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GREEN RIVER CE-QUAL-W2 PROJECT
A Hydrodynamic and Water Quality Study of the Green River King County, Washington

By

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Acknowledgements

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1.0 INTRODUCTION

This report describes the data processing and model calibration performed for a hydrodynamic and water quality model of the Green River, located in King County, Washington. Figure 1 shows the location of the river, and the limits of the section of river that was modeled.

The Green River flows from its headwaters in the Cascade Mountain foothills through the King County, Washington communities of Auburn, Kent, and Tukwila before discharging into the Duwamish River. Two sections of the river were modeled in this project. The Middle Green River begins in the Cascade Mountain foothills east of Tacoma, and continues downstream to the city of Auburn, WA. The Lower Green River continues from Auburn to the confluence with the Duwamish River, in the town of Tukwila.

Figure 1: Vicinity Map

The Green/Duwamish River system is unique in that it flows through a heavily urbanized and industrialized environment yet supports a large salmon population (Green/Duwamish Ecosystem Restoration Study, 2003). To protect the river and its prime salmon habitat, King County and the US Army Corps of Engineers have joined together on a study to identify and implement strategies for restoring and protecting the Green/Duwamish River System and its tributaries (Green/Duwamish Ecosystem Restoration Study, 2003).

As part of the Green-Duwamish Watershed Water Quality Assessment Program, King County contracted with Portland State University to develop a hydrodynamic and water quality model for the Lower and Middle Green River. This model will be used in Total Maximum Daily Load (TMDL) development, in assessing current water quality conditions in the river, and as a planning tool for evaluating the impacts of future development in the basin.

A hydrodynamic and water quality model, CE-QUAL-W2 Version 3.1 (Wells, 1997), has been applied to the river between Flaming Geyser State Park (River Mile 45.0) and the confluence with the Duwamish River, near Tukwila (RM 11.20). CE-QUAL-W2 is a two dimensional (longitudinal-vertical), laterally averaged, hydrodynamic and water quality model that has been under development by the Corps of Engineers Waterways Experiment Station (Cole and Wells, 2000).

This report is divided into the following sections:

- The Introduction Section describes the watershed and discusses the modeling effort.
- The Data Analysis and Model Preparation Section reviews the available data, provides an analysis of the data to determine model simulation periods, and documents procedures used in assembling model boundary conditions and tributary data.
- The Model Calibration section describes the process for calibrating model predictions of hydrodynamics (flow and water level), temperature, bacteria (fecal coliform), and eutrophication model parameters (such as nutrients, algae, dissolved oxygen, and organic matter). The model calibration periods were from May 25, 1995 to November 30, 1996 and April 1, 2001 to July 31, 2002.
- A Sensitivity Analysis section examines the affects on the model of a new channel connecting two sections of the river, which was opened up during a flood event in the winter of 1996. Survey information for this channel is not available. A sensitivity analysis was performed to determine the effects of this channel on hydrodynamics and water quality. A spillway was used in the model to control flow releases to this channel. Model runs were compared with and without the new channel.
- A sensitivity analysis was performed to evaluate changes in pH in the Middle Green River.

1.1 The Green-Duwamish Watershed

The headwaters of the Green River are located in the Cascade Mountains east of Tacoma, WA. There are two reservoirs on the Upper Green River: Howard Hanson Reservoir, which was constructed by the Army Corps of Engineers in the early 1960's as flood control protection for communities on the lower flood plain, and a diversion dam, located five km below Howard Hanson Reservoir, which diverts water for the city of Tacoma. The watershed above this dam is protected, and entry is prohibited (U.S. Army Corps of Engineers, 2003).

The Middle Green River begins below the diversion dam and continues downstream to the city of Auburn, WA. The upstream boundary of the model is 26 km below the diversion dam.

Major tributaries to the Middle Green River include Newaukum Creek, Crisp Creek, and Big Soos Creek, which is the largest tributary to the Green River. The surrounding landscape is primarily farming, production forestry and state parks, but residential development is growing in the region. The tributary creeks to the Middle Green River continue to support prime salmon habitat (Middle Green River Sub-Watershed, 2003). See Figure 2 for the location of these tributaries.

The Lower Green River continues from Auburn to the confluence with the Duwamish River, in the town of Tukwila. The Lower Green River watershed is heavily urbanized with commercial and industrial development. There is an extensive dike and levee system on the Lower Green protecting the surrounding area from flooding. There are a number of smaller tributaries that contribute flow to the Lower Green, including Auburn, Mill, and Midway Creeks, and Mullen Slough. The Lower Green is tidally influenced up the Duwamish River from Elliot Bay.

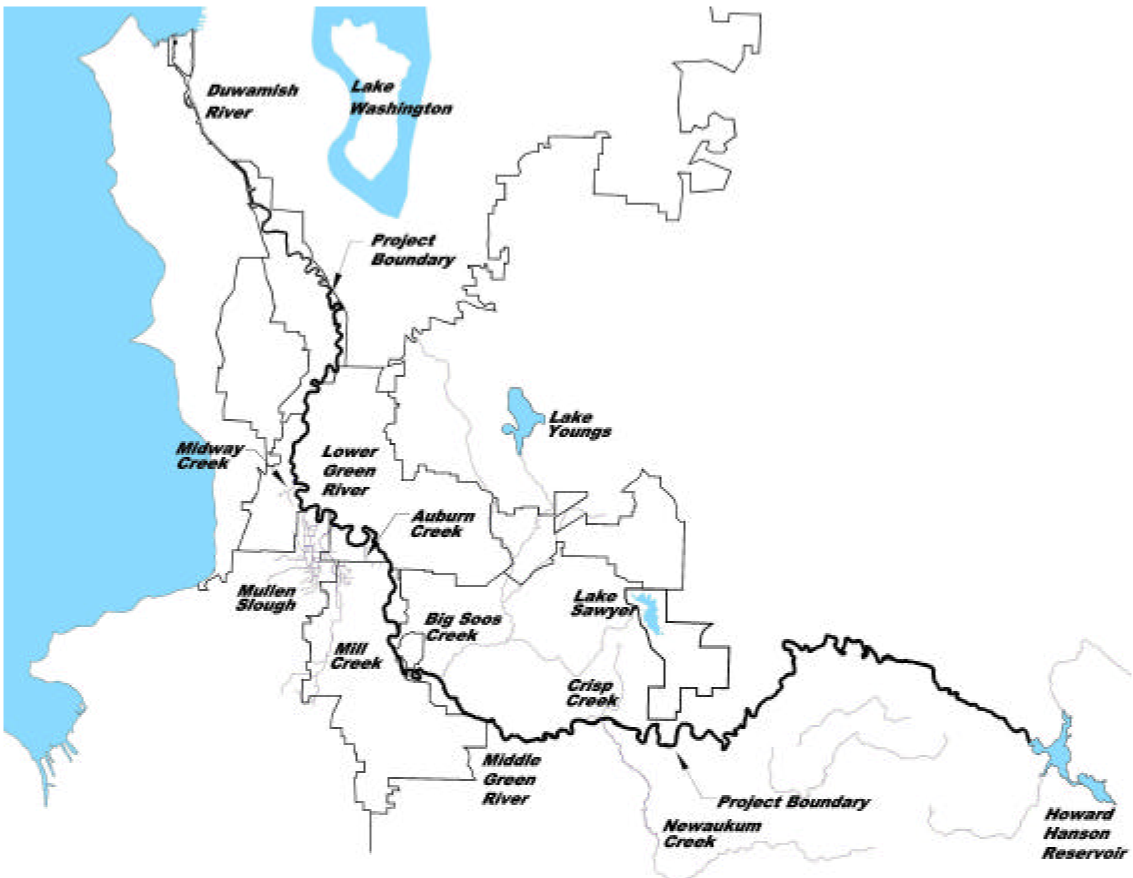


Figure 2: Green River and Major Tributaries

1.2 Prior Green River Models

Both the Middle Green River and the Lower Green River have been modeled with the Army Corps of Engineers program HEC2. HEC2 is a steady-state program that models one-dimensional river hydraulics and is commonly used for establishing flood plain elevations. King County modeled the Middle Green River with HEC2 in the middle 1990's, and in the late 1990's the Army Corps of Engineers converted both Lower and Middle Green River HEC2 data to HEC-RAS, which is the Army Corps of Engineer's Windows-based follow-up program to HEC2.

The Duwamish River and Elliot Bay have been modeled using Environmental Fluids Dynamic Computer Code, a three-dimensional hydrodynamic and transport model. This model was developed as part of a program to evaluate and simulate the impacts of combined sewer overflows on the river and bay (King County Combined Sewer Overflow Water Quality Assessment for Duwamish River and Elliot Bay, 1999).

2.0 DATA ANALYSIS AND MODEL PREPARATION

In order to model the system, the following data are required:

- Bathymetry of the river;
- Flow, temperature, and water quality characteristics for boundary conditions, major tributaries, and point sources;
- Stage data and tidal information;
- Meteorological conditions.

Many local, state and federal agencies have been collecting data on the Green River. This section of the report reviews the available data, provides an analysis of the data to determine model simulation periods, and documents procedures used in assembling model boundary conditions and tributary data.

2.1 Model Geometry

2.1.1 Bathymetry Data

Middle Green

For a HEC2 river modeling study conducted by King County in the mid-1990's, aerial photogrammetry was used to obtain topography of the floodplain and surrounding area, and a standard field survey was conducted to obtain elevations of river cross sections. King County provided AutoCAD® files with the aerial photogrammetry points, and HEC2 and HEC-RAS files from the previous floodplain work. The HEC data were imported into AutoCAD®, and three-dimensional lines were connected between each HEC2 river cross-section and between each bank point. These lines were used to create a 3-D terrain model of the river and surrounding land.

Lower Green

King County provided river bank and channel elevations for each cross-section from a 1980's HEC2 study. The HEC2 cross-sections are shown on Federal Emergency Management Flood Insurance Rate Maps (FIRMs). To place the cross-sections in the correct location on the river, digital FIRMs (tiff files) were obtained from FEMA. These maps were placed over GIS line work of the Lower Green River. The cross-sections on the FIRMs were then digitized into the drawing, and the section elevations from the HEC2 file were imported onto each cross-section. As with the Middle Green, three-dimensional fault lines were connected between each HEC2 river point and between each bank point. These three-dimensional faults were used to generate a contoured three-dimensional surface of the river and banks.

Digital elevation models (DEMs) of USGS quadrangles were obtained and added to the 3-D surface of the river. With these DEMs, a full model of the river valley and surrounding terrain was created.

A grid of the river and floodplain was generated from the terrain model. This grid consisted of x, y, and z points at three-meter intervals. This grid was then used to generate bathymetry files using SURFER®, a 3D mapping program.

King County also provided aerial photographs taken in 2000. These were used to compare cross-sectional data from the HEC models to river channel locations shown on the aerial photos. The river has changed significantly in three locations: at River Mile (RM) 32.40, downstream from the confluence with Big Soos Creek; near River Mile 36.00; and near RM 38.30. Figure 3 shows the locations of the revised channel locations. The effects of the new channel at River Mile 32.40 were examined in the Sensitivity Analysis of the report, but the bathymetry of the new channel was not incorporated into the model. The channel changes at River Mile 36.00 and River Mile 38.30 are small and would not affect river hydrodynamics.

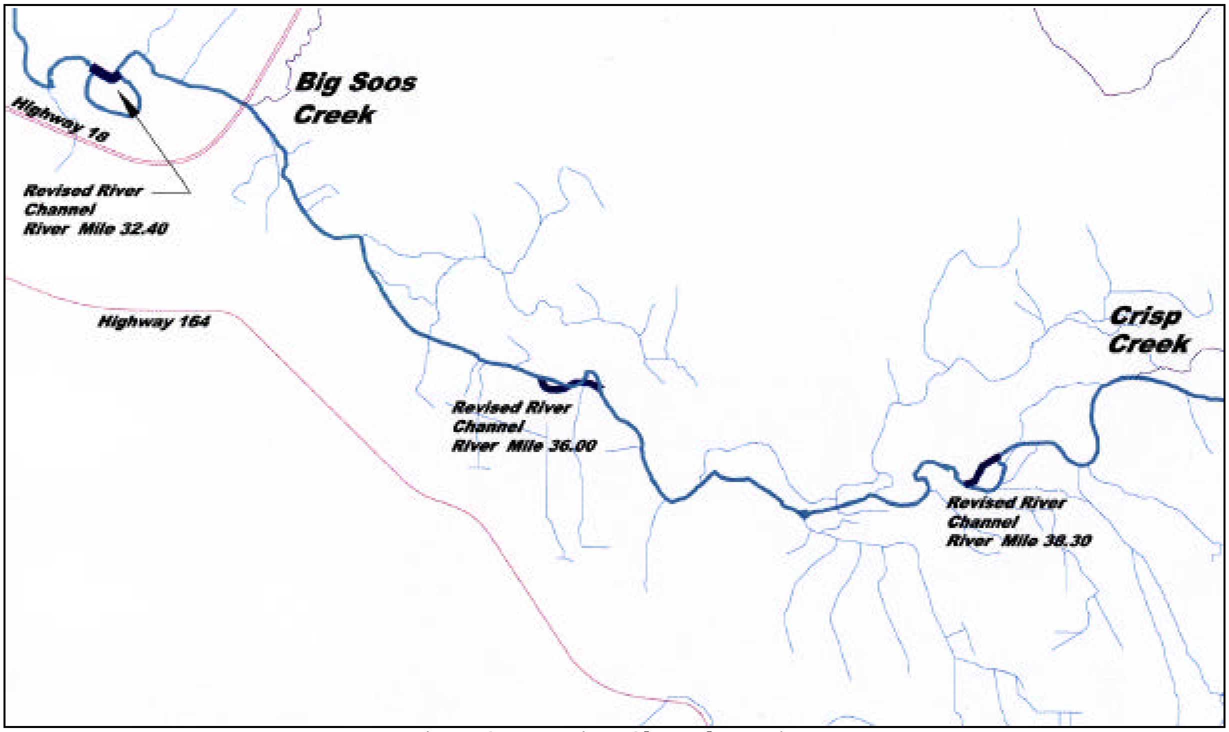


Figure 3: New River Channel Locations

When the consultant for the U.S. Army Corps of Engineers converted the HEC2 files to HEC-RAS, bathymetry discrepancies were noted where data for the Middle Green River and the Lower Green River studies overlap (RAS Notes, 1998). At the upstream end of the Lower Green River study, the river bottom elevation differs by nine feet from Middle Green study data. The Middle Green River HEC2 data were chosen for use in the model through this overlapping area for three reasons:

- The bathymetry data for the Lower Green River was obtained in the early 1980's, and the bathymetry data for the Middle Green River was obtained in the middle 1990's. The more recent data should better reflect current conditions.
- There was more detailed information available on the Middle Green River bathymetry, including information on datum, when the data were obtained, and how the data were obtained. There was no information provided on the bathymetry for the Lower Green River.
- River Mile 33.82 was the upper end of the Lower Green River study data. At this point the Lower Green study lists a river bottom elevation of 61.9, and the Middle Green River study lists an elevation of 69.9, a nine foot elevation difference. River Mile 33.55 was the lower end of the Middle Green River study. At this location the Lower Green River Study and the Middle Green River study both listed a river bottom elevation of 61.9. Therefore, using the Middle Green River data to River Mile 33.55, then switching to Lower Green River data provided a smooth transition between data from the different studies.

2.1.2 Model Grid Development

The river was modeled with 217 longitudinal segments, each approximately 250 meters long. Vertical grid layers were set at a thickness of 1.0 meter. Figure 4 shows the model segments and the branch locations, and Figure 5 shows a vertical profile of the river bottom created from the digital terrain model. As this figure shows, the river has three distinct slopes through the section being modeled. These slope breaks define three separate reaches that will be modeled as separate water bodies. Additionally, each water body contains separate branches, which are shown in Figure 4.

Table 1 provides a breakdown of the branches in each water body. Note that the segment numbers in Table 1 include the "null" segments that divide each branch.

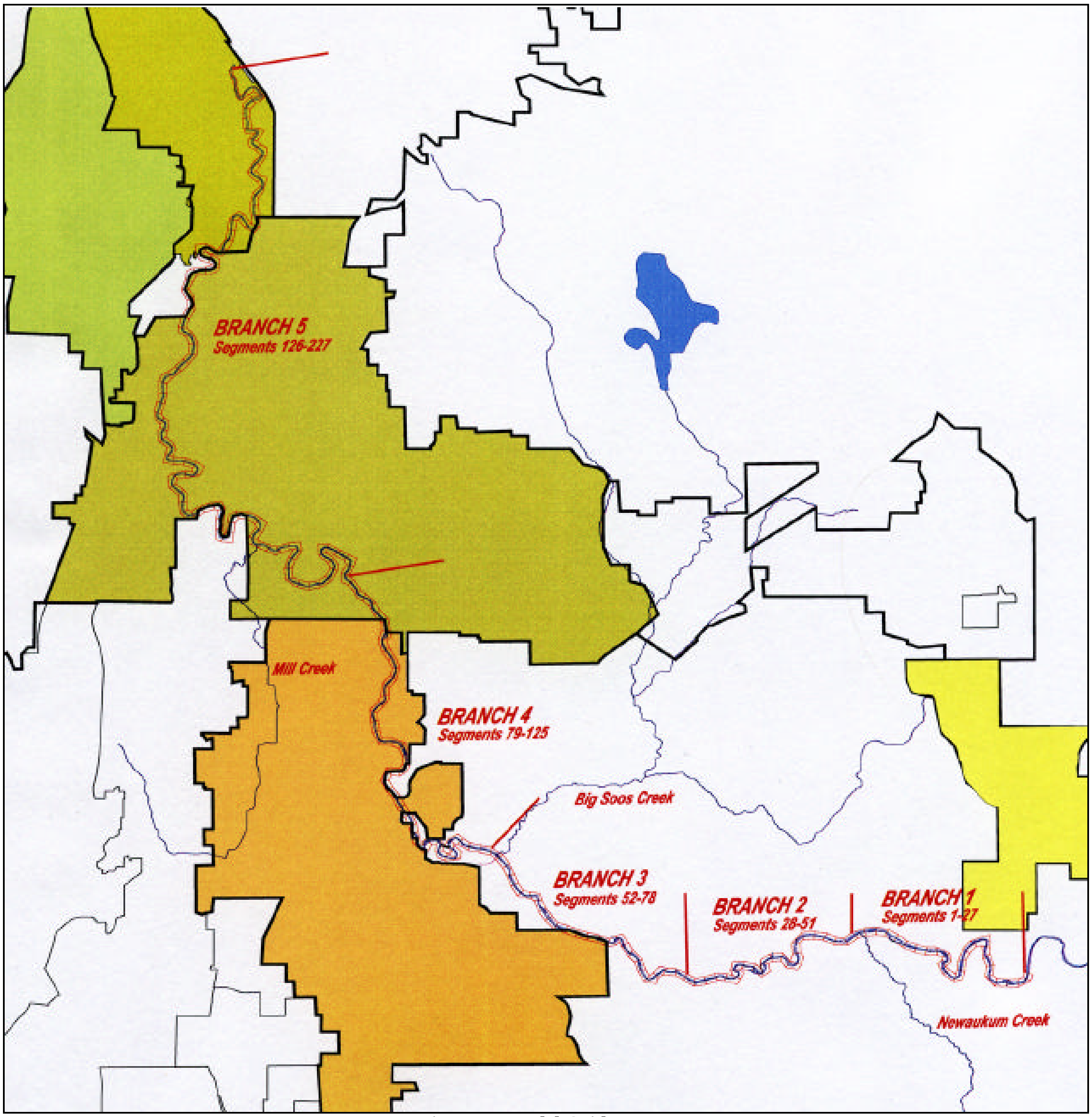


Figure 4: Model Grid Layout

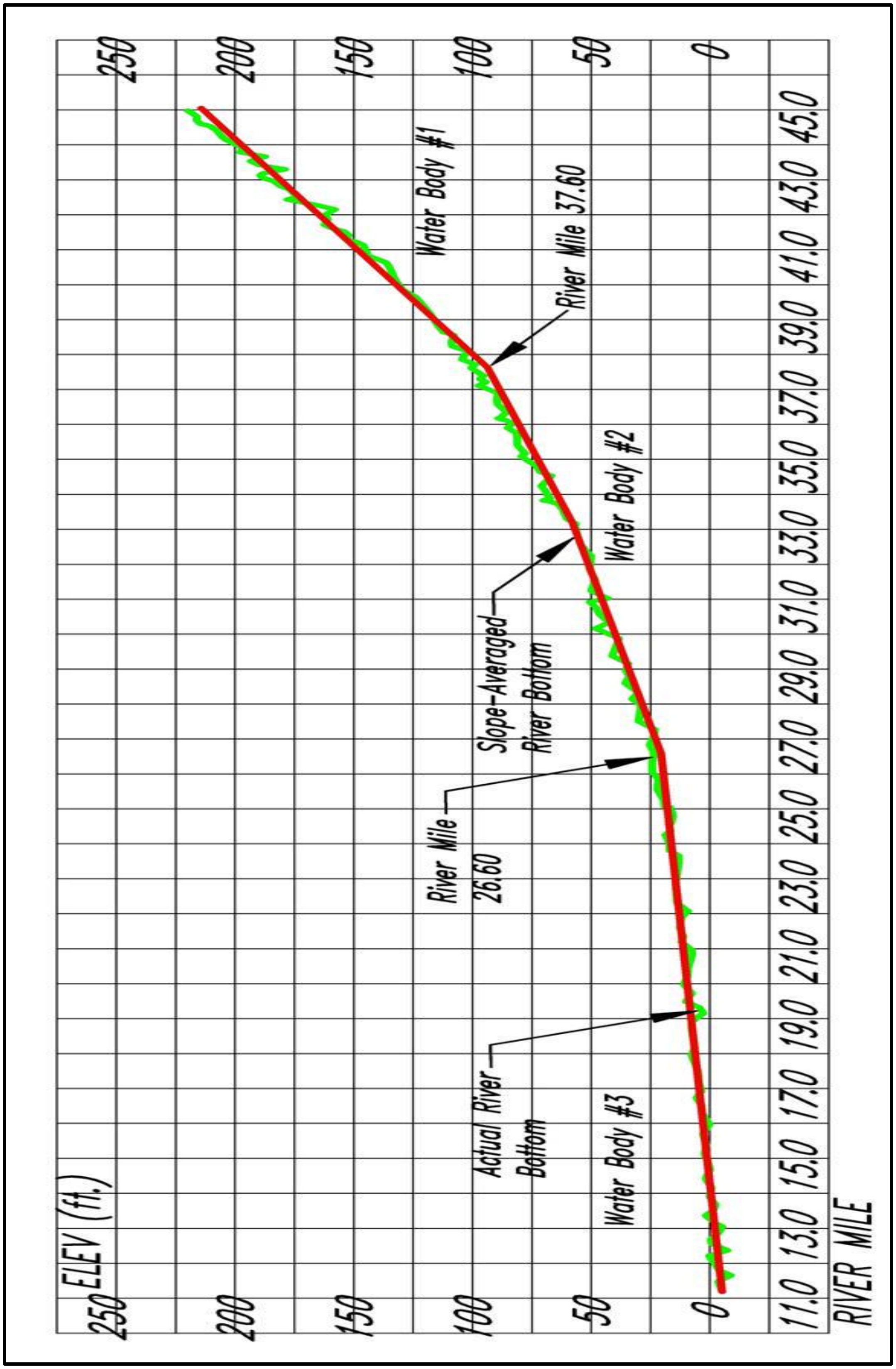


Figure 5: Profile of Actual and Averaged Green River Channel Bottom

Table 1: Water Body Characteristics

Water Body	Description	Branch	Segment Start	Segment End	Number of Segments	Average Slope
1	Flaming Geyser Park to east boundary of Auburn	1	1	27	51	0.31%
		2	28	51		
2	East boundary of Auburn to south boundary of Kent	3	52	78	74	0.13%
		4	79	125		
3	South Boundary of Kent to Tukwila	5	126	227	102	0.03%

2.2 Model Simulation Time Period

There are monitoring sites on the middle and lower reaches of the Green River, and many more on the various tributaries. King County and the United States Geological Survey (USGS) record flow on the river. King County, the Washington Department of Ecology, the University of Washington, and the USGS record temperature on the river, and King County, The Washington Department of Ecology, and the USGS sample water quality constituents. King County reviewed all gages on the river and assembled data from the relevant gages in database files for use in the model. They also compiled pertinent information in a document on bathymetry, meteorology, hydrology, shade, and water quality.

According to the data compilation report, most data were recorded in Pacific Daylight Time, so all other data were converted to this time.

The data compilation report was used to evaluate time periods for running the model. There was water quality data between 1995 and 2001 for the boundaries and most tributaries, and flow data was obtained back to the late 1980's. Temperature data proved to be the limiting factor when determining model calibration periods.

Criteria for choosing model run times included:

- Availability of upstream and downstream boundary condition data
- Availability of data for larger tributaries, including Newaukum Creek, Big Soos Creek, Crisp Creek, and Mill Creek.
- Availability of data for the remaining tributaries.

Table 2 lists the temperature data available for the boundary locations and tributary streams between 1995 and 2001, and Table 3 lists the temperature gages for the same locations, along with the dates of available and missing data.

Based upon information in these two tables and the temperature data constraints, the model run periods were from May 25, 1995 through November 1996, and from April 1, 2001 through July 2002. These time periods correspond to two major temperature studies by King County and have the most temperature data for the boundaries and tributaries. See Appendix E for a map showing the location of all stations and a table which shows the stations used for model data.

Table 2: Temperature Data Summary

Location	1995	1996	1997	1998	1999	2000	2001	2002
U/S Boundary	May - Nov	Jan - Nov	None	None	None	None	Apr - Dec	Jan-Sept
D/S Boundary	June - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan	None	July – Sept.
Newaukum Creek	None	July - Dec	Jan - Dec	Jan - Oct	None	None	July - Dec	Jan - Sept
Crisp Creek	None	None	Oct - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Aug
Big Soos Creek	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Aug
Mill Creek	None	None	None	None	Oct - Dec	Jan - Dec	Jan - Dec	Jan - Aug
Mullen Slough	None	None	None	None	None	None	None	None
Auburn Creek	None	None	None	None	None	None	None	None
Midway Creek	None	None	None	None	None	None	None	None

Table 3: Temperature gages at modeling locations

Location	Time Period of Data	Monitoring Station	Missing Data Periods
Green River Upstream Boundary	May 1995 –Nov. 1999	KC gage at Black Diamond (WHI)	Dec 1999 - April 2001
	July 24, 2001 – Aug. 2, 2002	GDWQA at Whitney Bridge (GRT10 and GRT10_2)	
	Apr 2001– Sept 2002	UW Gage (GR3-4)	
	July 24, 2001 – Oct. 17, 2001	UW Gage (GR5)	
Downstream Boundary	June 1995 – Nov 1996 Jan 1996 – Jan 2000 July 2002 – Sept. 2002	KC Gage (BIC) USGS Gage (12113390) GDWQA gage (GRT18)	January – June 1995 February 2000 – June 2002
Crisp Creek	Oct 1997 – Aug 2002	KC gage at mouth (40d)	1995 to Sept. 1997
Newaukum Creek	July 1996 – Oct 1998 July 2001 – Sept 2002	USGS gage (12108500) GDWQA gage (GRT09)	Nov 1998 to June 2001
Big Soos Creek	Oct 1994 – Aug 2002	KC gage (54A)	Data set is complete
Mill Creek	Oct 1999 – Aug 2002	KC gage (41a)	1995 to Sept 1999
Mullen Slough	July 1996 – Nov 1996	KC gage (FRA)	Nov 1996 to Dec 2002
Midway Creek	None		1995-2002
Auburn Creek	None		1995-2002

2.3 Water Quality Constituents

King County has provided water quality grab samples on the Lower and Middle Green River from 1990 to 2002. Table 4 lists the water quality monitoring sites between the lower and upper boundaries of the project (including tributaries), Table 5 lists constituents of interest that have been sampled, and Table 6 lists the constituents to be modeled.

The Washington Department of Ecology (WDOE) also monitors data at various locations on the Middle and Lower Green River. However, the river locations sampled and the constituents sampled were the same as King County's program, so this information was not used in the model.

Grab sample data were available at the locations in Table 4 on a monthly basis for both model periods. Longitudinal profiles were created using data from the four mainstem monitoring sites. Figure 6 shows a longitudinal profile for dissolved oxygen, and Appendix B contains longitudinal profiles for the remaining constituents listed in Table 5.

Table 4: Water Quality Monitoring Sites

Site ID	Description	RM	Agency
3106	Fort Dent Park	11.70	King County
0311	Interurban Avenue	12.40	King County
G319	Below Mullen Slough	21.30	King County
A319	Auburn-Black Diamond Road	33.80	King County
B319	Above Newaukum Creek	41.40	King County
Mullen1, Mullen2	Mouth of Mullen Slough	N/A	King County
A315	Mouth of Mill Creek	N/A	King County
A320	Big Soos	N/A	King County
0321	Crisp Creek	N/A	King County
0322	Newaukum Creek	N/A	King County

Table 5: Water Quality Constituents sampled by King County

Constituent Name	Constituent Name
Dissolved Oxygen	Temperature
Total Nitrogen	pH
Ammonia Nitrogen	Alkalinity
Nitrite-Nitrate	Conductivity
Total Phosphorus	Fecal Coliform
Ortho Phosphorus	Enterococcus
Turbidity	Escherichia coli.
Total Organic Carbon	Total Suspended Solids
Chlorophyll-A	Dissolved Organic Carbon
	Biochemical Oxygen Demand

Table 6: Water Quality Constituents included in the model

Constituent	Constituent Name	Constituent	Constituent Name
DO	Dissolved Oxygen, mg/L	TEMP	Temperature, Celsius
NH_4	Ammonia Nitrogen	pH	pH
NO_2-NO_3	Nitrite-Nitrate, mg/L	ALK	Alkalinity, CaCO3mg/L
L/R DOM and POM	Dissolved and Particulate Organic Matter, mg/L	COND	Conductivity, umhos/cm
PO_4	Ortho Phosphorus, mg/L	TIC	Total Inorganic Carbon, mg/L
ISS	Inorganic Suspended Solids, mg/L	ALG1	Algae, mg/L
		COLFRM	Fecal Coliform, ORG/100 ml

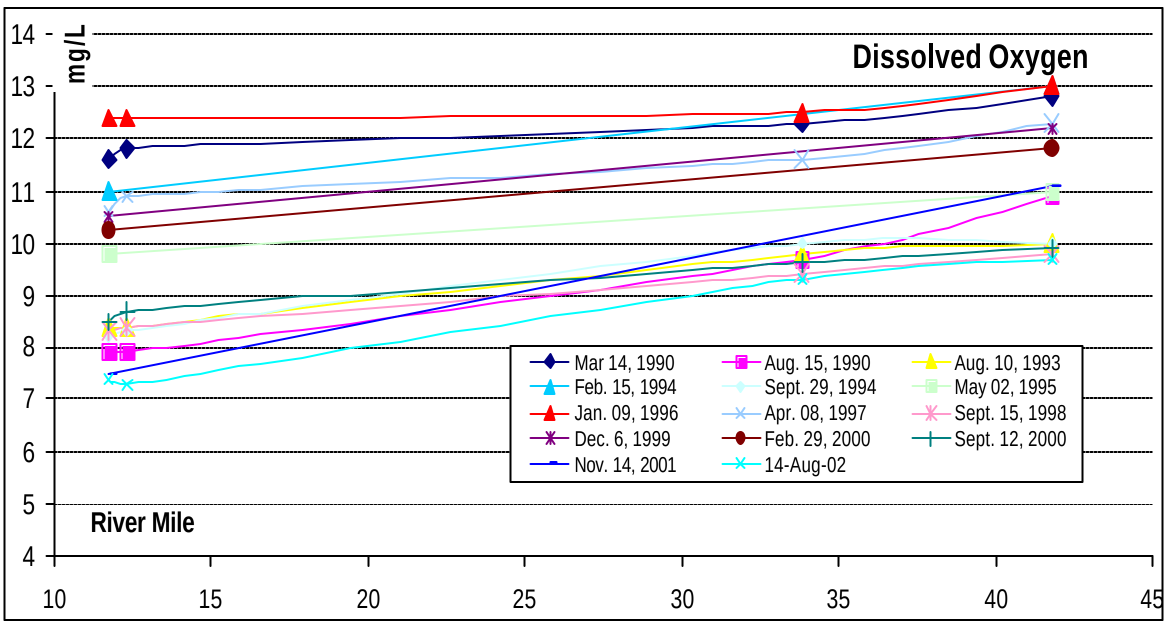


Figure 6: Dissolved Oxygen Longitudinal Profile

2.4 Model Boundary Conditions

The upstream boundary is at River Mile (RM) 45.0, in Flaming Geyser State Park, and the downstream boundary is at RM 11.20, downstream from Fort Dent State Park. The upstream boundary condition is characterized by flow, temperature, and water quality, and the downstream boundary is characterized by water surface elevation, temperature, and water quality.

2.4.1 Upstream Boundary

May 25, 1995 – November 1996

Flow

The closest flow gage to the upstream boundary is a USGS gage (12106700) near Palmer, Washington, approximately 26 km upstream from Flaming Geyser State Park. Flow data were obtained for this gage in 15-minute intervals from October 1994 to December 2002. Because this gage is so far upstream, a time-travel analysis was performed to see how long it takes flow from the Palmer gage to reach the Upstream Boundary. Flow data from the Palmer gage was shifted by six hours to account for travel time. Please see Appendix C for this analysis.

Groundwater and surface water contribute flow to the river between the Palmer gage and the upstream project boundary. There are numerous springs in the Green River Gorge (Luzier, 1969) and near Icy Creek (DeGasperi, 2003). Additionally, there are many small tributaries that flow into the river. To estimate surface water inflows for the area between the gage at Palmer and the upstream boundary, King County hydrologists used the modeling program HSPF (Hydrologic Simulation Program-Fortran) to estimate surface runoff. Daily average flow rates of surface runoff were provided from HSPF models for three basins tributary to the Green River. Figure 7 is a map of the three basins (MG1, MG2, and MG3), with the location of the Palmer gage also shown.

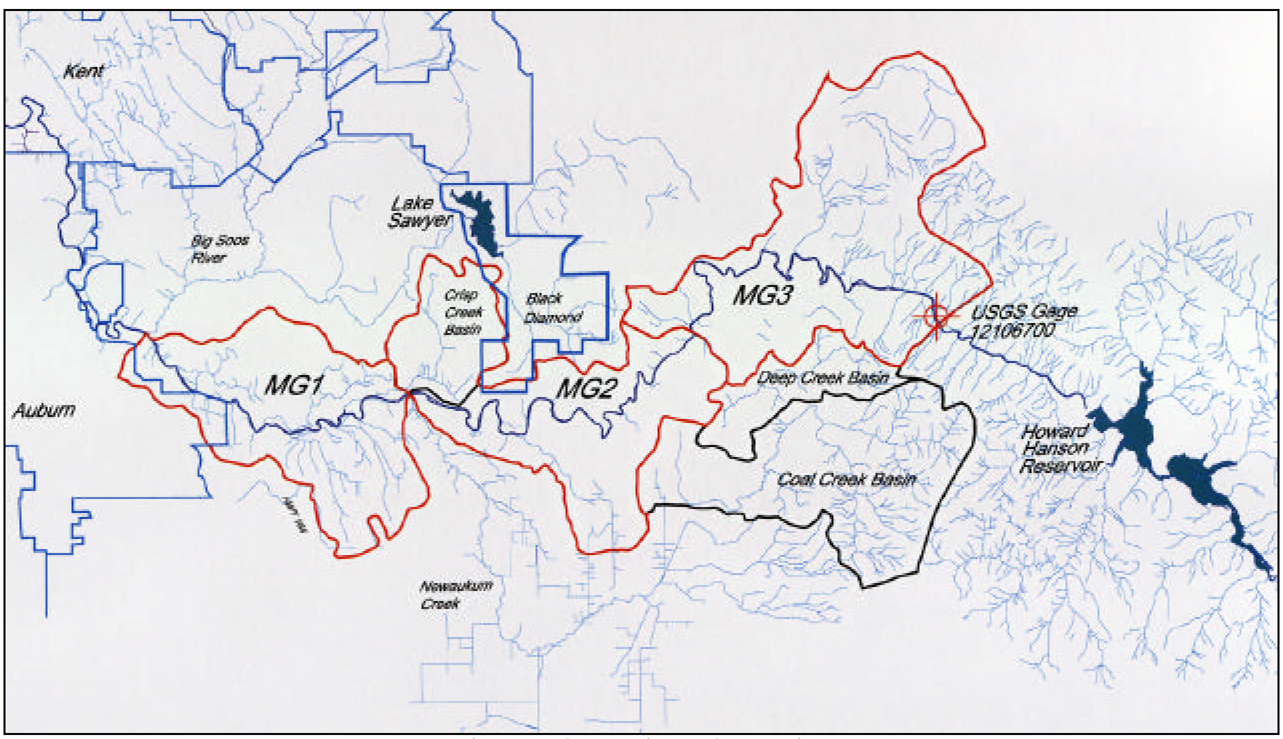


Figure 7: Green River HSPF Basins

All of Basin MG3 is upstream of the upstream project boundary. HSPF flow data for this basin were added to flow from the Palmer Gage. Basin MG2 includes the area tributary to Crisp Creek. This creek has gaged flow data available for input to the model, so it was modeled as a separate tributary. The size of the Crisp Creek Basin is approximately 28% of Basin MG2, so 72% of the HSPF flow for Basin MG2 was added to the Palmer Gage. Daily average values were provided for the HSPF data, and data in 15-minute intervals were obtained for the Palmer Gage, so the daily averaged data were linearly interpolated to 15-minute intervals to match the Palmer Gage.

Basin MG1 is below the upstream boundary and was added to the model as a distributed tributary. This is discussed in Section 2.7

The travel time analysis was also used to see how long it takes flow from the downstream end of Basin MG3 to reach the upstream boundary. The HSPF data for this basin was shifted by four hours before it was added to the upstream boundary flow from the Palmer Gage. Please see Appendix C for more information on establishing these times.

Deep Creek and Coal Creek Basins (See Figure 7) are closed drainages that do not discharge to any water body. King County hydrologists believe groundwater from these two streams makes its way to the Green River (DeGasperi, 2003; Green-Duwamish Watershed Water Quality Assessment, 2002). King County provided HSPF model approximations of surface runoff from these two basins. Although there is no information available indicating that all this flow makes to the Green River, all of the flow was added to flow from the Palmer Gage. Because daily average HSPF data were provided, linear interpolation was used to fill in the data for the 15-minute intervals for the Palmer gage. These flows will be re-examined once the hydrodynamic calibration is undertaken.

Groundwater is a major contributor to the Green River between the USGS gage at Palmer and the upstream boundary of the model. Luzier (1969) estimated that as much as 1.26 cubic meters per second (cms) summer flow and 6.30 cms winter flow contributes to the Middle Green River from springs in the Green River Gorge. These values were added to the flow data from the Palmer Gage, using 1.26 cms from April 1 to September 30, and 6.30 cms from October 1 to March 31. These flows will also be re-examined during model calibration. Figure 8 shows flow data for the model simulation period. Flow data from 1995 – 2002 is shown in Appendix A.

