Appendix 3: Algae/Aquatic Weeds, Dissolved Oxygen and pH TMDL Supplemental Information

This Document is supplemental to the Umpqua Basin algae/aquatic weeds, dissolved oxygen and pH TMDL (Chapter 4)

DEQ

State of Oregon
Department of
Environmental
Quality

SECTION 1: DISSOLVED OXYGEN AND PH MODELING OVERVIEW

QUAL2KW MODEL

The EPA supported water quality model QUAL2Kw was used to simulate streams with nutrient related water quality limitations in the Umpqua Basin (Chapra and Pelletier, 2004). QUAL2Kw is a river water quality model that is intended to represent a modernized version of the QUAL2E model. The model is one-dimensional (assumes that the channel is well-mixed vertically and laterally), employs steady state hydraulics, uses a diel heat budget, computes diel water-quality kinetics, and simulates point and nonpoint loads and abstractions. The model is especially useful for the South Umpqua River because it can simulate sediment-water interactions, bottom algae, and pH, in addition to temperature, DO and floating algae. DEQ downloaded the model from the Washington Department of Ecology website (http://www.ecy.wa.gov/programs/eap/models/qual2kw51b33_xls.zip).

QUAL2Kw is similar to Q2E in the following respects (QUAL2Kw Documentation and User Manual, 2003):

- **One dimensional.** The channel is well-mixed vertically and laterally.
- **Steady state hydraulics**. Non-uniform, steady flow is simulated.
- **Diurnal heat budget.** The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale.
- **Diurnal water-quality kinetics.** All water quality variables are simulated on a diurnal time scale.
- **Heat and mass inputs.** Point and non-point loads and abstractions are simulated.

The QUAL2Kw framework includes the following new elements:

- **Software Environment and Interface**. Q2Kw is implemented within the Microsoft Windows environment. It is programmed in the Windows macro language: Visual Basic for Applications (VBA). Excel is used as the graphical user interface.
- **Model segmentation.** Q2E segments the system into river reaches comprised of equally spaced elements. In contrast, Q2Kw uses unequally-spaced reaches. In addition, multiple loadings and abstractions can be input to any reach.
- **Carbon speciation.** Q2Kw uses two forms of carbon, rather than BOD, to represent organic carbon. These forms are a slowly oxidizing form (slow carbon) and a rapidly oxidizing form (fast carbon). In addition, non-living particulate organic matter (detritus) is simulated. This detrital material is composed of particulate carbon, nitrogen and phosphorus in a fixed stoichiometry (ratio).
- **Anoxia**. Q2Kw accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations.
- **Sediment-water interactions.** Sediment-water fluxes of dissolved oxygen and nutrients from aerobic/anaerobic sediment diagenesis are simulated internally rather than being prescribed. That is, oxygen (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters.
- **Bottom algae.** The model explicitly simulates attached bottom algae.
- **Light extinction.** Light extinction is calculated as a function of algae, detritus and inorganic solids.
- **pH.** Both alkalinity and total inorganic carbon are simulated. The river's pH is then simulated based on these two quantities.
- **Pathogens.** A generic pathogen is simulated. Pathogen removal is determined as a function of temperature, light, and settling.

- **Hyporheic exchange and sediment pore water quality**. The model incorporates hyporheic exchange and sediment pore water quality including optional simulation of the metabolism of heterotrophic bacteria in the hyporheic zone.

Description of Nutrient Processes

Large diel (daily cyclical) fluctuations of pH and dissolved oxygen result in water quality limitations in portions of the Umpqua Basin. Stream specific water quality models, based on intensive sampling, are used to determine the total maximum daily load (TMDL) necessary to achieve water quality standards.

Dissolved oxygen and pH concentrations are functions of barometric pressure and water temperature. Additionally, the growth and respiration of attached algae cause diel fluctuations in DO and pH concentrations. Algae photosynthesis releases oxygen into the water and respiration consumes oxygen. At nighttime, when photosynthesis ceases, respiration will cause a reduction in DO. Additionally, sediment oxygen demand (SOD) and biochemical oxygen demand (BOD) depress dissolved oxygen concentrations through the aerobic decomposition of organic material.

Inorganic carbon (i.e., carbon dioxide) is also consumed and released through photosynthesis and respiration. Through the carbonate balance, as inorganic carbon is consumed, the concentration of the hydrogen ion decreases, increasing the pH. Alkalinity, which dampens the diel swing in pH, is naturally low in most of the Umpqua Basin.

Nutrient loading, specifically phosphorus and nitrogen, encourages algae growth. The preferred forms are soluble reactive phosphorus (SRP) (also generally referred to as inorganic phosphorus and dissolved orthophosphate as P) and ammonia. There are a number of natural processes that add nutrients to the river: runoff and leaching from the soil, degradation of plant material, and fish returning to spawn from the ocean. As the algae grow, they consume phosphorus and nitrogen. As algae respire and die, nutrients are released back into the river.

Algae consume nitrogen and phosphorus at a fixed ratio. Therefore, if one nutrient is in short supply, it will limit the growth of algae regardless of the concentration of the other nutrient. The limiting nutrient can vary longitudinally (along the length of the stream). Attached algae can also be limited by available suitable substrate, light, and temperature.

Meteorology plays an important role in determining water quality. It is an integral part of the energy balance that determines water temperature. Water temperature, along with solar energy, directly influences the growth of algae and hence nutrient dynamics, DO and pH.

The parameters which control algae growth and nutrient cycling are presented in Table 1 for the models of Calapooya, Elk, Jackson and Steamboat Creeks. The South Umpqua River and Cow Creek models used a newer version of Qual2Kw which has slightly different parameters and are present in the South Umpqua River Appendix 5 below.

Table 1. Parameters for a potion of the water quality models. South Umpqua River and Cow Creek used a newer version of Qual2kw which had slightly different parameters which are presented in the South Umpqua River Appendix 5 below.

Parameter	Calapooya Creek	Elk Creek	Jackson Creek	Steamboat Creek	Literature Range / Default Value	Units
Sediment thermal conductivity	20	10	4	20.0	0.36 - 4.18	W/m/degC
Sediment thermal diffusivity	0.007	0.0126	0.0126	0.0126	0.0012 - 0.0126	cm^2/sec
Sediment zone thickness	10	25	25	25	10 - 100	cm
Bottom algae rates and constants						
Zero order growth rate	10	15	15	10	60	gD/m^2/d
Respiration	1	1	1.2	1	0.5	/d
Excretion	0.2	0.1	0.05	0.1	0.5	/d
Death	0.5	0.1	0.5	1	0.25	/d
Temperature Correction for above 4 parameters	1.07	1.07	1.07	1.07	1.07	
N half-saturation	300	300	300	300	300	ugN/l
P half-saturation	100	100	100	100	100	ugP/l
Light constant (half saturation)	50	50	50	50	50	cal/cm^2/d
NH4 preference	25	25	25	25	25	ugN/l
Inorganic suspended solids						
Settling velocity	0.5	1	1	1	1	m/d
Global stoichiometry:						
Carbon	40	40	40	40	40	mgC
Nitrogen	7.2	7.2	7.2	7.2	7.2	mgN
Phosphorus	1	1	1	1	1	mgP
Dry weight	100	100	100	100	100	mgD
Chlorophyll	1	1	1	1	1	mgA
Slow C:						
Hydrolysis rate	1	0.5	2	2	2	/d at 20 deg C
Temp Correction	1.047	1.047	1.047	1.047	1.047	
Fast C:						
Oxidation rate	4	4	4	4	6	/d at 20 deg C
Temp Correction	1.047	1.047	1.047	1.047	1.047	
Dissolved Organic N:						
Hydrolysis	0.2	0.1	1	1	0.2	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Ammonium:						
Nitrification	2	0.1	0.5	1	2	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Nitrate						
Denitrification	1	1	1	1	1	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Sed Denitrification Transfer Coeff	0	0	0.05	0	0	m/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Dissolved Organic P:						

Parameter	Calapooya Creek	Elk Creek	Jackson Creek	Steamboat Creek	Literature Range / Default Value	Units
Hydrolysis	0.25	0.25	0.25	0.5	0.25	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Phytoplankton:						
Max Growth	2	2.5	2.5	2.5	2	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Basal Respiration	0.1	0.05	0.05	0.05	0.1	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Excretion of N and P	0.1	0.05	0.05	0.05	0.1	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Death	0.1	0.05	0.05	0.05	0.1	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Nitr Half Sat Constant	15	15	15	15	15	ugN/l
Phos Half Sat Constant	3	2	2	2	3	ugP/l
Light Model	Half Saturation	Half Saturation	Half Saturation	Half Saturation	Half Saturation	
Light Constant	35	57.6	57.6	57.6	35	langleys/d
Ammonia preference	80	25	25	25	80	ugN/l
Settling velocity	0.15	0.15	0.15	0.15	0.15	m/d
Detritus (POC, PON, POP):						
Hydrolysis	2	1	1	5	2	/d at 20 deg C
Temp Correction	1.07	1.07	1.07	1.07	1.07	
Settling Velocity	0	0	1	1	0	m/d
Half-saturation constants for CO2 or HCO3- limitation of photosynthesis (moles/liter)						
half-saturation for phytoplankton	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	moles/l
HCO3- used by phytoplankton	Yes	Yes	Yes	Yes	Yes	
half-saturation for bottom algae	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	moles/l
HCO3- used by bottom algae	Yes	Yes	Yes	Yes	Yes	
Bottom algae stoichiometry, subsistence quota, and maximum nutrient uptake parameters:						
Carbon	40	40	40	40	40	mgC
Nitrogen	7.2	7.2	7.2	7.2	7.2	mgN
Phosphorus	1	1	1	1	1	mgP
Dry weight	100	100	100	100	100	mgD
Chlorophyll	1	1	1	1	1	mgA
Subsistence quota of intracellular N	7.2	7.2	7.2	7.2	7.2	mgN/gD
Subsistence quota of intracellular P	1	1	1	1	1	mgP/gD
Maximum normalized N uptake rate	500	100	720	720	720	mgN/gD/day
Maximum normalized P uptake rate	200	50	100	100	100	mgP/gD/day
Internal N half-saturation	9	9	9	9	9	mgN/gD
Internal P half-saturation	1.3	1.3	1.3	1.3	1.3	mgP/gD
Phytoplankton stoichiometry, subsistence quota, and maximum nutrient uptake parameters:						
Carbon	40	40	40	40	40	mgC
Nitrogen	7.2	7.2	7.2	7.2	7.2	mgN

Parameter	Calapooya Creek	Elk Creek	Jackson Creek	Steamboat Creek	Literature Range / Default Value	Units
Phosphorus	1	1	1	1	1	mgP
Dry weight	100	100	100	100	100	mgD
Chlorophyll	1	1	1	1	1	mgA
Subsistence quota of intracellular N	7.2	7.2	7.2	7.2	7.2	mgN/gD
Subsistence quota of intracellular P	1	1	1	1	1	mgP/gD
Maximum normalized N uptake rate	720	720	720	720	720	mgN/gD/day
Maximum normalized P uptake rate	100	100	100	100	100	mgP/gD/day
Internal N half-saturation	9	9	9	9	9	mgN/gD
Internal P half-saturation	1.3	1.3	1.3	1.3	1.3	mgP/gD

SECTION 2: CALAPOOYA CREEK NUTRIENT TMDL TECHNICAL DOCUMENTATION

MODEL SETUP AND BOUNDARY CONDITIONS

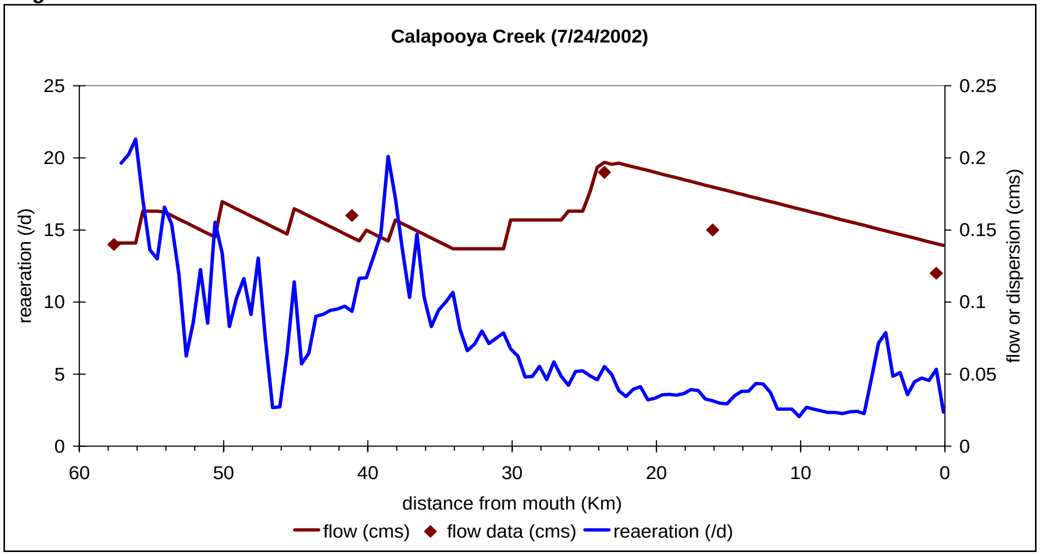
The model was developed for a single day, July 24, 2002, from river km 0.1 to 57.6. Water quality data collected from a synoptic survey on July 24, 2002. The model assumes steady state hydraulics and variable water quality over the course of a day. Meteorology, channel morphology and shade were taken from the temperature TMDL model (see Chapter 3 Temperature -Appendix). The river was segmented to 0.5 km reaches at an 11.25 minute time step. The model was run until water quality conditions did not vary significantly from that of the previous day which was approximately 20 days (two times the predicted time of travel from headwaters to mouth).

The tributary and diffuse inflow discharge was adjusted to match measured Calapooya Creek discharge measurements collected by DEQ. Withdrawals from Calapooya Creek were estimated from the points of diversion database provided by Oregon Water Resources Department. Because temperature is important in algae dynamics, temperature was also calibrated using QUAL2Kw using sediment thermal conductivity, sediment thermal diffusivity, and sediment zone thickness. The sediment thermal conductivity value determined through the temperature calibration to be greater than the reported literature range (Pelletier and Chapra, 2004). This is likely compensating for hyporheic flow, which was not explicitly included in this modeling effort, or direct solar heating of the substrate which is not included in QUAL2Kw. Current and system potential shade values were taken directly from the temperature TMDL model for the current calibration and the TMDL scenario.

MODEL CALIBRATION DATA

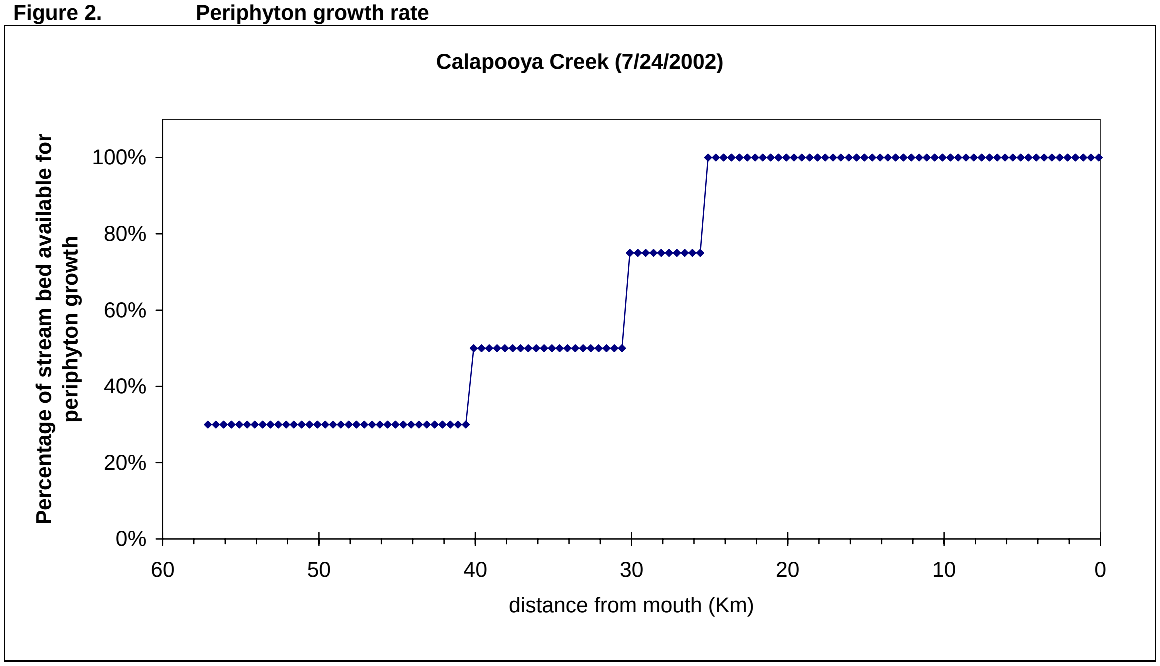
DO, pH and nutrient calibration was completed by adjusting a number of key parameters so that the model reproduced observed water quality conditions in July 2002 (see Table 1, Appendix 3). Re-aeration rates were originally estimated using the "pool-riffle" formulation; however, they were reduced by 50% to better capture the timing and magnitude of the diel fluctuations of DO and pH, see Figure 1. The percentage of the bed that is available for periphyton growth was estimated to increase in the downstream direction from 30% to 100% (Figure 2). The model performed better with spatially variable bed availability than with a constant value. SOD was specified at 1.5 grams of oxygen per square meter per day (g O2 / m2 / d) from river KM 20.1 to 25.6. The specified rate was adjusted to match observed DO concentrations.

Figure 1. Model calibration: flow and re-aeration.



Floating algae, or phytoplankton, is included in the water quality calculations, however no data was available to calibrate. It is believed that periphyton is the major contributor to water quality violations in Calapooya Creek.

Figure 2. Periphyton growth rate



The headwater boundary condition was derived from measured instream data (Table 2 and 3). No tributary water quality data was available and was assumed to be contributing loads at the computed background concentrations (see discussion concerning the South Umpqua River).

Table 2. Summary of boundary conditions.

Site Name	River KM	Discharge *CMS*	Temperature *Deg C*	Conductivity *umhos/cm*	DO *mg/l*	pH
Headwaters	57.70	0.1410	14.9 – 18.6	61 – 63	8.4 – 9.2	7.5-7.7
Coon Creek	55.65	0.022	18.6	100	8.8	7
Hinkle Creek	50.55	0.027	17.2	100	8.8	7
Gassy Creek LB	45.3	0.02	21.2	100	8.8	7
Banks Creek	40.2	0.01	21.2	100	8.8	7
Foster Creek	38.5	0.017	21.2	100	8.8	7
Oldham Creek	30.6	0.02	21.2	100	8.8	7
Pollock Creek	26.35	0.006	23.2	100	8.8	7
Oakland WWTP	22.75	0.002	23.8	718	4.2	6.9
Diffuse Inflow #1	24 – 25	0.034	20	300	8.0	8.0
Diffuse Outflow #1	34.1 – 54.2	- 0.1	NA	NA	NA	NA
Diffuse Outflow #2	0 – 23.7	- 0.06	NA	NA	NA	NA

The water quality model was able to generally capture the magnitude and spatial variability of temperature, dissolved oxygen and pH (Figures 3 – 14).

Table 3. Summary of boundary conditions data from July 2002 survey.

Site Name	Slow Dissolved Organic C (4)	Fast Dissolved Organic C (5)	Dissolved Organic N (6)	Ammonia N	Nitrate + Nitrite N	Dissolved Organic P (7)	Soluble Reactive P	Particulate Organic C	Particulate Organic N	Particulate Organic P	Alkalinity
	mgC/l	*mgC/l*	*ugN/l*	*ugN/l*	*ugN/l*	*ugP/l*	*ugP/l*	*mgC/l*	*mgN/l*	*mgP/l*	*mgCaCO3/l*
Headwaters (1)	0	0.07	180.00	20.00	54	0	20	0	0	0	30
Coon Creek (2)	1	0	216	18	23	9	5	0	0	0	75
Hinkle Creek (2)	1	0	216	18	23	9	5	0	0	0	75
Gassy Creek (2)	1	0	216	18	23	9	5	2	0	0	75
Banks Creek (2)	1	0	216	18	23	9	5	2	0	0	10
Foster Creek (2)	1	0	216	18	23	9	5	2	0	0	10
Oldham Creek (2)	1	0	216	18	23	9	5	0	0	0	75
Pollock Creek (2)	1	0	216	18	23	9	5	2	0	0	75
Oakland WWTP (3)	0	1.49	2200	7700	17500	590	4380	15	0	0	75
Diffuse Inflow #1	1	0	216	18	23	9	5	0	0	0	50

Notes:
Laboratory results that were reported as less than the reporting limit were enter into the model as 0.8 of reporting limit
C = Carbon; N = Nitrogen; P = Phosphorus
1. Based on sample collected on July 24, 2002.
2. Determined through estimates and mass balance.
3. Based on average July 2002 DMR data when available and DEQ sample collect on July 24, 2002
4. Slow Dissolved Organic C = Total organic C - Fast Dissolved Organic C
5. Fast Dissolved Organic = C-BOD / 2.69
6. Dissolved Organic N = Total Kjeldahl Nitrogen - Ammonia
7. Dissolved Organic P = Total P – Soluble Reactive P

Figure 3. Model calibration: temperature

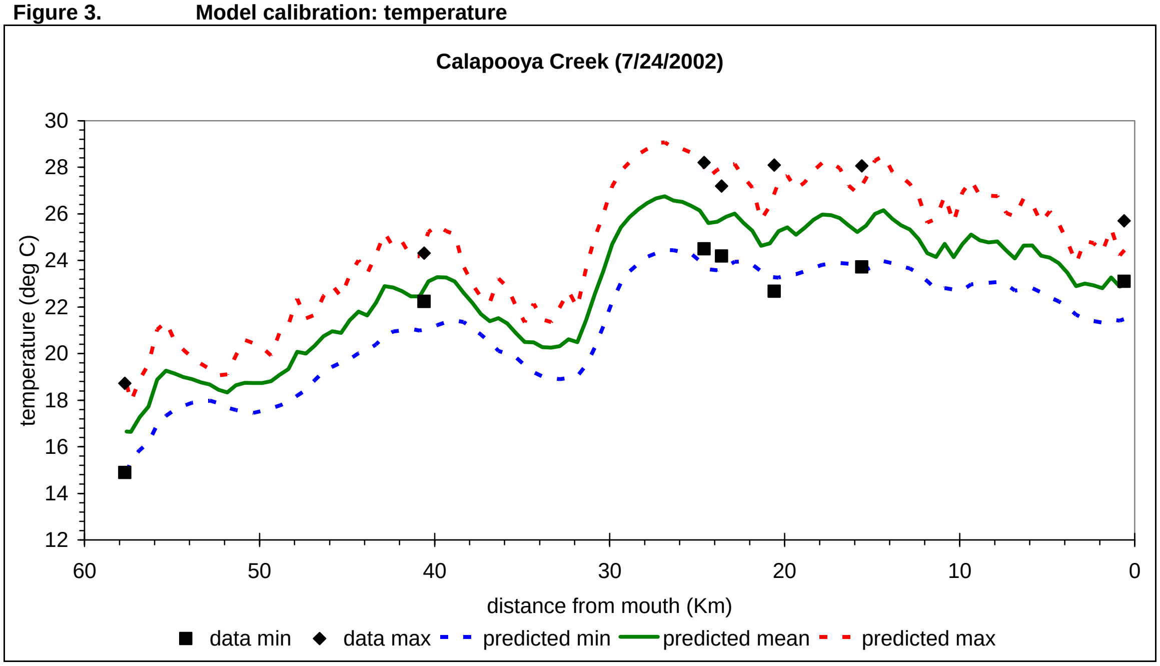


Figure 4. Model calibration: conductivity

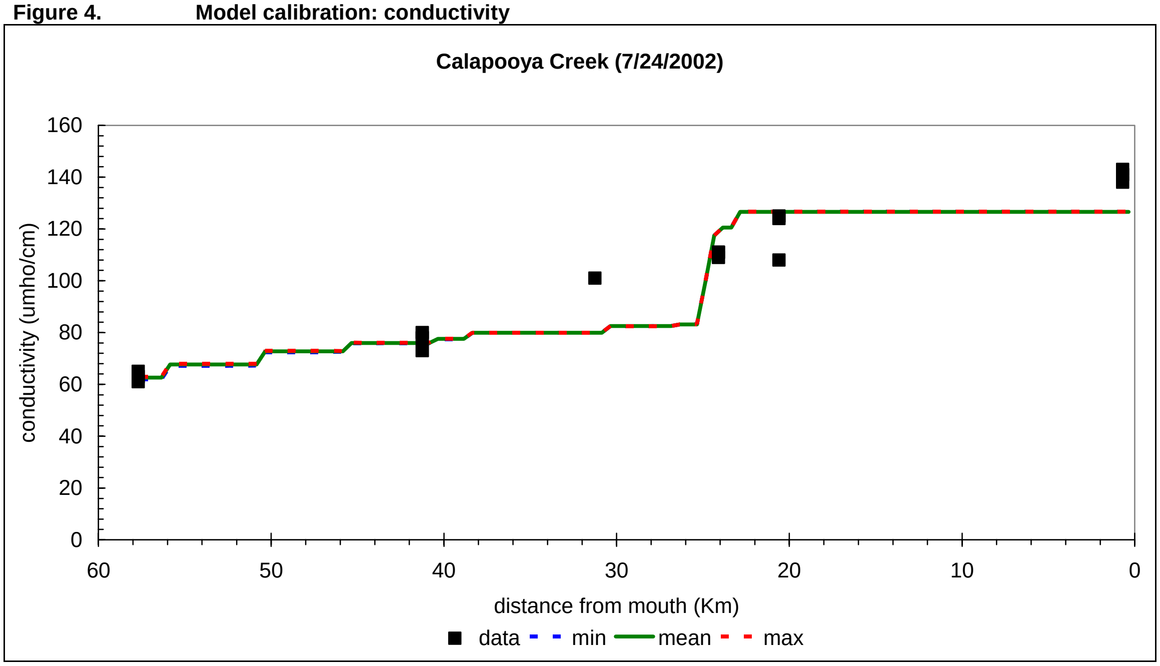


Figure 5. Model calibration: dissolved oxygen

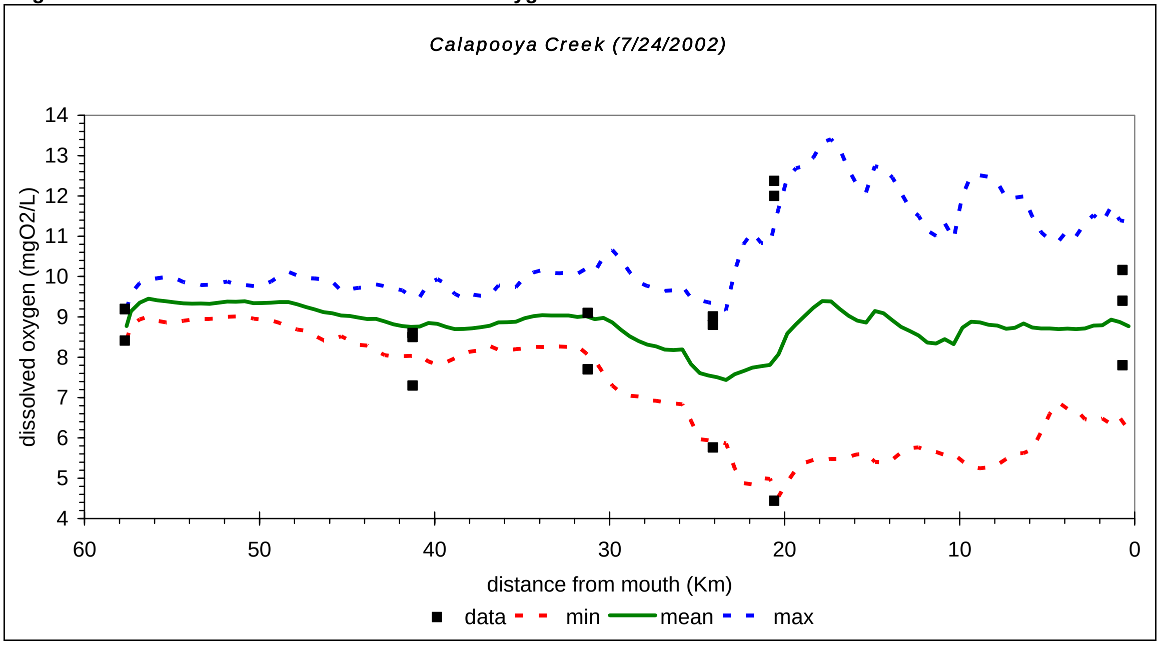


Figure 6. Model calibration: dissolved organic nitrogen

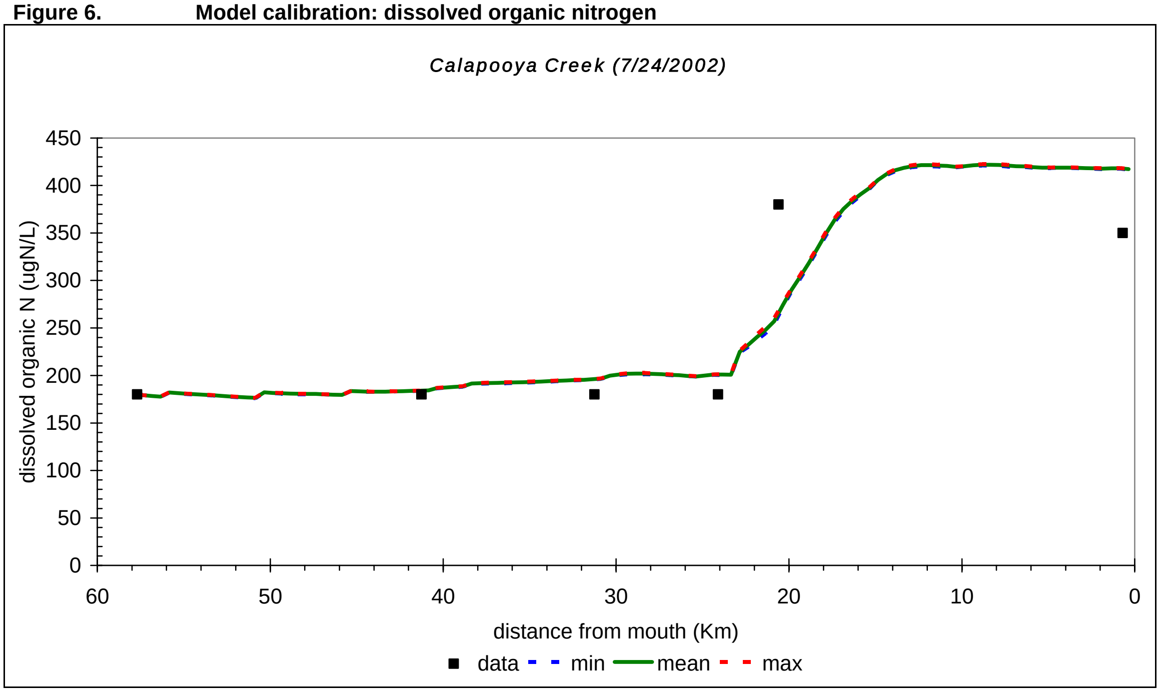


Figure 7. Model calibration: ammonia

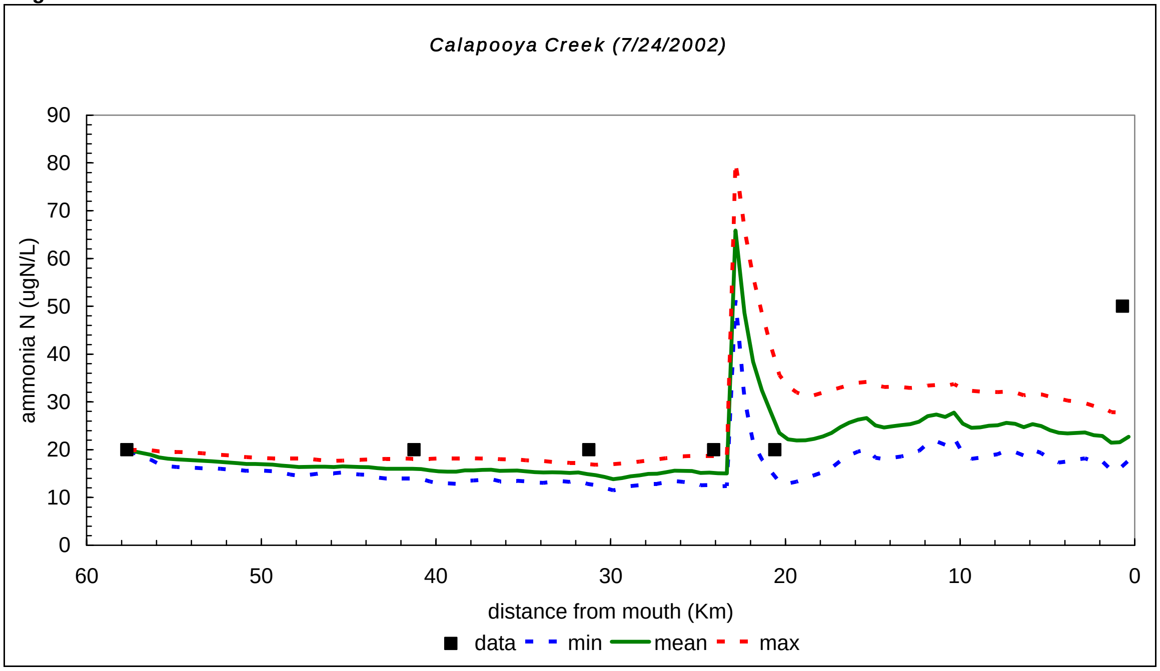


Figure 8. Model calibration: sum of nitrate and nitrite.

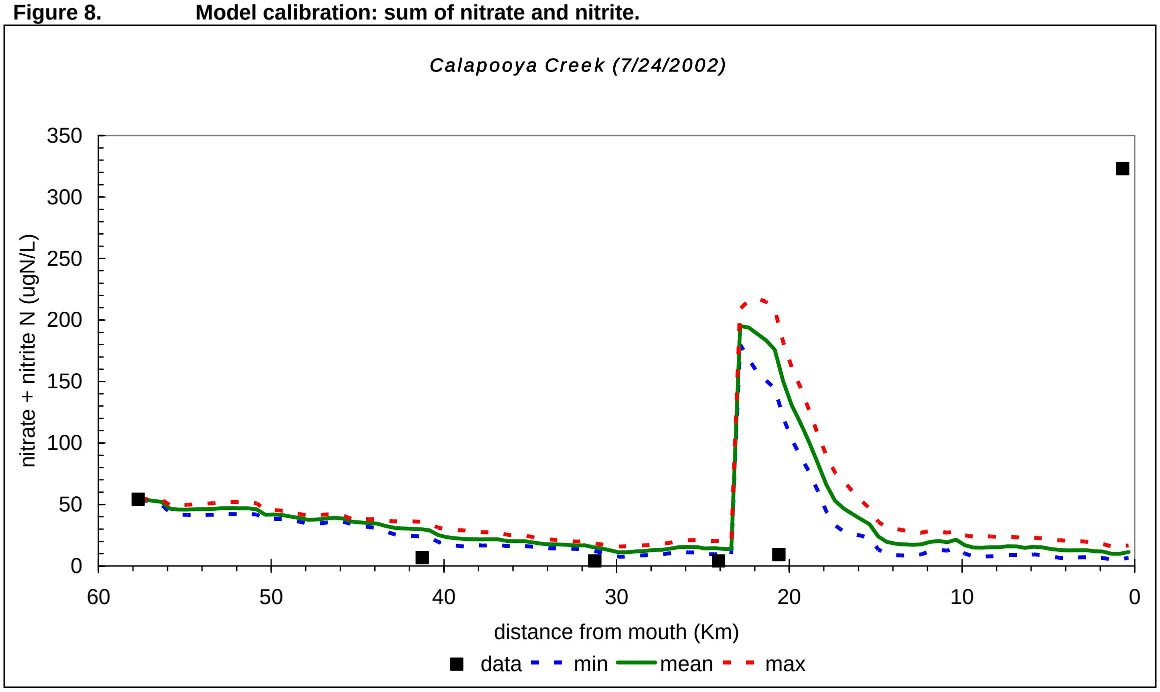


Figure 9. Model calibration: soluble reactive phosphorus

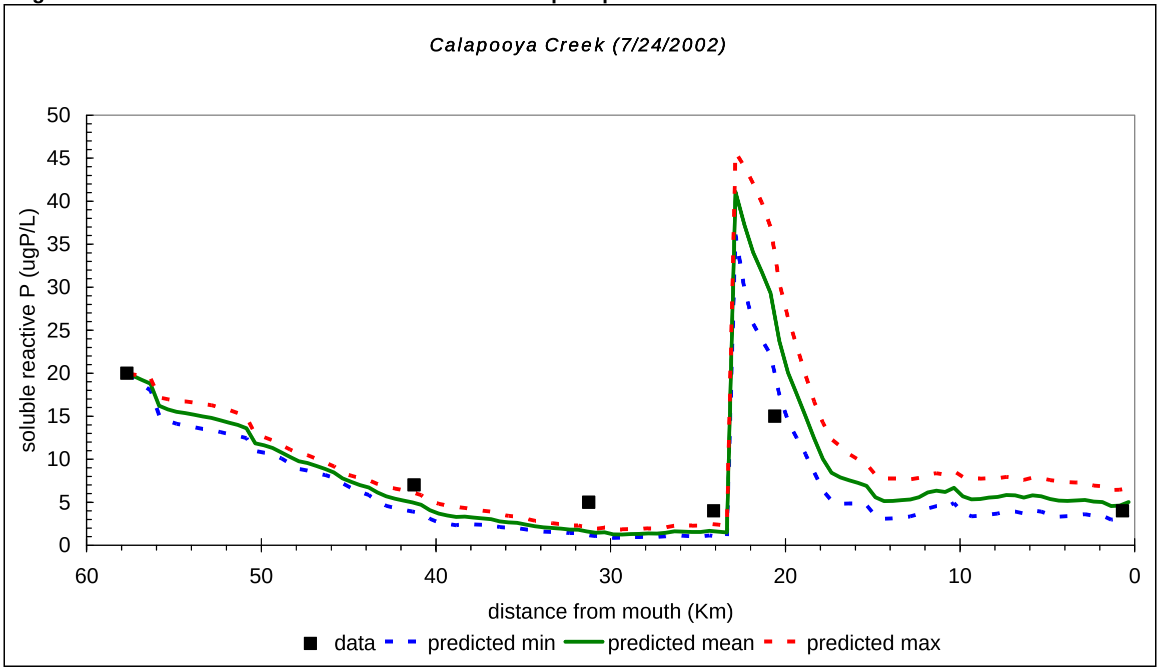


Figure 10. Model calibration: dissolved organic phosphorus.

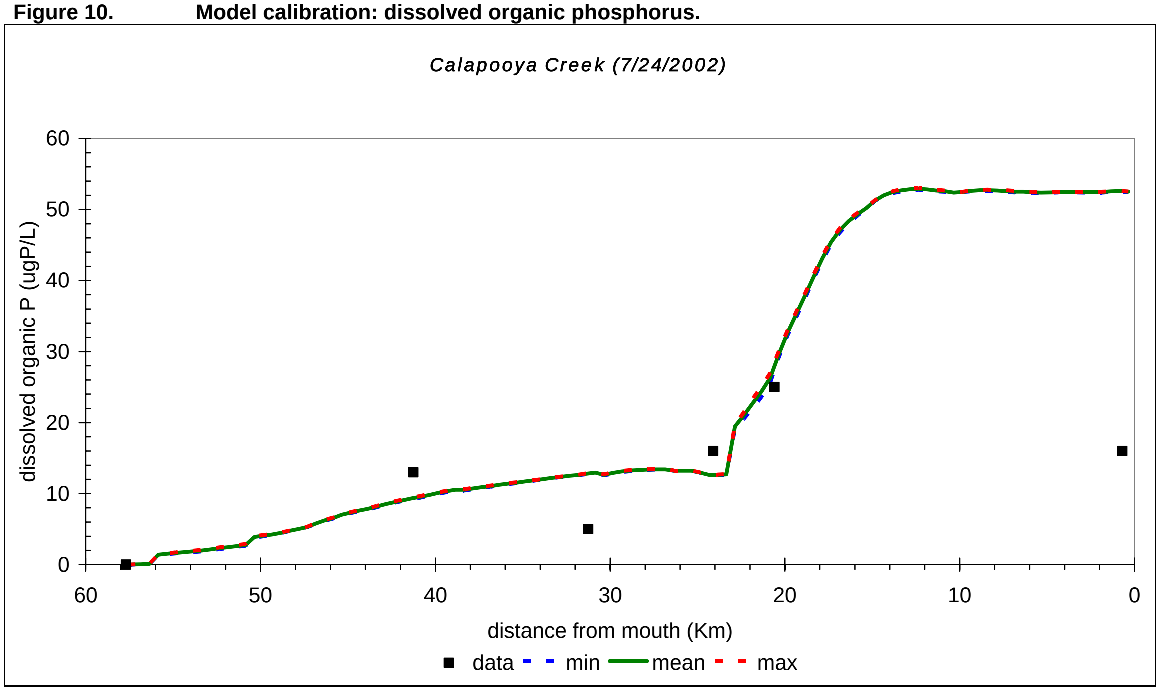


Figure 11. Model calibration: alkalinity.

