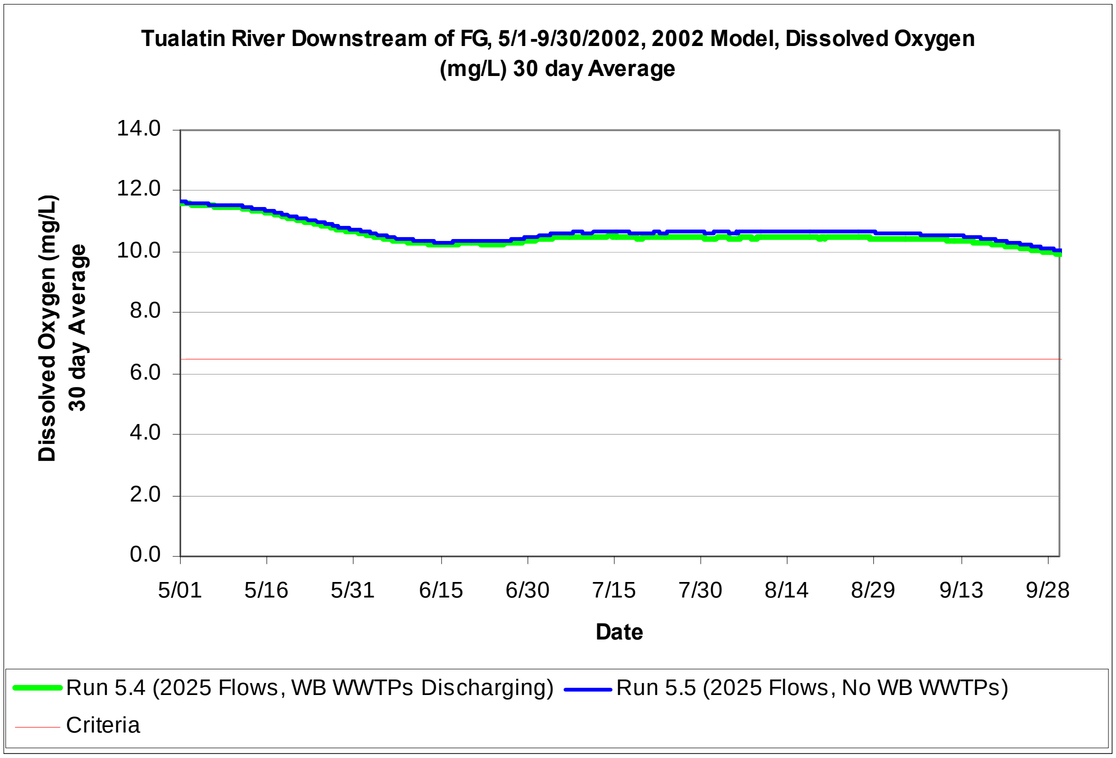
Time Series – Dissolved Oxygen (7-Day Average of Daily Minimum)

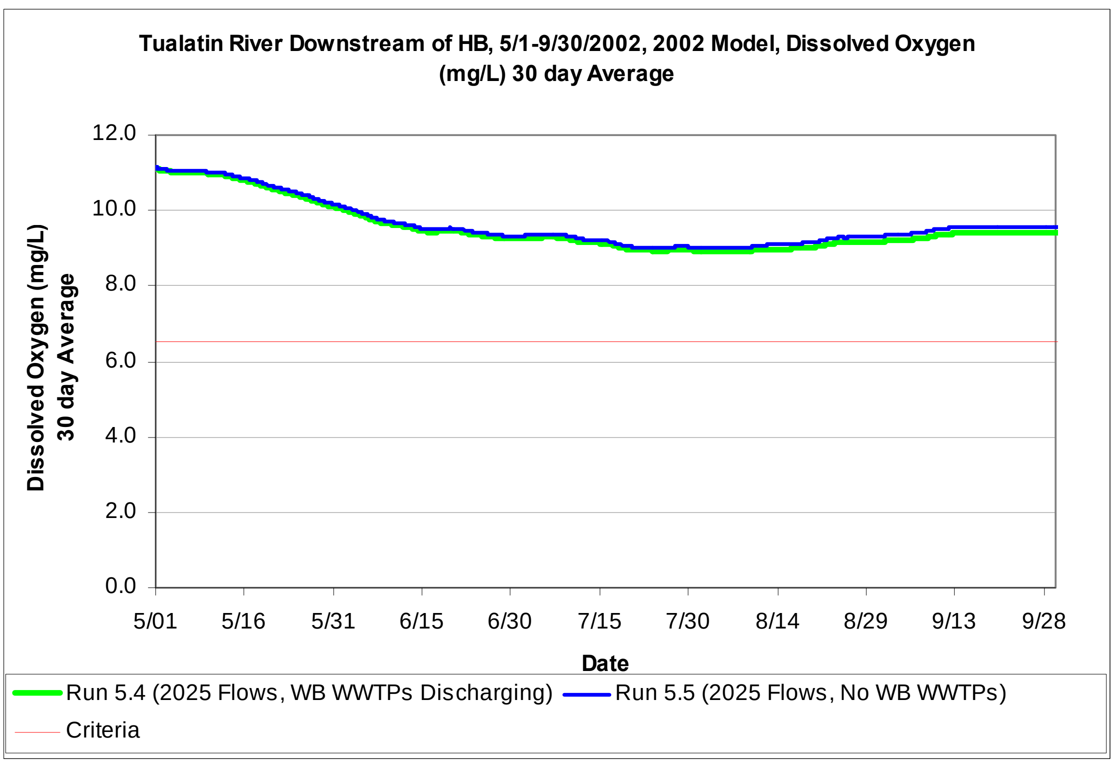


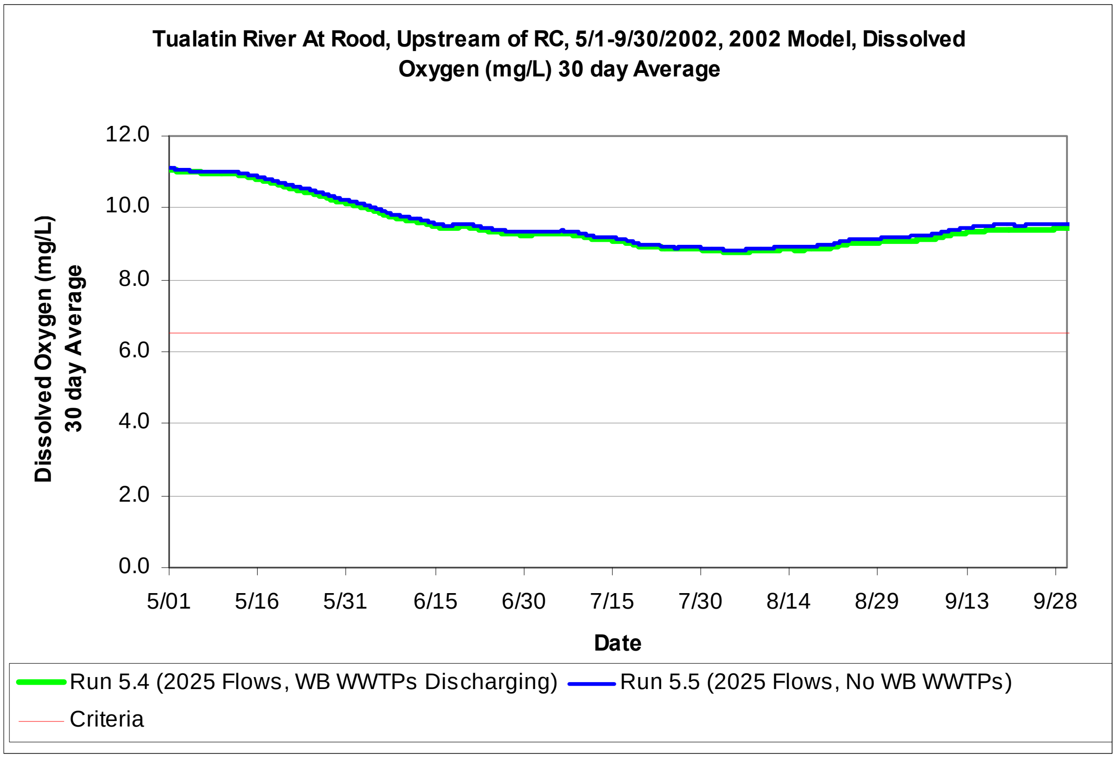



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Dissolved Oxygen (mg/L) 7 day Average of Daily Minimum
Dissolved Oxygen (mg/L) 7 day Average of Daily Minimum
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (2025 Flows, WB WWTPs Discharging)
Run 5.5 (2025 Flows, No WB WWTPs)
Criteria

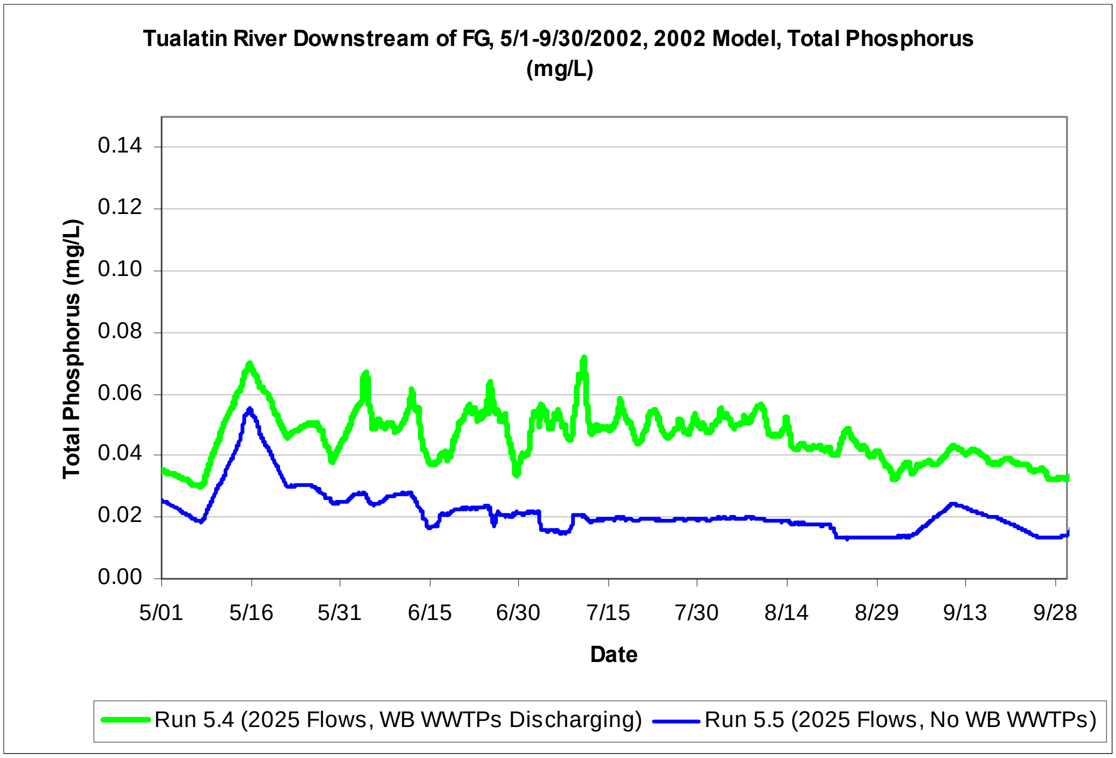
Time Series – Dissolved Oxygen (30-Day Average)

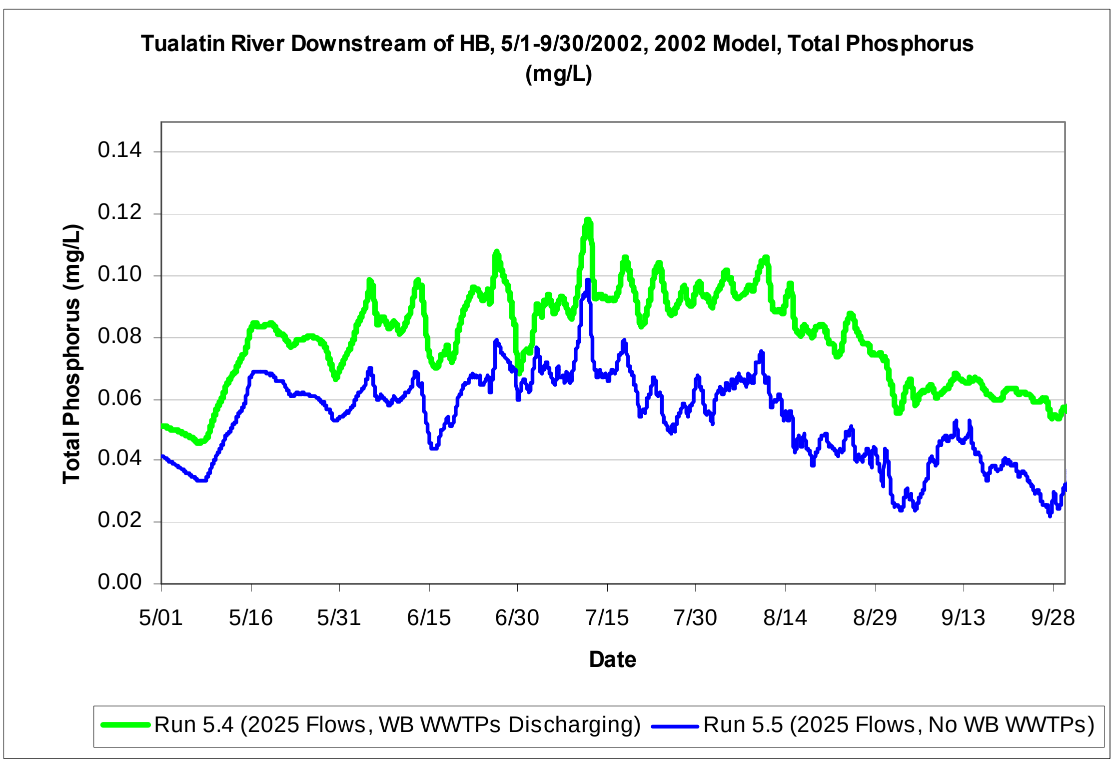


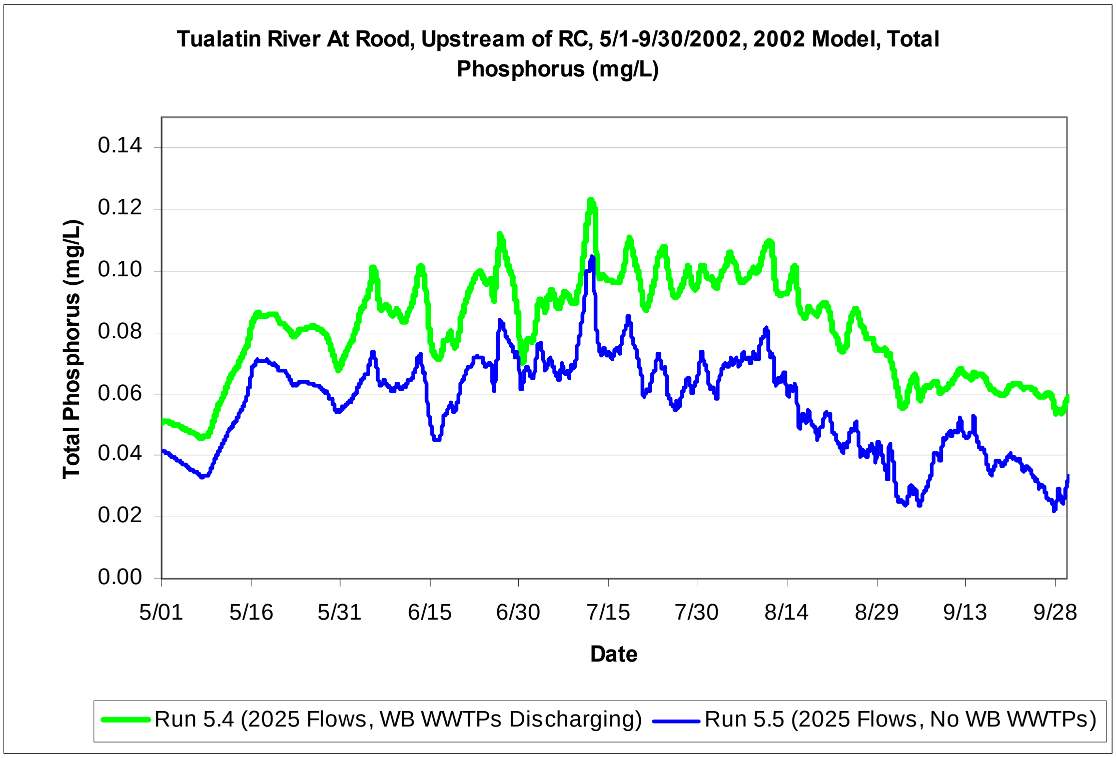



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Dissolved Oxygen (mg/L) 30 day Average
Dissolved Oxygen (mg/L) 30 day Average
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (2025 Flows, WB WWTPs Discharging)
Run 5.5 (2025 Flows, No WB WWTPs)
Criteria