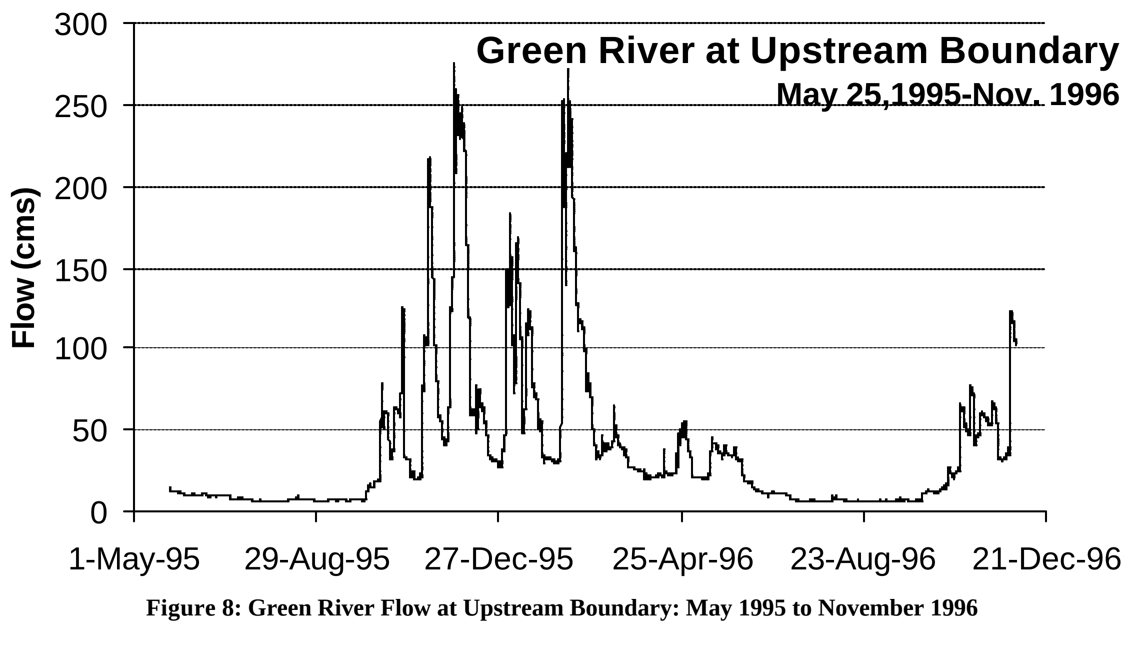


Figure 8: Green River Flow at Upstream Boundary: May 1995 to November 1996

Temperature

Monitoring station WHI is located about four km downstream of the first model segment. Temperature was recorded at this station in 1995 and 1996. This station has two data gaps for the model calibration period: from May 1, 1996 to June 7, 1996, and from July 26, 1996 to August 13, 1996. To fill these data gaps, data from monitoring station 54a, located at the mouth of Big Soos Creek, was correlated with station WHI from July 1995 through October 1995. The temperature relationship between the two stations is as follows:

$$\text{WHI Temp} = (\text{Sta 54a})(1.3412) - 3.1517$$

Figure 9 shows the data for the two stations with the line from the correlation equation, Figure 10 shows the correlated data and monitored data, and Figure 11 shows the temperatures for the model calibration period. Appendix A contains a graph of temperature for all gages used at the upstream boundary from 1995 through September 2002.

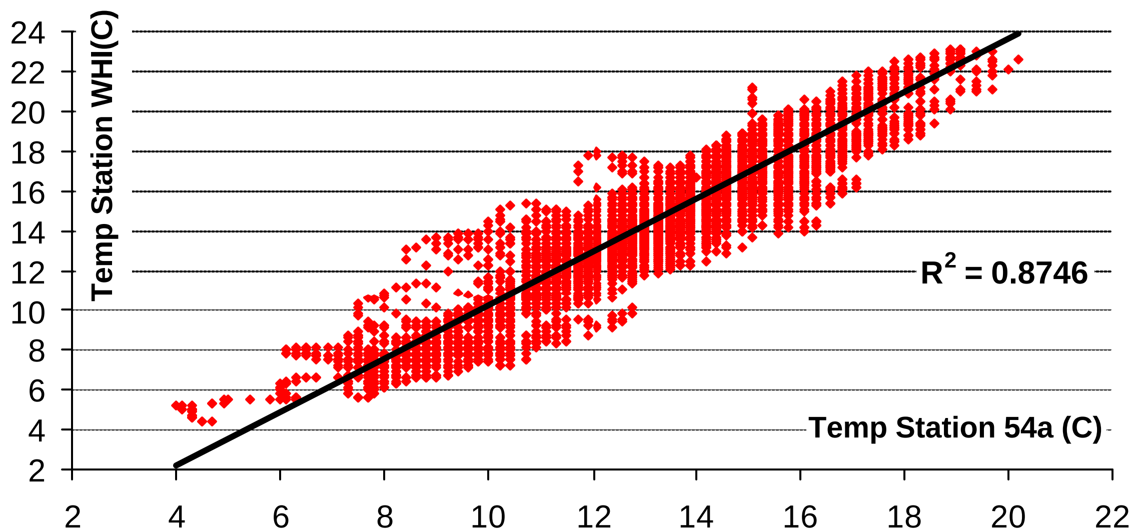


Figure 9: Correlation between Stations WHI and 54a

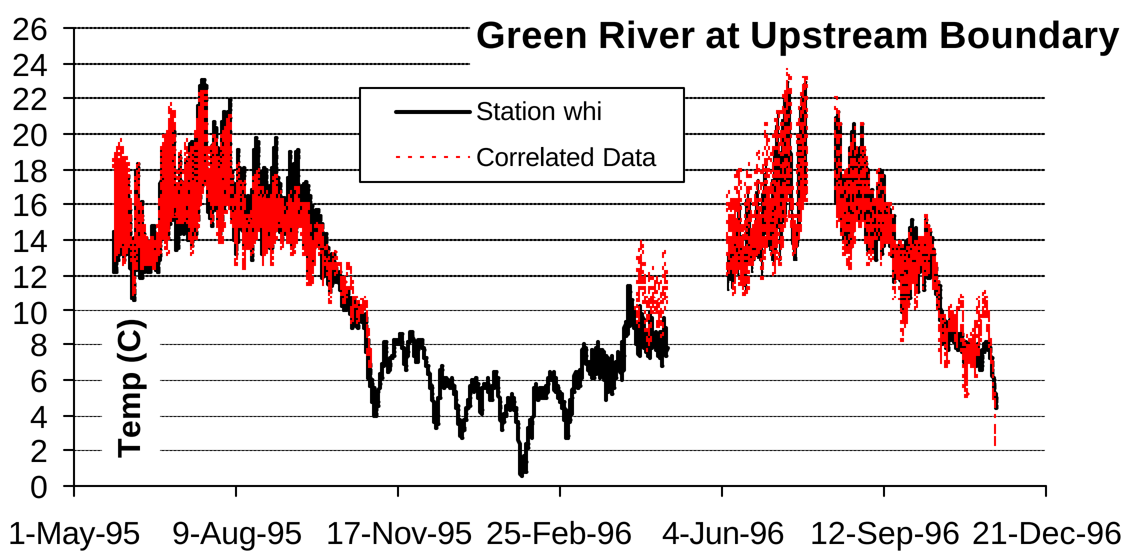


Figure 10: Upstream Boundary: Station versus Correlated Data, 1995-1996

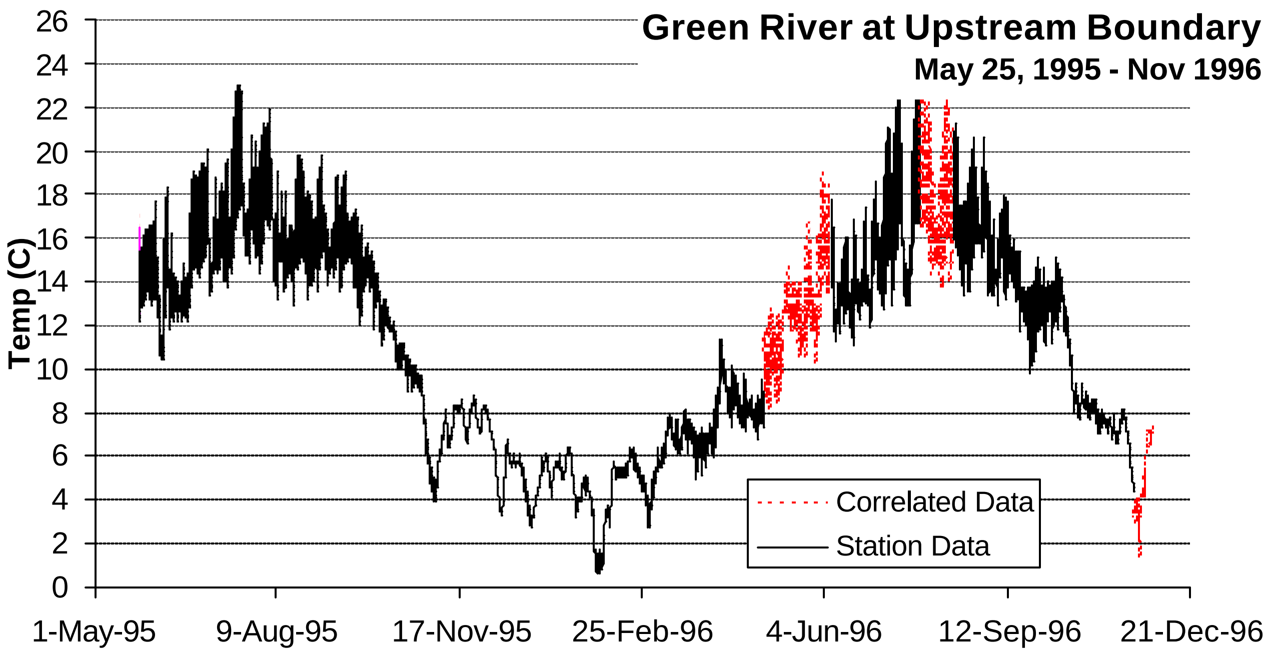


Figure 11: Green River Temperature at Upstream Boundary: May 1995 to November 1996

Water Quality

Water quality data from Sampling Site B319 (located four km below the upstream boundary) was used as the upstream boundary condition. Data were available for all constituents except alkalinity and chlorophyll a. Figure 12 through Figure 26 plot the water quality constituents for the upstream boundary condition for the 1995 - 1996 model calibration period. The procedure used for developing the water quality files, including filling data gaps, is included in Appendix D. Appendix A contains graphs of water quality data from 1995 – 2002 for all of King County's sampling locations.

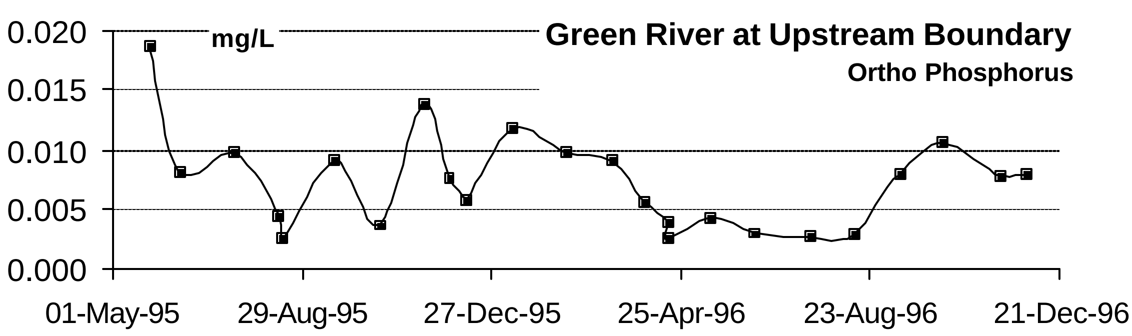


Figure 12: Ortho phosphorus at Upstream Boundary: May 1995 to November 1996

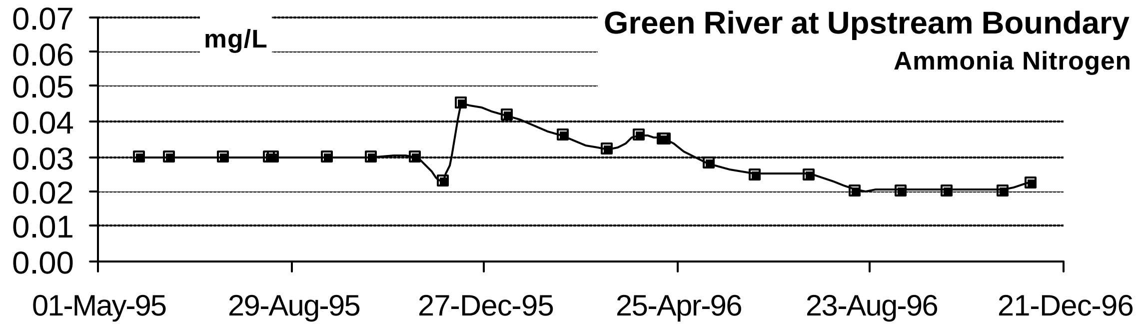


Figure 13: Ammonia at Upstream Boundary: May 1995 to November 1996

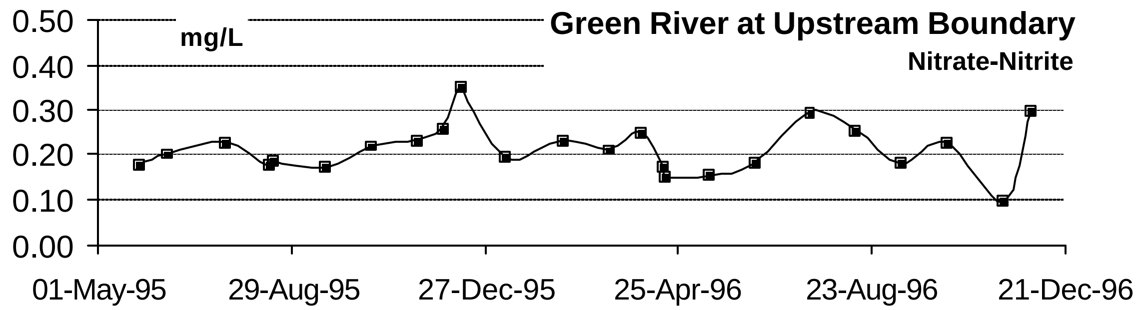


Figure 14: Nitrate-Nitrate at Upstream Boundary: May 1995 to November 1996

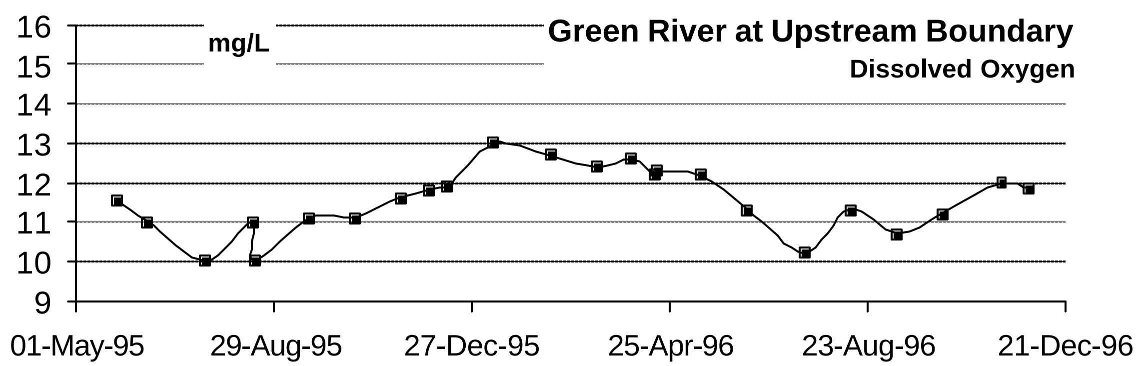


Figure 15: DO at Upstream Boundary: May 1995 to November 1996

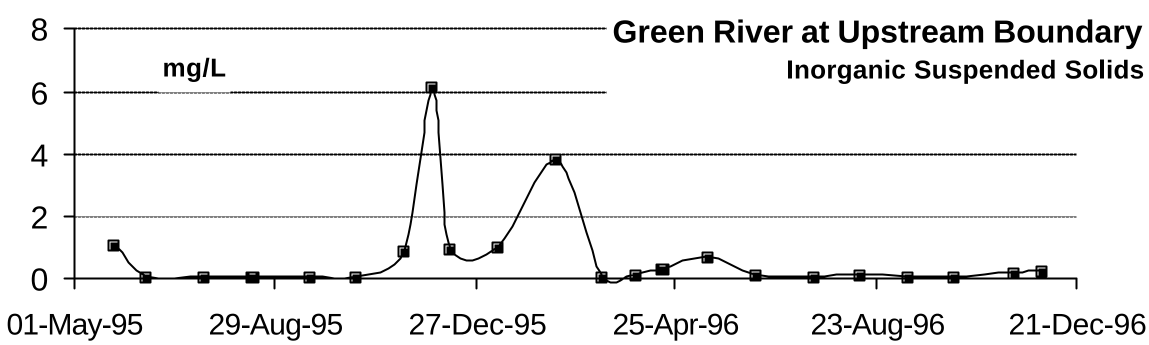


Figure 16: ISS at Upstream Boundary: May 1995 to November 1996

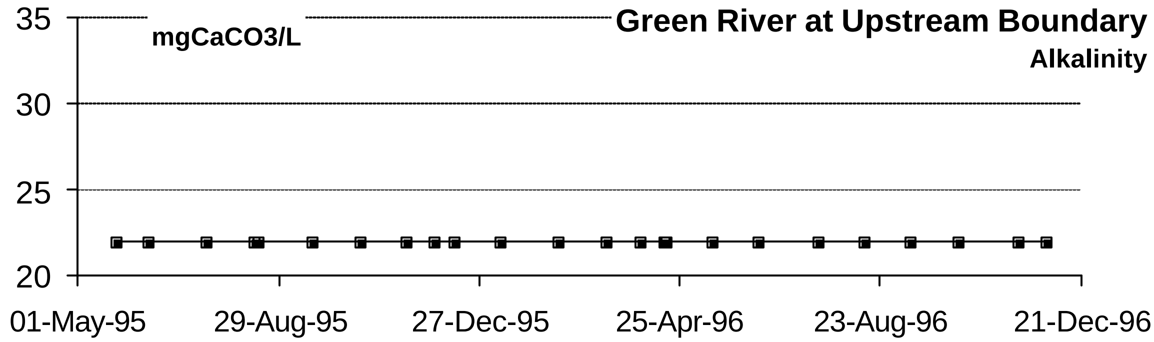


Figure 17: Alkalinity at Upstream Boundary: May 1995 to November 1996

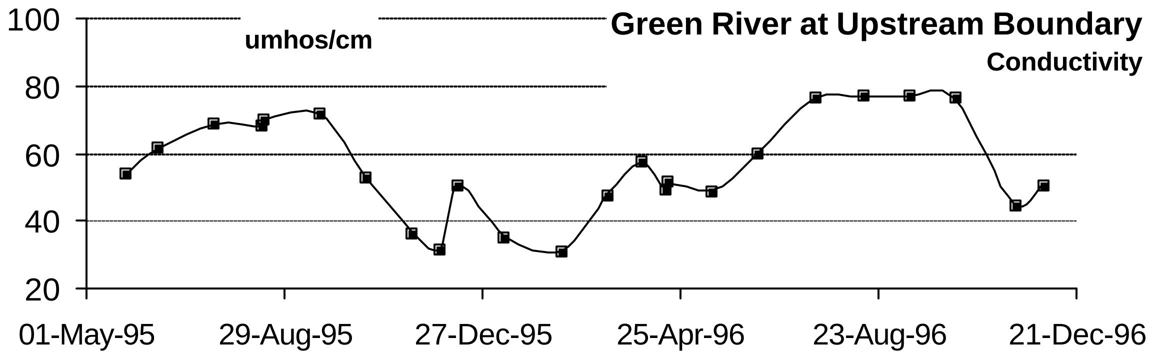


Figure 18: Conductivity at Upstream Boundary: May 1995 to November 1996

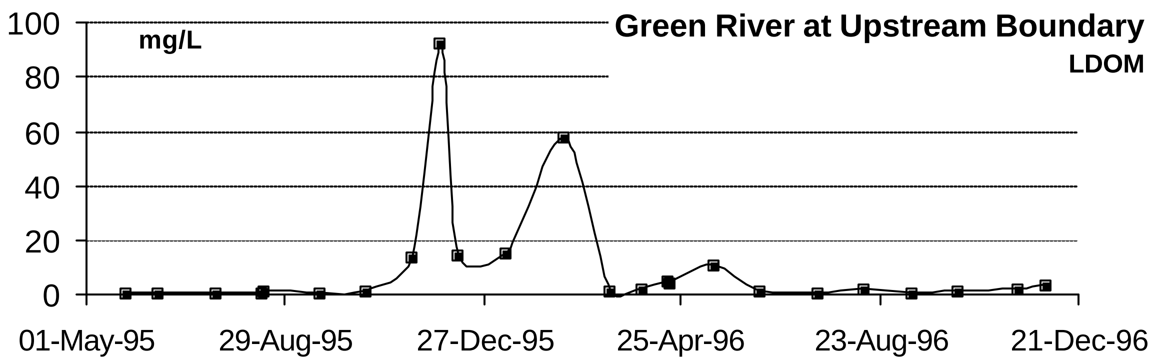


Figure 19: LDOM at Upstream Boundary: May 1995 to November 1996

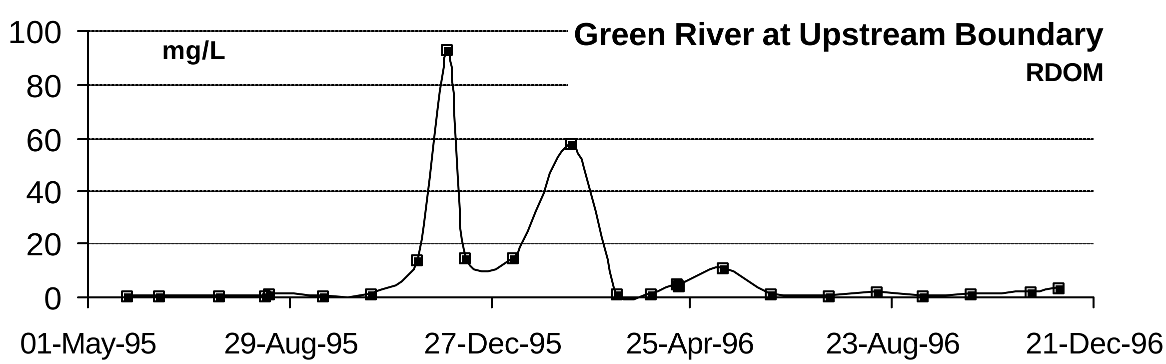


Figure 20: RDOM at Upstream Boundary: May 1995 to November 1996

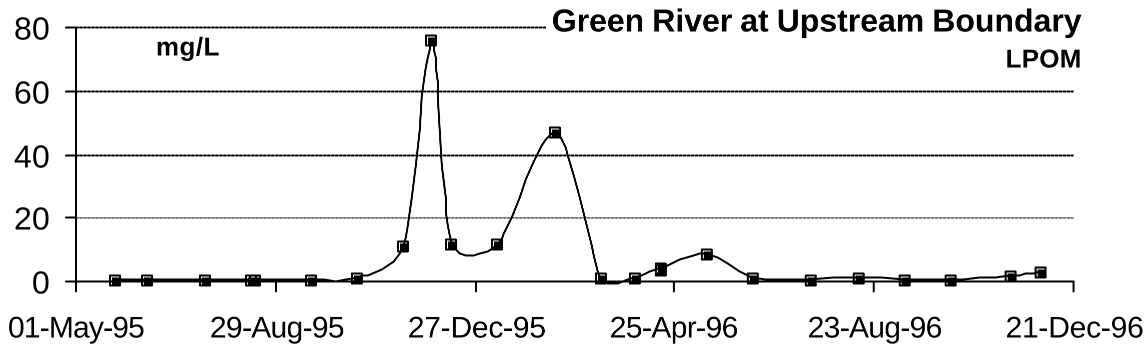


Figure 21: LPOM at Upstream Boundary: May 1995 to November 1996

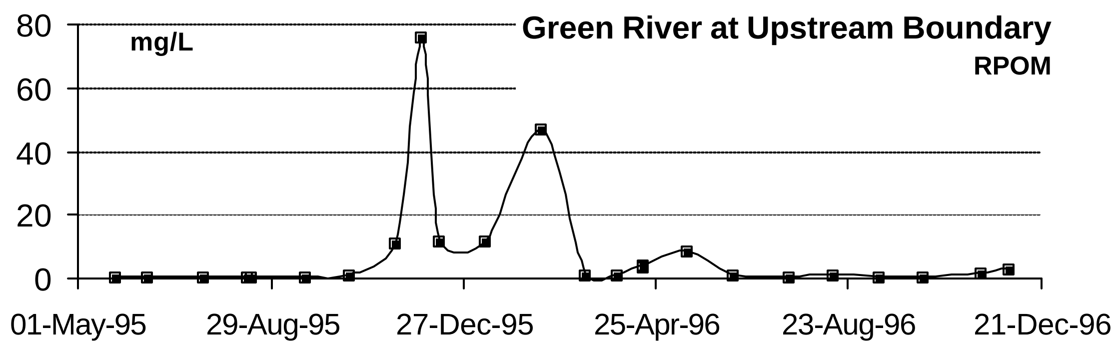


Figure 22: RPOM at Upstream Boundary: May 1995 to November 1996

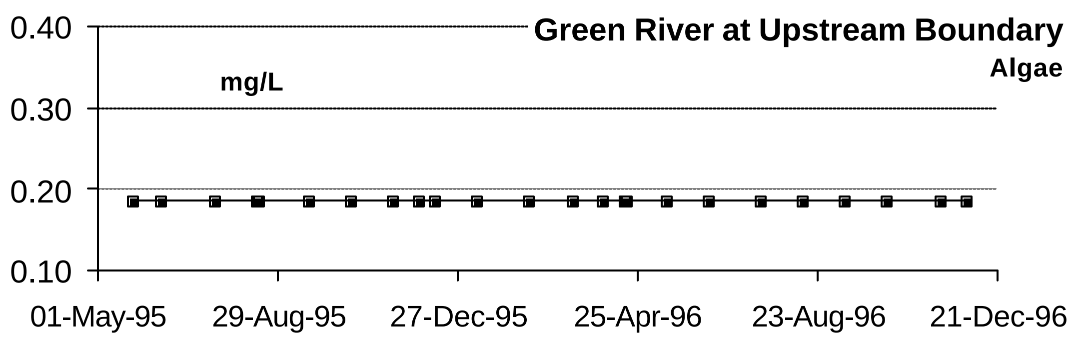


Figure 23: Algae at Upstream Boundary: May 1995 to November 1996

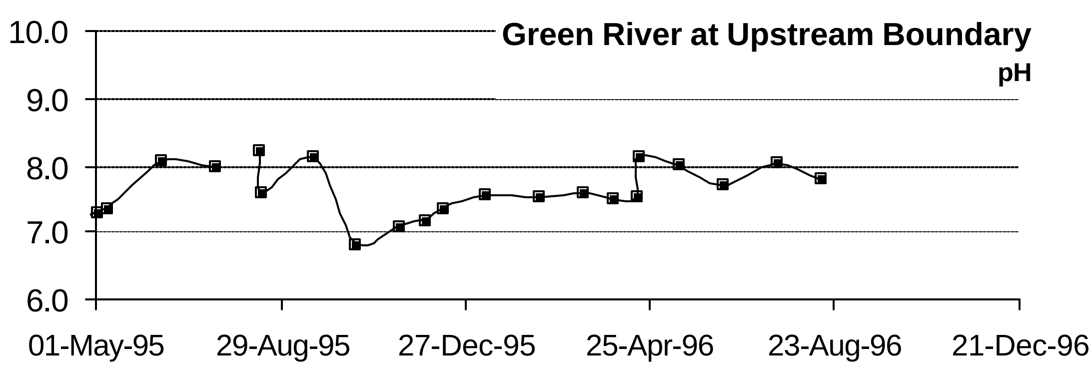


Figure 24: pH at Upstream Boundary: May 1995 to November 1996

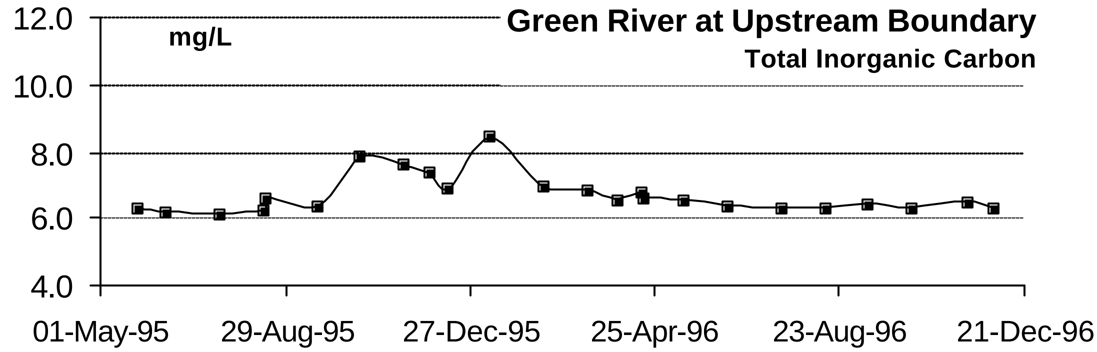


Figure 25: TIC at Upstream Boundary: May 1995 to November 1996

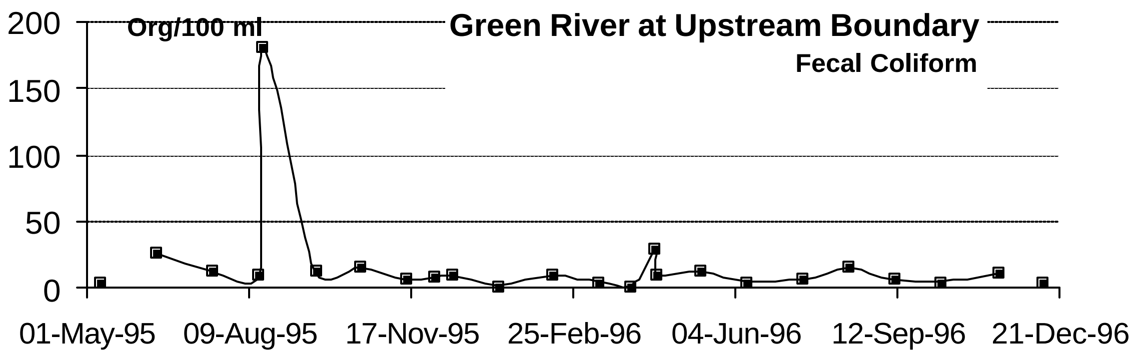


Figure 26: Fecal Coliform at Upstream Boundary: May 1995 - Nov 1996

April 2001 –July 2002

Flow

The Palmer flow gage (USGS 12106700) was used for the upstream boundary condition for the 2001 to 2002 model calibration period. As with the May 1995 – November 1996 calibration period, daily HSPF model output were added to the Palmer gage with the same lag for travel time. Figure 27 shows the estimated flows for the model calibration period.

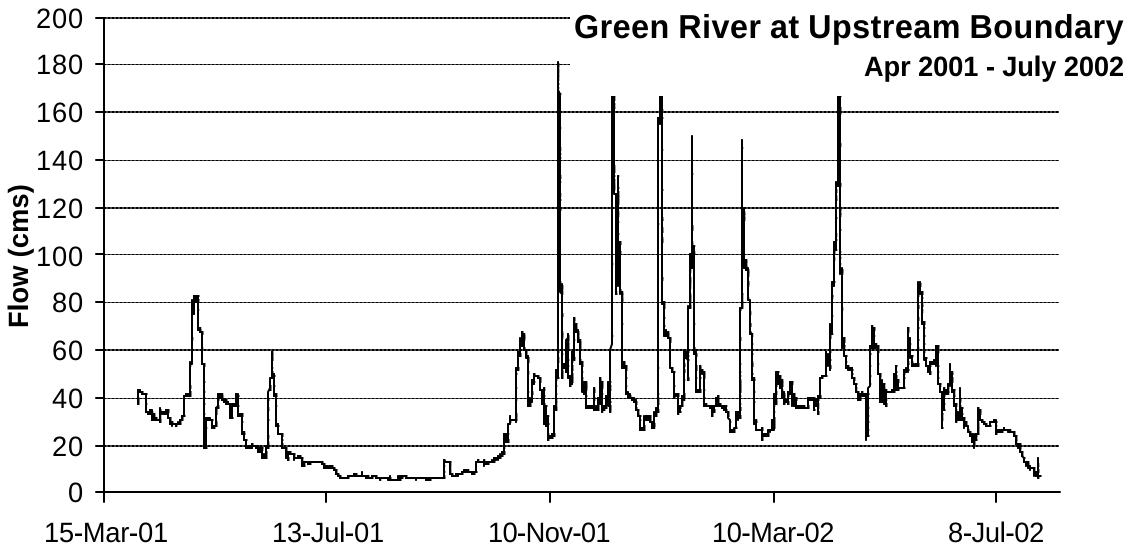


Figure 27: Green River Flow at Upstream Boundary: Apr 2001 – July 2002

Temperature

The University of Washington monitored temperature at Station GR5, which is located at the upstream boundary, and at Station GR3-4, approximately four km downstream of GR5. Temperature data were available at these stations for the following periods:

- At GR5 from July 24, 2001 to October 17, 2001,
- At GR3-4 from March 30, 2001 to June 20, 2001, from July 24, 2001 to October 17, 2001, and from July 29, 2002 to September 12, 2002.

Data were correlated with each other to see how significant the temperature differences are at these stations. As Figure 28 shows the temperature between the two stations is almost identical, so temperature from both stations was used at the upstream boundary. All available data from GR5 was used (July 24, 2001 to October 17, 2001), and data from GR3-4 was used from April 1, 2001 to June 20, 2001.

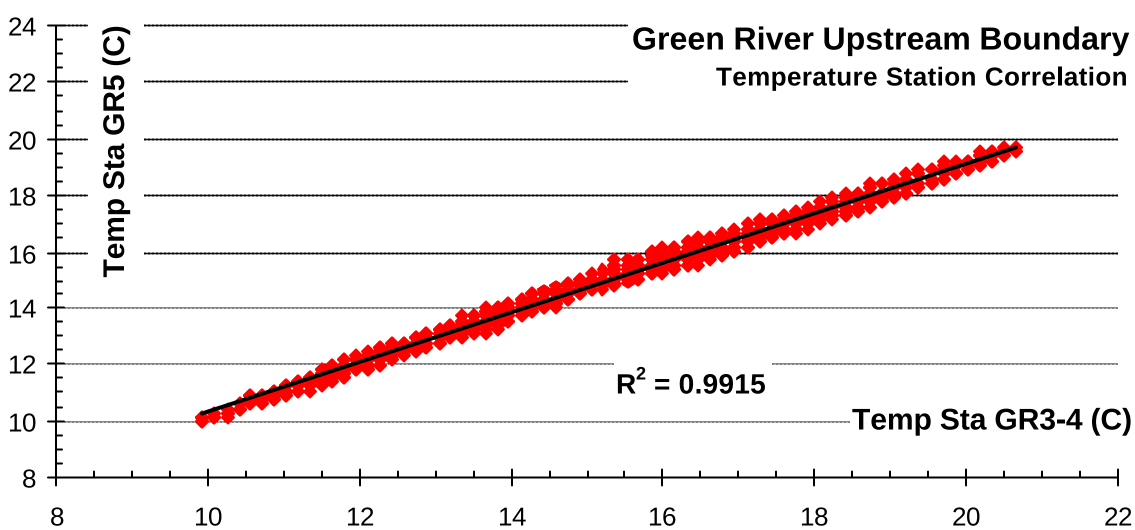


Figure 28: Correlation between Stations GR5 and GR3-4

According to King County, the University of Washington stations record in Coordinated Universal Time (UTC), so these data were converted to Pacific Daylight Time.

At the same location as Station GR3-4, the King County Green-Duwamish Water Quality Assessment program recorded continuous temperature data at Site GRT10 from July 24, 2001 to September 6, 2001, from November 16, 2001 to February 22, 2002, and from March 14, 2002 to August 2, 2002. These data were used at the upstream boundary, and were correlated to data from Station GR3-4. The relationship between GR3-4 and GRT10 is defined as follows:

$$GR3\text{-}4 = (GRT10)(0.8395) + 2.0076$$

Correlated values from GRT10 will then be used between November 16, 2001 and February 22, 2002, and between March 14, 2002 and July 31, 2002. Figure 29 shows the correlation between the two stations and Figure 30 shows temperature data and correlated values.

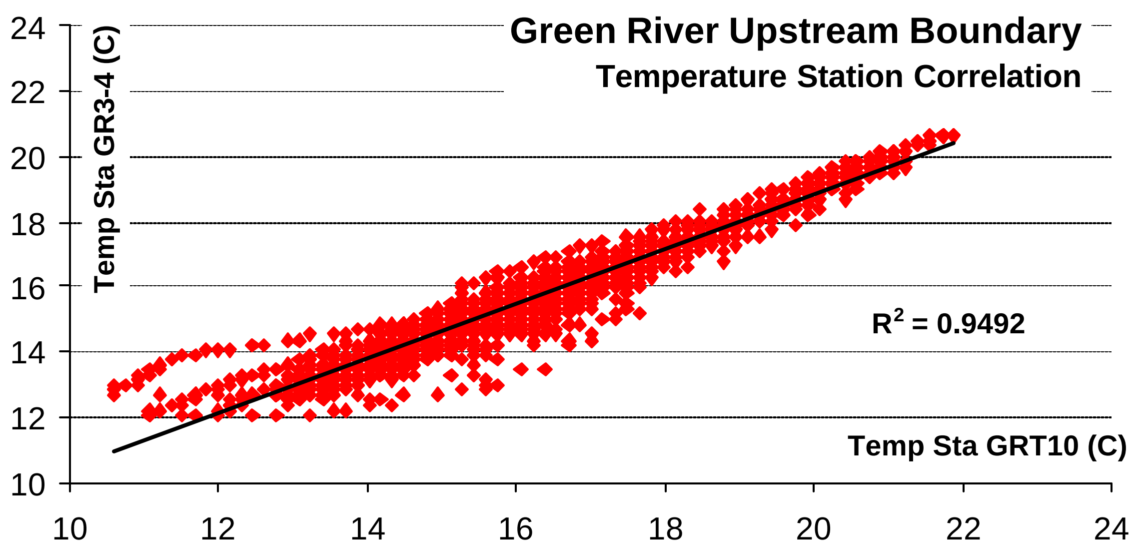


Figure 29: Upstream Boundary: Correlation between Stations GRT10 and GR3-4

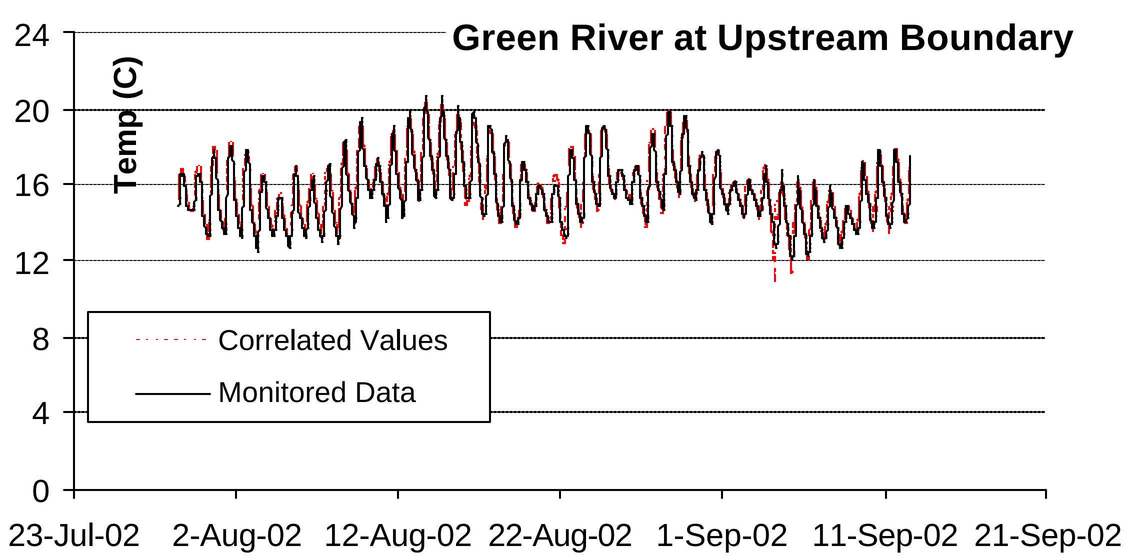


Figure 30: Station GR3-4 Data versus Correlated GRT10 Data, 2001-2002

Figure 31 shows the temperature data at the upstream boundary from the three temperature stations.