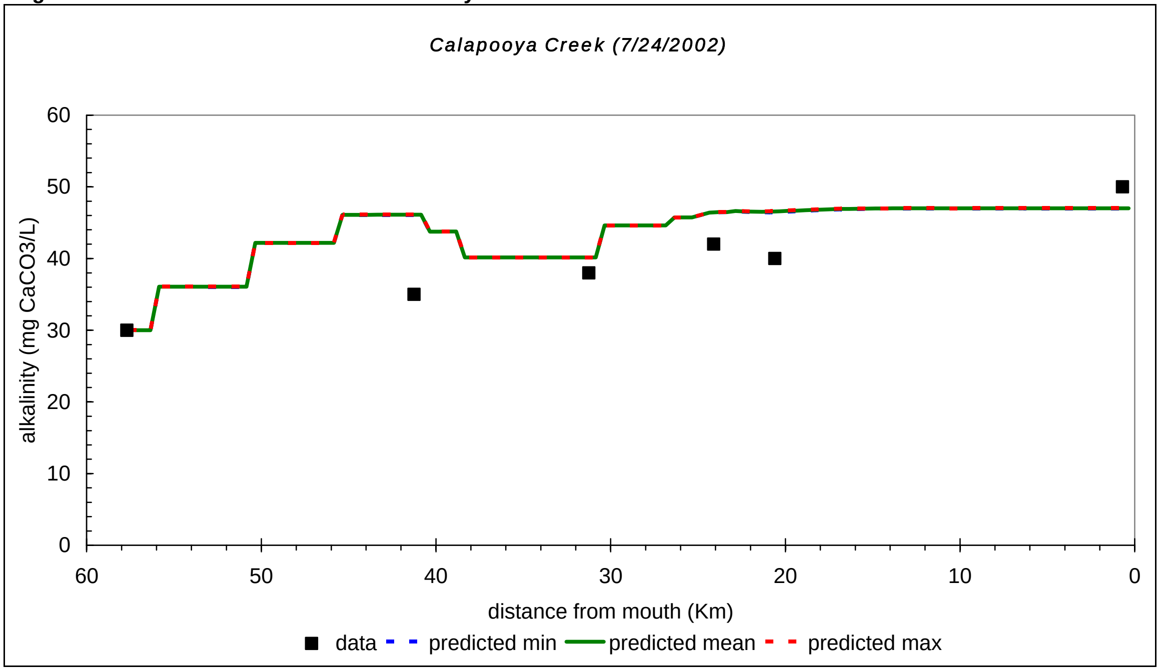


Figure 12. Model calibration: pH

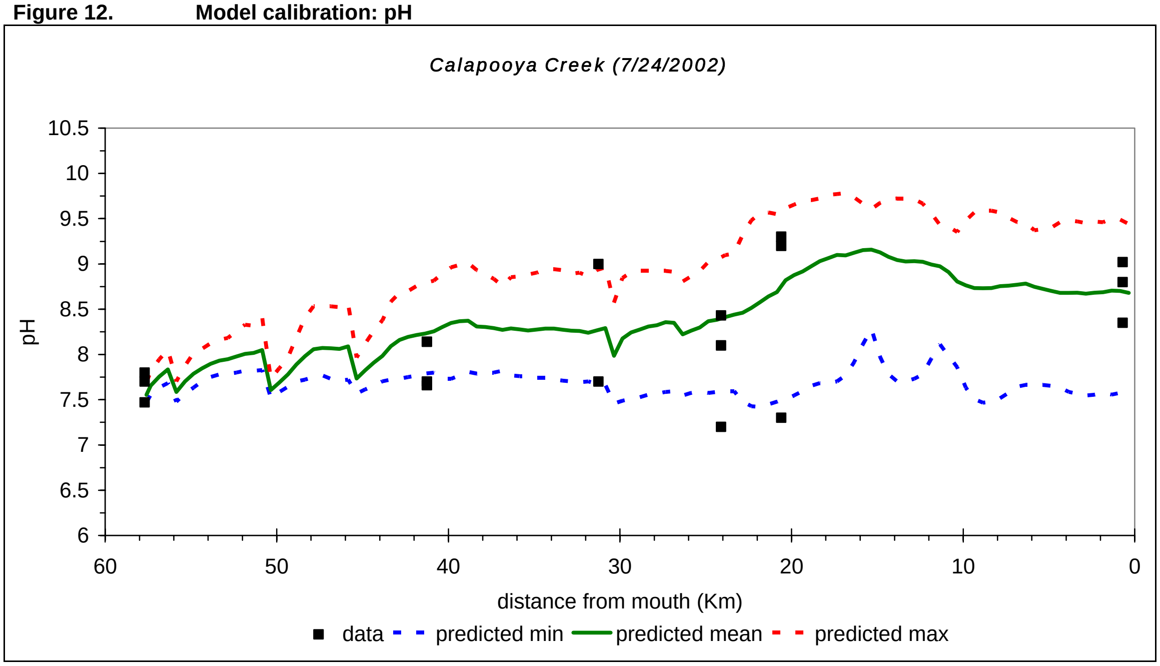
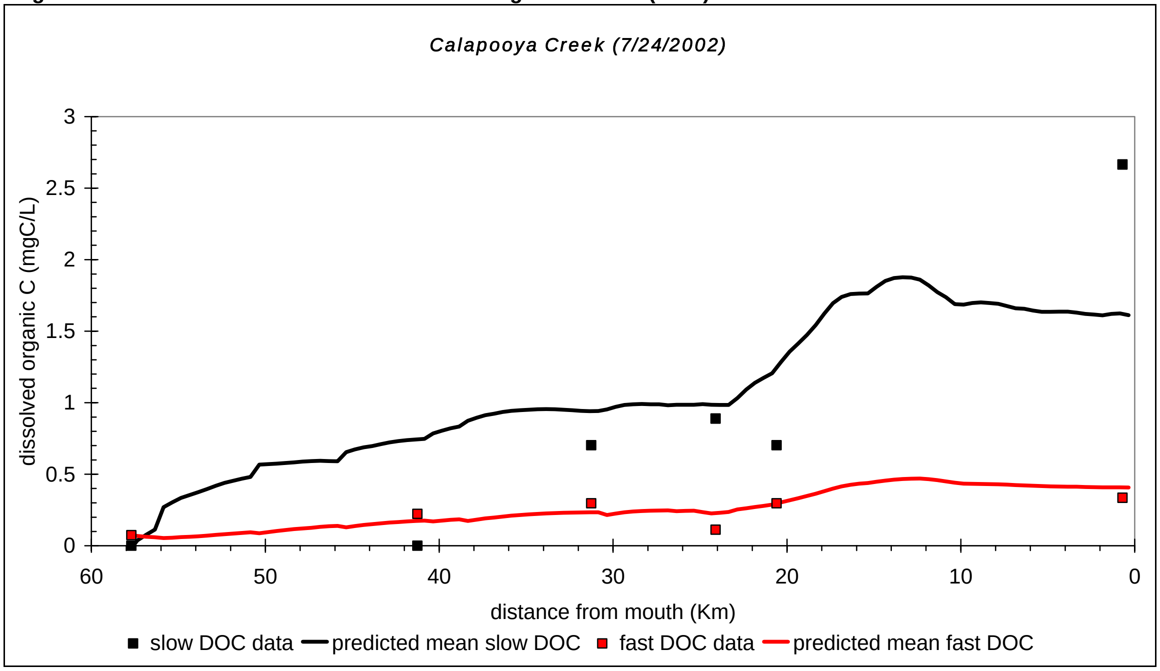


Figure 13. Model calibration: dissolved organic carbon (DOC).

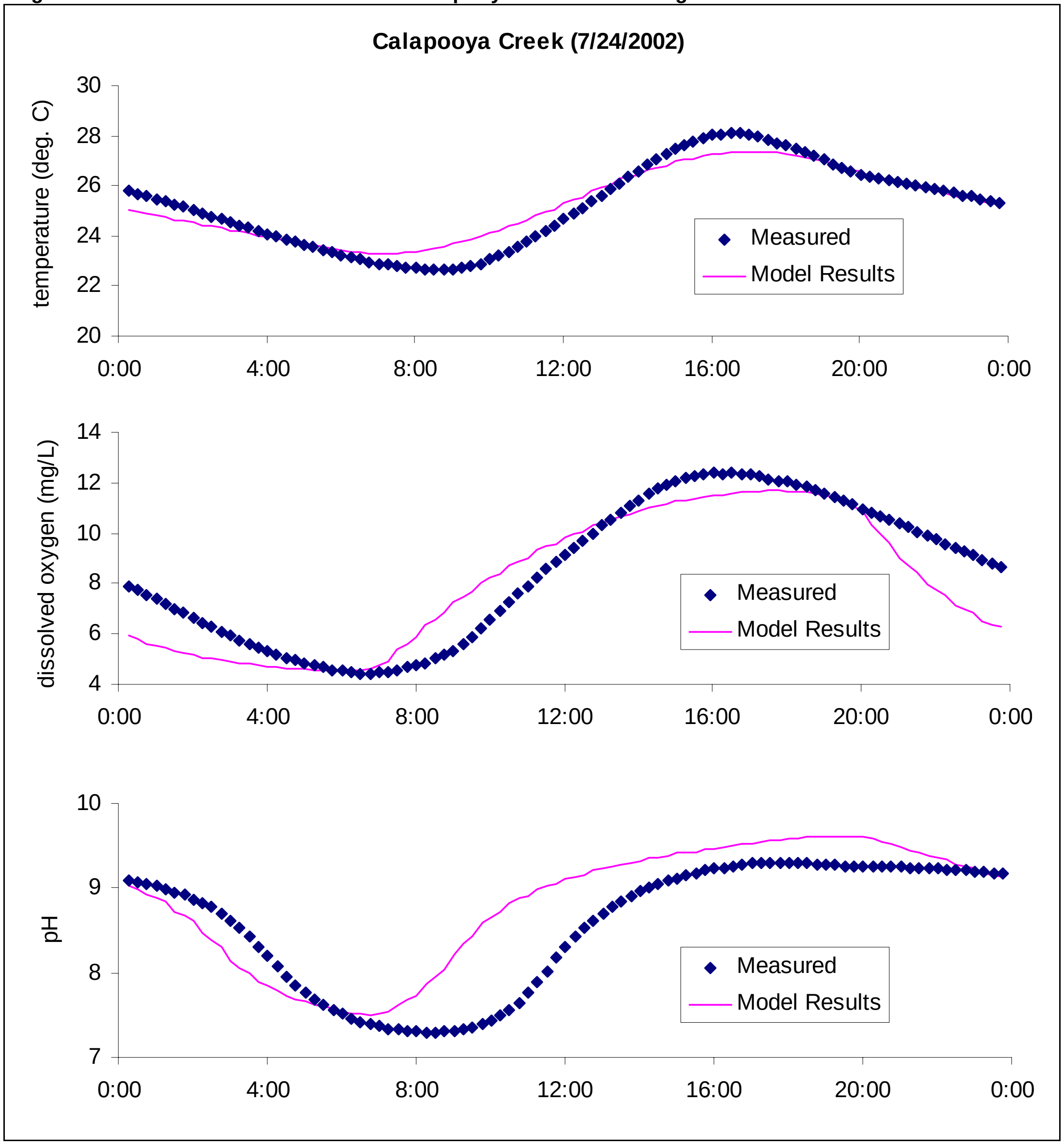


The least successful calibration point was near the mouth of Calapooya Creek at Umpqua (river KM 0.7) (Table 4). The continuous data collected at this site did not have a single afternoon peak in temperature, DO and pH as did the other sites. The bed at the site consisted of exposed bedrock and given the low flow conditions the stream was shallow and separated into multiple channels with stagnant pools. It was difficult to locate a flowing location deep enough for the continuous monitor. Likely, the data collected at this site is representative of very localized conditions and therefore this model at a 0.5 km scale reach cannot be calibrated for this location. Overall though, the model was able to generally reproduce observed data and is a suitable tool to evaluate water quality in Calapooya Creek.

Table 4. Calibration statistics.

			Temperature			Dissolved Oxygen			pH		
ID #	Description	river KM	ME	AME	RMSE	ME	AME	RMSE	ME	AME	RMSE
10996	At Umpqua	0.7	-1.3	1.3	1.5	0.1	1.4	1.4	0.0	0.6	0.7
13245	At I-5 Bridge	20.6	0.0	0.4	0.5	-0.4	1.0	1.2	0.3	0.4	0.5
12800	At Oakland Drinking Wtr. Intake	23.5	0.1	0.5	0.5	0.0	0.8	1.0	0.7	0.7	0.8
12803	At Sutherlin Drinking Wtr Intake	41.25	-0.7	0.8	0.9	0.9	0.9	0.9	0.3	0.3	0.4
	AVERAGE		-0.5	0.8	0.9	0.2	1.0	1.1	0.3	0.5	0.6

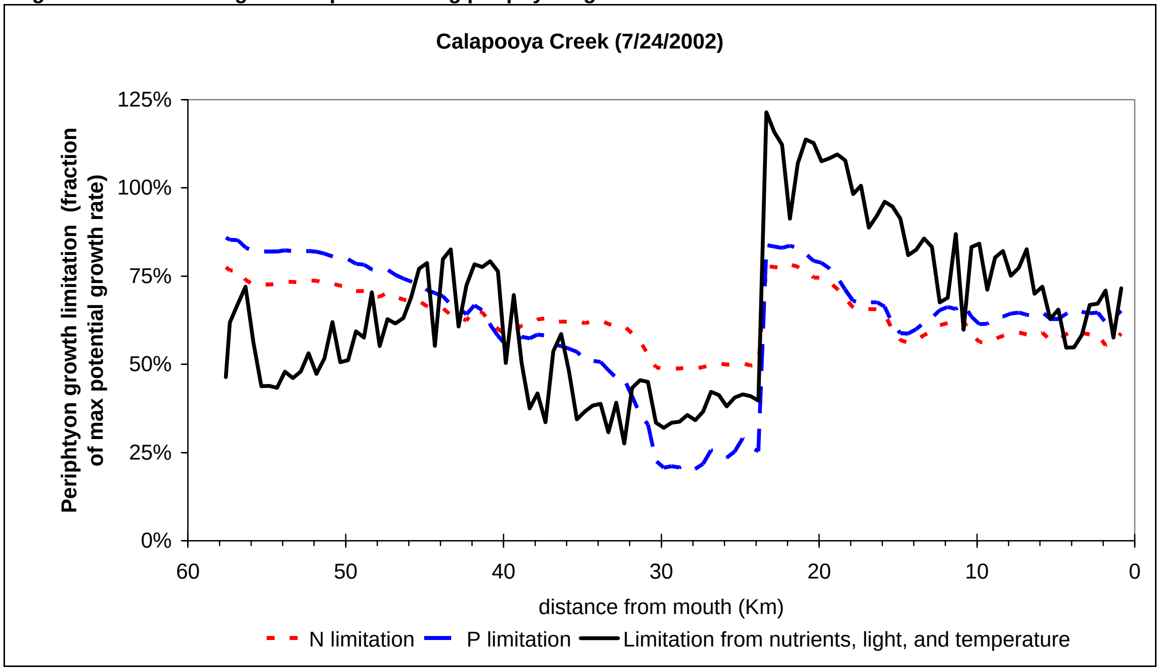
Figure 14. Calibration results for Calapooya Creek at I-5 bridge



SOURCE IDENTIFICATION

The model indicates that phosphorus is limiting periphyton growth upstream of the WWTP at river KM 23 (Figure 15). No anthropogenic nonpoint sources of phosphorus loading were identified through this sampling and modeling project (Figures 16 and 17). Headwater concentrations of 20 ug/l of total phosphorus are believed to be typical of streams in the region. Similar concentrations, 10 to 40 ug/l, were observed in Jackson and Steamboat Creeks which drain forested landscapes managed by US Forest Service and have had no recent applications of fertilizer (Michael Jones, USFS, personal communication).

Figure 15. Longitudinal plot showing periphyton growth limitation at 4:52 PM under calibrated conditions.



SOD is the oxygen demand exerted by the aerobic decomposition of sediments on the stream bottom. SOD is likely caused by organic solids settling into the pool and as part of their degradation, consuming oxygen.

Figure 16. Watershed wide sources of inorganic phosphorus.

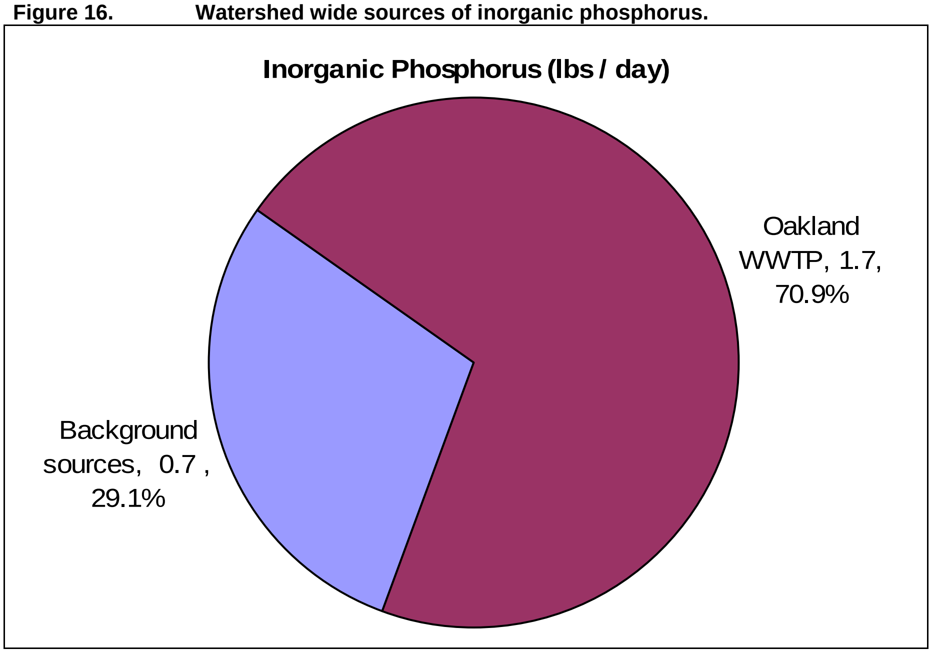
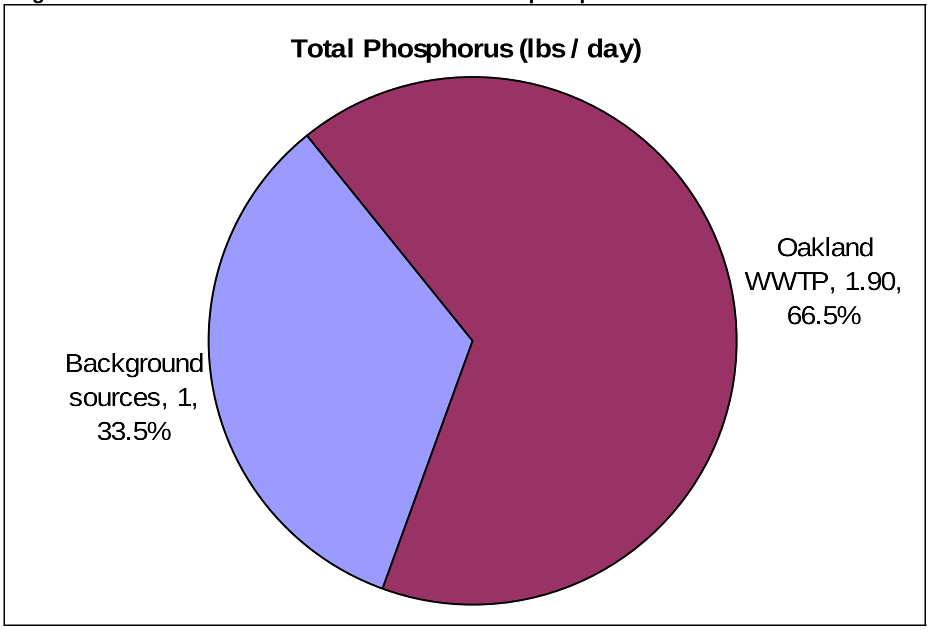


Figure 17. Watershed wide sources of total phosphorus.



MODEL ANALYSIS SCENARIOS

In addition to the calibration model run, the analysis included three scenarios under critical flow condition: 2002 loading, nonpoint source only loading, and the TMDL. The critical flow condition is defined as the low flow that is expected to occur every three years when averaged over a 14-day period (14Q3). The 14Q3 at Calapooya Creek near Oakland (USGS# 14320700) is 0.093 cms or 3.3 cfs when computed using data from 1955 until 2001. The critical flow condition was achieved by reducing the headwater discharge while not adjusting the tributary and diffuse flows. The water quality concentrations at the headwaters were not changed from the calibration. The same climate data was used as the model calibration.

Scenario I: 2002 Loading

The scenario with July 2002 loading with critical flow condition serves as a baseline to compare the different loading scenarios. The flows at the mouth were reduced from 0.14 cms to 0.08 cms. The model predicts that the decreased flows exacerbate water quality conditions with the lowest daily minimum DO dropping from 4.5 mg/l under the calibrated condition to 3.8 mg/l under the critical flow condition (see main document for graphics). Similarly, the highest daily maximum pH increased from 9.8 to 9.9

Scenario II: Nonpoint Source Loading only

The nonpoint source loading only scenario is the same as the 2002 loading scenario but with zero flow coming from Oakland WWTP. This is actually more representative current conditions because Oakland WWTP no longer discharges effluent during the summer. Despite the reduction in load, daily mean and minimum dissolved oxygen and daily maximum pH do not meet their numeric criteria (see main document for graphics).

Scenario III: TMDL

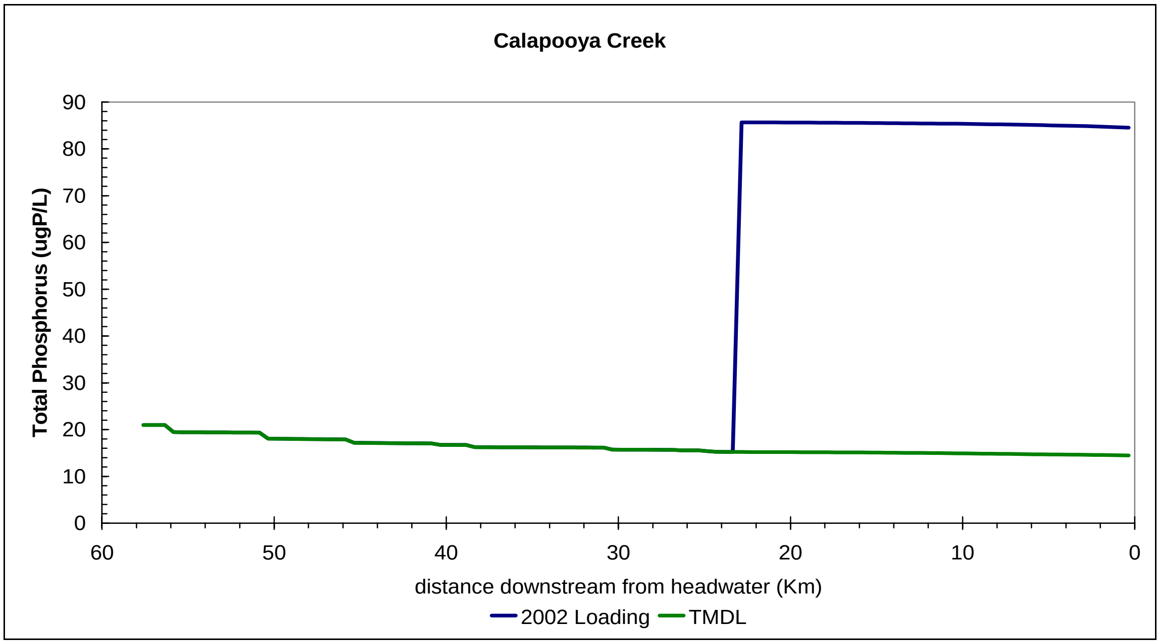
Total phosphorus load reductions and SOD rate reductions are necessary from the 2002 loading to meet the DO and pH standard (Table 5 and Figure 18). Because there are no WWTPs that currently have a permit to discharge effluent during the summer, the wasteload allocations were assigned no measurable impact to DO or pH. No anthropogenic nonpoint sources of phosphorus were identified during this study and hence the load allocation for total phosphorus was set to “no measurable increase” in pH. The nonpoint source component of phosphorus loading is attributed to background loading, or natural sources, and hence is allocated its current contribution.

Table 5. SOD rates between river KM 20.1 and 25.6.

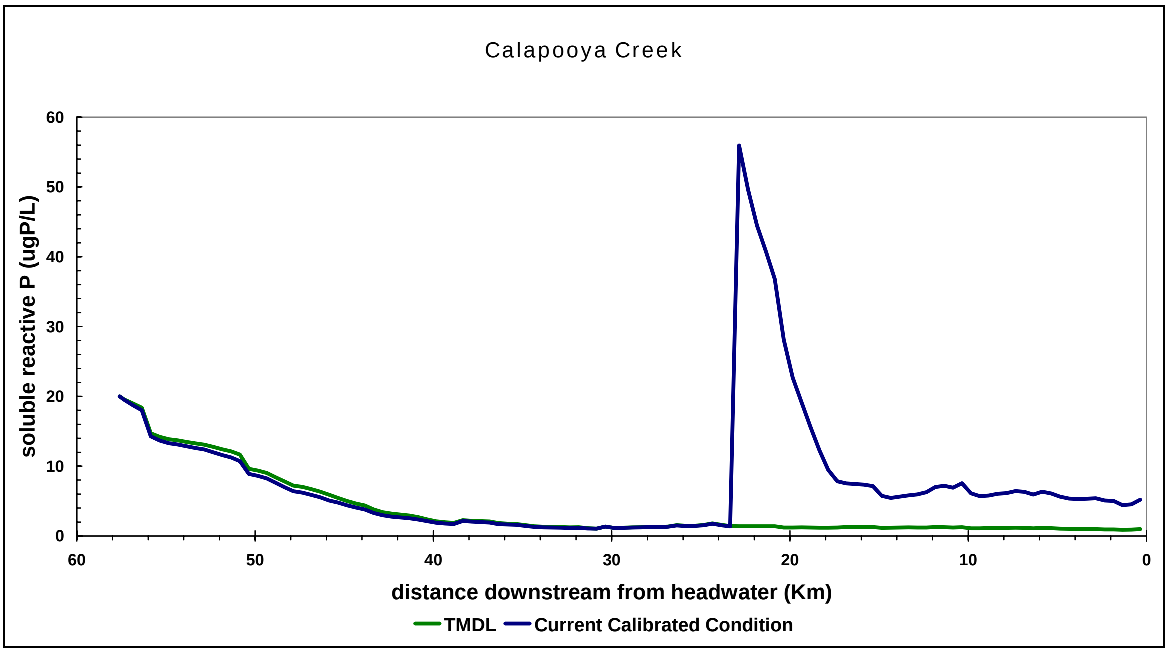
Scenario	SOD	Units
Current Calibrated Conditions	1.5	g O_2 / m^2 / d
TMDL	0.5	g O_2 / m^2 / d

Figure 18. Predicted total phosphorus (A) and inorganic phosphorus (B) targets compared to current calibrated conditions.

A



B



SECTION 3: ELK CREEK NUTRIENT TMDL TECHNICAL DOCUMENTATION

MODEL SETUP AND BOUNDARY CONDITIONS

The model was developed for a single day: September 25, 2002, from river km 0 to 42.5. This sampling period was chosen to address both spawning and non-spawning time periods. However, knowledge about the time period in which spawning occurs has since been refined and this data set is not appropriate to address the spawning time period of October 15 to May 15. The model assumes steady state hydraulics and variable water quality over the course of a day. Meteorology, channel morphology and shade were taken from the temperature TMDL model (see Appendix __). The river was segmented to 0.5 km reaches at an 11.25 minute time step. The initial conditions for the model day were determined by computing water quality parameters until a steady-state condition was achieved (20 days – 1.3 times the predicted time of travel from headwaters to mouth).

Hourly air temperatures are from the Roseburg meteorological station acquired from Oregon Climate Service. The station is located approximately 30 miles from Elk Creek. The relative humidity was estimated to range from 62% to 90% and was used to compute dew point temperature. The wind speed was estimated to be zero because of the large amount of riparian vegetation. These assumptions provided for a good temperature calibration. No cloud cover was reported at the meteorological station at the Roseburg airport, so no cloud cover was used in the model.

The tributary and diffuse inflow discharges were adjusted to match measured Elk Creek discharge measurements collected by DEQ. Withdrawals from Elk Creek were estimated from the points of diversion database provided by Oregon Water Resources Department and adjusted to match instream flows. Because temperature is important in algae dynamics, temperature was also calibrated with QUAL2Kw using sediment thermal conductivity, sediment thermal diffusivity, and sediment zone thickness. The sediment thermal conductivity value was determined through the temperature calibration to be greater than the reported literature range (Pelletier and Chapra, 2004). This is likely compensating for hyporheic flow, which was not explicitly included in this modeling effort, or direct solar heating of the substrate which is not included in QUAL2Kw. Current and system potential shade values were taken directly from the temperature TMDL model for the current calibration and the TMDL scenario.

MODEL CALIBRATION DATA

DO and nutrient calibration was completed by adjusting a number of key parameters so that the model reproduced observed water quality conditions in September 2002 (see Table 1, Appendix 3). Re-aeration rates were originally estimated using the “Thackston-Dawson” formulation; however, specific reaches were reduced by 50% to better capture the timing and magnitude of the diel fluctuations of DO (figure 19). The percentage of the bed that is available for periphyton growth longitudinally varied in order to capture the DO patterns (figure 20). The model performed better with spatially variable bed availability than with a constant value. Floating algae, or phytoplankton, are included in the water quality calculations; however, no data was available for calibration. In order to match observed DO concentrations, a sediment oxygen demand rate (SOD) of 2.5 grams of oxygen per square meter per day (g 02 / m2 / d) was specified between river KM 36.5 and 38.5.

Figure 19. Model calibration: Flow and reaeration.

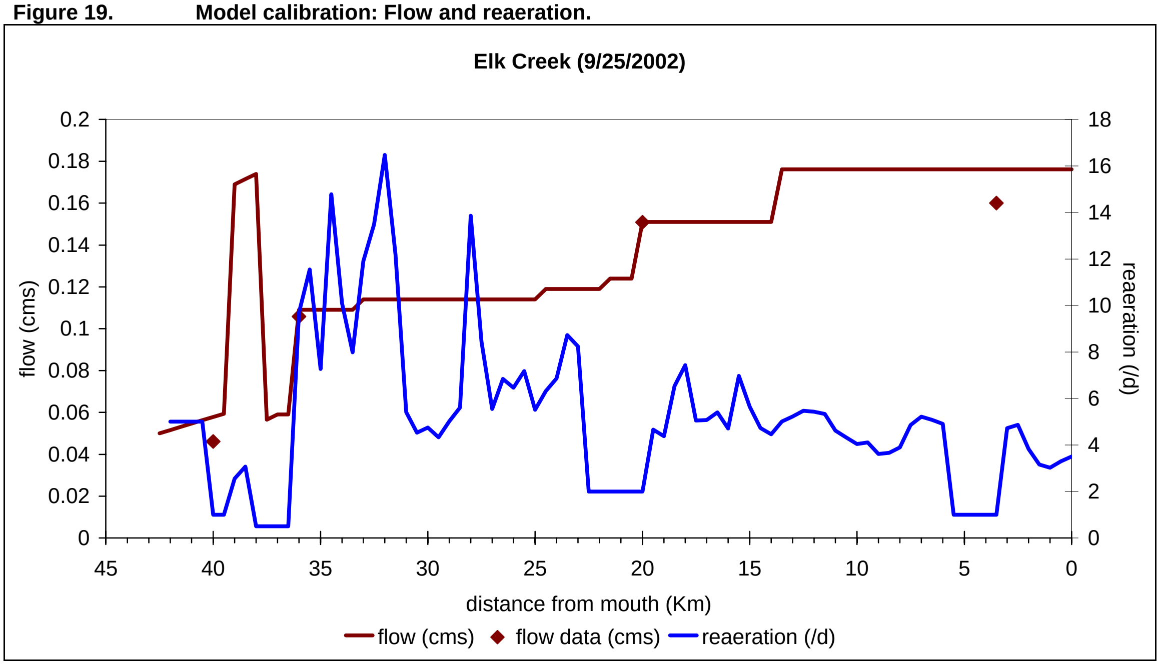


Figure 20. Percentage of stream bottom available for periphyton growth.

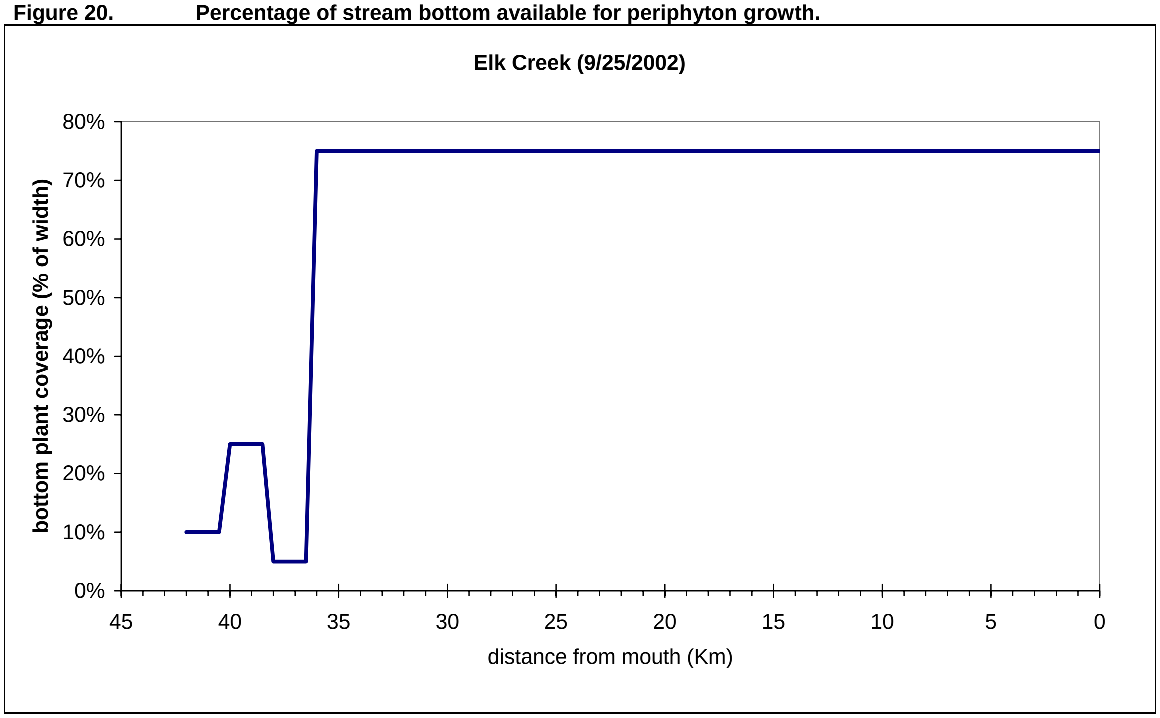
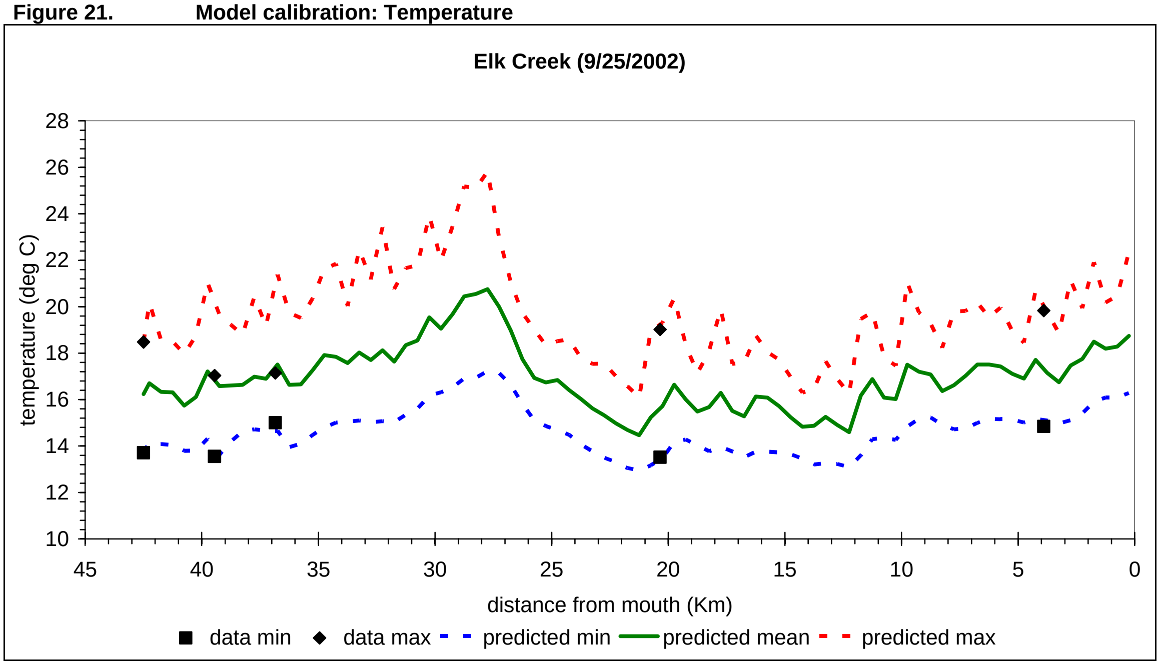


Figure 21. Model calibration: Temperature



The headwater boundary condition was derived from measured instream data (Table 6). Flow data was available for Elk Creek, Pass Creek, and Billy Creek. Tributary water quality data was collected for Pass Creek on 7/24/2002 and 10/15/2002. An average of the two dates was used as boundary conditions information. The remainder of the tributaries and diffuse sources were based on estimates and mass balance calculations (Table 7).

The water quality model was able to generally capture the magnitude and spatial variability of temperature, dissolved oxygen and nutrients (Figures 21 – 29). The model also generally captures the timing and magnitude of diel variability of temperature and dissolved oxygen (Table 8 and Figure 30).

Table 6. Summary of boundary conditions

Site Name	River KM	Discharge *CMS*	Temperature *Deg C*	Conductivity *umhos/cm*	DO *mg/l*
Headwaters	42.5	0.05	13.7 – 18.5	320 – 323	8.1 – 9.7
Pass Creek	39.3	0.109	11.4 – 20.1	163	7.2
Billy Creek	36.4	0.05	11.4 – 20.1	163	7.2
Hardscrabble Creek	33.5	0.005	11.4 – 20.1	163	7.2
Parker Creek	25.0	0.005	11.4 – 20.1	163	7.2
Green Creek	22.0	0.005	11.4 – 20.1	163	7.2
Brush Creek	20.1	0.027	11.4 – 20.1	163	7.2
Tom Folly Creek	13.9	0.025	11.4 – 20.1	163	7.2
Diffuse source #1	39.3 – 42.5	0.01	18	400	8.0
Diffuse source #2	37.0 – 39.0	0.01	18	100	8.0
Withdraw	38.0	-0.12	na	na	na

Table 7. Summary of boundary conditions.