Time Series – Total Phosphorus

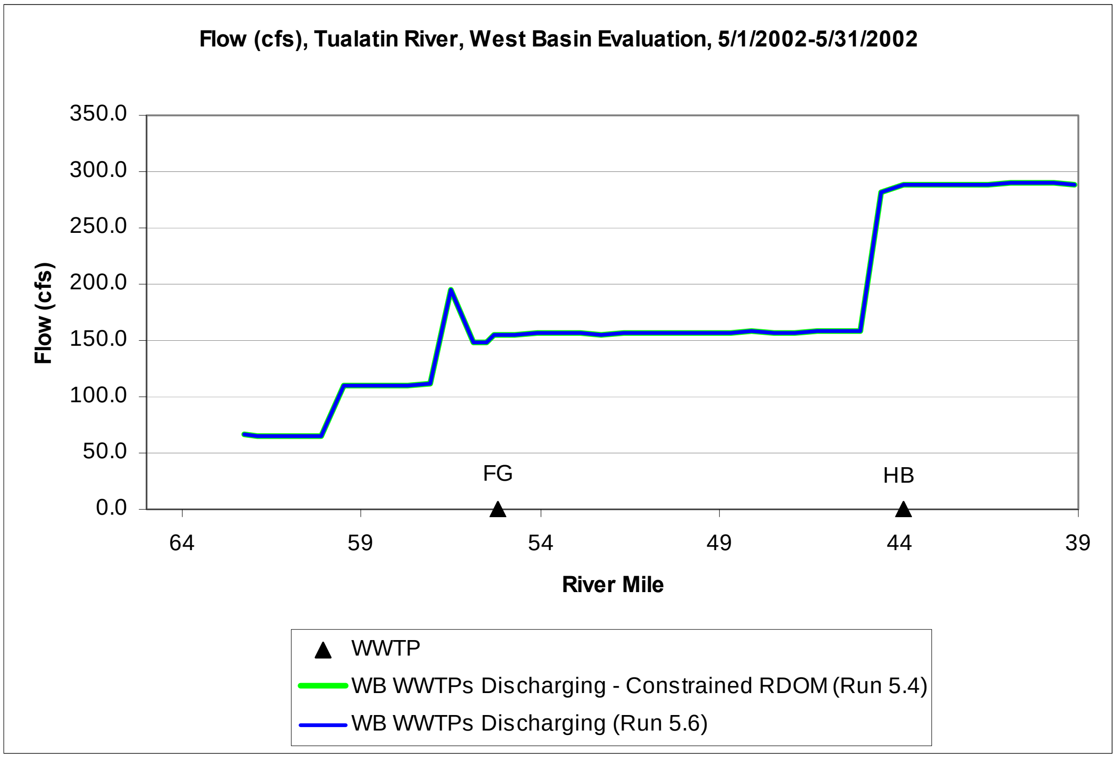


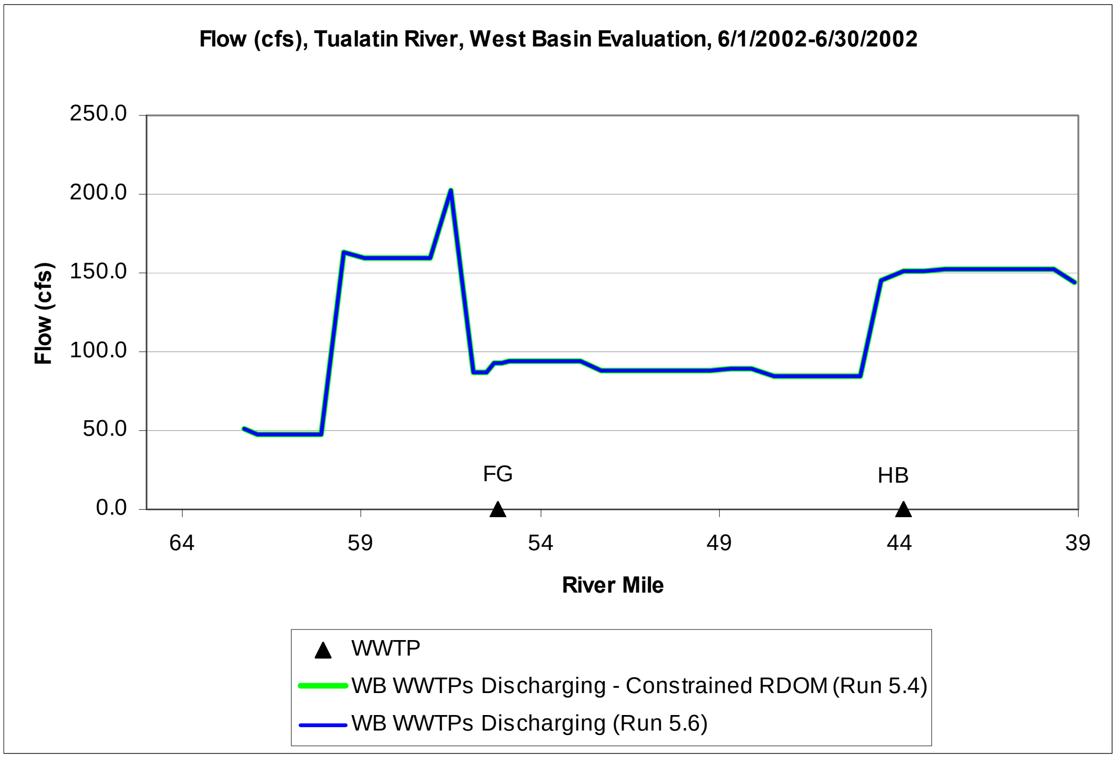


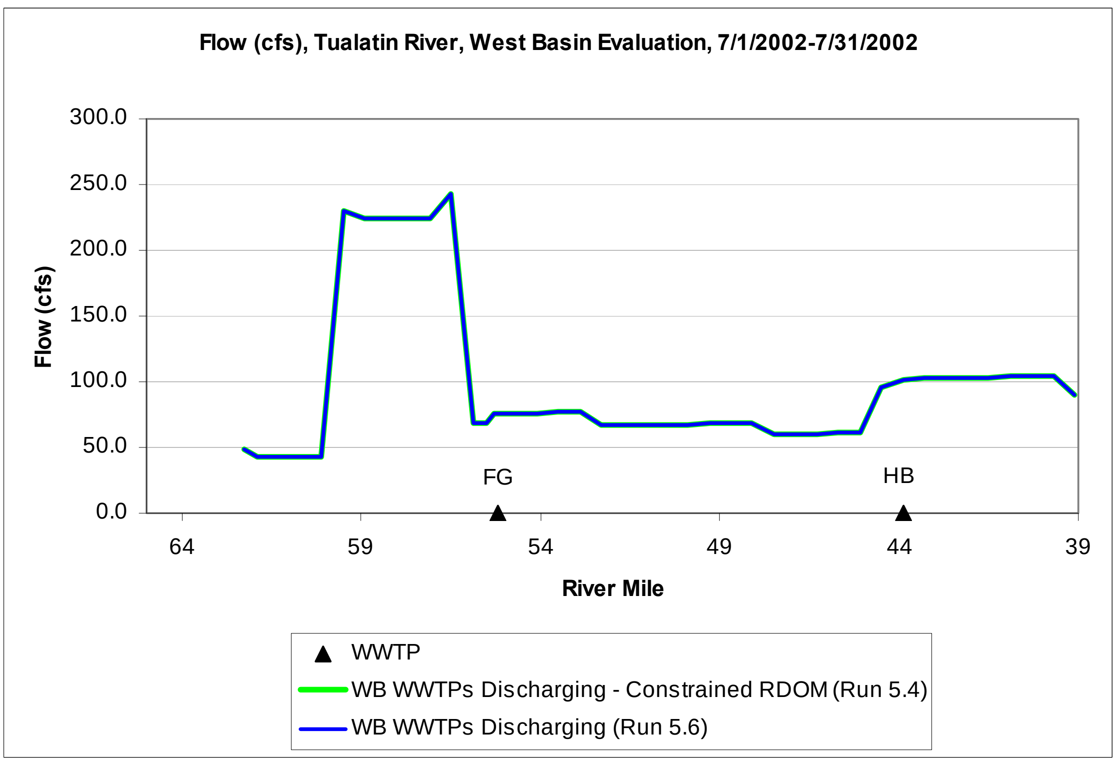

Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Total Phosphorus (mg/L)
Total Phosphorus (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (2025 Flows, WB WWTPs Discharging)
Run 5.5 (2025 Flows, No WB WWTPs)

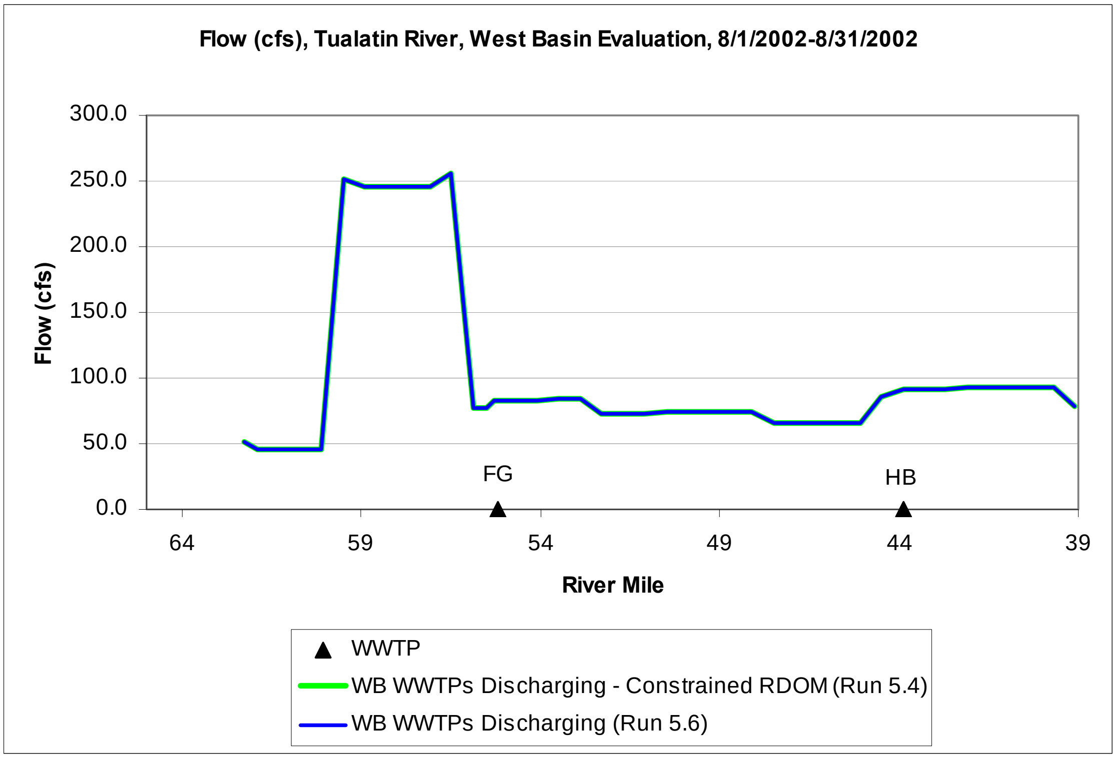
West Basin Discharge Scenarios – Constrained RDOM Evaluation (Runs 5.4 vs. 5.6)

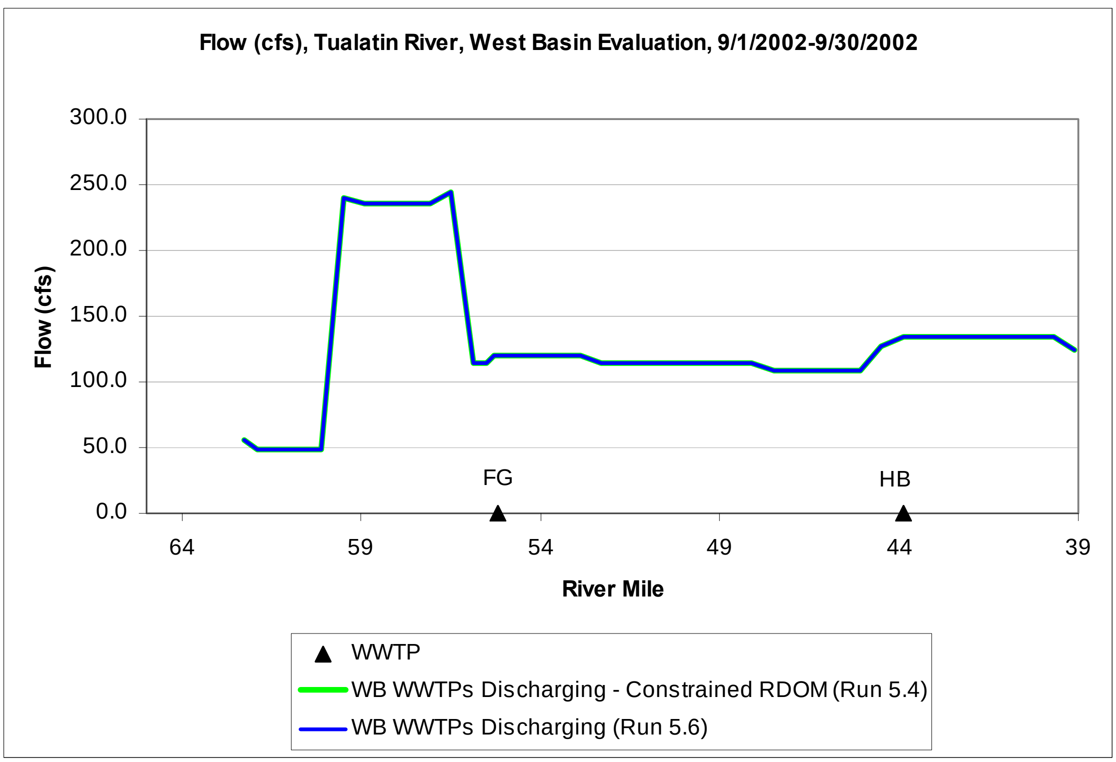
Longitudinal – Flow



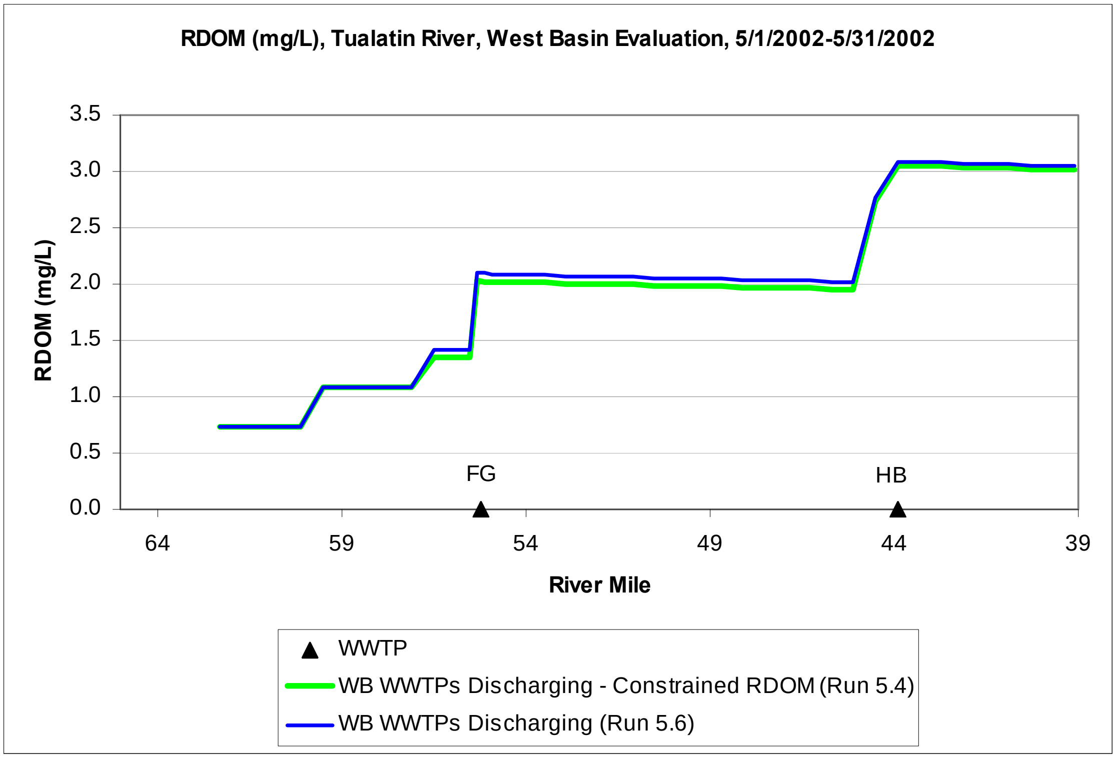

Flow (cfs), Tualatin River, West Basin Evaluation, 6/1/2002-6/30/2002
250.0
200.0
150.0
100.0
50.0
0.0
Flow (cfs)
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

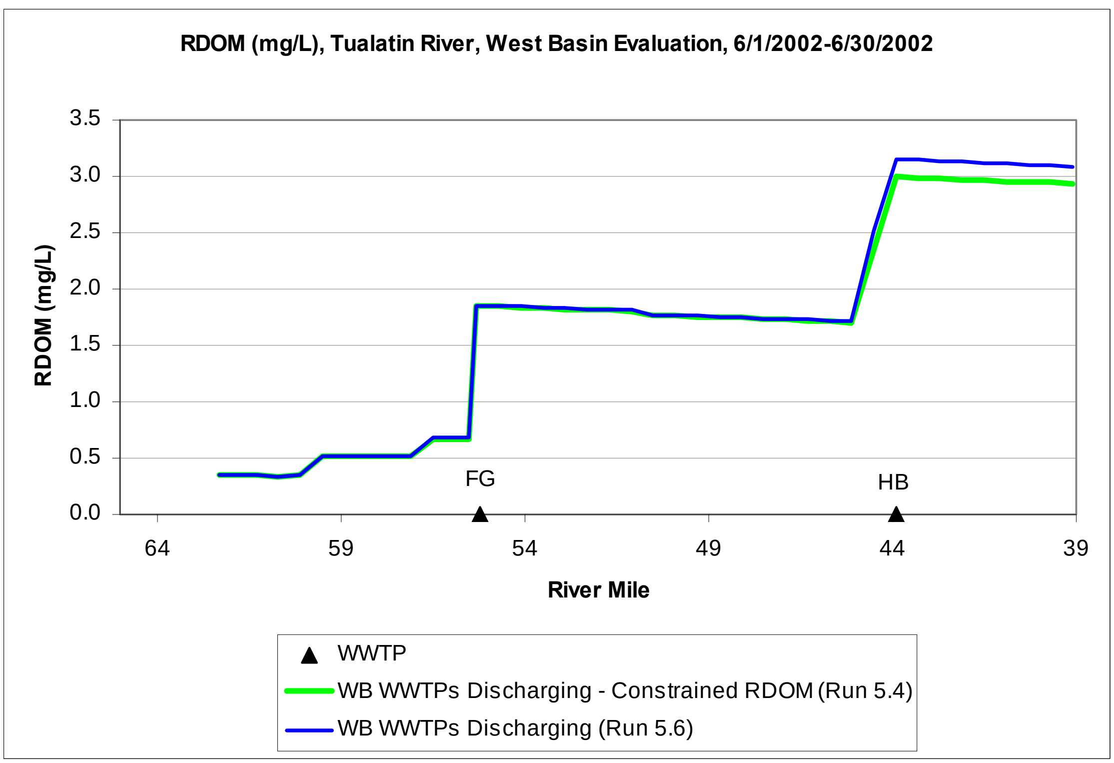

Flow (cfs), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Flow (cfs)
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

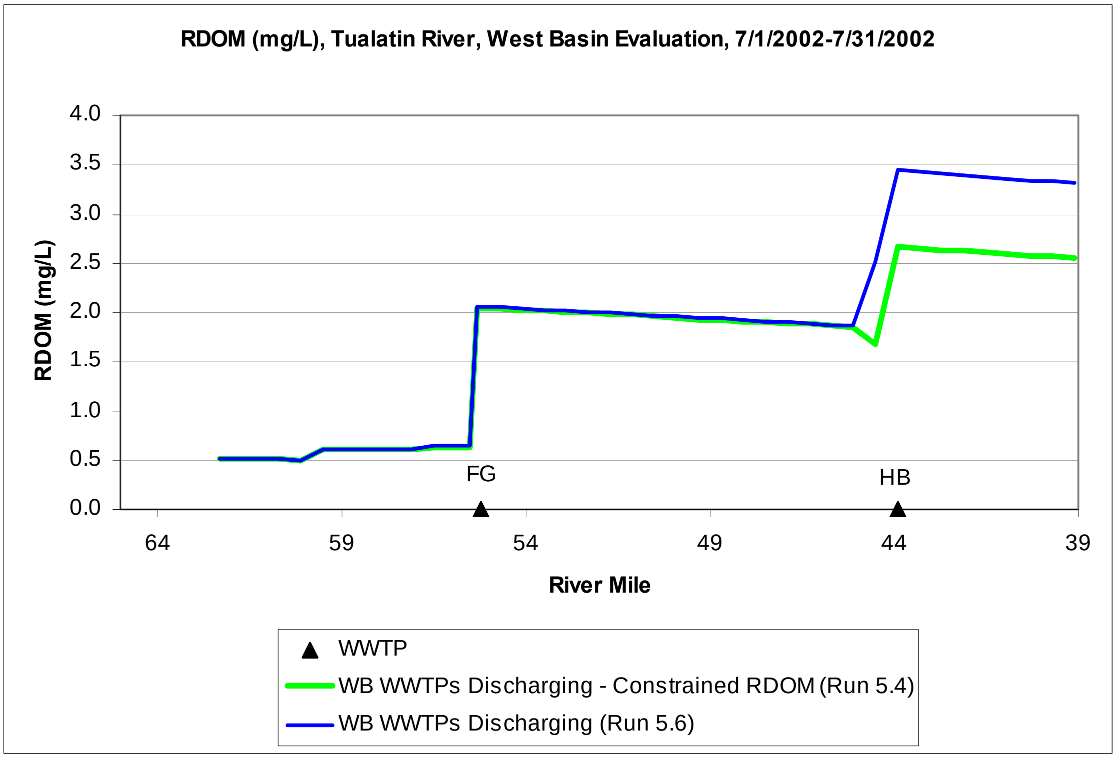

Flow (cfs), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Flow (cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

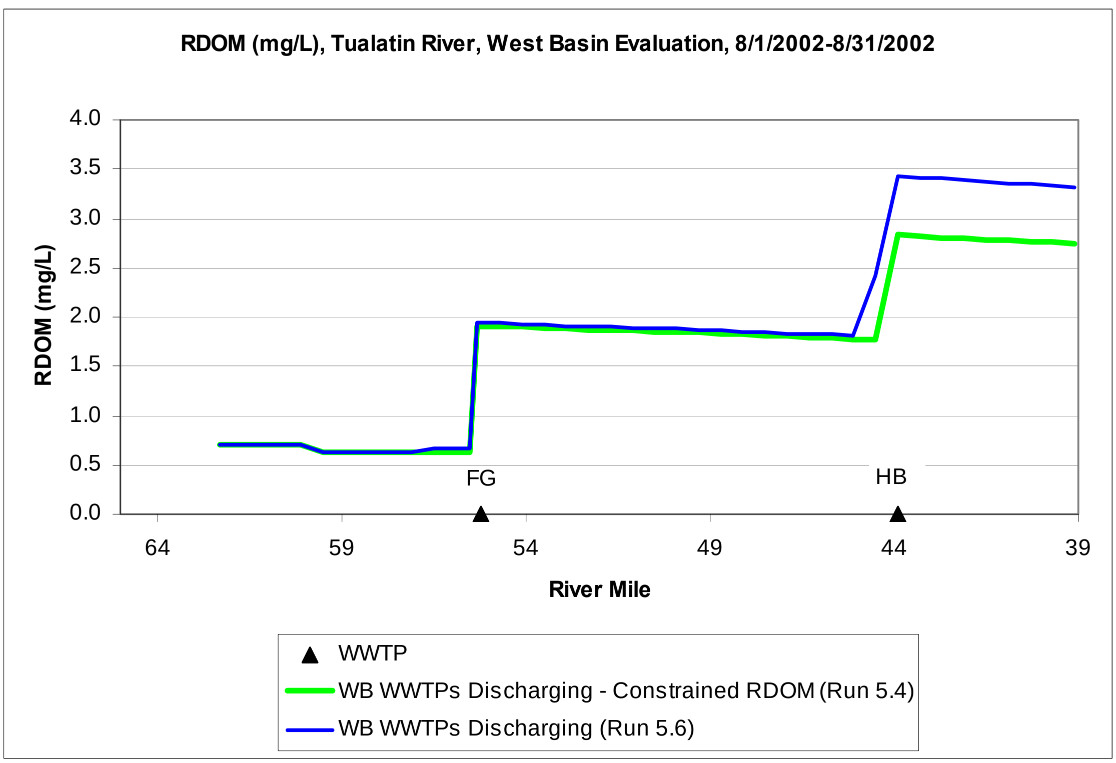

Flow (cfs), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Flow (cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