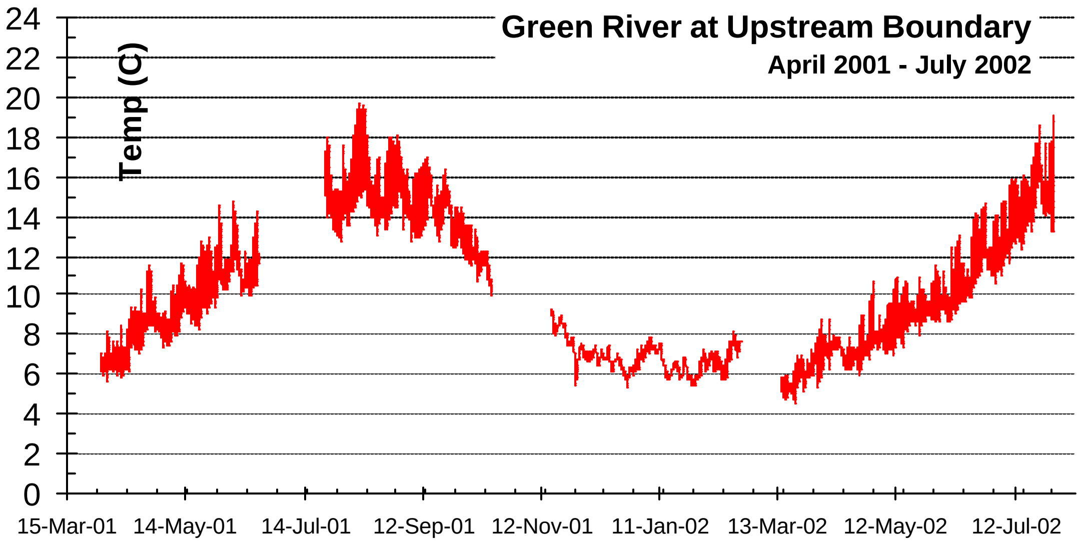


Figure 31: Stations GR5 and GR3-4, 2001-2002

As Figure 31 shows, there are still three data gaps to be filled:

- June 20, 2001 to July 24, 2001
- October 17, 2001 to November 16, 2001
- February 23, 2002 to March 14, 2002

To fill these remaining data gaps, data from two temperature stations located further downstream were used. The University of Washington monitored data at Station GR1, approximately 18 km below the upstream boundary. Data from this station were correlated with temperature data from GR5 to fill both the June 20, 2001 to July 24, 2001 data gap and the February 23, 2002 to March 14, 2002 data gap. Figure 32 shows the correlation between the two stations. The correlation equation is:

$$\text{GR5 correlated values} = (\text{GR1})(0.8099) + 2.18$$

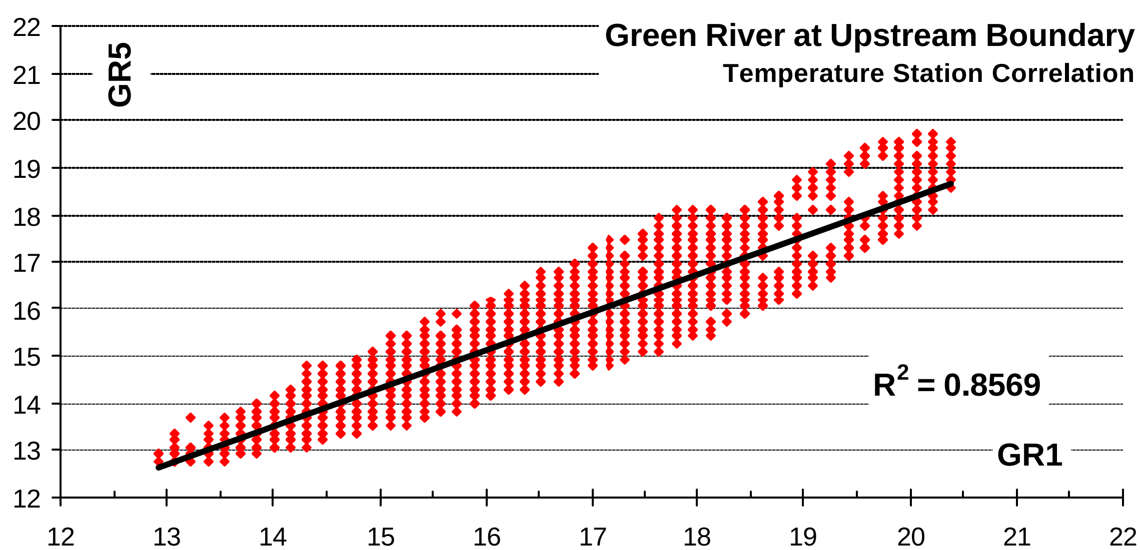


Figure 32: Correlation between GR1 Temperature and GR5, 2001-2002

The King County Green-Duwamish Water Quality Assessment Program monitored temperature at Site GRT04, approximately 17 km below the upstream boundary. Data from this station was correlated with GR5 to fill the last data gap, from October 17, 2001 to November 16, 2001. Figure 33 shows the correlation between the two stations. The correlation equation is:

GR5 correlated values = (GRT04)(0.779) + 2.76

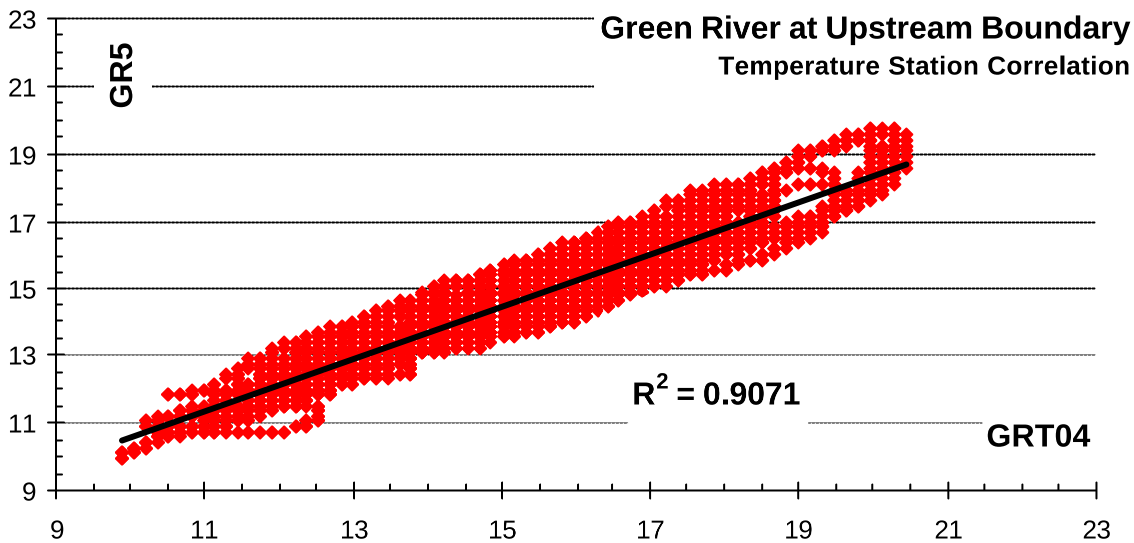


Figure 33: Correlation between GRT04 Temperature and GR5, 2001-2002

Figure 34 shows the assembled temperature data for the upstream boundary for the entire model run period.

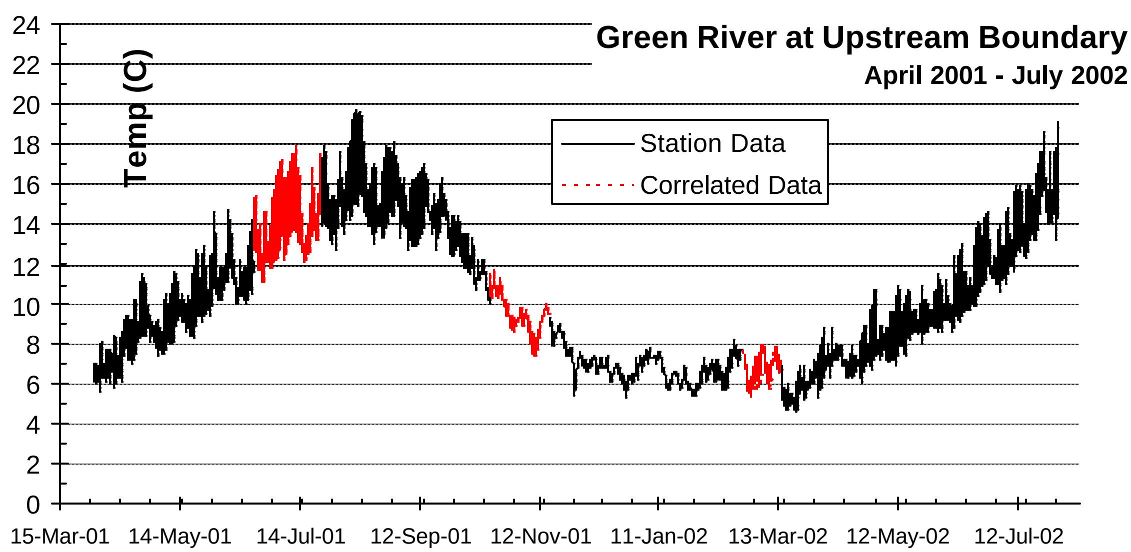


Figure 34: Green River Temperature at Upstream Boundary: Apr 2001 – July 2002

Water Quality

King County sampled water quality constituents downstream from Flaming Geyser State Park near the temperature stations GR3-4 and GRT10 (Site B319). Data were available for all constituents for the model run period. Figure 35 through Figure 49 show the constituents to be modeled for the model calibration period of April 2001 to June 2002. See Appendix D for procedures used in developing the upstream water quality boundary condition

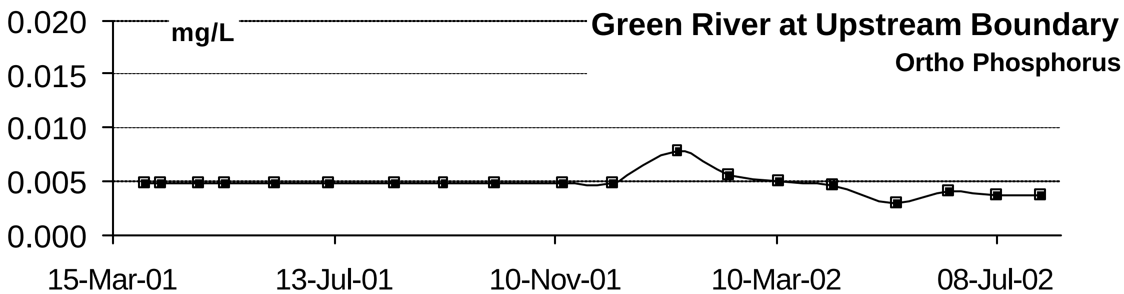


Figure 35: Ortho phosphorus at Upstream Boundary: Apr 2001 – July 2002

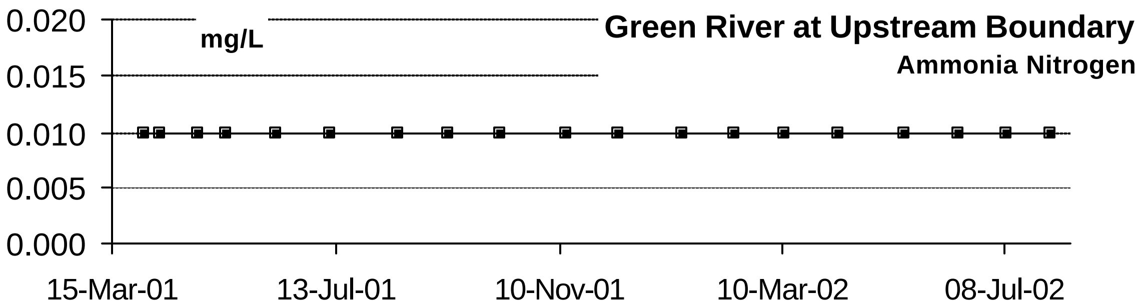


Figure 36: Ammonia at Upstream Boundary: Apr 2001 – July 2002

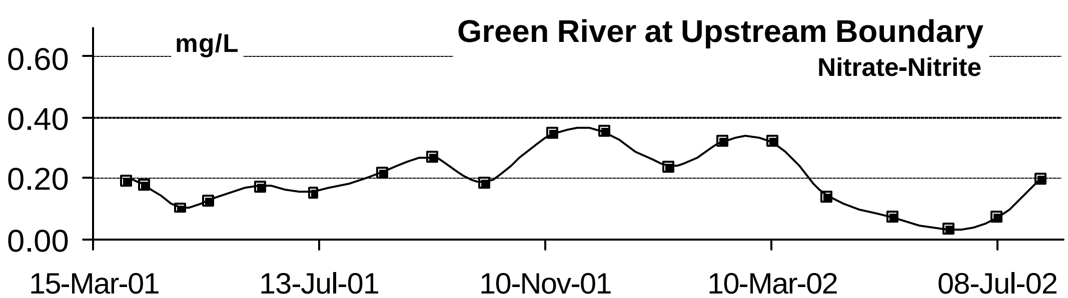


Figure 37: Nitrate-Nitrite at Upstream Boundary: Apr 2001 – July 2002

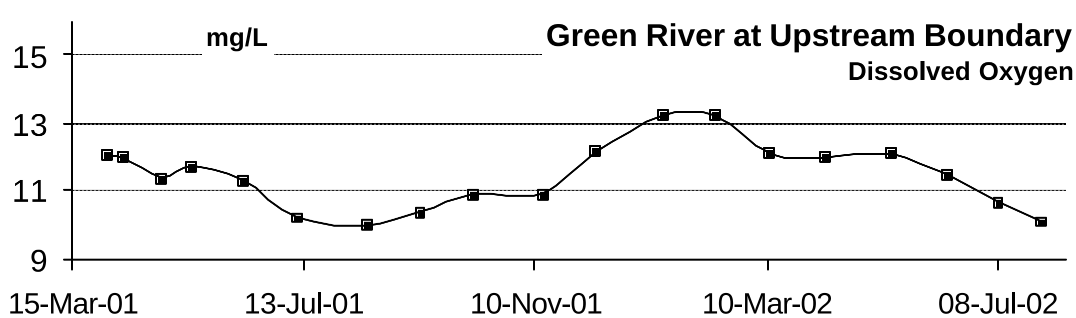


Figure 38: DO at Upstream Boundary: Apr 2001 – July 2002

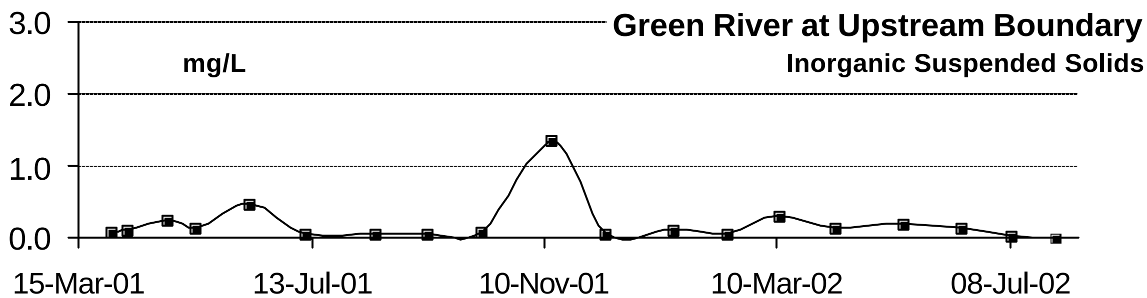


Figure 39: ISS at Upstream Boundary: Apr 2001 – July 2002

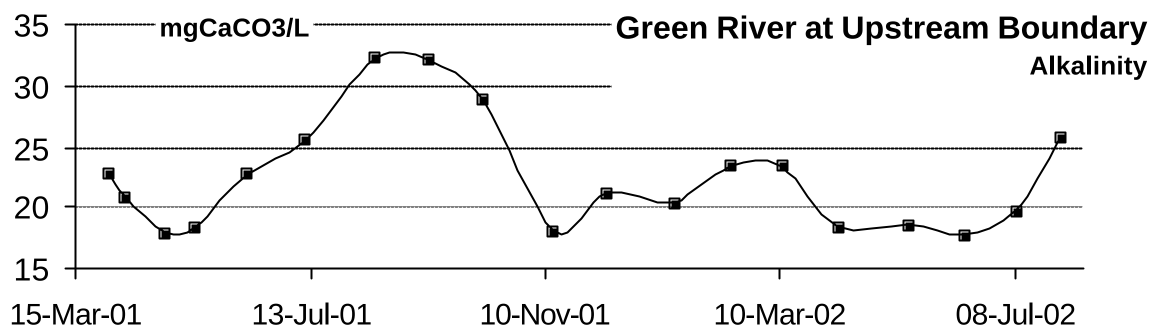


Figure 40: Alkalinity at Upstream Boundary: Apr 2001 – July 2002

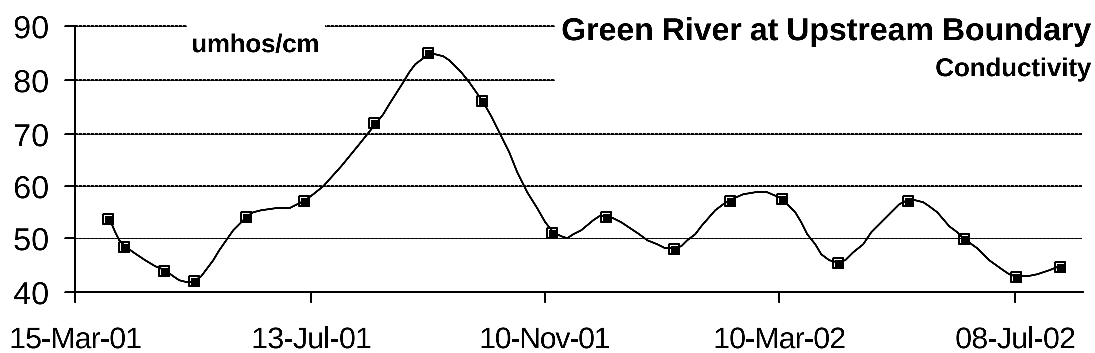


Figure 41: Conductivity at Upstream Boundary: Apr 2001 - July 2002

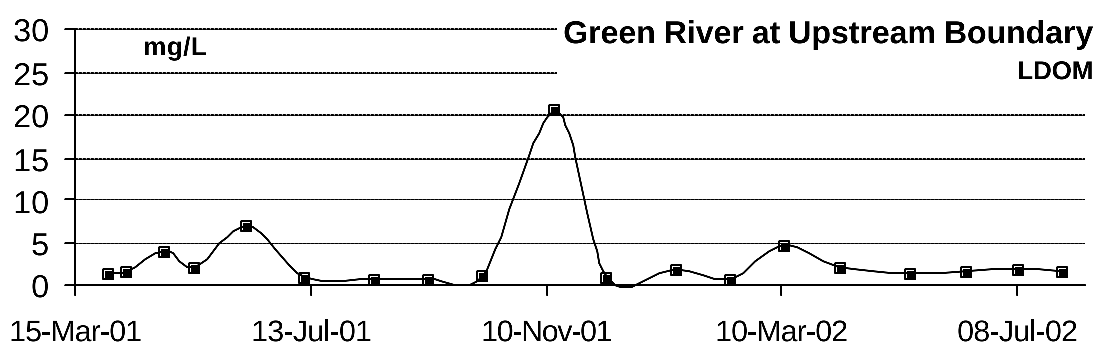


Figure 42: LDOM at Upstream Boundary: Apr 2001 - July 2002

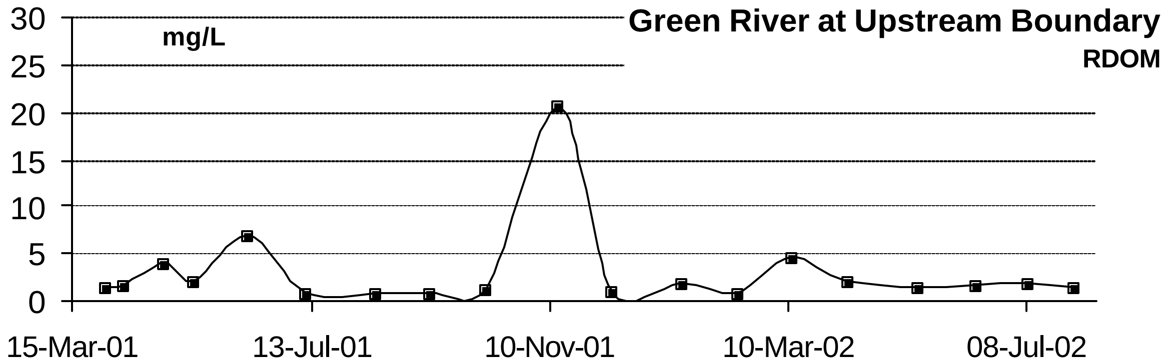


Figure 43: RDOM at Upstream Boundary: Apr 2001 – July 2002

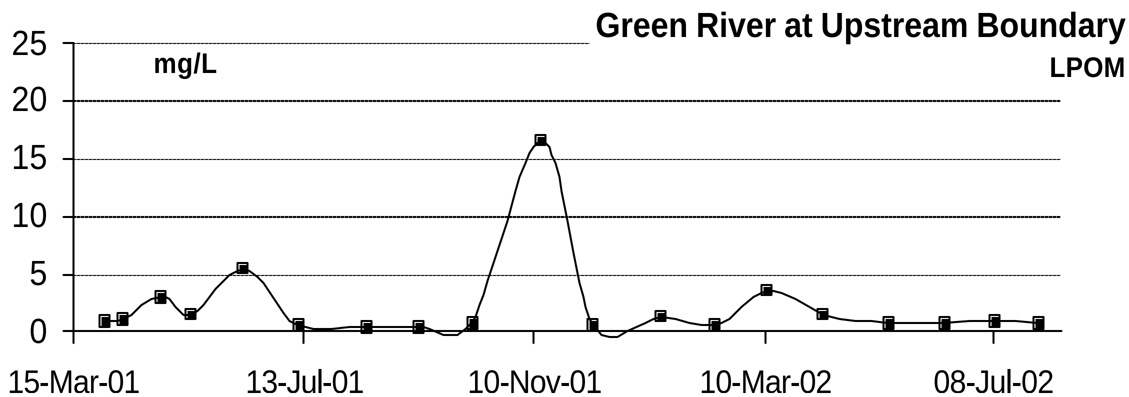


Figure 44: LPOM at Upstream Boundary: Apr 2001 – July 2002

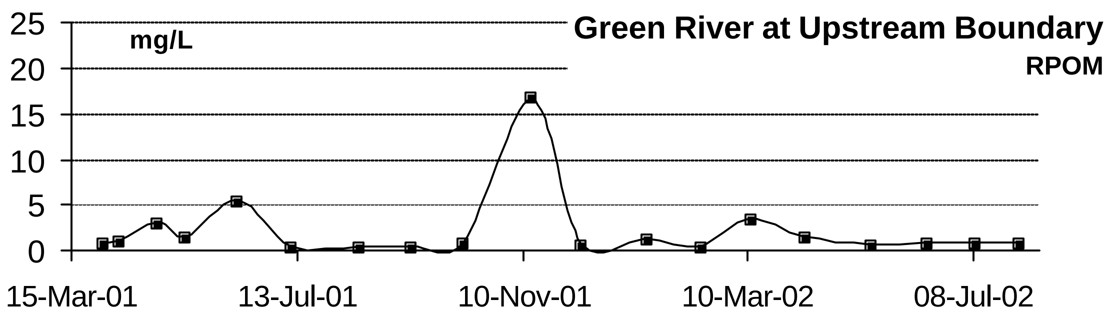


Figure 45: RPOM at Upstream Boundary: Apr 2001 - July 2002

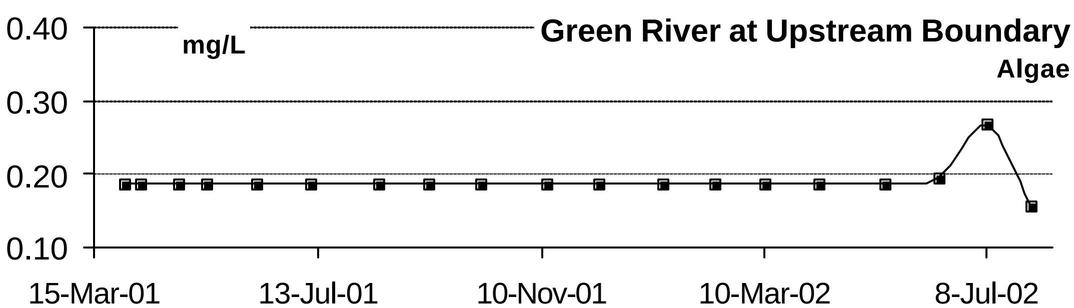


Figure 46: Algae at Upstream Boundary: Apr 2001 – July 2002

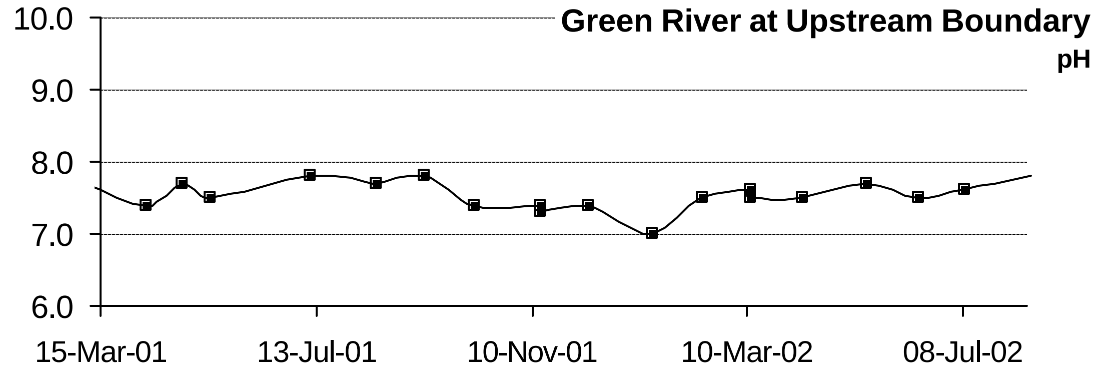


Figure 47: pH at Upstream Boundary: Apr 2001 - July 2002

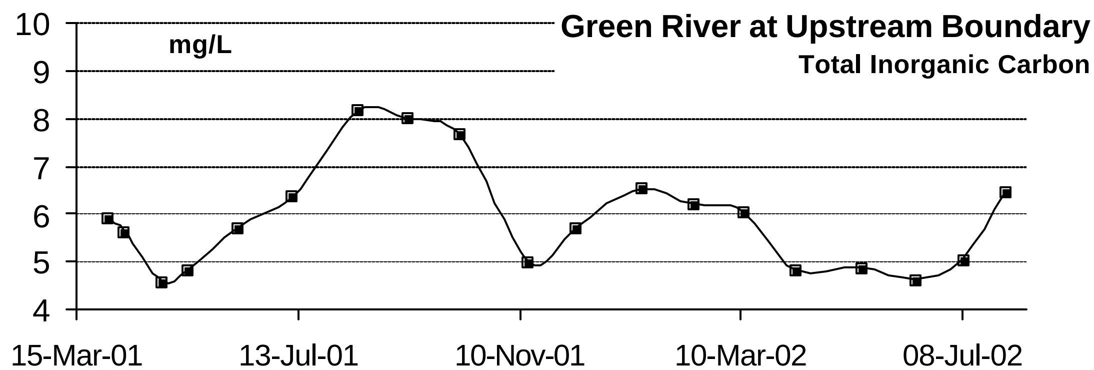


Figure 48: TIC at Upstream Boundary: Apr 2001 – July 2002

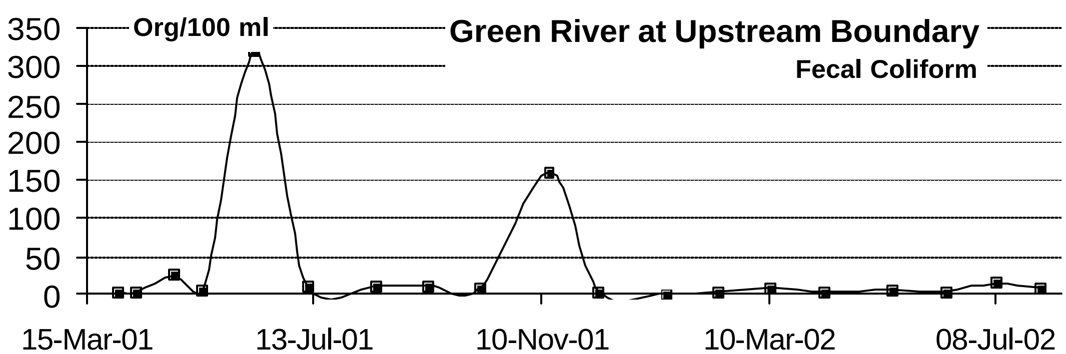


Figure 49: Fecal Coliform at Upstream Boundary: Apr 2001 - July 2002

2.4.2 Downstream Boundary

The downstream boundary is at Fort Dent, in Tukwila at River Mile 11.2, where the Green River enters the Duwamish River. The boundary condition is characterized by water surface elevation, temperature, and water quality. This section of the river is tidally influenced, and flow data were recorded at this location until 1987. A review of this data indicates that the tide does not reverse flow in the river, but may influence flow velocities. A graph of flow from 1960 to 1987 is included in Appendix A.

May 25, 1995 – November 1996

Stage

Hourly stage data were obtained from the USGS gage (12113350) at Fort Dent and used for the external downstream boundary condition. This gage has bad or missing data from May 24, 1995 to May 8, 1996. A good correlation with data from another source has not been found. Stage data from May 24, 1997 to May 8 1998 was used in the model. Figure 50 shows the stage data for the model calibration period.

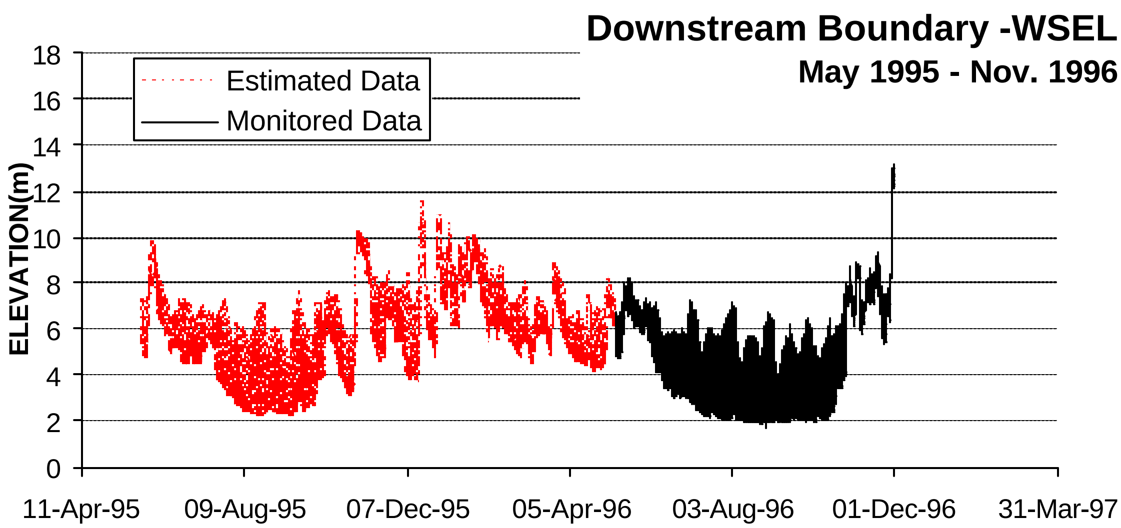


Figure 50: Stage at downstream boundary, May 25, 1995 - Nov 1996

Temperature

King County conducted a temperature study in 1995-1996 which monitored temperature approximately 2.0 km upstream of the downstream boundary location at Station BIC. There is missing data from April 30, 1996 to June 7, 1996. Data from a temperature station on Big Soos Creek (Station 54a) were correlated with data from Station BIC to fill this gap. The equation is:

$$BIC = 1.3147(\text{Big Soos Temp}) - 0.9051$$

Figure 51 shows the temperature correlation for the two stations, Figure 52 shows correlated values and monitored data for the correlation period, and Figure 53 shows the completed temperature record for the model calibration period with correlated values included.

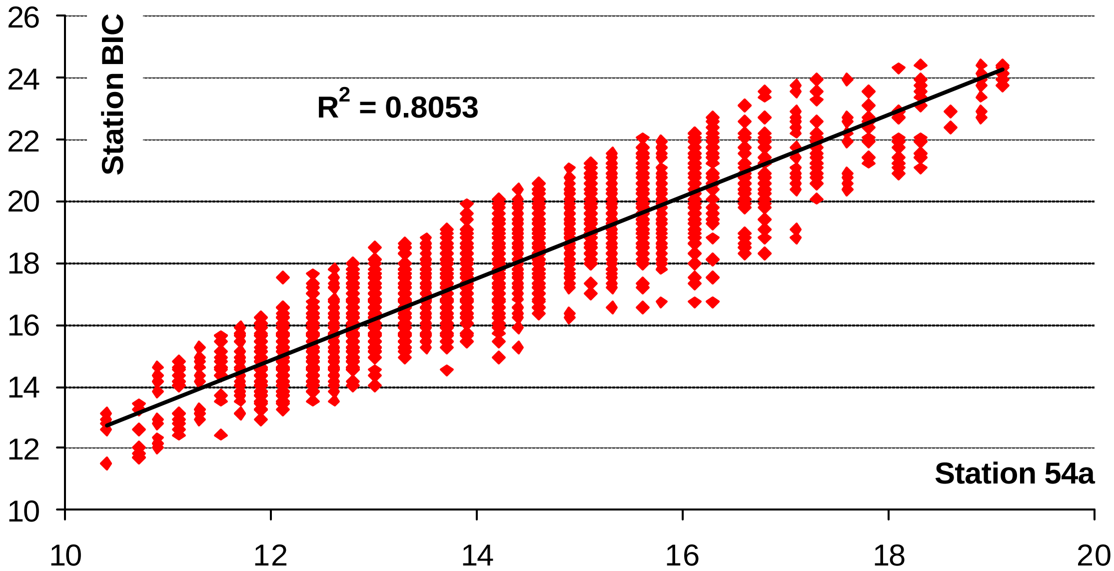


Figure 51: Correlation between Big Soos Temperature and D/S boundary station

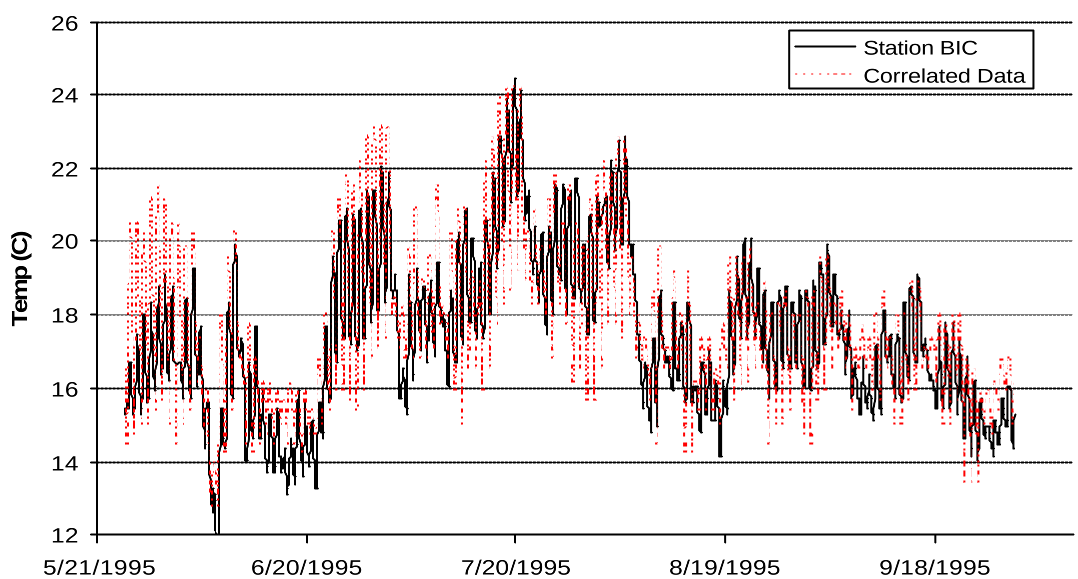


Figure 52: Downstream Boundary: Station versus correlated data, 1995-1996

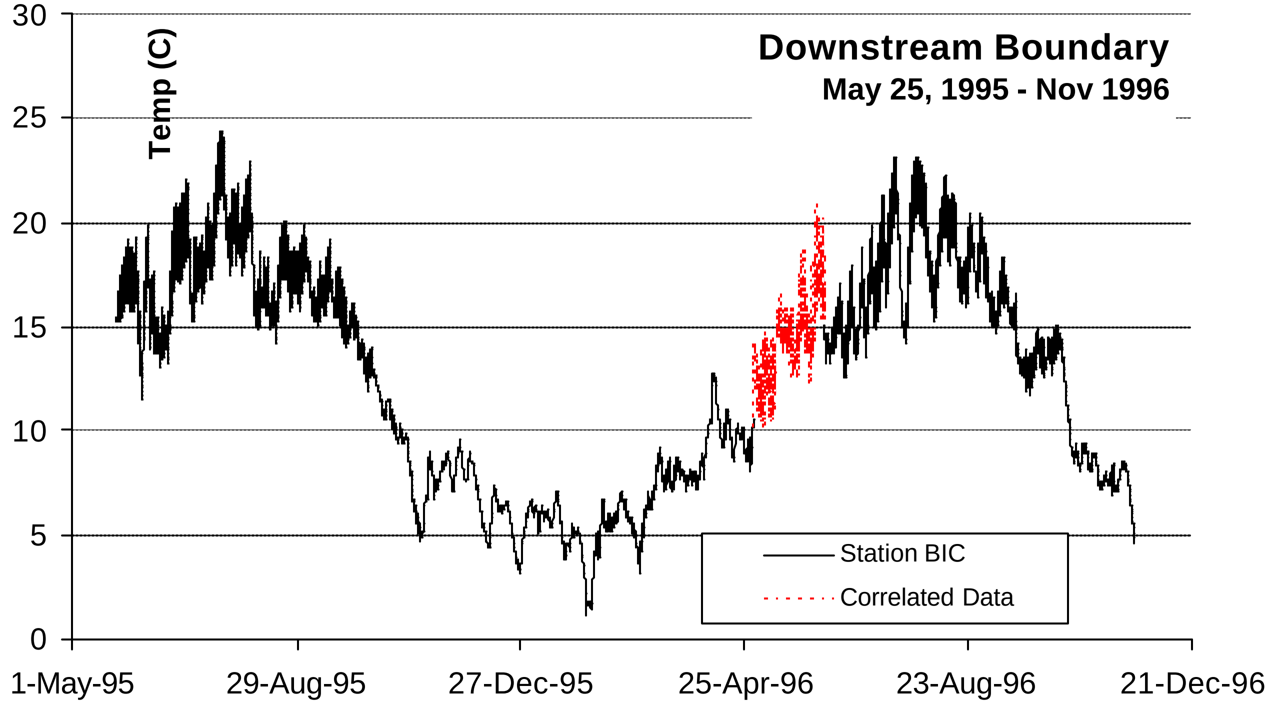


Figure 53: Green River Temperature at Downstream Boundary: May 25, 1995 – Nov 1996

Water Quality

King County collects water quality at Monitoring Station 3106 which is located at the downstream boundary. Data are available for all constituents except chlorophyll a and alkalinity for the model calibration period. Figure 54 through Figure 68 shows the constituent data for the model calibration period. See Appendix D for procedures used in developing the downstream water quality boundary condition, including filling data gaps.