Site Name	Slow Dissolved Organic C (4) *mgC/L*	Fast Dissolved Organic C (5) *mgC/L*	Dissolved Organic N (6) *ugN/l*	Ammonia N *ugN/l*	Nitrate + Nitrite N *ugN/l*	Dissolved Organic P (7) *ugP/l*	Soluble Reactive P *ugP/l*	Particulate Organic C *mgC/l*	Particulate Organic N *mgN/l*	Particulate Organic P *mgP/l*	Alkalinity *mgCaCO3/l*
Headwaters (1)	0.41	0	270	30	5	32	8	0	0	0	74
Pass Creek (2)	0.24	0	206	25	23	21	19	0	0	0	36
Billy Creek (3)	0.5	0	300	30	23	18	10	0	0	0	50
Hardscrabble Creek (3)	0.5	0	500	30	23	18	22	0	0	0	36
Parker Creek (3)	0.5	0	500	30	23	18	22	0	0	0	36
Green Creek (3)	0.5	0	500	30	23	18	22	0	0	0	36
Brush Creek (3)	0.5	0	500	30	23	18	50	0	0	0	36
Tom Folly Creek (3)	0.5	0	500	30	23	60	50	0	0	0	36
Diffuse source #1	1.0	0	750	18	100	9	5	0	0	0	100
Diffuse source #2	1.0	0	500	250	23	9	5	0	0	0	100

Notes:
Laboratory results that were less than the reporting limit were entered into the model as 0.8 of reporting limit.
C = Carbon; N = Nitrogen; P = Phosphorus
1. Based on sample collected on September 25, 2002.
2. Average of samples collected on 7/24/2002 and 10/15/2002.
3. Determined through estimates and mass balance.
4. Slow Dissolved Organic C = Total organic C - Fast Dissolved Organic C
5. Fast Dissolved Organic = C-BOD / 2.69
6. Dissolved Organic N = Total Kjeldahl Nitrogen - Ammonia
7. Dissolved Organic P = Total P – Soluble Reactive P

Figure 22. **Model calibration: Conductivity**

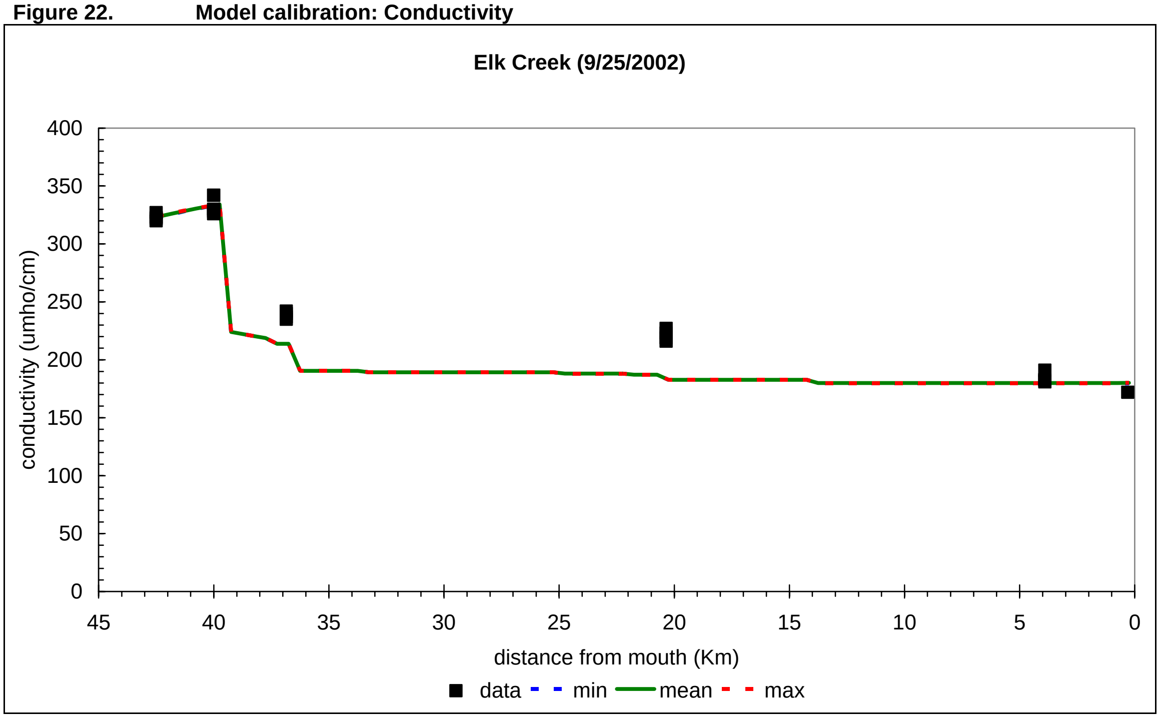


Figure 23. **Model calibration: Dissolved oxygen**

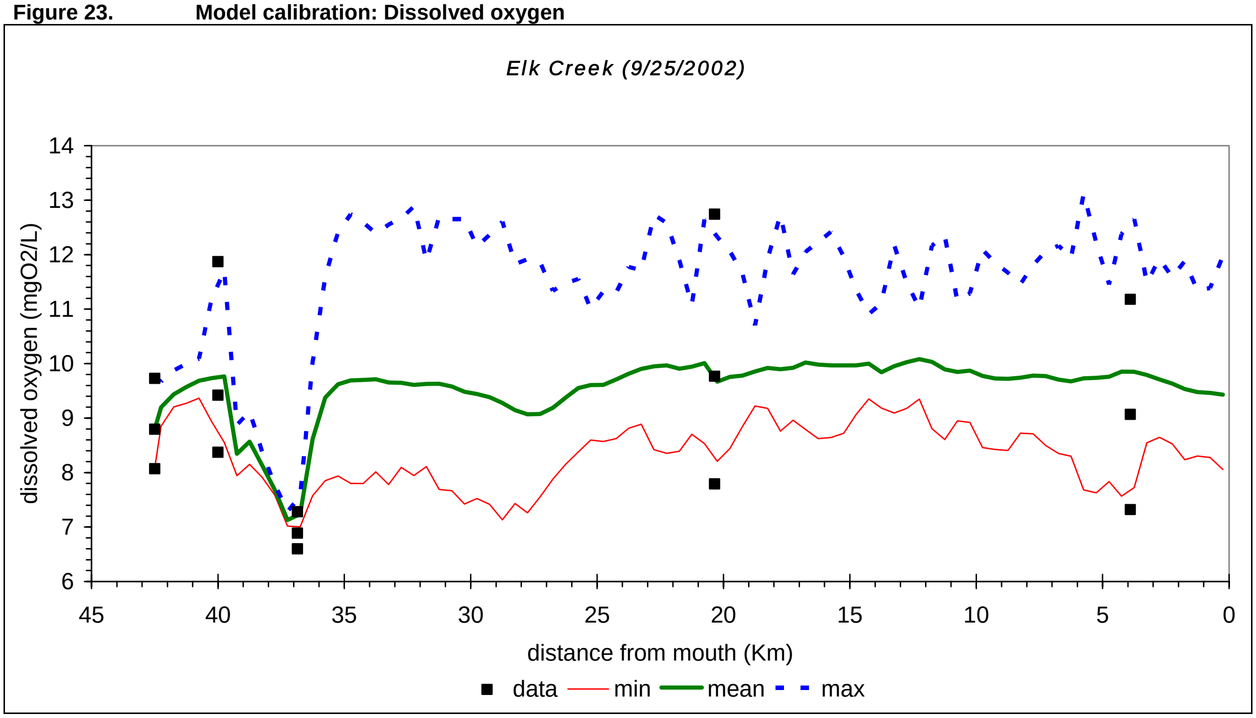


Figure 24. **Model calibration: dissolved organic nitrogen**

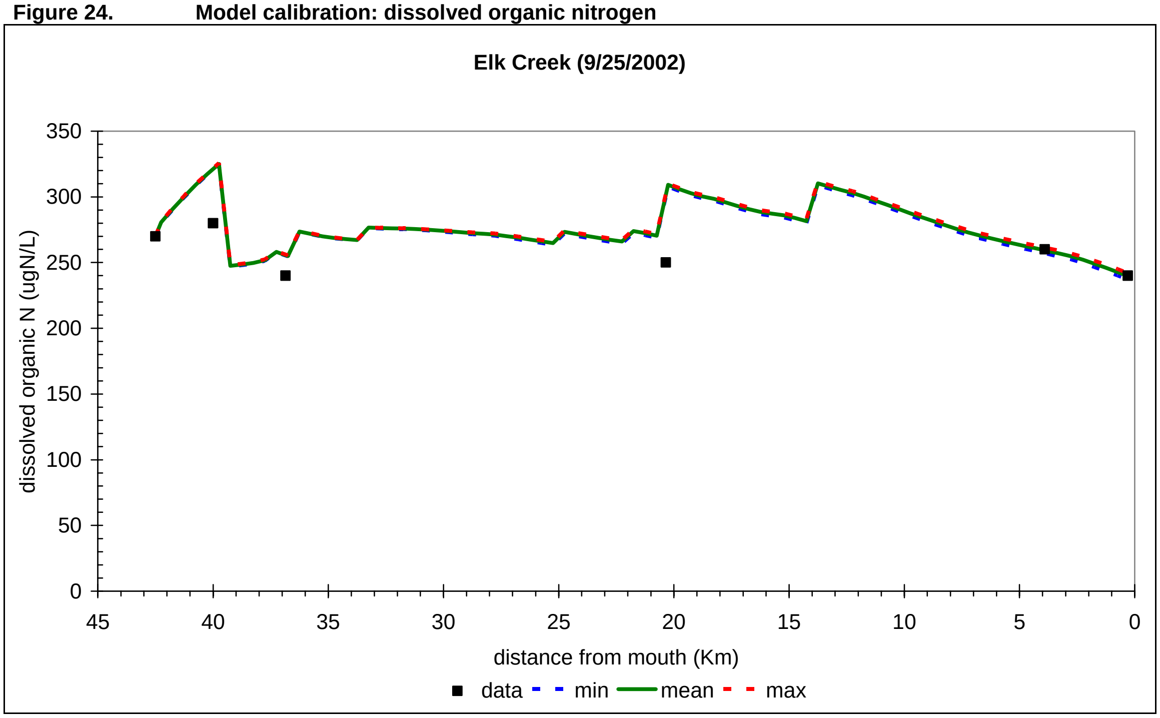


Figure 25. **Model calibration: Ammonia**

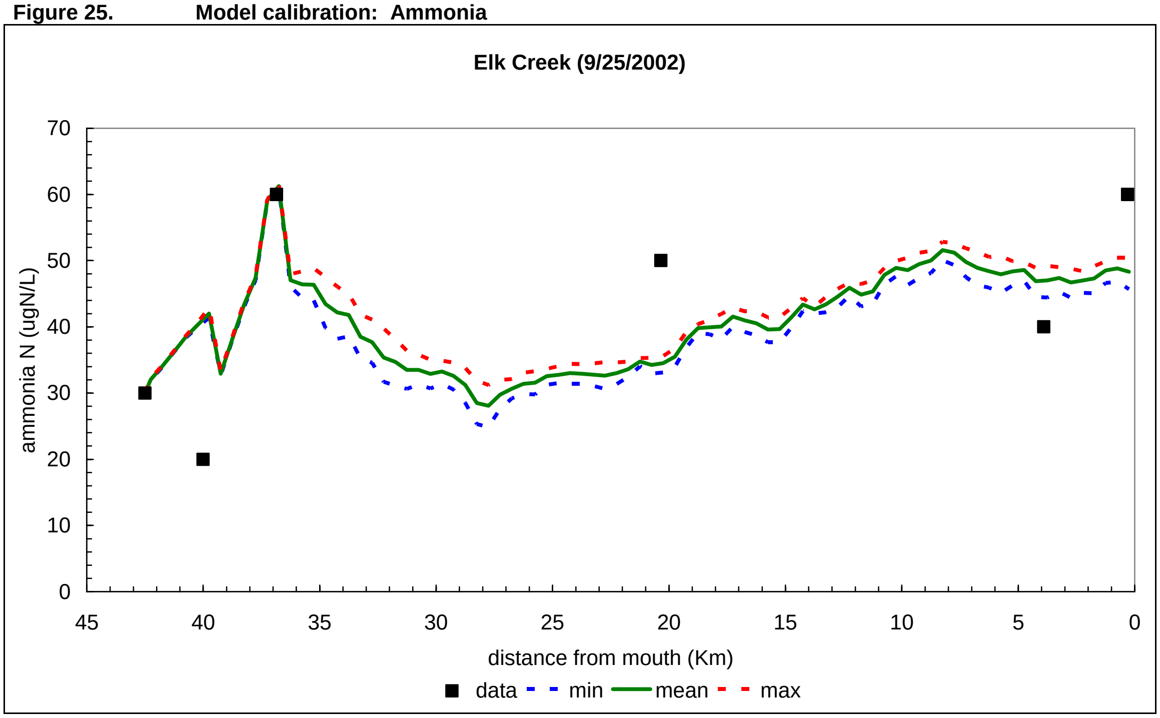


Figure 26. Model calibration: sum of nitrate and nitrite.

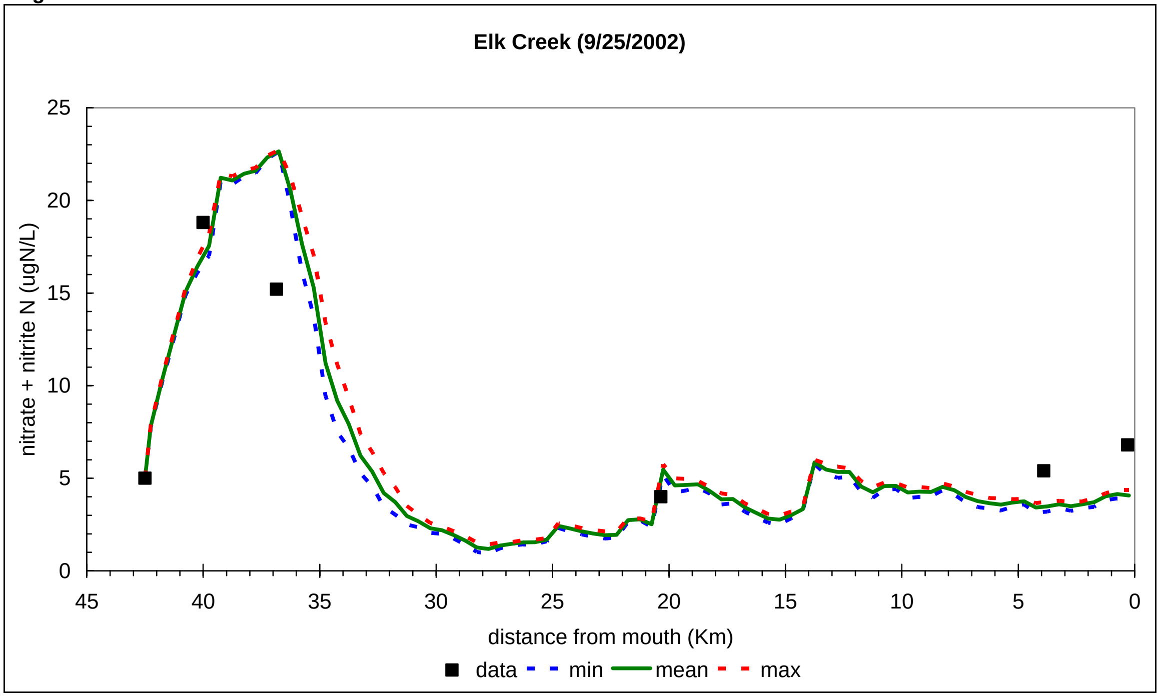


Figure 27. Model calibration: soluble reactive phosphorus

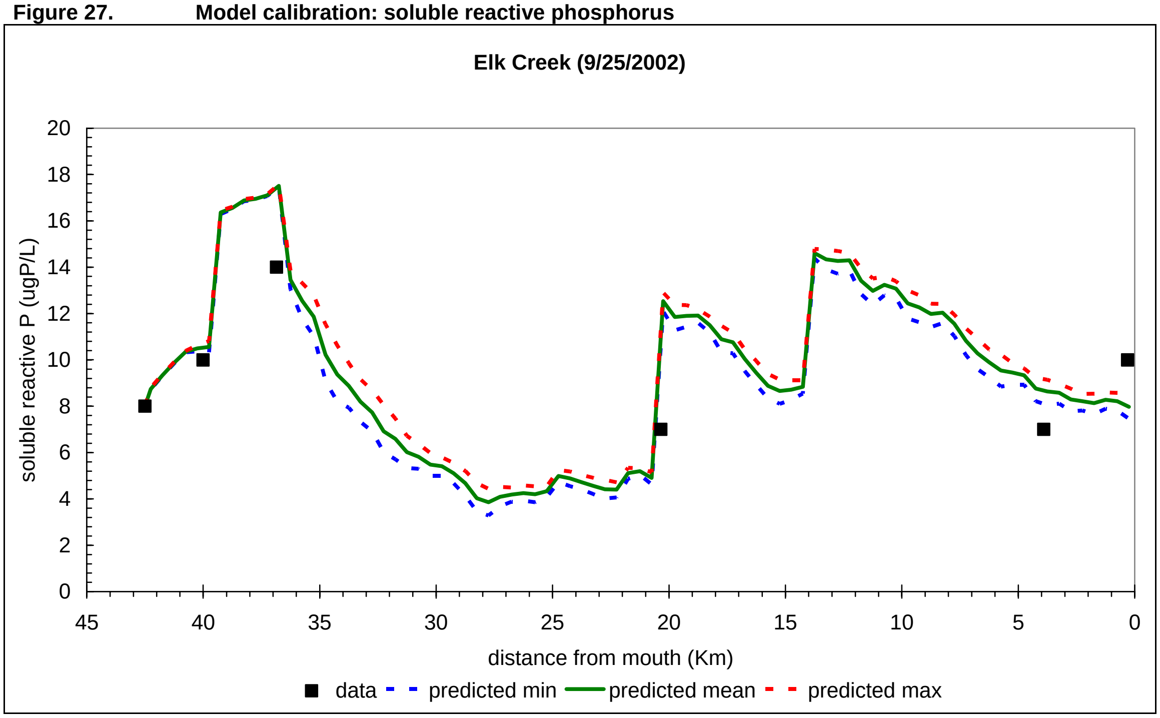


Figure 28. Model calibration: dissolved organic phosphorus.

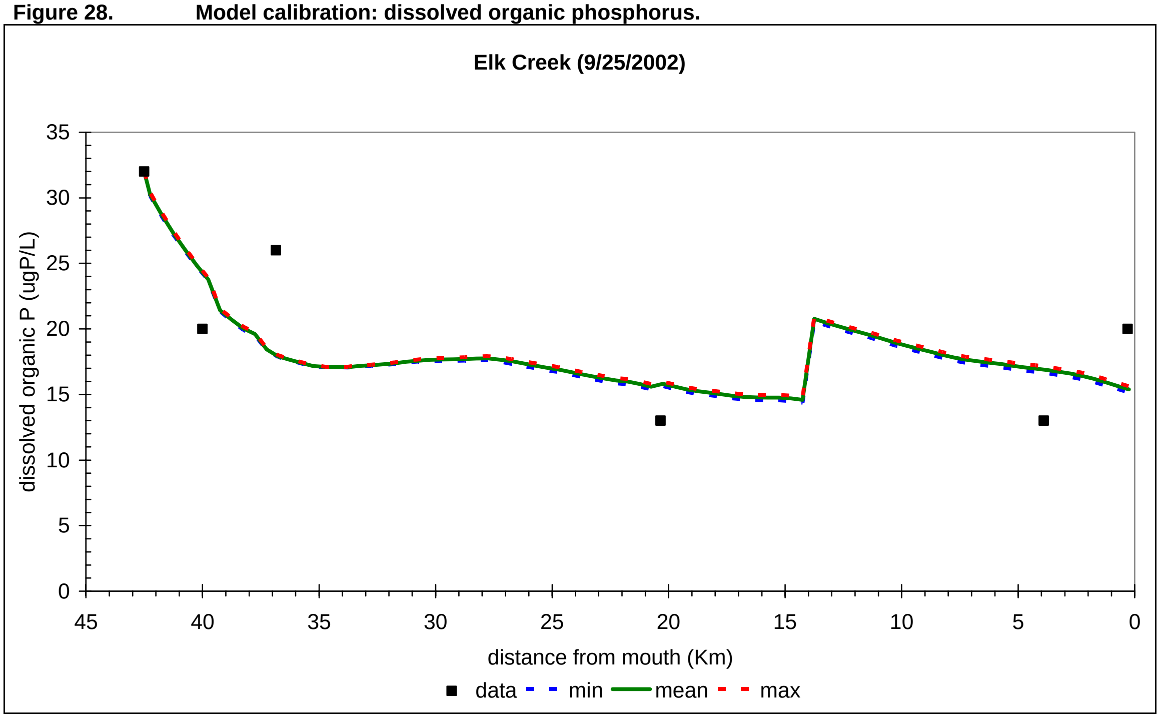


Figure 29. Model calibration: dissolved organic carbon (DOC).

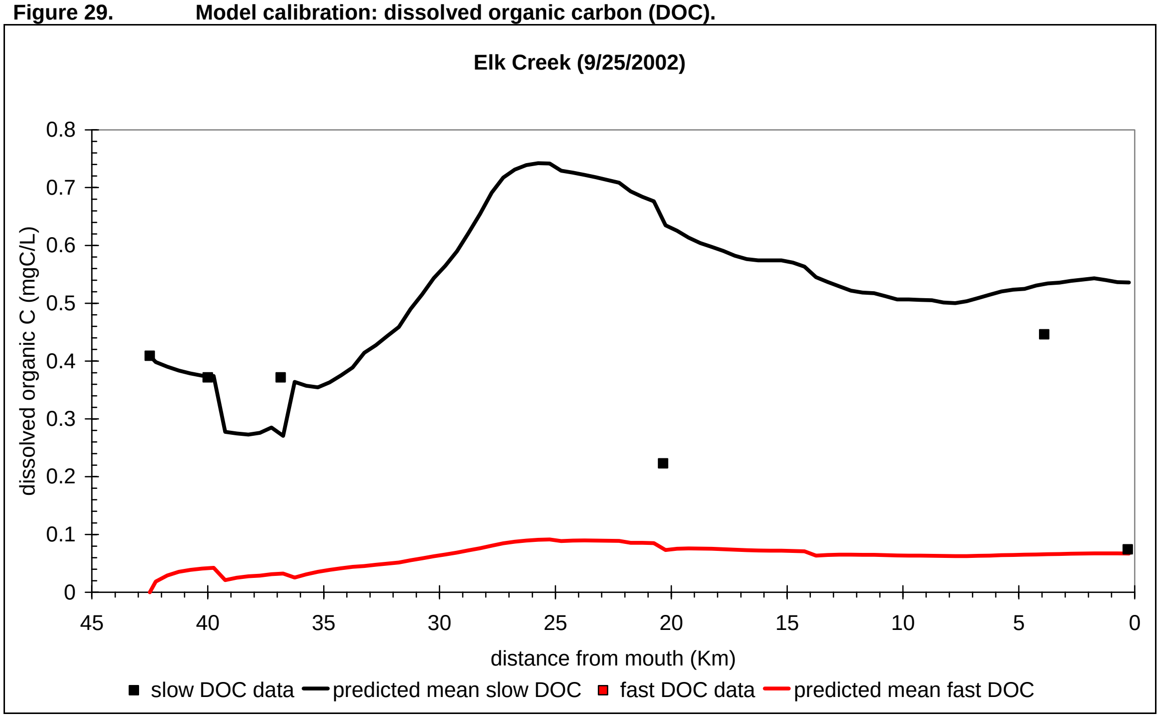
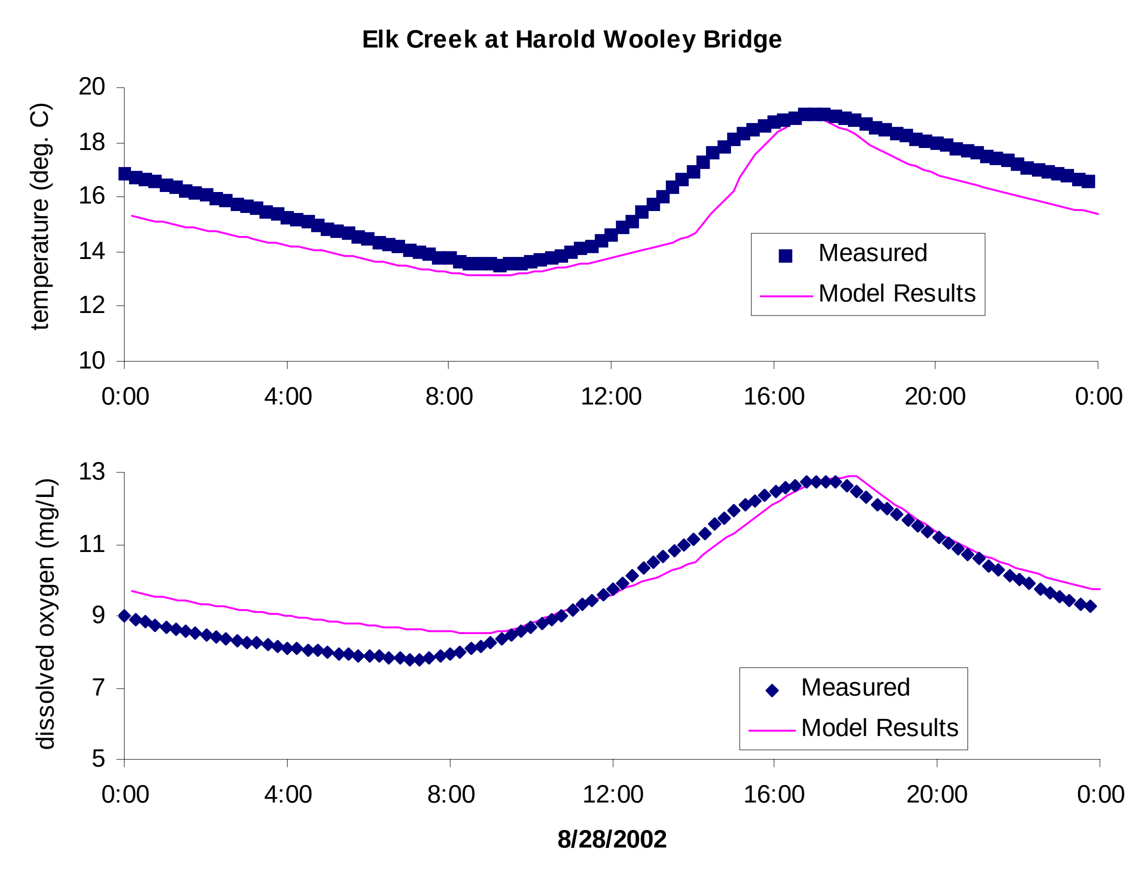


Table 8. Calibration results. ME = mean error; AME = absolute mean error; RMSE = root mean square error.

			Temperature			Dissolved Oxygen		
ID #	Description	river KM	ME	AME	RMSE	ME	AME	RMSE
28998	Elk Creek above Pass Creek	39.45	1.7	1.7	2.2	0.3	0.7	0.8
11304	Elk Creek @ Hayhurst Road Bridge	36.85	1.7	1.8	2.2	0.4	0.4	0.5
25172	Elk Creek @ Harold Wooley Bridge	20.35	-0.9	0.9	1.1	0.2	0.5	0.6
29286	Elk Creek 1.8 miles on rd.	3.9	0.1	0.3	0.4	0.8	0.8	0.9
	Average		**0.8**	**1.5**	**1.8**	**0.3**	**0.5**	**0.6**

Figure 30. Calibration results for Elk Creek at Harold Wooley Bridge



Source Identification

Elk Creek forms a pool in the low gradient reach near Hayhurst Road downstream of Drain at river KM 36.9. As velocities decreases and depth increases, reaeration rates decrease. Because of the low reaeration, sediment oxygen demand (SOD) is able to lower the dissolved oxygen concentrations. Sediment oxygen demand is the oxygen demand exerted by the aerobic decomposition of sediments on the stream bottom, and is likely caused by organic solids settling into the pool and decomposing, consuming oxygen. The Drain WWTP is a source of organic solids: There were 12 reported sewage overflows into Elk Creek between September 2000 and September 2002. Overflows at the facility continue to occur during the wet season. Another source of organic material is likely attached algae that have sloughed off upstream and settles in the low velocity pool.

TMDL SCENARIO

In addition to the calibration model run, a scenario was run to determine the TMDL. The specified SOD from river KM 36.5 to 38.5 was gradually reduced until the mean DO was greater than 8.0 mg/L (see main document for figures). Flow conditions were not altered because of the lack of recent gage information to determine the critical condition. In order to meet water quality standards the SOD rate was decreased 40% from 2.5 to 1.5 (gO2/m^2/d). Decreasing boundary condition ammonia concentrations did not have a significant impact on mean DO concentrations (<0.1 mg/L).

MARGIN OF SAFETY

The margin of safety is implicit because the allocation is to reduce SOD until water quality standards are met. The 40% reduction computed above is an estimate of the necessary reduction.

SECTION 4: JACKSON CREEK SUMMER NUTRIENT TMDL TECHNICAL ANALYSIS REPORT

MODEL SETUP

The model was setup using for August 28, 2002 using continuous monitoring data collected by DEQ between August 26 and August 29. The model was developed for Jackson Creek from its mouth to just upstream of Falcon Creek at river KM 33.5. The stream was represented in the model as 67 reaches; each 500 meters long. Water quality was computed for each of these reaches and the information was passed in the downstream direction. The model was run with an 11.25 minute time step using the Euler's numerical integration method. There was a four day flushing period so that the model was a steady state; total travel time was 2.1 days. Results are reported for the 5th day of the simulation.

Meteorological Data

Hourly air temperatures are from the Buckeye meteorological station downloaded from the Western Regional Climate Center. The station is located approximately 4 miles from Jackson Creek. Air temperature was corrected for elevation differences using the adiabatic lapse rate which was an equivalent shift in temperature by +2.3 degrees C. The relative humidity values from the Buckeye meteorological station were used to compute the hourly dew point temperatures. The wind speed was estimated to be zero because of the large amount of riparian vegetation. This assumption provided for a good temperature calibration. No cloud cover was reported at the meteorological station at the Roseburg airport, so no cloud cover was used in the model.

Discharge, Conductivity, and Reaeration Rates

The model headwater, tributary, and main stem flows were measured by WRD during August 2002 (Table 9). To match observed flows and conductivity, diffuse sources were included in the model (Table 10). Reaeration rates were estimated using the Owen-Gibbs formulation with a maximum value of 75 /day (figure 31). This formulation provided for reaeration rates which allowed for the calibration of pH.

Table 9. Summary of boundary conditions measured by DEQ on August 28, 2002, except where noted.

		Flow (1)	**Temperature**	**Conductivity**	**Dissolved Oxygen**	**pH**
Site Name	**River KM**	(CMS)	°C	umhos/cm	Mg/L	s.u.
Headwater	33.5	0.098	11.9 – 16.1	85 – 86	8.9 – 9.9	7.5 – 7.8
Falcon Creek	33.30	0.028	15.4	90	9.1	7.5
Squaw Creek	18.25	0.130	14.2	74	9.5	7.6
Black Canyon Creek	17.55	0.005	17.3	121	9.9	8.4
Beaver Creek	6.75	0.029	22.6	140	9.5	7.9

1. Flow measured August 27-28, 2002 by WRD.

Table 10. Diffuse sources determined through water balance, temperature, and conductivity calibrations.

Up	Down	Diffuse Outflow	Diffuse Inflow	Temperature	Conductivity	Dissolved Oxygen	pH
(km)	(km)	(m^3/s)	(m^3/s)	°C	umhos/cm	Mg/L	s.u.
33	24		0.070	15	120	8	7.0
17	0		0.020	15	500	8	7.0

Figure 31. Measured flow versus model flow.

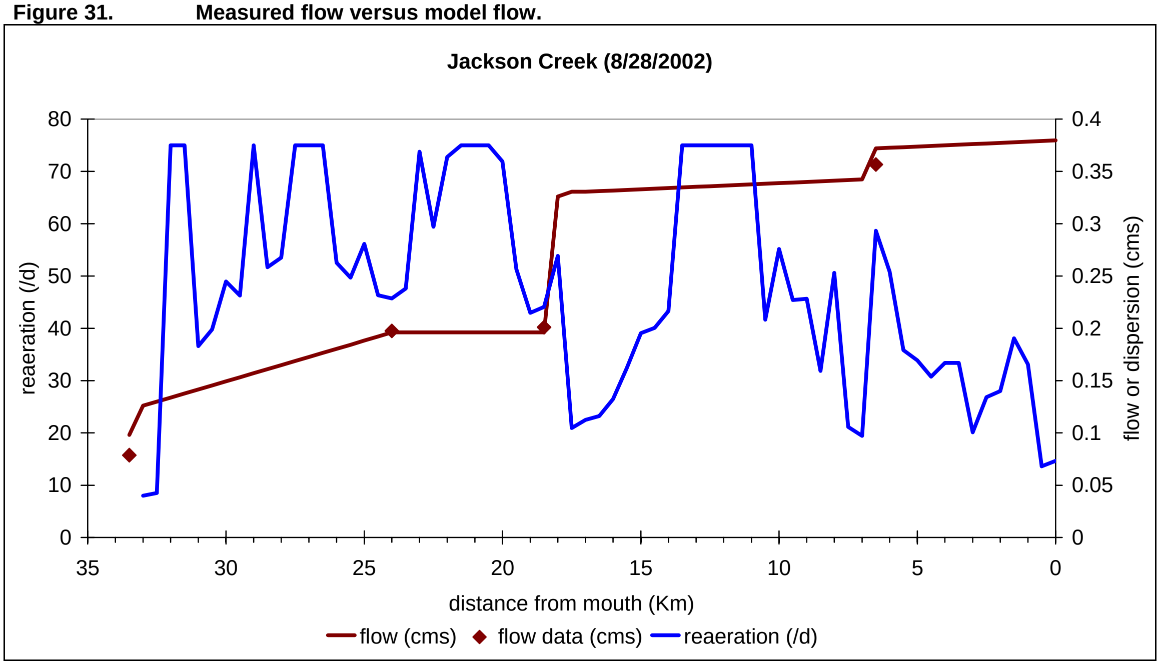
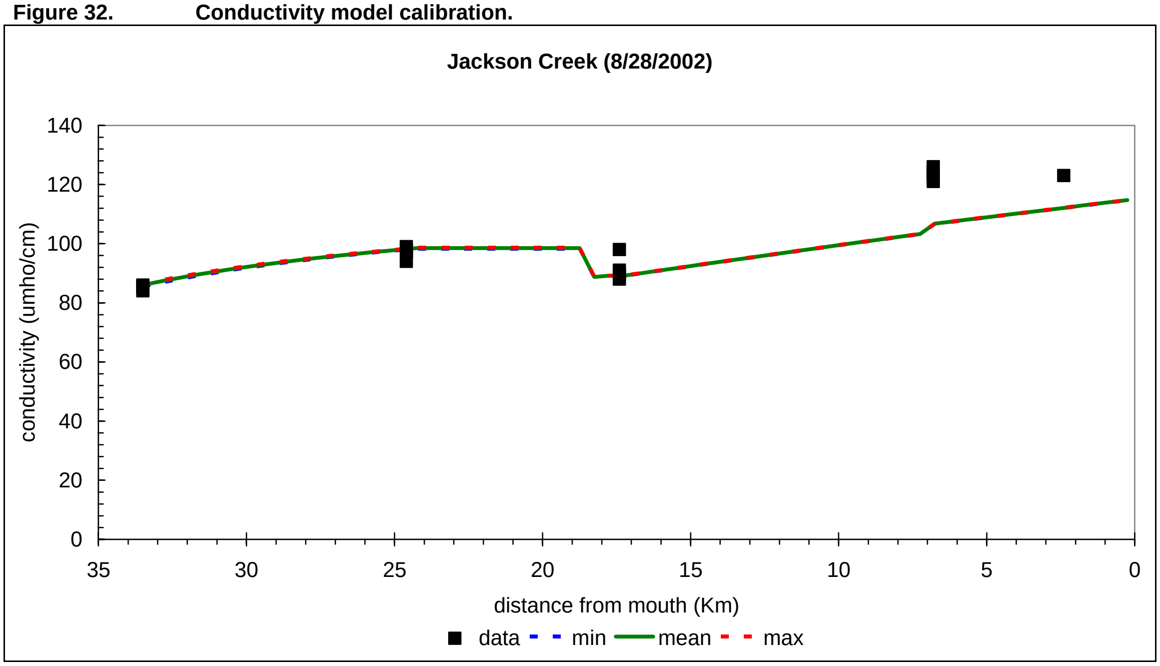


Figure 32. Conductivity model calibration.



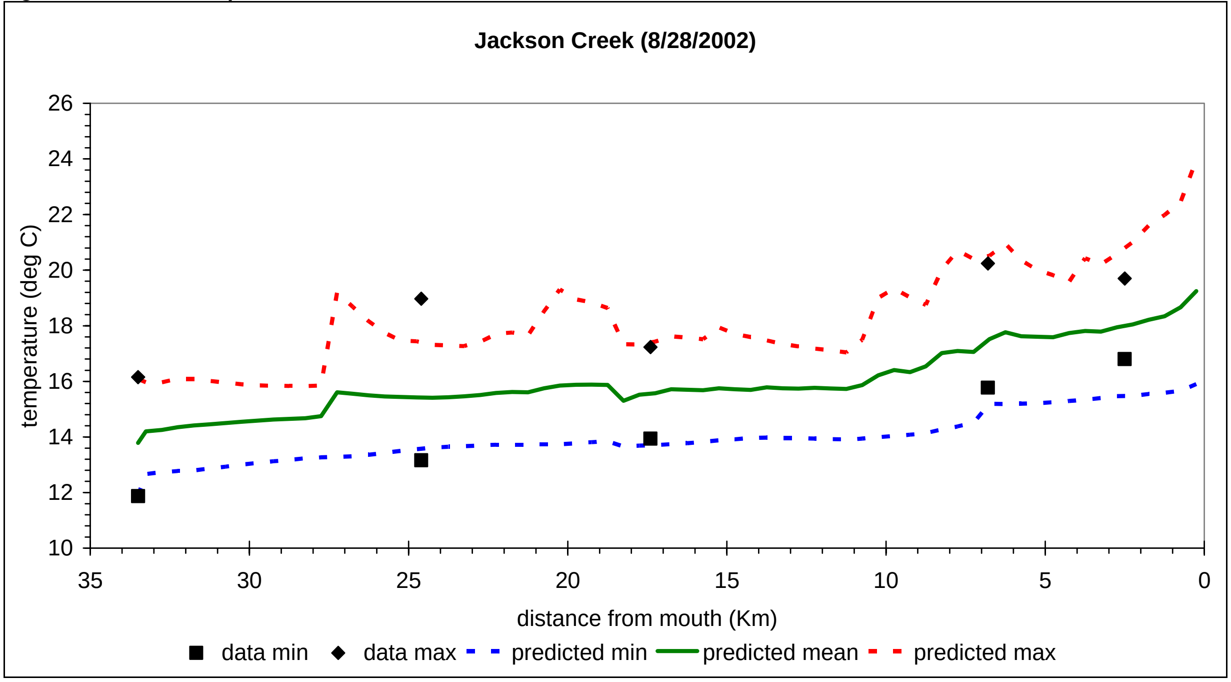
Channel morphology along with flow determines the hydraulics of the system which defines the travel time, depth and width of the river. Each reach in the model was set at a 500-meter length. The bank full width was determined through digitizing aerial photographs and field data (see temperature TMDL for full discussion). Bankfull width, the slope of the side of the channel, and a width-to-depth ratio are used to estimate the bottom width of a trapezoidal channel. The slope of a reach was determined using a 10-meter digital elevation model. The Manning's n for each reach was determined through hydraulic calibration in Heat Source (see temperature TMDL).

Temperature

In general, the energy balance in Heat Source (the model used for the temperature TMDL) and Qualk2k are alike. Both account for solar radiation, long wave radiation, the effect of shade, substrate conduction, evaporation, convection and hyporheic exchange. Although similar, the energy balance in Heat Source and Qual2k do vary slightly, these differences however do not have a large impact on the results (less than 0.5 degrees). Differences include that Heat Source accounts for diffuse radiation and solar radiation passing through the water column into the substrate. Values for shade were taken directly from the temperature TMDL analysis. Hyporheic flow was assumed to have a negligible impact on temperature and water quality in Jackson Creek. No measurements or estimates of hyporheic exchange were available. Sediment thermal conductivity, thermal diffusivity and thickness were used as calibration parameters for the temperature analysis.

The model was able to reproduce observed water column temperatures with an average root mean square error of 0.7 when compared with diel measurements (Figure 33 and Table 11, below).

Figure 33. Temperature calibration results



BOUNDARY CONDITIONS

Water quality conditions must be input into the model at the model's upstream boundary and for all tributaries and point sources entering the river. Whenever possible, headwater and tributary conditions were based on data collected on 8/28/2002 (Table 11 and 12). Diffuse flow was first assumed at concentrations representative of background loading (see South Umpqua Nutrient TMDL discussion) or secondly was adjusted to match instream concentrations.

Table 11. Summary of boundary conditions.

Site Name	River KM	Inorganic Suspended Solids (1)	Slow Dissolved Organic C (2)	Fast Dissolved Organic C (3)	Dissolved Organic N (4)	Ammonia N	Nitrate + Nitrite N	Dissolved Organic P	Soluble Reactive P	Particulate Organic C (5)	Alkalinity
		mg/L	*mgC/L*	*mgC/L*	*ugN/L*	*ugN/L*	*ugN/L*	*ugP/L*	*ugP/L*	*mgC/L*	*mgCaCO3/L*
Jackson Creek Above Falcon Creek (Trib of S. Ump)	33.50	1	0	0.04	144	16	4	5	35	0.8	33
Falcon Creek (LB)	33.30	0	0	0.1	140	20	5	15	25	0.7	35
Squaw Creek (LB)	18.25	0	0	0.11	140	20	9	16	14	0.7	33
Black Canyon Creek (LB)	17.55	1	0	0.3	140	20	9	0	20	0.7	50
Beaver Creek (LB)	6.75	0	0	0.2	130	30	20	6	24	0.6	45

C = Carbon; N = Nitrogen; P = Phosphorus
Underlined indicates that values were set to background loading conditions as determined in the South Umpqua River TMDL.
Italics indicate that values were adjusted so that in stream measurements could be duplicated.
Measurements that were below the method reporting limit were input into the model as 80% of the reporting limit.
1. Inorganic suspended solids is a subset of the total suspended solids.
2. Assumed to be negligible
3. Fast Dissolved Organic = C-BOD / 2.69
4. Dissolved Organic N = Total Kjeldahl Nitrogen - Ammonia
5. Particulate Organic C = total organic C – dissolved organic C

Particulate Organic Nitrogen and Phosphorus and phytoplankton assumed to be negligible.

MODEL CALIBRATION

pH and nutrient calibration was completed by adjusting a number of key parameters so that the model reproduced observed water quality conditions in August 2004 (see Table 1, Appendix 3, Table 12, and Figures 34 - 41). The model performed better when accounting for luxury uptake of nutrients. Periphyton growth, respiration, excretion, and death rates were adjusted so that the model could reproduce the diel variation in pH. The rates governing the fate of nutrients were adjusted so the model could reproduce the general pattern of nutrient concentrations. Phytoplankton and dissolved oxygen were included in the model calculation, however they were considered in the calibration. The percentage of the bed that is available for periphyton growth was assumed to be 75%. The model was able to reproduce the observed patterns of pH (average RMSE 0.3 S.U.) and capture the general trend of nutrients. The model predicts that periphyton growth would be nitrogen limited in the upper reaches of the model transitioning to phosphorus limited near the mouth (Figure 42). However, other factors are like stream temperature and available solar radiation are limiting periphyton growth more than nutrient availability.

Table 12. Error statistics for Jackson Creek water quality model. ME = mean error, AME = absolute mean error, RMSE = root mean square error.