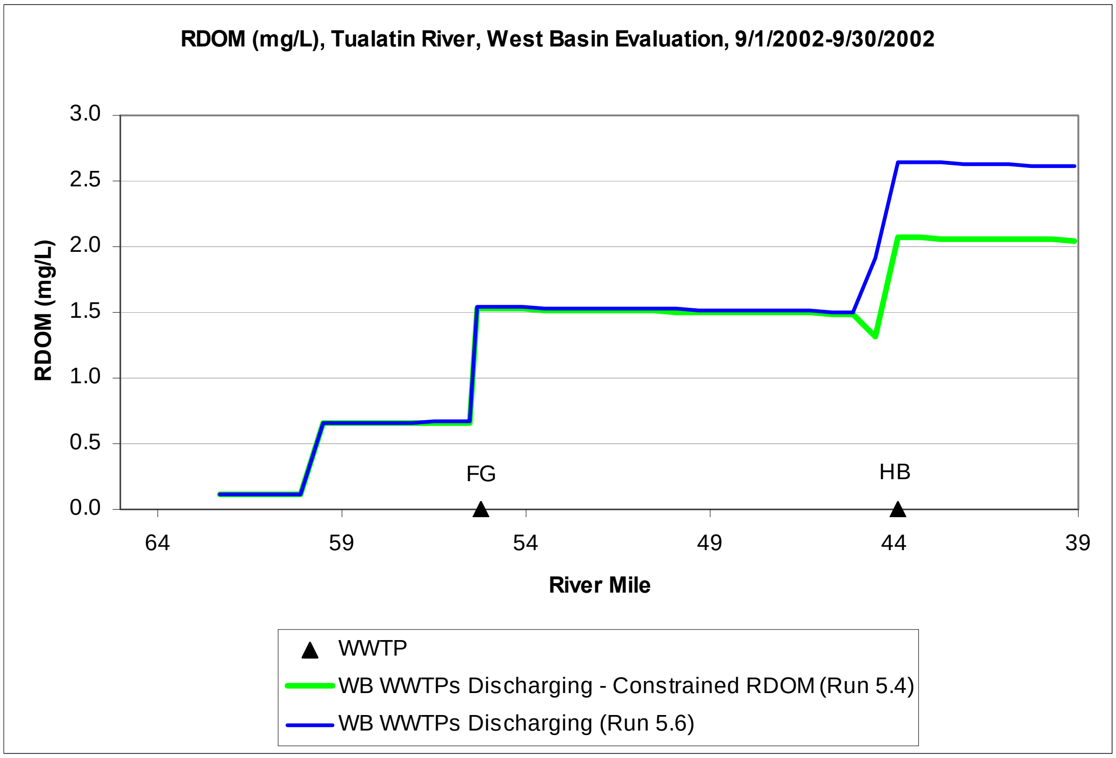
Longitudinal – RDOM





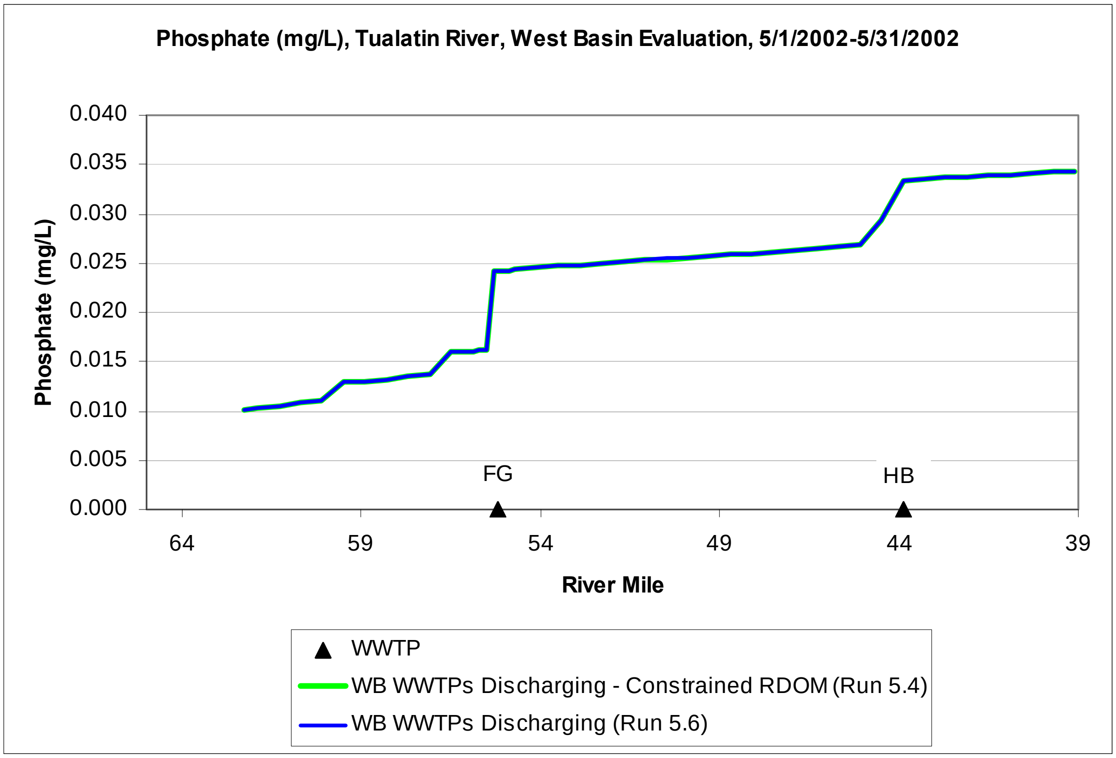

RDOM (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
RDOM (mg/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

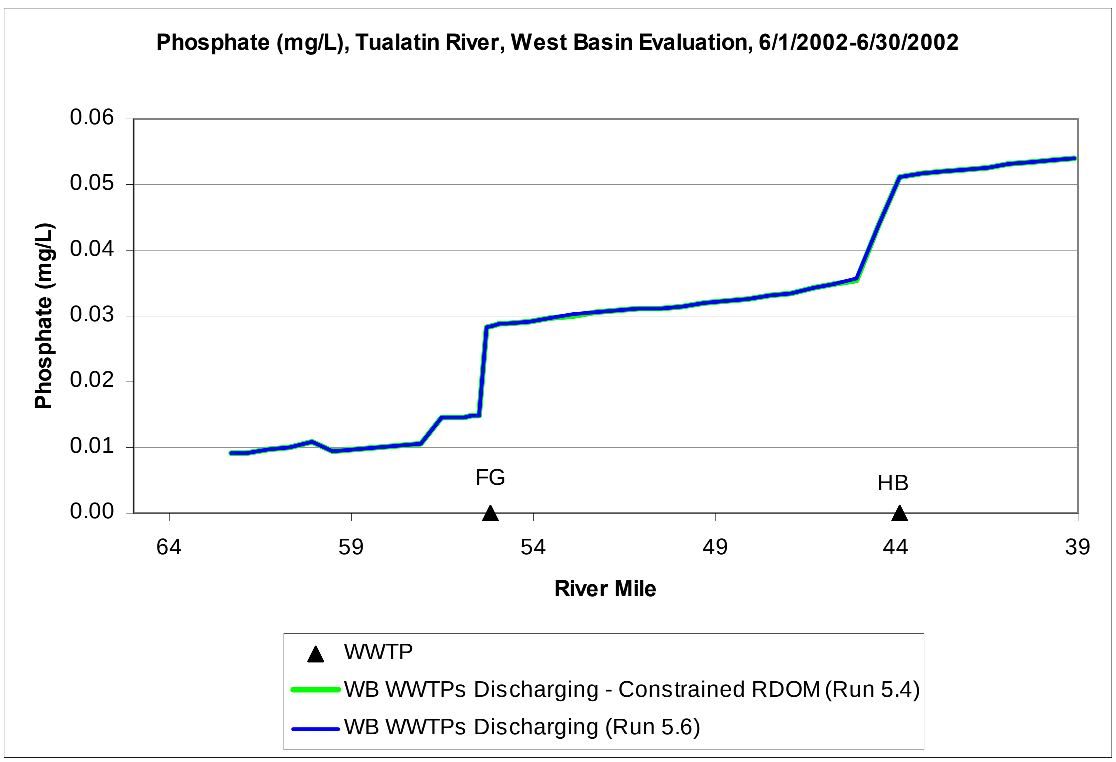

RDOM (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
RDOM (mg/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

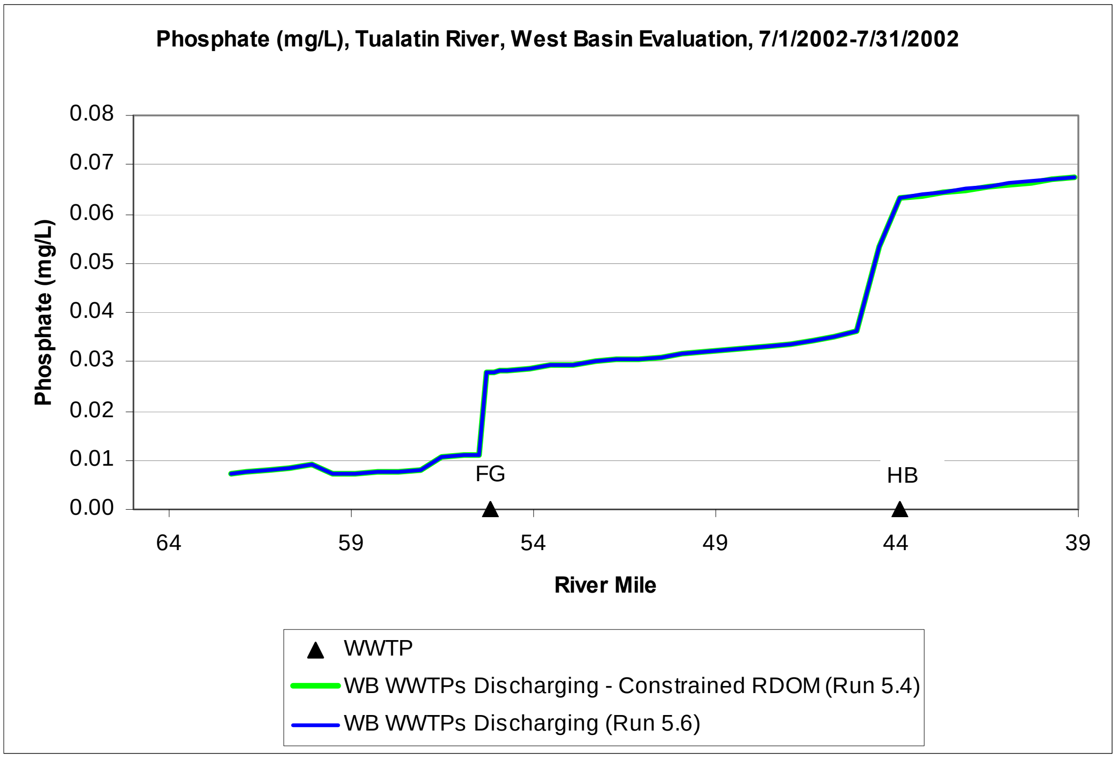


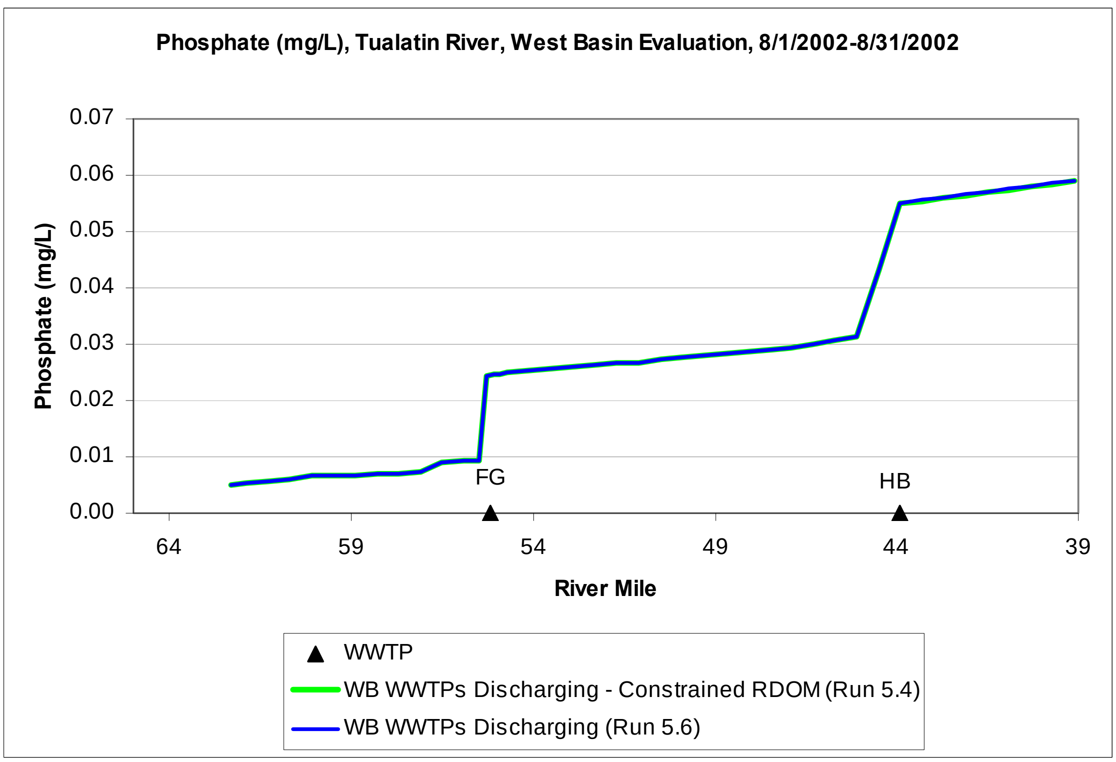
RDOM (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
RDOM (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

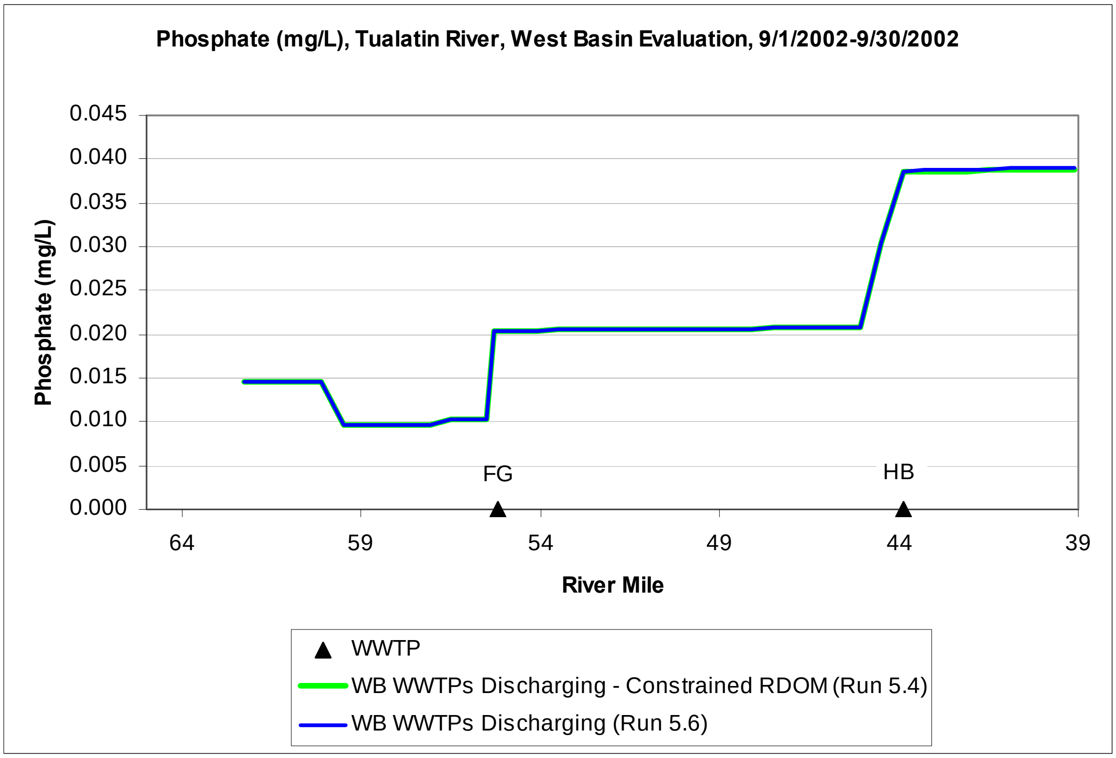
Longitudinal – Phosphate (PO_4 as P)



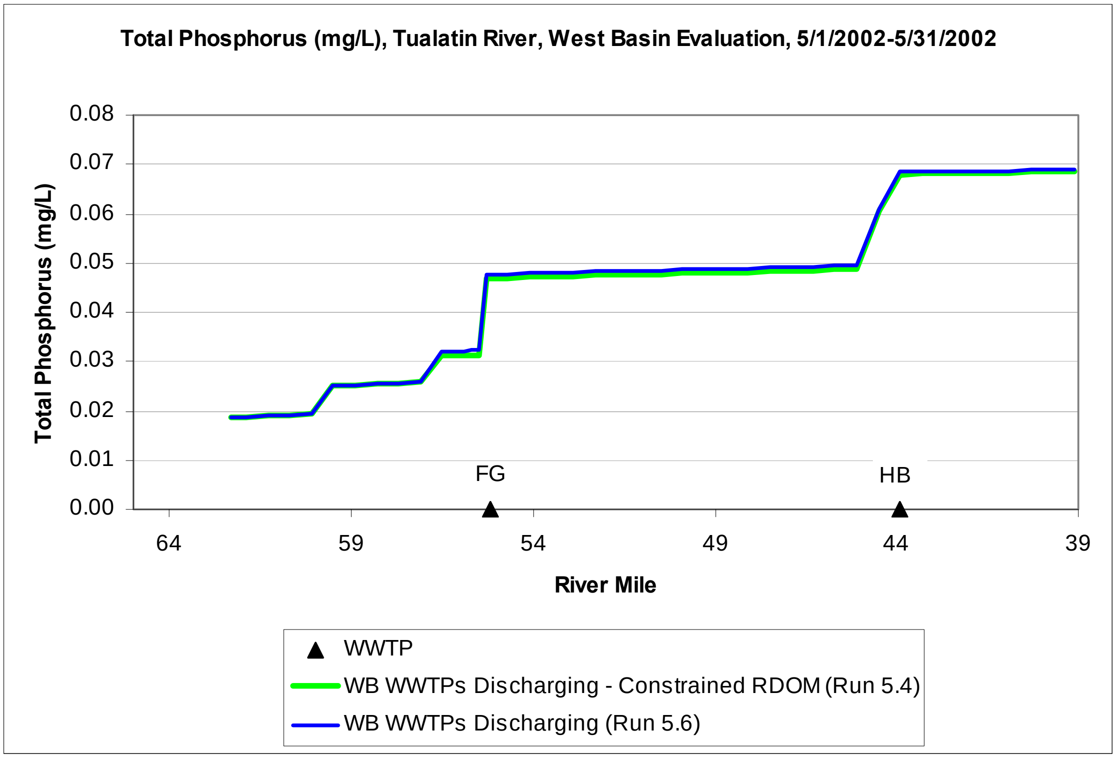


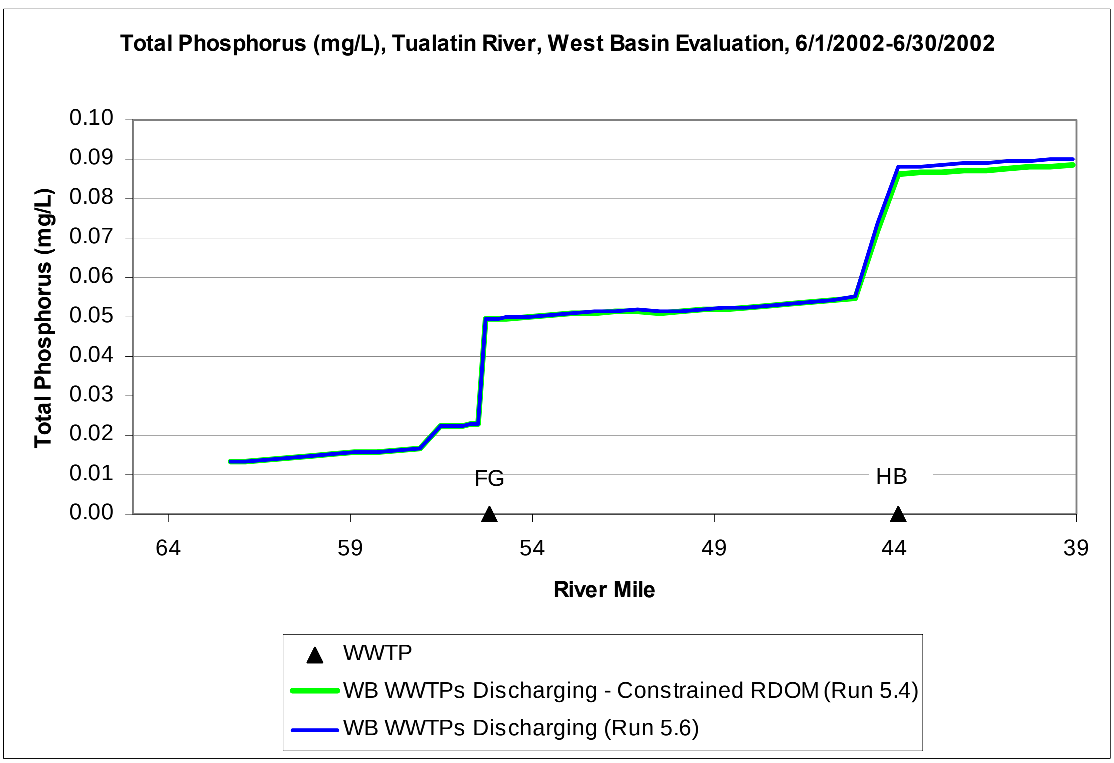

Phosphate (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Phosphate (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