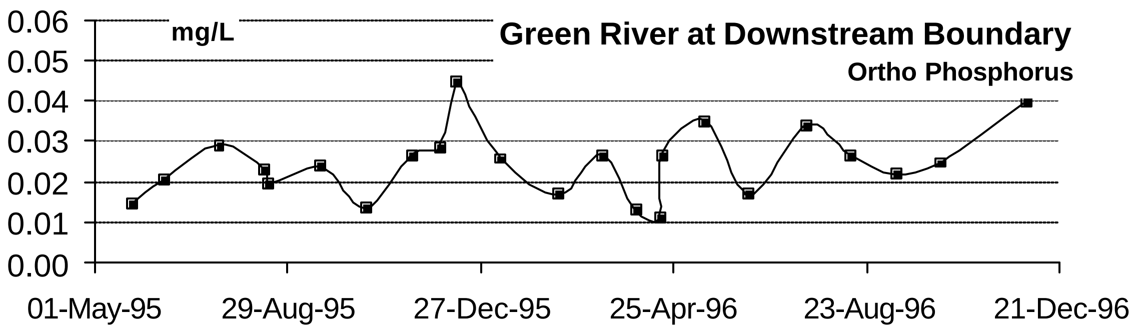


Figure 54: Ortho phosphorus at Downstream Boundary: May 1995 to November 1996

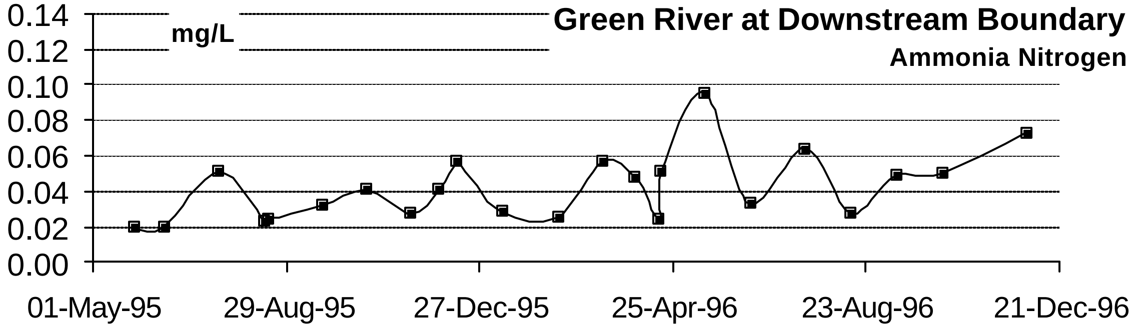


Figure 55: Ammonia at Downstream Boundary: May 1995 to November 1996

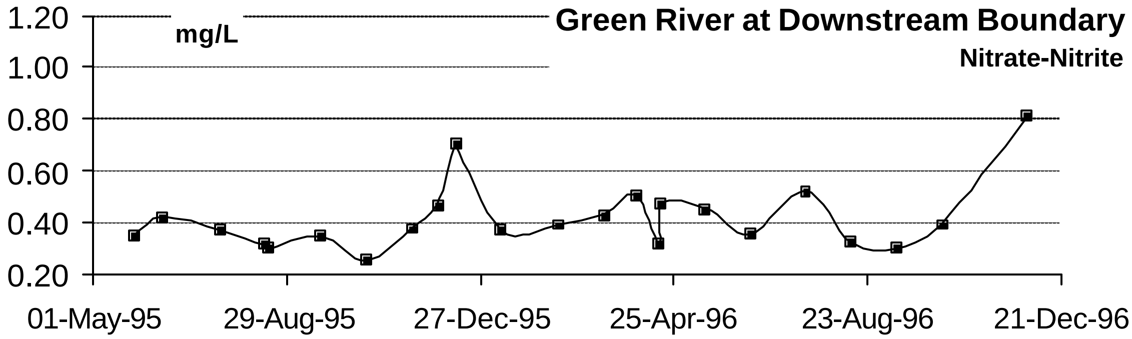


Figure 56: Nitrate-Nitrite at Downstream Boundary: May 1995 to November 1996

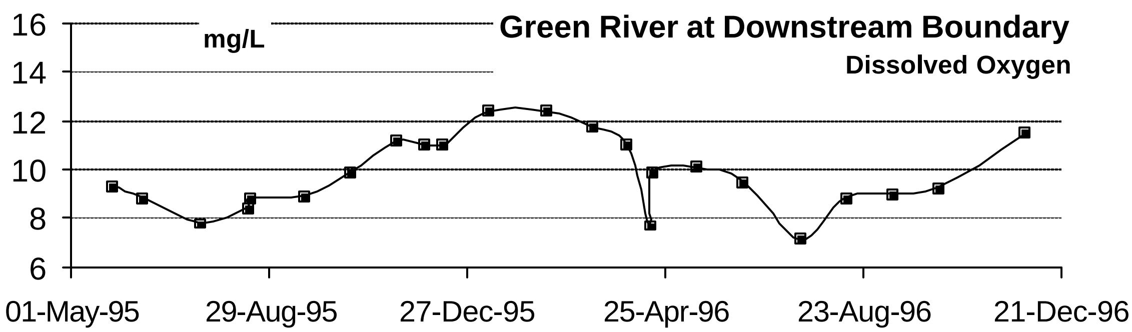


Figure 57: DO at Downstream Boundary: May 1995 to November 1996

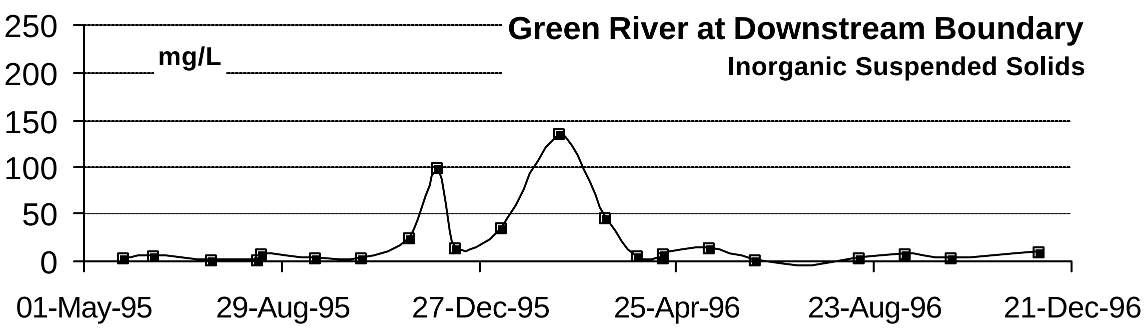


Figure 58: ISS at Downstream Boundary: May 1995 to November 1996

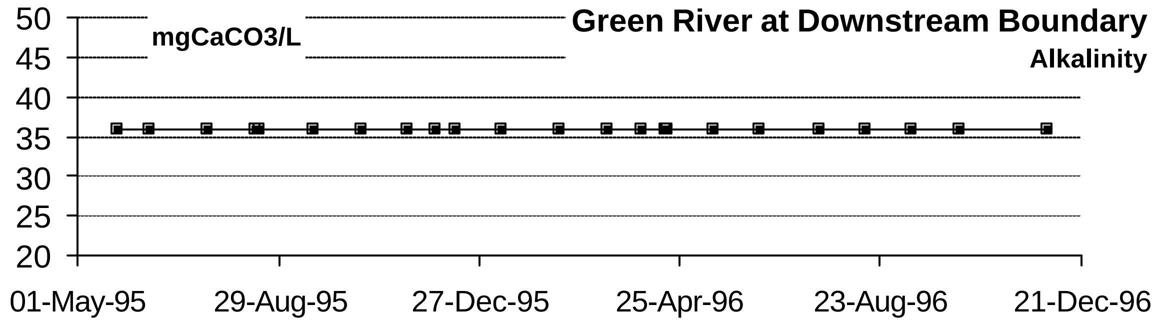


Figure 59: Alkalinity at Downstream Boundary: May 1995 to November 1996

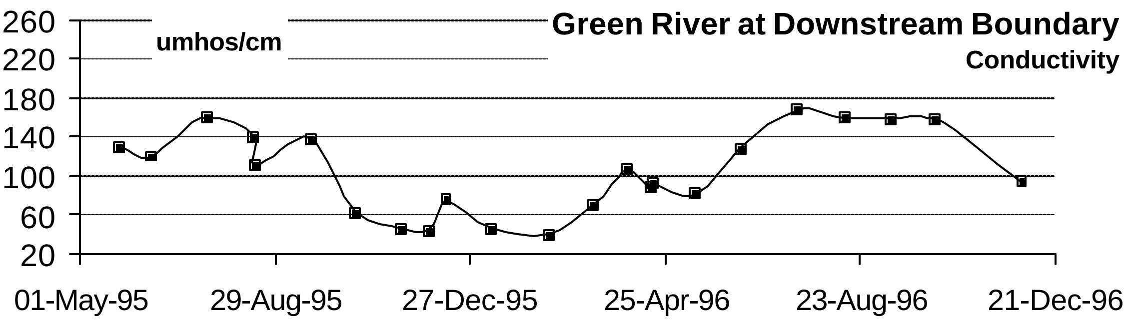


Figure 60: Conductivity at Downstream Boundary: May 1995 to November 1996

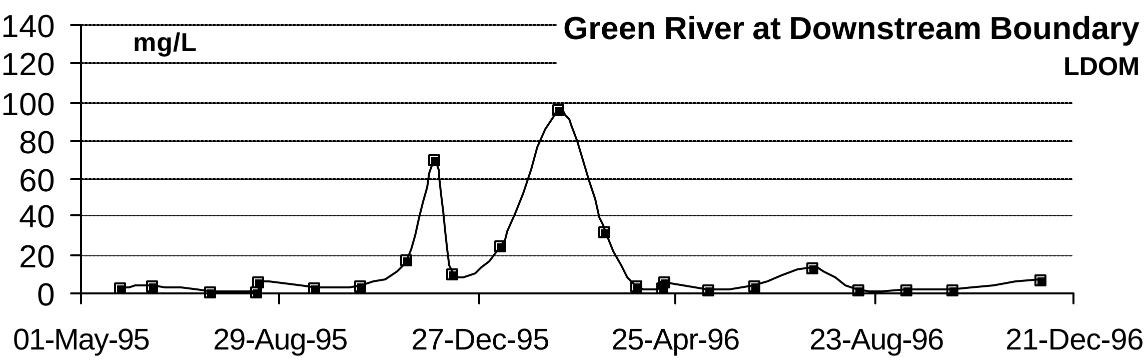


Figure 61: LDOM at Downstream Boundary: May 1995 to November 1996

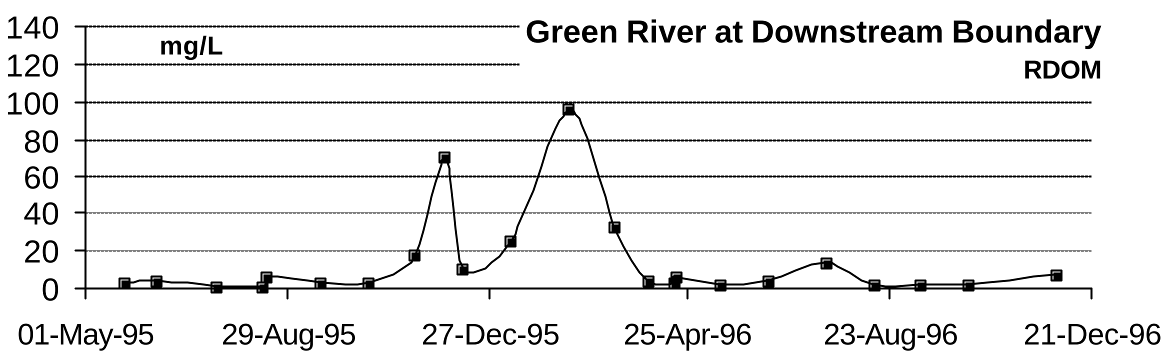


Figure 62: RDOM at Downstream Boundary: May 1995 to November 1996

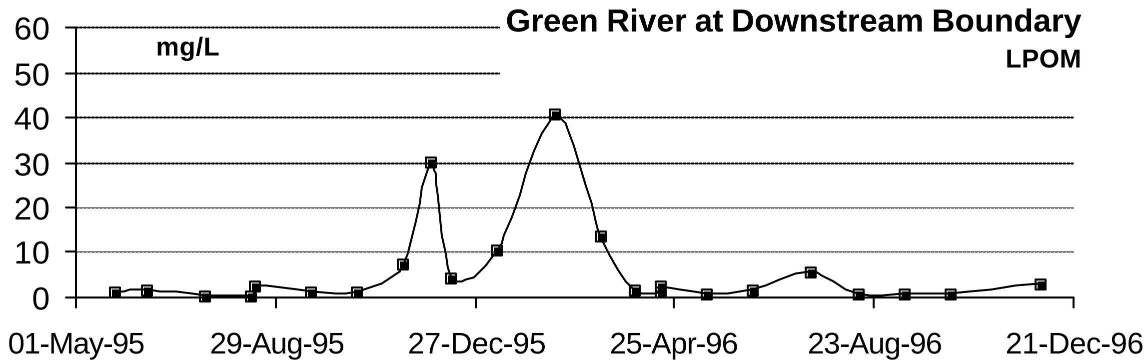


Figure 63: LPOM at Downstream Boundary: May 1995 to November 1996

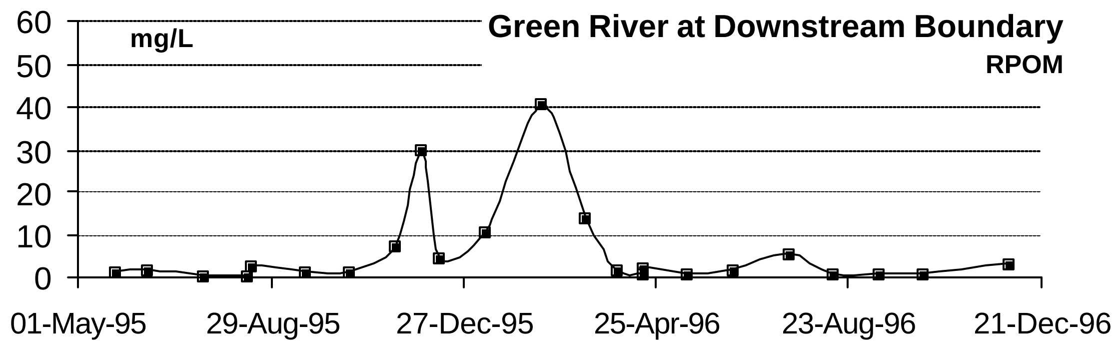


Figure 64: RPOM at Downstream Boundary: May 1995 to November 1996

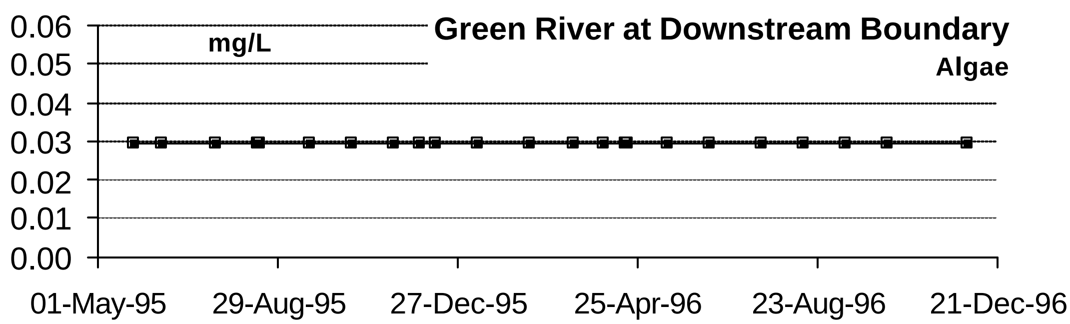


Figure 65: Algae at Downstream Boundary: May 1995 to November 1996

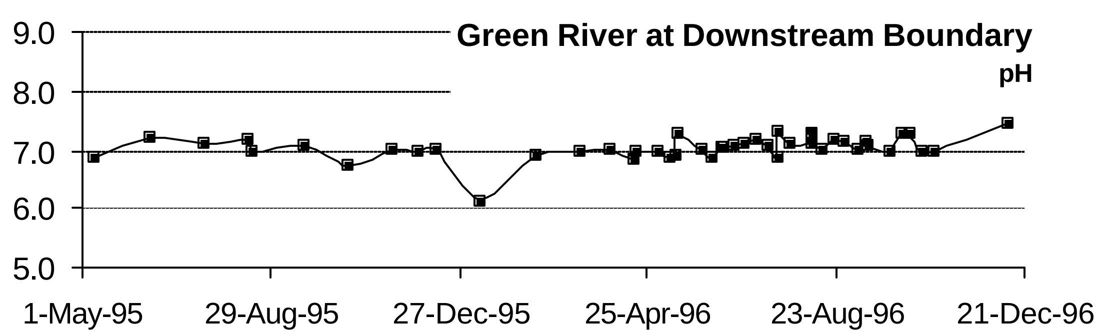


Figure 66: pH at Downstream Boundary: May 1995 - November 1996

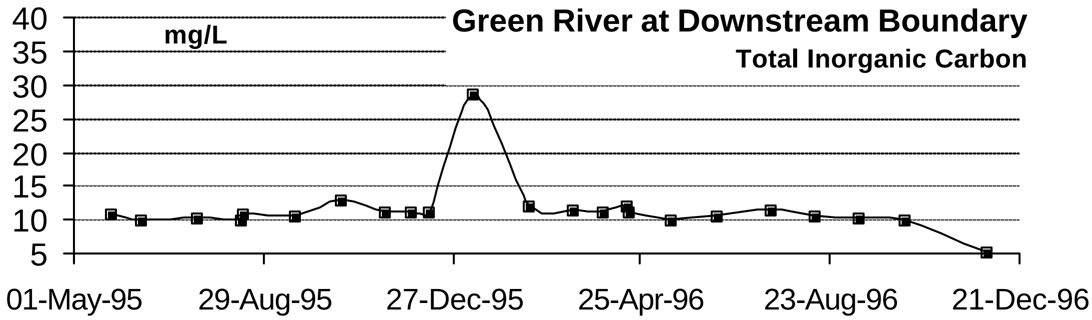


Figure 67: TIC at Downstream Boundary: May 1995 to November 1996

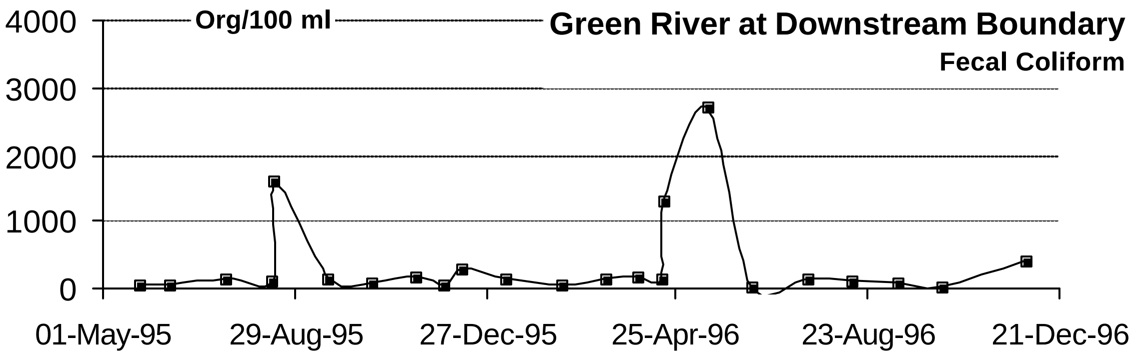


Figure 68: Fecal Coliform at Downstream Boundary: May 1995 to November 1996

April 2001 – July 2002

Stage

Downstream stage data from USGS Gage 13113500 was available from April 2001 to June 18, 2002. To complete the data set through the end of July 2002, an average of the data from 1996 to 2001 for the same time period were used. The gage at Fort Dent was also missing data for two days in February 2002. Data from other years for the same two day time period were used to fill in the missing time period. Figure 69 shows the stage data for the model period. A graph of stage data from this gage from 1995 through June 18, 2002 is included in Appendix A.

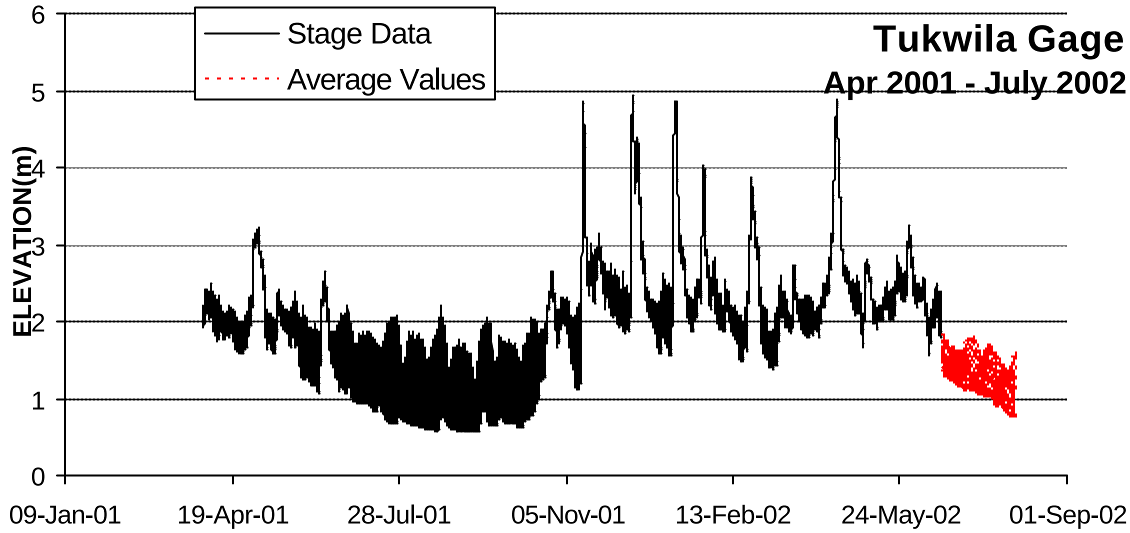


Figure 69: Green River Stage at Downstream Boundary: Apr 2001 – July 2002

Temperature

King County began monitoring water temperature at this location in July 2002, and data were provided through September 2002 (Station GRT18). To develop temperatures for April 2001 to July 2002, a correlation was developed with temperature data monitored by the University of Washington approximately 20 km upstream (Station GR1). The correlation period was between July 9, 2002 and September 12, 2002. The equation used to fill the data is as follows:

$$\text{D/S Bdy. Temp} = 0.8632(\text{GR1}) + 3.5519$$

Figure 70 shows the temperature correlation for the two stations, Figure 71 shows a graph of data from GRT18 and correlated values, and Figure 72 shows the data used for the model calibration period.

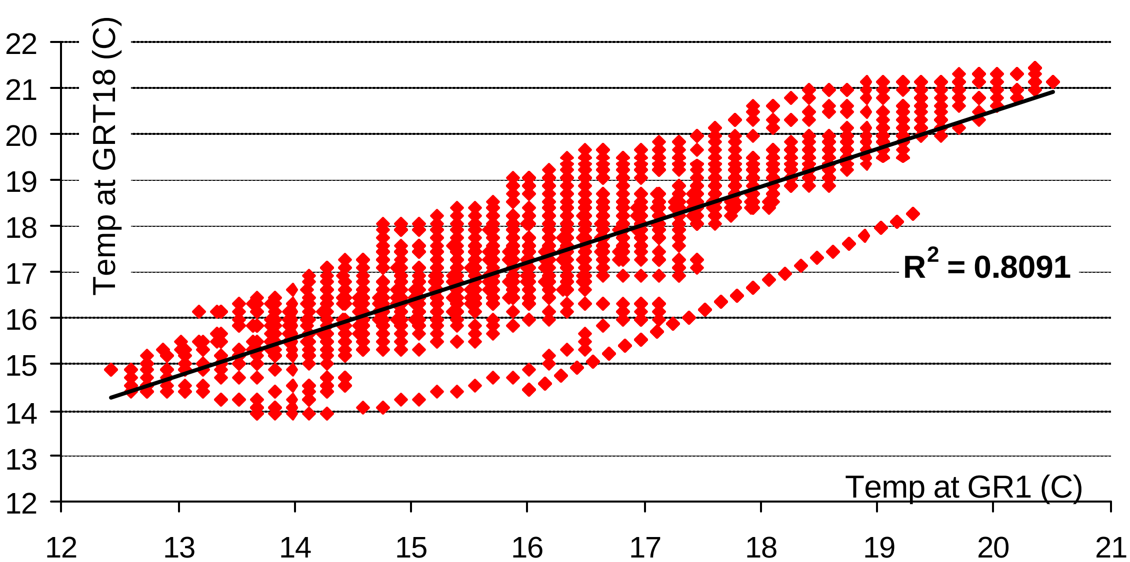


Figure 70: Correlation between Station GR1 and D/S boundary station GRT18

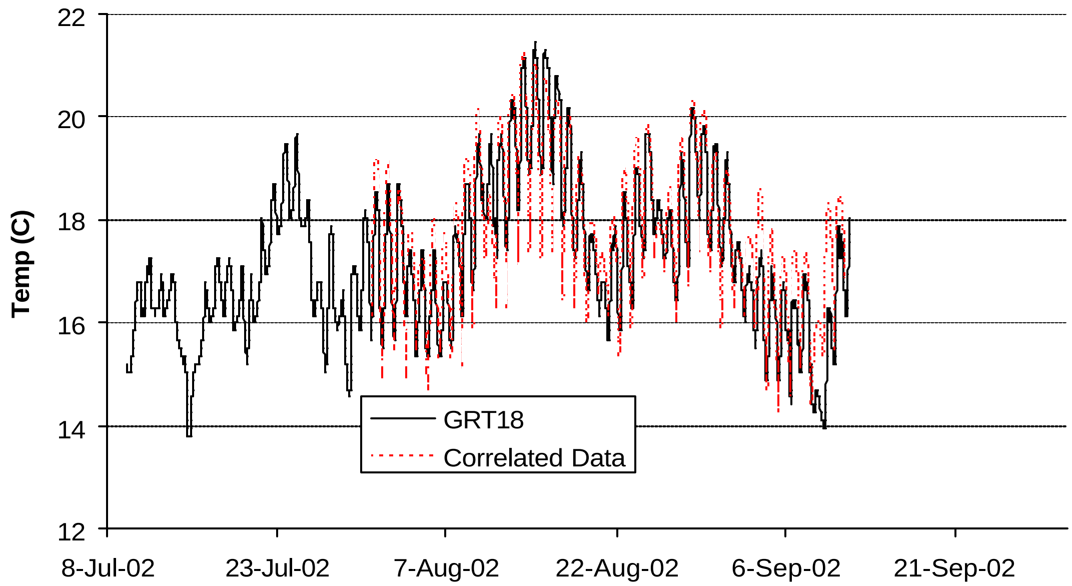


Figure 71: Downstream Boundary: Station versus correlated data, 2001-2002

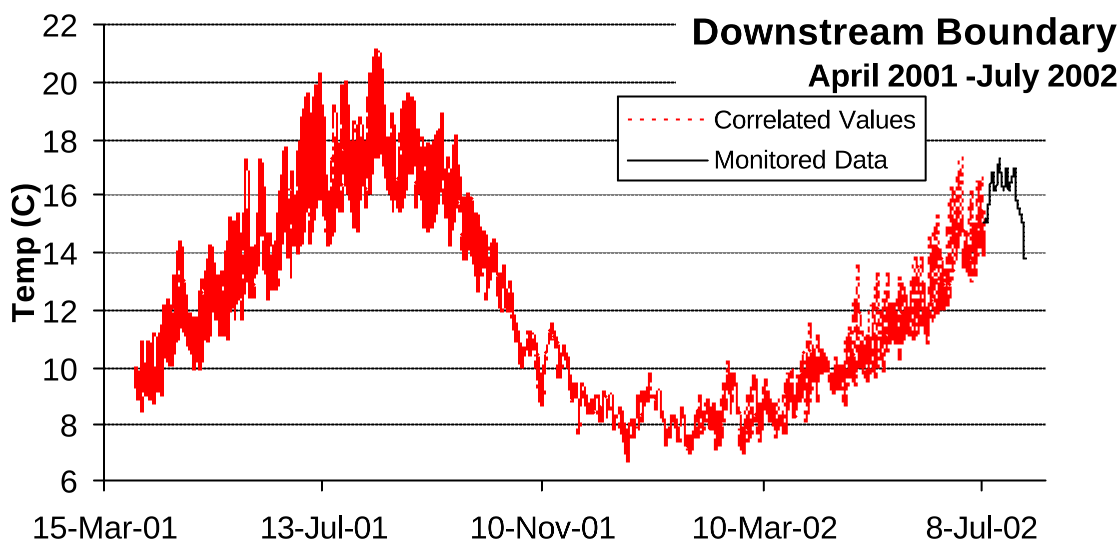


Figure 72: Green River Temperature at Downstream Boundary: Apr 2001 – July 2002

Water Quality

Water quality was monitored at the downstream boundary (Site 3106) for all constituents, but with only minimal data available for chlorophyll a. These data are shown in Figure 73 through Figure 87. See Appendix D for procedures used in developing the water quality boundary condition.