River KM	Jackson Creek Station Name	pH ME	pH AME	pH RMSE
24.6	Jackson Creek u/s of Twomile Creek	0.1	0.2	0.2
17.4	Jackson Creek d/s of Black Canyon Creek	0.3	0.3	0.4
6.8	Jackson Creek d/s of Beaver Creek	0.2	0.3	0.4
	Average	0.2	0.3	0.3

Figure 34. Comparison of measured dissolved organic nitrogen with model results

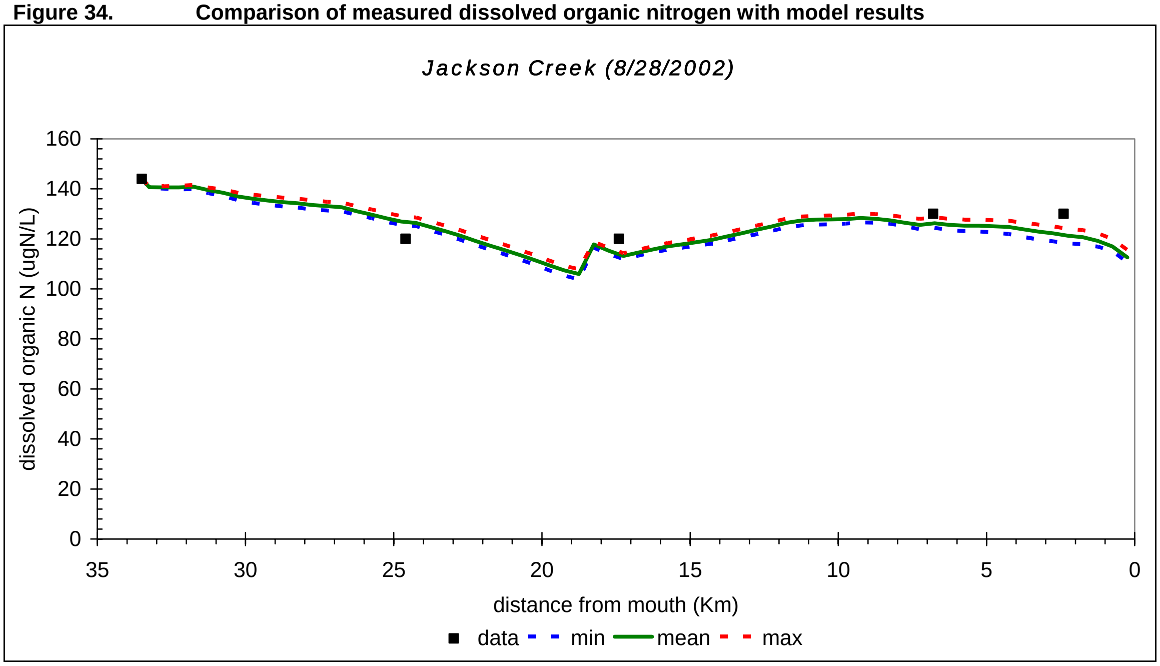


Figure 35. Comparison of measured nitrite and nitrate with model results

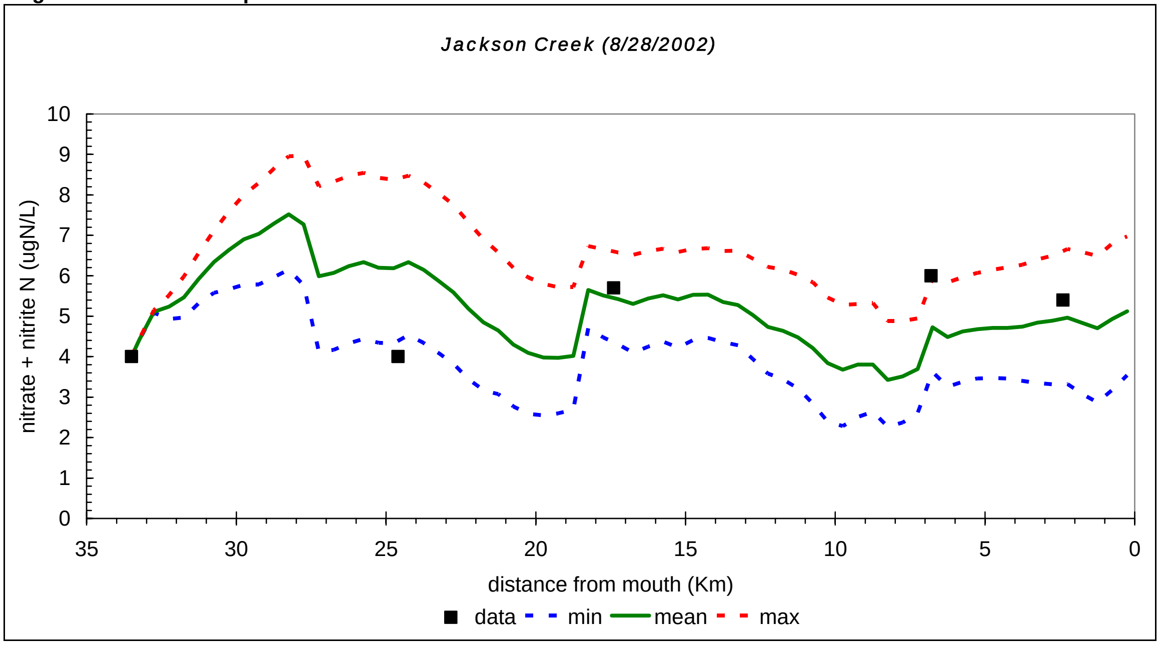


Figure 36. Comparison of measured ammonia with model results

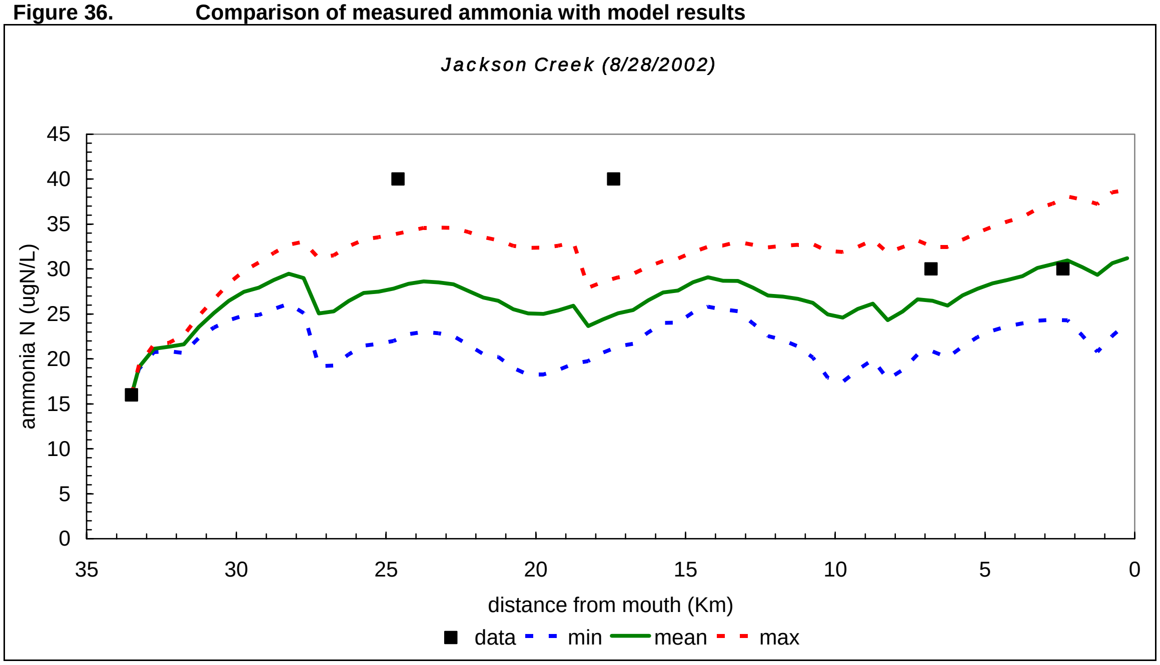


Figure 37. Comparison of measured dissolved organic phosphorus with model results

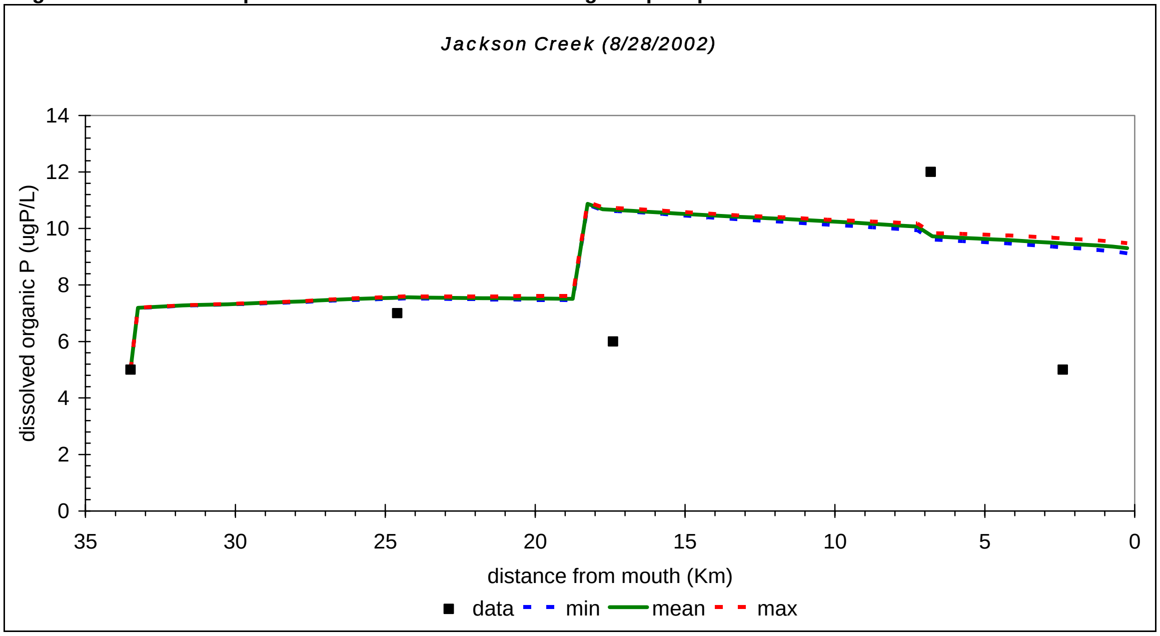


Figure 38. Comparison of measured soluble reactive phosphorus with model results

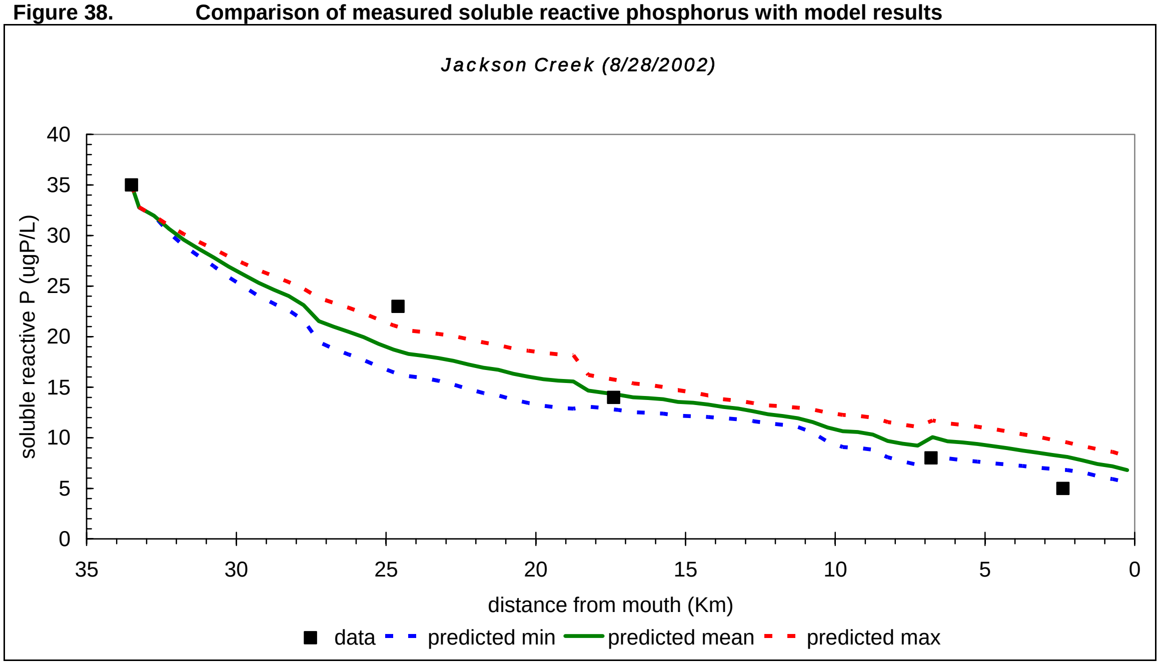


Figure 39. Comparison of measured alkalinity with model results

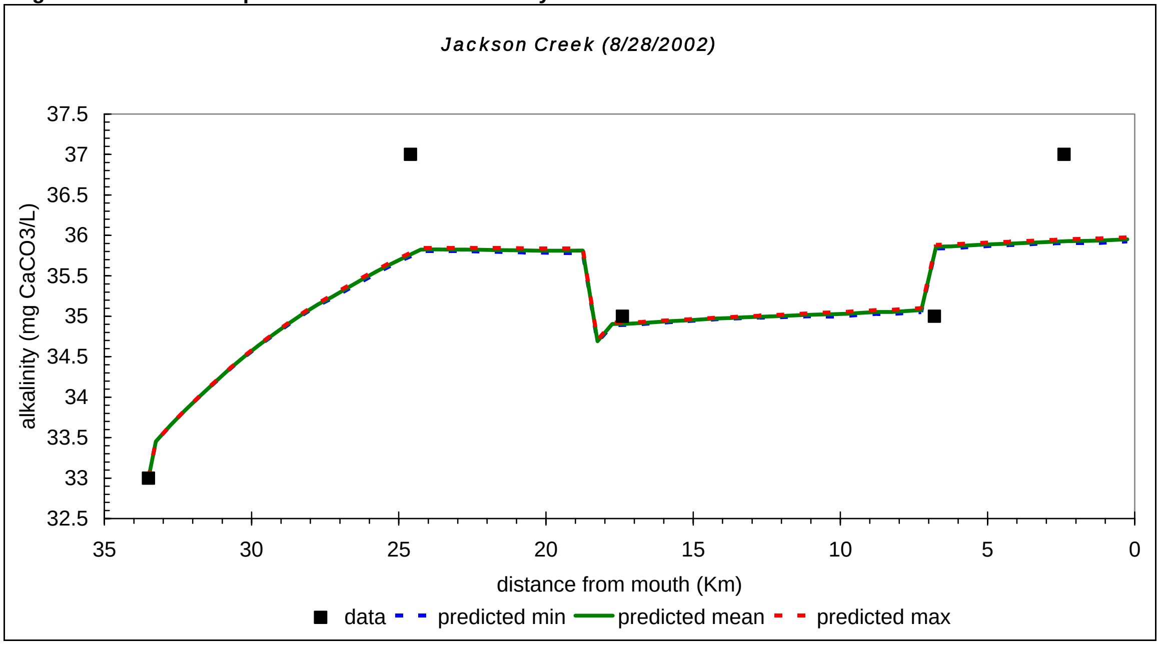


Figure 40. Comparison of measured pH with model results

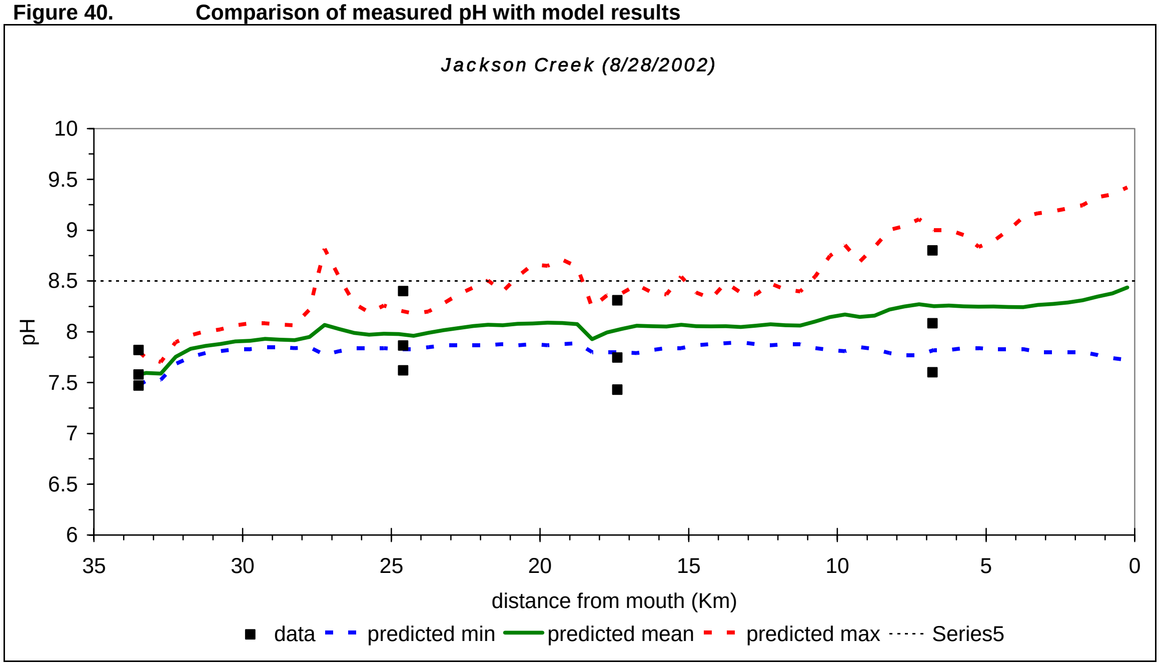


Figure 41. Comparison of continuous pH measurements with model results

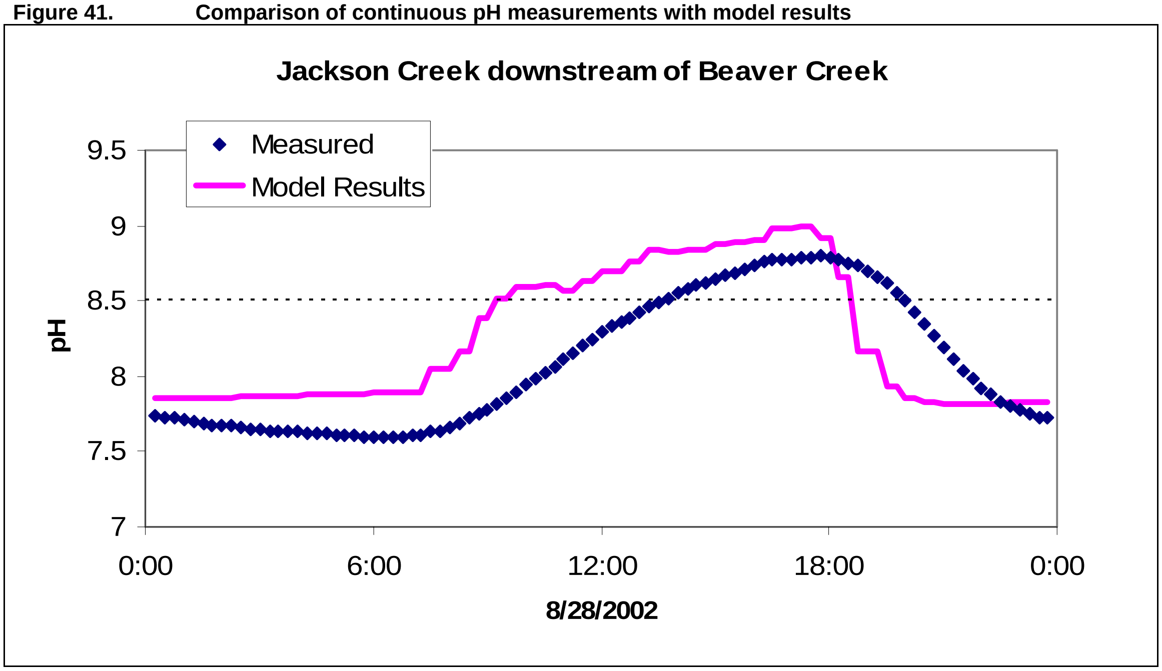
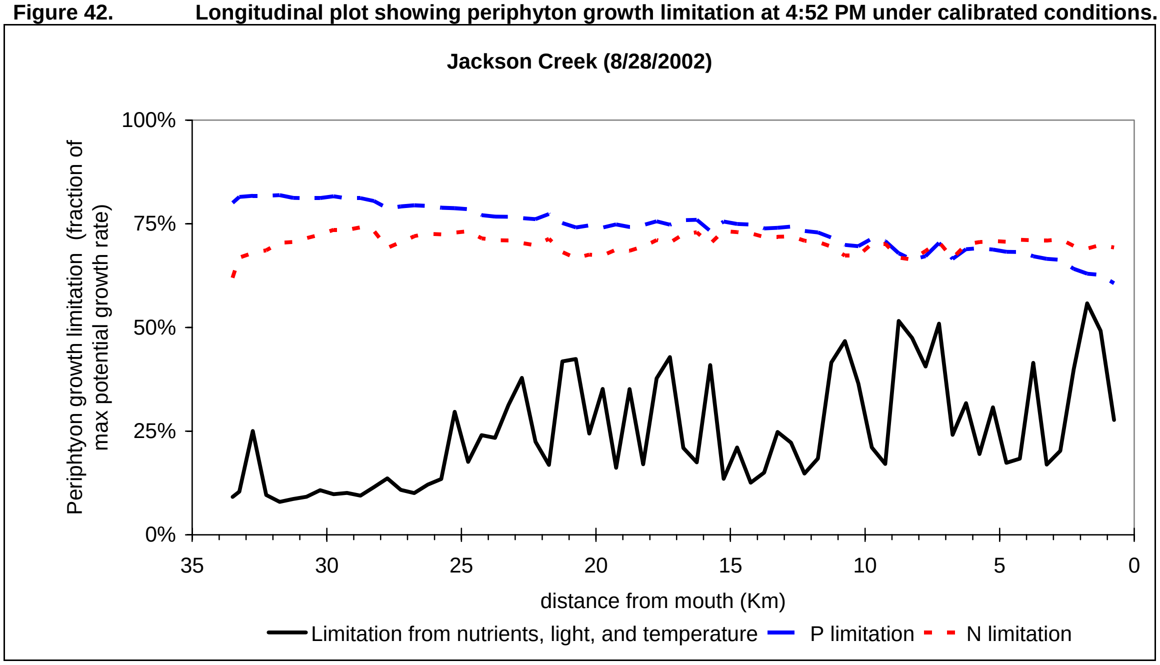


Figure 42. Longitudinal plot showing periphyton growth limitation at 4:52 PM under calibrated conditions.



SCENARIO: TMDL FOR CURRENT LOADING

In addition to the calibrated period in August 2002, one other scenario was modeled: current loading with system potential shade. This scenario is the TMDL because no sources of anthropogenic nutrient loading were identified. Scenarios are compared with the calibration from 2002. The scenarios were run with the same climate data as the August 2002 run. The flow in the model was not altered from the calibration run because there is limited recent gage data to determine a critical low flow. In other part of the South Umpqua subbasin, August 2002 was a period of very low flows with Cow Creek and the South Umpqua River well below there three-year low flow condition (calculated based on a 14-day average). With system potential shade, the model predicts an average decrease in daily maximum pH of 0.1 and a maximum decrease of 0.5 (see Jackson Creek TMDL).

SECTION 5: STEAMBOAT CREEK SUMMER NUTRIENT TMDL TECHNICAL ANALYSIS REPORT

General Model Setup

The model was set up using the August 9, 2000 continuous monitoring data collected by DEQ. The model was developed for Steamboat Creek from its mouth to just below of City Creek at river KM 28.7. The stream was represented in the model as 57 reaches, each 500 meters in length. Water quality is computed for each of these reaches and the information is passed in the downstream direction. The model was run with an 11.25 minute time step using the Euler's numerical integration method. There was a five day flushing period so that the model was a steady state; total travel time was 2.1 days. Results are reported for the 6th day of the simulation.

Meteorological Data

Meteorology plays an important role in determining water quality. It is an integral part of the energy balance that determines water temperature. Water temperature, along with solar energy, directly influences the growth of algae and hence nutrient dynamics, DO and pH.

Hourly air temperatures are from the Grandad meteorological station downloaded from the Western Regional Climate Center. The station is located within the Steamboat watershed. A good temperature calibration could not be achieved using the dew point temperatures from Grandad. This is likely because the meteorological station is located on a ridge and would be expected to have much lower dew point temperatures than in the riparian zone. Model dew point temperatures ranged between 13.2 and 25.7. The wind speed was estimated to be zero because of the large amount of riparian vegetation. This assumption provided for a good temperature calibration. No cloud cover was reported at the meteorological station at the Roseburg airport, so no cloud cover was used in the model.

Discharge, Conductivity, and Reaeration Rates

Main stem flows were measured by DEQ during August 2000. Tributary and diffuse flow was adjusted to match observed flows (Table 13 and Figure 43). Tributary conductivity was estimated using a mass balance approach (Figure 44). Reaeration rates were specified to match the diel variation in DO and pH. Temperature, dissolved oxygen and pH were estimated for the tributaries and diffuse sources.

Table 13. Summary of boundary conditions

		Flow (1)	Temperature	Conductivity	Dissolved Oxygen	pH
Site Name	River KM	(CMS)	°C	umhos/cm	Mg/L	s.u.
Headwater (1)	28.65	0.1400	14.8 – 20.1	73	8.2 – 9.3	7.7 – 8.3
Little Rock Creek	28.45	0.04	13.0 – 18.0	76	8	7.9
Longs Creek	25.45	0.03	13.0 – 18.0	76	8	7.9
Buster Creek	24.5	0.03	13.0 – 18.0	76	8	7.9
Cedar Creek	21.9	0.03	13.0 – 18.0	76	8	7.9
Big Bend Creek	17.6	0.40	13.0 – 18.0	76	8	7.9
Reynolds Creek	16.2	0.09	13.0 – 18.0	76	8	7.9
Singe Creek	11.1	0.08	13.0 – 18.0	76	8	7.9
Deep Creek	9.85	0.05	13.0 – 18.0	76	8	7.9

Steelhead Creek	8.85	0.09	13.0 – 18.0	76	8	7.9
Canton Creek	0.9	0.43	13.0 – 18.0	76	8	7.9
Diffuse source	0 – 1.8	0.360	12.0	76	8	7.0

2. Based on continuous measurements from August 9, 2000.

Figure 43. Measured flow versus model flow.

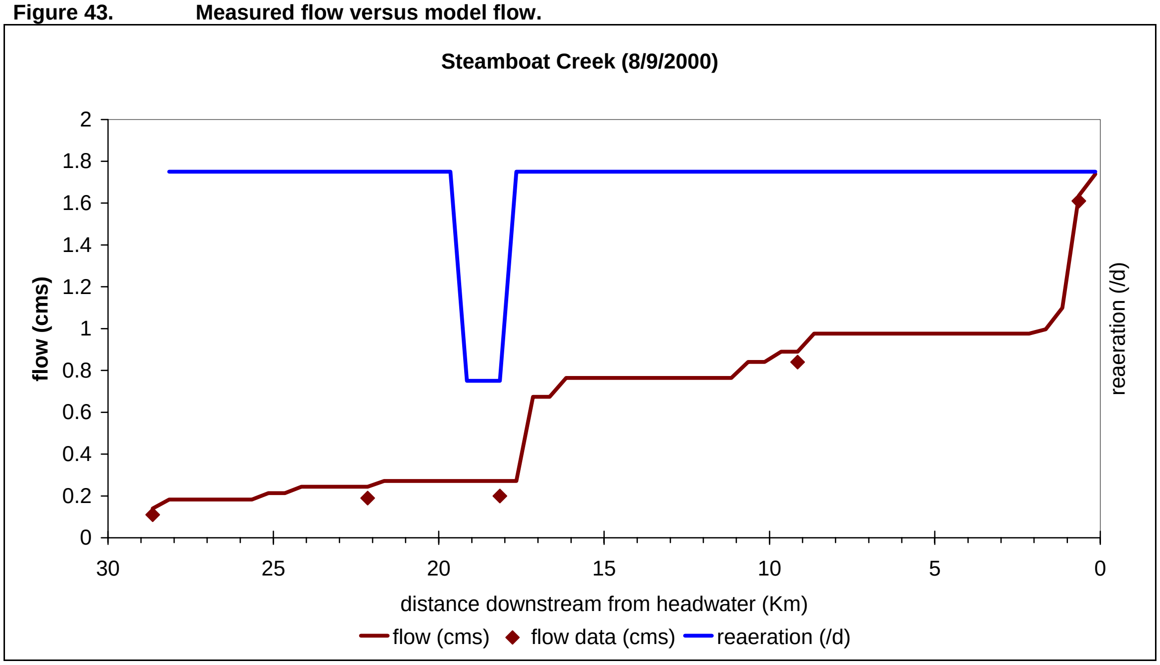
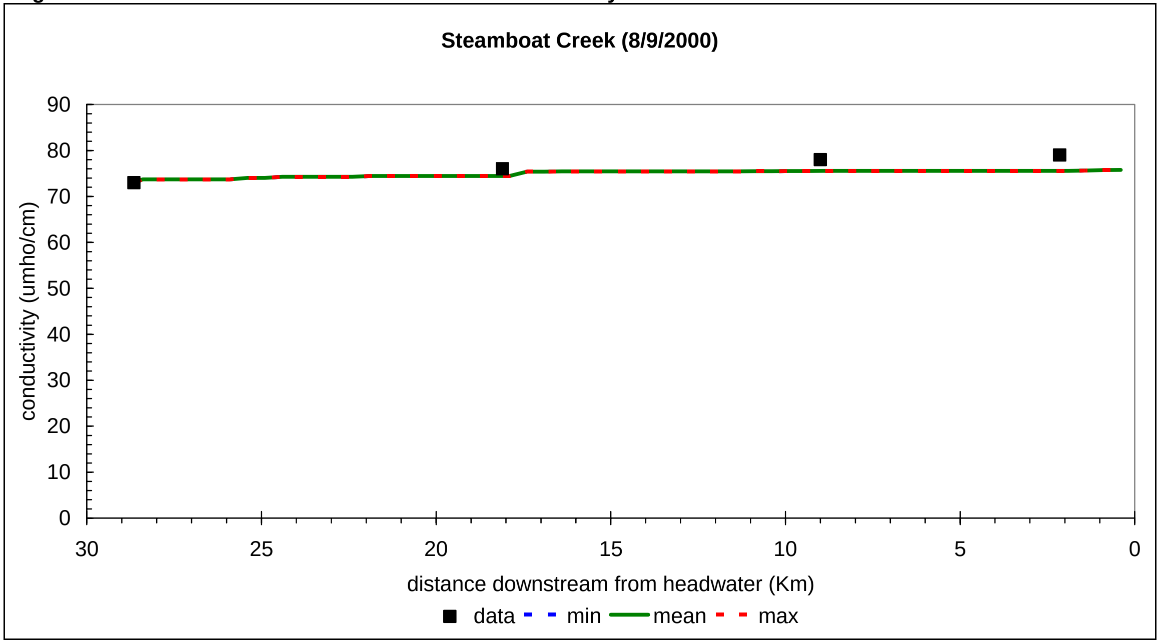


Figure 44. Measured flow versus model conductivity.



Channel morphology along with flow determines the hydraulics of the system which defines the travel time, depth and width of the river. Each reach in the model was set at a 500-meter length. The bankfull width was determined through digitizing aerial photographs and field data (see temperature TMDL for full discussion). Bankfull width, the slope of the side of the channel, and a width-to-depth ratio were used to estimate the bottom width of a trapezoidal channel. The slope of a reach was determined using a 10-meter digital elevation model. The Manning's n for each reach was determined through hydraulic calibration in Heat Source (see temperature TMDL).

Temperature

In general, the energy balance in Heat Source (the model used for the temperature TMDL) and Qualk2k are alike. Both account for solar radiation, long wave radiation, the effect of shade, substrate conduction, evaporation, convection and hyporheic exchange. Although similar, the energy balance in Heat Source and Qual2k do vary slightly, these differences however do not have a large impact on the results (less than 0.5 degrees). Differences include that Heat Source accounts for diffuse radiation and solar radiation passing through the water column into the substrate. Values for shade were taken directly from the temperature TMDL analysis. Sediment thermal conductivity, thermal diffusivity and thickness were used as calibration parameters for the temperature analysis (Table 14). The sediment thermal conductivity value was determined through the temperature calibration was greater than the reported literature range (Pelletier and Chapra, 2004). This is likely compensating for hyporheic flow, which was not explicitly included in this modeling effort, or direct solar heating of the substrate which is not included in Qual2k. No measurements or estimates of hyporheic exchange were available.

Table 14.

Parameter	Value	Literature Range	Units
Sediment thermal conductivity	20	0.36 - 4.18	(W/m/degC)
Sediment thermal diffusivity	0.0126	0.0012 - 0.0126	(cm^2/sec)
Sediment zone thickness	25	10 - 100	(cm)

The model was able to approximate observed water column temperatures with an average root mean square error of 0.7 when compared with diel measurements (Figure 45 and Table 15).

Figure 45. Temperature calibration results.

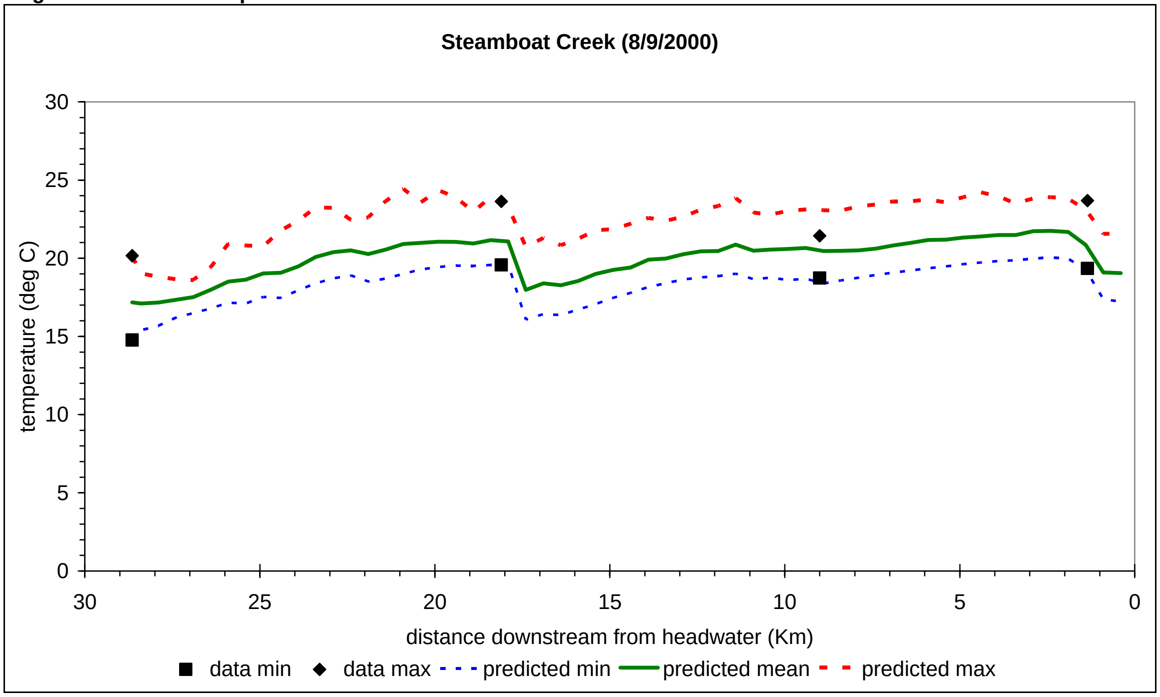


Table 15. Temperature calibration results. ME = mean error, AME = absolute mean error, and RMSE = root mean square error.

			Temperature		
rKM	Station #	Name	ME	AME	RMSE
24.6	26973	u/s of Twomile Creek	-0.4	0.7	0.9
17.4	29271	d/s of Black Canyon Creek	-0.2	0.3	0.4
6.8	29220	d/s of Beaver Creek	-0.4	0.4	0.5
		Average	**-0.3**	**0.5**	**0.6**

Boundary Conditions

Water quality conditions must be input into the model at the model's upstream boundary and for all tributaries and diffuse sources entering the river. Except for the headwaters, no other boundary condition data was collected. Phosphorus concentrations were based on background loading estimates from the South Umpqua River TMDL. Nitrogen and other parameter concentrations were computed using mass balance (Table 16).

Table 16. Summary of boundary conditions.

Site Name	River KM	Inorganic Suspended Solids mg/L	Slow Dissolved Organic C (3) mgC/L	Fast Dissolved Organic C (4) mgC/L	Dissolved Organic N (5) ugN/L	Ammonia N ugN/L	Nitrate + Nitrite N ugN/L	Dissolved Organic P (6) ugP/L	Soluble Reactive P ugP/L	Particulate Organic C mgC/L	Alkalinity mgCaCO3/L
Headwater (1)	28.65	0.5	0.4	0.1	90	10	17.8	0	21	0	
Little Rock Creek (2)	28.45	1	2.0	1.0	100	9	11.5	9	5	0	34
Longs Creek (2)	25.45	1	2.0	1.0	100	9	11.5	9	5	0	34
Buster Creek (2)	24.5	1	2.0	1.0	100	9	11.5	9	5	0	34
Cedar Creek (2)	21.9	1	2.0	1.0	100	9	11.5	9	5	0	34
Big Bend Creek (2)	17.6	1	1.0	1.0	100	9	11.5	9	5	0	34
Reynolds Creek (2)	16.2	1	2.0	1.0	100	9	11.5	9	5	0	34
Singe Creek (2)	11.1	1	2.0	1.0	100	9	11.5	9	5	0	34
Deep Creek (2)	9.85	1	2.0	1.0	100	9	11.5	9	5	0	34
Steelhead Creek (2)	8.85	1	2.0	1.0	100	9	11.5	9	5	0	34
Canton Creek (2)	0.9	1	2.0	1.0	100	9	11.5	9	5	0	34
Diffuse source (2)	0 – 1.8	0	0	0	100	9	11.5	9	5	0	35

C = Carbon; N = Nitrogen; P = Phosphorus
1. Based on sample from August 10, 2000.
2. Determined through estimates and mass balance.
3. Slow Dissolved Organic C = Total organic C - Fast Dissolved Organic C
4. Fast Dissolved Organic = C-BOD / 2.69
5. Dissolved Organic N = Total Kjeldahl Nitrogen - Ammonia
6. Dissolved Organic P = Total P – Soluble Reactive P
Laboratory results that were reported as less than the reporting limit were entered into the model as half of reporting limit

CALIBRATION

DO, pH and nutrient calibration was completed by adjusting a number of key parameters so that the model reproduced observed water quality conditions in August 2000 (see Table 1, Appendix 4). The model performed better when accounting for luxury uptake of nutrients. Periphyton growth, respiration, excretion, and death rates were adjusted so that the model could reproduce the diel variation in pH. The rates governing the fate of nutrients were adjusted so the model could reproduce the general pattern of nutrient concentrations. Phytoplankton was included in the calculations; however, they were not considered in the calibration. The percentage of the bed that is available for periphyton growth was set to 50% from river KM 28.2 - 18.8 and to 100% from river KM 18.8 - 0. The model was able to reproduce the observed patterns of DO and pH (average RMSE 0.5 mg/L and 0.3, respectively) and captured the general trend of nutrients (Table 17 and Figures 46 - 53). The model predicts that nitrogen is the limiting nutrient in the headwaters transitioning into phosphorus limitation (Figure 54).

Table 17. Error statistics for South Umpqua water quality model. ME = mean error, AME = absolute mean error, RMSE = root mean square error.

			Dissolved Oxygen			pH		
ID #	Description	river KM	ME	AME	RMSE	ME	AME	RMSE
23885	Above Big Bend Creek	18.10	0.7	0.7	0.9	0.2	0.3	0.4
23884	Above Steelhead Creek	9.00	0.0	0.2	0.3	0.0	0.2	0.3
23936	Above Canton Creek	1.35	-0.1	0.3	0.4	0.1	0.2	0.2
	AVERAGE		0.2	0.4	0.5	0.1	0.2	0.3

Figure 46. Comparison of dissolved oxygen measurements with model results

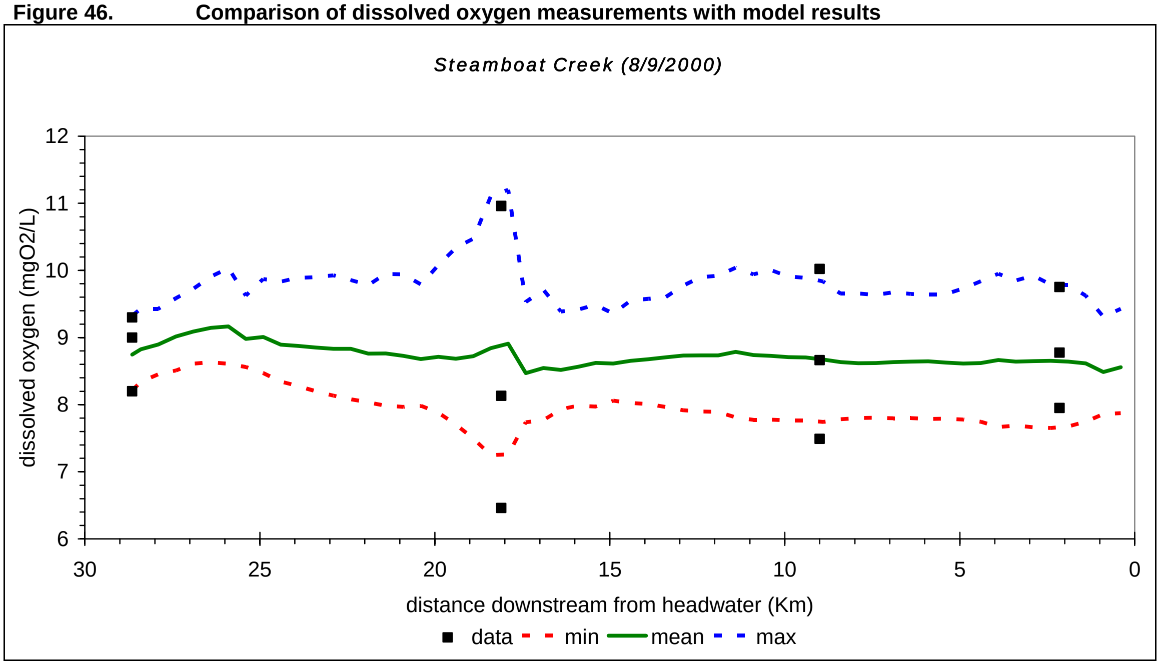


Figure 47. Comparison of estimated dissolved organic nitrogen concentrations with model results

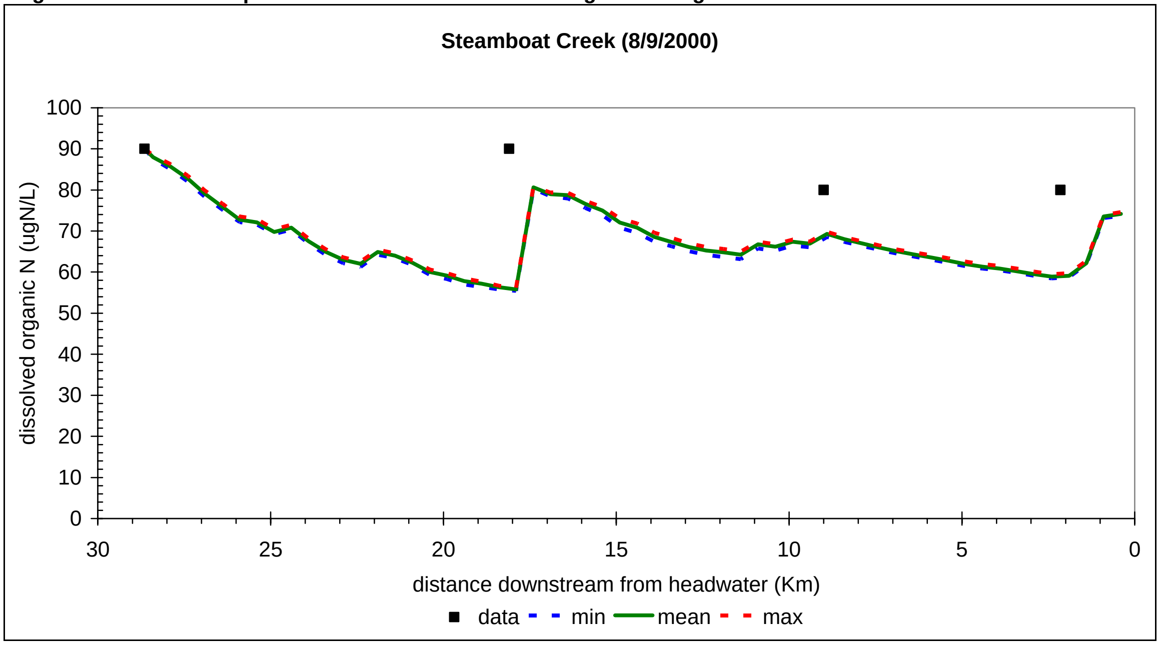


Figure 48. Comparison of ammonia measurements with model results

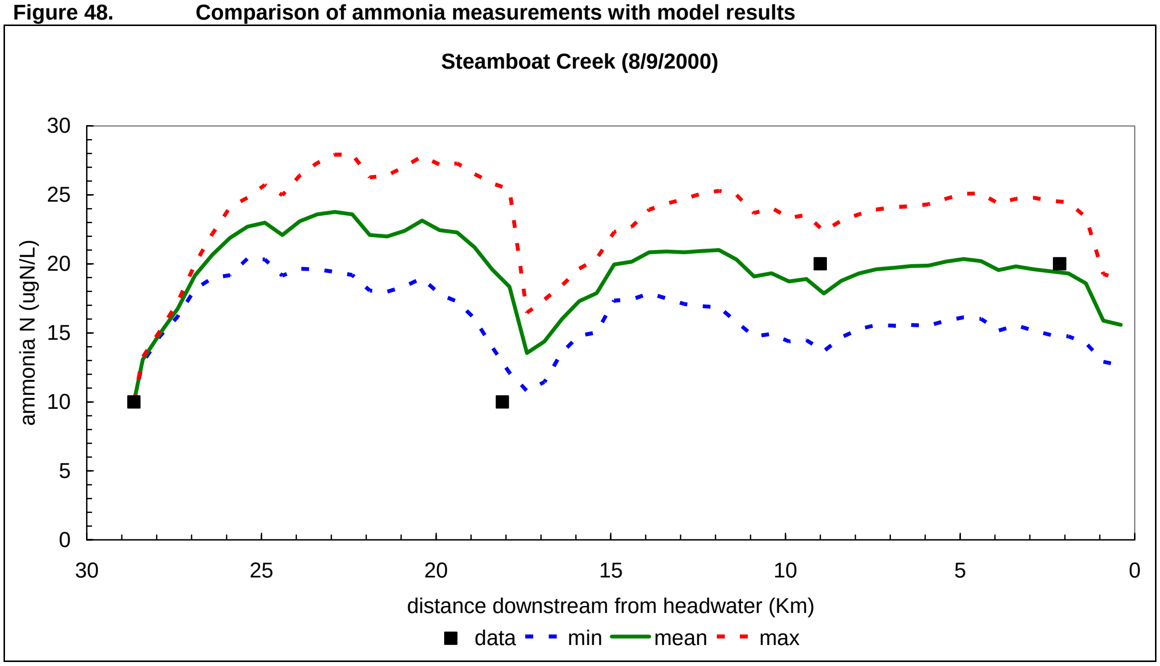


Figure 49. Comparison of nitrate + nitrite measurements with model results

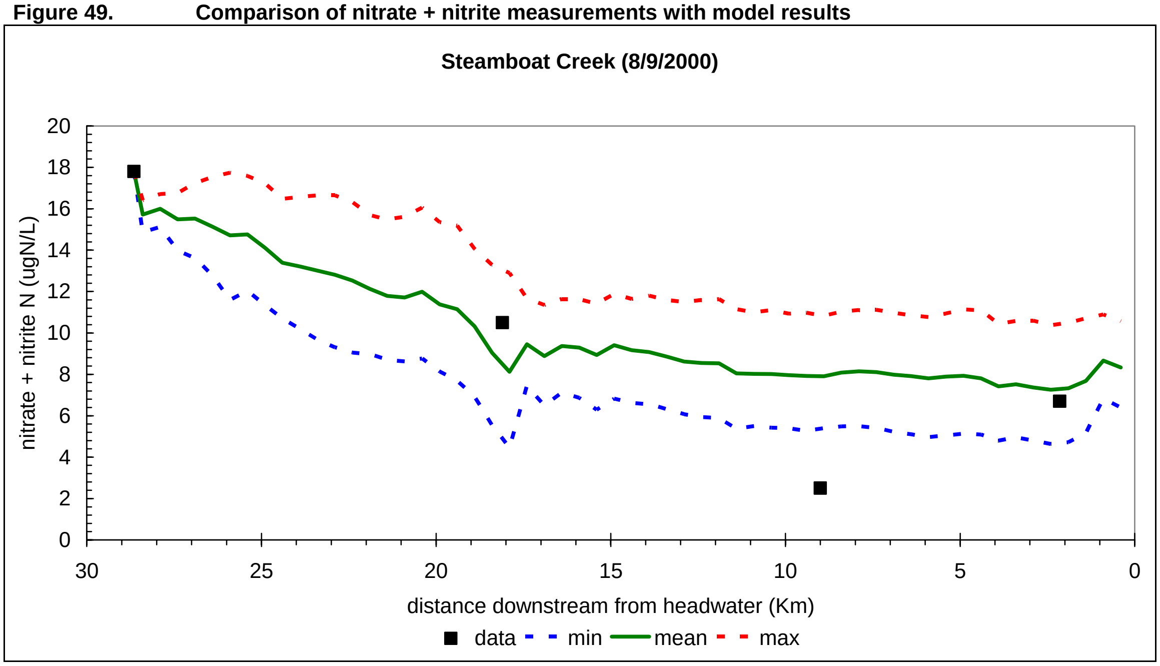


Figure 50. Comparison of estimated dissolved organic phosphorus concentrations with model results