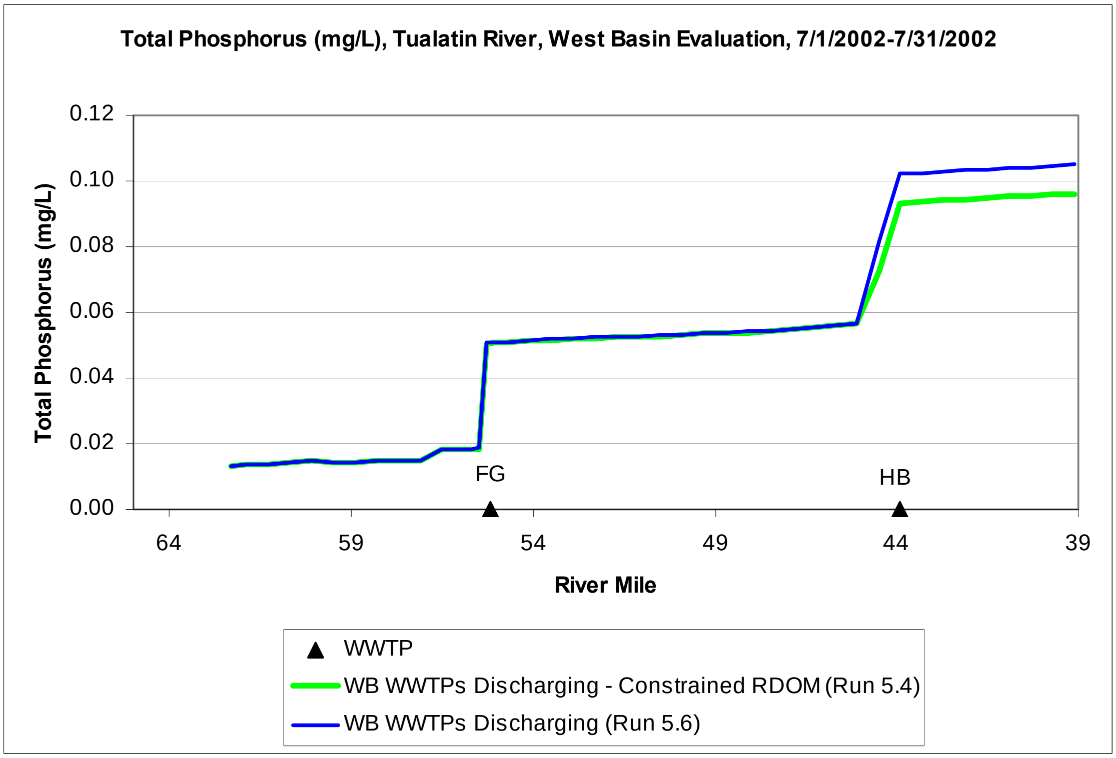

Phosphate (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Phosphate (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

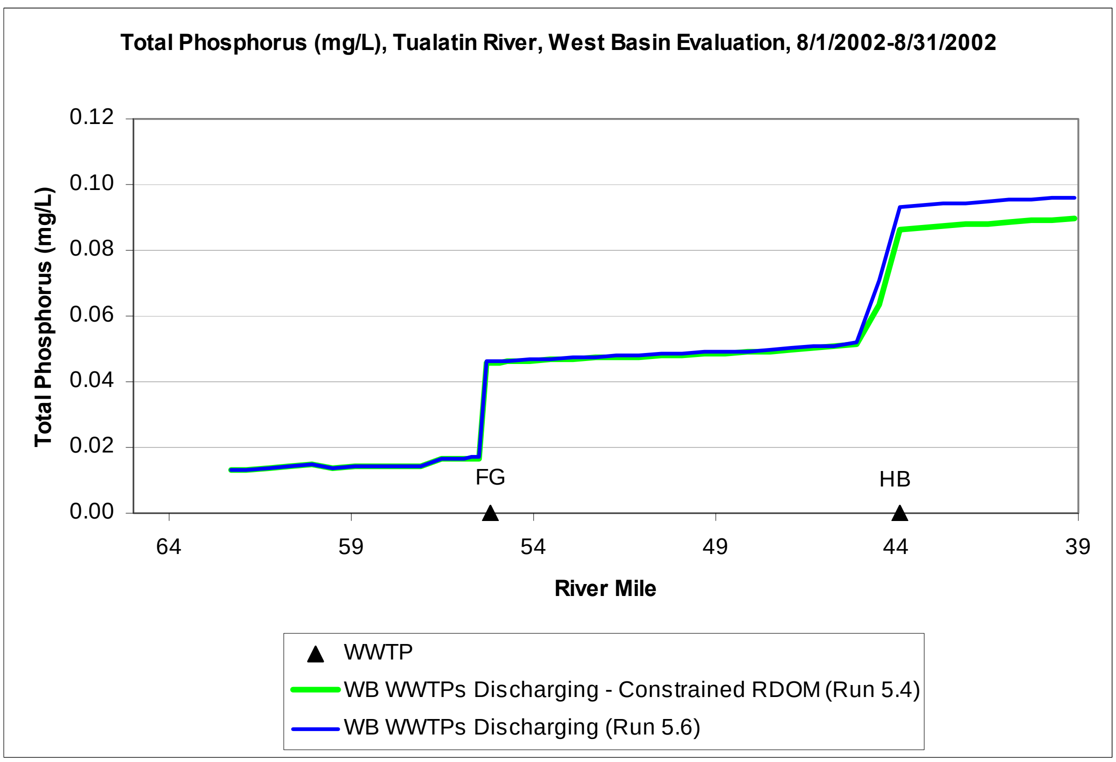

Phosphate (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Phosphate (mg/L)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

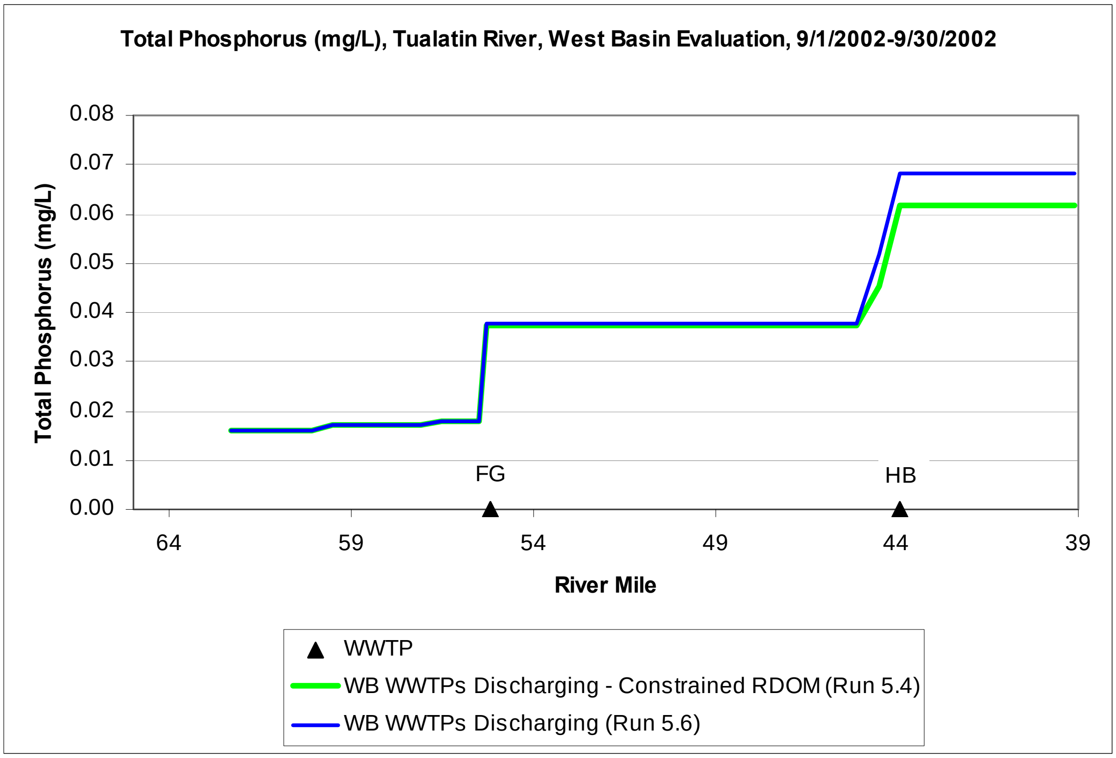
Longitudinal – Total Phosphorus



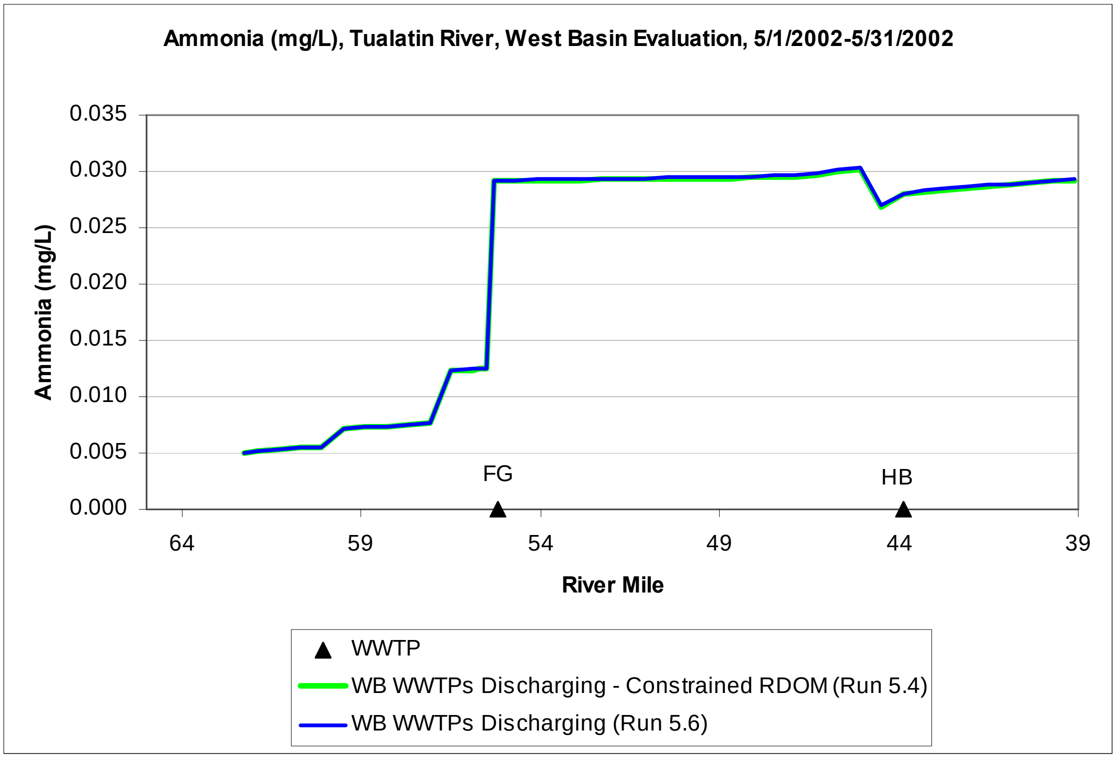


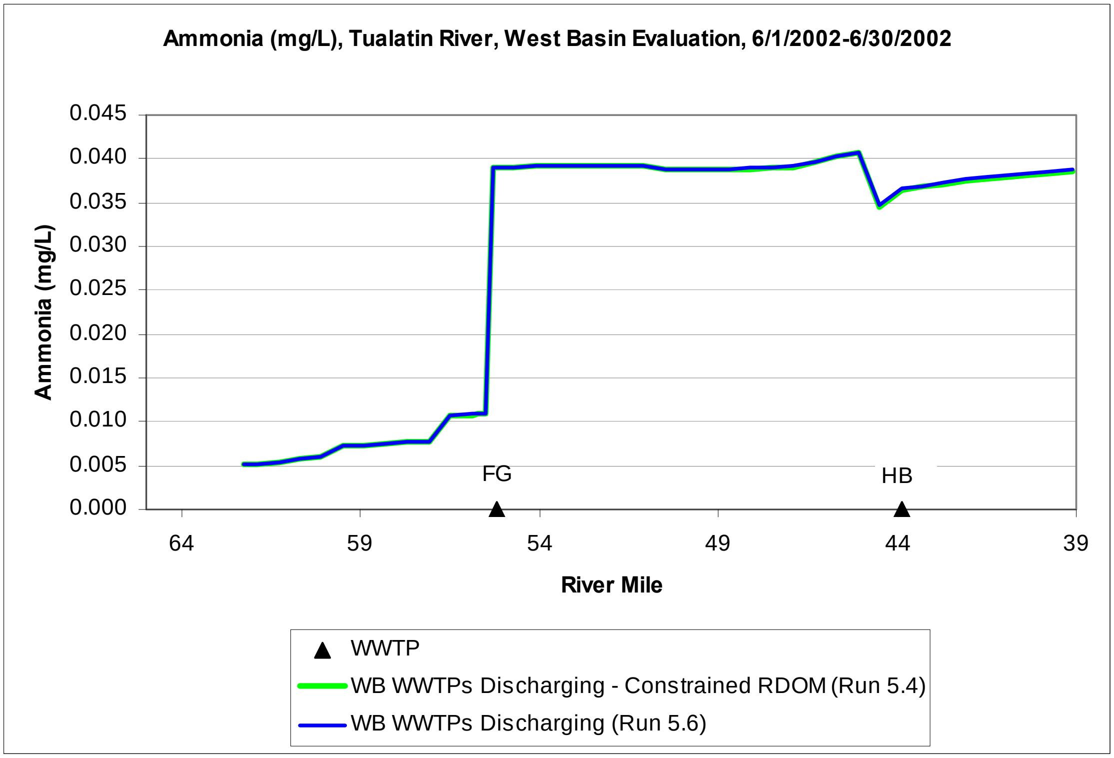

Total Phosphorus (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Total Phosphorus (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

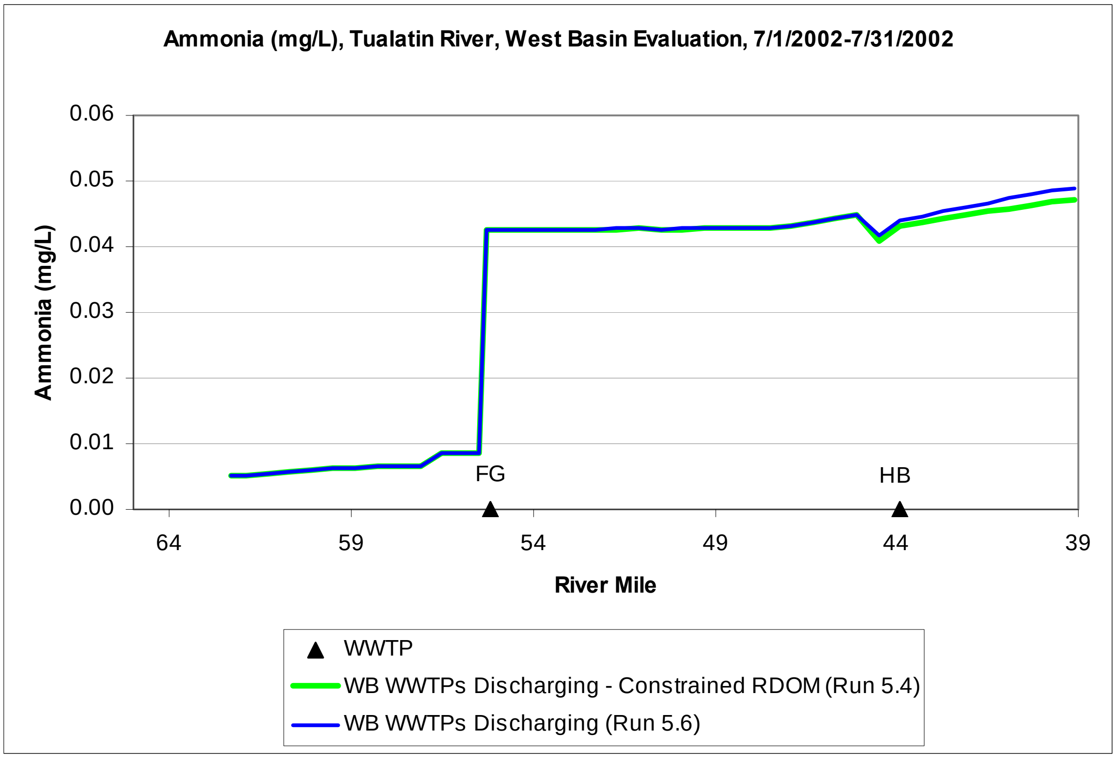

Total Phosphorus (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Total Phosphorus (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

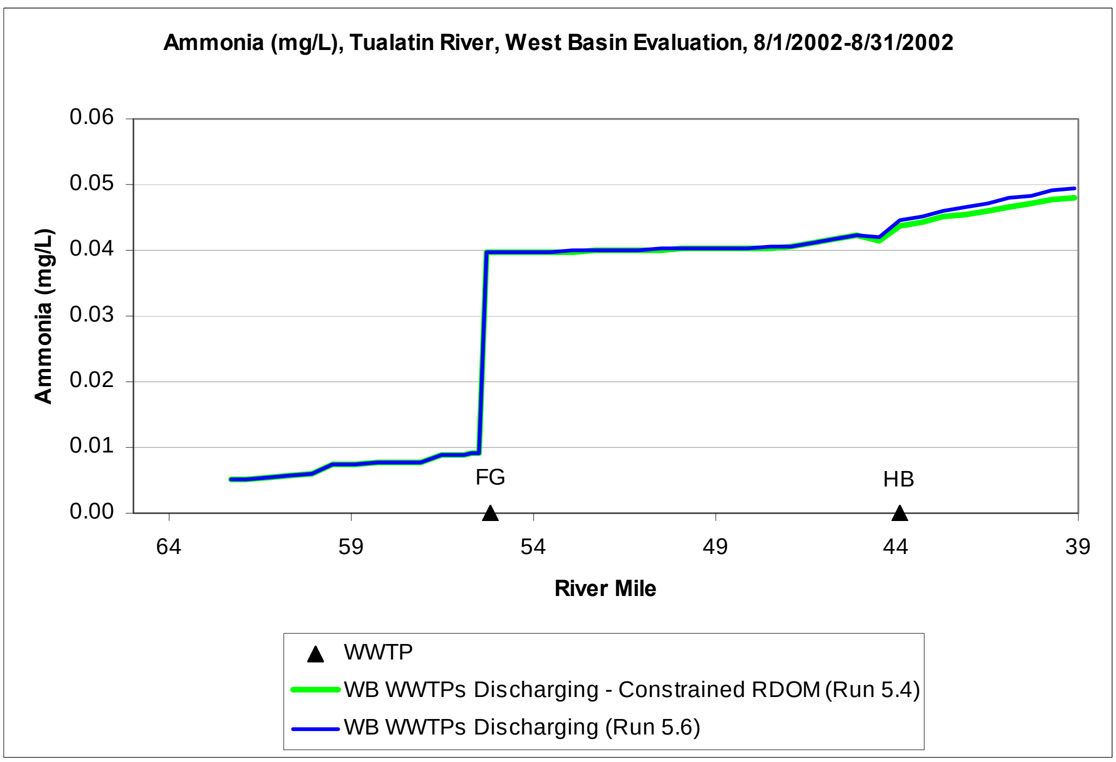

Total Phosphorus (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Total Phosphorus (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

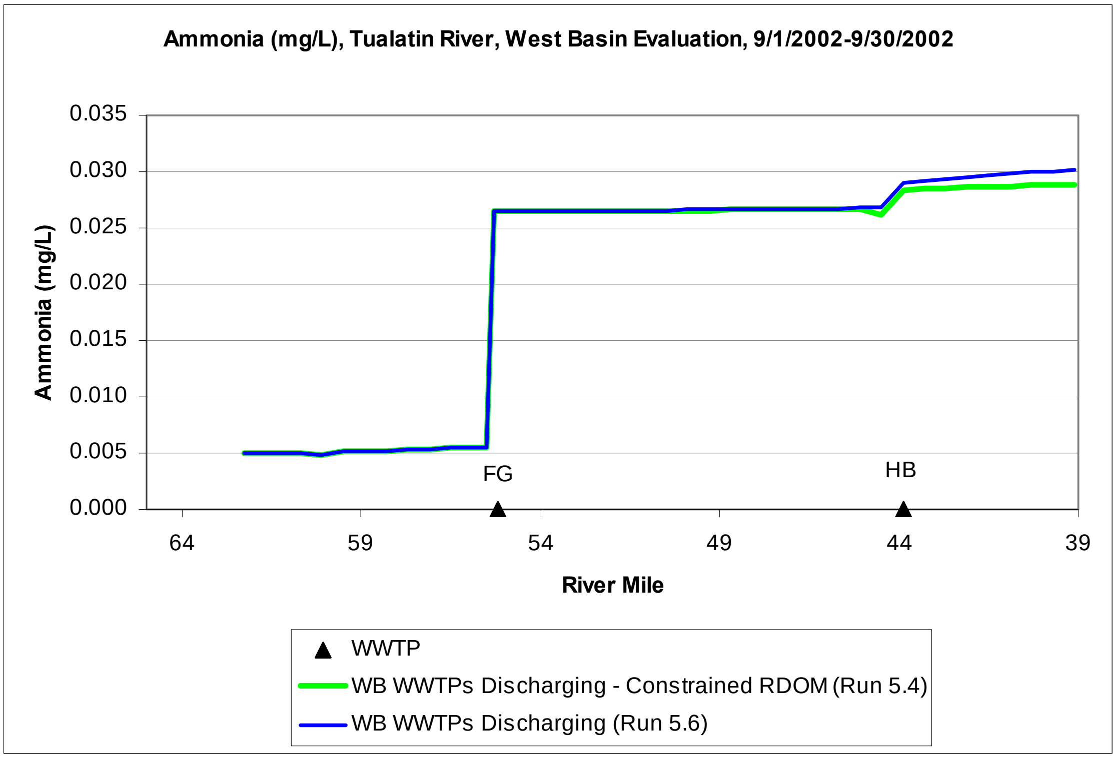
Longitudinal – Ammonia (NH_4 as N)