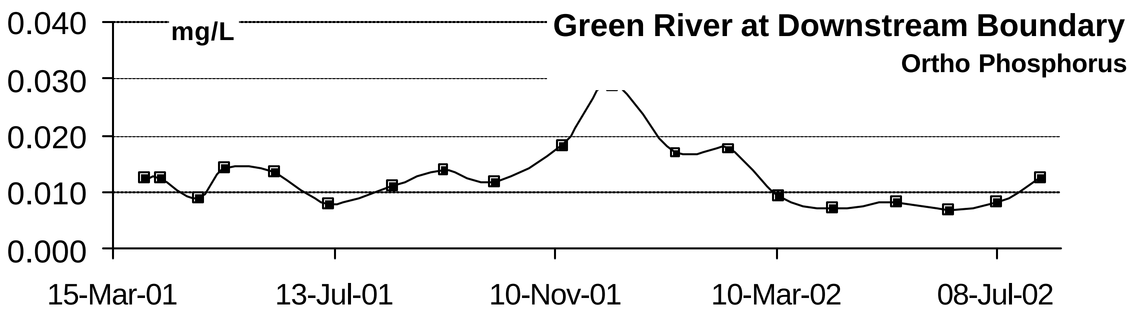


Figure 73: Ortho phosphorus at Downstream Boundary: Apr 2001 – July 2002

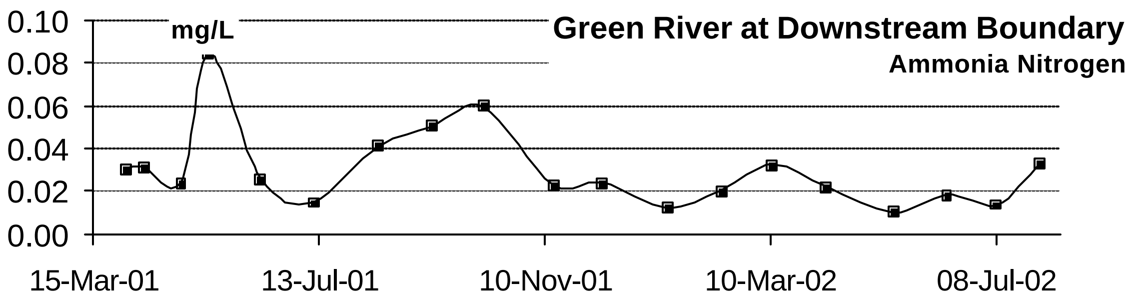


Figure 74: Ammonia at Downstream Boundary: Apr 2001 – July 2002

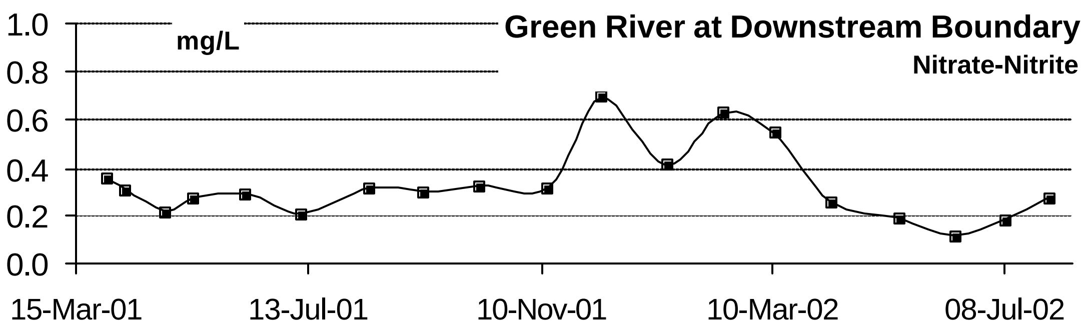


Figure 75: Nitrate-Nitrite at Downstream Boundary: Apr 2001 – July 2002

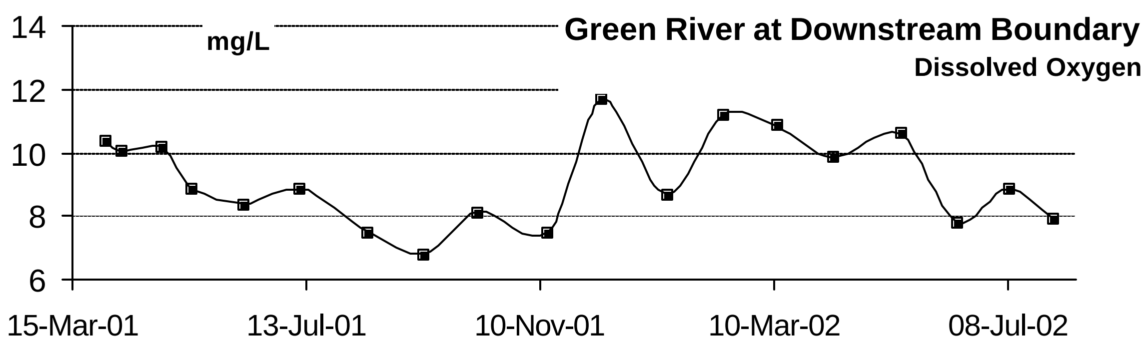


Figure 76: DO at Downstream Boundary: Apr 2001 – July 2002

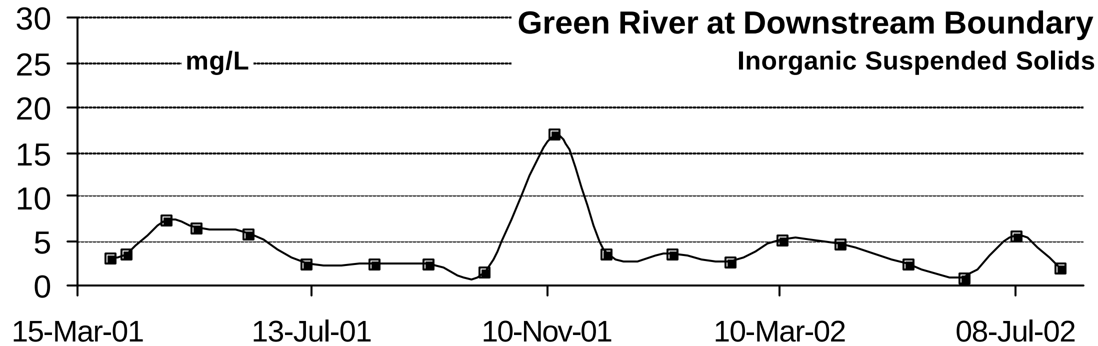


Figure 77: ISS at Downstream Boundary: Apr 2001 – July 2002

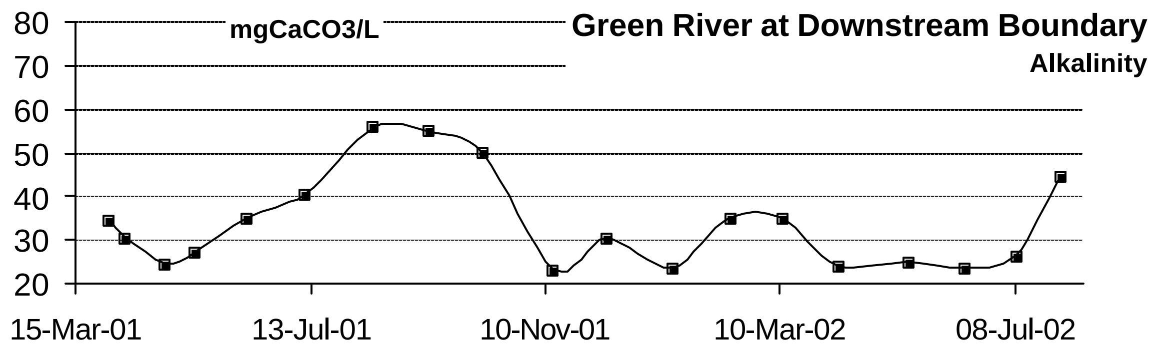


Figure 78: Alkalinity at Downstream Boundary: Apr 2001 – July 2002

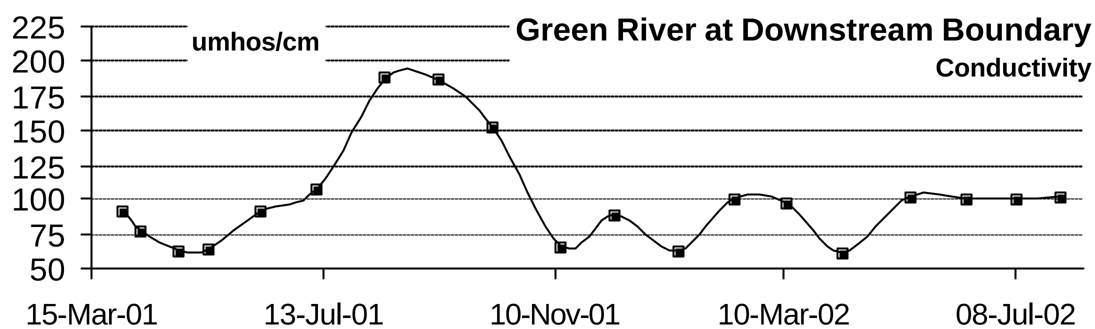


Figure 79: Conductivity at Downstream Boundary: Apr 2001 – July 2002

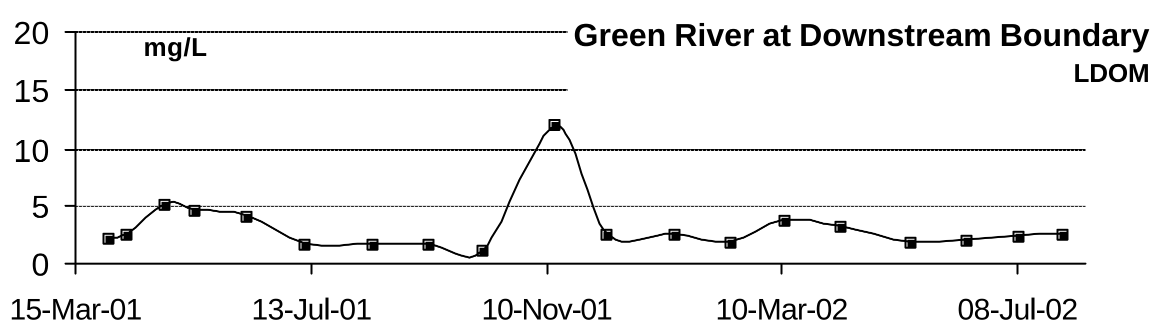


Figure 80: LDOM at Downstream Boundary: Apr 2001 – July 2002

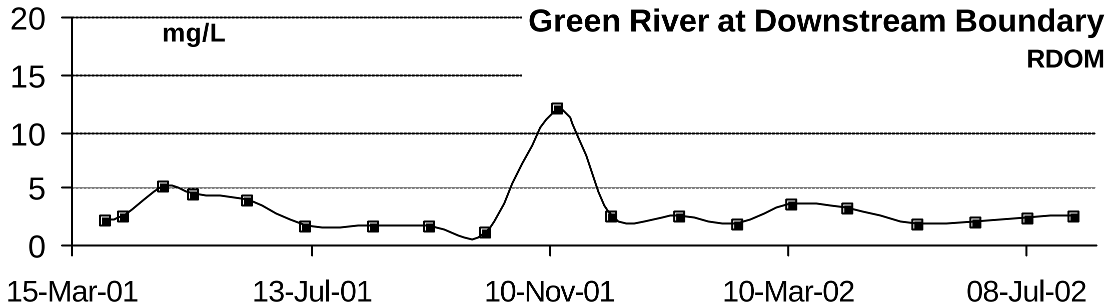


Figure 81: RDOM at Downstream Boundary: Apr 2001 – July 2002

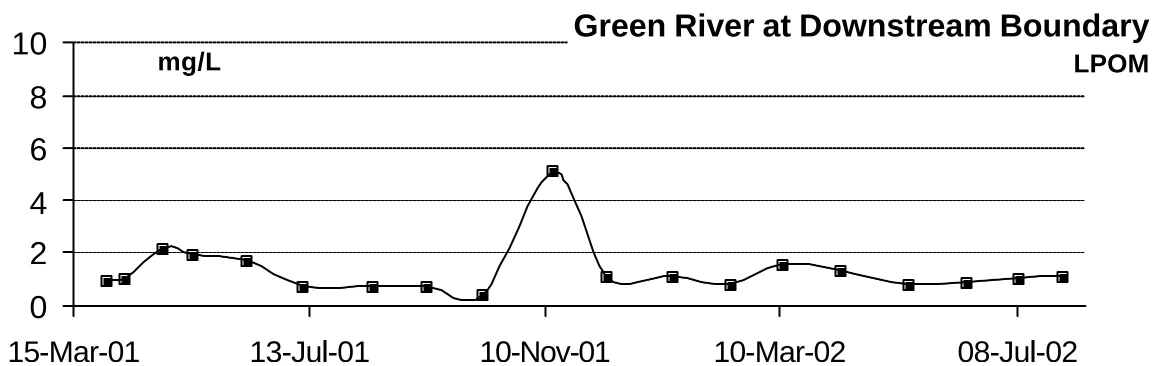


Figure 82: LPOM at Downstream Boundary: Apr 2001 – July 2002

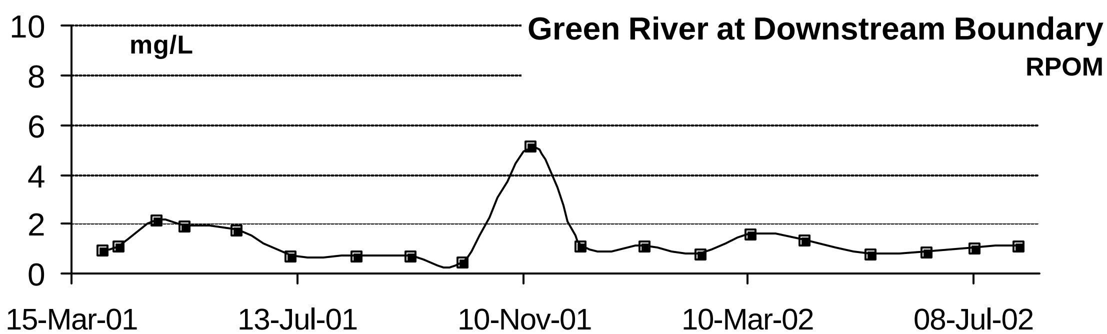


Figure 83: RPOM at Downstream Boundary: Apr 2001 – July 2002

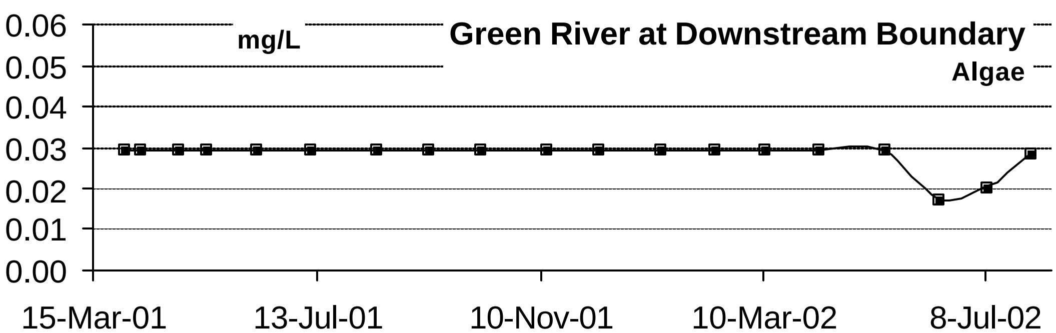


Figure 84: Algae at Downstream Boundary: Apr 2001 – July 2002

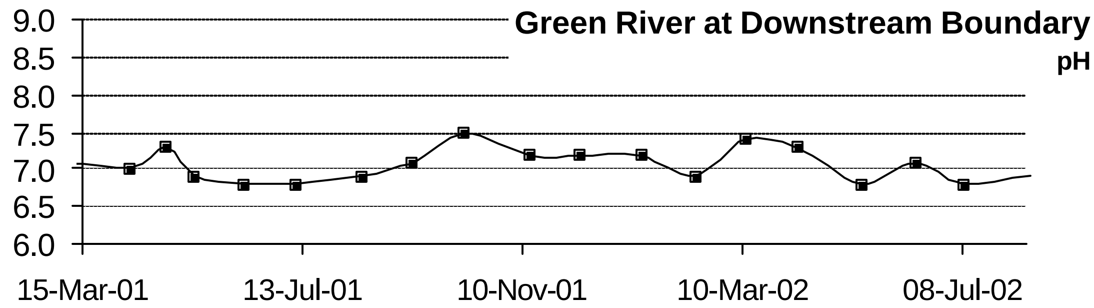


Figure 85: pH at Downstream Boundary: Apr 2001 - July 2002

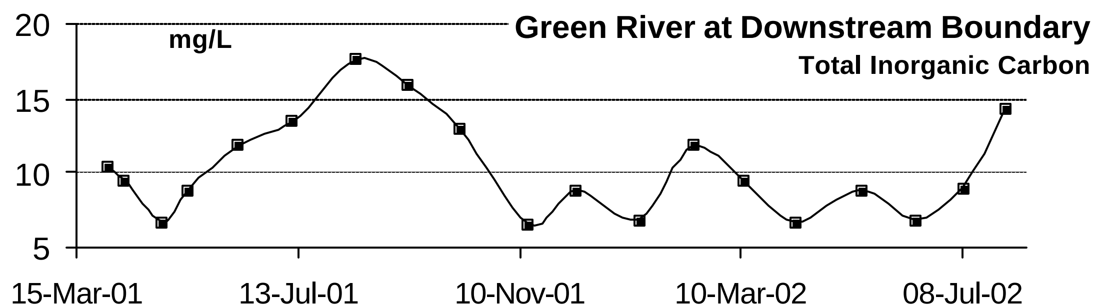


Figure 86: TIC at Downstream Boundary: Apr 2001 – July 2002

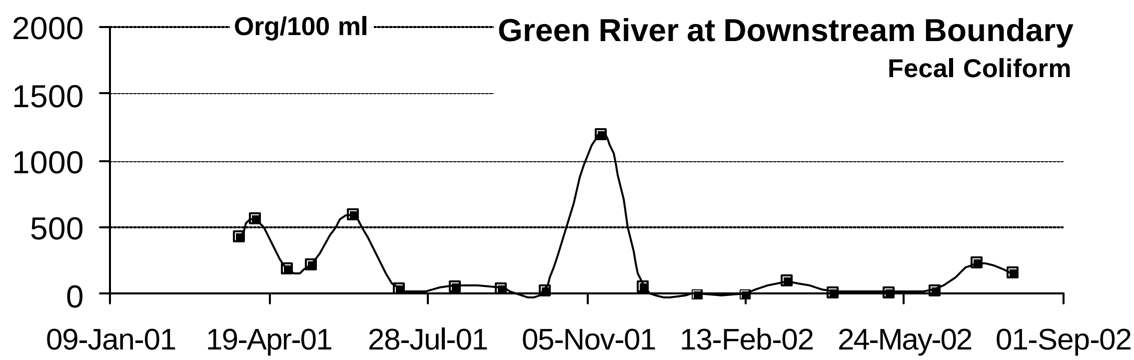


Figure 87: Fecal Coliform at Downstream Boundary: Apr 2001 - July 2002

2.5 Tributaries

There are seven tributaries to be included in this model: Newaukum Creek, Crisp Creek, Big Soos Creek, Auburn Creek, Mill Creek, Mullen Slough, and Midway Creek.

Figure 88 shows the location of these tributaries in the Green River basin, and Table 7 lists the river mile and model segment number for each tributary.

Each tributary was characterized by flow, temperature, and water quality. The larger tributaries (Big Soos, Newaukum, Crisp, Mill) have some gaged or sampled data available. The three smaller tributaries (Midway, Mullen Slough, Auburn) have no gaged or sampled data available.

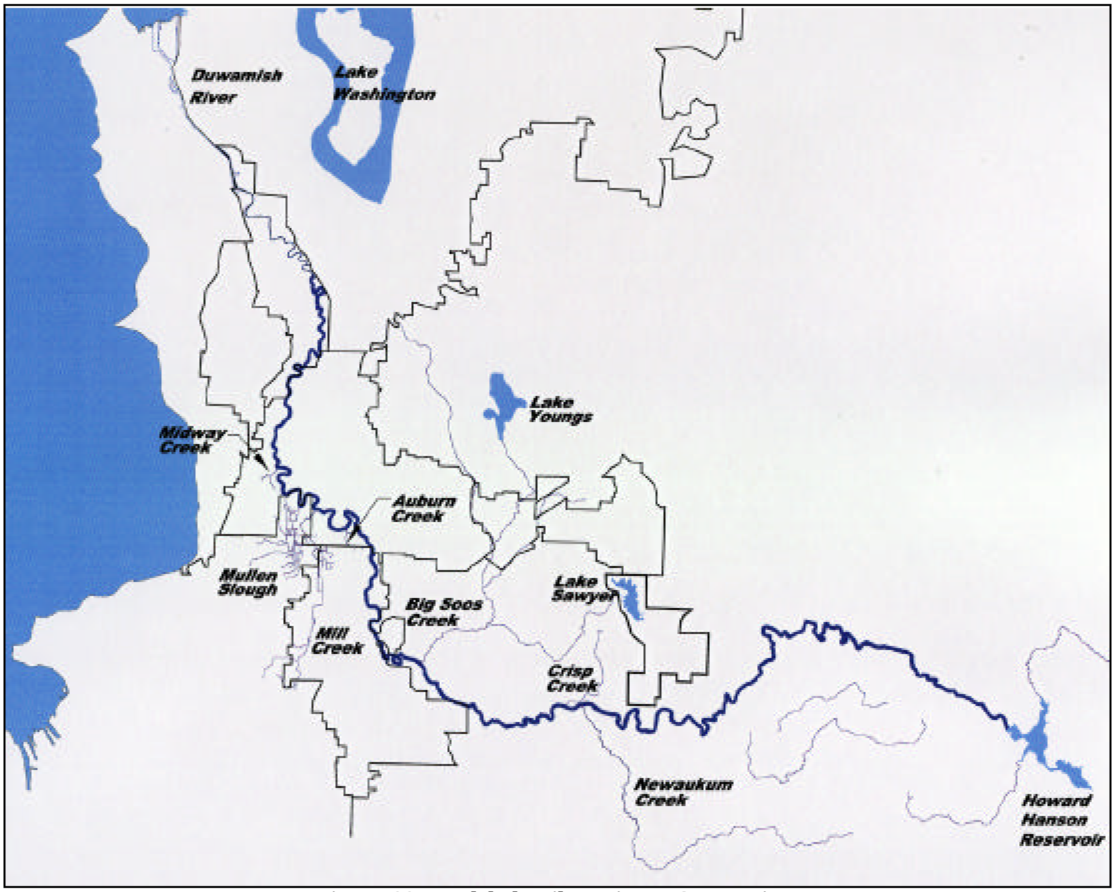


Figure 88: Modeled Tributaries to Green River

Table 7: Tributary River Miles and Segment Numbers

Tributary	River Mile	Model Segment Number
Newaukum Creek	41.10	26
Crisp Creek	40.40	32
Big Soos Creek	33.80	77
Auburn Creek	25.50	134
Mill Creek	23.80	145
Mullen Slough	21.60	159
Midway Creek	19.60	171

2.5.1 Newaukum Creek

Newaukum Creek is approximately six km below the upstream boundary, at River Mile 41.1. It is a large tributary, with a basin size of approximately 7,200 hectares (17,800 acres).

May 1995 – Nov 1996

Flow

USGS has a flow gage (12108500) approximately 1.50 km upstream of the confluence of Newaukum Creek with the Green River. Data were obtained in 15-minute intervals for this gage from October 1, 1994 to December 31, 2002. Figure 89 shows the data for the model simulation period. The complete data set is included in Appendix A.

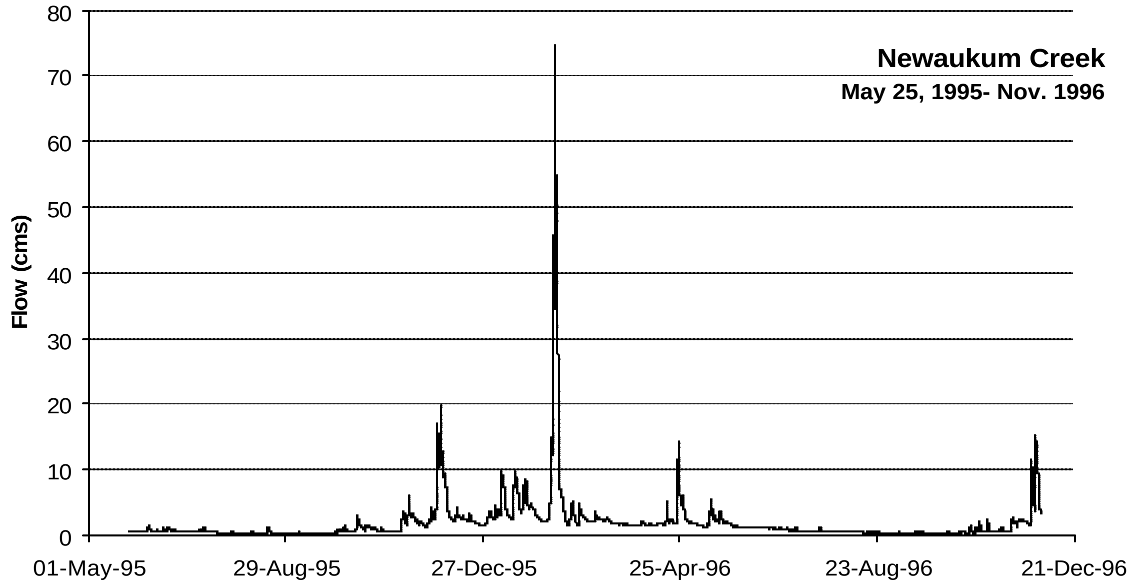


Figure 89: Newaukum Creek Flow: May 25, 1995 – Nov 1996

Temperature

USGS monitored hourly temperatures on Newaukum Creek from July 1996 to September 1998 at the same location as flow, 1.50 km upstream of the confluence with Green River. There were no data available from May 25, 1995 to July 1996 during the model calibration period. To fill this gap, data from July 1996 to September 1998 were compared to data from Big Soos Creek (Station 54a) for the same time period. The resulting correlation equation is:

$$\text{Station 12108500} = 0.9529(\text{Station 54a}) + 0.3982$$

Figure 90 shows the temperature correlation for the two stations, Figure 91 shows the correlated values with the data, and Figure 92 shows the completed temperature record for the model calibration period.

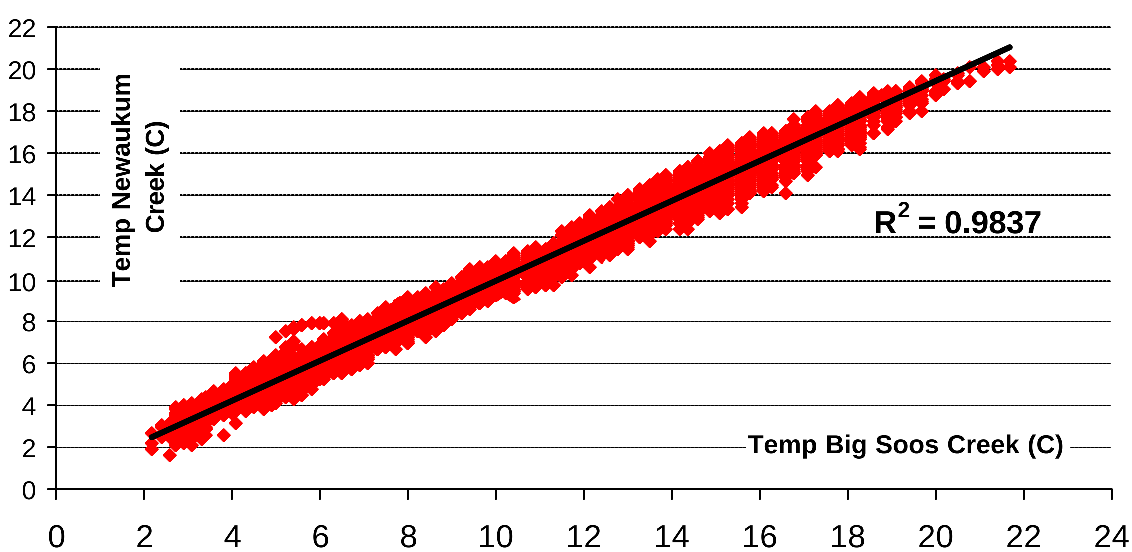


Figure 90: Correlation between Big Soos Temperature and Newaukum Creek station

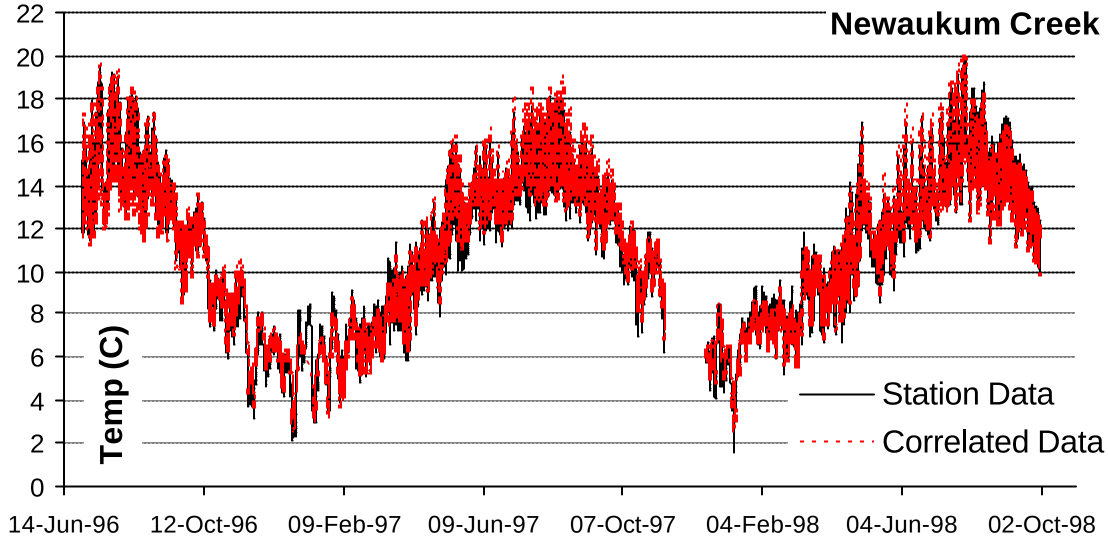


Figure 91: Newaukum Creek: Station versus correlated data, 1995-1996

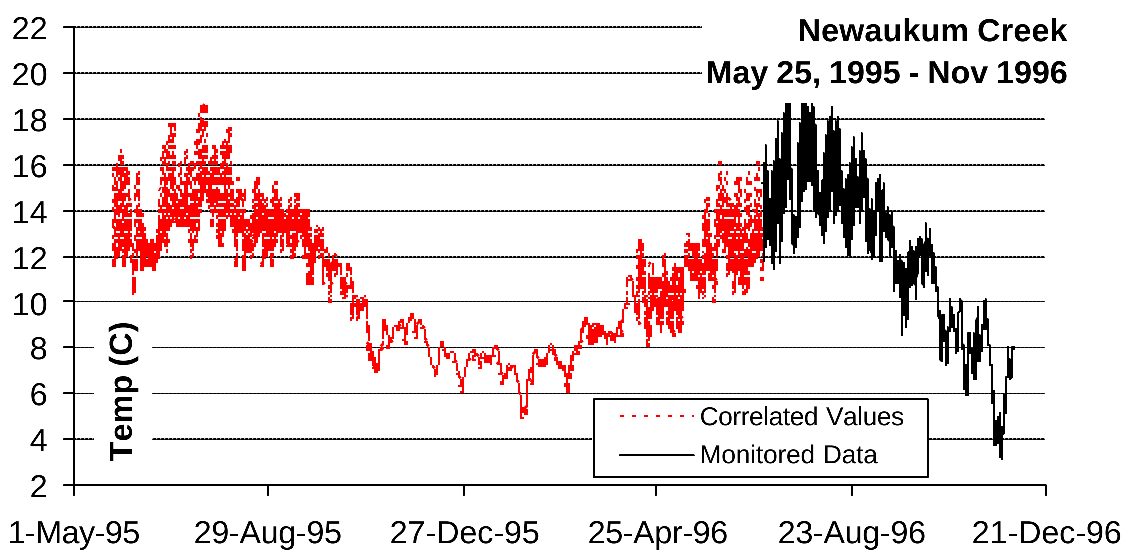


Figure 92: Newaukum Creek Temperature: May 25, 1995 – Nov 1996

Water Quality

King County monitored all the water quality constituents during the model calibration period except chlorophyll a and alkalinity (Locator 0322). Figure 93 through Figure 107 shows the water quality conditions for Newaukum Creek during the model calibration period. See Appendix D for procedures used in developing the water quality tributary condition, including filling data gaps.

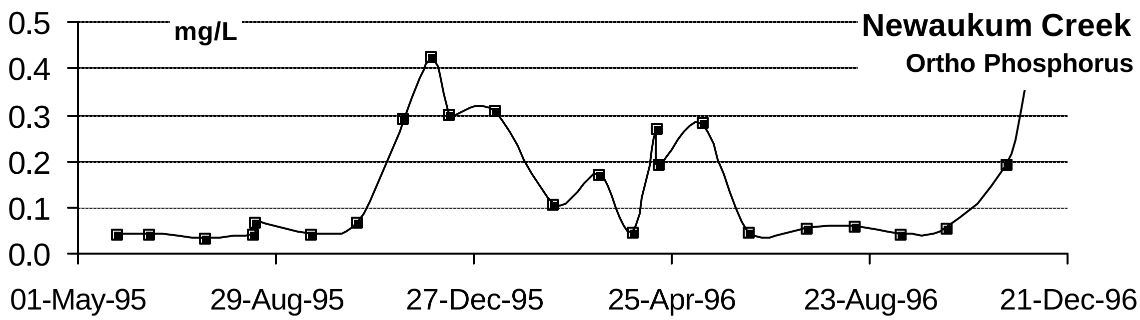


Figure 93: Ortho phosphorus Newaukum Creek: May 25, 1995 – Nov 1996

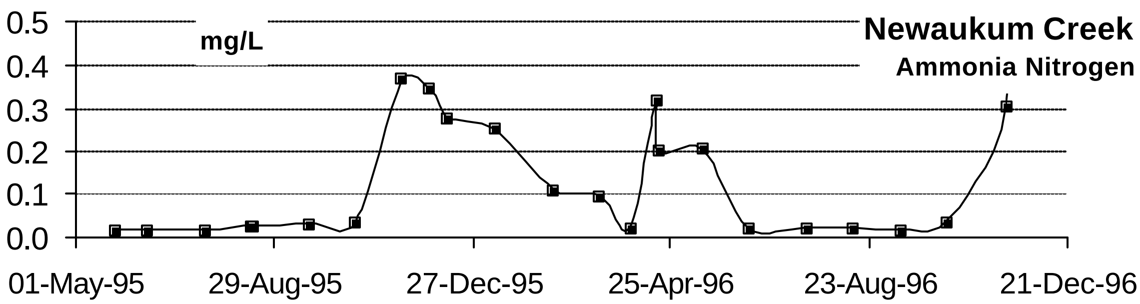


Figure 94: Ammonia Newaukum Creek: May 25, 1995 – Nov 1996

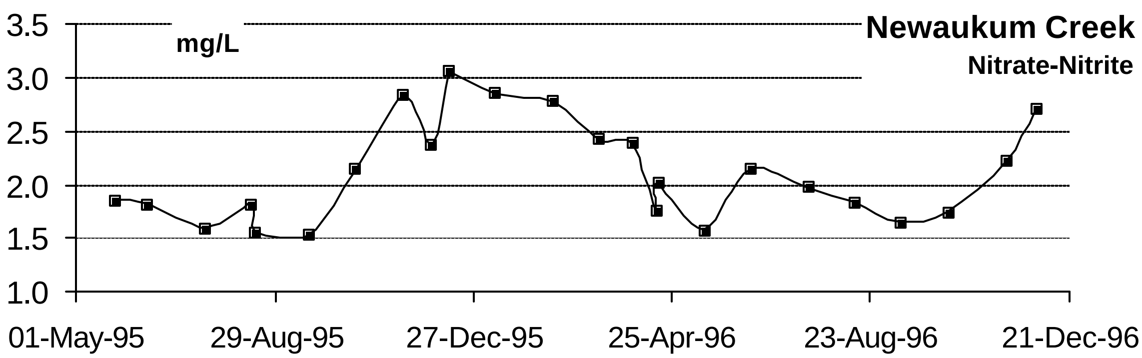


Figure 95: Nitrate-Nitrite Newaukum Creek: May 25, 1995 – Nov 1996

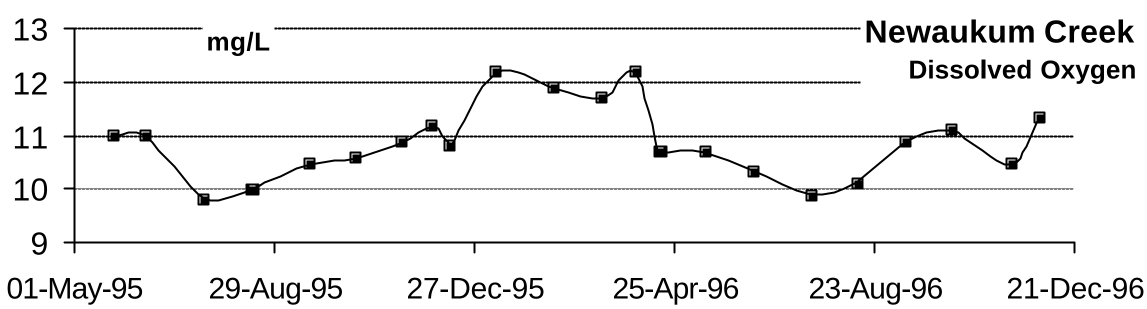


Figure 96: DO Newaukum Creek: May 25, 1995 – Nov 1996

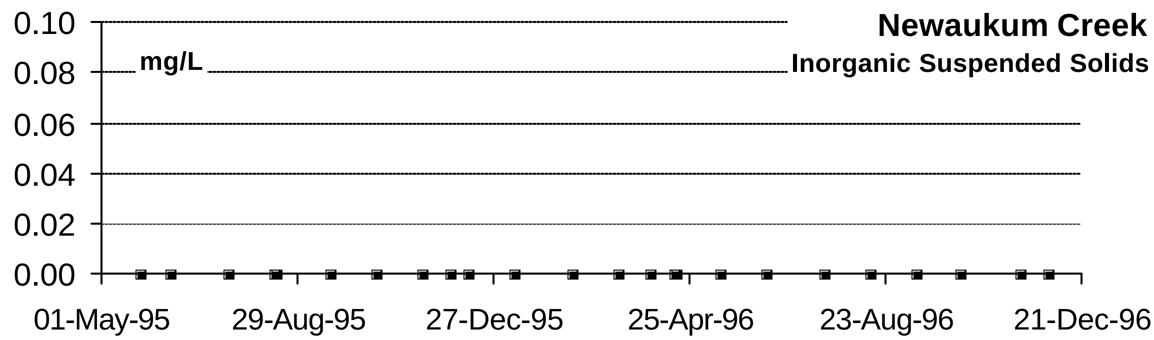


Figure 97: ISS Newaukum Creek: May 25, 1995 – Nov 1996

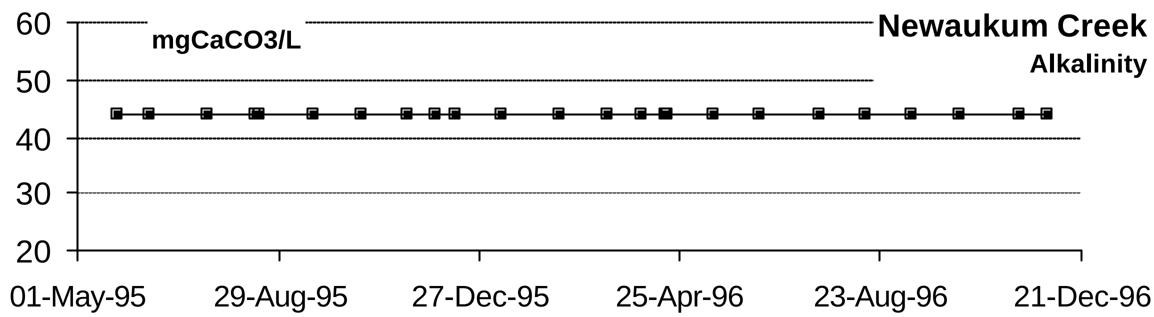


Figure 98: Alkalinity Newaukum Creek: May 25, 1995 – Nov 1996

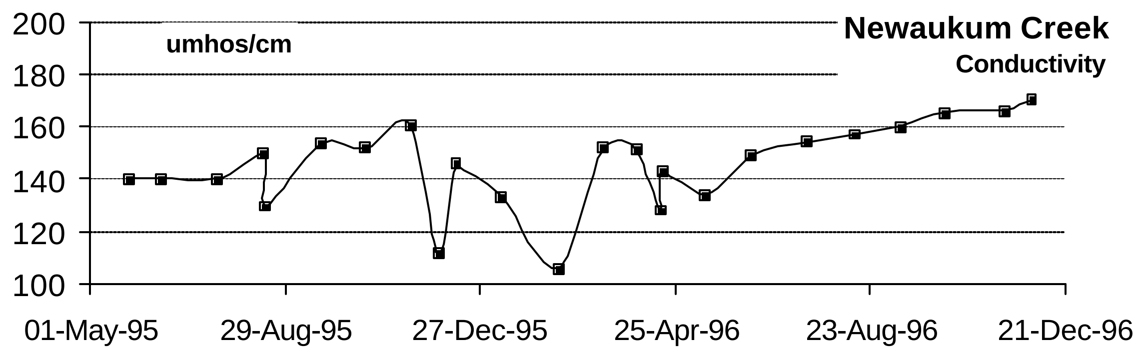


Figure 99: Conductivity Newaukum Creek: May 25, 1995 – Nov 1996

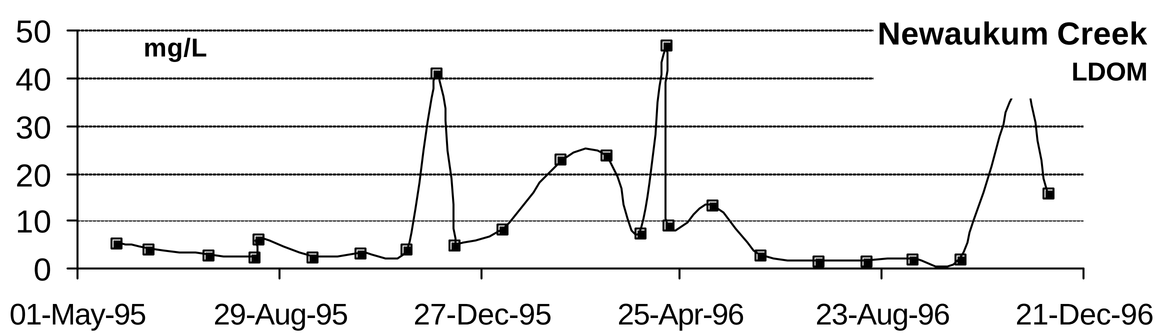


Figure 100: LDOM Newaukum Creek: May 25, 1995 – Nov 1996

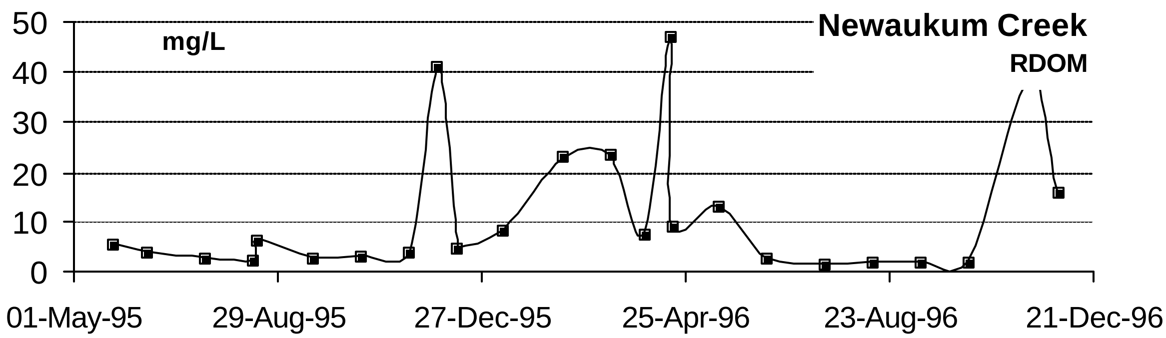


Figure 101: RDOM Newaukum Creek: May 25, 1995 – Nov 1996

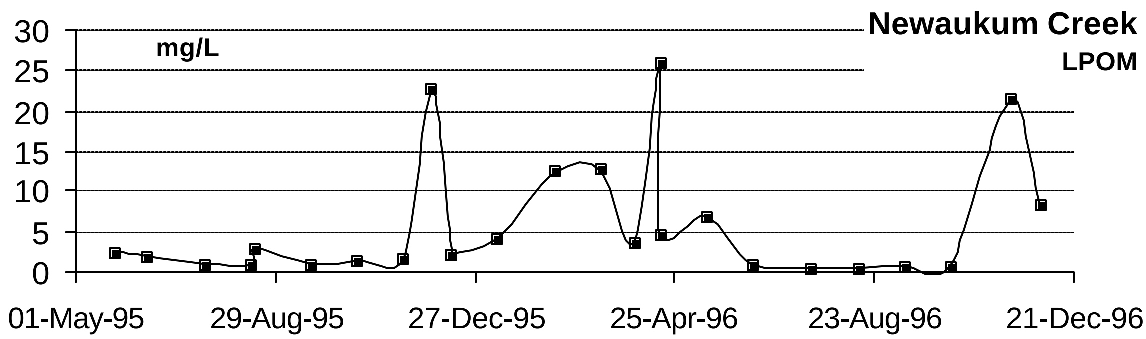


Figure 102: LPOM Newaukum Creek: May 25, 1995 – Nov 1996

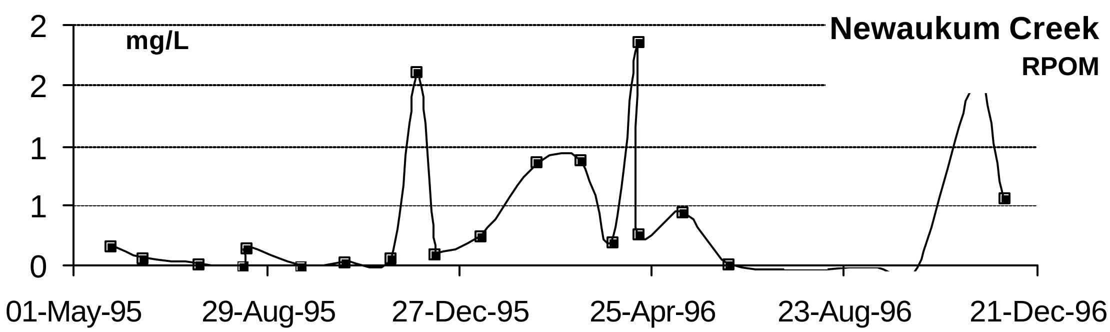


Figure 103: RPOM Newaukum Creek: May 25, 1995 – Nov 1996

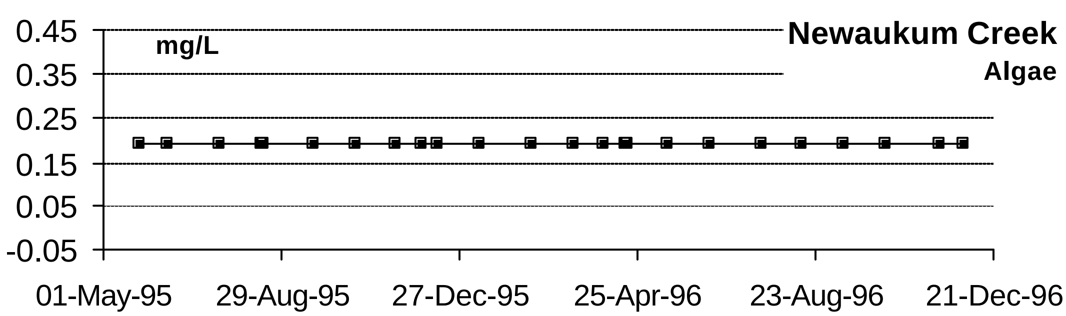


Figure 104: Algae Newaukum Creek: May 25, 1995 – Nov 1996

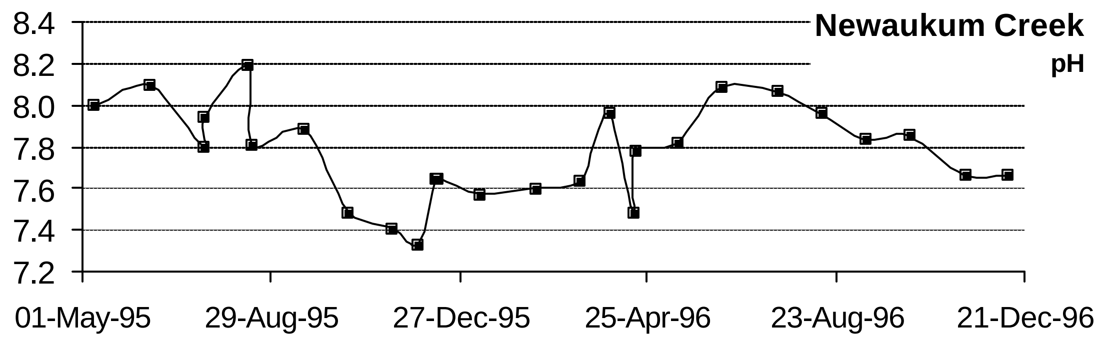


Figure 105: pH Newaukum Creek: May 25, 1996 - Nov 1996

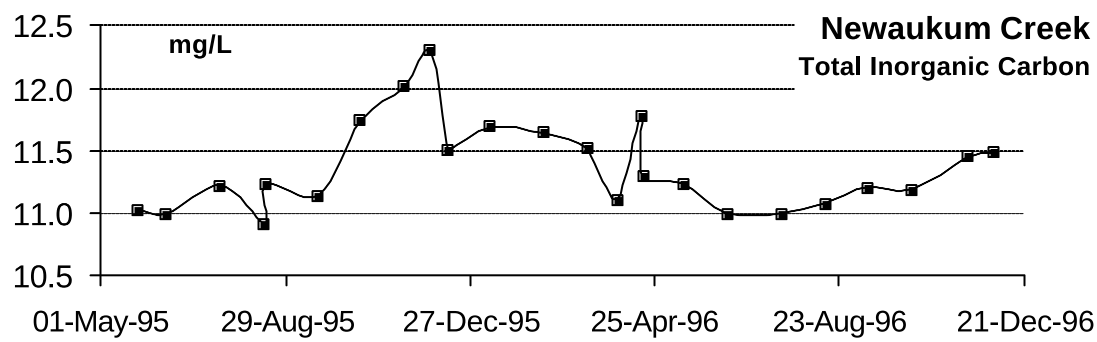


Figure 106: TIC Newaukum Creek: May 25, 1995 – Nov 1996

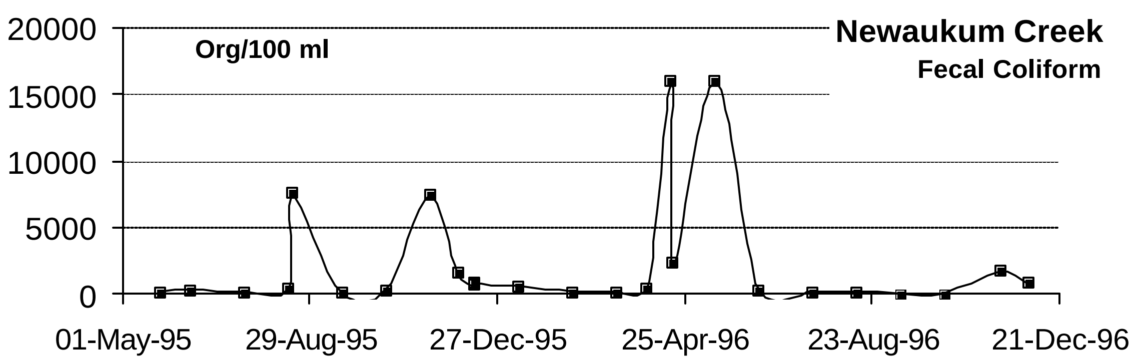


Figure 107: Fecal Coliform Newaukum Creek: May 25, 1995 - Nov 1996

April 2001 – July 2002

Flow

The USGS gage (12108500) on Newaukum Creek was used for this model calibration period. Figure 108 shows the data for the model calibration period. The complete data set is included in Appendix A.