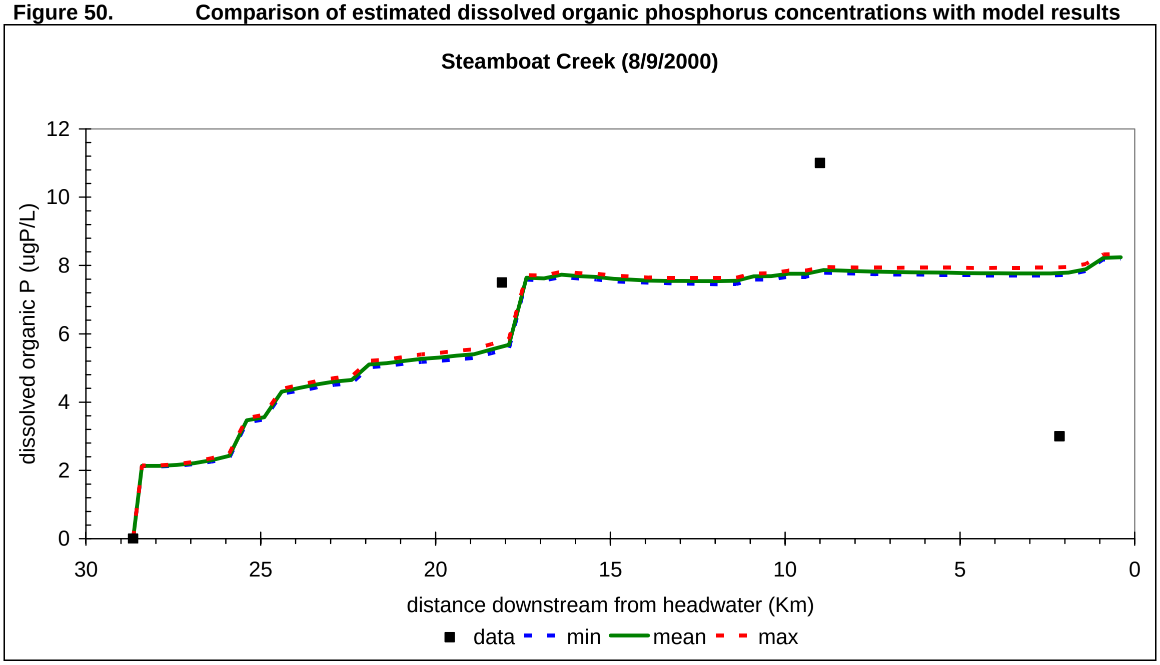


Figure 51. Comparison of soluble reactive phosphorus measurements with model results

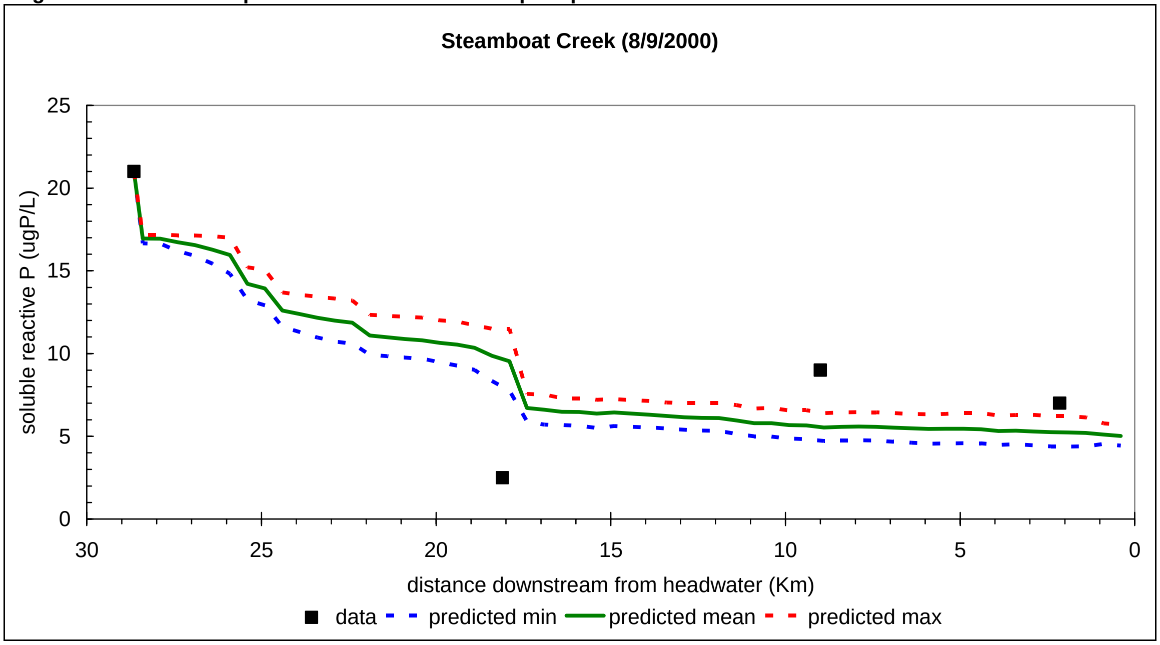


Figure 52. Comparison of alkalinity measurements with model results

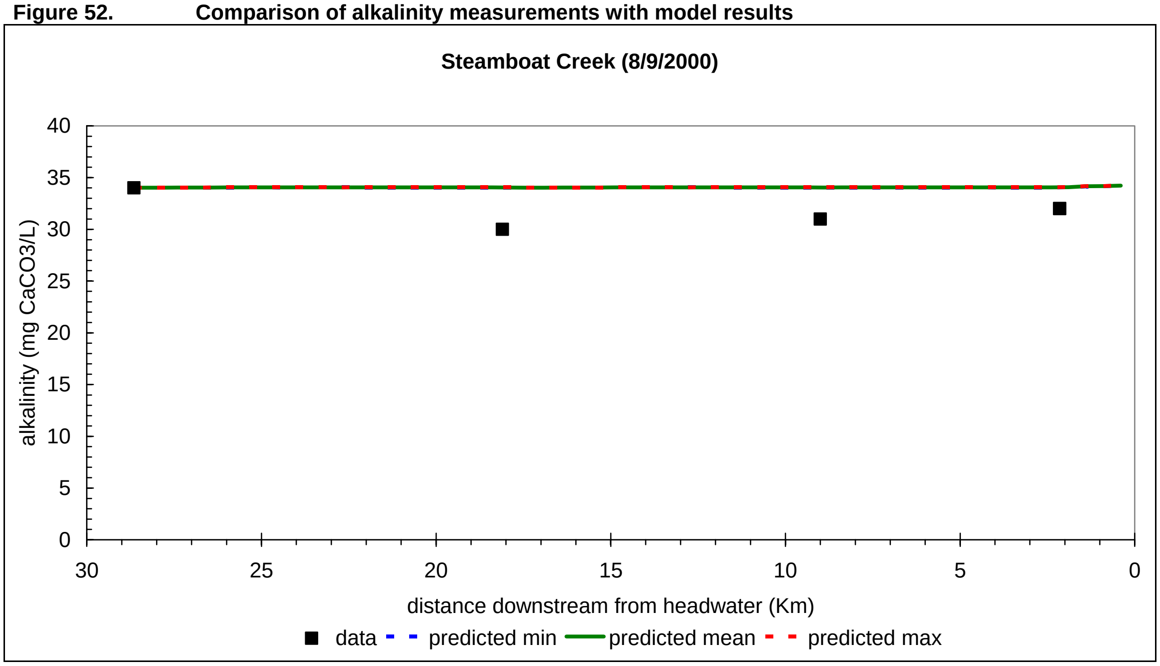


Figure 53. Comparison of pH measurements with model results

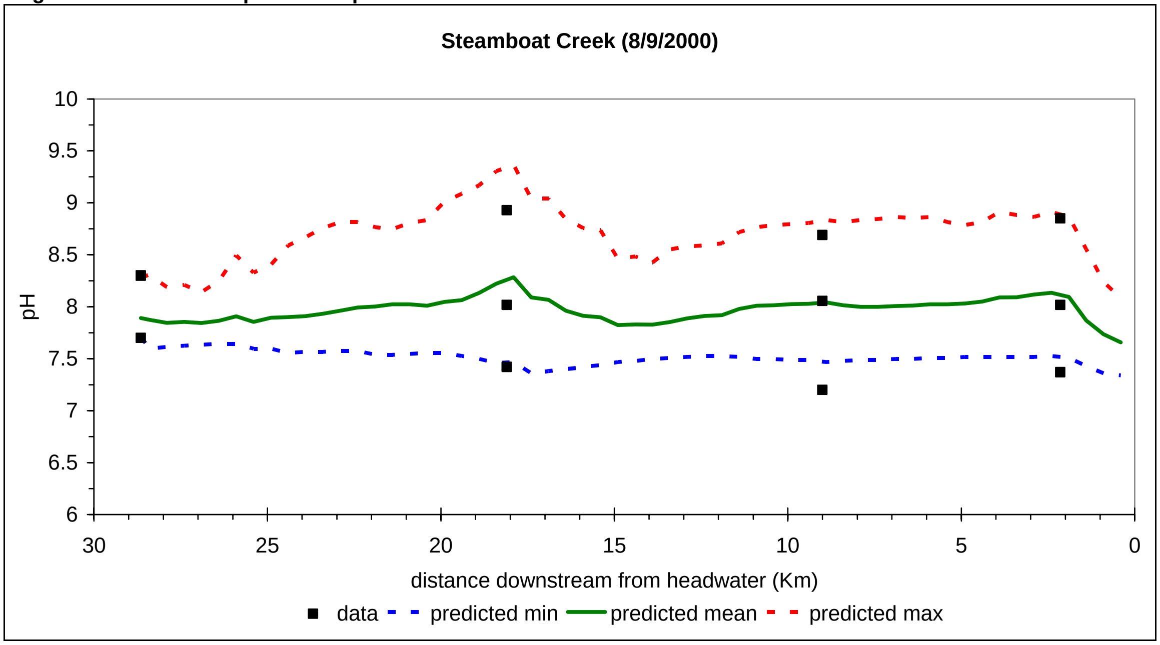


Figure 54. Comparison of estimated dissolved organic carbon concentrations with model results

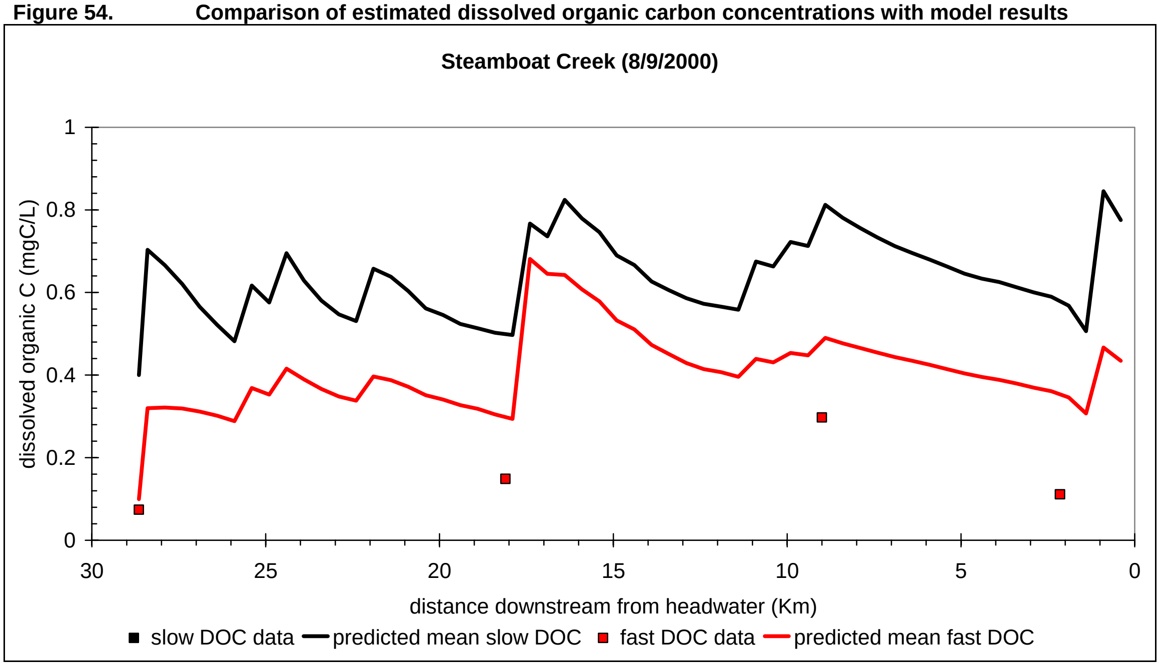


Figure 55. Comparison of continuous measurements with model results

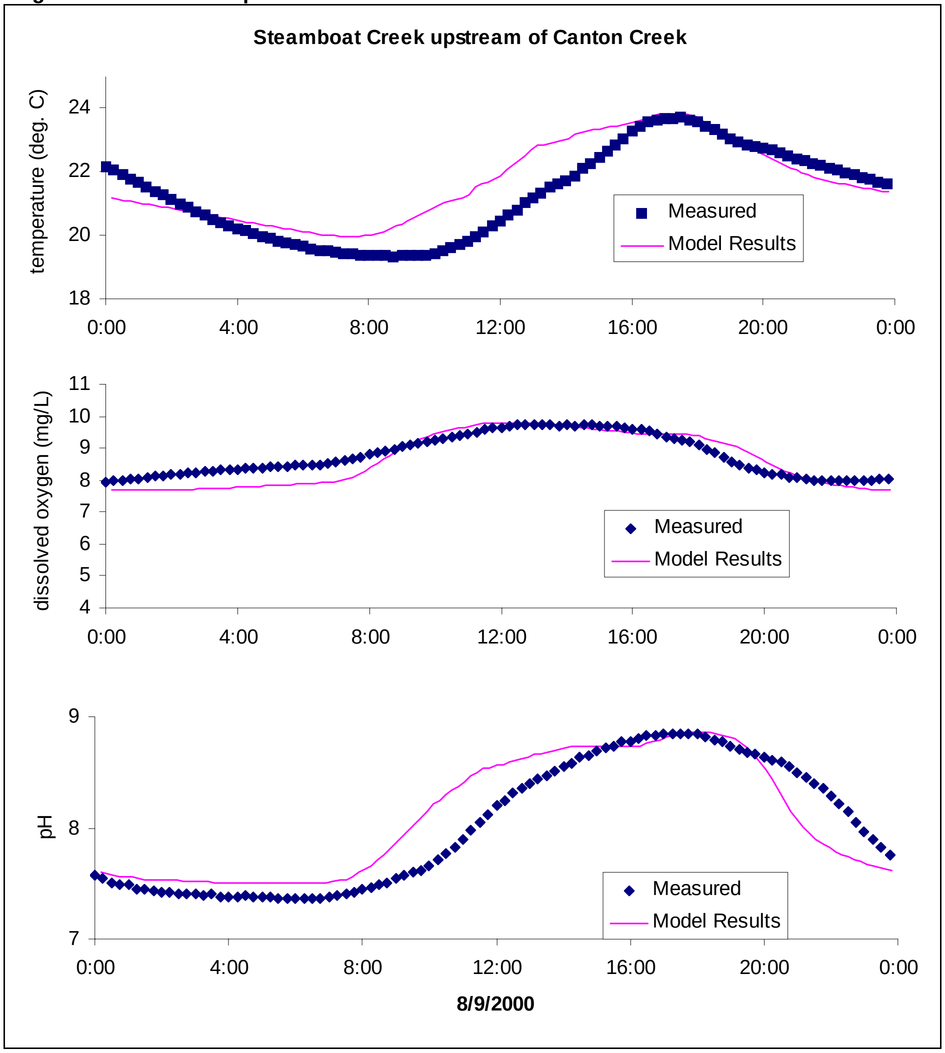
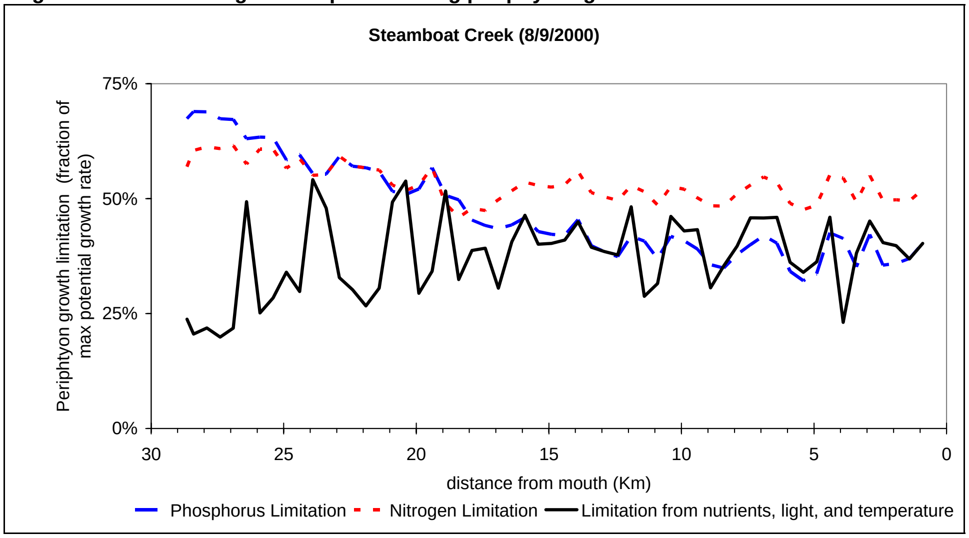


Figure 56. Longitudinal plot showing periphyton growth limitation at 4:52 PM under calibrated conditions



SCENARIO: TMDL CURRENT LOADING

In addition to the calibrated period in August 2000, one other scenario was modeled: current loading with system potential shade. This scenario is the TMDL because no sources of anthropogenic nutrient loading were identified. The scenario is compared with the calibration from 2000. The scenarios were run with the same climate data as the August 2000 run. The flow in the model was not altered from the calibration run. With system potential shade, the model predicts an average decrease in daily maximum pH of 0.1 and a maximum decrease of 0.2. The TMDL loading shows compliance with the dissolved oxygen numeric criteria with a daily minimum greater than 6.0 mg/L and daily mean greater than 8.0 mg/L and with the pH standard when accounting for natural conditions (Figures 57 and 58).

Figure 57. Comparison of predicted dissolved oxygen concentrations under TMDL conditions with current calibrated conditions.

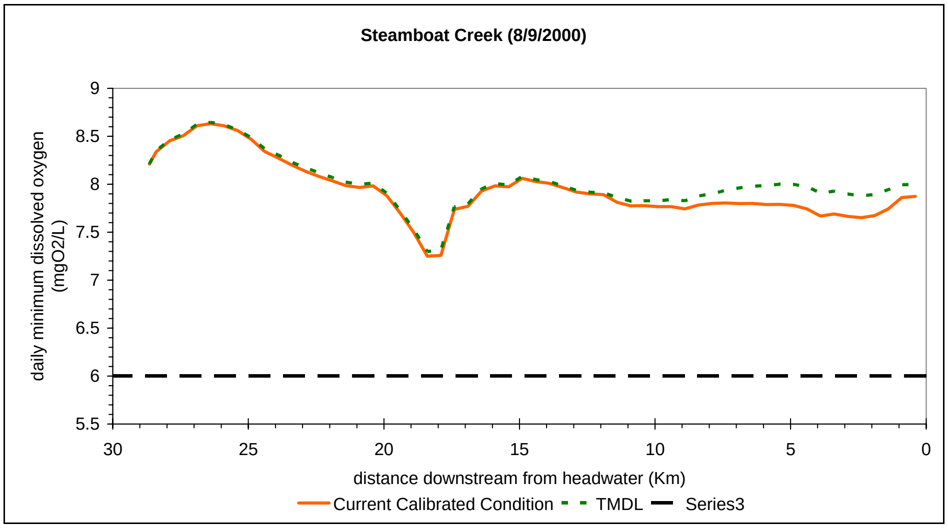
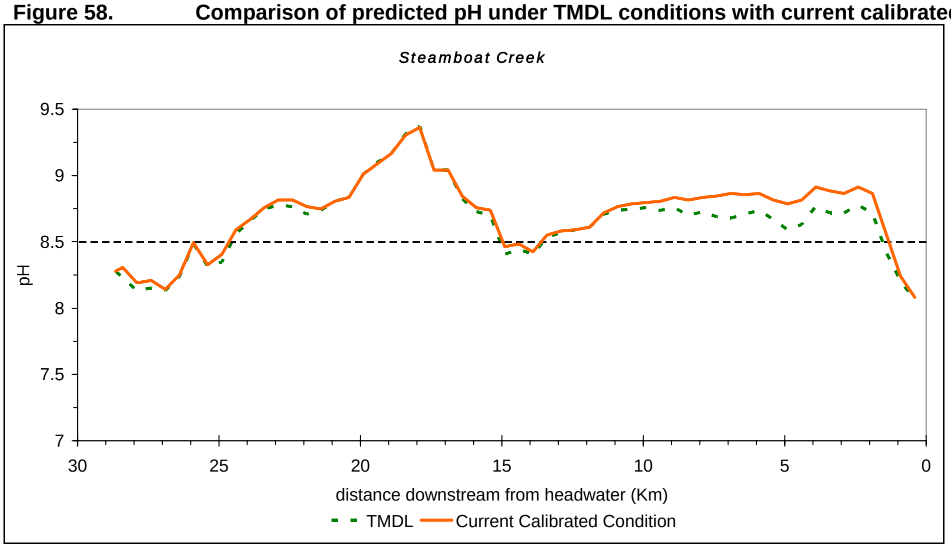


Figure 58. Comparison of predicted pH under TMDL conditions with current calibrated conditions.



SECTION 6: COW CREEK SUMMER NUTRIENT TMDL TECHNICAL ANALYSIS REPORT

Model Setup

The model was set up for August 28, 2002, using continuous monitoring data collected by DEQ between August 26 and August 29. The model was developed for Cow Creek from its mouth to 2 km downstream of Galesville Reservoir (river KM 96). The river was represented in the model as 188 reaches, each 500 meters in length. The model computes water quality for each of these reaches and the model results are used in the computations for the reach downstream. The model was run with a 5.6 minute time step using the Euler's numerical integration method.

Meteorological Data

Hourly air temperatures were collected by DEQ at Windy Creek near the confluence with Cow Creek. Dew point temperatures were not available from a site within the model reach. Dew point temperatures were estimated based on the assumption that the riparian area would have high relative humidity ranging from 60% in the afternoon to 100% in the early morning. Wind speed was assumed to be 0 m/s because the influence of riparian vegetation and cloud cover were assumed to be zero. These assumptions allowed for a good temperature calibration (see below).

Discharge, Conductivity, and Reaeration Rates

The model headwater, tributary, and main stem flows were measured by WRD during August 2002 and by the USGS stream gage network (Table 18 and Figure 59). To match observed flows and conductivity, diffuse sources were included in the model (Table 19 and Figure 60). Reaeration rates were estimated using the Thackston-Dawson formulation because it provided for reaeration rates which allowed for the calibration of dissolved oxygen (Figure 59).

Table 18. Summary of boundary conditions measured by DEQ on August 28, 2002, except where noted.

Site Name	River KM	Flow (CMS)	Temperature °C	Conductivity umhos/cm	Dissolved Oxygen Mg/L	pH s.u.
Headwaters	94.0	0.631	6.9 - 10.7	88 – 91	9.7 – 11.0	7.4 – 7.7
Starveout Creek (1)	91.0	0	--	--	--	--
Windy Creek (1) (5)	66.8	0.002	18.9	354	9.1	8.2
Glendale WWTP (2)	65.9	**0.004**	**21.0**	506	4.8	**6.9**
Middle Creek (1)	43.1	0.037	18.9	354	9.1	8.2
West Fork Cow (3)	42.5	0.149	22.5	135	9.8	8.7
Riddle WWTP (2)	3.2	**0.004**	**22.1**	568	**2.4**	**7.1**
Mitchell Creek (4) (5)	1.4	0.011	18.9	354	9.1	8.2

BOLD indicates average value from August 2002 discharge monitoring report.

3. Flow measured between August 19 and August 28, 2002 by WRD.
4. 0.004 cms = 0.08 million gallons per day (MGD)
5. Flow measured by USGS gage
6. No flow data, estimated.
7. No water quality data, used Middle Creek as estimate.

Table 19. Diffuse sources determined through water balance and temperature calibration.

Up	Down	Diffuse Outflow	Diffuse Inflow	Temperature	Conductivity	Dissolved Oxygen	pH
(km)	(km)	(m^3/s)	(m^3/s)	°C	umhos/cm	Mg/L	s.u.
96.4	59.75	0.46					
80	66		0.030	15	500	8	6.5
35.6	33.75		0.07	22	150	9	8.0
10	5		0.07	22	150	9	8.0
10.6	0	0.1					

Figure 59. Measured flow versus model flow and calculated reaeration rates.

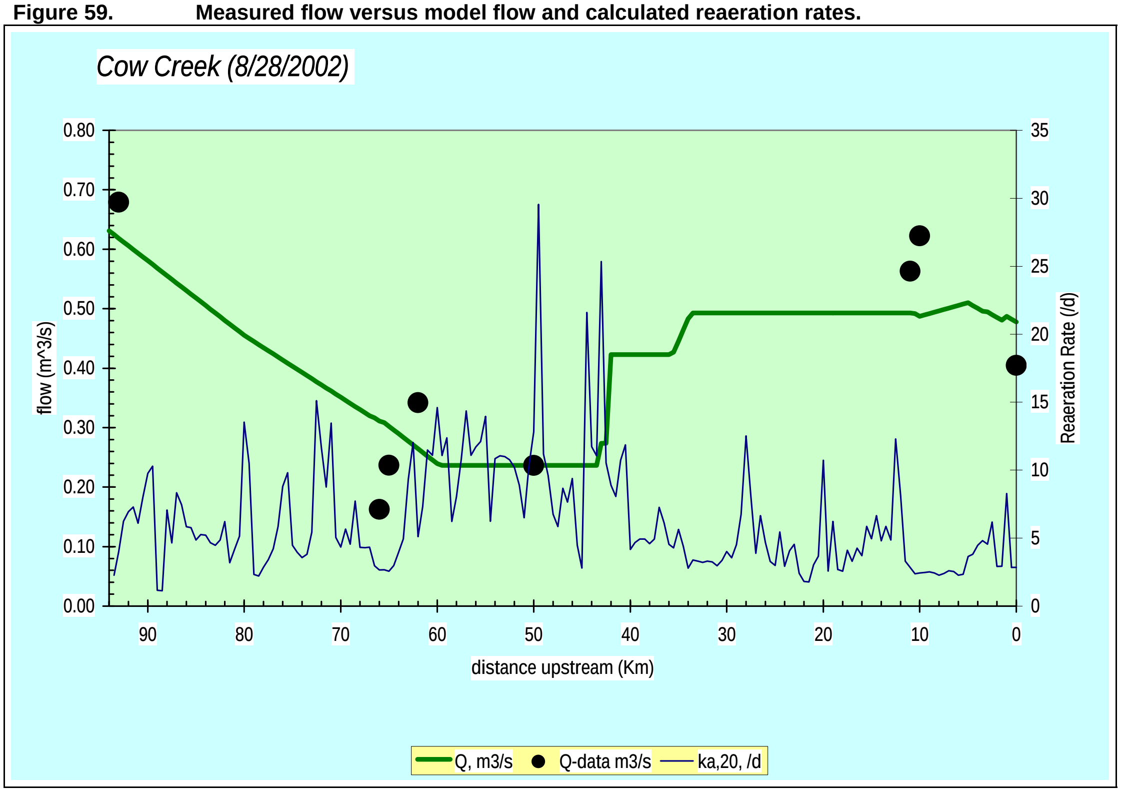
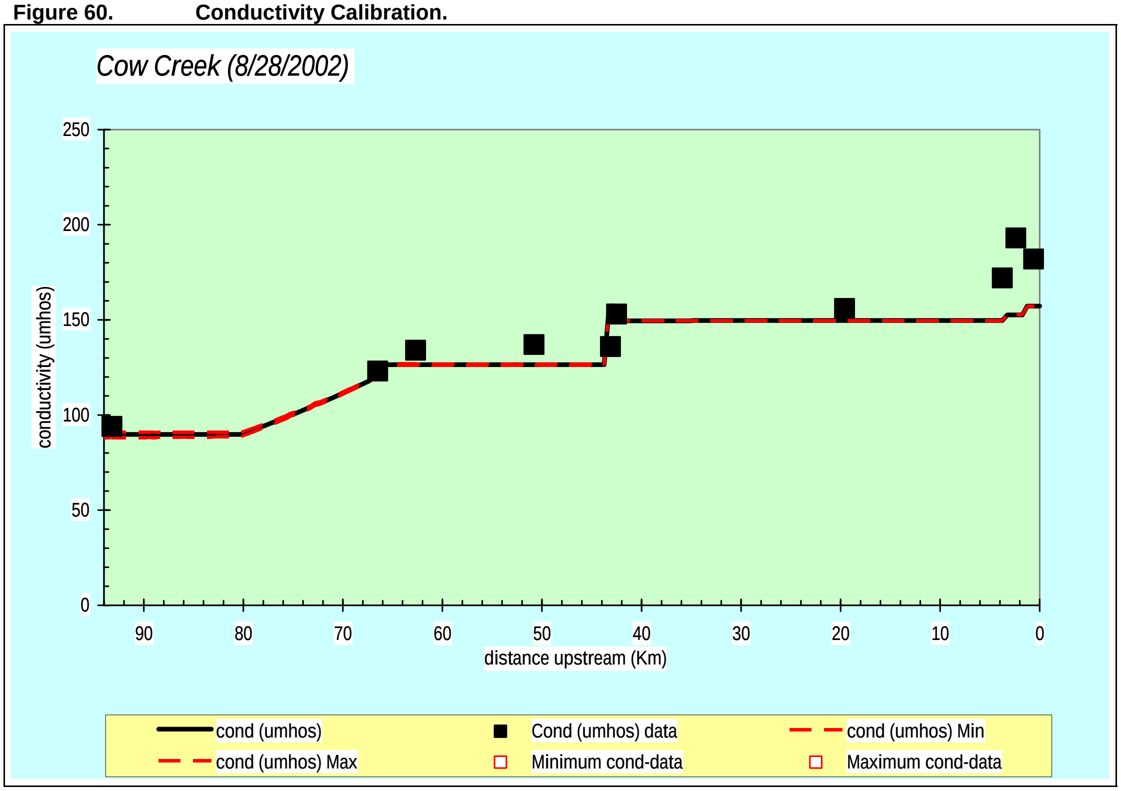


Figure 60. Conductivity Calibration.



Channel morphology along with flow determines the hydraulics of the system which defines the travel time, depth and width of the river. Each reach in the model was set at a 500-meter length. The bank full width was determined through digitizing aerial photographs and field data (see temperature TMDL for full discussion). Bankfull width, the slope of the side of the channel, and a width-to-depth ratio are used to estimate the bottom width of a trapezoidal channel. The slope of a reach was determined using a 10-meter digital elevation model. The Manning's n for each reach was determined through hydraulic calibration in the temperature model Heat Source (see temperature TMDL).

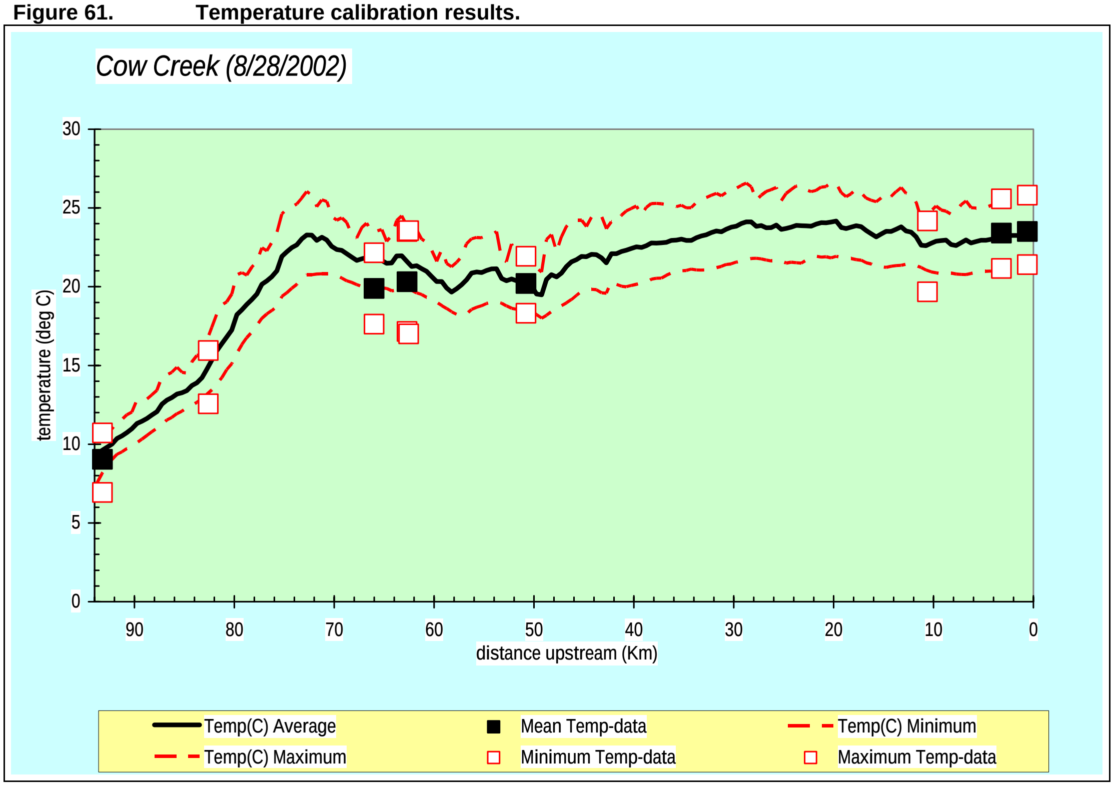
Temperature

In general, the energy balance in Heat Source (the model used for the temperature TMDL) and Qualk2k are alike. Both account for solar radiation, long wave radiation, the effect of shade, substrate conduction, evaporation, convection and hyporheic exchange. Although similar, the energy balance in Heat Source and Qual2k do vary slightly; these differences, however, do not have a large impact on the results (less than 0.5 degrees). Differences include that Heat Source accounts for diffuse radiation and solar radiation passing through the water column into the substrate. Values for shade were taken directly from the temperature TMDL analysis. Hyporheic flow was assumed to have a negligible impact on temperature and water quality in Cow Creek. No measurements or estimates of hyporheic exchange were available. Sediment thermal conductivity was used as a calibration parameter for the temperature analysis (Table 20). The calibrated value is outside of the reported literature range and is possibly compensating for hyporheic exchange, direct solar heating of substrate, or transfer of heat from exposed rock to water. The model was able to generally reproduce the measured stream temperatures (Figure 61).

Table 20. Parameterization of channel properties

Parameter	Value
Bottom Algae Coverage	100%
Bottom SOD Coverage	100%
Sediment thermal cond (W/m/degC)	20.0
Sediment thermal diff (cm^2/sec)	0.0070
Sediment/hyporheic zone thickness (cm)	10
Hyporheic exchange flow (fraction of stream flow)	0%
Hyporheic sediment porosity (fraction of volume)	34%
Initial biomass of periphyton mgA/m^2	100%

Figure 61. Temperature calibration results.



Boundary Conditions

Water quality conditions must be input into the model at the model's upstream boundary and for all tributaries and point sources entering the river. Whenever possible, headwater and tributary conditions were based on data collected on 8/28/2002 (Table 21 and 16). When available, conditions for the WWTPs were first based on average conditions from the August 2002 discharge monitoring reports (DMRs) and secondly from samples collected by DEQ on 8/28/2002. Diffuse flow was first assumed at concentrations representative of background loading (see South Umpqua Nutrient TMDL discussion) or secondly was adjusted to match instream concentrations. If laboratory results indicated concentrations less than the method reporting limit, 80% of the method reporting limit was used; except for the headwaters where concentrations were reduced further for calibration purposes.

Table 21. Summary of boundary conditions.

Site Name	River KM	Inorganic Suspended Solids (1)	Slow C-BOD (2)	Fast C-BOD (3)	Dissolved Organic N (4)	Ammonia N	Nitrate + Nitrite N	Dissolved Organic P (5)	Soluble Reactive P (6)	Detritus (7)	Alkalinity
		mg/L	*mgC/L*	*mgC/L*	*ugN/L*	*ugN/L*	*ugN/L*	*ugP/L*	*ugP/L*	*mgC/L*	*mgCaCO3/L*
Cow Creek downstream of Galesville Reservoir (model headwaters)	94	0	1.9	0.8	140	8	5	10	0	2 (5)	40
Windy Creek (9)	66.75	0.2	0.08	0.00	144	16	2.5	0	4	0.8	54
Glendale WWTP	65.9	49	0.00	**7.9**	4000	18000	1010	439	3651	**1.6**	142
Middle Creek	43.05	0.2	0.08	0.00	144	16	2.5	0	4	0.8	54
West Fork Cow	42.5	0.0	0.10	0.00	130	30	13.8	14	6	0.8	44
Riddle WWTP	3.22	53	0.08	**7.3**	2000	**13960**	4140	350	2750	**6.0**	132
Mitchell Creek (9)	1.4	0.2	0.08	0.00	144	16	2.5	0	4	0.8	54
Diffuse flow:	66 - 80	0 (8)	0 (8)	0 (8)	216	18	*500*	9	5	0 (8)	*150*
Diffuse flow:	33.8 - 35.6	0 (8)	0 (8)	0 (8)	216	18	23	9	5	0 (8)	*100*
Diffuse flow:	5 - 10	0 (8)	*6.0*	*6.0*	*500*	*200*	*500*	9	*100*	0 (8)	*100*

C = Carbon; N = Nitrogen; P = Phosphorus

BOLD indicates average 2002 DMR value.

Underlined indicates that values were set to background loading conditions as determined in the South Umpqua River TMDL.

Italics indicate that values were adjusted so that in stream measurements could be duplicated.

1. Inorganic suspended solids = total suspended solids – detritus
2. Slow Dissolved Organic C = 5-day BOD for stream sites.
3. Fast Dissolved Organic C = C-BOD for WWTPs; assumed to negligible for stream sites.
4. Dissolved Organic N = Total Kjeldahl Nitrogen - Ammonia [note: suspended solids typically 2% of total solids]
5. Dissolved Organic P = Total Phosphate as P – Soluble Reactive P
6. Soluble Reactive P = Dissolved Orthophosate as P
7. Detritus = total organic C – CBOD
8. No data available. Assumed to be negligible.
9. No data available. Assumed to be same concentration as Middle Creek.

Calibration

DO, pH and nutrient calibration was completed by adjusting a number of key parameters so that the model reproduced observed water quality conditions on August 28, 2002 (Table 33, Appendix 3). Periphyton growth, respiration, excretion, and death rates were adjusted so that the model could reproduce the diel variation in DO and pH. The rates governing the fate of nutrients were adjusted so the model could reproduce the general pattern of nutrient concentrations. Phytoplankton calculations were included in the model however limited data exists to perform a calibration and, furthermore, it is believed that periphyton processes have a much larger impact on water quality. The model was able to approximate the observed patterns of DO and pH and capture the general trend of nutrients (Table 22, Figures 62 – 72).