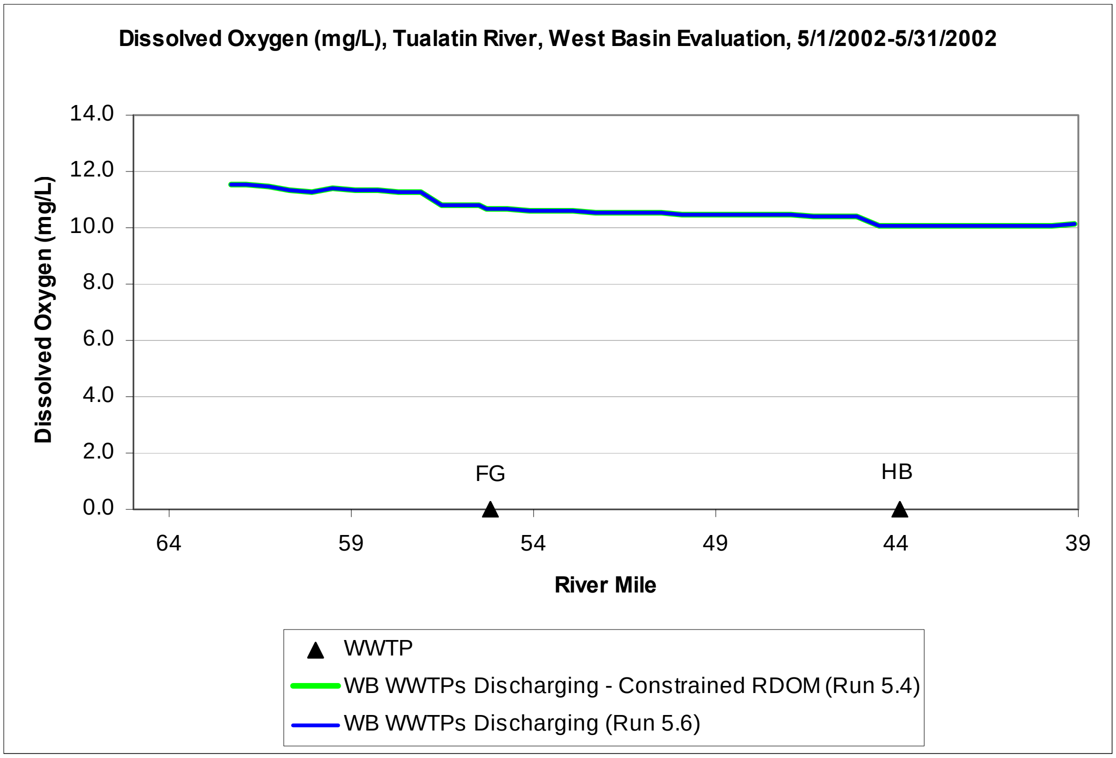


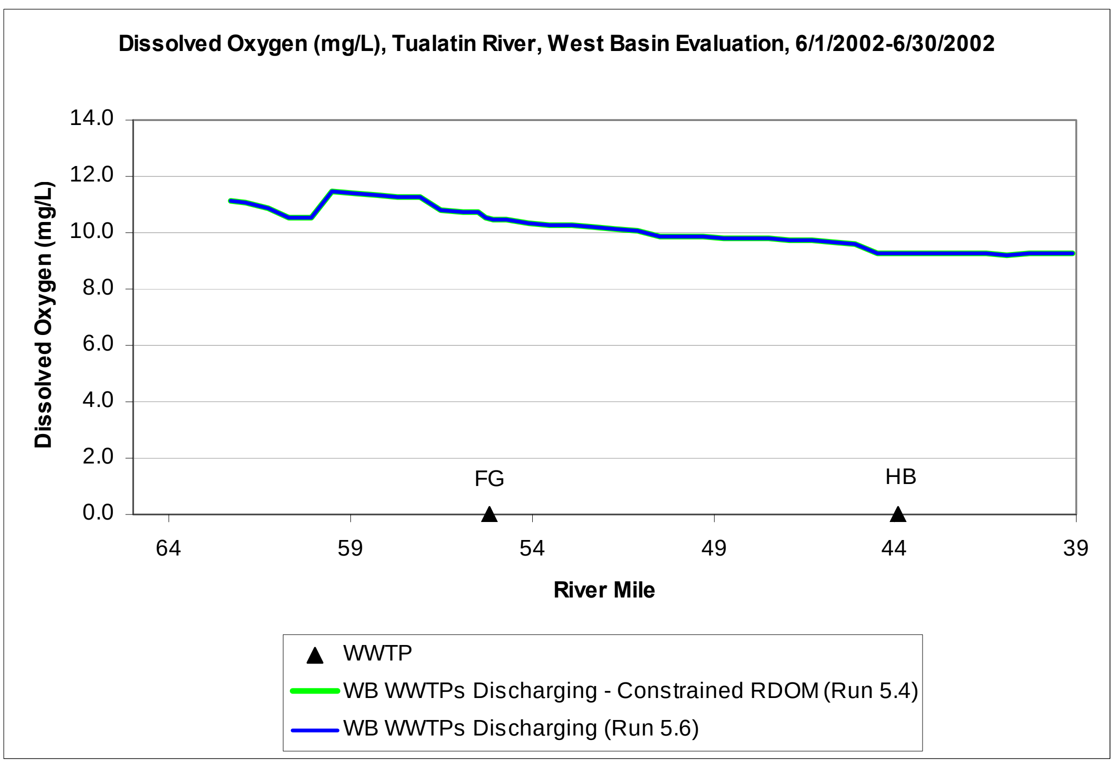

Ammonia (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Ammonia (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

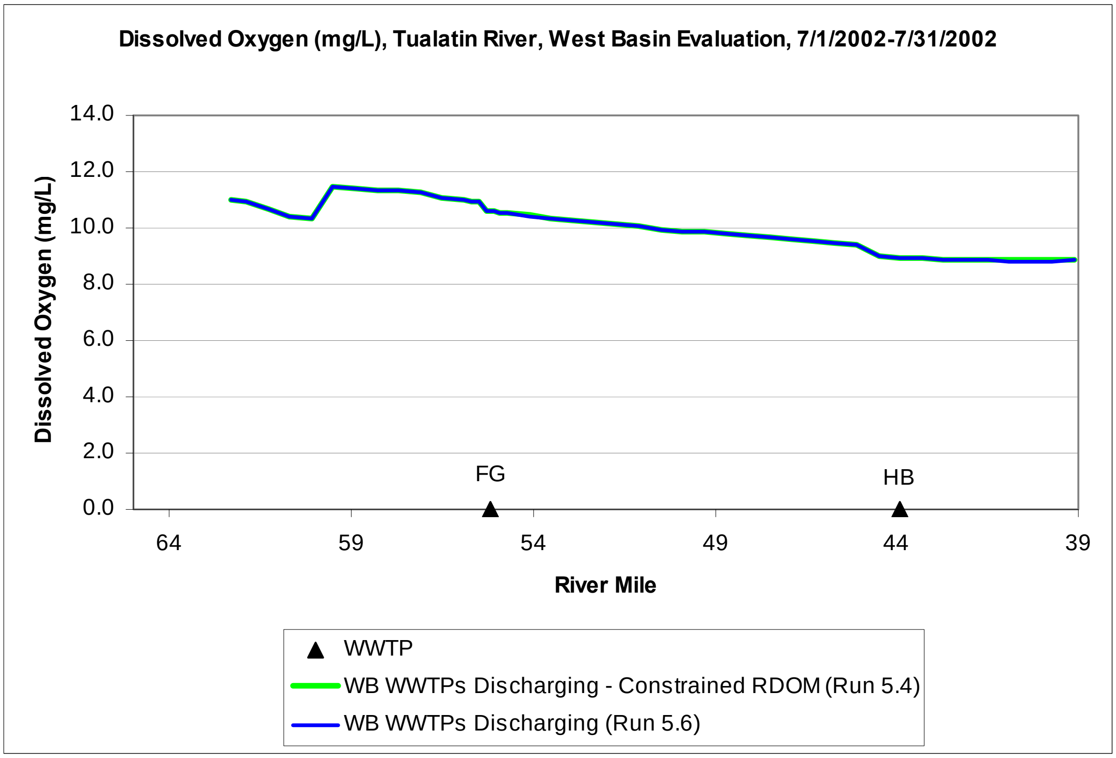

Ammonia (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Ammonia (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)


Ammonia (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Ammonia (mg/L)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

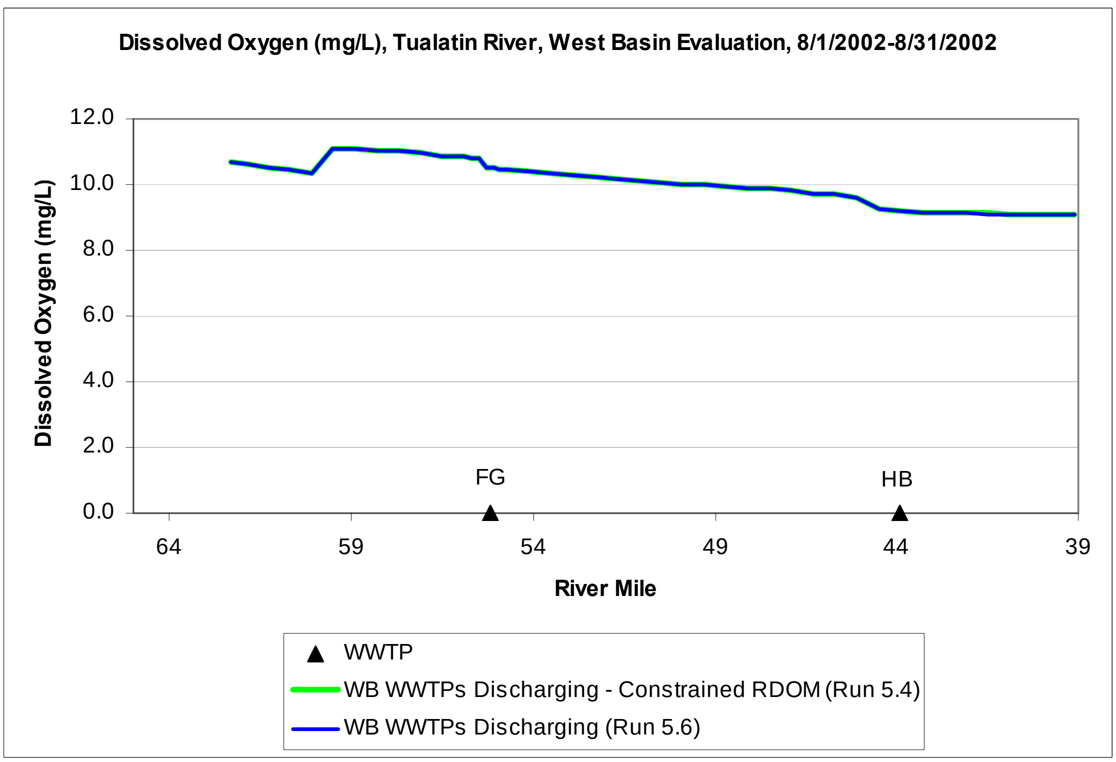
Longitudinal – Dissolved Oxygen



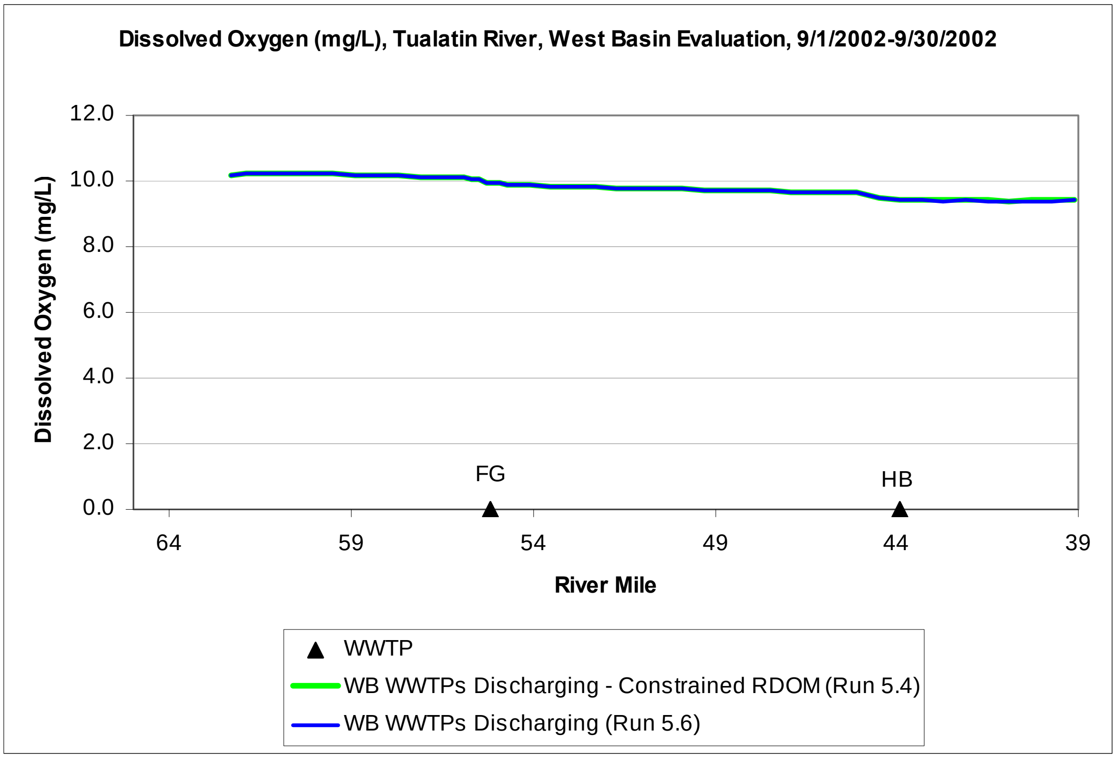




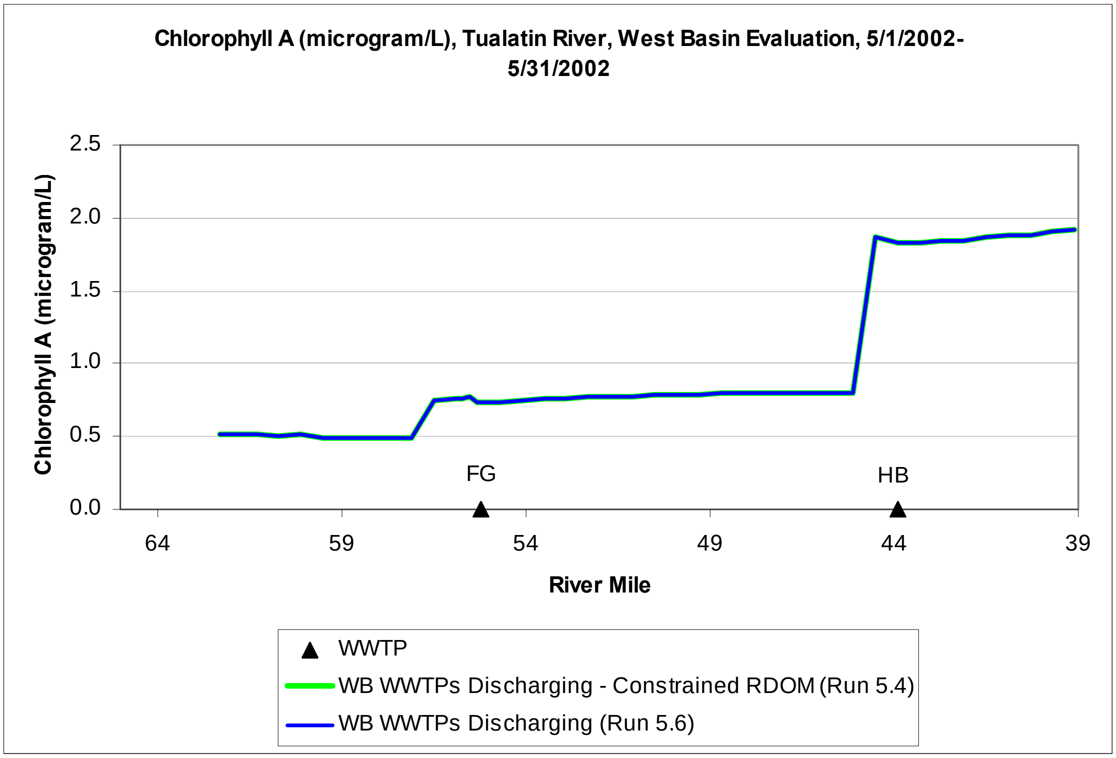
Dissolved Oxygen (mg/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Dissolved Oxygen (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

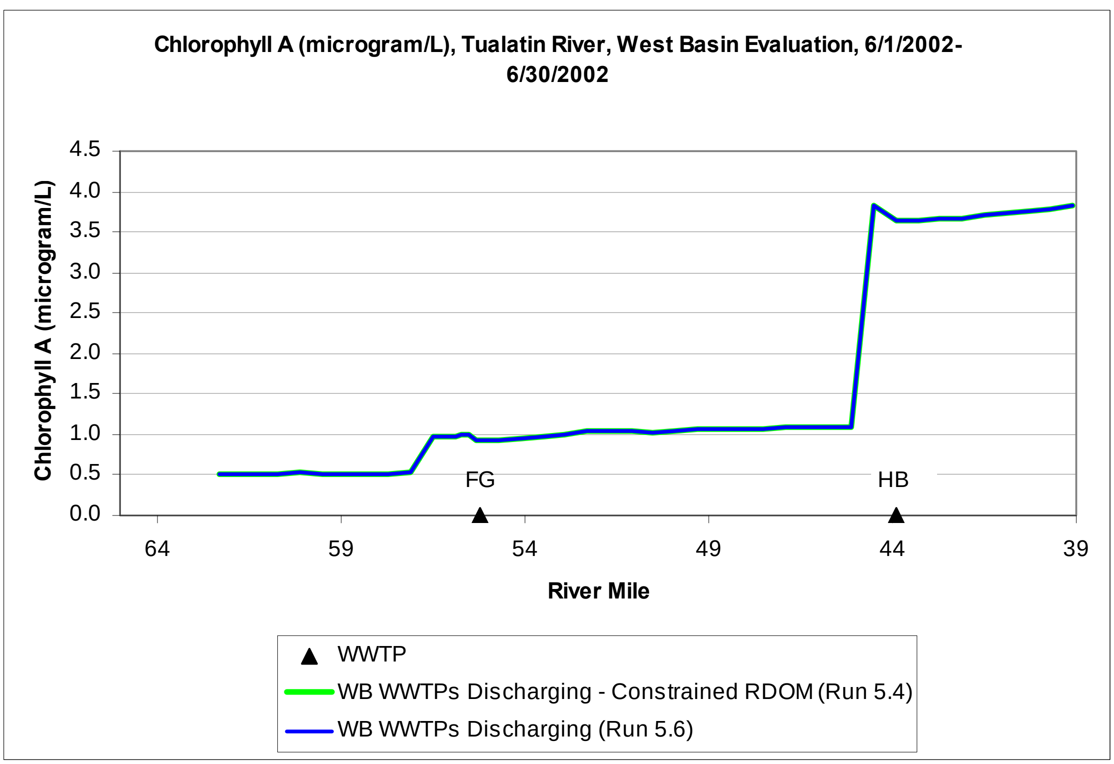


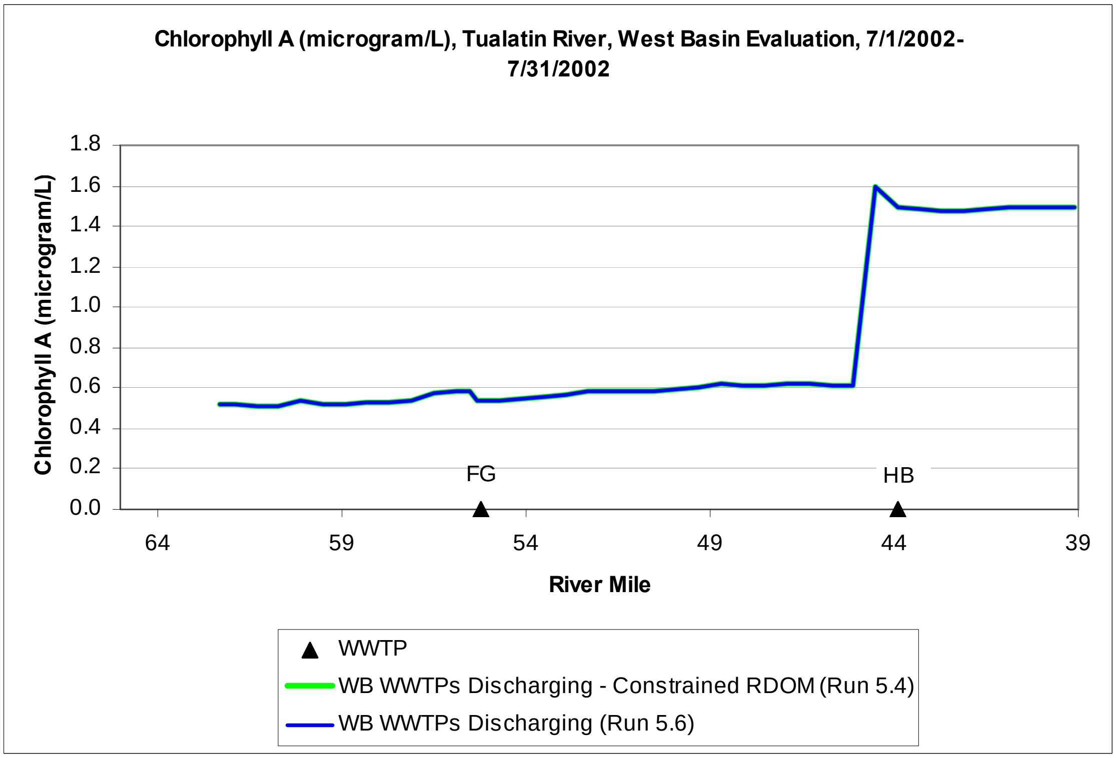
Dissolved Oxygen (mg/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Dissolved Oxygen (mg/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