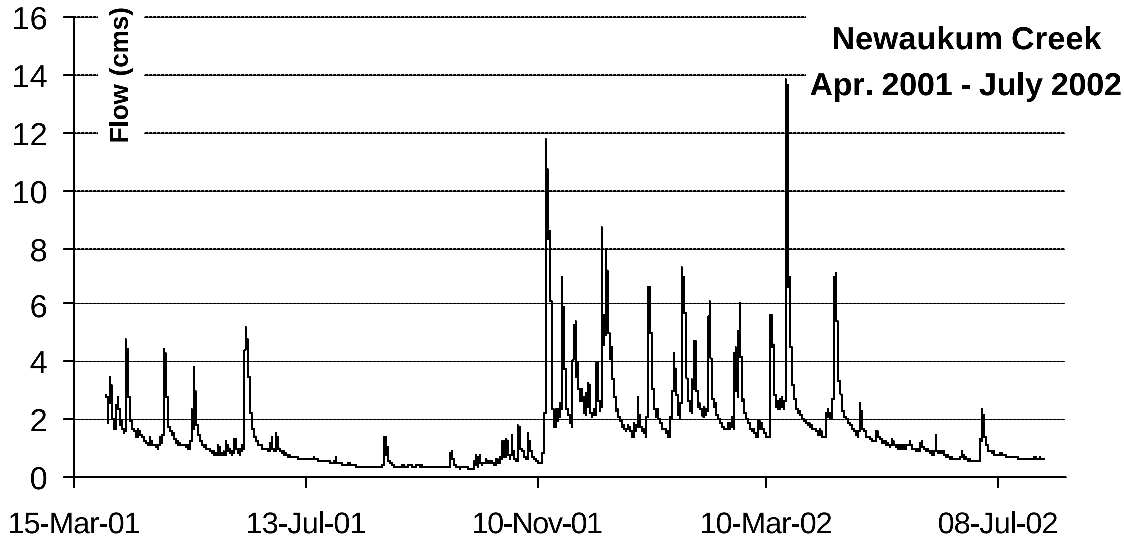


Figure 108: Newaukum Creek Flow: Apr 2001 – July 2002

Temperature

The Green-Duwamish Water Quality Assessment study (Site GRT09) recorded temperatures on the lower Newaukum River from July 23, 2001 to October 25, 2001, and from March 14, 2002 through the end of the model run period. There were two data gaps to be filled: From April 1, 2001 through July 23, 2001 and from October 26, 2001 through March 14, 2002. The data gaps were filled by correlating Crisp Creek temperatures (Site 0321) with Newaukum Creek temperature data using the following equation:

Newaukum Creek temperature = (1.63)(Crisp Creek temperature) - 6.21

Figure 109 shows the temperature correlation between the sites, Figure 110 compares correlated values to actual data from Newaukum Creek, and Figure 111 shows the temperature record for this calibration period with correlated values included.

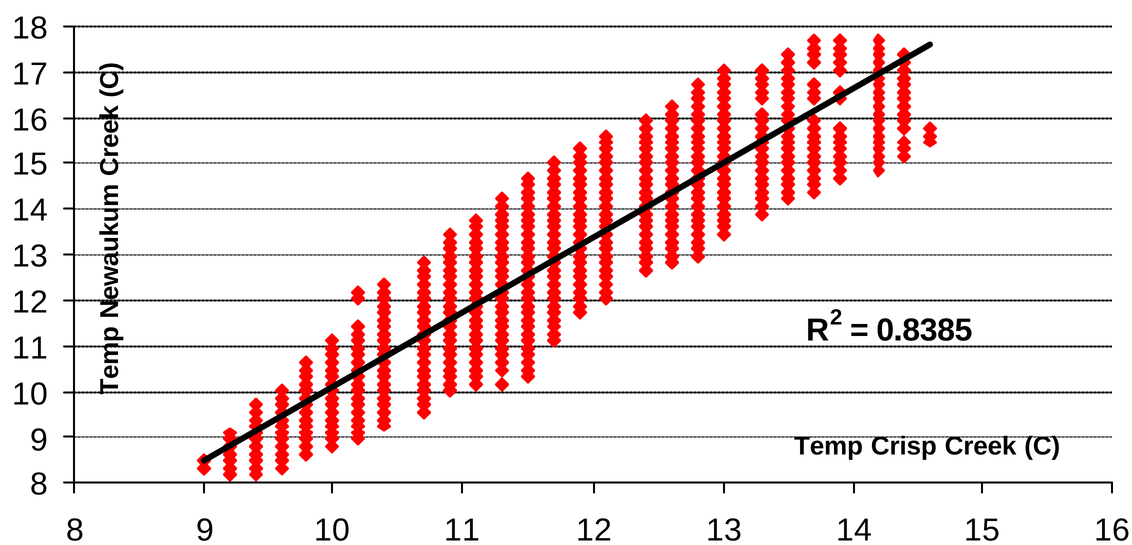


Figure 109: Correlation between Crisp Creek and Newaukum Creek Temperature

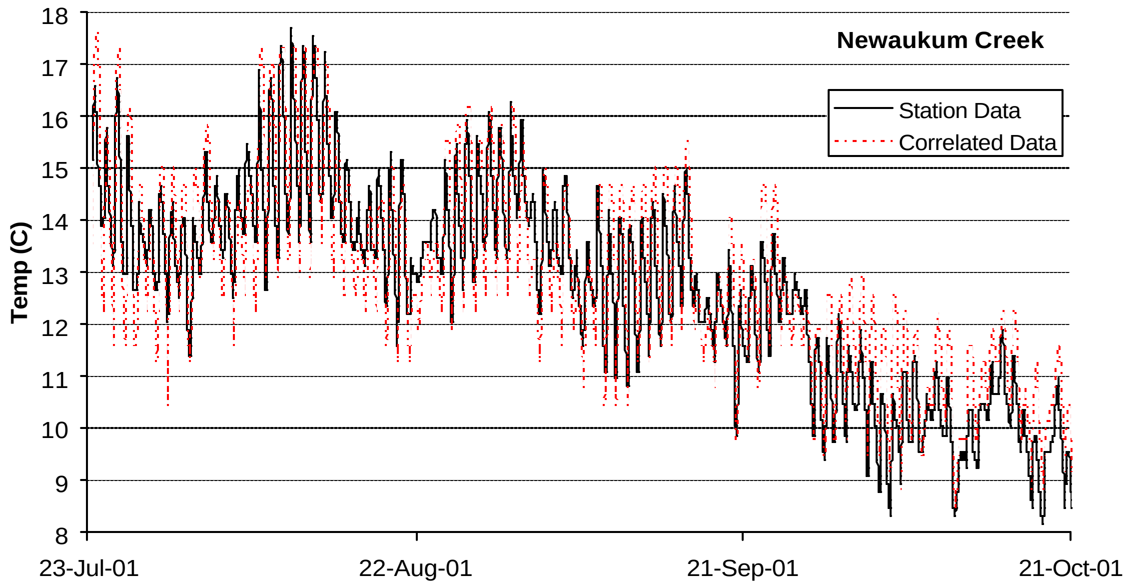


Figure 110: Station versus correlated data, 2001-2002

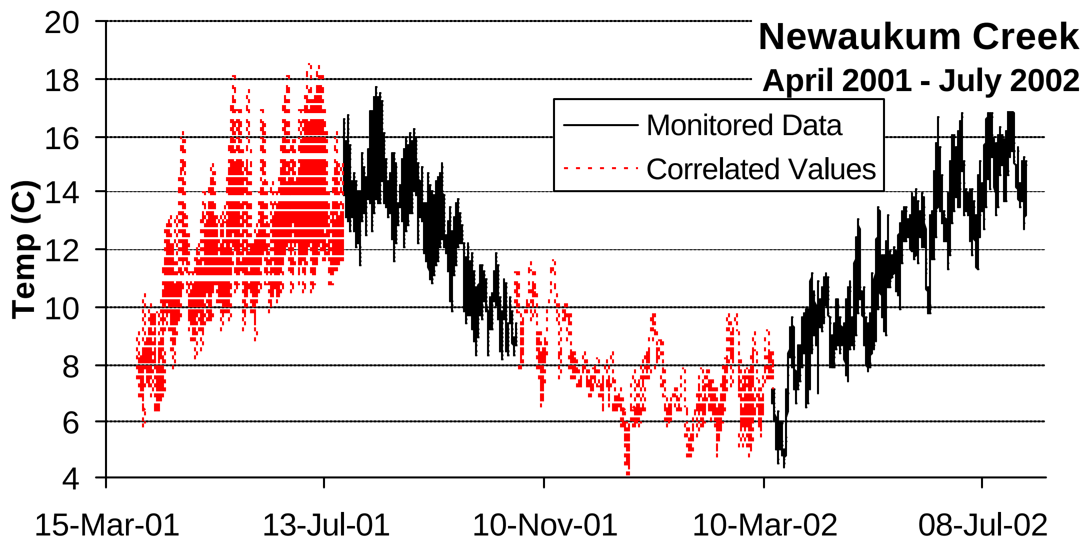


Figure 111: Newaukum Creek Temperature: Apr 2001 – July 2002

Water Quality

King County provided water quality samples on Newaukum Creek from 1995 to 2002 (Locator 0322) for all water quality constituents except chlorophyll a. Figure 112 through Figure 126 show the water quality conditions for the model calibration period. Data for the complete time period are included in Appendix A See Appendix D for procedures used in developing the water quality tributary condition, including filling data gaps.

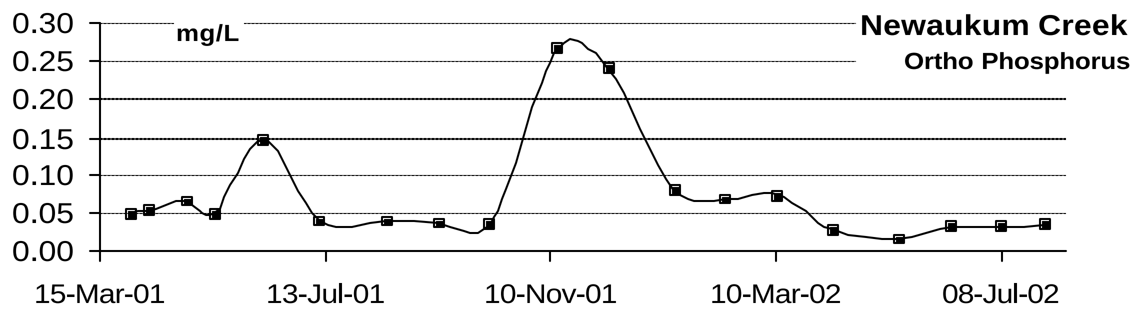


Figure 112: Ortho phosphorus Newaukum Creek: Apr 2001 – July 2002

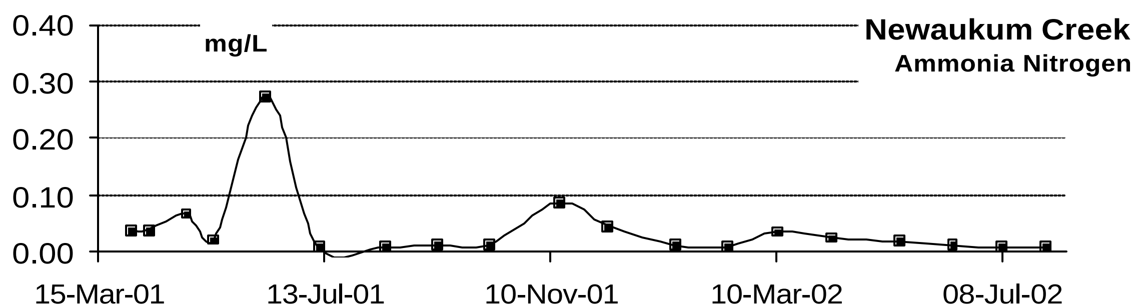


Figure 113: Ammonia Newaukum Creek: Apr 2001 – July 2002

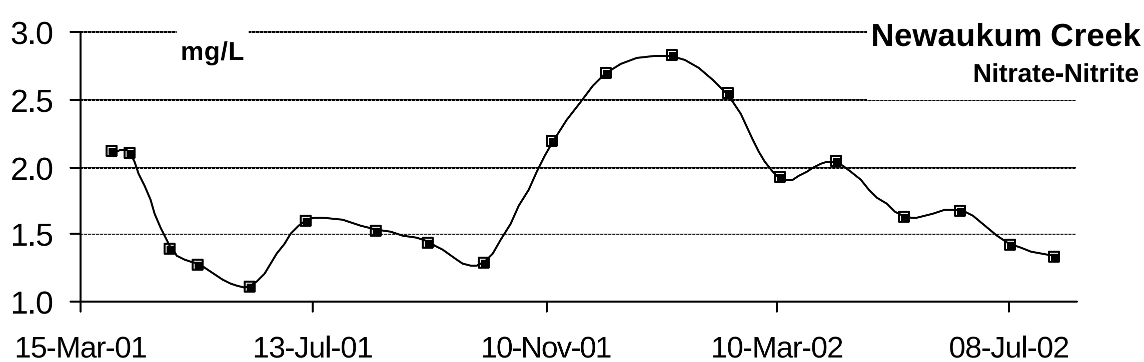


Figure 114: Nitrate-Nitrite Newaukum Creek: Apr 2001 – July 2002

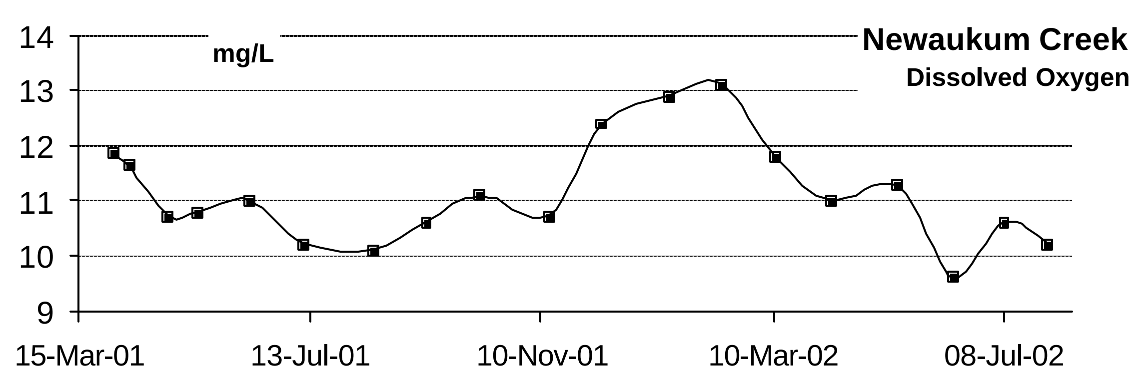


Figure 115: DO Newaukum Creek: Apr 2001 – July 2002

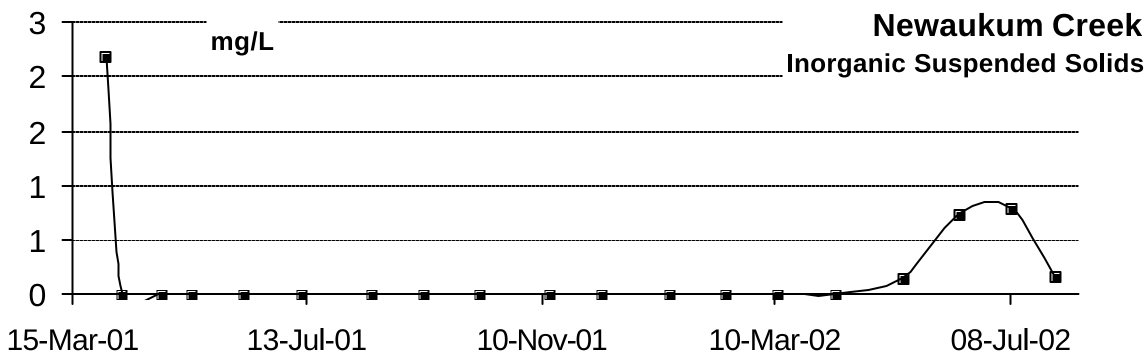


Figure 116: ISS Newaukum Creek: Apr 2001 – July 2002

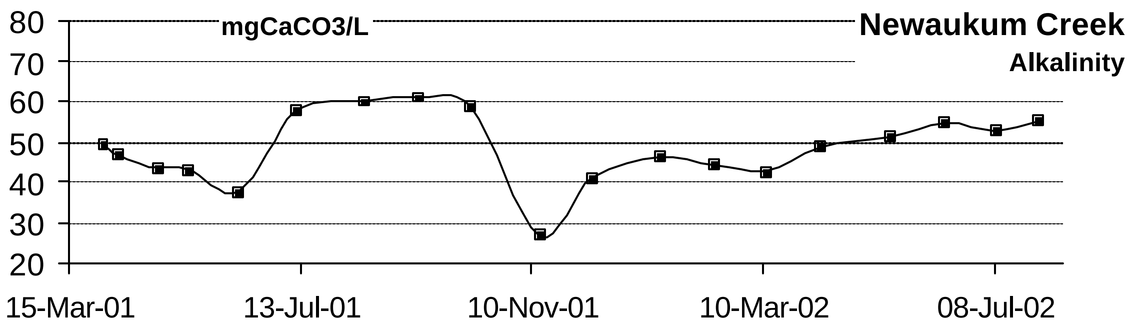


Figure 117: Alkalinity Newaukum Creek: Apr 2001 – July 2002

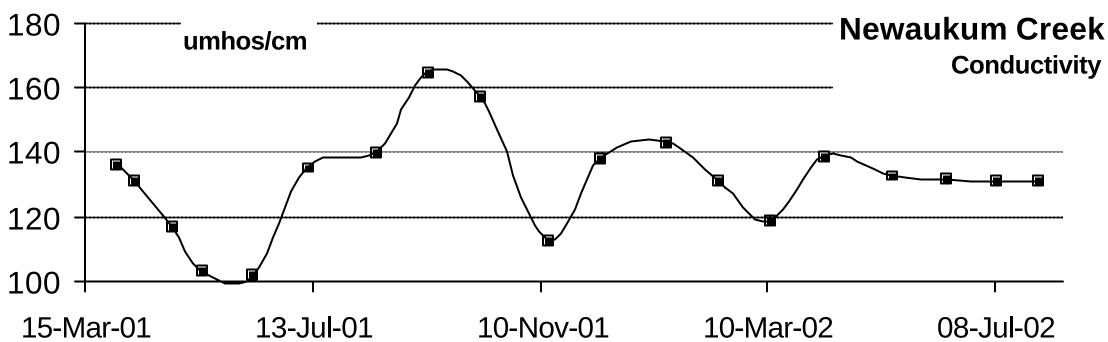


Figure 118: Conductivity Newaukum Creek: Apr 2001 – July 2002

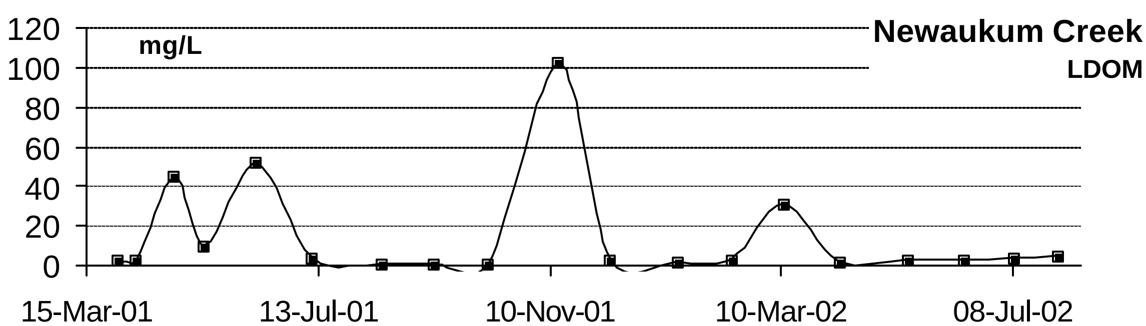


Figure 119: LDOM Newaukum Creek: Apr 2001 – July 2002

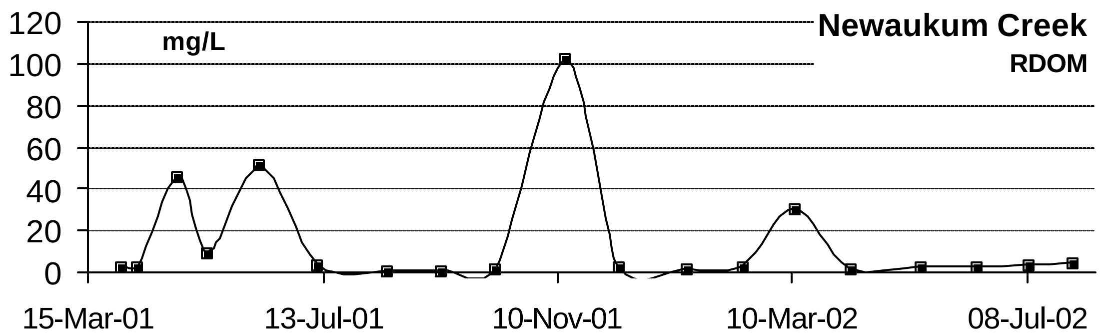


Figure 120: RDOM Newaukum Creek: Apr 2001 – July 2002

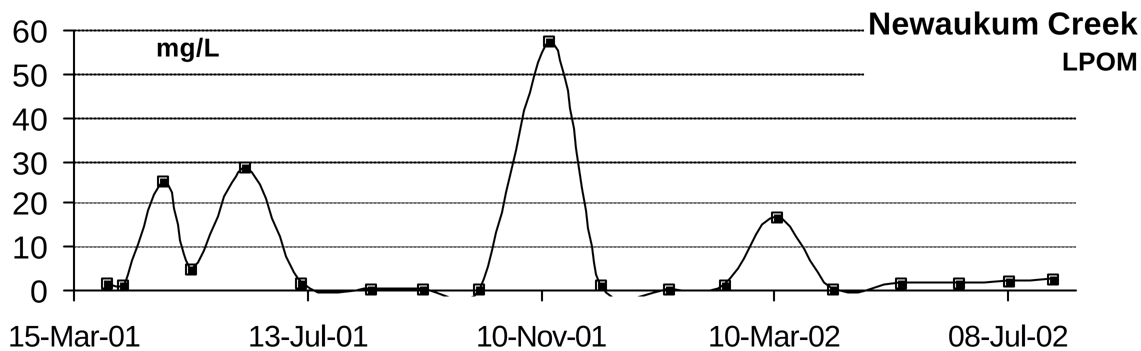


Figure 121: LPOM Newaukum Creek: Apr 2001 – July 2002

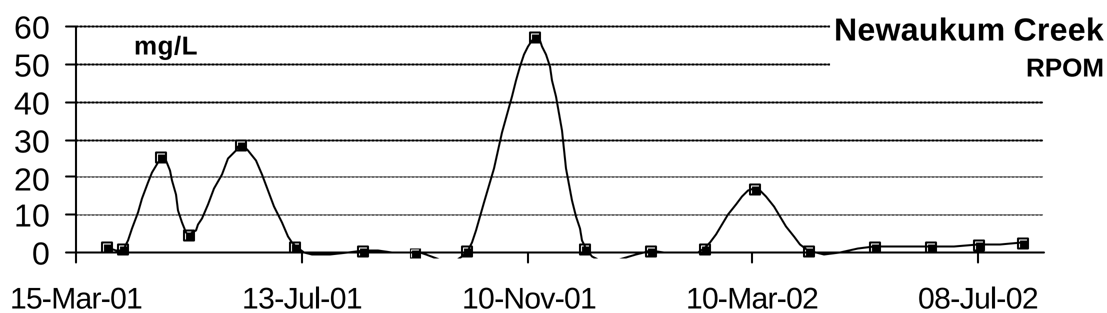


Figure 122: RPOM Newaukum Creek: Apr 2001 – July 2002

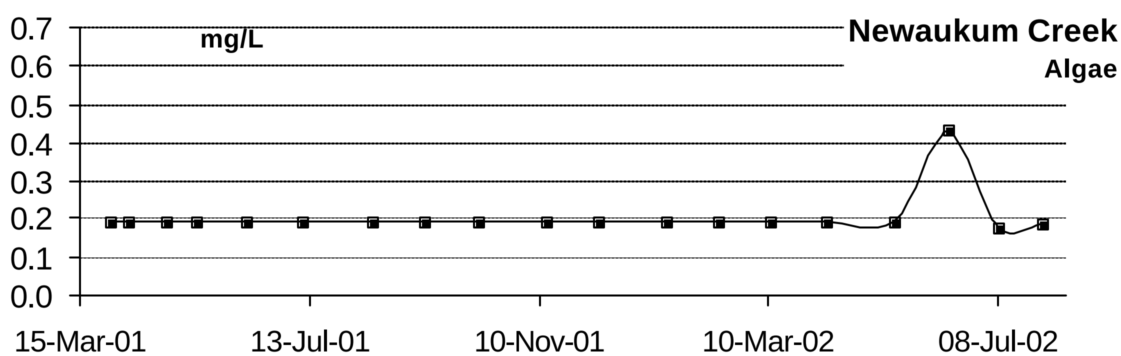


Figure 123: Algae Newaukum Creek: Apr 2001 – July 2002

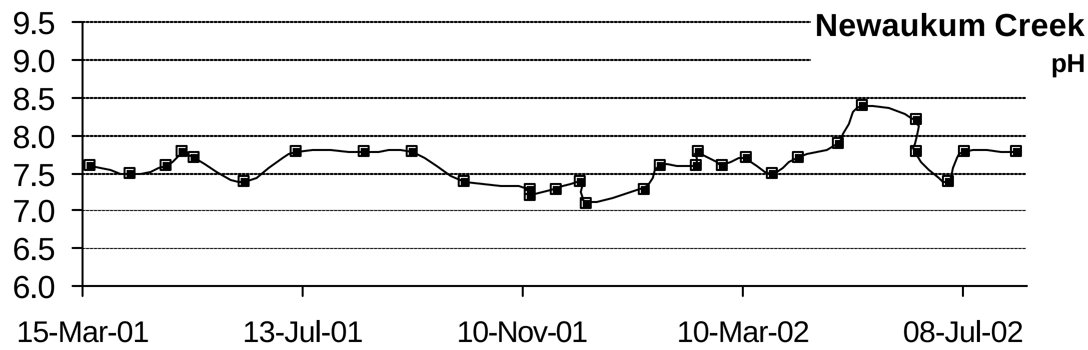


Figure 124: pH Newaukum Creek: Apr 2001 - July 2002

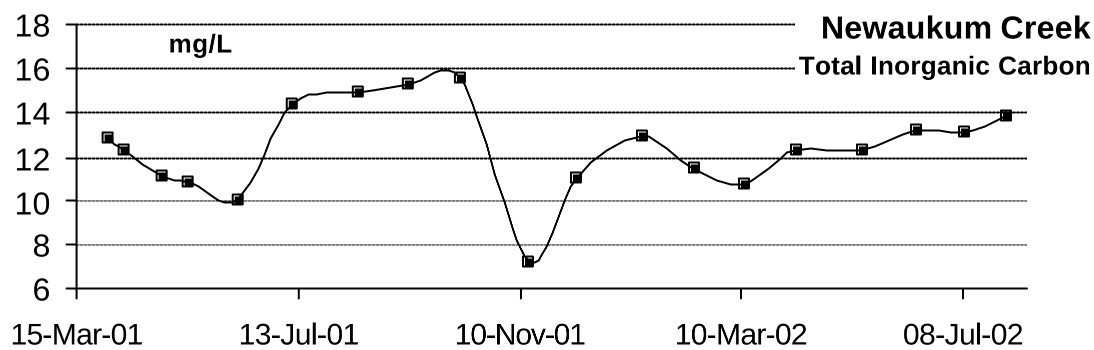


Figure 125: TIC Newaukum Creek: Apr 2001 – July 2002

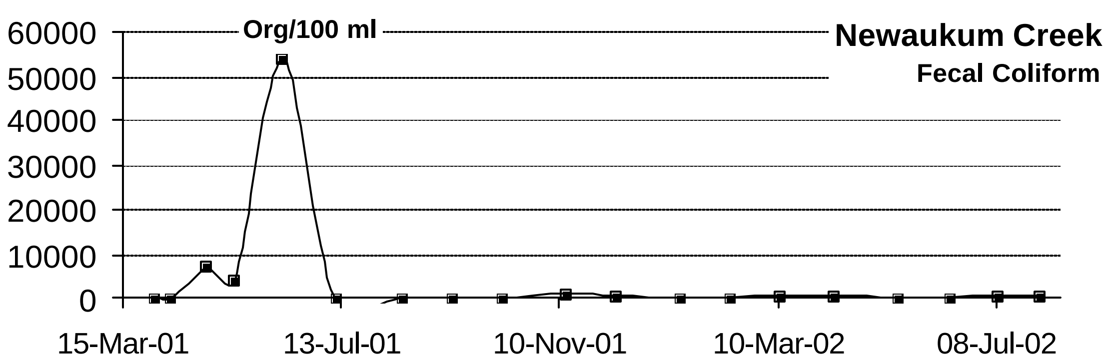


Figure 126: Fecal Coliform Newaukum Creek: Apr 2001 - July 2002

2.5.2 Crisp Creek

Crisp Creek enters the Green River approximately eight km downstream from Flaming Geyser State Park, at River Mile 40.4. King County monitors flow, temperature, and water quality at a fish hatchery approximately 3.0 km upstream of the confluence with the Green River.

May 25, 1995 – November 1996

Flow

King County gage #40d records flow every 15-minutes on Crisp Creek approximately 3.0 km upstream from the confluence with the Green River. Flow data for this gage were provided by King County from August 25, 1994 to March 18, 2003. Figure 127 is a graph showing flow for the model period. The entire data set are included in Appendix A.

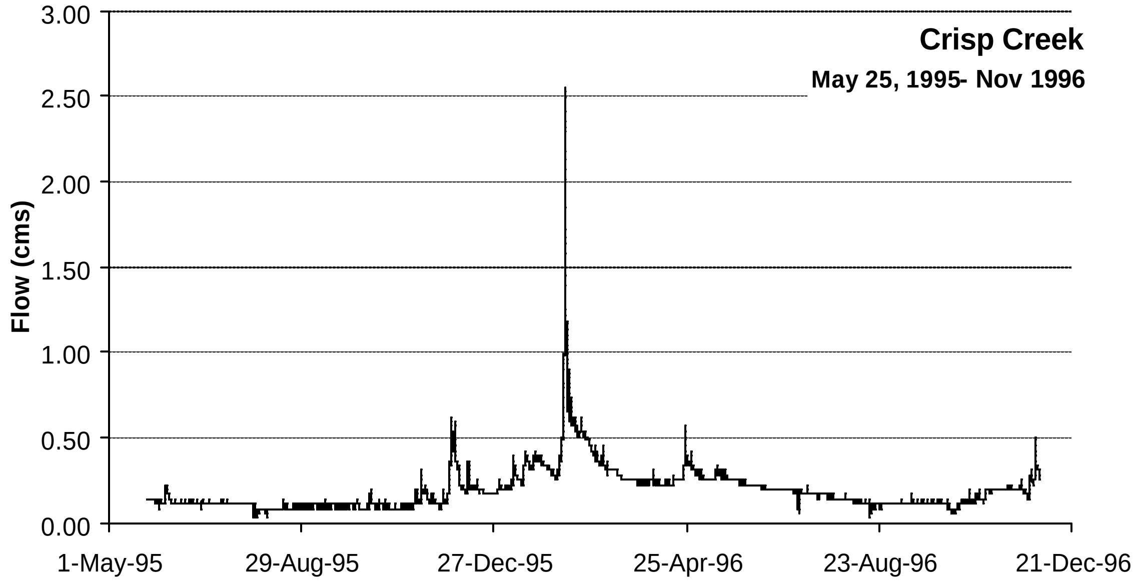


Figure 127: Crisp Creek Flow: May 25, 1995 – Nov 1996

Temperature

King County station #40d records temperature at 15-minute intervals, but did not begin monitoring until October 10, 1997. Therefore, compelted tempearture data was needed for this model run period. Comparing temperatures recorded on Big Soos Creek with temperatures from Crisp Creek from October 1997 to June 1999, the following correlation was obtained:

$$\text{Crisp Creek Temp} = 0.5731(\text{Big Soos Temp}) + 3.7364$$

Figure 128 shows the temperature correlation between the two sites, Figure 129 compares correlated values to monitored data from Crisp Creek, and Figure 130 shows the correlated temperature values for this model run period .

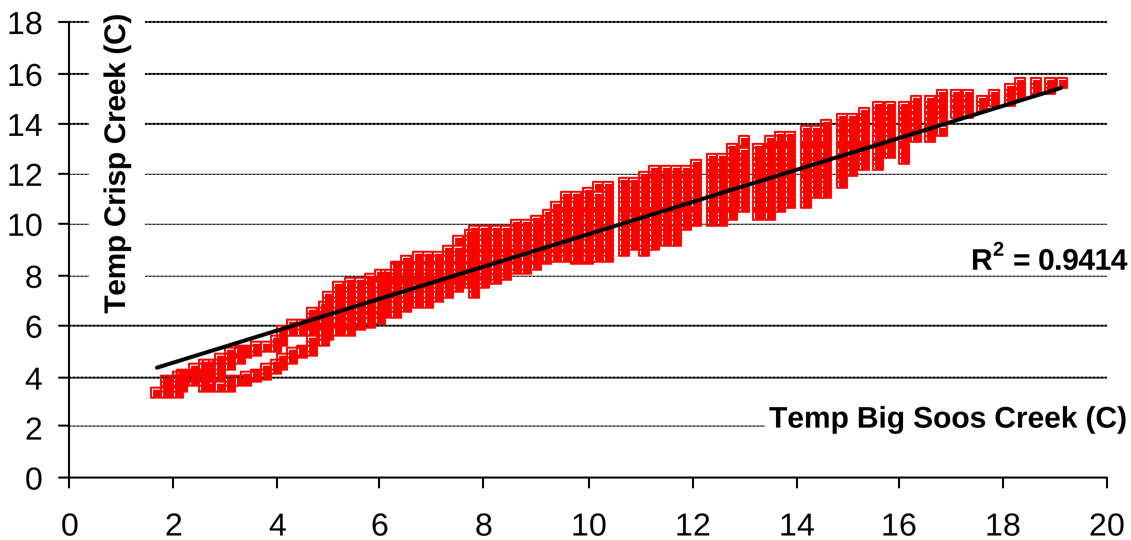


Figure 128: Correlation between Big Soos Temperature and Crisp Creek

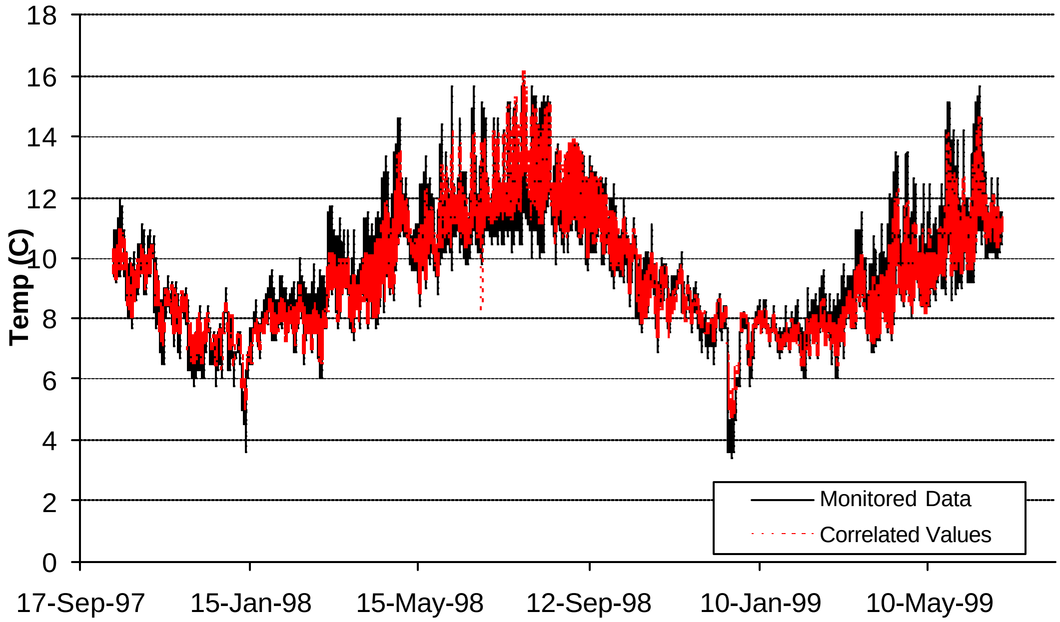


Figure 129: Crisp Creek: Station versus correlated data, 1995-1996

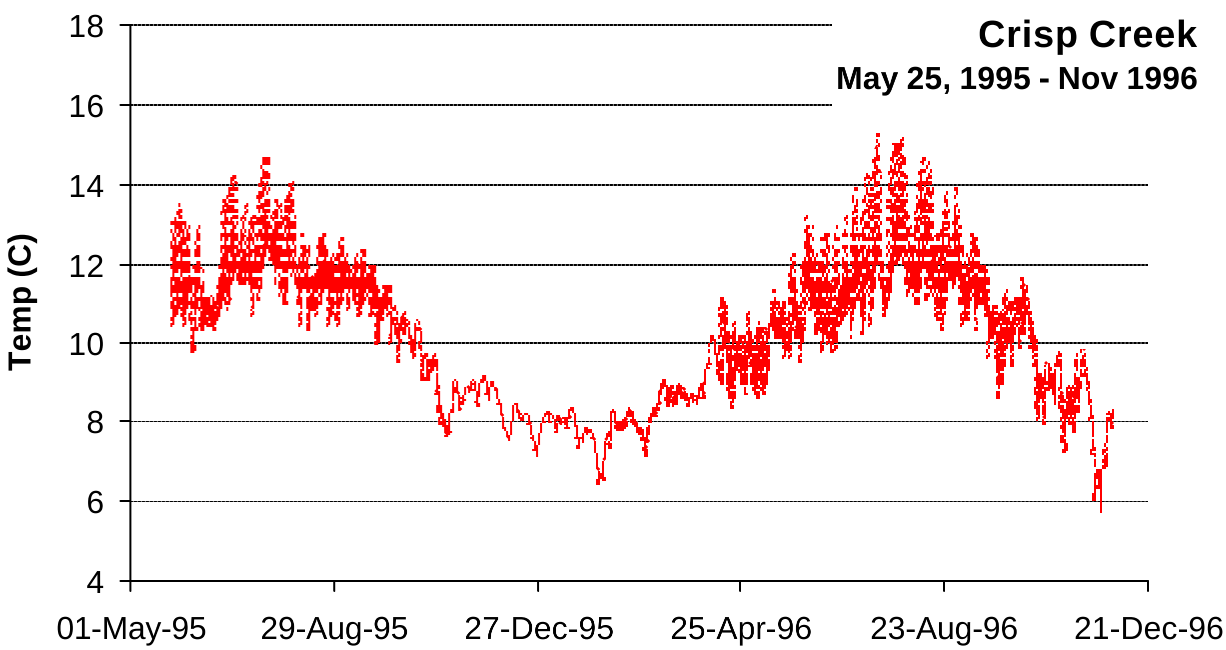


Figure 130: Crisp Creek Temperature: May 25, 1995 – Nov 1996

Water Quality

King County has provided water quality samples on Crisp Creek from 1995 to 2002 (Locator 0322). Monthly grab samples are available for the model calibration period for all constituents except chlorophyll a and alkalinity. See Appendix D for procedures used in developing the water quality tributary condition, including filling data gaps, and Figure 131 through Figure 145 for the constituents for the model calibration period.