Figure 62. Comparison of minimum and maximum pH measurements with model results

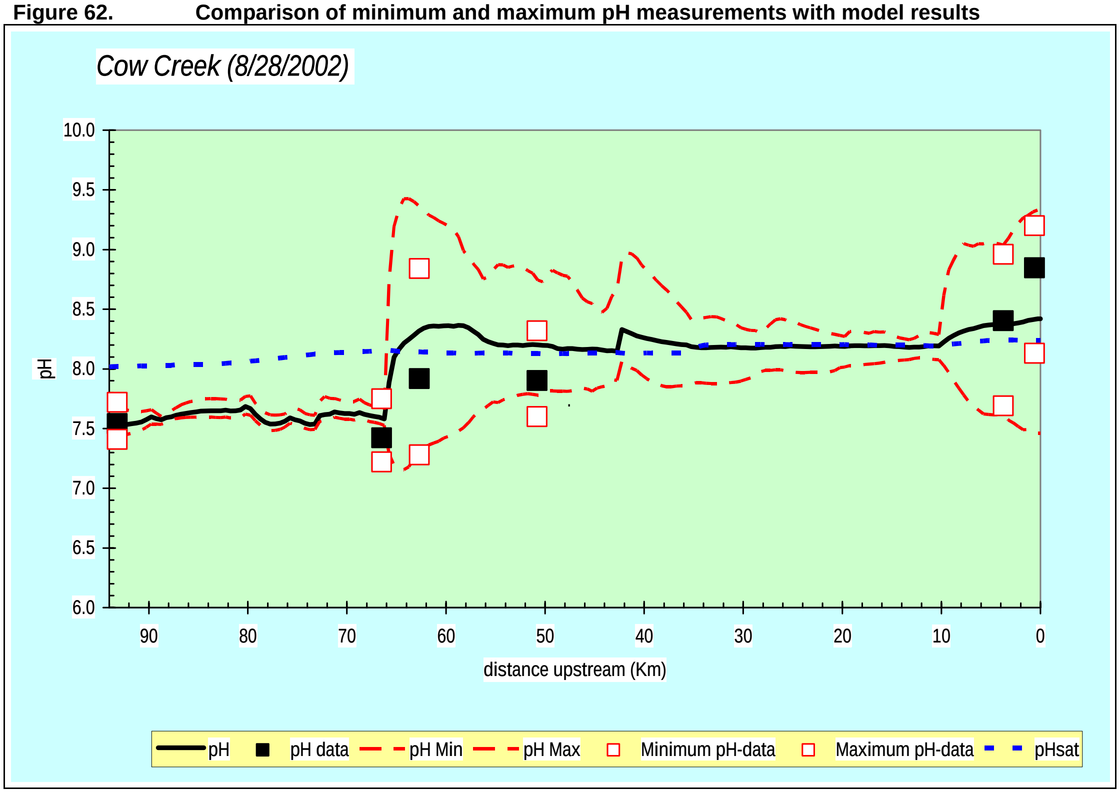


Figure 63. Comparison of minimum and maximum dissolved oxygen measurements with model results

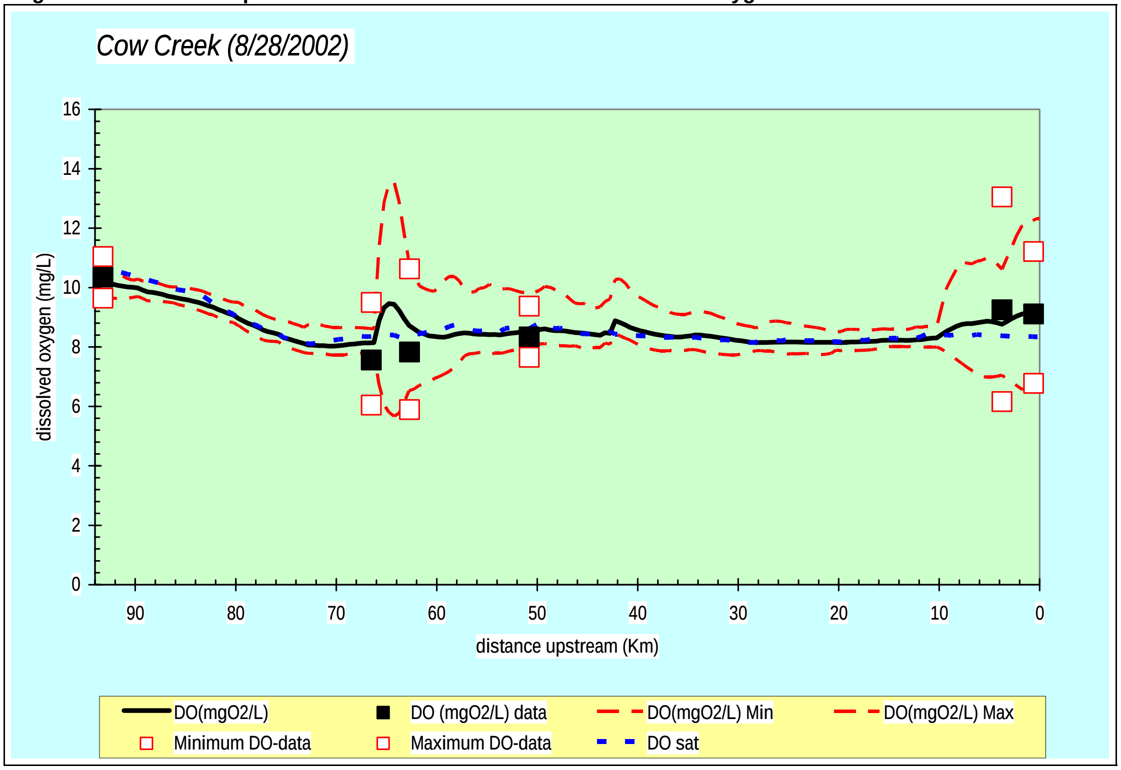


Figure 64. Comparison of derived detritus (based on measurements) with model results

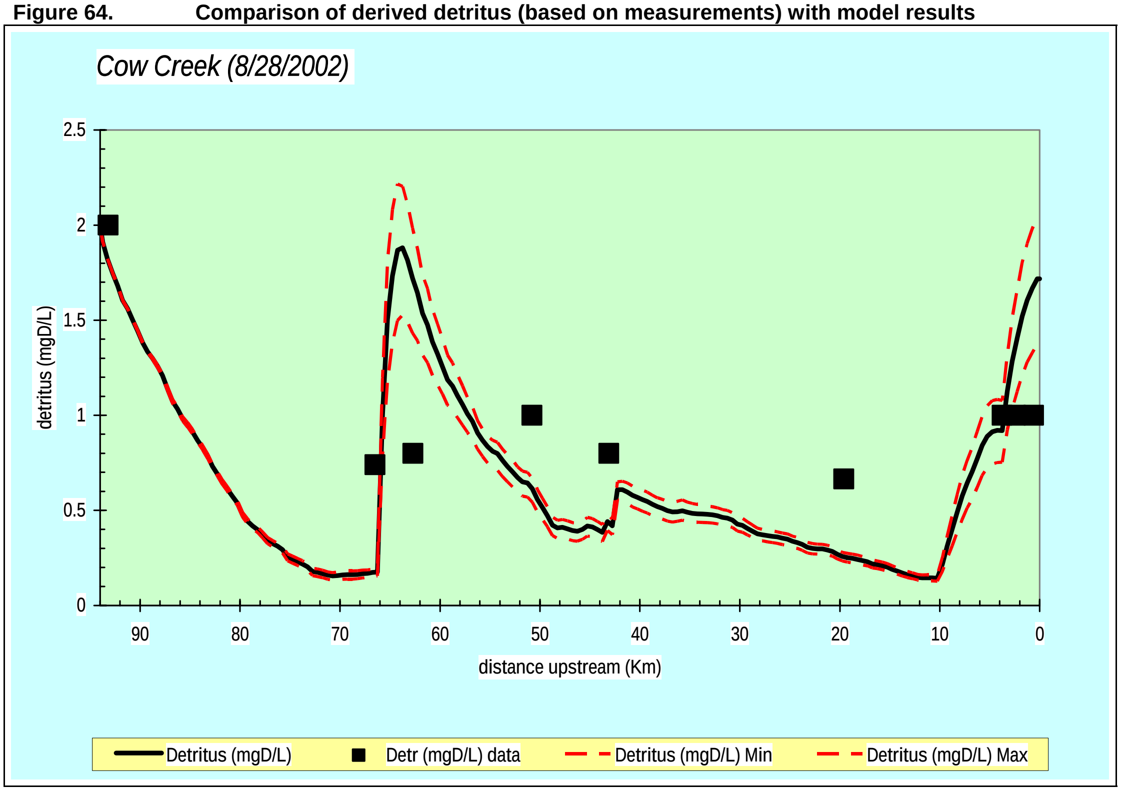


Figure 65. Comparison of CBOD measurements with model results

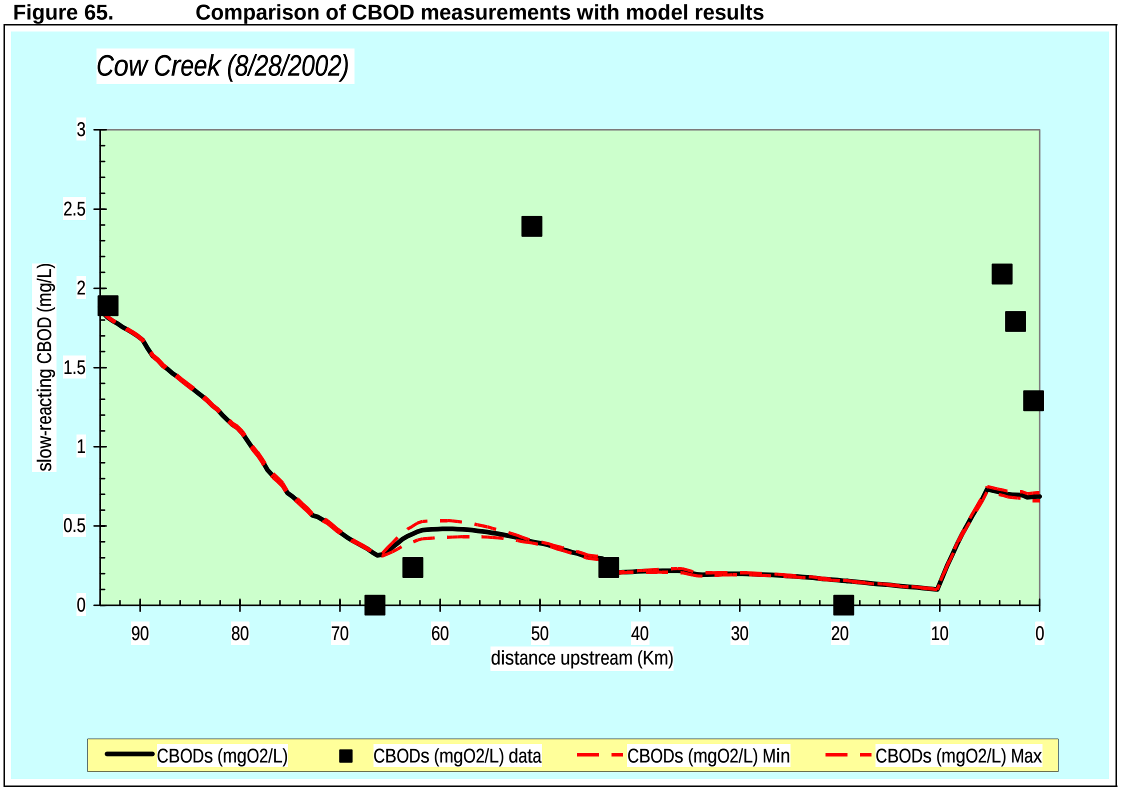


Figure 66. Comparison of organic nitrogen measurements with model results

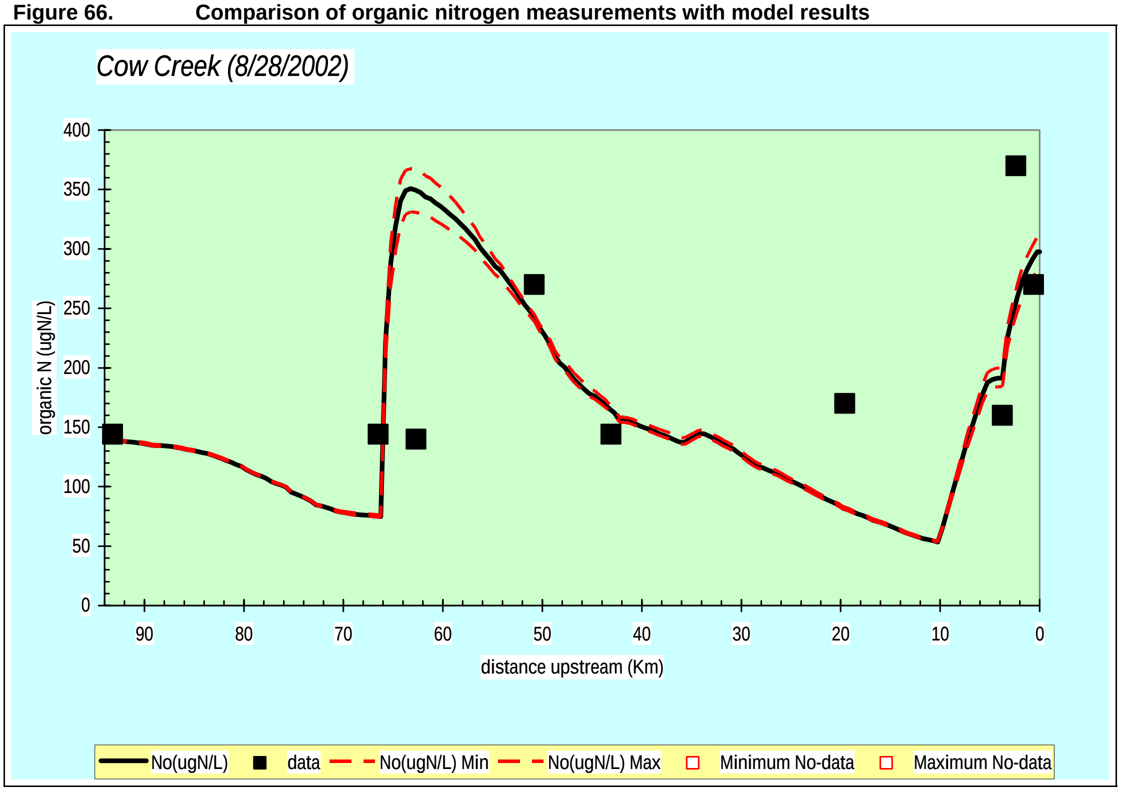


Figure 67. Comparison of ammonia measurements with model results

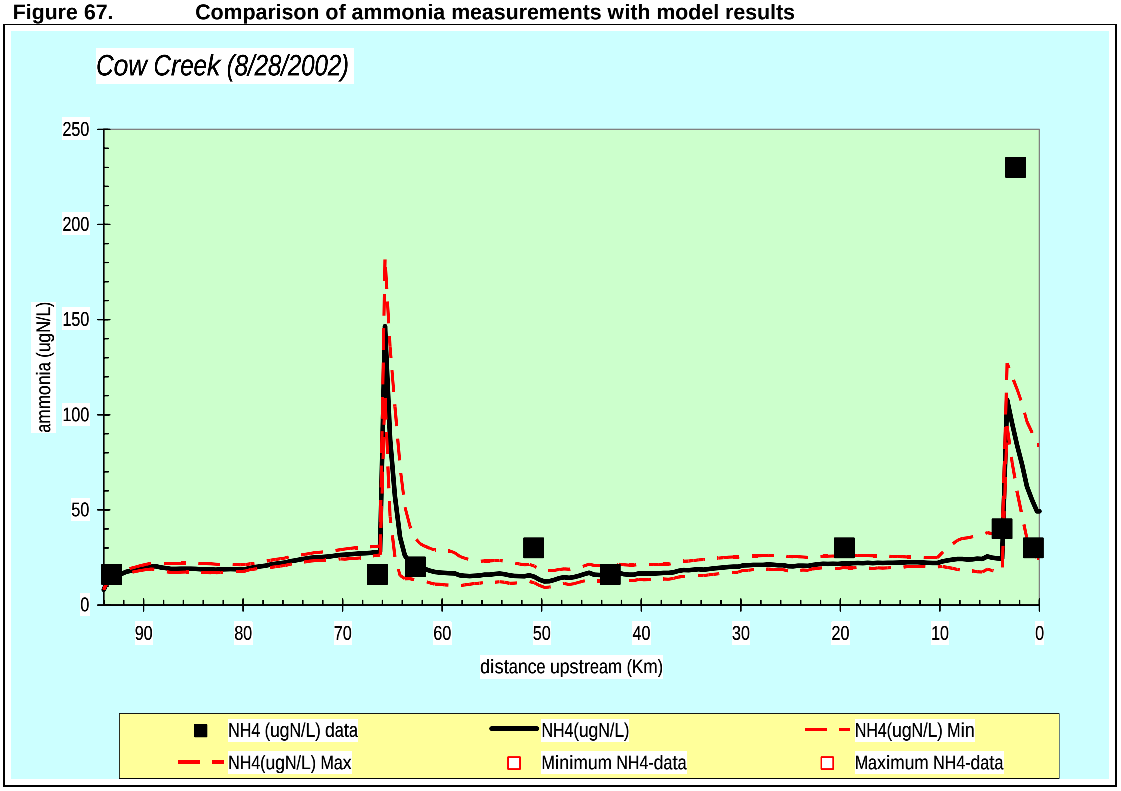


Figure 68. Comparison of nitrite and nitrate measurements with model results

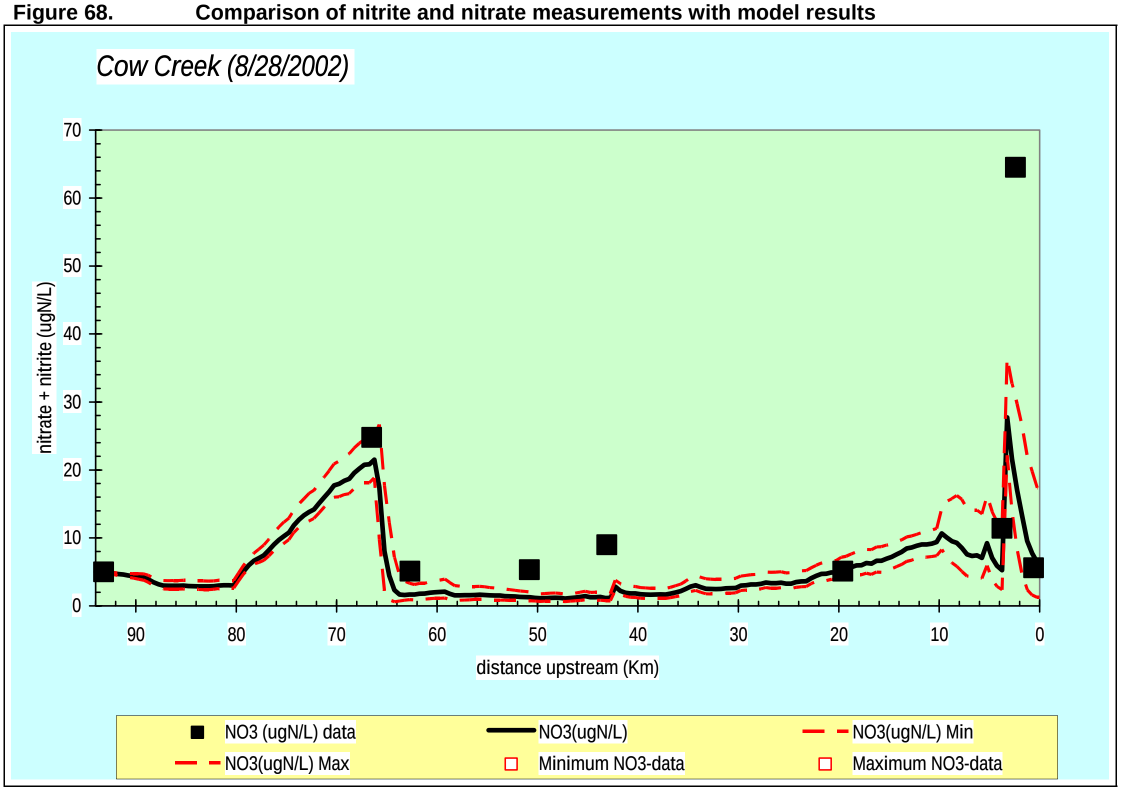


Figure 69. Comparison of organic phosphorus measurements with model results

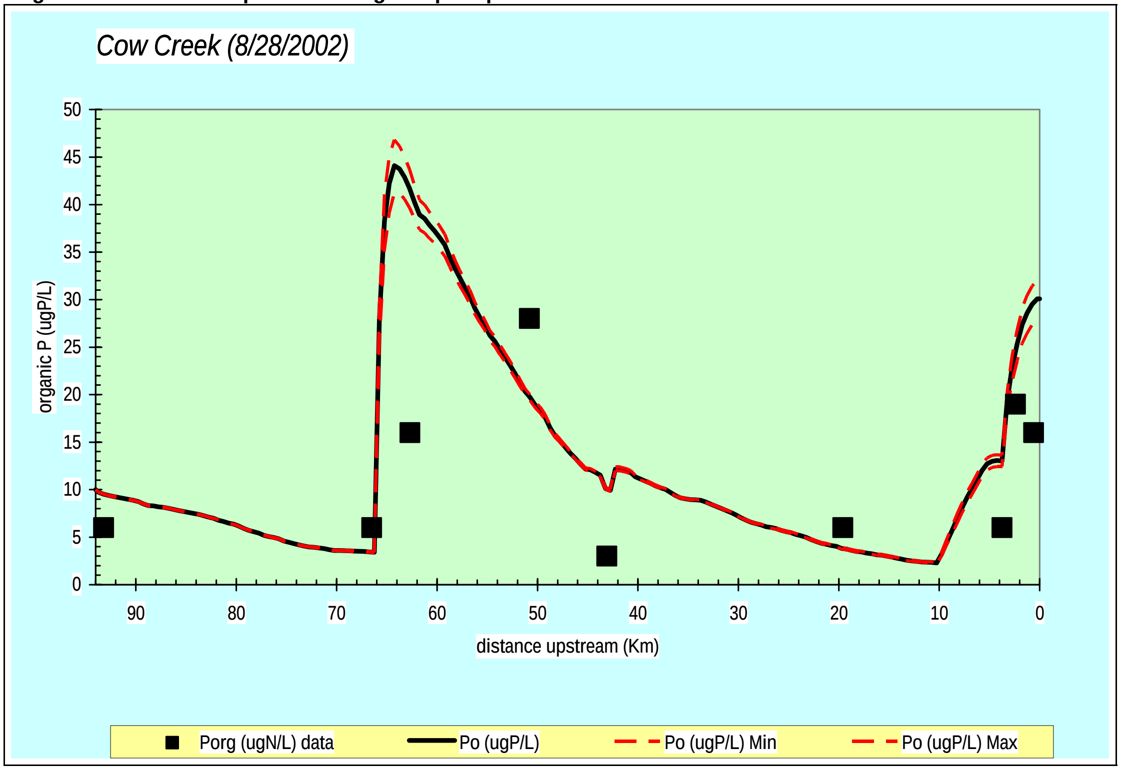


Figure 70. Comparison of inorganic phosphorus measurements with model results

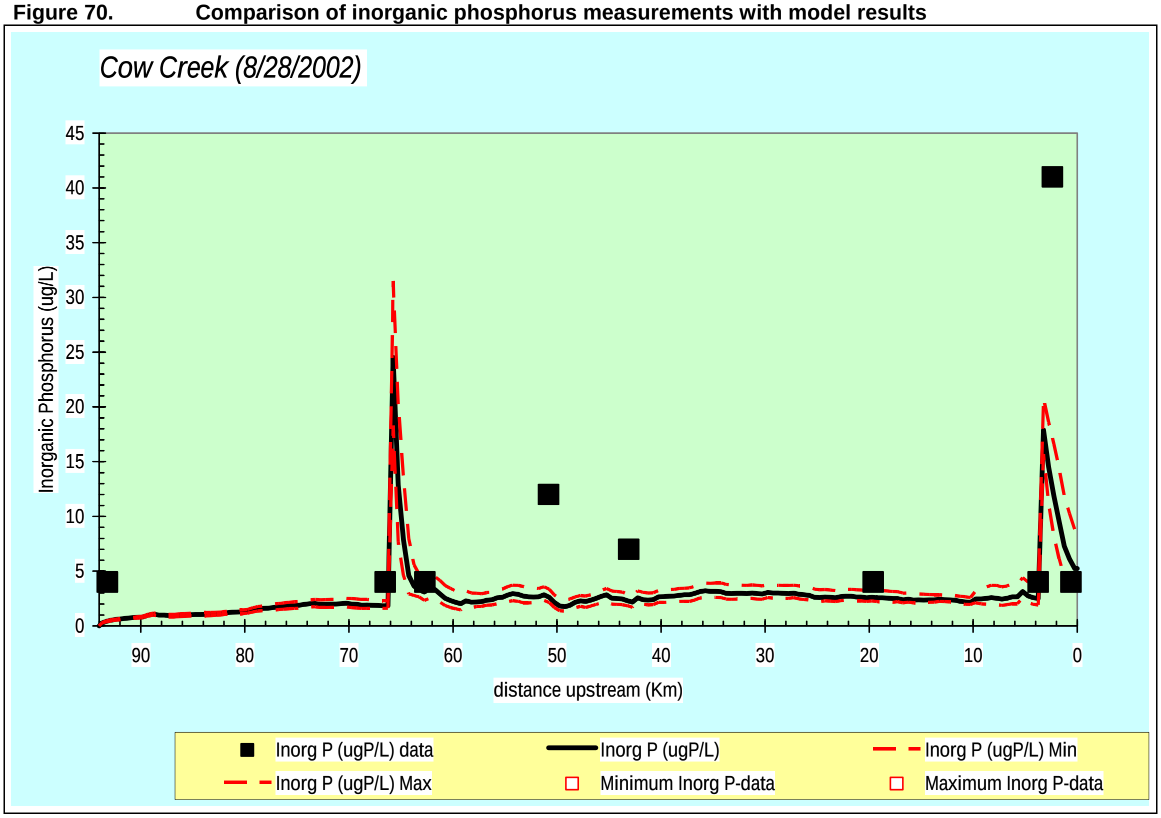


Figure 71. Comparison of alkalinity measurements with model results

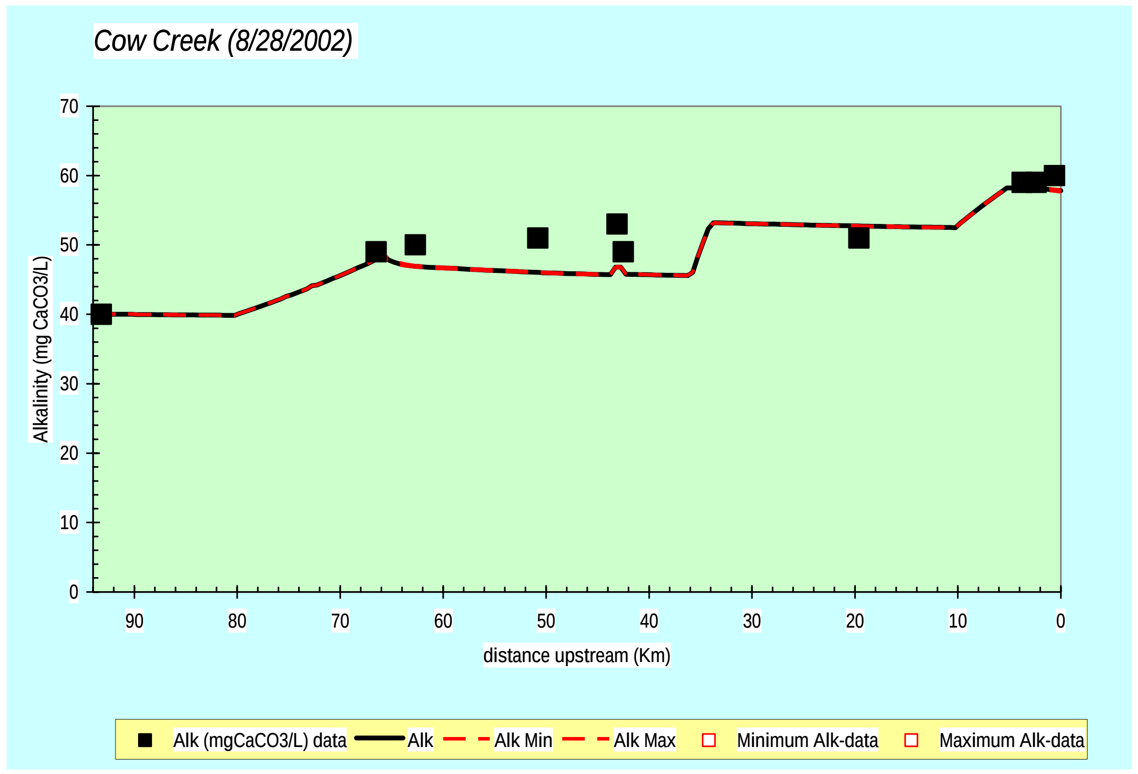
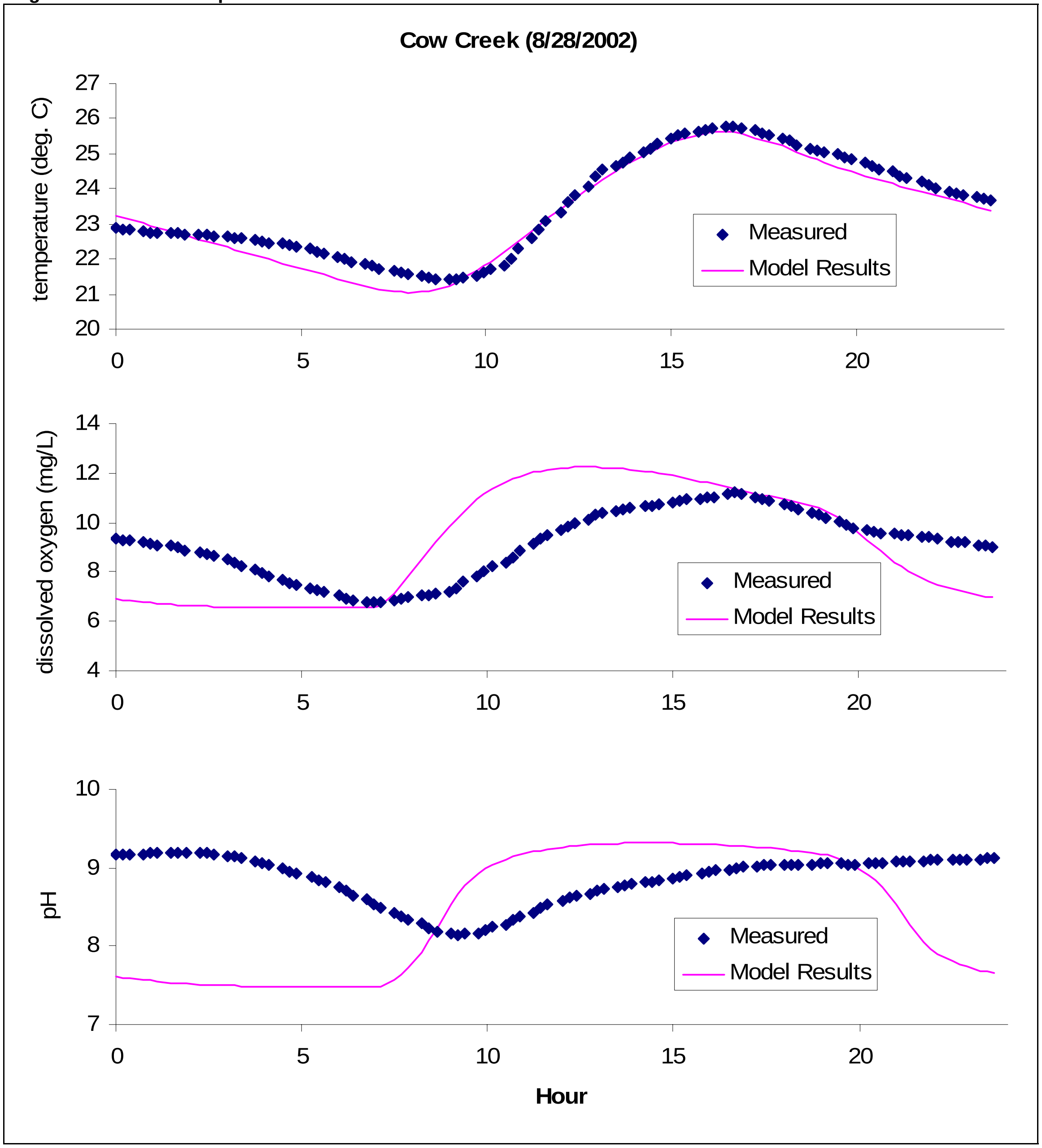


Table 22. Calibration statistics for Cow Creek water quality model. ME = mean error, AME = absolute mean error, RMSE = root mean square error.

River KM	Station #	Cow Creek Station Name	Temperature			Dissolved Oxygen			pH		
			ME	AME	RMSE	ME	AME	RMSE	ME	AME	RMSE
82.6		Below Quines Creek	0.5	0.5	0.6						
66	13050	100 Ft. U/S Glendale WWTP Outfall	1.8	1.8	1.9	0.6	1.2	1.3	0.2	0.2	0.2
62.7	29231	Below McCullough Creek	1.3	1.5	1.7	0.9	0.9	1.2	0.4	0.5	0.7
50.8	29227	At Brandt Bridge	0.5	0.7	1.0	0.2	0.3	0.4	0.3	0.3	0.4
10.6		Cow Creak near Riddle	0.7	1.0	1.1						
3.2	12913	150 Yds U/S Riddle Outfall	-0.3	0.5	0.5	-0.5	1.3	1.5	0.0	0.4	0.5
0.6	10997	At Mouth	-0.2	0.3	0.3	0.0	1.4	1.7	-0.4	0.9	1.0
		Averages	**0.6**	**0.9**	**1.0**	**0.2**	**1.0**	**1.2**	**0.1**	**0.5**	**0.6**

Figure 72. Comparison of diel measurements with model results



SCENARIOS

In addition to the calibrated period for August 2004, three other scenarios were modeled: (1) current loading with critical flow conditions, (2) background loading only with critical flow conditions, and (3) TMDL allocations with critical flow conditions. The scenarios were run with the same climate data as the August 2004 run. The flow at the headwater was increased so that the flow at the Riddle gage matched the calculated critical condition flow of 1.4 cms (50 cfs). The calibrated condition (August 28, 2002) flow at the Riddle gage was 0.62 cms (22 cfs). The critical condition is defined as the low flow that is expected to occur every three years when averaged over a 14-day period (14Q3). The shade allocations from the temperature TMDL were included in the scenarios. An additional analysis was included in order to refine allocations for the 'shoulder season' (i.e., May, June and October).

Scenario I: Current Loading with critical flow

Scenario #1 predicts water quality conditions under the critical flow conditions with current loading. Current loading is a bit of a misnomer because concentrations were held constant at boundary condition while flow was altered. Because the model was calibrated to a period of extreme low flows, scenario #1 shows an improvement in water quality. Scenario #1 predicts that Cow Creek will meet the daily mean and minimum dissolved oxygen water quality standard (mean greater than 8.0 mg/L and minimum greater than 6.0 mg/L). The model predicts that daily maximum pH concentrations will exceed the pH target of 8.8 near the mouth.

Scenario II: Background Loading

Natural conditions were estimated by using critical condition flow, eliminating sources of anthropogenic nutrient loading, and decreasing solar radiation by estimating system potential shade (see temperature TMDL). The anthropogenic sources of nutrient loading determined in the source assessment are the Glendale WWTP, Riddle WWTP, and nonpoint source loading of phosphorus upstream Riddle.

The model predicts that with background loading the daily maximum pH will not exceed the numeric criteria of 8.5 with a maximum of 8.5 just downstream of the confluences with the Middle and West Fork of Cow Creek.

Scenario III: TMDL

The model was used to determine the maximum phosphorus load that could be allocated without exceeding the pH target (Figures 73 and 74 with additional figures in the main document). The TMDL scenario also shows compliance with the daily average and daily minimum DO targets. Glendale WWTP was kept at current loading because the model shows that it does not contribute to pH exceedances downstream. The diffuse nonpoint loading between river KM 5 and 10 that is attributed to anthropogenic sources was reduced by 62%, the same percentage that Riddle WWTPs inorganic phosphorus load was reduced. The current ratio between inorganic phosphorus and total phosphorus was used to determine load allocations for other forms of phosphorus contributed by Riddle WWTP.

Figure 73. Predicted inorganic phosphorus target compared with current conditions.

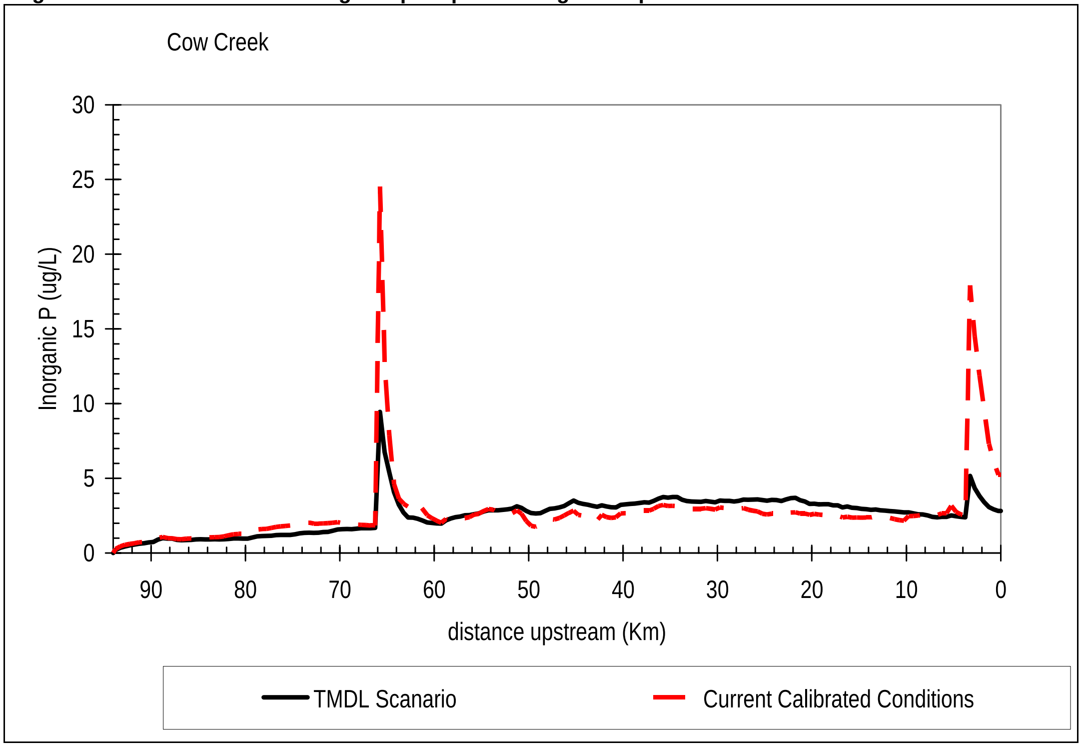
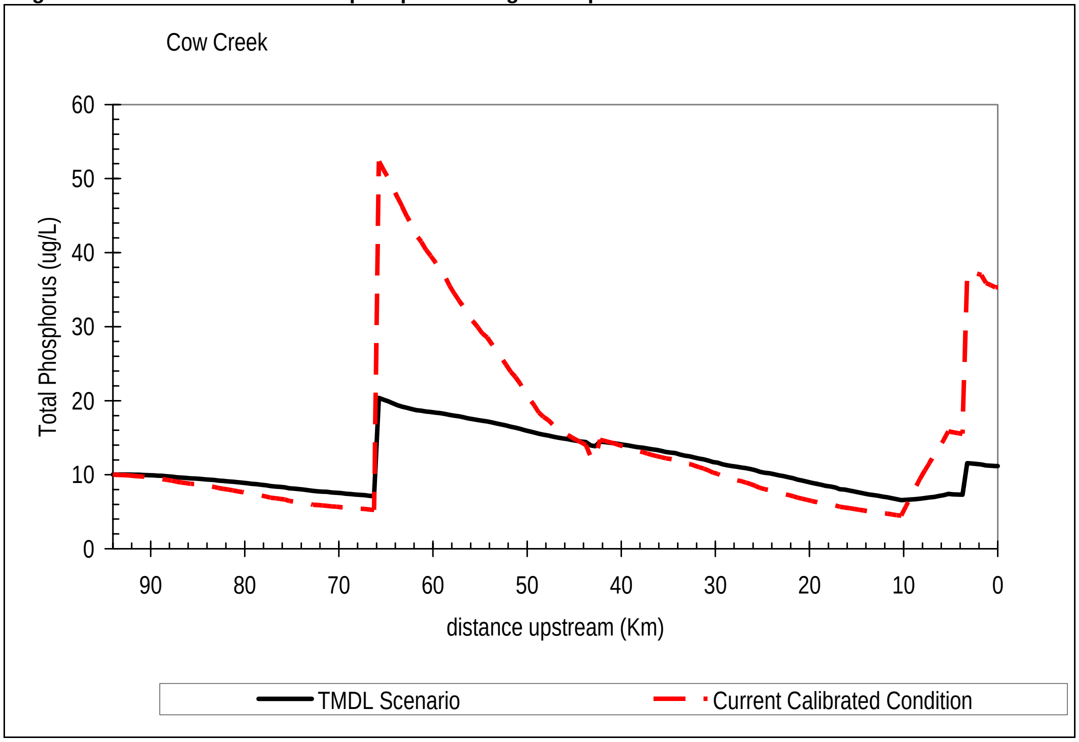


Figure 74. Predicted total phosphorus target compared with current conditions.



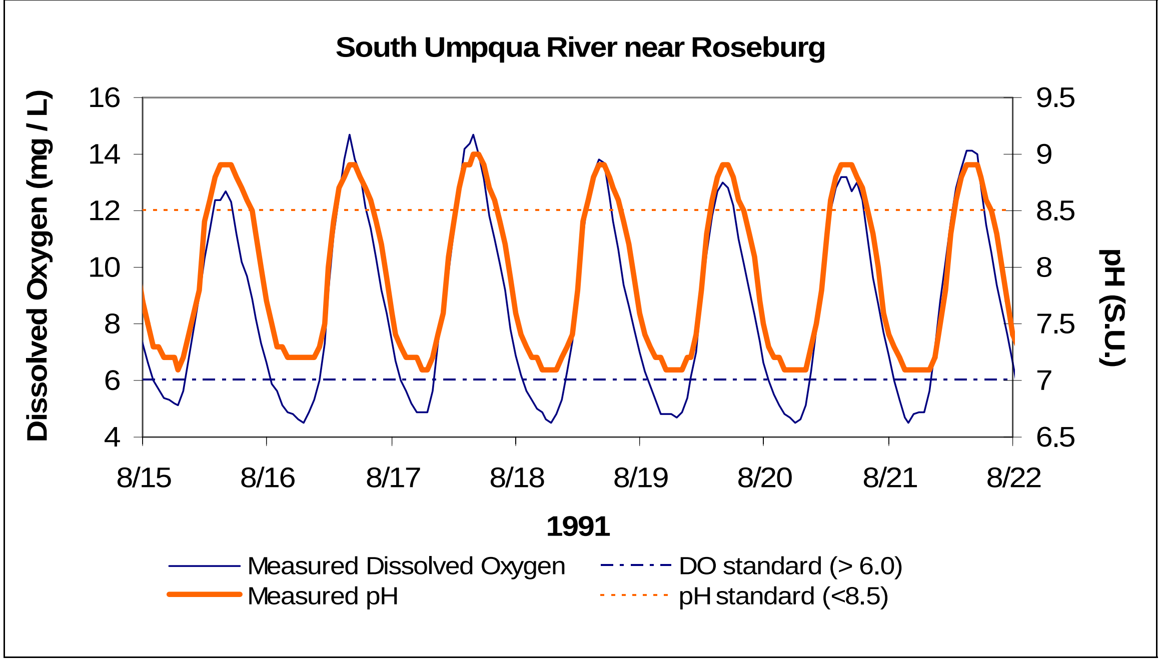
SECTION 7: SOUTH UMPQUA SUMMER NUTRIENT TMDL TECHNICAL ANALYSIS REPORT

GENERAL MODEL SETUP

A water quality model is a simplified, mathematical representation of the processes that lead to poor water quality. A model allows for the integration of meteorology, hydrology, hydraulics, and biological data and processes into a framework that can support decision making processes.