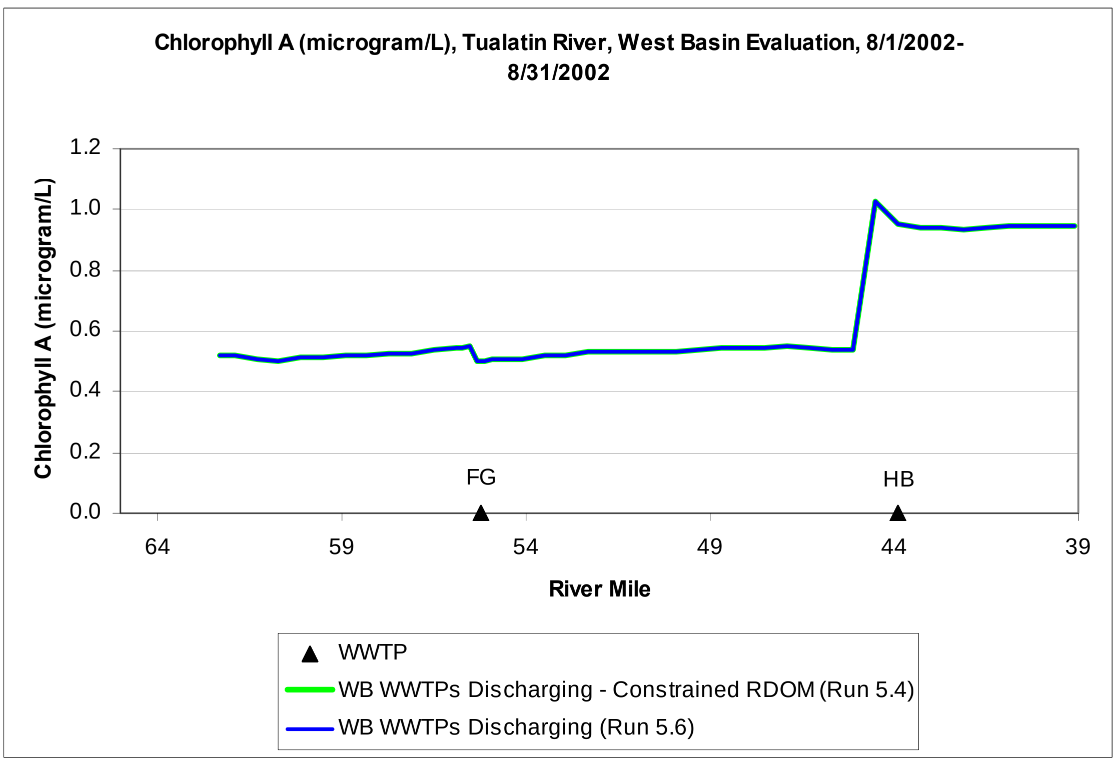

Dissolved Oxygen (mg/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Dissolved Oxygen (mg/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

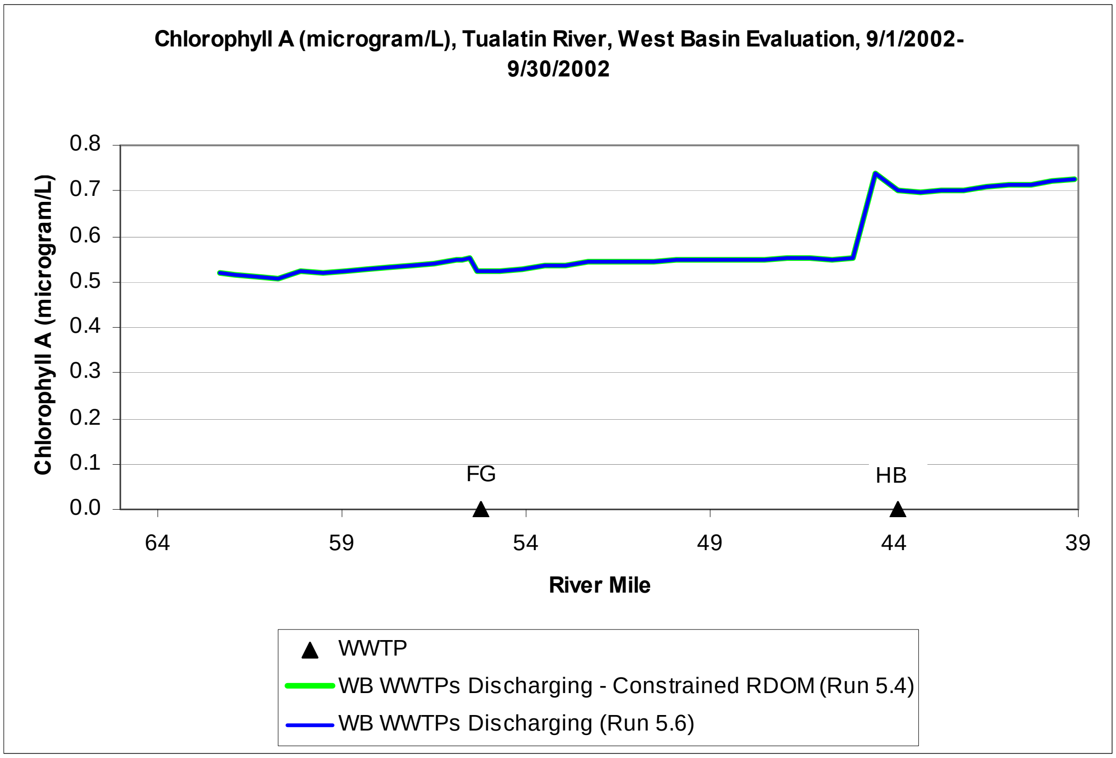
Longitudinal – Chlorophyll A



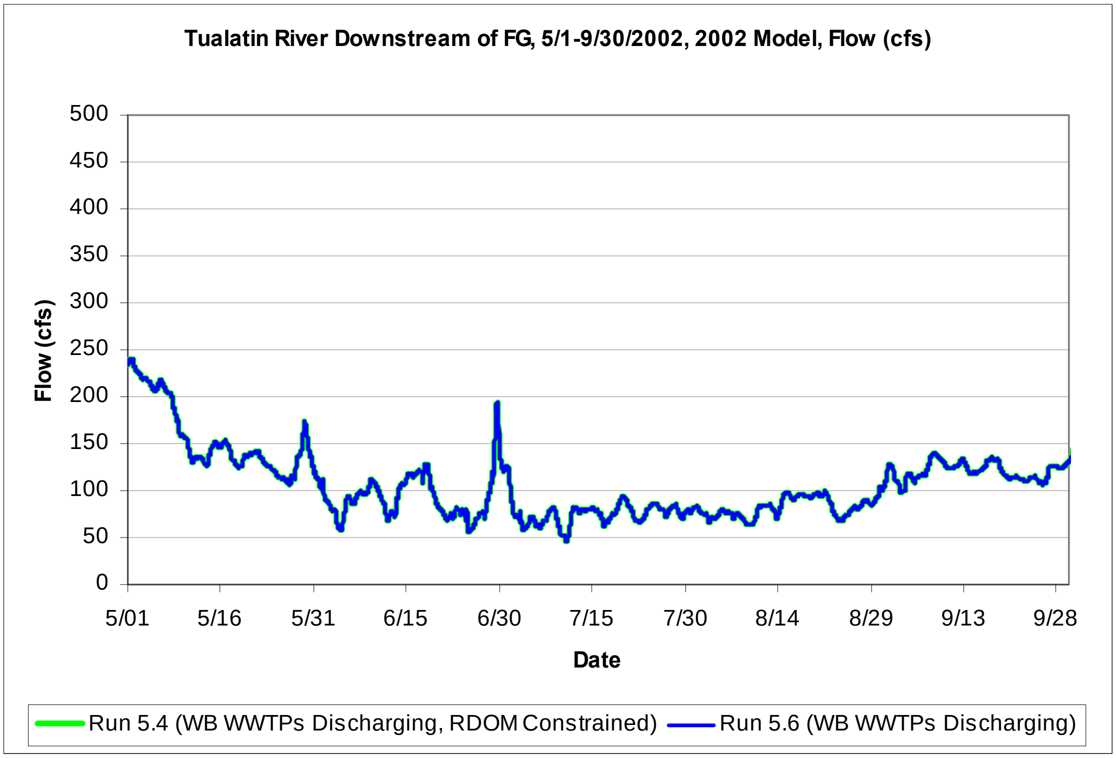


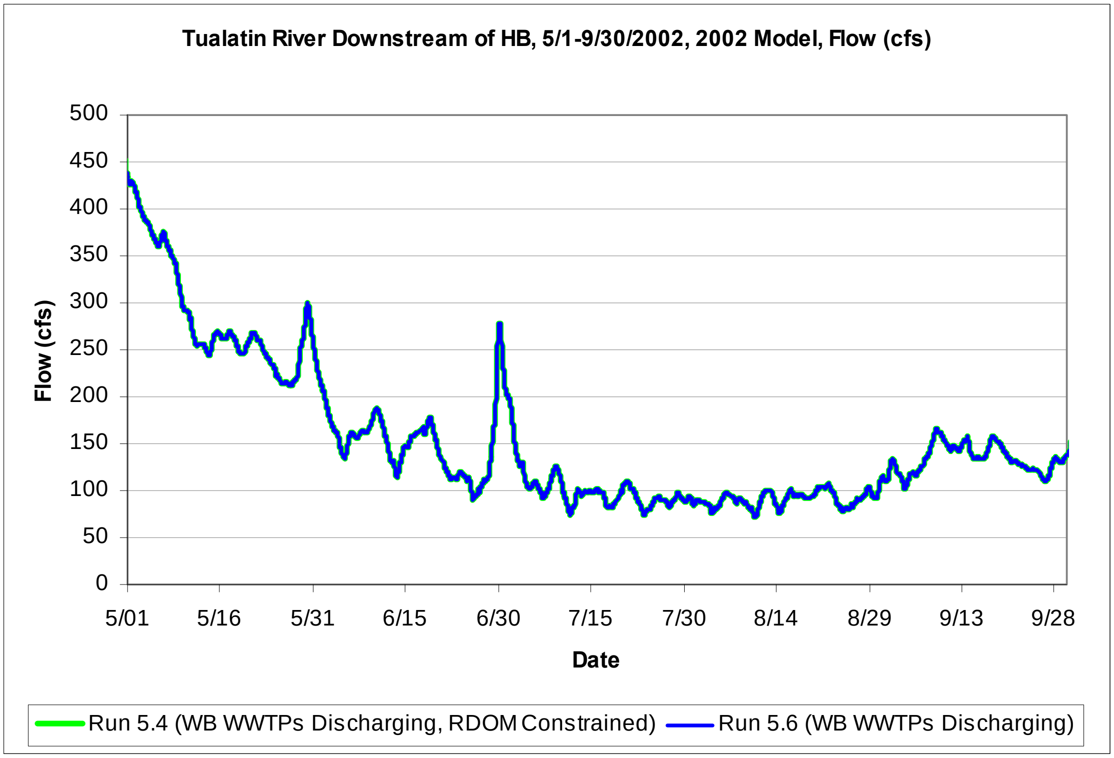

Chlorophyll A (microgram/L), Tualatin River, West Basin Evaluation, 7/1/2002-7/31/2002
Chlorophyll A (microgram/L)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

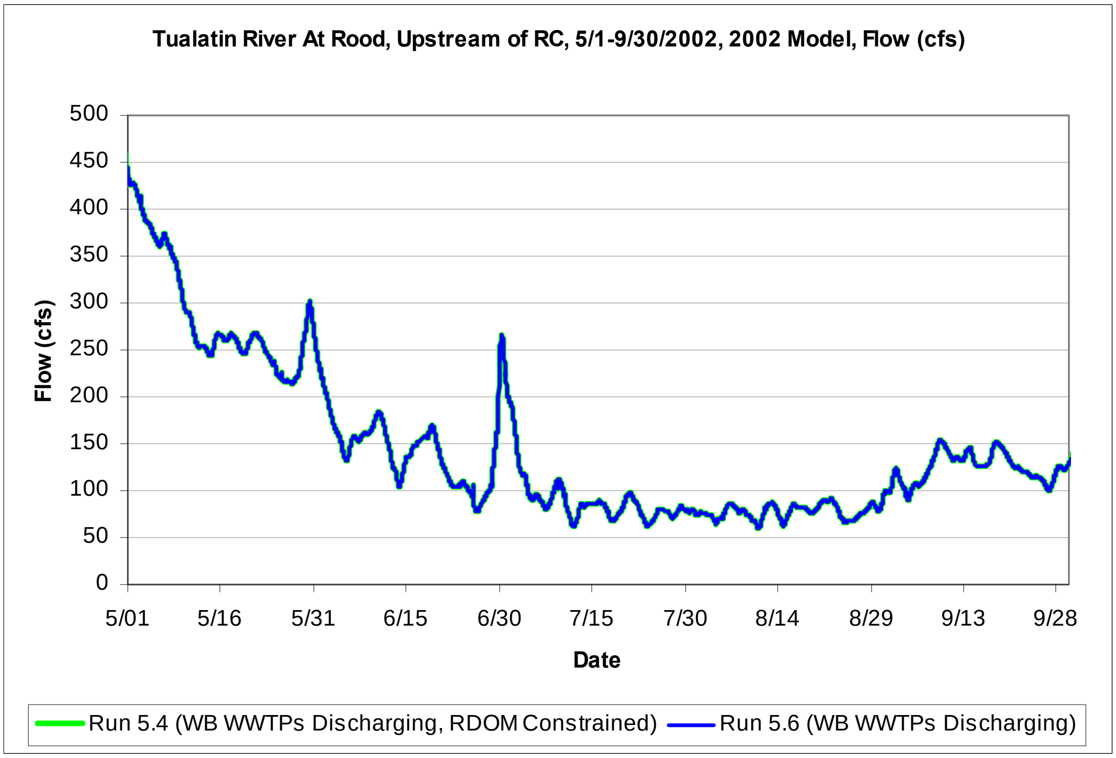

Chlorophyll A (microgram/L), Tualatin River, West Basin Evaluation, 8/1/2002-8/31/2002
Chlorophyll A (microgram/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)


Chlorophyll A (microgram/L), Tualatin River, West Basin Evaluation, 9/1/2002-9/30/2002
Chlorophyll A (microgram/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
FG
HB
64
59
54
49
44
39
River Mile
WWTP
WB WWTPs Discharging - Constrained RDOM (Run 5.4)
WB WWTPs Discharging (Run 5.6)

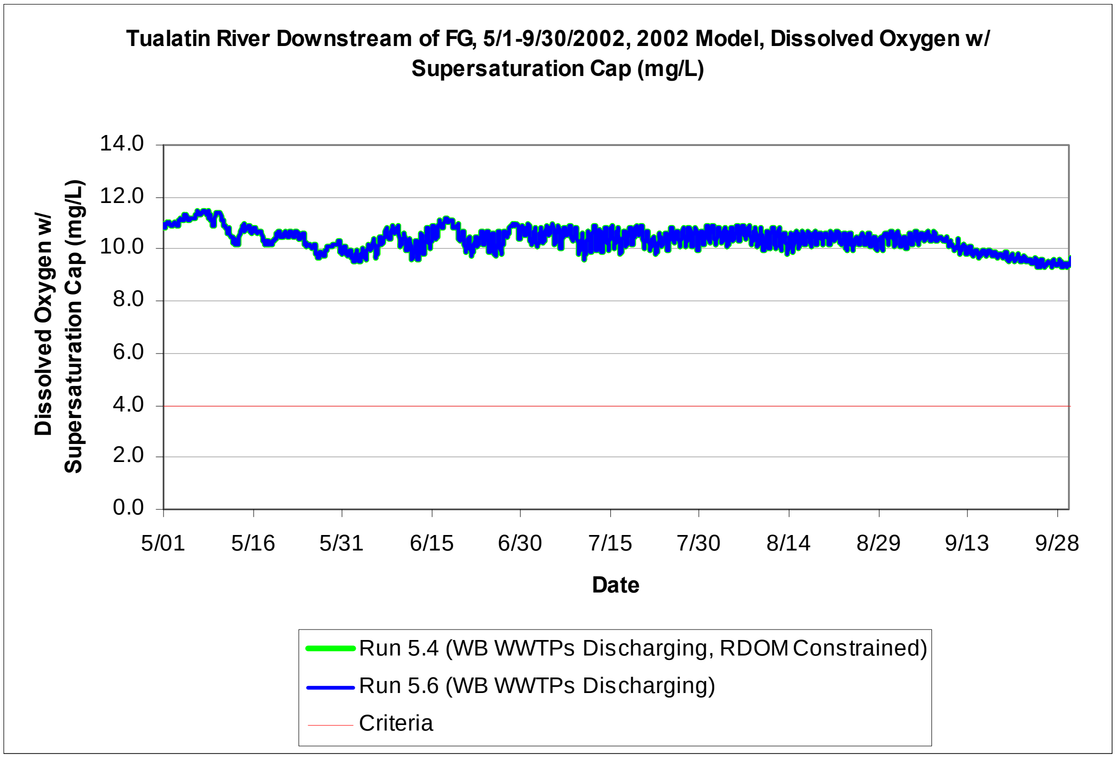
Time Series – Flow

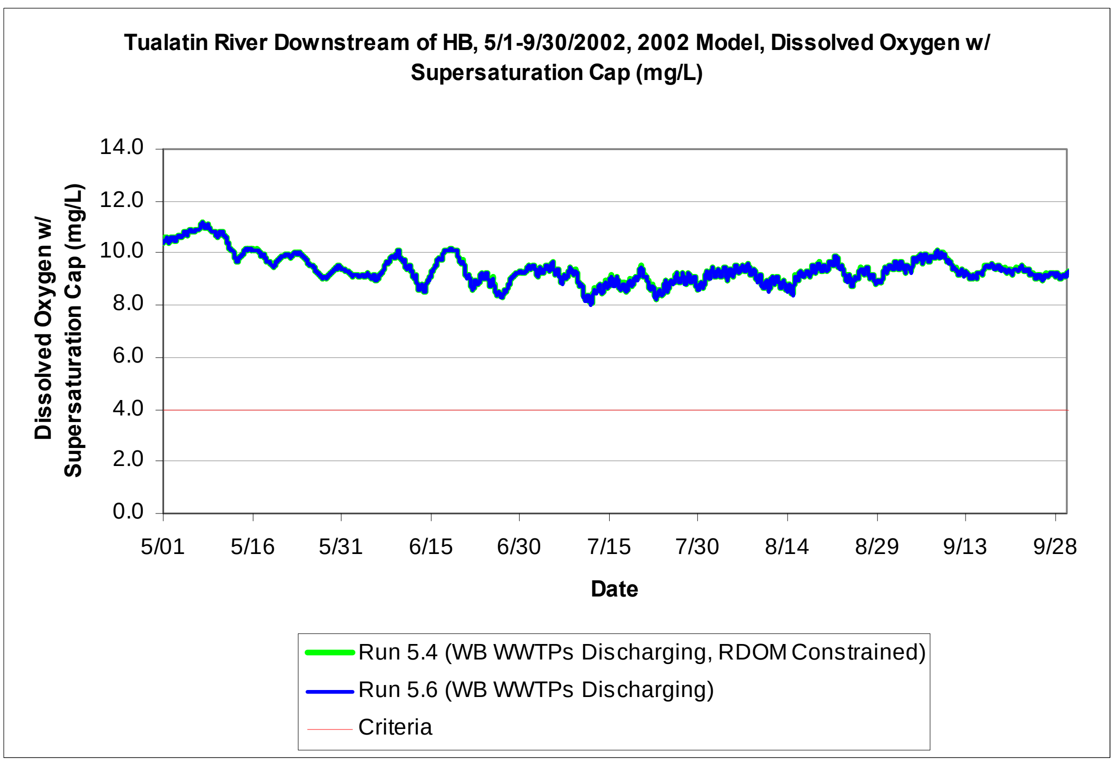


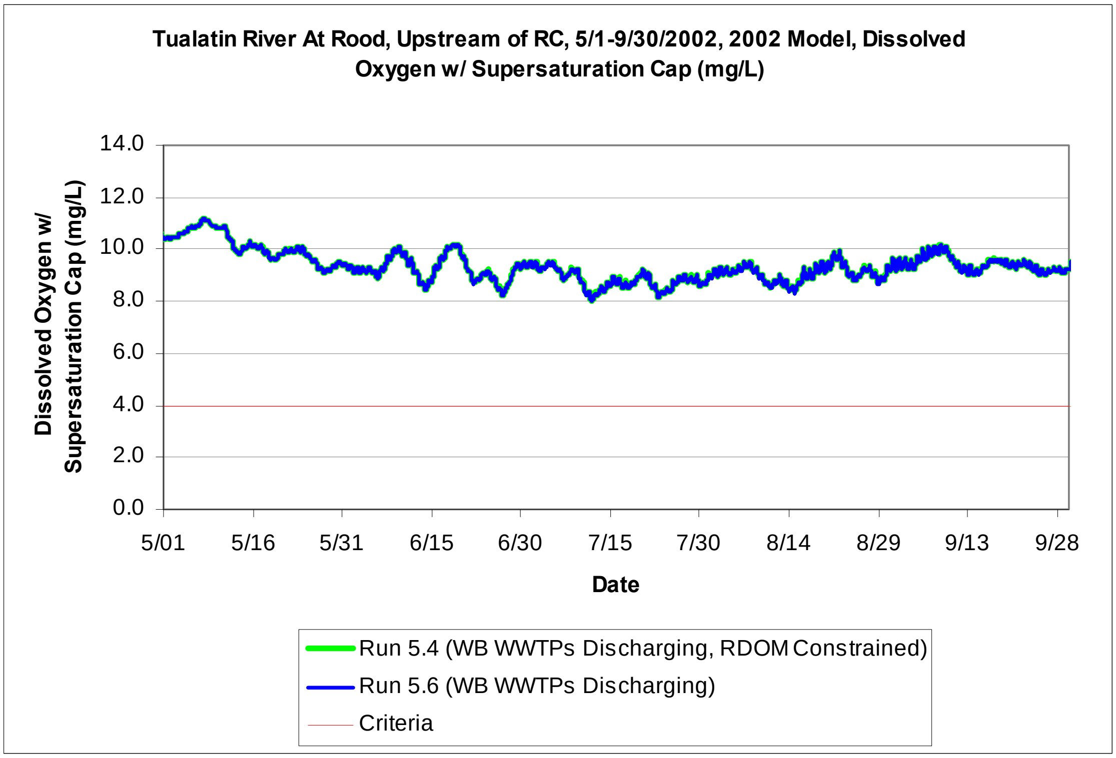



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Flow (cfs)
Flow (cfs)
500
450
400
350
300
250
200
150
100
50
0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (WB WWTPs Discharging, RDOM Constrained)
Run 5.6 (WB WWTPs Discharging)