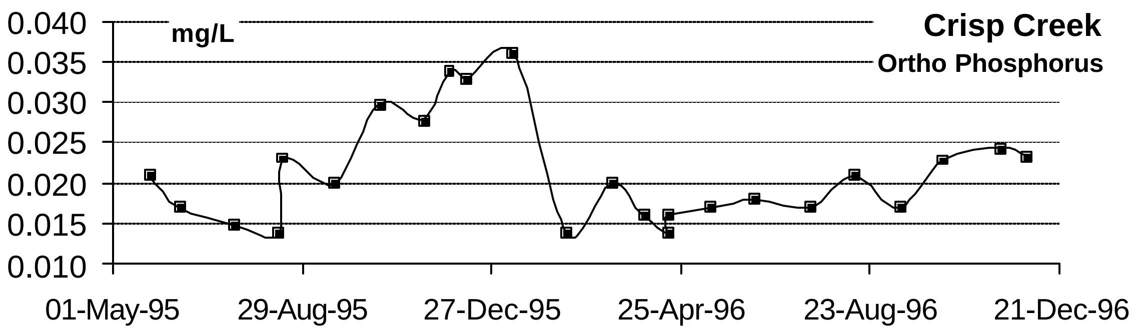


Figure 131: Ortho phosphorus Crisp Creek: May 25, 1995 – Nov 1996

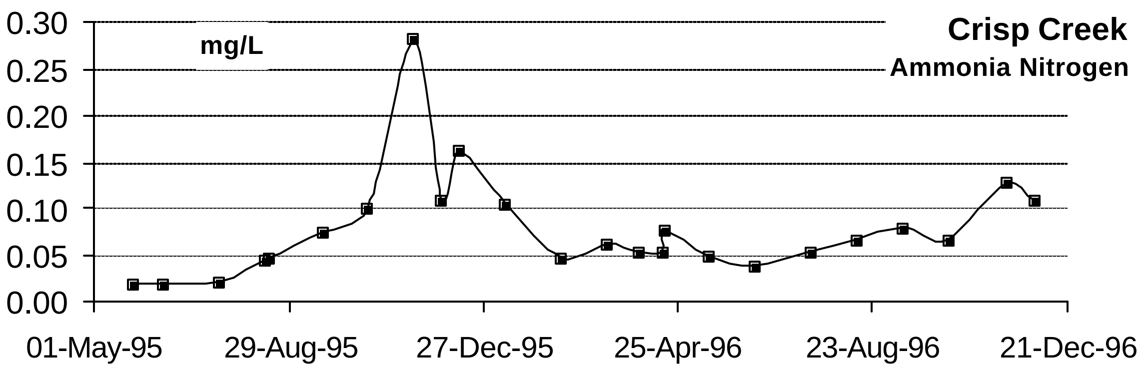


Figure 132: Ammonia Crisp Creek: May 25, 1995 – Nov 1996

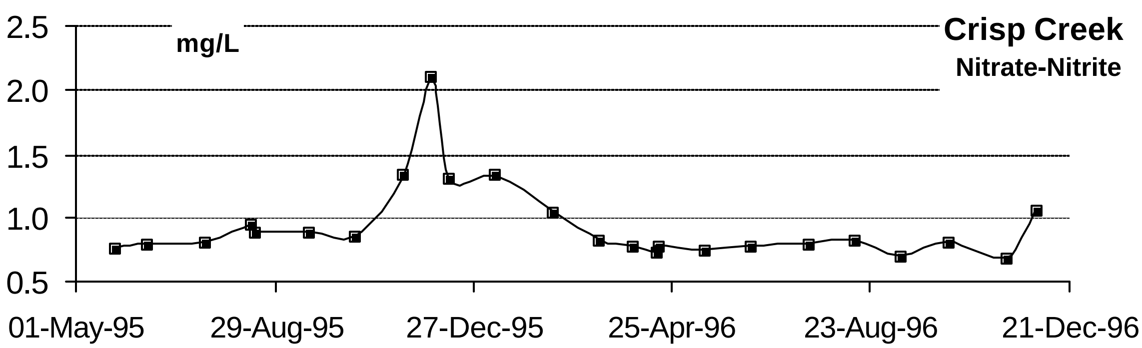


Figure 133: Nitrate-Nitrite Crisp Creek: May 25, 1995 – Nov 1996

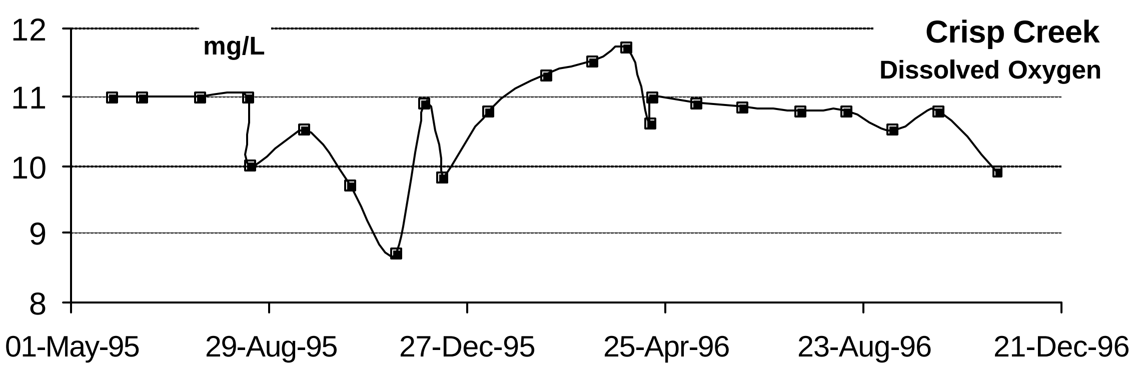


Figure 134: DO Crisp Creek: May 25, 1995 – Nov 1996

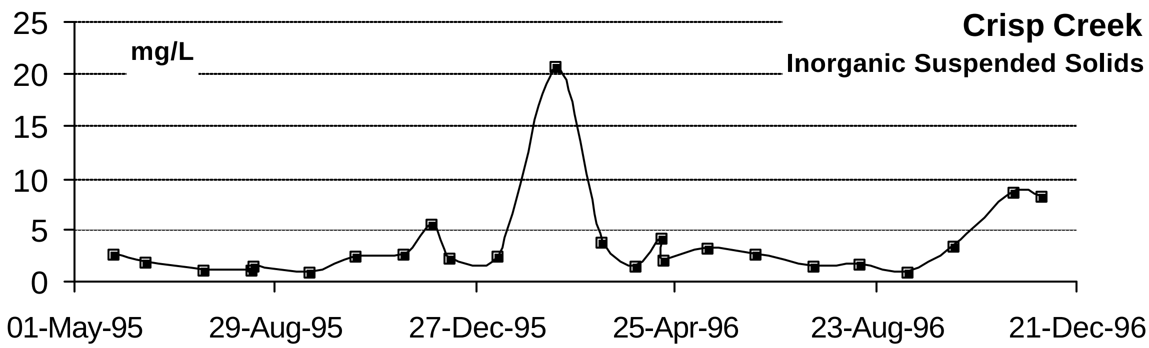


Figure 135: ISS Crisp Creek: May 25, 1995 – Nov 1996

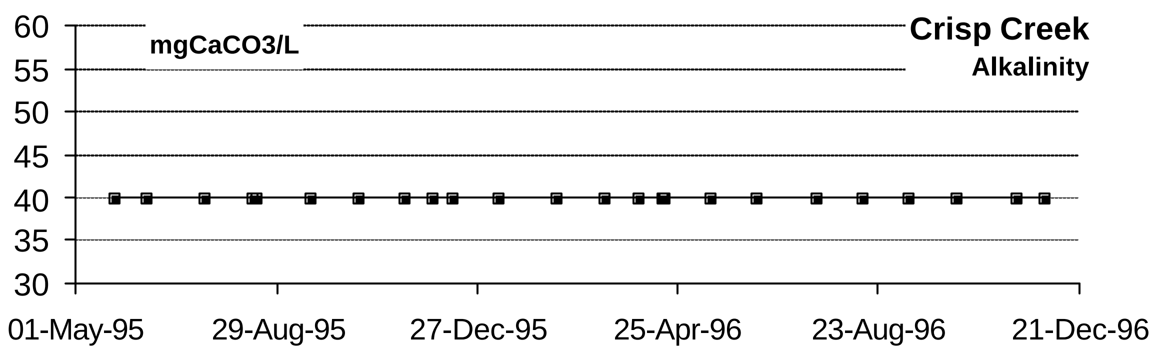


Figure 136: Alkalinity Crisp Creek: May 25, 1995 - Nov 1996

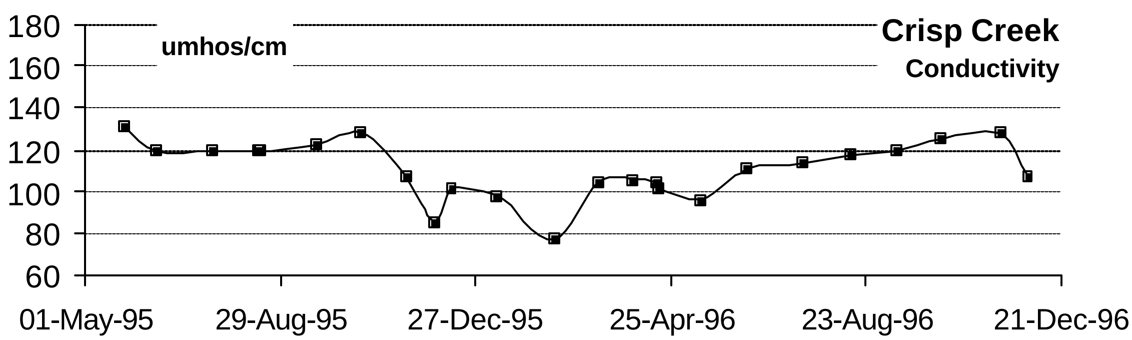


Figure 137: Conductivity Crisp Creek: May 25, 1995 – Nov 1996

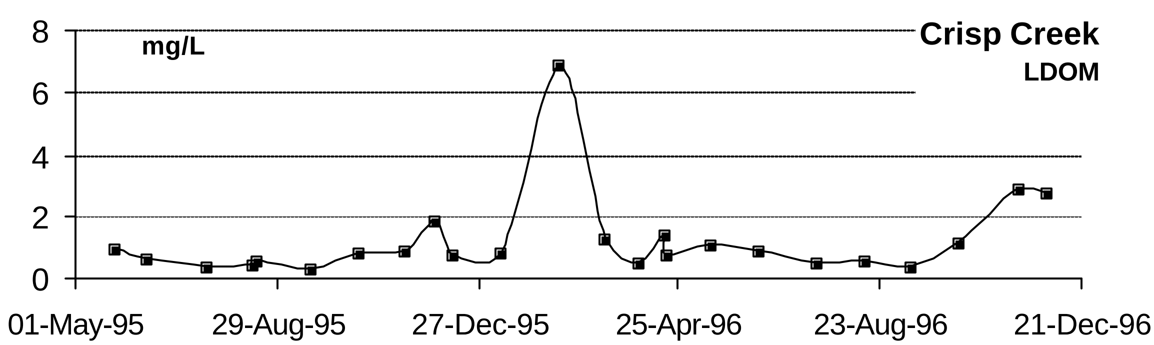


Figure 138: LDOM Crisp Creek: May 25, 1995 – Nov 1996

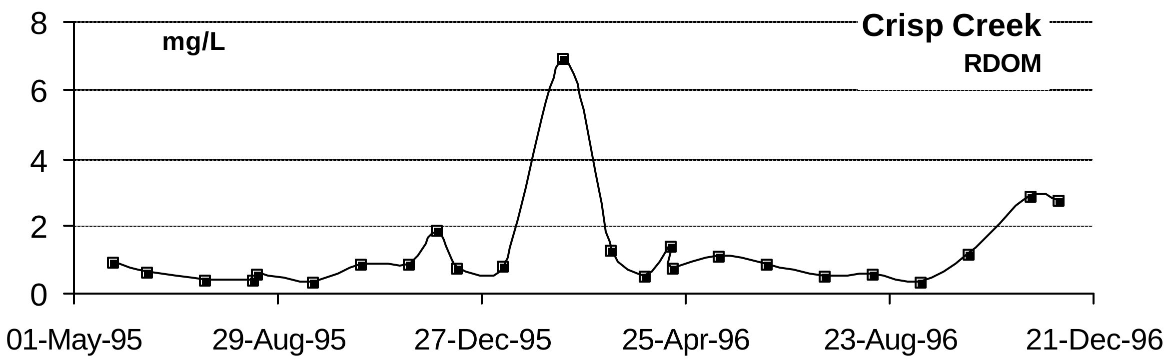


Figure 139: RDOM Crisp Creek: May 25, 1995 – Nov 1996

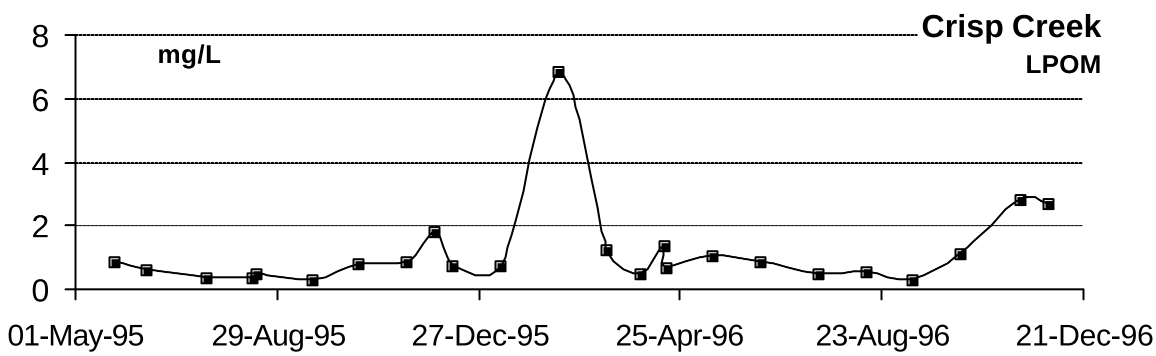


Figure 140: LPOM Crisp Creek: May 25, 1995 – Nov 1996

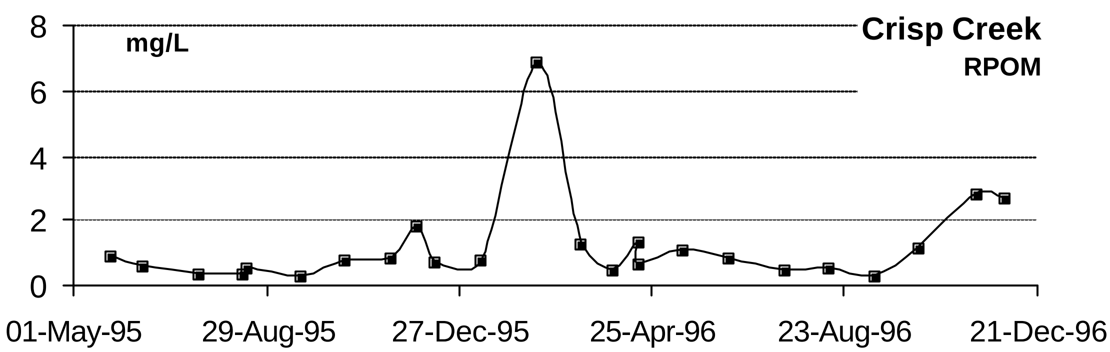


Figure 141: RPOM Crisp Creek: May 25, 1995 – Nov 1996

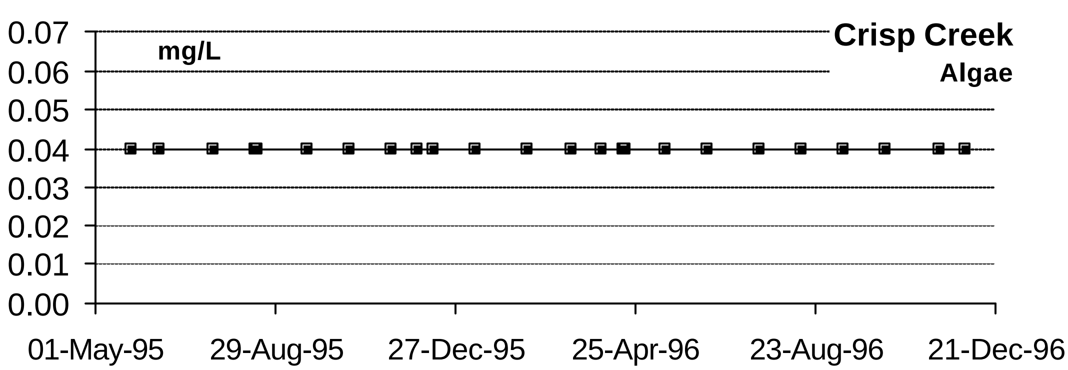


Figure 142: Algae Crisp Creek: May 25, 1995 – Nov 1996

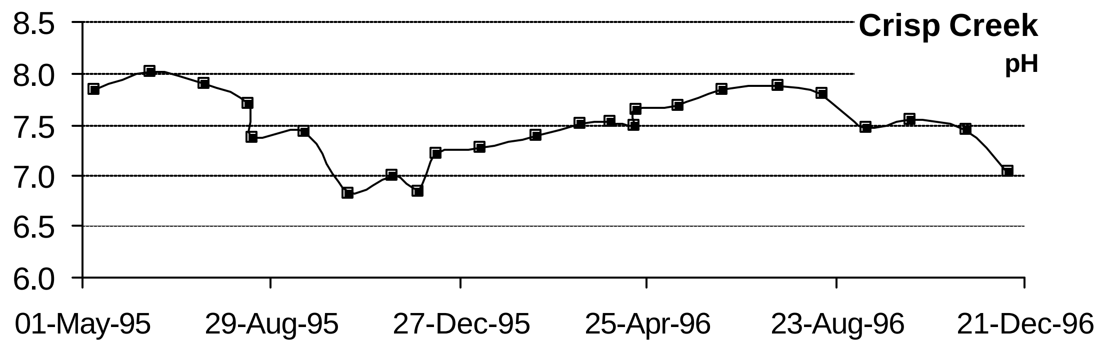


Figure 143: pH Crisp Creek: May 25, 1995 - Nov 1996

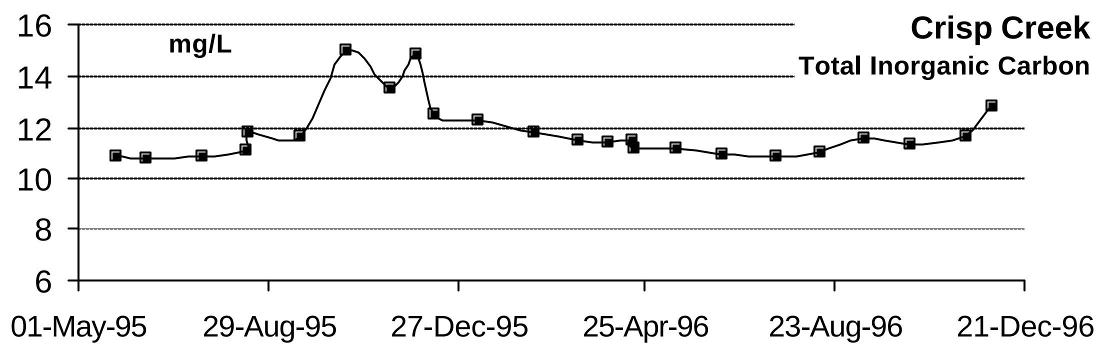


Figure 144: TIC Crisp Creek: May 25, 1995 – Nov 1996

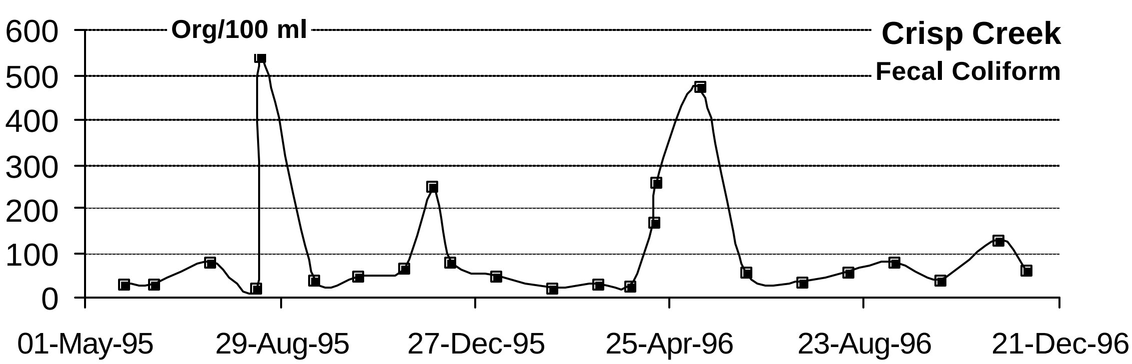


Figure 145: Fecal Coliform Crisp Creek: May 25, 1995 - Nov 1996

April 2001 – July 2002

Flow

King County gage #40d has flow data for this model calibration period in 15-minute intervals. The entire data set are included in Appendix A, and Figure 146 is a graph showing flow for the model calibration period.

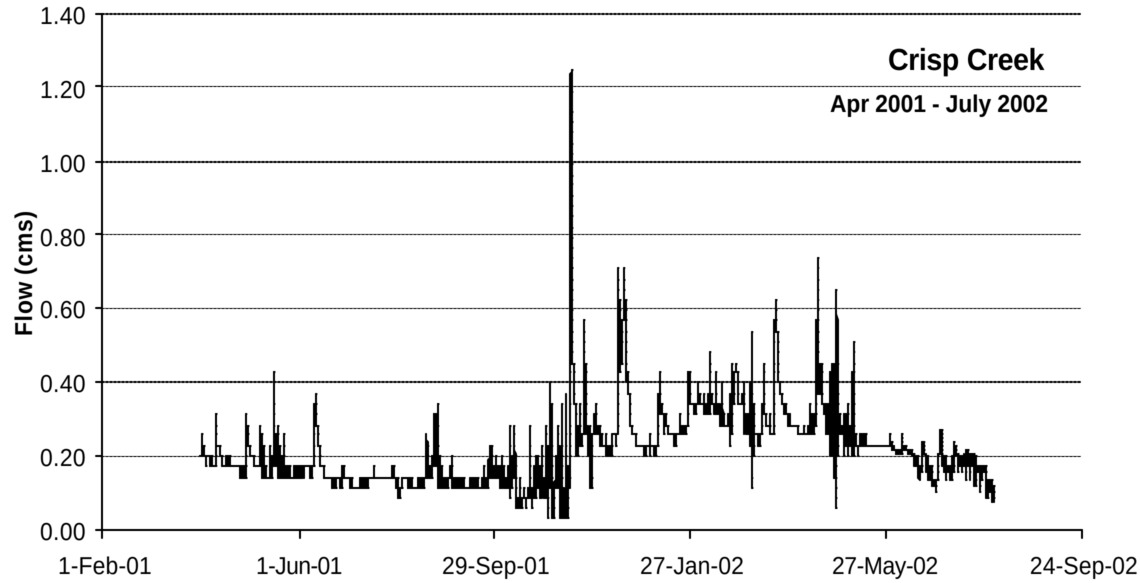


Figure 146: Crisp Creek Flow: Apr 2001 – July 2002

Temperature

Station #40d also recorded temperature for this model calibration period. Figure 147 shows the data for the model simulation period.

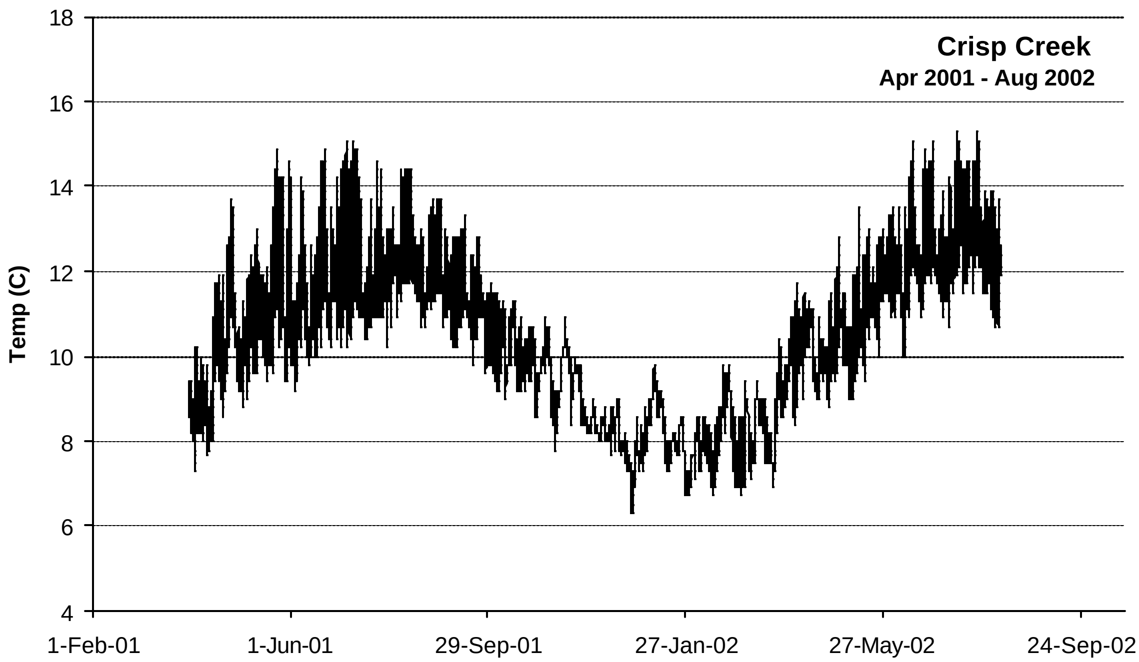


Figure 147: Crisp Creek Temperature: Apr 2001 – July 2002

Water Quality

King County has provided water quality samples on Crisp Creek from 1995 to 2002 (Locator 0321). Data are available for all constituents except chlorophyll a for the model calibration period. Figure 148 through Figure 162 shows data for the model calibration period. See Appendix D for procedures used in assembling the water quality data, including estimating missing data.