The model was setup and calibrated to two days: August 20, 1991 and August 12, 2004. A USGS survey was conducted between August 16 and August 21, 1991. Data for the entire river was not available on the same day. Using data from different days is an acceptable practice if water quality conditions do not vary significantly between the days during this time period. Daily dissolved oxygen minimums ranged from 4.5 to 5.1 mg / L over this period at the South Umpqua near Roseburg fixed monitoring station (Figure 75). Daily pH maximums ranged from 8.9 to 9.0. This data supports the assumption that the system is at steady-state. An additional synoptic survey was conducted on August 12, 2004 by DEQ to confirm that current water quality conditions are similar to conditions of the early 1990s and to better define nonpoint sources of nutrients

Figure 75. DO and pH data from USGS station #1432260 over the period of interest.



The model was developed for the South Umpqua River from its mouth to 0.5 km upstream of the confluence with Day's Creek at river km 92.7. The river was represented in the model as 92 reaches, each 1,000 meters long. Water quality was computed for each of these reaches and the information was passed in the downstream direction. The model was run with a 5.6 minute time step using the Euler's numerical integration method and the Newton-Raphson calculation for pH. Running the model at much higher resolution (100 meter reaches at 1.4 minute time step) did not significantly impact results. The difference (root mean square error) between minimum DO results was 0.07 mg/L and 0.04 SU for maximum pH. The model was run for 25 repeating days, so that steady-state conditions were achieved.

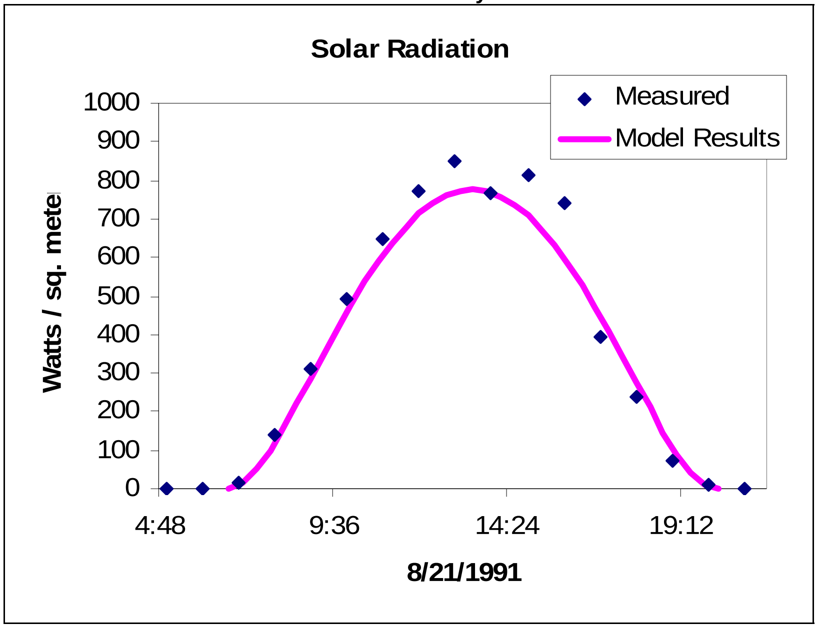
Meteorological Data

Meteorology plays an important role in determining water quality. It is an integral part of the energy balance that determines water temperature. Water temperature, along with solar energy, directly influences the growth of algae and hence nutrient dynamics, DO and pH.

For the 1991 model run, daily maximum and minimum temperatures were available from Riddle (Station # 357169) and were acquired via the internet from Oregon Climate Services. A sine curve was fit through this data to generate hourly values. No data was available for dew point temperature, wind speed or cloud cover. Dew point temperatures were estimated by using the daily minimum air temperature. Wind speed was assumed to be 0.5 m/s and cloud cover were assumed to be zero. These assumptions allowed for a good temperature calibration. For the 2004 model run, data from Roseburg Airport was used. Wind speed was assumed to be constant at 2.0 m/s.

Hourly solar radiation measurements were collected by the USGS as part of the water quality assessment, however, QUAL2K does not allow for input of measured solar radiation. Solar radiation was modeled using the Bras method with an atmospheric turbidity coefficient of 2.7. This method did a good job reproducing measured solar radiation (Figure 76). Brutsaert's method was used for calculating atmospheric longwave radiation with the TVA 1972 cloud adjustment (Chapra and Pellertier, 2004). The Brady-Graves-Geyer method was used to compute evaporation's impact on the energy balance. The background light extinction was set to zero based on date presented in Tanner and Anderson, 1996. Default values were used for other parameters influencing light.

Figure 76. Measured versus modeled solar radiation. Measurements taken by USGS atop the Winston-Green wastewater treatment facility.



Discharge and Conductivity

The model headwater and tributary inflows were measured by USGS during August 1991 (Table 23 and Figure 77, see Anderson et. al., 1994) and by DEQ / WRD in August 2004 (Table 24 and Figure 77). In August 1991, the flow of the South Umpqua River near at Brockway was 3.79 cms (134 cfs) and the flow at the mouth of Cow Creek was 2.24 (79 cfs). During 1992, composite samples were collected at the WWTP treatment plant outflows (Anderson et. al., 1994). The model uses an average of the August 1992 composite samples to estimate flow during the model (Table 25) and discharge monitoring reports to estimate effluent flow during August 2004 (Table 26). The total of the measured inflows (4.76 cms) exceeded the measured flow nearest the mouth (South Umpqua River at Melrose Bridge, river KM 7.8) of 3.99 cms. Points of outflow between river KM 52 and 92.7 were included and totaled 0.47 cms (Tables 27 and 28). The points of outflow were based on the flow balance computation completed during the temperature TMDL analysis and was based on points of diversion data. The mainstem conductivity measurements were used to back calculate diffuse conductivity concentrations (Figures 78 and 79).

Table 23. Summary of boundary conditions for 1991 model run. A range of values indicates diel variability. Data from Anderson, Tanner, and Lee (1994) measured in August 26 – 28, 1991

		Flow	Temperature	Conductivity	Dissolved Oxygen	pH
Site Name	River KM	(CMS)	°C	umhos/cm	Mg/L	s.u.
South Umpqua at Days Creek	92.7	1.9	24.2-26.8	130-134	7.3-8.8	7.8-8.8
Days Creek	92.2	0.005	19.0	294	8.8	8.2
Canyon Creek	81.1	0.040	16.5	198	9.8	8.1
Cow Creek	74.8	2.24	23.5 - 25.5	136	9.2	7.6 - 8.9
Myrtle Creek (u/s WWTP)	61.9	0.105	22.0	257	10.2	8.2
Lookingglass Creek	39.9	0.159	19.0	102	9.5	7.8
Deer Creek	17.7	0.062	17.5	441	7.6	7.7

Table 24. Summary of tributary inflow into the South Umpqua water quality 2004 model based on measurements collected on August 12, 2004 by DEQ. Flow data collected by WRD between 8/11 and 8/31, 2004.

Site Name	River KM	Flow (CMS)	Temp	Cond	DO	pH
South Umpqua at Days Creek (model headwater)	92.7	1.68	24.4-26.5	129	6.6-9.2	7.8-8.7
Days Creek (1) (2)	92.20	0.005	20.3-23.9	291	7.9-10.6	7.9-8.4
Canyon Creek (2)	81.05	0.030	20.3-23.9	291	7.9-10.6	7.9-8.4
Cow Creek	74.75	1.240	24.3-27.1	139	5.6-10.6	7.7-9.2
Myrtle Creek (1)	61.90	0.028	20.3-23.9	291	7.9-10.6	7.9-8.4
Lookingglass Creek	39.9	0.370	23.3-27.1	100	6.7-8.8	7.6-8.2
Deer Creek	17.7	0.030	20.6-25.0	552	5.9-10.2	7.7-8.4
Newton Creek	13.9	0.009	20.1-23.0	506	7.1-7.7	8.1-8.2

1. Flow data estimated
2. Water quality data not collected. Used Myrtle Creek data to estimate conditions.

Table 25. Summary of WWTP inflow into the South Umpqua water quality 1991 model using data from Anderson, Tanner, and Lee measured in August 1992 (average).

		Flow	Flow	Temperature	Conductivity	Dissolved Oxygen	pH
Source	River KM	(CMS)	(MGD)	°C	umhos/cm	Mg/L	s.u.
Canyonville WWTP	81.2	0.01	0.1	21.0	502	5.3 (1)	7.7
Myrtle Creek WWTP	61.9	0.03	0.6	26.0	515	2.6 (1)	7.4
Winston-Green WWTP	33.1	0.04	0.8	26.6	586	4 (2)	7.4
RUSA	12.2	0.15	3.4	26.0	422	4 (2)	7.4

1. Not available from USGS study. Used August 2002 DMRs to Estimate.
2. No data available. Estimate.

Table 26. Summary of WWTP inflow into the South Umpqua water quality 2004 model. Data based on average August 2004 DMR values when available, else based on grab data collected by DEQ in 2002.

	Distance From Mouth	Point Inflow	Point Inflow	Temper-ature	Conductivity	Dissolved Oxygen	pH
Name	(km)	(m^3/s)	(MGD)	°C	umhos/cm	mg/L	s.u.
Canyonville WWTP	81.20	**0.009**	**0.2**	**22**	*305*	**5.7**	**7.2**
Myrtle Creek WWTP	61.9	**0**	**0.0**	**23.6**	<u>515</u>	5.4 (1)	**7.3**
Winston-Green WWTP	33.05	**0.05**	**1.1**	*26.6*	*260*	*5.7*	**7.1**
RUSA	12.15	**0.14**	**3.1**	**26**	*480*	*4.9*	**7.0**

BOLD = reported as average August 2004 value in DMR
<u>Underlined</u> = Average concentration from August 1992, USGS
Italic = collected by DEQ in 2002.
1. No data available, assumed to be the average of the other WWTPs

Decreased temperature and increased conductivity were observed between river KM 50 to 35 accompanied by a decrease in discharge. The likely cause of this pattern is groundwater / surface water interaction. This was accommodated in the model through diffuse inflow and outflow.

Table 27. 1991 model: diffuse sources determined through water balance and conductivity mass balance.

Up	Down	Diffuse Outflow	Diffuse Inflow	Temperature	Conductivity	Dissolved Oxygen	pH
(km)	(km)	(m^3/s)	(m^3/s)	°C	umhos/cm	Mg/L	s.u.
47	33.4		0.2	12	380	8	7
50	35	0.4					

Table 28. 2004 model: diffuse sources determined through water balance and conductivity mass balance.

Up	Down	Diffuse Outflow	Diffuse Inflow	Temperature	Conductivity	Dissolved Oxygen	pH
(km)	(km)	(m^3/s)	(m^3/s)	°C	umhos/cm	Mg/L	s.u.
85	82		0.1	15	170	8	7
60	55		0.1	20	300	8	7
47	33.4		0.2	12	380	8	7
92	52	0.43					
73.7	33.2	0.87					
33.2	18.7	0.38					

Figure 77. Comparison of measured flow versus model results.

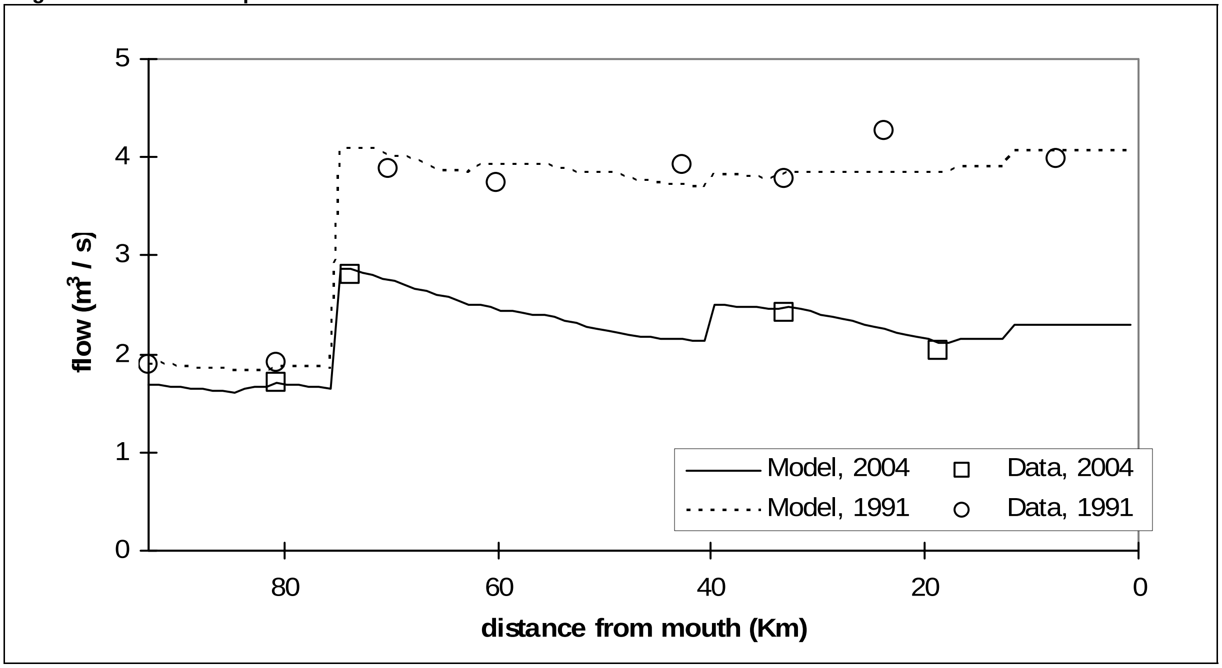


Figure 78. 1991 Model: conductivity calibration model results

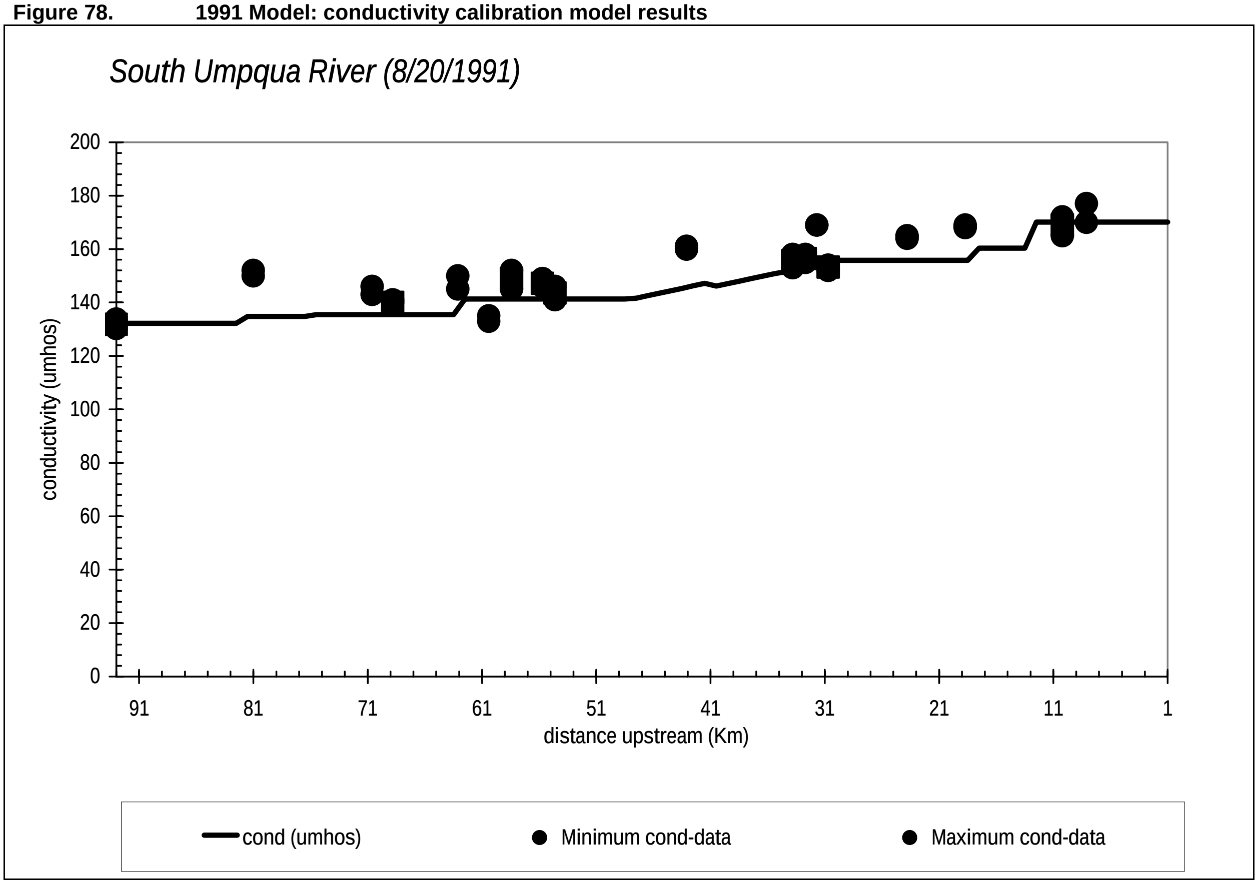
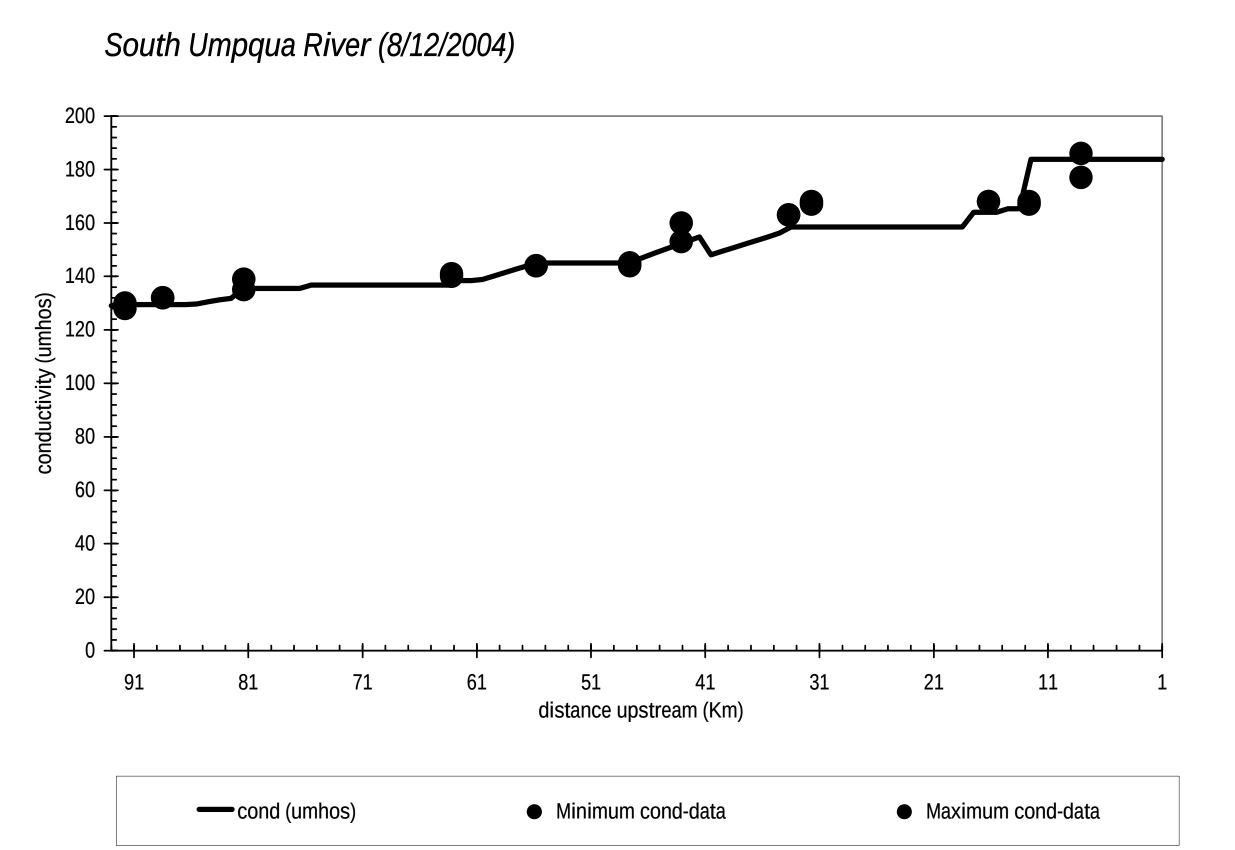


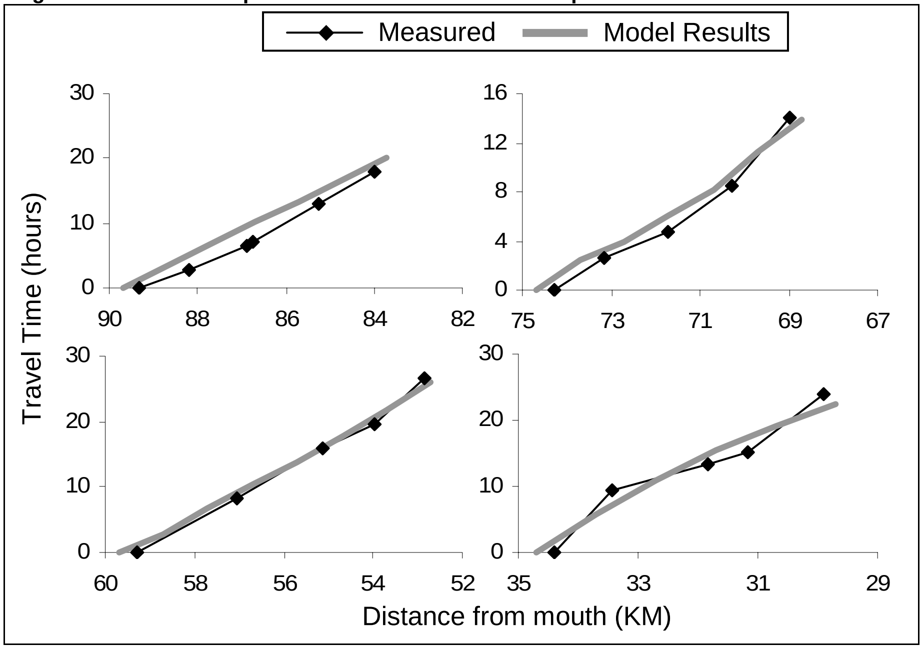
Figure 79. 2004 Model: conductivity calibration model results



Channel Properties and Temperature

Channel morphology and flow determine the hydraulics which defines the travel time, depth and width of the river. The bankfull width was determined through digitizing aerial photographs and field data (see temperature TMDL for full discussion). Bankfull width, the slope of the side of the channel, and a width-to-depth ratio are used to estimate the bottom width of a trapezoidal channel. The slope of a reach was determined using a 10-meter digital elevation model. Manning's roughness coefficients from 0.2 and 0.4 provided for general agreement between predicted and measured travel times (Figure 80).

Figure 80. Comparison of measured and model predicted travel times.



In general, the energy balance in Heat Source (the model used for the temperature TMDL) and Qualk2k are alike. Both account for solar radiation, long wave radiation, the effect of shade, substrate conduction, evaporation, convection and hyporheic exchange. Although similar, the energy balance in Heat Source and Qual2k do vary slightly, these differences however do not have a large impact on the results (less than 0.5 degrees). Differences include that Heat Source accounts for diffuse radiation and solar radiation passing through the water column into the substrate. Values for shade were taken directly from the temperature TMDL analysis. Table 29 presents the parameterization of channel properties in Qual2K. The model was able to reproduce observed water column temperatures (Figure 81 and 82).

Table 29. Channel parameters in QUAL2Kw

Parameter	**Value**
Bottom Algae Coverage	**100%**
Bottom SOD Coverage	**100%**
Sediment thermal cond (W/m/degC)	**1.6**
Sediment thermal diff (cm^2/sec)	**0.0064**
Sediment/hyporheic zone thickness (cm)	**10**
Hyporheic exchange flow (fraction of stream flow)	**0%**
Hyporheic sediment porosity (fraction of volume)	**40%**
Initial biomass of periphyton mgA/m^2	**1000**

Figure 81. 1991 model: temperature calibration results.

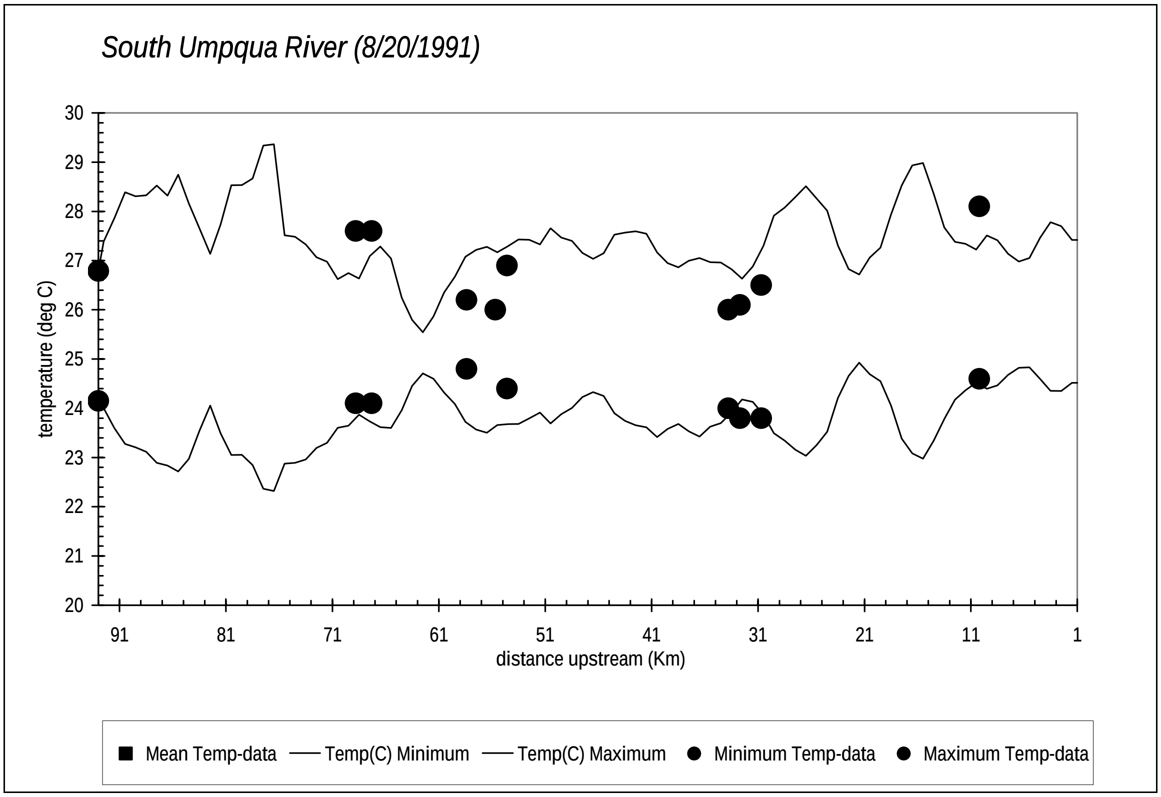
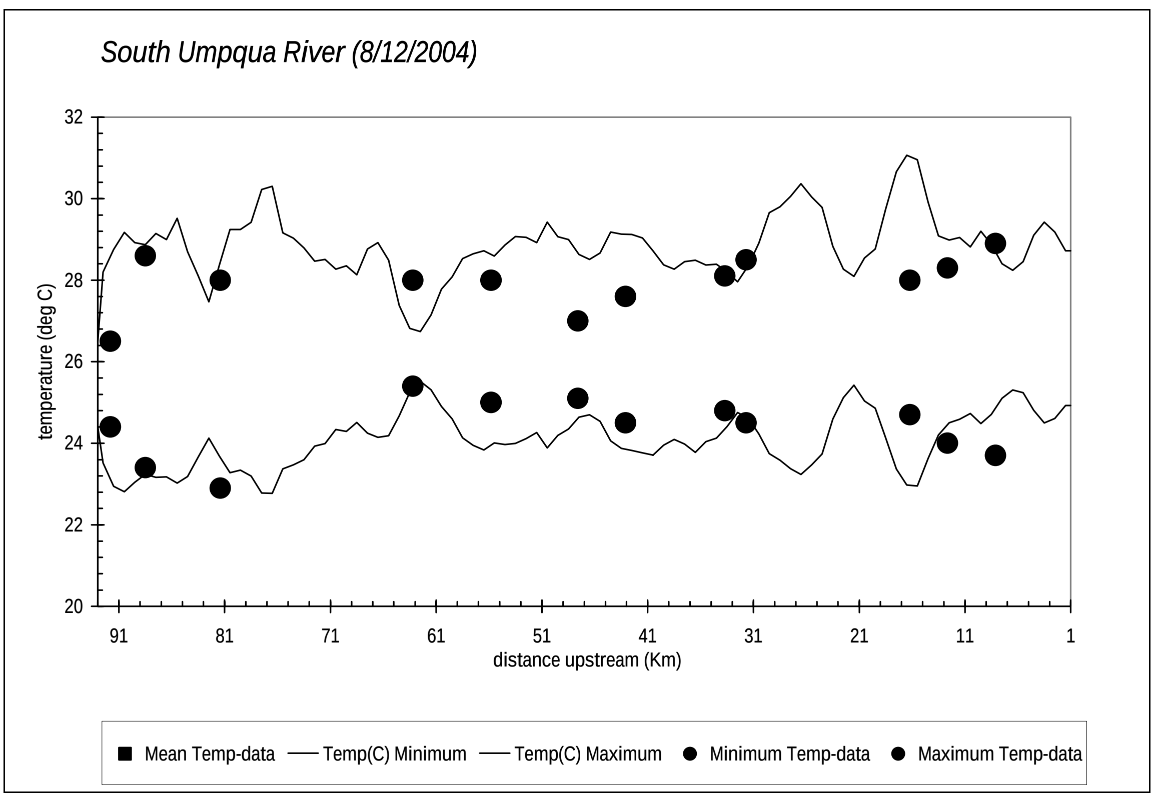


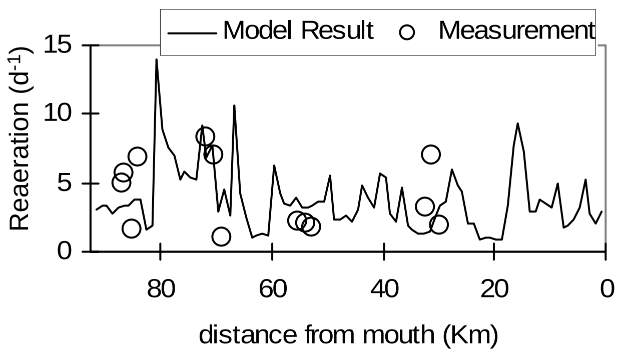
Figure 82. 2004 model: temperature calibration results.



Reaeration Rates

Ideally, reaeration measurements made by Laenen and Woo (1994) could have been used to confirm one of the eight reaeration models within QUAL2k. Measurements were made between September 9 and 13, 1991. The flow gage at Brockway measured 3.65 cms while the modeling period occurred at a similar flow of 3.79 cms. However, none of the reaeration models performed particularly well. This is likely due to the relative coarse scale of the channel morphology that was used in the model. A reaeration model was necessary, though, because of the sparseness of the data collected. Reaeration rates were approximated using the Melching-Flores (pool-riffle) method (Figure 83). The Smith wind reaeration model was used. The rest of the parameters influencing oxygen were default values.

Figure 83. Reaeration rate predicted using the Melching-Flores (pool-riffle) method versus measured reaeration rates (Laenen and Woo, 1994).



Boundary Conditions

The model extends from the mouth of the South Umpqua River to 0.5 km upstream of the confluence with Day's Creek (river km 92.7). Water quality conditions must be input into the model at the model's upstream boundary and for all tributaries and point sources entering the river. Whenever possible, boundary conditions were based on data collected in close proximity to 8/20/1991 (Table 30 and 31). The tributary data was generally collected on 8/26 – 8/28/1991 and is believed to represent conditions during the model day. Composite sampling occurred during August 1992 at the WWTPs and would likely also represent average conditions during August 1991. Data was collected at the mouths of the tributaries during the 2004 survey and discharge monitoring reports were used to estimate contributions by WWTPs. Diffuse flow was assumed at concentrations representative of background loading (see discussion below under model scenarios).

Table 30. 1991 Model: Summary of boundary conditions.

Site Name	River KM	Inorganic Suspended Solids (1) *mg/L*	Slow CBOD *mgC/L*	Fast CBOD *mgC/L*	Dissolved Organic N (5) *ugN/L*	Ammonia N *ugN/L*	Nitrate + Nitrite N *ugN/L*	Organic P *ugP/L*	Inorganic P *ugP/L*	Detritus (10) *mgD/L*	Alkalinity *mgCaCO3/L*
South Umpqua at Days Creek (model headwaters)	92.7	1.0	0.3 (2)	0	598	2	4	16	3	0	49(10)
Days Creek (11)	92.2	1.0	1.9	0	297	3	59	5	1	0	90
Canyonville WWTP	81.2	0.0	0 (3)	10.7 (7)	1448	3341	2721	333	2500	0	119
Canyon Creek	81.1	1.0	1.9 (4)	0	283	17	4	7	3	0	76
Cow Creek	74.8	1.0	0.5 (2)	0	150	10	4	7	1	0	63
Myrtle Creek (u/s WWTP)	61.9	1.0	1.9 (4)	0	297	3	59	5	1	0	90
Myrtle Creek WWTP	61.9	0.0	0 (3)	2.7 (7)	5243	8614	2714	629	3143	0	89
Lookingglass Creek	39.9	1.0	1.9 (4)	0	481	19	4	7	2	0	39
Winston-Green WWTP	33.1	0.0	0 (3)	2.7 (7)	2871	5686	9371	661	2739	0	66
Deer Creek	17.7	1.0	1.9 (2)	0	905	95	189	29	23	0	97
RUSA	12.2	0.0	0 (3)	8.0 (7)	2422	6544	7189	589	3144	0	49
Diffuse flow:	33.4 - 47	0	0	0	216	18	23	9	5	0	100

C = Carbon; N = Nitrogen; P = Phosphorus

1. Inorganic suspended solids is not a parameter that has been monitored on the South Umpqua River. ISS is a subset of Total Suspended Solids which is typically very low during the July through September (median of 1 mg/L at Melrose Bridge)
2. From DEQ Ambient Monitoring Network (July - August 1991)
3. CBOD from WWTPs was assumed to be fast CBOD.
4. No data available; used Deer Creek Data as an estimate.
5. Dissolved Organic N = Total Kjeldahl Nitrogen - Ammonia [note: suspended solids typically 2% of total solids]
6. No data available. Assumed to be negligible.
7. Not available from USGS study. Used August 2002 DMRs to Estimate.
8. No data available. Estimate.
9. Data reported less than the method reporting limit was assumed to be 0.8 of the reporting limit.
10. No data collected. TSS typically low during the summer season, thus assumed to be zero.
11. Laboratory analytical work not available, assumed to be same values as Myrtle Creek

Table 31. 2004 Model: Summary of boundary conditions. Based on data collected August 12, 2004 except where noted.

	Fast CBOD (1)	Dissolved Organic N (2)	Ammonia N	Nitrate + Nitrite N	Organic P (3)	Inorganic P	Detritus (4)	Alkalinity
Name	mgC/L	ugN/L	ugN/L	ugN/L	ugP/L	ugP/L	mgC/L	mgCaCO3/L
South Umpqua at Days Creek (model headwater)	0.26	350	50	5.9	16	4	0	44
Days Creek (5)	7.7	140	20	58	21	19	0	97
Canyonville WWTP	**5.9**	*18400*	**7600**	**11600**	**1590**	*3170*	**2.4**	*167*
Canyon Creek (1)	7.7	140	20	58	21	19	0	97
Cow Creek	1.1	144	16	8	10	10	1.5	55
Myrtle Creek	7.7	140	20	58	21	19	0	97
Myrtle Creek WWTP	**2.1**	**2380**	**50**	**7700**	***615***	**3070**	**0.6**	***89***
Lookingglass Creek	1.4	144	16	4	15	5	0	35
Winston-Green WWTP	**3.3**	*1030*	**170**	*14500*	*60*	*3040*	**1.6**	*64*
Deer Creek	1.0	120	40	62	47	3	0	120
Newton Creek	1.1	170	30	288	34	56	0	220
RUSA	**5.9**	**3820**	**10400**	**10470**	*400*	*4050*	**2.4**	*90*
Diffuse 1 (rKM 82 – 85)	0	216	18	23	9	5	0	<u>60</u>
Diffuse 2 (rKM 55 – 60)	0	<u>10000</u>	18	23	<u>400</u>	5	0	<u>130</u>
Diffuse 3 (rKM 33.4 – 47)	0	216	18	23	9	5	0	<u>100</u>

C = Carbon; N = Nitrogen; P = Phosphorus
BOLD = reported as average August 2004 value in DMR; bold italics = Average concentration from August 1992, USGS;
Italic = collected by DEQ in 2002;
<u>Underlined</u> values were back calculated based on observed in stream concentrations and assumed to be attributed to anthropogenic nonpoint source loading.
Inorganic suspended solids, slow dissolved organic carbon, particulate organic nitrogen, and particulate organic phosphorus assumed to be negligible;
(1) 5-day BOD assumed to measure predominately Fast CBOD.;
(2) Dissolved Organic N = Total Kjeldahl Nitrogen - Ammonia [note: suspended solids typically 2% of total solids];
(3) Dissolved Organic Phosphorus = Total Phosphate as P – Soluble Reactive P;
(4) Detritus = Total Suspended Solids * 0.4;
(5) Water quality data not collected. Used Myrtle Creek data to estimate conditions;

Calibration

DO, pH and nutrient calibration was completed by adjusting a number of key parameters so that the model reproduced observed water quality conditions in 1991 and 2004. Periphyton and phytoplankton growth, respiration, excretion, and death rates were adjusted so that the model could reproduce the diel variation in DO and pH (Table 32). The rates governing the fate of nutrients were adjusted so the model could reproduce the general pattern of nutrient concentrations. Phytoplankton rates were adjusted so that the phytoplankton concentrations at the mouth matched the average measured concentration of 4.9 ug/L (no phytoplankton chlorophyll a samples were collected during the synoptic water quality surveys). Stoichiometry was based the average of samples collected by the USGS (Anderson et. al., 1994) and were slightly less than the suggested parameter range. These values also influenced nutrient uptake rates. The model was generally able to reproduce the DO, pH, and nutrient concentrations observed during the water quality surveys (Table 33 and Figures 84 – 92).

Table 32. Parameterization of the South Umpqua River and Cow Creek (discussed in separate chapter) water quality models

				Suggested Range	
Parameter	***South Umpqua Value***	***Cow Creek Value***	***Units***	***Min value***	***Max value***
Stoichiometry:					
Carbon	**28.5**	40	**gC**	**30**	**50**
Nitrogen	**2.8**	7.2	**gN**	**3**	**9**
Phosphorus	**0.4**	1	**gP**	**0.4**	**2**
Dry weight	**100**	100	**gD**	**100**	**100**
Chlorophyll	**1**	1	**gA**	**0.4**	**2**
Inorganic suspended solids:					
Settling velocity	**0.5**	0.5	**m/d**	**0**	**2**
Oxygen:					
Reaeration model	**USGS(pool-riffle)**	**Thackston-Dawson**			
Temp correction	**1.024**	**1.024**			
Reaeration wind effect	**None**	**None**			
O2 for carbon oxidation	**2.69**	**2.69**	**gO_2/gC**		
O2 for NH4 nitrification	**4.57**	**4.57**	**gO_2/gN**		
Oxygen inhib model CBOD oxidation	**Exponential**	**Exponential**			
Oxygen inhib parameter CBOD oxidation	**0.60**	**0.60**	**L/mgO2**	**0.60**	**0.60**
Oxygen inhib model nitrification	**Exponential**	**Exponential**			
Oxygen inhib parameter nitrification	**0.60**	**0.60**	**L/mgO2**	**0.60**	**0.60**
Oxygen enhance model denitrification	**Exponential**	**Exponential**			
Oxygen enhance parameter denitrification	**0.60**	**0.60**	**L/mgO2**	**0.60**	**0.60**
Oxygen inhib model phyto resp	**Exponential**	**Exponential**			
Oxygen inhib parameter phyto resp	**0.60**	**0.60**	**L/mgO2**	**0.60**	**0.60**
Oxygen enhance model bot alg resp	**Exponential**	**Exponential**			
Oxygen enhance parameter bot alg resp	**0.60**	**0.60**	**L/mgO2**	**0.60**	**0.60**

Slow CBOD:					
Hydrolysis rate	**1**	**1**	**/d**	**0**	**5**
Temp correction	**1.047**	**1.047**		**1**	**1.07**
Oxidation rate	**0.31565**	**0.31565**	**/d**	**0**	**5**
Temp correction	**1.047**	**1.047**		**1**	**1.07**
Fast CBOD:					
Oxidation rate	**3**	**2**	**/d**	**0**	**5**
Temp correction	**1.047**	**1.047**		**1**	**1.07**
Organic N:					
Hydrolysis	**0.6**	**0.5**	**/d**	**0**	**5**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Settling velocity		**0.1**	**m/d**	**0**	**2**
Ammonium:					
Nitrification	**1**	**1**	**/d**	**0**	**10**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Nitrate:					
Denitrification	**1**	**1**	**/d**	**0**	**2**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Sed denitrification transfer coeff	**0**	**0**	**m/d**	**0**	**1**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Organic P:					
Hydrolysis	**1.5**	**1.5**	**/d**	**0**	**5**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Settling velocity	**0**	**0.1**	**m/d**	**0**	**2**
Inorganic P:					
Settling velocity	**0**	**0**	**m/d**	**0**	**2**
Sed P oxygen attenuation half sat constant	**0**	**0**	**mgO_2/L**	**0**	**2**
Phytoplankton:					
Max Growth rate	**1**	**1**	**/d**	**1.5**	**3**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Respiration rate	**0.1**	**0.1**	**/d**	**0**	**1**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Death rate	**0.1**	**0.1**	**/d**	**0**	**1**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Nitrogen half sat constant	**15**	**15**	**ugN/L**	**0**	**150**
Phosphorus half sat constant	**2**	**2**	**ugP/L**	**0**	**50**
Inorganic carbon half sat constant	**1.30E-05**	**1.30E-05**	**moles/L**	**1.30E-06**	**1.30E-04**
Phytoplankton use HCO3- as substrate	**Yes**	**Yes**			
Light model	**Half saturation**	**Half saturation**			

Light constant	**57.6**	**57.6**	**langleys/d**	**28.8**	**115.2**
Ammonia preference	**25**	**25**	**ugN/L**	**25**	**25**
Settling velocity	**0**	**0**	**m/d**	**0**	**5**
Bottom Algae:					
Growth model	**Zero-order**	**Zero-order**			
Max Growth rate	**500**	**300**	**mgA/m^2/d or /d**	**0**	**500**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
First-order model carrying capacity	**1000**	**1000**	**mgA/m^2**	**1000**	**1000**
Respiration rate	**0.1**	**0.3**	**/d**	**0**	**0.5**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Excretion rate	**0.05**	**0.3**	**/d**	**0**	**0.5**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
Death rate	**0.1**	**0.3**	**/d**	**0**	**0.5**
Temp correction	**1.07**	**1.07**		**1**	**1.07**
External nitrogen half sat constant	**15**	**30**	**ugN/L**	**0**	**300**
External phosphorus half sat constant	**10**	**10**	**ugP/L**	**0**	**100**
Inorganic carbon half sat constant	**2.50E-06**	**2.50E-06**	**moles/L**	**1.30E-06**	**1.30E-04**
Bottom algae use HCO3- as substrate	**Yes**	**Yes**			
Light model	**Half saturation**	**Half saturation**			
Light constant	**3.58588**	**3.58588**	**langleys/d**	**1**	**100**
Ammonia preference	**22.48993**	**22.48993**	**ugN/L**	**1**	**100**
Subsistence quota for nitrogen	**2.8**	**7.2**	**mgN/mgA**	**0.0072**	**7.2**
Subsistence quota for phosphorus	**0.4**	**1**	**mgP/mgA**	**0.001**	**1**
Maximum uptake rate for nitrogen	**2.8**	**15**	**mgN/mgA/d**	**1**	**500**
Maximum uptake rate for phosphorus	**0.4**	**5**	**mgP/mgA/d**	**1**	**500**
Internal nitrogen half sat ratio	**1.01**	**1.01**		**1.05**	**5**
Internal phosphorus half sat ratio	**1.01**	**1.01**		**1.05**	**5**
Detritus (POM):					
Dissolution rate	**0.5**	**0.5**	**/d**	**0**	**5**
Temp correction	**1.07**	**1.07**		**1.07**	**1.07**
Settling velocity	**1**	**0.5**	**m/d**	**0**	**5**
pH:					
Partial pressure of carbon dioxide	**375**	**375**	**ppm**		

Table 33. Error statistics for 1991 South Umpqua water quality model for site with continuous measurements. ME = mean error, AME = absolute mean error, RMSE = root mean square error.