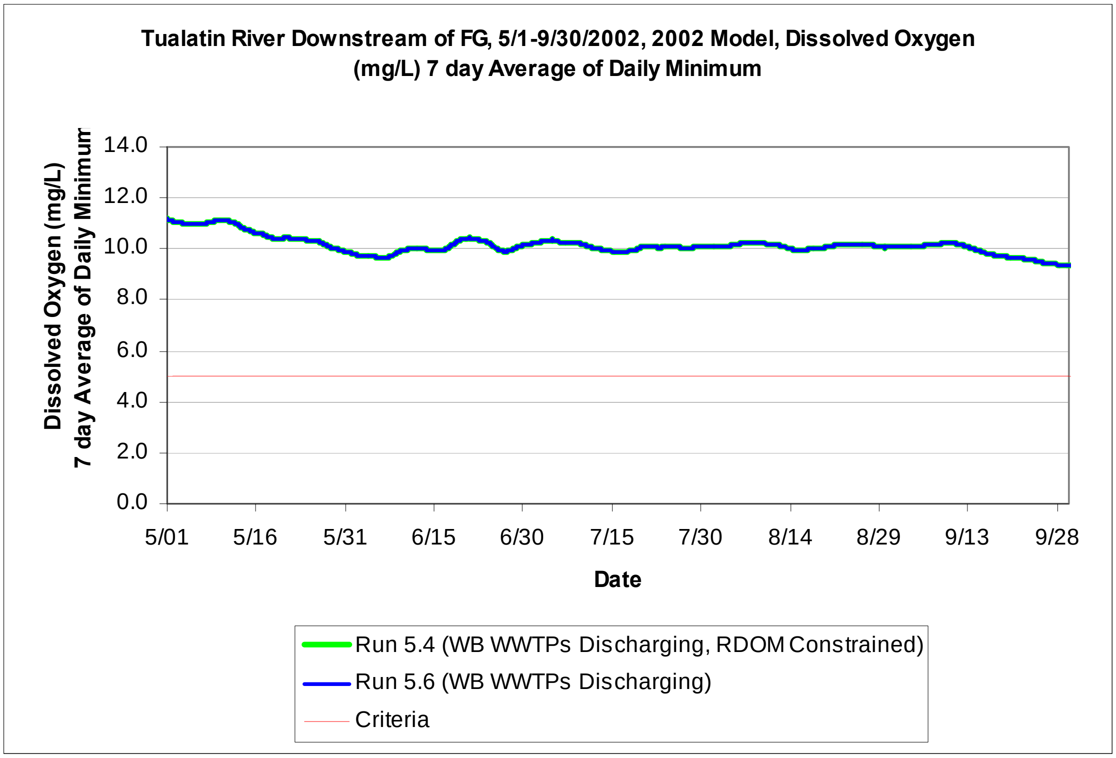
Time Series – Dissolved Oxygen (Instantaneous with Supersaturation Cap)

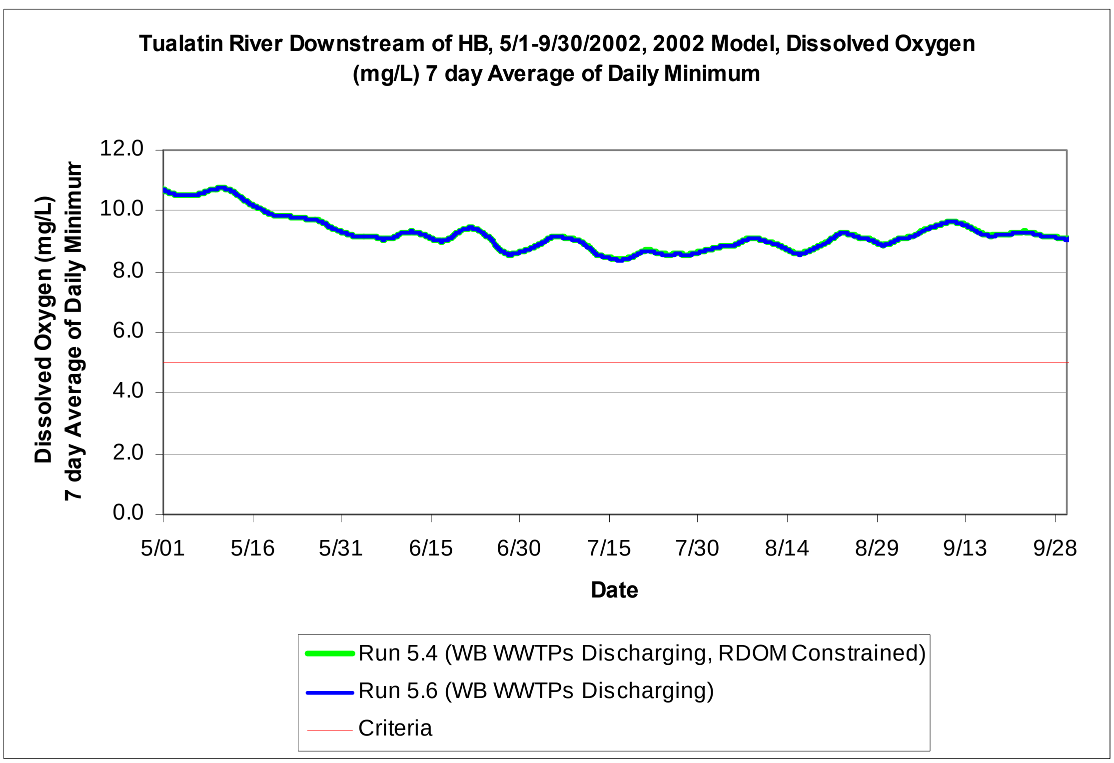


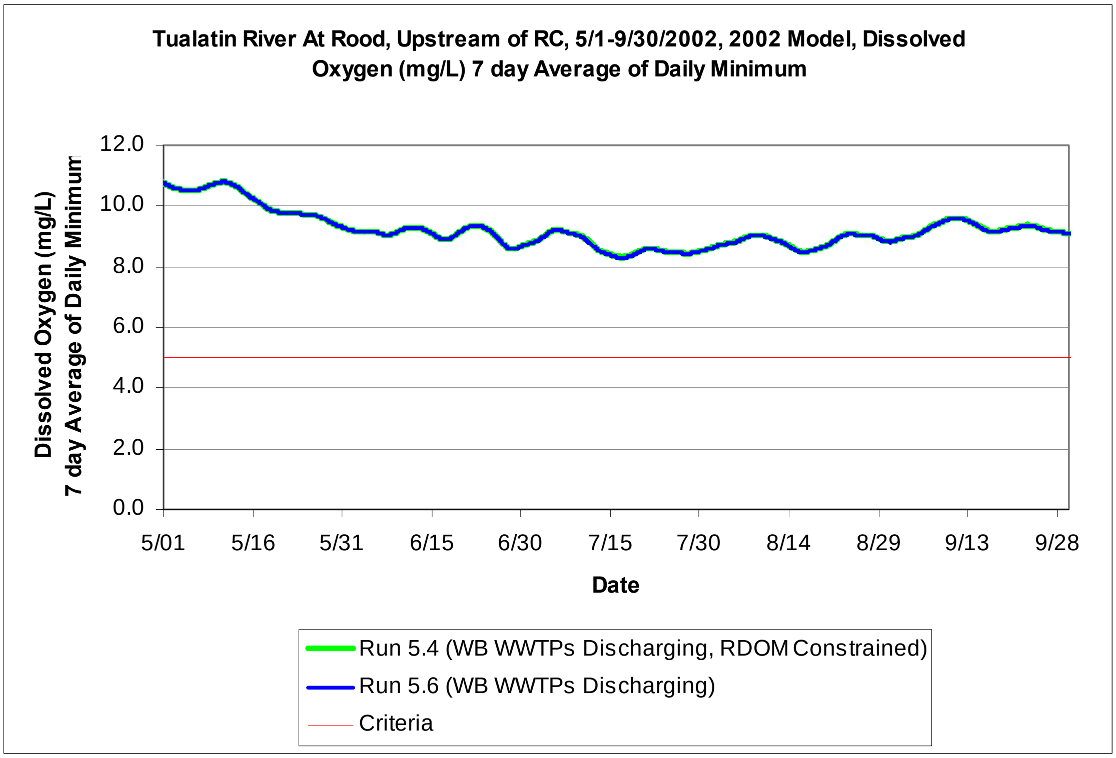



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Dissolved Oxygen w/ Supersaturation Cap (mg/L)
Dissolved Oxygen w/ Supersaturation Cap (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (WB WWTPs Discharging, RDOM Constrained)
Run 5.6 (WB WWTPs Discharging)
Criteria

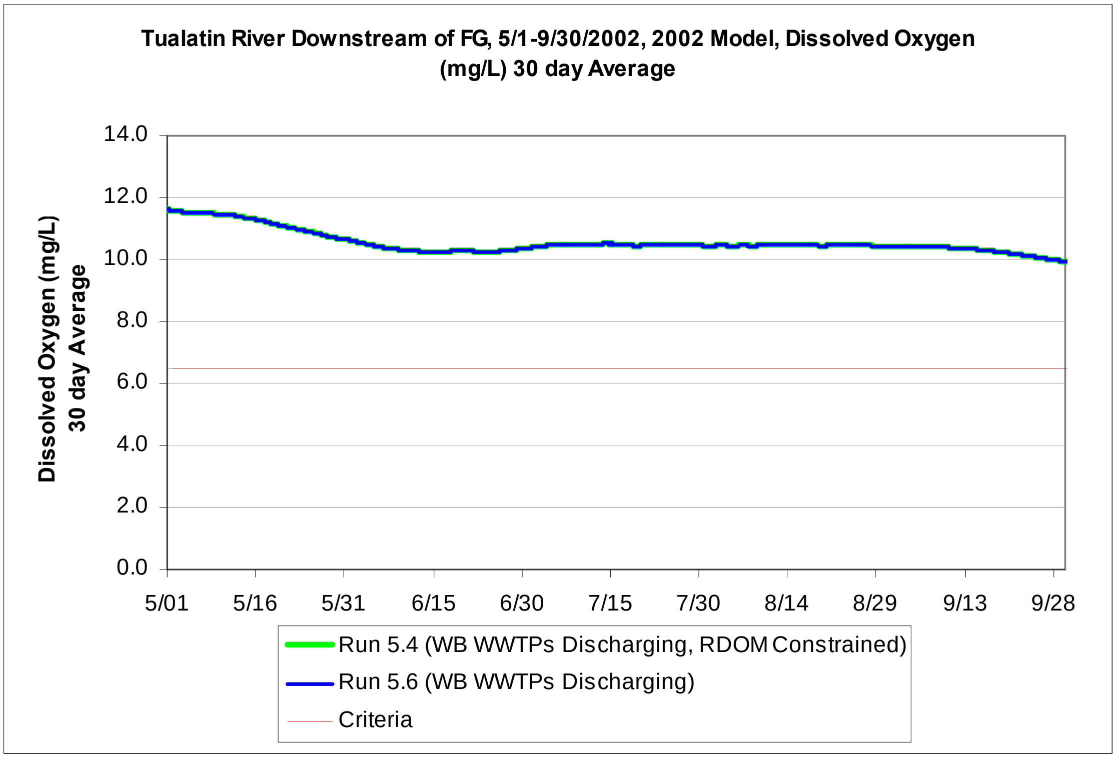
Time Series – Dissolved Oxygen (7-Day Average of Daily Minimum)

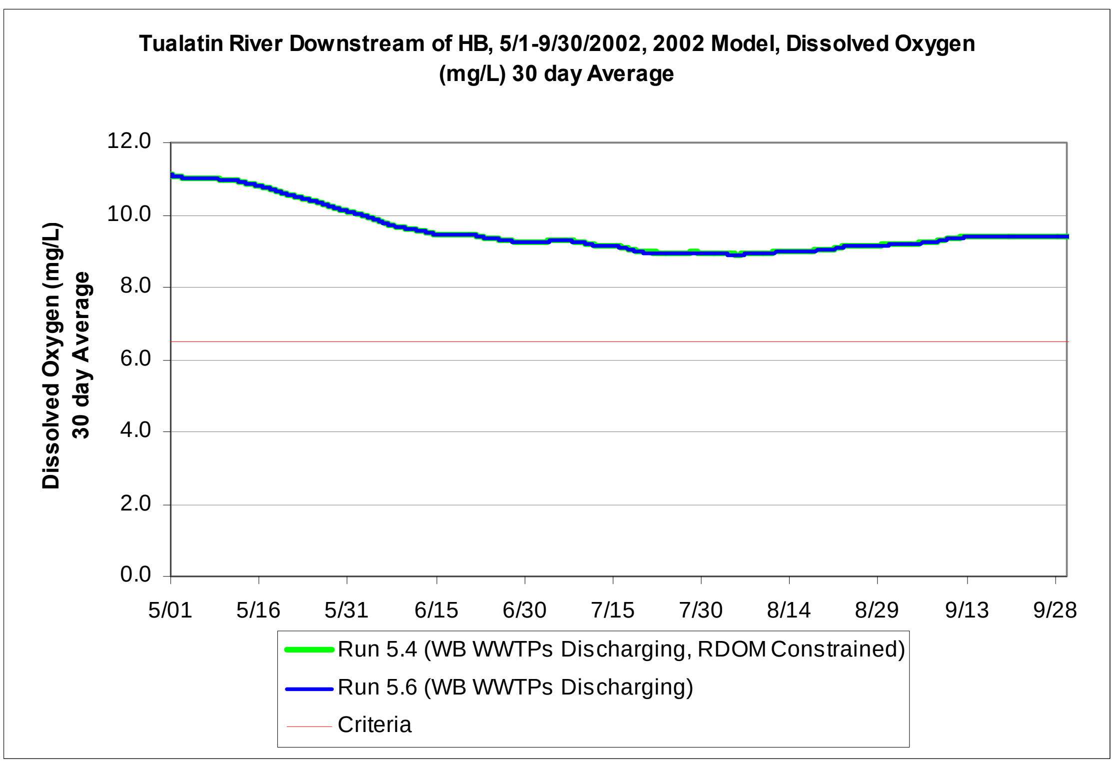


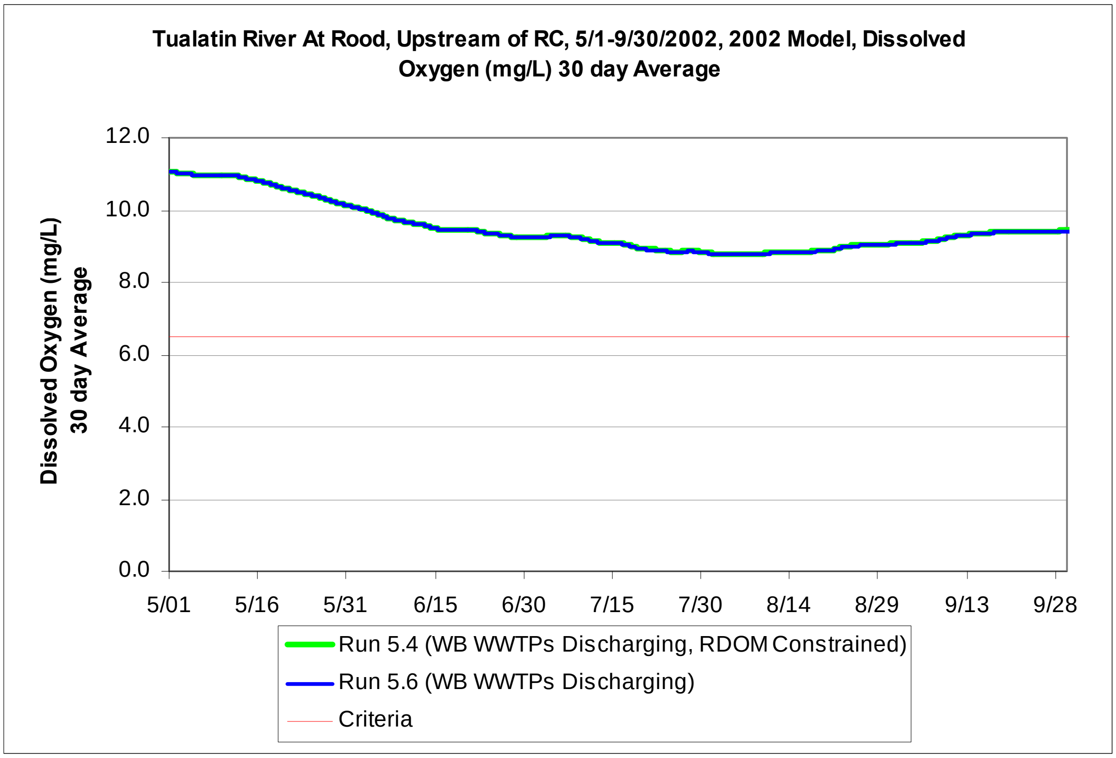



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Dissolved Oxygen (mg/L) 7 day Average of Daily Minimum
Dissolved Oxygen (mg/L)
7 day Average of Daily Minimum
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (WB WWTPs Discharging, RDOM Constrained)
Run 5.6 (WB WWTPs Discharging)
Criteria

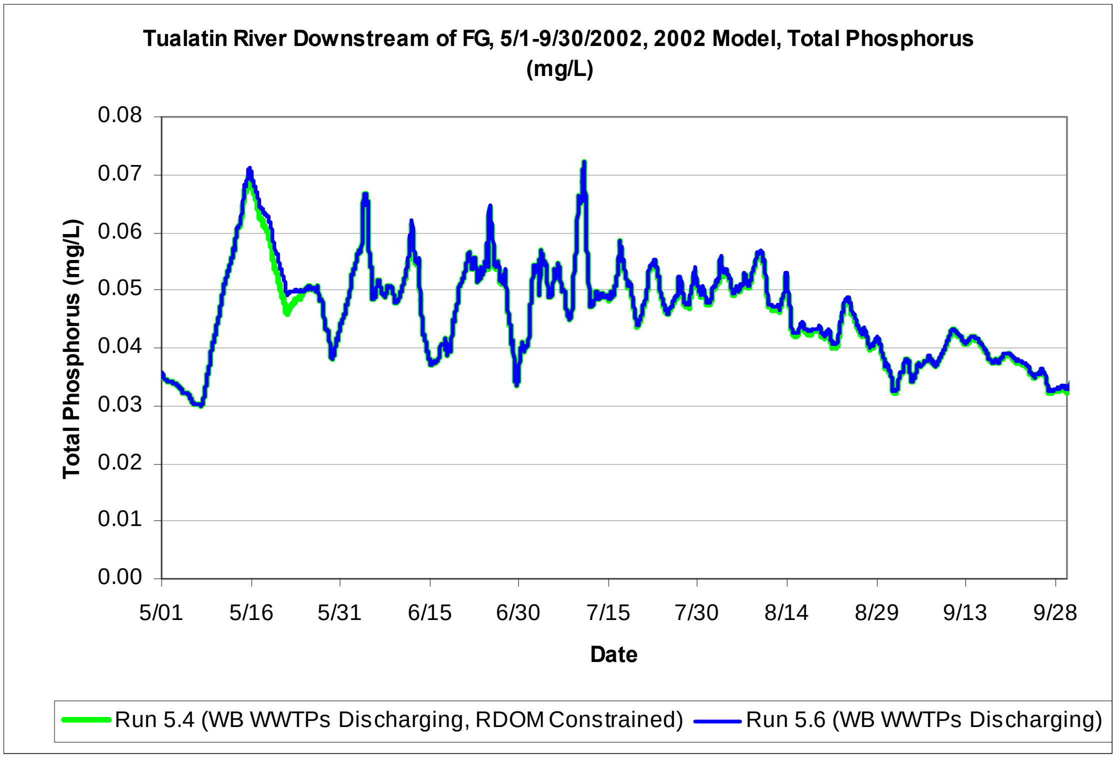
Time Series – Dissolved Oxygen (30-Day Average)