River KM	USGS South Umpqua River Station Name	Temperature			Dissolved Oxygen			pH		
		ME	AME	RMSE	ME	AME	RMSE	ME	AME	RMSE
68.5	At river mile 154.9, near Riddle	-0.5	0.5	0.6	0.4	0.7	0.8	0.0	0.2	0.2
67	At river mile RM 154, near Tricity	-0.7	0.8	0.9	-0.6	0.9	1.1	0.0	0.2	0.2
58.1	Near Boomer Hill Road	-0.1	0.8	0.8	1.0	1.0	1.1	0.3	0.4	0.4
55.4	At Ruckles	0.5	0.8	0.9	0.8	0.8	1.0	0.4	0.4	0.5
54.3	At river mile RM 146, above I-5 Bridge near Ruckles	0.0	0.6	0.7	0.2	0.4	0.5	0.3	0.3	0.3
33.5	Near Brockway	0.4	0.4	0.5	0.7	1.2	1.3	0.0	0.3	0.4
32.4	Below treatment plant near Brockway	0.5	0.5	0.5	1.0	1.1	1.4	0.3	0.4	0.5
30.4	Above Happy Valley Road near Winston	0.6	0.6	0.7	0.8	0.9	1.1	0.3	0.3	0.4
9.9	Near Roseburg	-0.3	0.5	0.6	0.1	1.2	1.3	0.9	0.9	0.9
	Averages	**0.0**	**0.6**	**0.7**	**0.5**	**0.9**	**1.1**	**0.3**	**0.4**	**0.4**

Figure 84. Example of measured concentrations and model results.

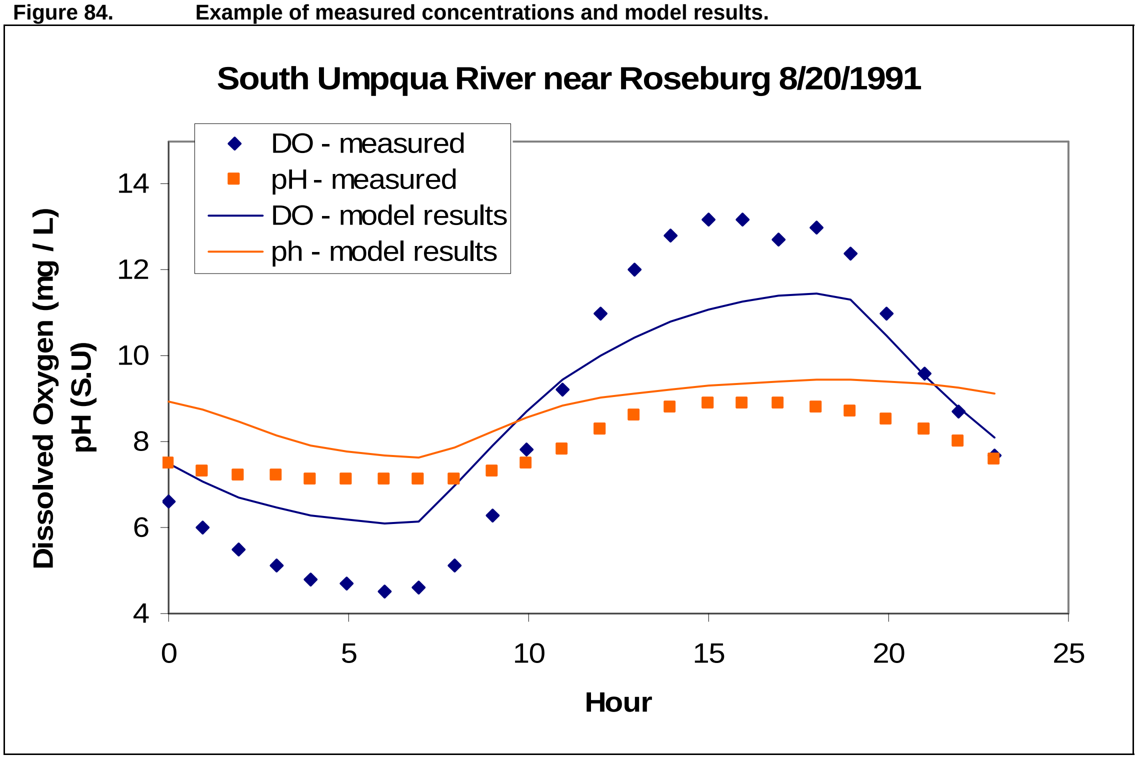


Figure 85. Dissolved Oxygen Calibration (1991 Model). DO saturation line represents the average DO saturation throughout the day.

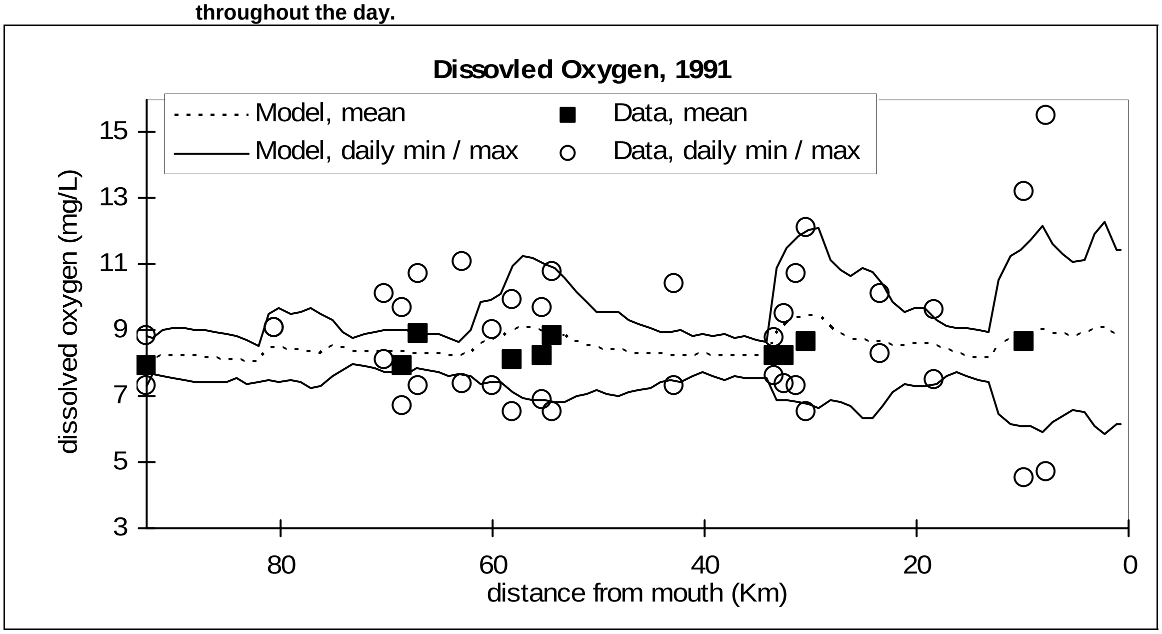


Figure 86. Dissolved Oxygen Calibration (2004 Model). DO saturation line represents the average DO saturation throughout the day.

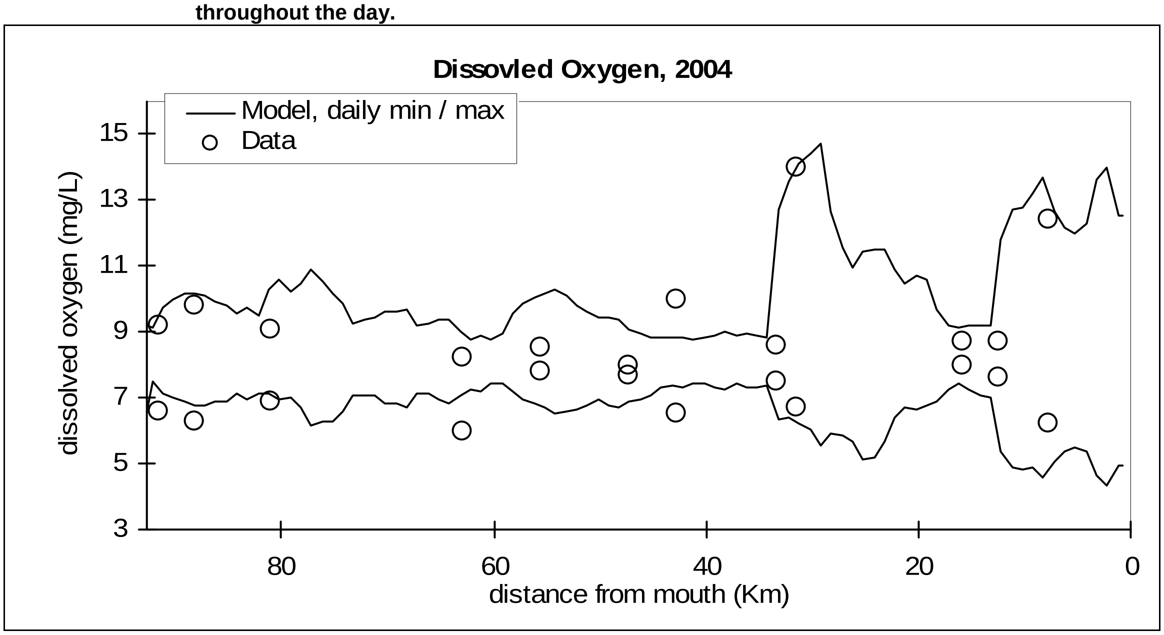


Figure 87. pH Calibration (1991 Model)

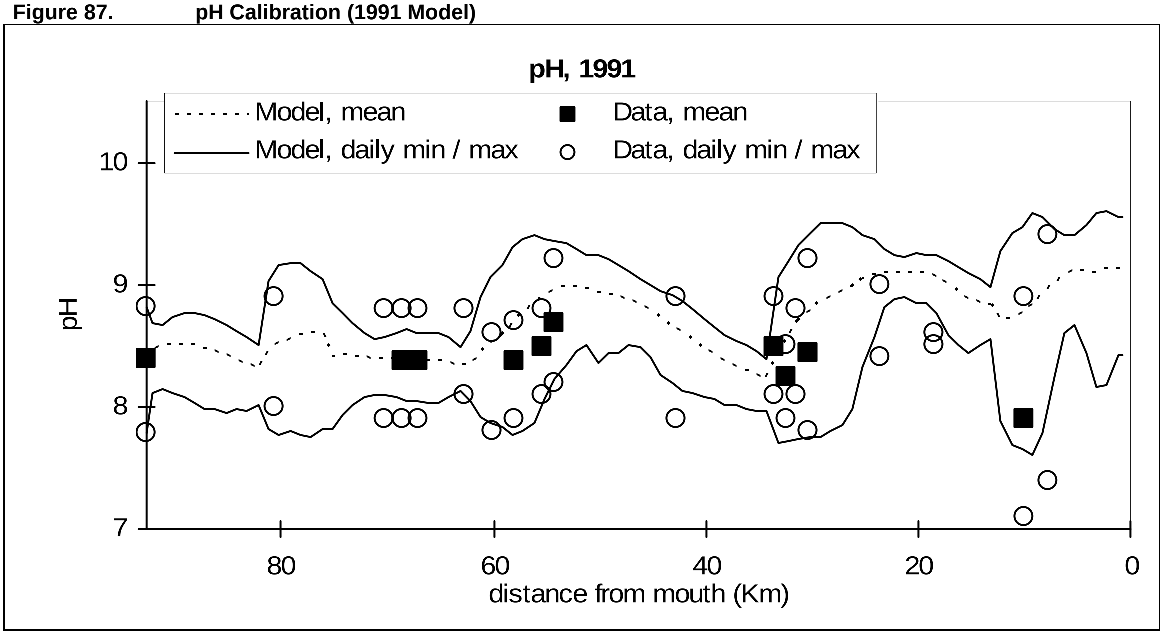


Figure 88. pH Calibration (2004 Model)

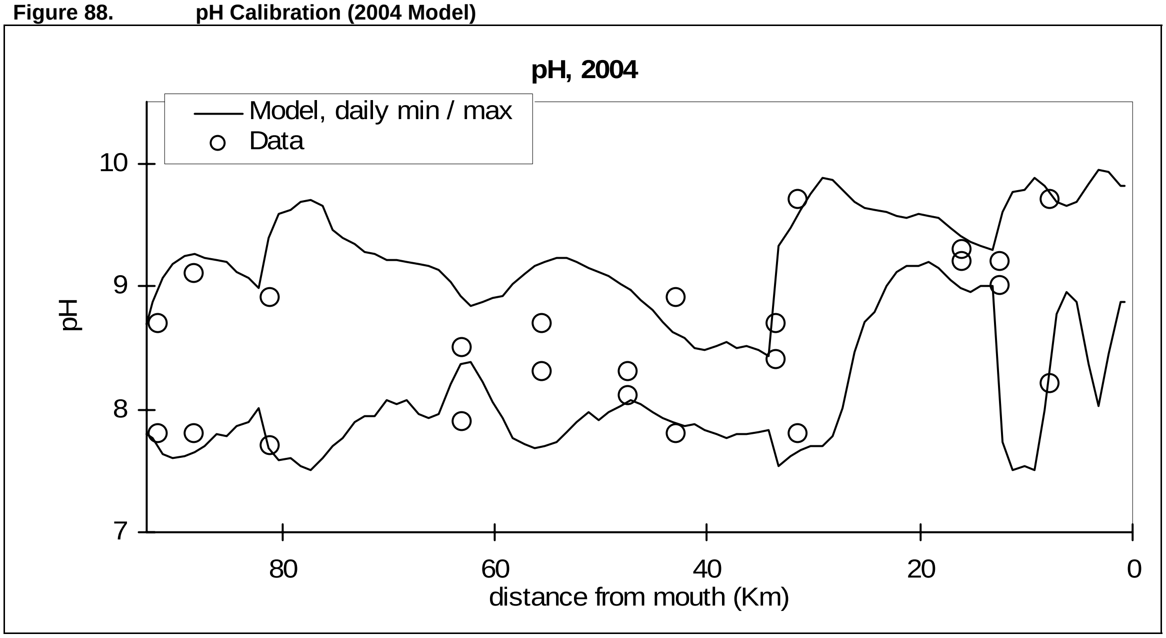


Figure 89. Selected nutrient comparisons between measurements and model results.

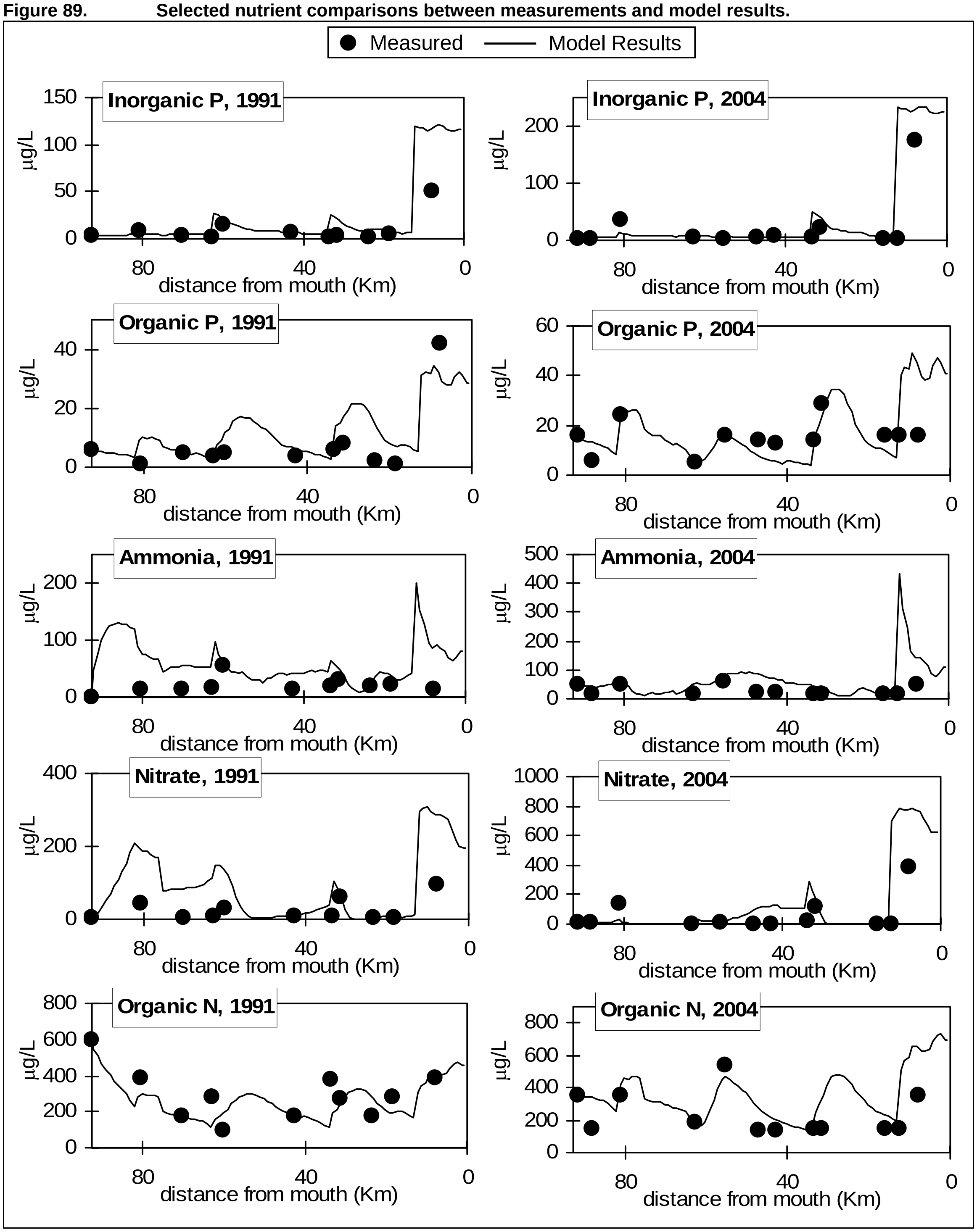


Figure 90. **Phytoplankton calibration (2004). No grab sample data was collected during the survey. Model results are compared to average values.**

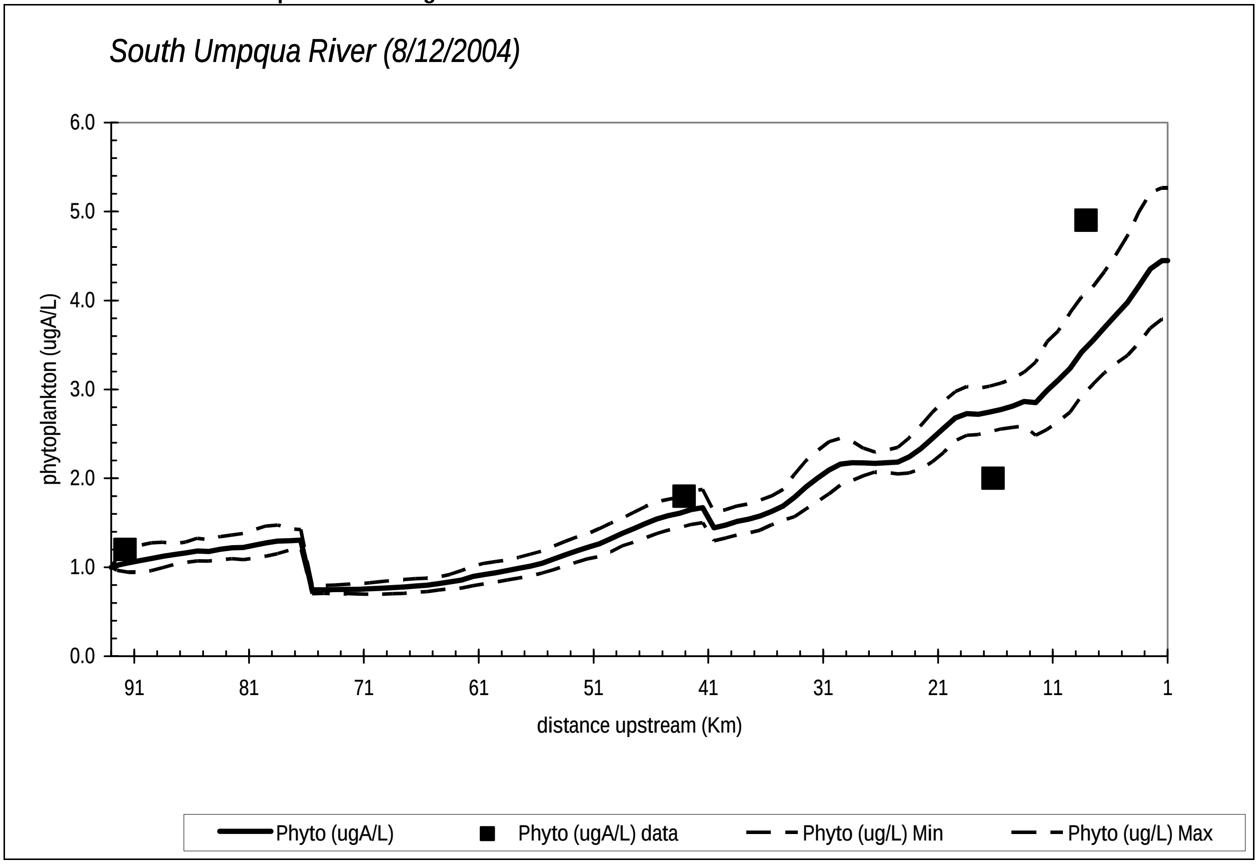


Figure 91. Alkalinity calibration (1991).

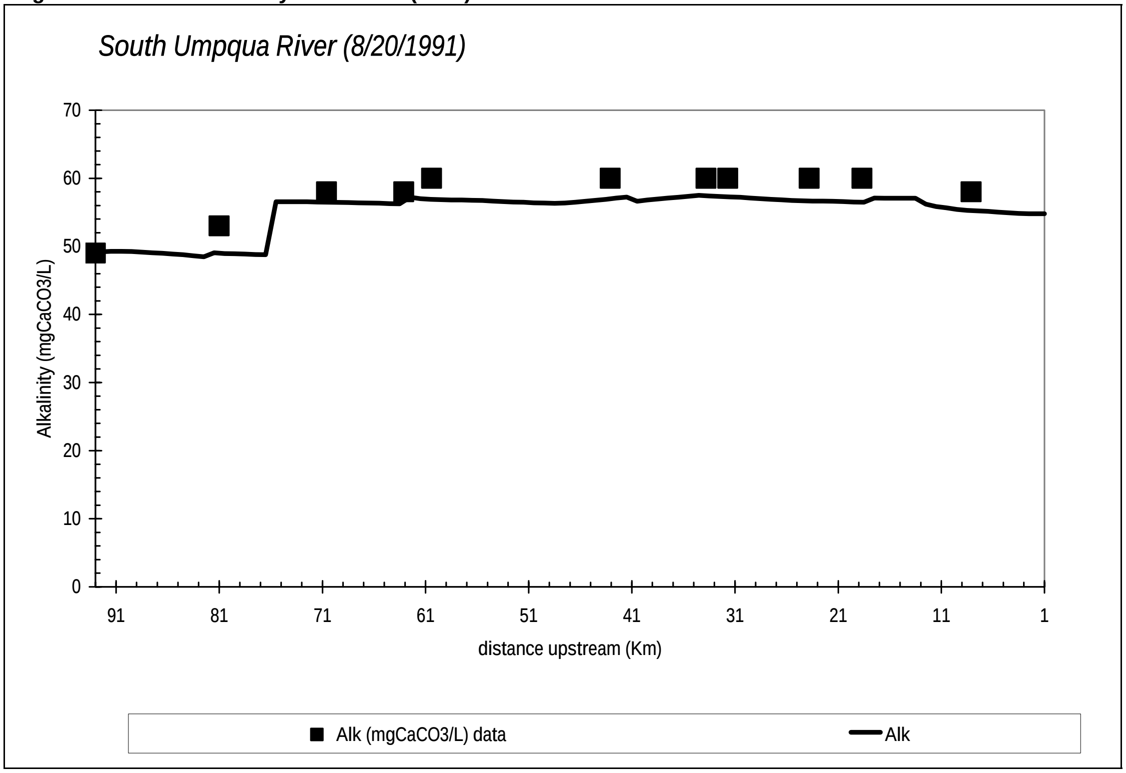
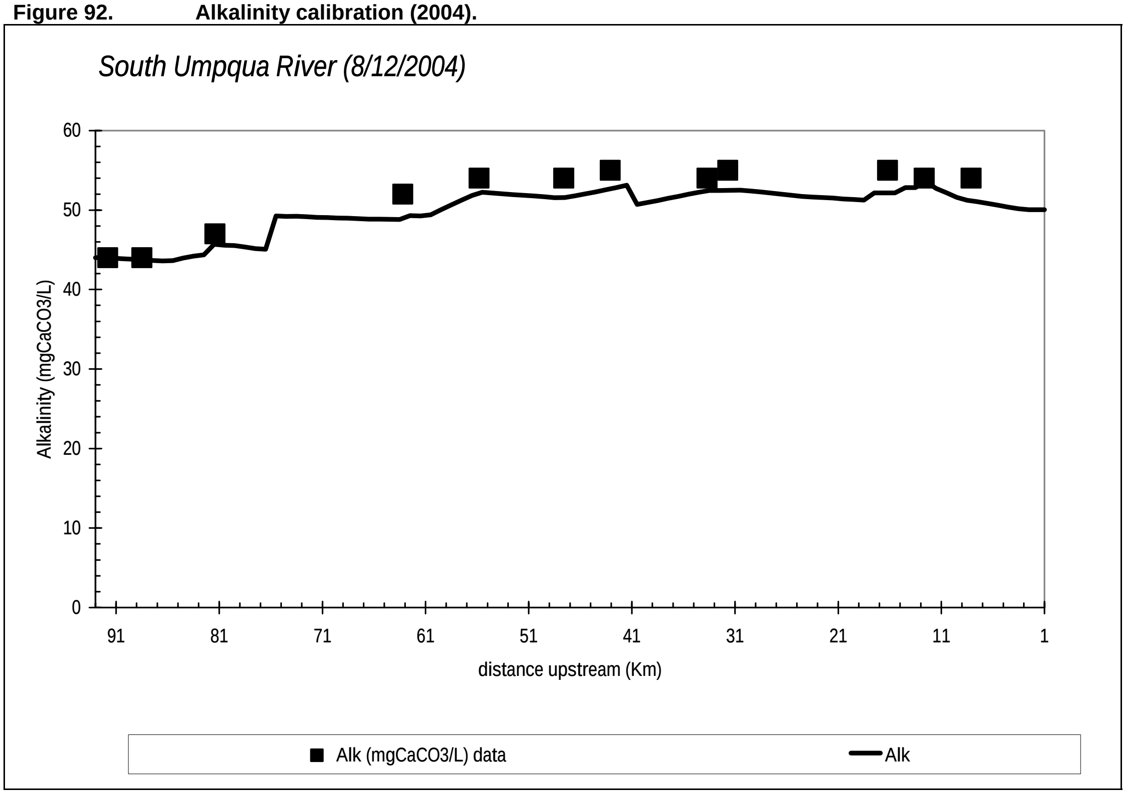


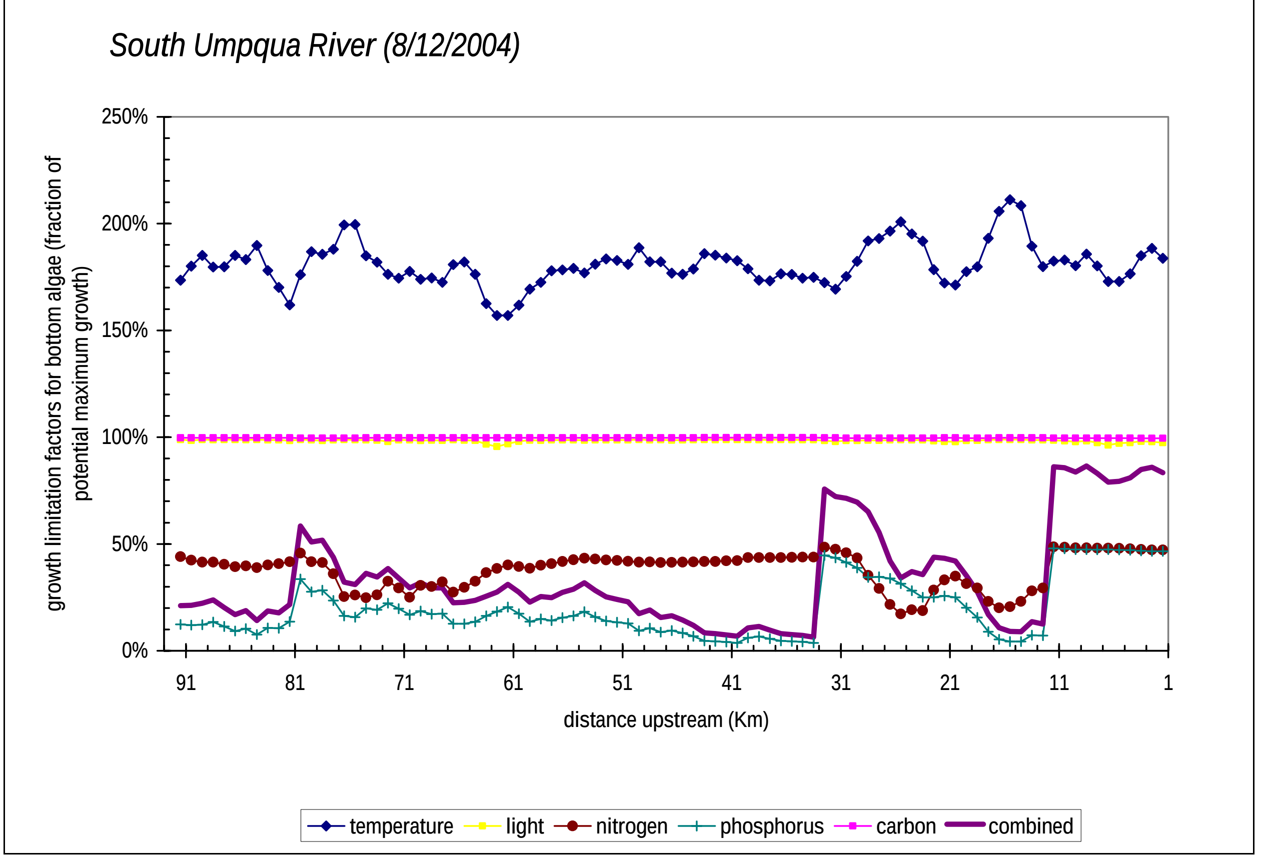
Figure 92. Alkalinity calibration (2004).



Nutrient Limitation

Current conditions upstream of the WWTPs and background loading conditions indicate that phosphorus limits the growth of attached algae in the analyzed portion of the South Umpqua River (Figures 93). The ratio of dissolved inorganic nitrogen (nitrate and nitrite plus ammonia) to inorganic phosphorus for background concentrations is 8.2. A ratio greater than 7 is an indication that there is possible phosphorus limitation. The hypothesis that the South Umpqua is phosphorus limited under background loading is supported by data from Jackson Creek, a major tributary of the South Umpqua River. Jackson Creek data shows that the ratio of dissolved organic nitrogen to soluble reactive phosphorus increases in the downstream direction. The upper reaches are likely nitrogen limited while near the mouth is likely phosphorus limited. There are no known anthropogenic sources of nutrients to Jackson Creek.

Figure 93. South Umpqua River attached algae growth limitation at 5:00 PM under current calibrated conditions.



SCENARIOS

In addition to the calibrated period for 1991 and 2004, three other scenarios were modeled: current nonpoint source loading only, background loading only, and the TMDL. Scenarios are compared with the calibration from 2004 because it is the most current data set. The scenarios were run with the same climate data as the August 2004 run. The August 2004 flow at the Brockway gage was 82 cfs which is very close to the computed critical condition flow of 84 cfs. Therefore, the flow regime from 2004 was used to calculate critical conditions. The critical condition is defined as the low flow that is expected to occur every three years when averaged over a 14-day period (14Q3). The shade allocations from the temperature TMDL were included in the scenarios however their impact on water temperature is minimal (<0.5 deg. C).

Scenario I: Nonpoint Source Loading Only

The nonpoint source loading only scenario is for informational purposes. It was determined by reducing the flow and hence loading from the WWTPs that discharge directly to the model reach to zero. The WWTPs that discharge into Cow Creek were also accounted for by using the Cow Creek TMDL model. Model results predict that portions of the South Umpqua would continue to be water quality limited for DO and pH with no discharge from the WWTPs (see figures in main document).

Scenario II: Background Loading

Natural conditions were estimated using the 2004 model as a base but changing the boundary conditions to background concentrations (Table 34). Background nutrient concentrations were determined by taking the average concentration from samples collected at the mouths of tributaries that are believed not to be significantly impacted by anthropogenic nutrient sources and which drain into the South Umpqua River (i.e. Jackson Creek, Elk Creek, and South Umpqua River at Tiller). The concentration for Cow Creek was based on the natural condition for Cow Creek model run developed during the Cow Creek TMDL.

Table 34. Background concentrations.

Dissolved Organic N	*Ammonia N*	*Nitrate + Nitrite N*	*Dissolved Organic P*	*Inorganic P*
ugN/L	*ugN/L*	*ugN/L*	*ugP/L*	*ugP/L*
216	18	23	9	5

The model predicts that the minimum DO criteria (6.0 mg/L) and the daily mean DO criteria (8.0 mg/L) would be met under background loading conditions. Furthermore, the model predicts that under background loading the maximum pH criteria of 8.5 will be exceeded in portions of the South Umpqua River. The background loading scenario is used as a “natural condition” in terms of comparison to standards (see Standard Interpretation Section).

Scenario III: TDML

The background loading scenario and data analysis indicates that without anthropogenic loading, the South Umpqua River would likely be phosphorus limited. Therefore, load allocations are discussed in terms of inorganic phosphorus (measured as dissolved orthophosphate as phosphorus) and total phosphorus.

Preliminary allocations were determined based on the assimilative capacity at the four WWTPs: Canyonville, Myrtle Creek, Winston-Green, and Roseburg Urban Sanitary Authority (RUSA). Assimilative capacity is the load that can be added to the river in addition to background loading without violations of the water quality standards. The load from the two WWTPs that discharge to Cow Creek is limited more by local conditions than the assimilative capacity in the South Umpqua River. Tiller Ranger Station WWTP is relatively small facility and discharges 17 miles upstream of the modeled reach, therefore its impact on downstream assimilative capacity is assumed to be negligible (discussed below).

Phosphorus is not a conservative constituent; its concentration can vary along the river without dilution or loading. The assimilative capacity of the river varies longitudinally because of different reaeration rates, channel volume, and background nutrient concentrations (Figures 94 and 95). Given the difficultly of quantifying locations, timing and magnitude of anthropogenic nonpoint source phosphorus loading, the nonpoint source allocation load was set to the estimated background load.

With phosphorus reductions, the model predicts an average 70% reduction in attached algae abundance in the South Umpqua River (Figure 96). These reductions should satisfy the narrative criteria concerning aquatic weeds and algae water quality limitation. If after implementation of the TMDL, deleterious effects from bottom algae continue, above background conditions, additional load reductions may be necessary.

Figure 94. Inorganic phosphorus TMDL target for the critical flow condition.

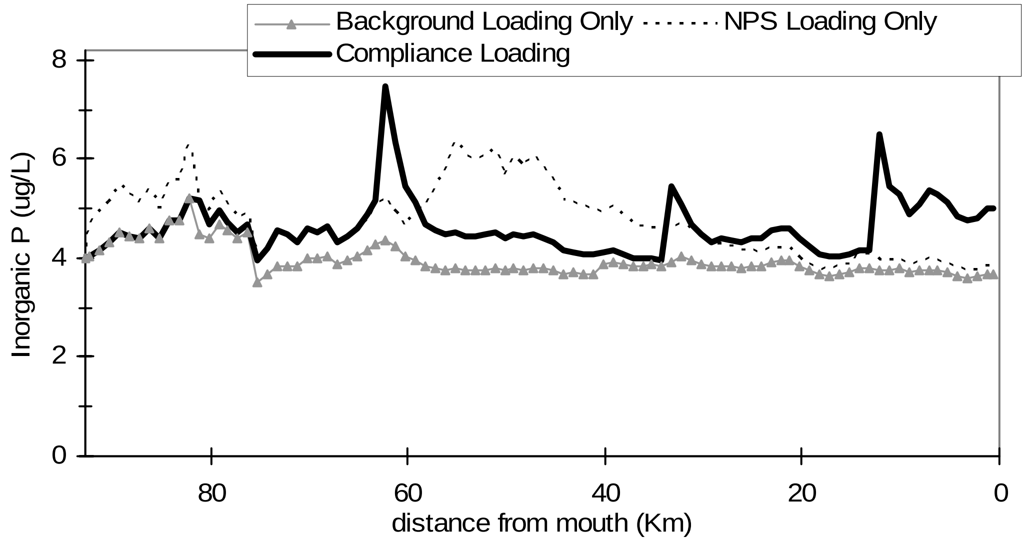


Figure 95. Total phosphorus TMDL target for the critical flow condition.

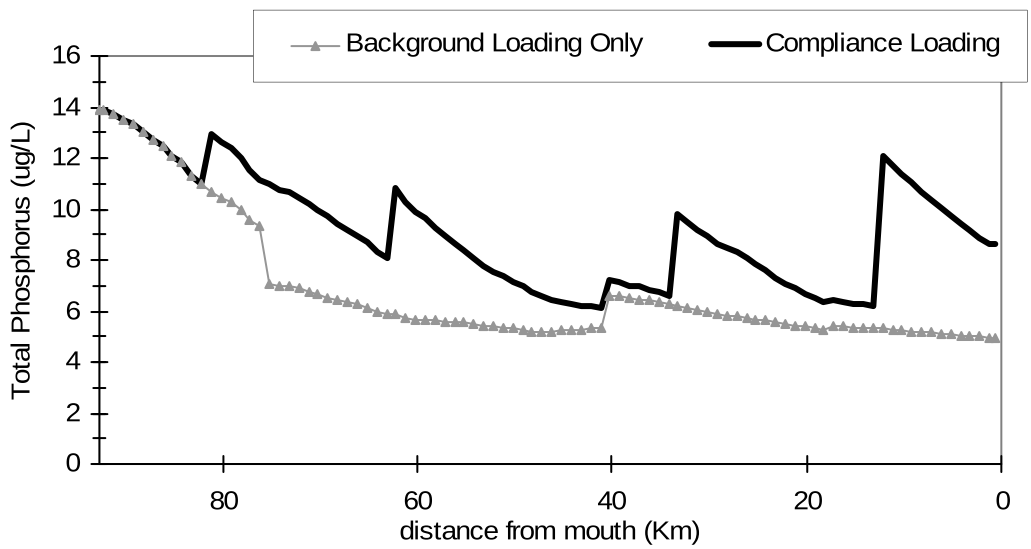
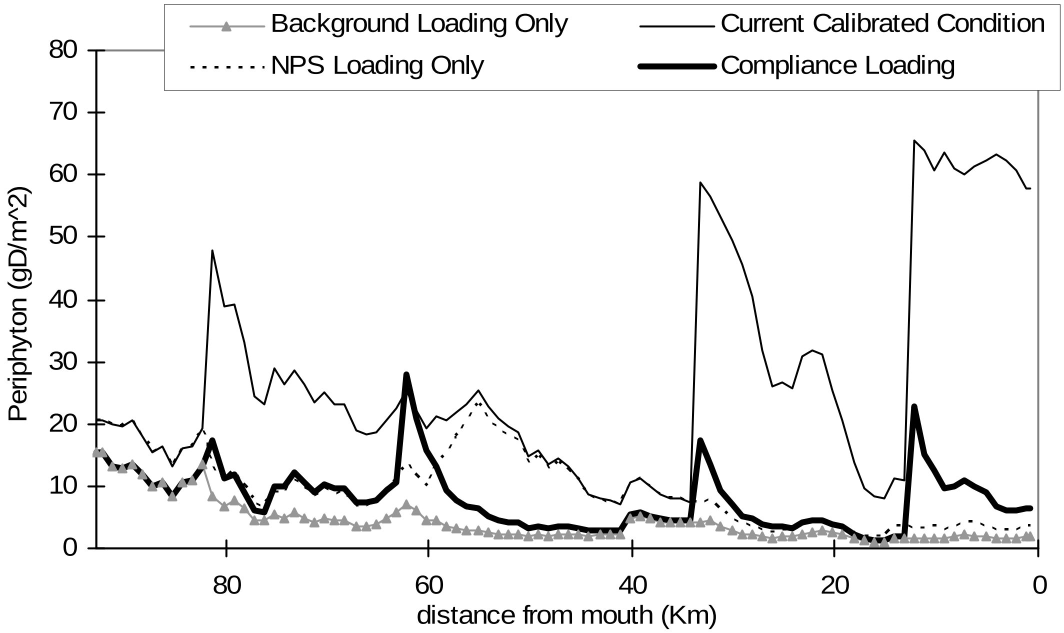


Figure 96. **Predicted periphyton abundance in grams dry weight per square meter based on modeling scenarios under critical flow condition. Change in periphyton between scenarios likely more accurate than actual values.**



MODEL LIMITATIONS AND FURTHER STUDY

The next generation of water quality model for the South Umpqua River should be a hydro-dynamic model which could represent more accurately the shoulder seasons and the dynamic growth and die-off of attached algae throughout the course of the year. No data existed for the South Umpqua River on periphyton limitation by suitable substrate habitat. Anecdotal evidence exists for substrate limitation that is flow dependent: field staff reports that sections of the river begin to grow large of amounts of periphyton only during periods with very low velocities.

SECTION 8: REFERENCES

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