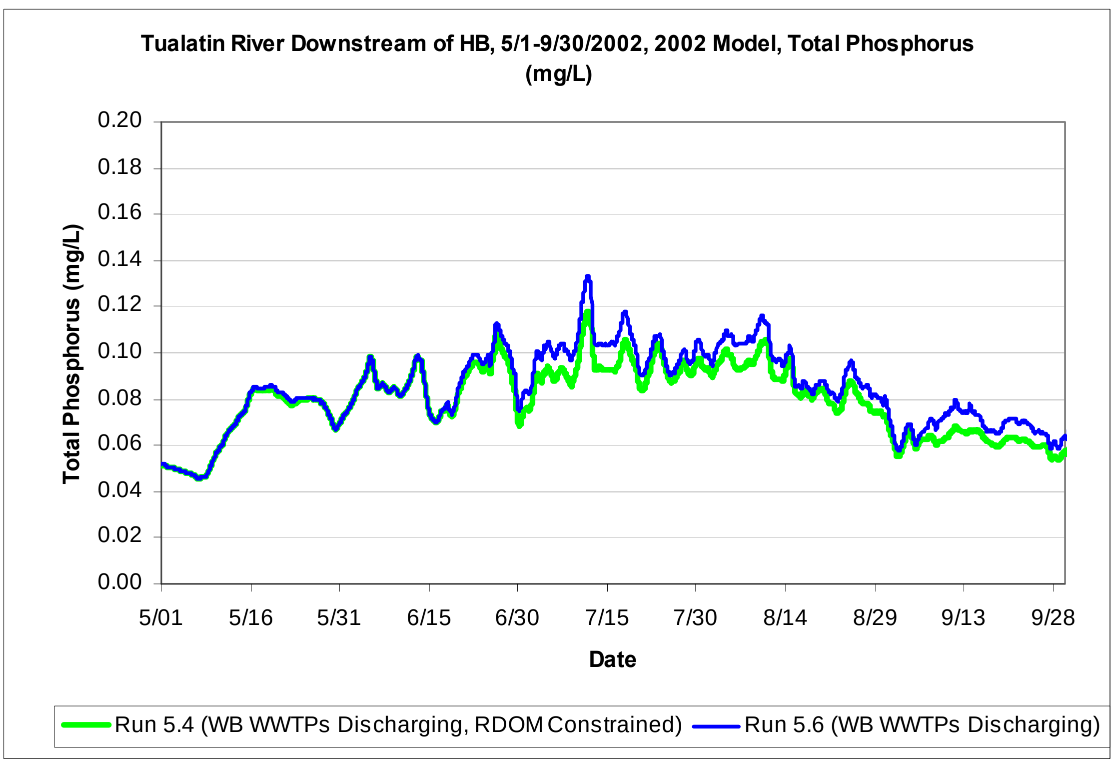


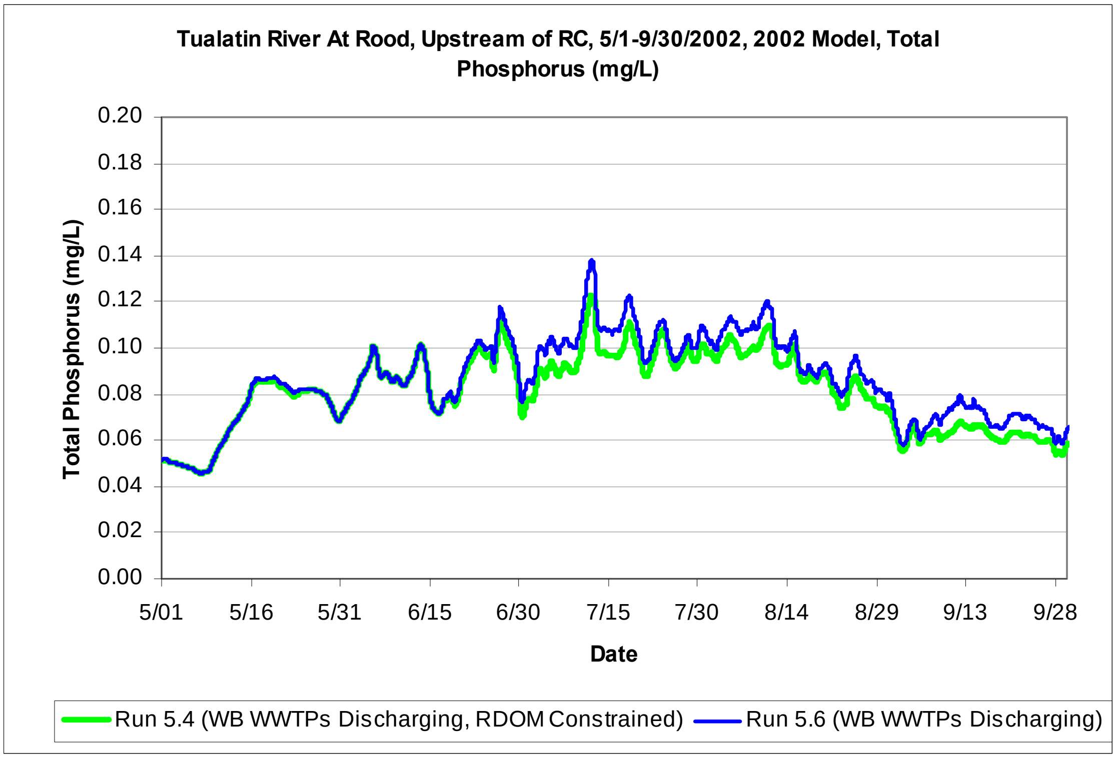



Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Dissolved Oxygen (mg/L) 30 day Average
Dissolved Oxygen (mg/L) 30 day Average
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Run 5.4 (WB WWTPs Discharging, RDOM Constrained)
Run 5.6 (WB WWTPs Discharging)
Criteria

Time Series – Total Phosphorus






Tualatin River At Rood, Upstream of RC, 5/1-9/30/2002, 2002 Model, Total Phosphorus (mg/L)
Total Phosphorus (mg/L)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
5/01
5/16
5/31
6/15
6/30
7/15
7/30
8/14
8/29
9/13
9/28
Date
Run 5.4 (WB WWTPs Discharging, RDOM Constrained)
Run 5.6 (WB WWTPs Discharging)

Appendix H

CE-QUAL-W2 Water Surface Elevations and Segments

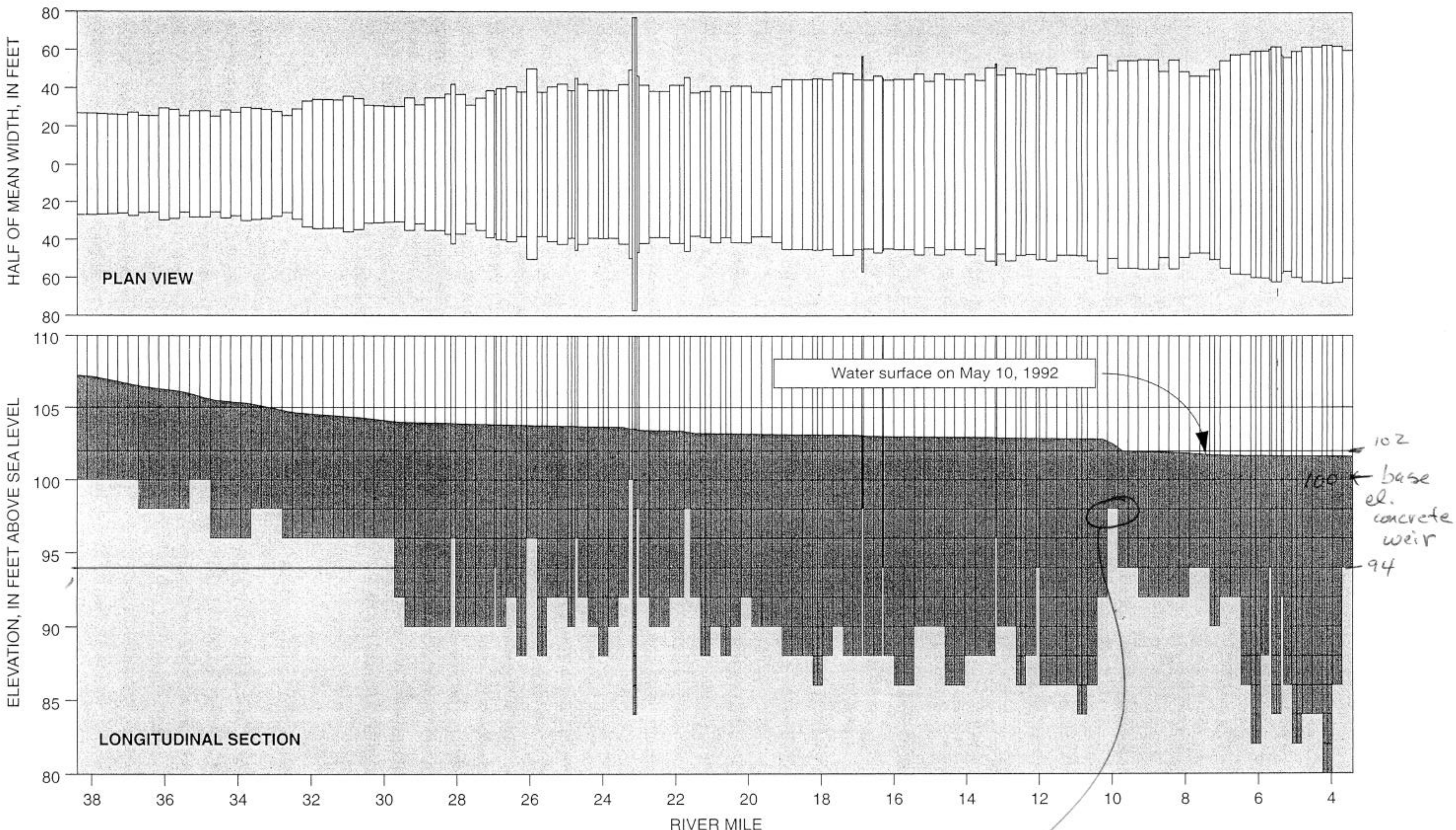
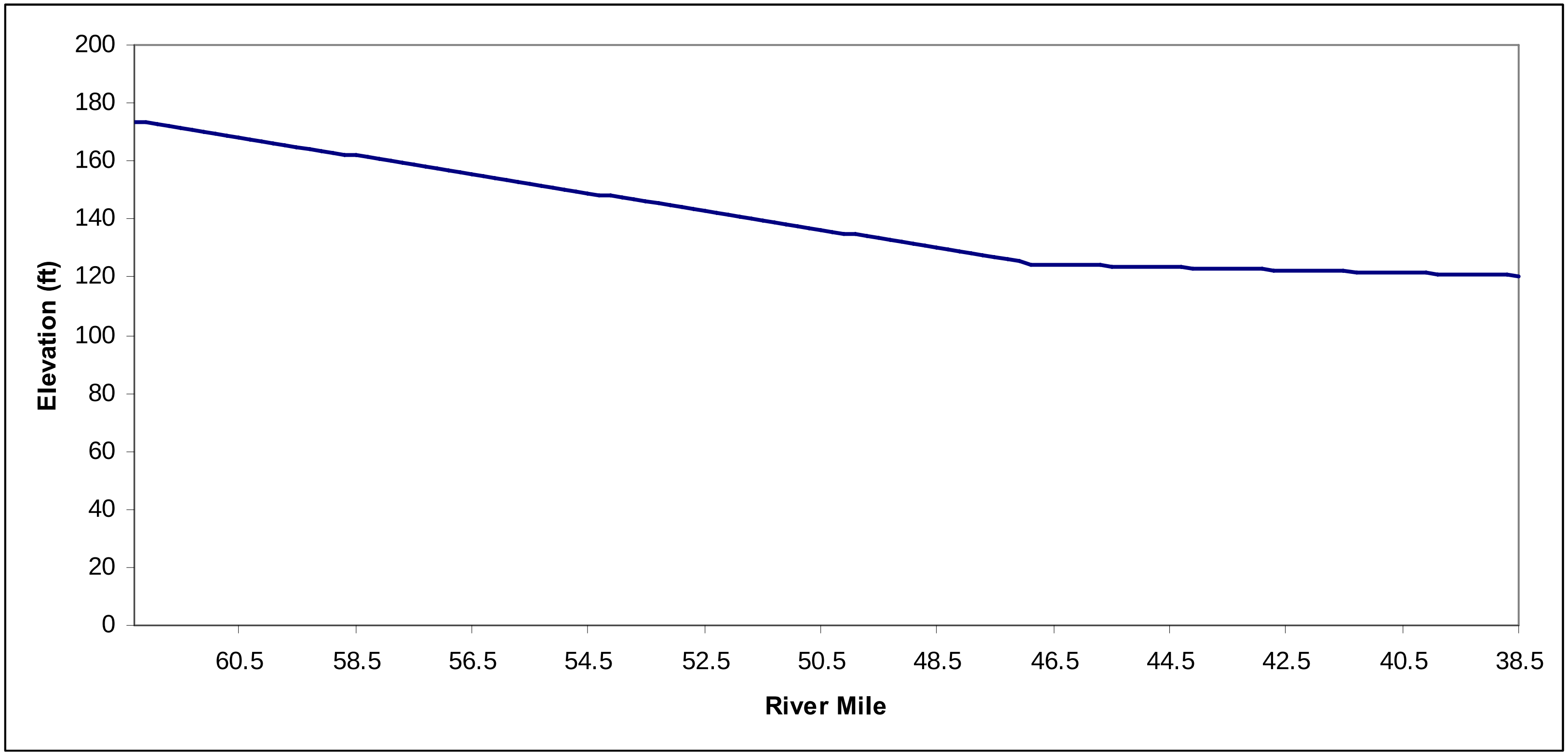


Figure 11. The two-dimensional grid used to represent the Tualatin River in CE-QUAL-W2. (Horizontal lines are layer boundaries; vertical lines are segment boundaries. The water surface on May 10, 1992, is representative of high-flow conditions.)

Cook Park
RM 10



Elevation (ft)
200
180
160
140
120
100
80
60
40
20
0
60.5
58.5
56.5
54.5
52.5
50.5
48.5
46.5
44.5
42.5
40.5
38.5
River Mile

Appendix I

Oxygen-Demand Trading Provisions in Watershed Permit

(2) **Phosphorus**

The phosphorus reduction period begins May 1 and ends October 31.

Outfall Number	Parameter	Monthly Median Effluent Concentration
D001	Total Phosphorus	0.11 mg/L
R001	Total Phosphorus	0.10 mg/L

(3) **Ammonia**

(a) The ammonia reduction period is May 1 through November 15, except as noted below;

(b) Between September 1 and November 15 when the seven-consecutive-day median of daily mean flow at the Farmington gauge is at least 350 cfs, ammonia reduction does not apply; and

(c) The ammonia loadings as ammonia-nitrogen shall not exceed the Weekly Median Maximum Ammonia Load limitation, calculated using the formula and variables given below.

Outfall Number	Parameter	Weekly Median Maximum Load, lbs/day
D001, R001	Ammonia (NH_3-N)	Weekly Median Maximum Ammonia Load = (Farmington Flow)(Concentration Variable) (5.39) lbs/day, where: Farmington Flow is the previous calendar weekly consecutive-day median of the daily mean flow at the Farmington gauge in cfs, and Concentration Variable is NH_3-N in mg/L during the applicable period as follows:

Concentration Variable (NH_3-N, mg/L) (The applicable tier is based on the instream dissolved oxygen concentration as described below)		Applicable Time Period
Tier 1	Tier 2	
1.4	1.4	May and June
1.4	0.8	July
1.4	0.3	August
0.8	0.21	September through November 15

(d) The Tier 1 concentration variable is in effect for any week when ammonia reduction is required unless the following conditions occur, in which case the Tier 2 concentration variable is in effect.

(i) For Rock Creek AWTF: Either the weekly mean of the daily mean DO concentrations, with no credit for supersaturation, at RM 24.5 (Neals), for the ***previous*** week is less than 6.7 mg/L or the weekly mean of the daily mean DO concentrations, with no credit for supersaturation, at RM 3.4 (Oswego Dam), for the ***previous*** week is less than 6.7 mg/L. (See Note 2)

(ii) For Durham AWTF: The weekly mean of the daily mean DO concentrations at RM 3.4 (Oswego Dam), with no credit for supersaturation, for the ***previous*** week is less than 6.7 mg/L. (See Note 2)

(4) Water Quality Trading Plan for Oxygen Demanding Parameters

Water Quality Trading Credits for oxygen demanding parameters ($CBOD_5$ and ammonia) between the Durham and Rock Creek Advanced Wastewater Treatment Facilities (AWTF) are authorized by Schedule D of this permit provided that the permittee uses the following equations to define the available assimilative capacity. Whenever the combined load as calculated by the equation in Schedule A, 1.a.(4)(b) is less than or equal to the combined load limitation as calculated by the equation in Schedule A, 1.a.(4)(a), (the baseline for purposes of water quality trading) the permittee shall be deemed to be in compliance with the $CBOD_5$ and ammonia-nitrogen effluent limitations of this permit.

(a) Oxygen Demand Load Limitation

Outfall Number	Parameter	Combined Rock Creek and Durham Oxygen Demand Load Limitation at Oswego Dam (lb/day)
D001 , R001	$CBOD_5$ and NBOD	R001 NBOD Limit (lb/day) + R001 $CBOD_5$ Limit (lb/day) + D001 NBOD Limit (lb/day) + D001 $CBOD_5$ Limit (lb/day) Where, R001 NBOD Limit = Weekly R001 NH_3-N Load Limit, lb/day (see Schedule A.1.a.(3)) x 4.33 x Fraction R001 ammonia decayed at dam (see Table 2) R001 $CBOD_5$ Limit = Weekly R001 $CBOD_5$ concentration, mg/L, (see Table 1) x Actual Weekly Median Rock Creek Effluent Flow, MGD x 8.34 x 4.9 x Fraction R001 $CBOD_{ultimate}$ decayed at dam (see Table 2) D001 NBOD Limit = Weekly D001 NH_3-N Load Limit, lb/day (see Schedule A.1.a.(3)) x 4.33 x Fraction D001 ammonia decayed at dam (see Table 2) D001 $CBOD_5$ Limit = Weekly D001 $CBOD_5$ concentration, mg/L, (see Table 1) x Actual Weekly Median Durham Effluent Flow, MGD x 8.34 x 4.9 x Fraction D001 $CBOD_{ultimate}$ decayed at dam (see Table 2)

Note: 4.33 = NBOD:NH_3 ratio
4.9 = $CBOD_{ultimate}$:$CBOD_5$ ratio
8.34 = pound conversion

Water Quality Trading Credit for oxygen demanding substances authorized under the water quality trading program in Schedule A, 1.a.(4) shall not be allowed if the trade results in an exceedance of the $CBOD_5$ mass limitations for outfalls D001 or R001.

(b) Calculation of Combined Rock Creek and Durham Actual Discharged Oxygen Demand Load at Oswego Dam: *(applies on a calendar week basis)*

Actual Discharged Oxygen Demand Load at Oswego Dam (lb/day) =
R001 NBOD Discharge (lb/day) + R001 $CBOD_5$ (lb/day) +D001 NBOD Discharge (lb/day) +D001 $CBOD_5$ Discharge (lb/day)

Where:

R001 NBOD Discharge =
Actual Weekly Median R001 NH_3-N Concentration, mg/L x Actual Weekly Median Rock Creek Effluent Flow, MGD x 8.34 x 4.33 x Fraction Rock Creek ammonia decayed at dam (see Table 2)

R001 $CBOD_5$ Discharge =
Actual Weekly Median R001 $CBOD_5$ Concentration, mg/L x Actual Weekly Median Rock Creek Effluent Flow, MGD x 8.34 x 4.9 x Fraction Rock Creek $CBOD_{ultimate}$ decayed at dam (see Table 2)

D001 NBOD Discharge =
Actual Weekly Median D001 NH_3-N Concentration, mg/L x Actual Weekly Median Durham Effluent Flow, MGD x 8.34 x 4.33 x Fraction Durham ammonia decayed at dam (see Table 2)

D001 $CBOD_5$ Discharge =
Actual Weekly Median D001 $CBOD_5$ Concentration, mg/L x Actual Weekly Median Durham Effluent Flow, MGD x 8.34 x 4.9 x Fraction Durham $CBOD_{ultimate}$ decayed at dam (see Table 2)

Table 1. Weekly $CBOD_5$ Concentrations

Rock Creek AWTF	Durham AWTF
1.4 mg/L	3.9 mg/L

Table 2. Fraction Decayed at Oswego Dam

Farmington flow, cfs	River temperature, °C	Rock Creek AWTF		Durham AWTF	
		Ammonia	CBOD	Ammonia	CBOD
120 – 175	≤10	0.61	0.33	0.22	0.10
	>10 to 15	0.70	0.40	0.27	0.12
	>15 to 20	0.79	0.48	0.33	0.15
	>20 to 25	0.86	0.56	0.40	0.19
>175 – 200	≤10	0.48	0.24	0.15	0.07

	>10 to 15	0.56	0.29	0.19	0.09
	>15 to 20	0.65	0.36	0.24	0.11
	>20 to 25	0.74	0.43	0.29	0.14
>200 – 250	≤10	0.43	0.21	0.14	0.06
	>10 to 15	0.52	0.26	0.17	0.08
	>15 to 20	0.60	0.32	0.21	0.10
	>20 to 25	0.69	0.39	0.26	0.12
>250 – 300	≤10	0.37	0.17	0.11	0.05
	>10 to 15	0.44	0.22	0.14	0.06
	>15 to 20	0.52	0.27	0.17	0.08
	>20 to 25	0.61	0.33	0.22	0.10
>300 – 350	≤10	0.32	0.15	0.09	0.04
	>10 to 15	0.38	0.18	0.12	0.05
	>15 to 20	0.46	0.23	0.15	0.06
	>20 to 25	0.55	0.28	0.18	0.08
Values for each range set at low end of range for flow and high end for temperature					

(5) **Temperature**

The effluent temperature limitations in this Schedule, the temperature monitoring requirements of Schedule B, the Clean Water Services Temperature Management Plan required by Schedule C, and the thermal load to offset and water quality trading provisions of Schedule D, constitute the primary elements of the permittee's Department approved surface water temperature management plan pursuant to OAR 340-041-0026(3)(a)(D)(vi). The permittee and the Department may amend the plan during the course of this permit to include additional elements if necessary. The permittee is deemed to be in compliance with in-stream water quality standards and shall not be deemed to be causing or contributing to a violation of the Tualatin Basin temperature TMDL or water quality standards for temperature if the permittee is in compliance with this approved surface water temperature management plan.

Outfall Number	Parameter	Limitation
D001	Effluent Temperature (See Note 3)	77° F daily maximum
D001	Allowable Thermal Load (See Note 4)	2.0 x 10^7 kcal/day
R001	Effluent Temperature (See Note 3)	77° F daily maximum
R001	Allowable Thermal Load (See Note 4)	2.4 x 10^7 kcal/day