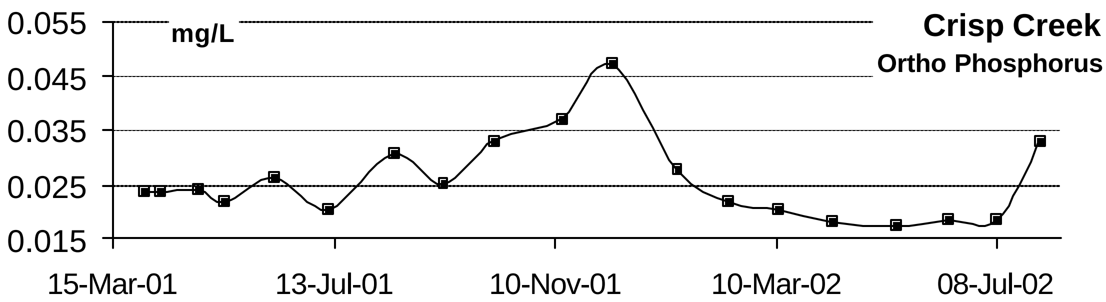


Figure 148: Ortho phosphorus Crisp Creek: Apr 2001–July 2002

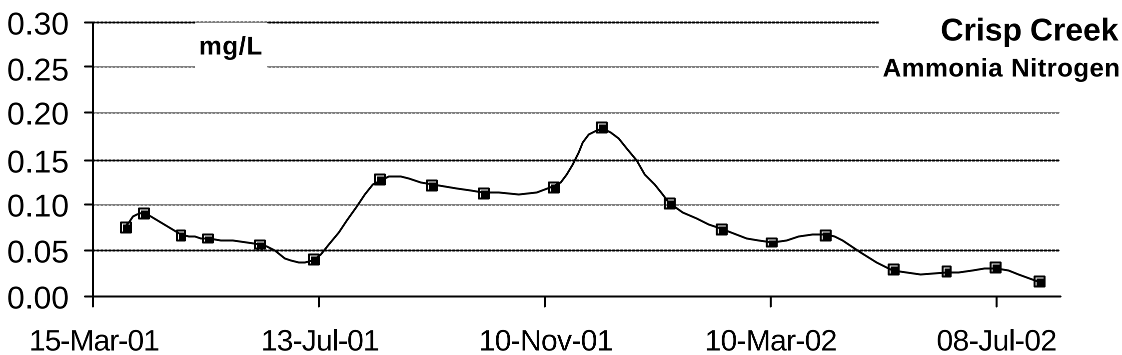


Figure 149: Ammonia Crisp Creek: Apr 2001–July 2002

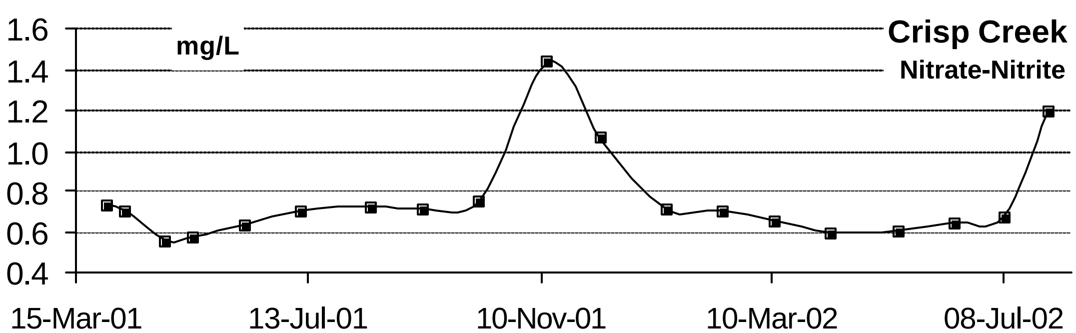


Figure 150: Nitrate-Nitrite Crisp Creek: Apr 2001–July 2002

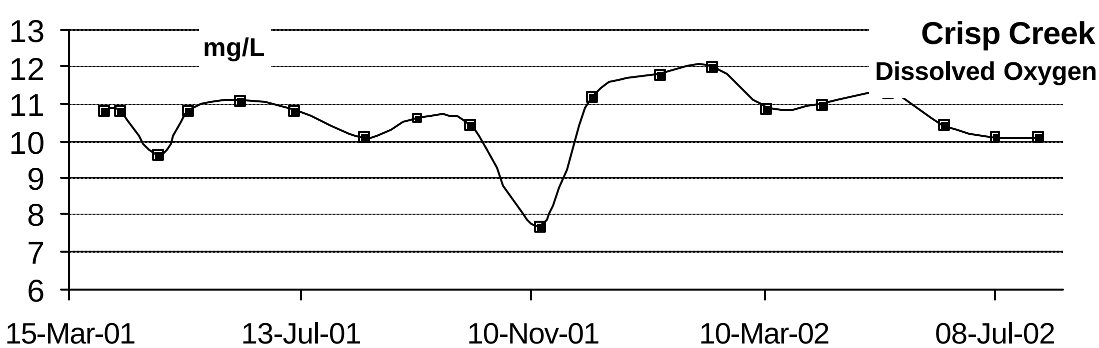


Figure 151: DO Crisp Creek: Apr 2001–July 2002

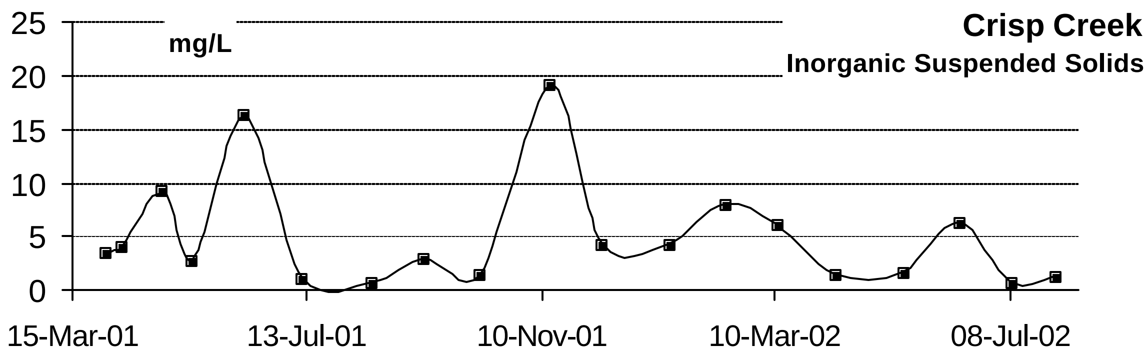


Figure 152: ISS Crisp Creek: Apr 2001–July 2002

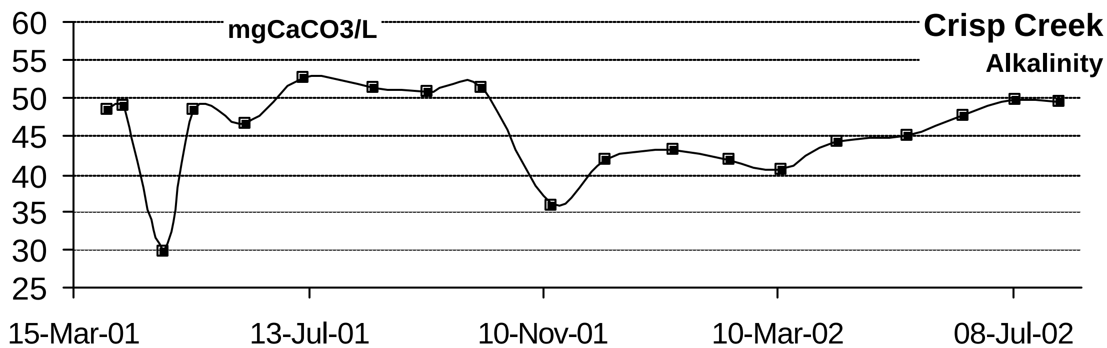


Figure 153: Alkalinity Crisp Creek: Apr 2001–July 2002

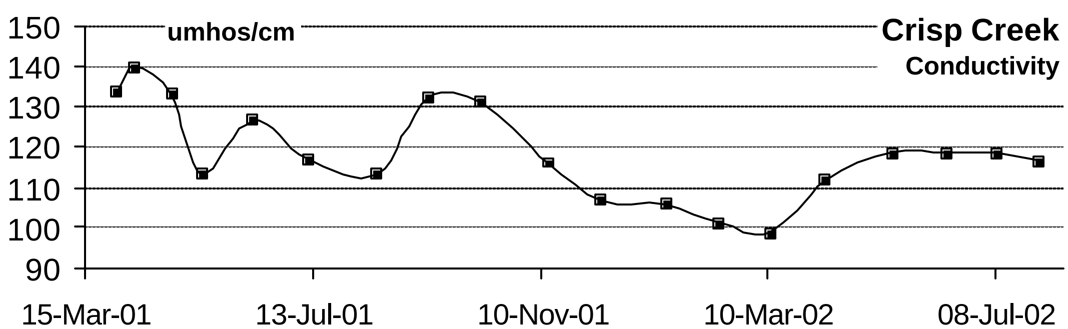


Figure 154: Conductivity Crisp Creek: Apr 2001–July 2002

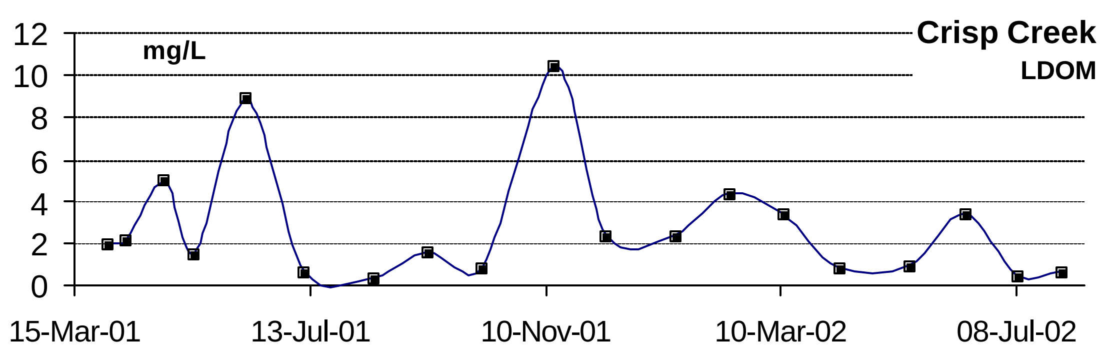


Figure 155: LDOM Crisp Creek: Apr 2001–July 2002

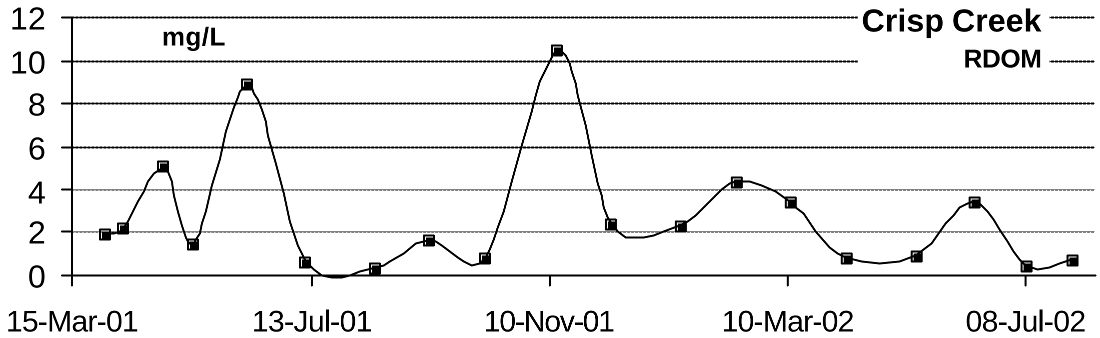


Figure 156: RDOM Crisp Creek: Apr 2001–July 2002

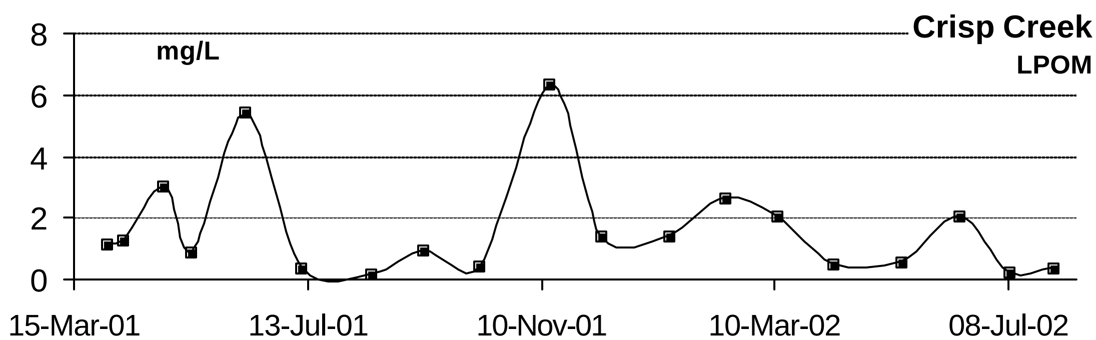


Figure 157: LPOM Crisp Creek: Apr 2001–July 2002

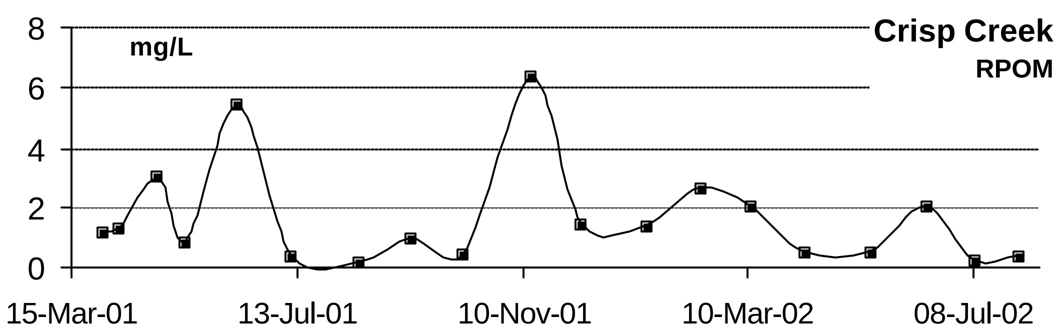


Figure 158: RPOM Crisp Creek: Apr 2001–July 2002

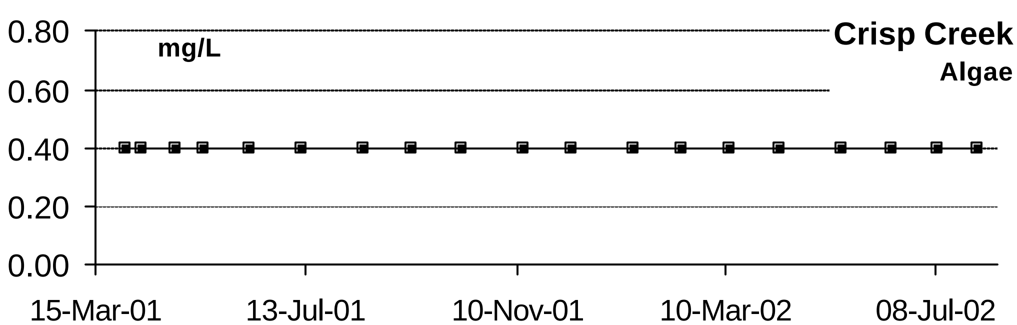


Figure 159: Algae Crisp Creek: Apr 2001–July 2002

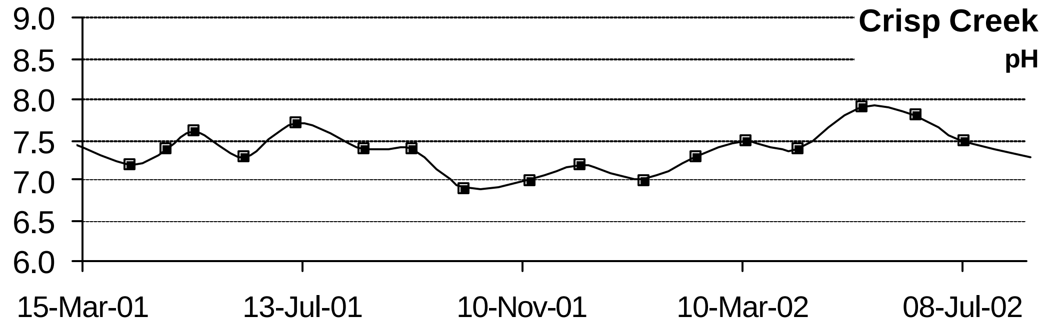


Figure 160: pH Crisp Creek: Apr 2001-July 2002

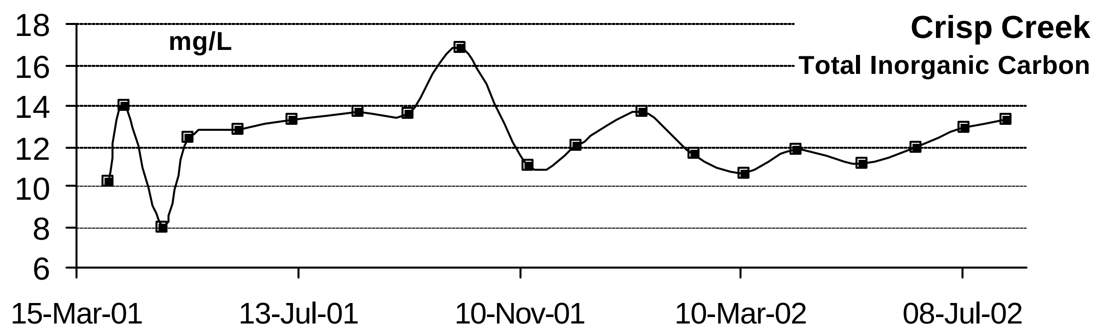


Figure 161: TIC Crisp Creek: Apr 2001–July 2002

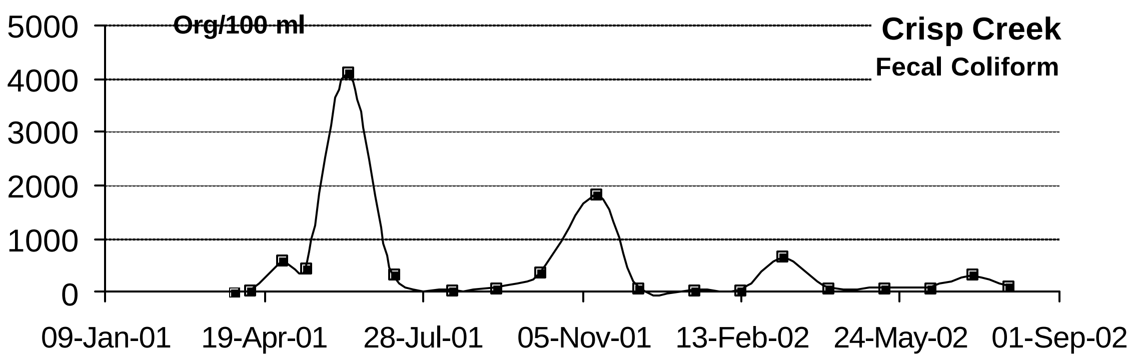


Figure 162: Fecal Coliform Crisp Creek: Apr 2001 - July 2002

2.5.3 Big Soos Creek

Big Soos Creek is the largest tributary contributing flow to the Green River. Big Soos Creek enters Green River at River Mile 33.80. The tributary basin is approximately 17,500 hectares (310,000 acres).

May 25, 1995 – Nov 1996

Flow

Flow data from USGS Gage 12112600 are available in 15-minute intervals from October 1, 1994, to December 31, 2002. The complete data set is included in Appendix A, and Figure 163 shows the flow data for the model simulation period.

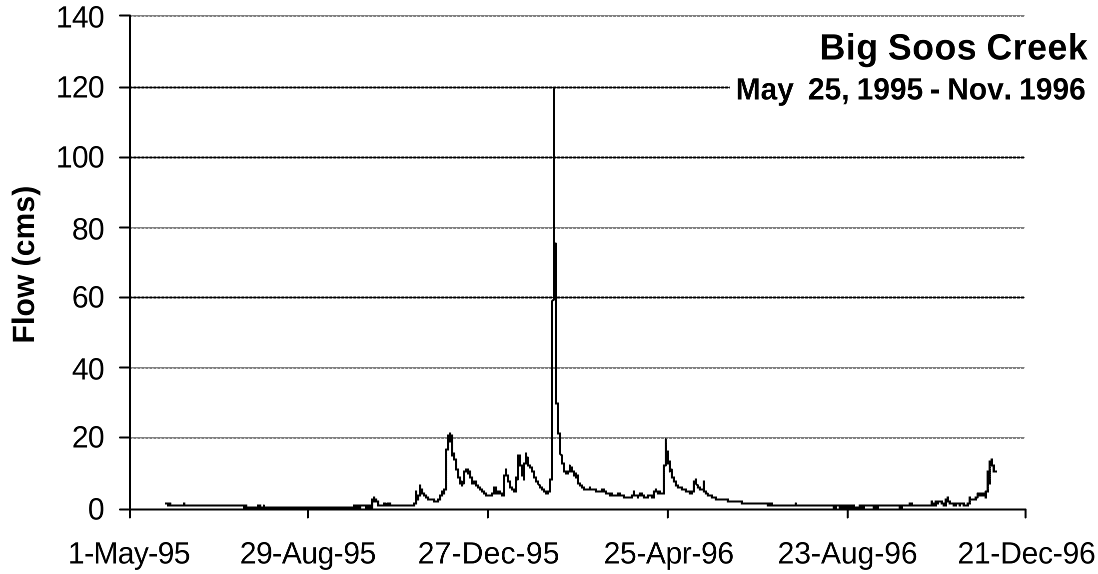


Figure 163: Big Soos Creek Flow: May 25, 1995 – Nov 1996

Temperature

There is one gap in temperature from October 30, 1995 to April 12, 1996. There is little temperature data available during this time period, so to fill this data gap Station BIC, on the Green River near Tukwila, was used. The correlation equation is as follows:

Temperature at Station 54a = (0.5682)(Temperature at Station BIC) + 4.0774

Figure 164 shows the temperature correlation between the two sites, Figure 165 compares correlated values to monitored data from Big Soos Creek, and Figure 166 shows the temperature data for this calibration period with correlated values included. Note that Station 54a records temperature in 15-minute intervals, and Station BIC recorded in half-hour intervals, so the correlated data are also in half-hour intervals.

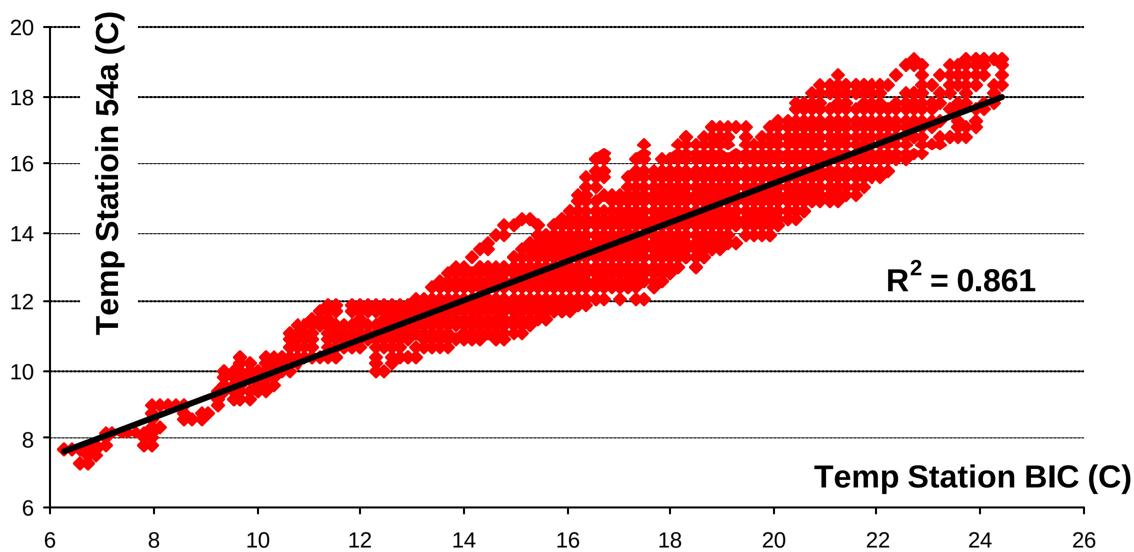


Figure 164: Correlation between Big Soos Creek and Station BIC

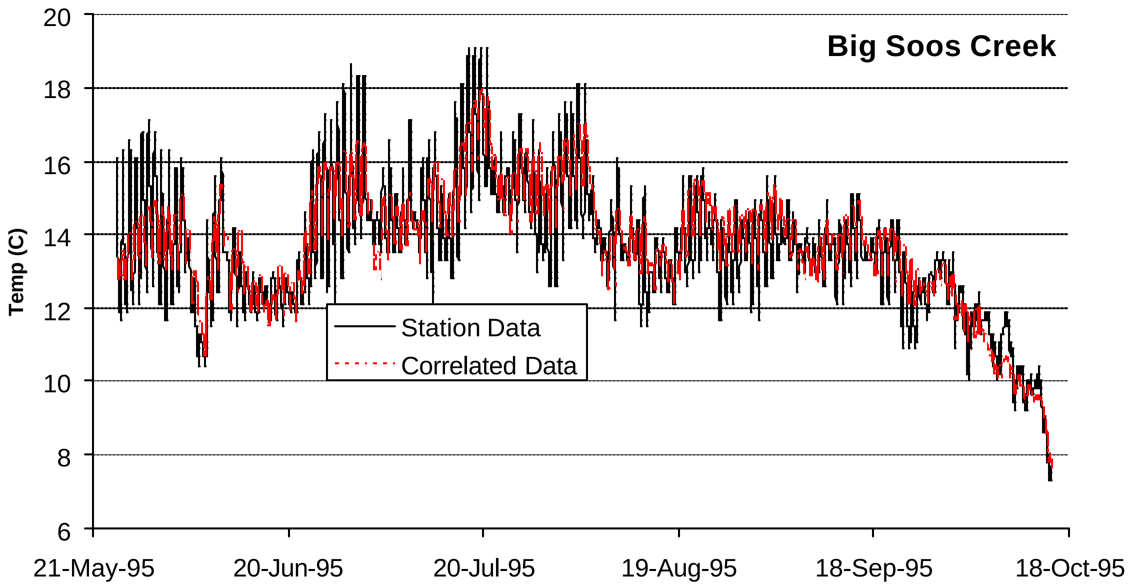


Figure 165: Big Soos Creek: Station data versus correlated values, 1995 - 1996

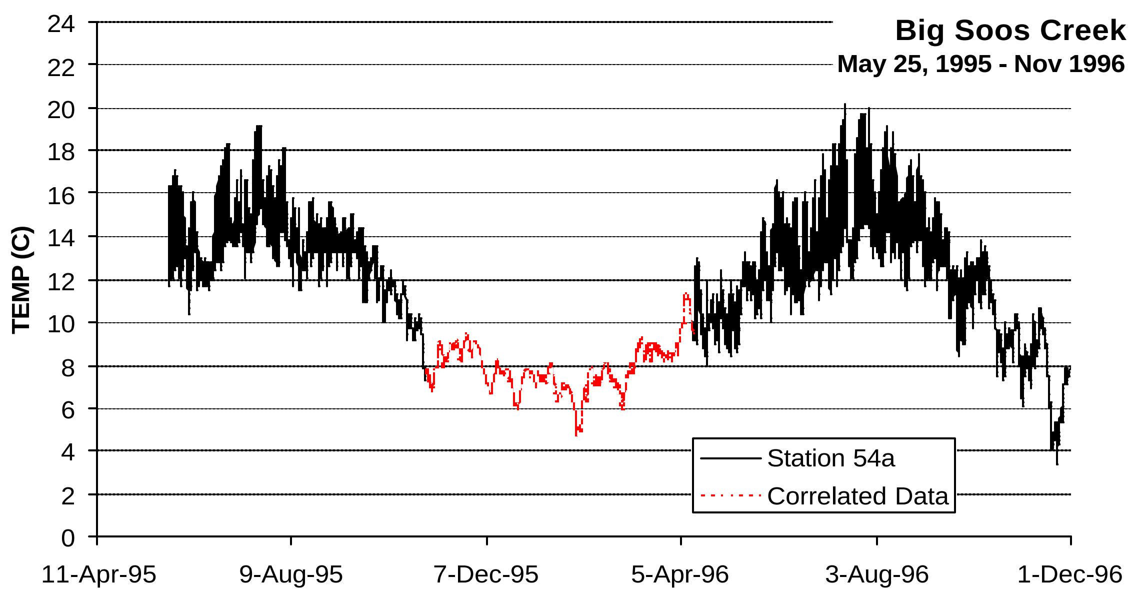


Figure 166: Big Soos Creek Temperature: May 25, 1995 – Nov 1996

Water Quality

King County has been collecting water quality samples at the mouth of Big Soos since 1995 (Locator A320). Data are available for all constituents except chlorophyll a and alkalinity. Figure 167 through Figure 181 shows graphs of the water quality constituents for the model calibration period. See Appendix D for procedures used in assembling the water quality data, including estimating missing data.

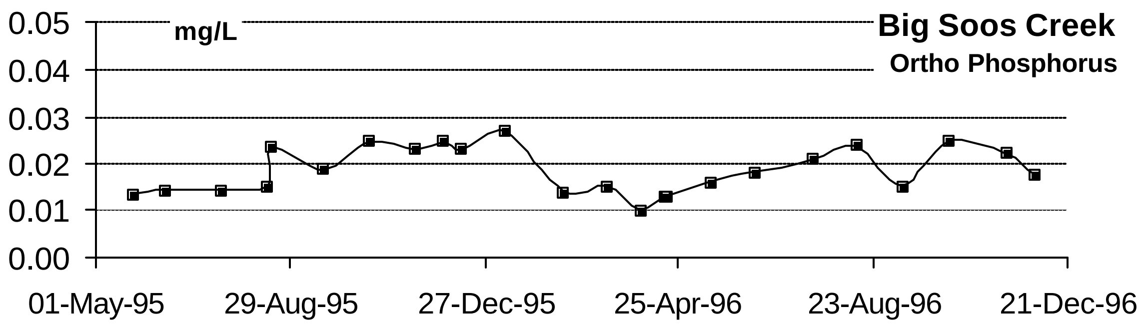


Figure 167: Ortho phosphorus Big Soos Creek: May 25, 1995 – Nov 1996

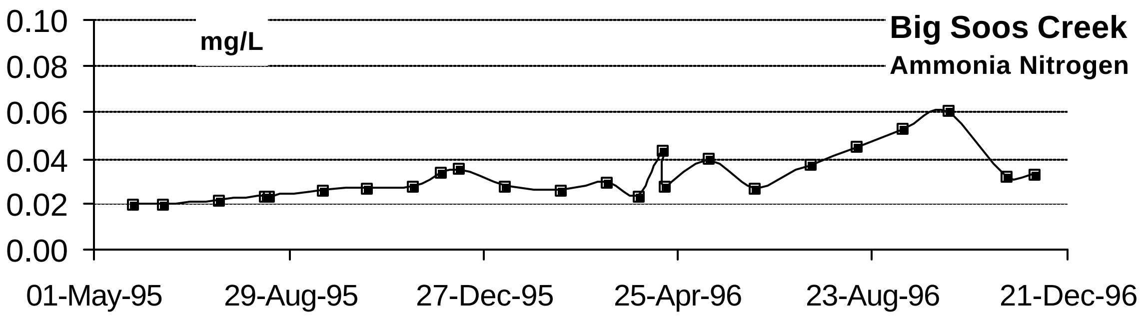


Figure 168: Ammonia Big Soos Creek: May 25, 1995 – Nov 1996

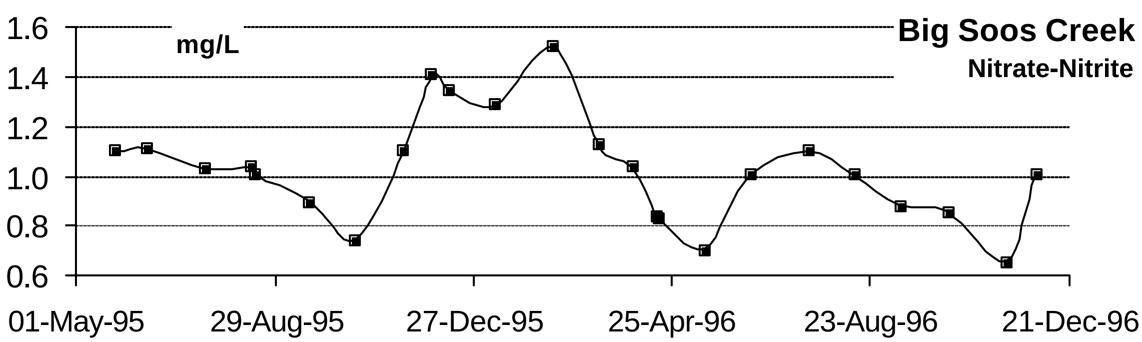


Figure 169: Nitrate-Nitrite Big Soos Creek: May 25, 1995 – Nov 1996

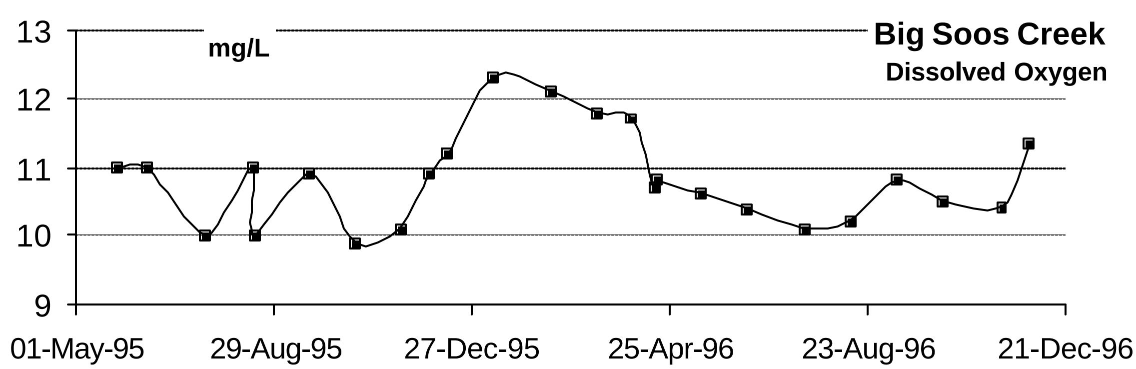


Figure 170: DO Big Soos Creek: May 25, 1995 – Nov 1996

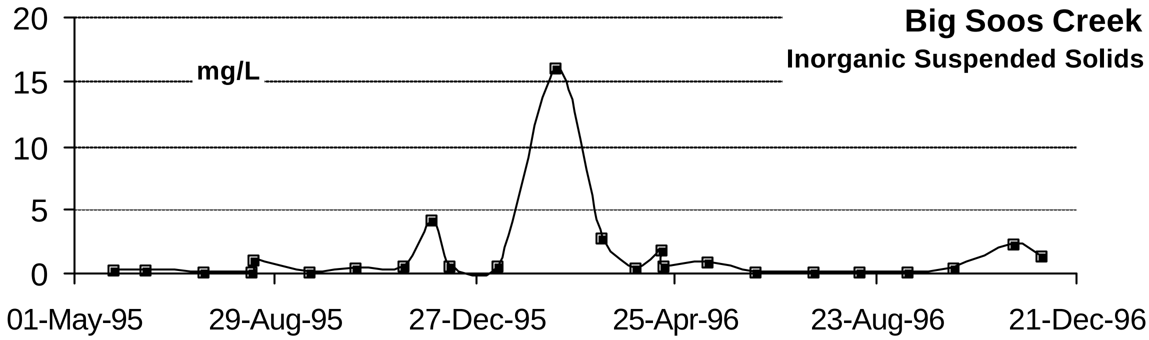


Figure 171: Big Soos: ISS Creek: May 25, 1995 – Nov 1996

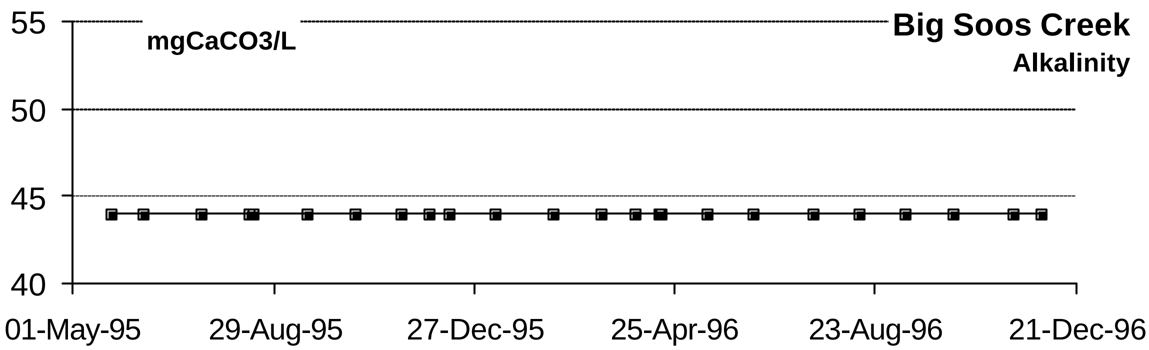


Figure 172: Alkalinity Big Soos Creek: May 25, 1995 – Nov 1996

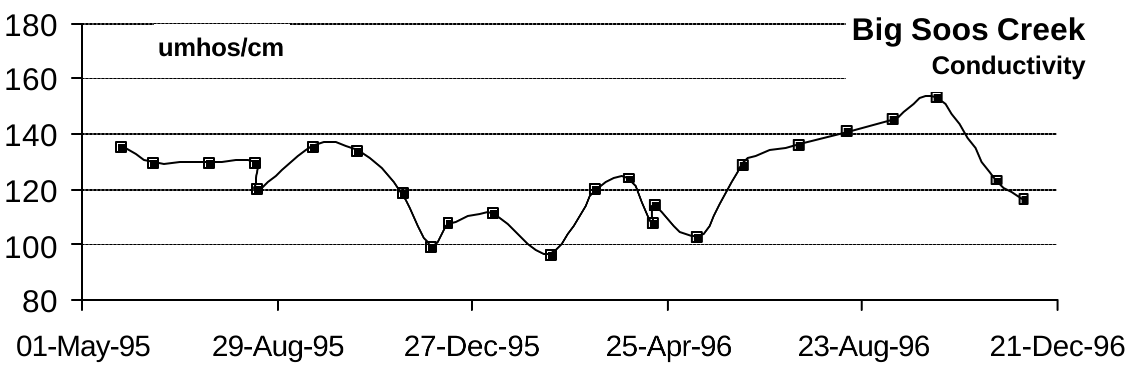


Figure 173: Conductivity Big Soos Creek: May 25, 1995 – Nov 1996

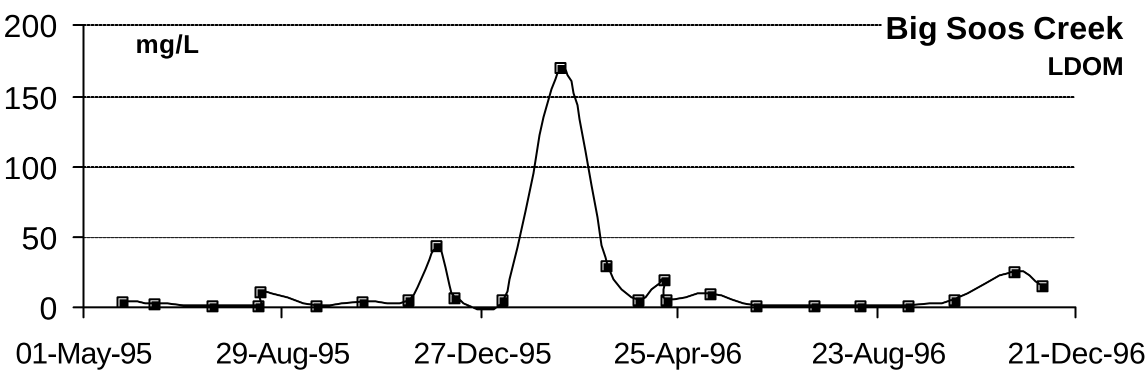


Figure 174: LDOM Big Soos Creek: May 25, 1995 – Nov 1996

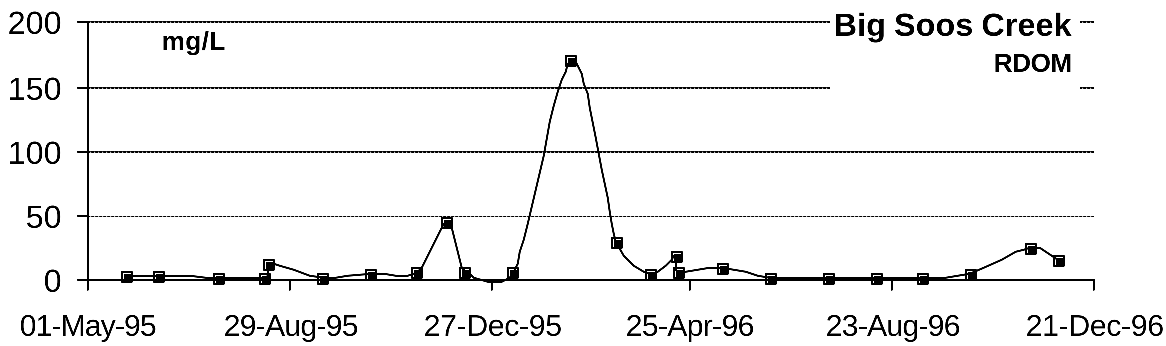


Figure 175: RDOM Big Soos Creek: May 25, 1995 – Nov 1996

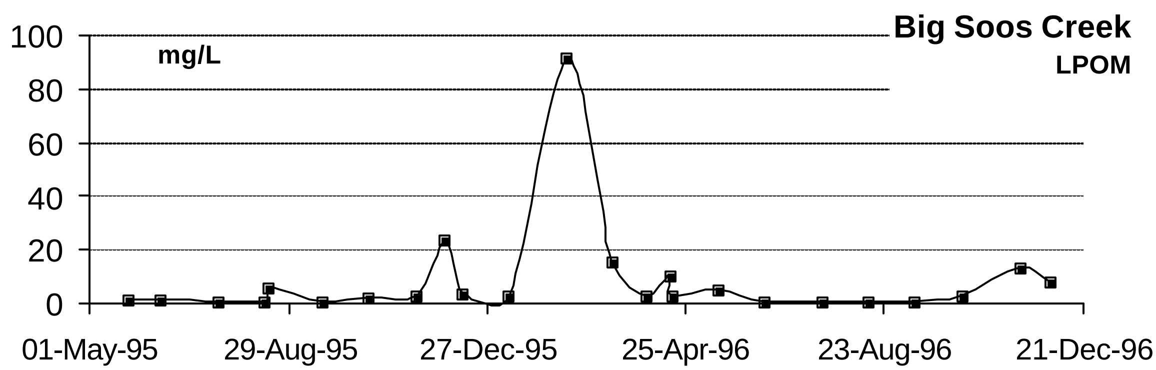


Figure 176: LPOM Big Soos Creek: May 25, 1995 – Nov 1996

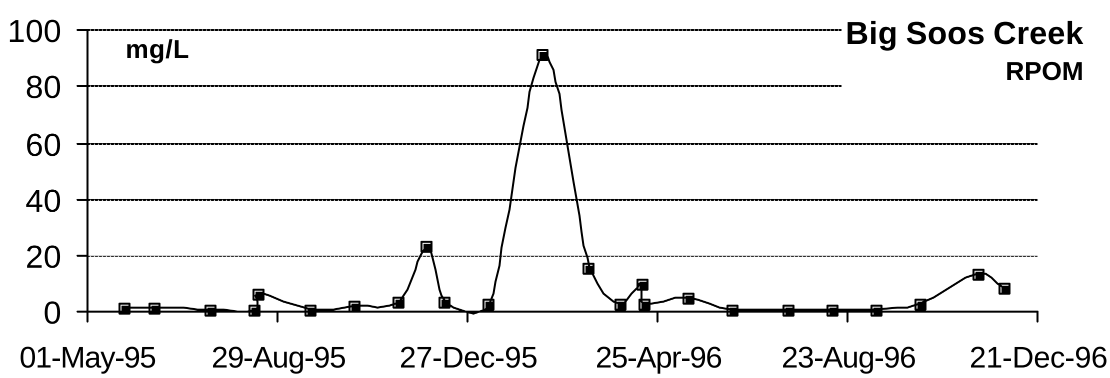


Figure 177: RPOM Big Soos Creek: May 25, 1995 – Nov 1996

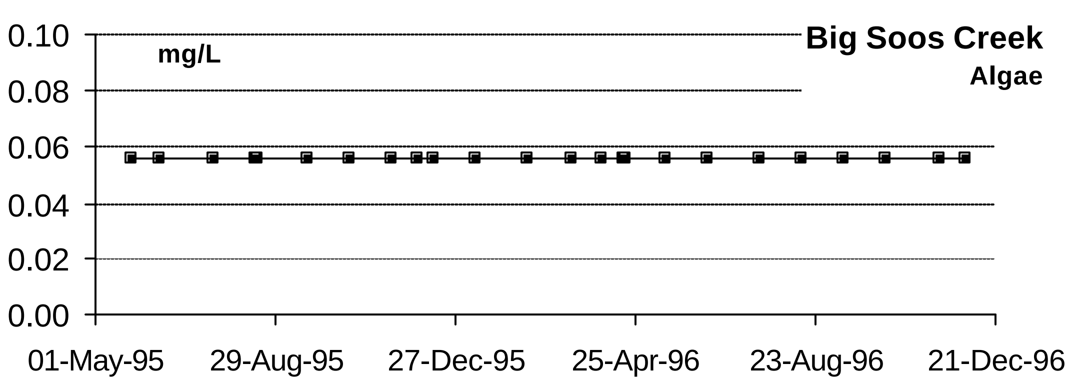


Figure 178: Algae Big Soos Creek: May 25, 1995 – Nov 1996

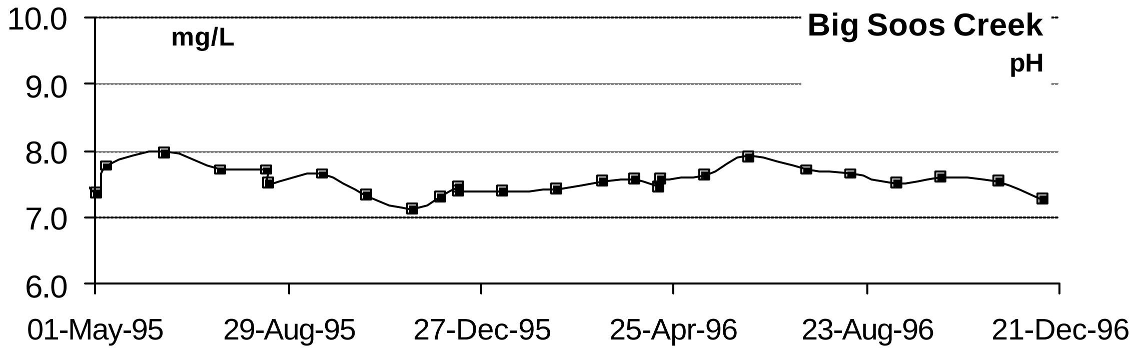


Figure 179: pH Big Soos Creek: May 25, 1995 - Nov 1996

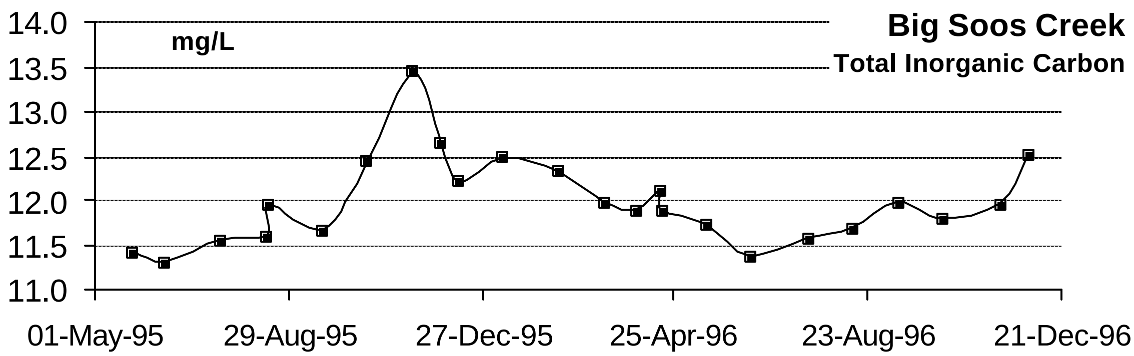


Figure 180: TIC Big Soos Creek: May 25, 1995 – Nov 1996

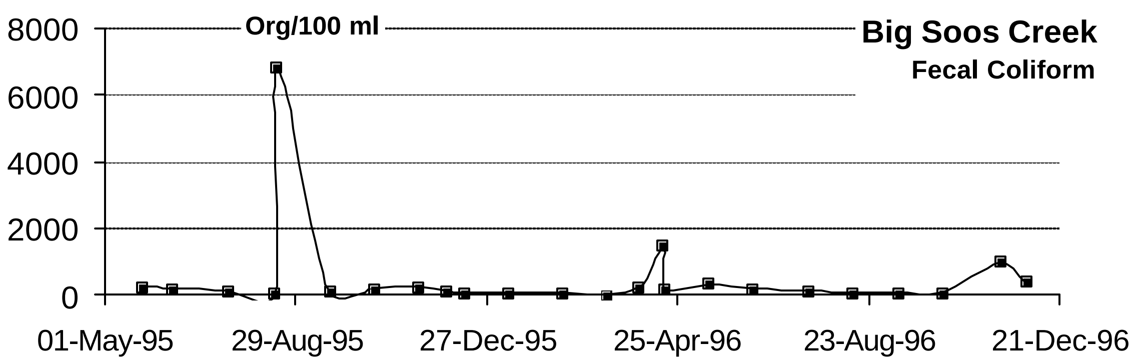


Figure 181: Fecal Coliform: May 25, 1995 - Nov 1996

April 2001 – July 2002

Flow

Flow data from USGS Gage 12112600 were also used for this model calibration period. The complete data set is included in Appendix A, and Figure 182 shows the flow data for the model simulation period.

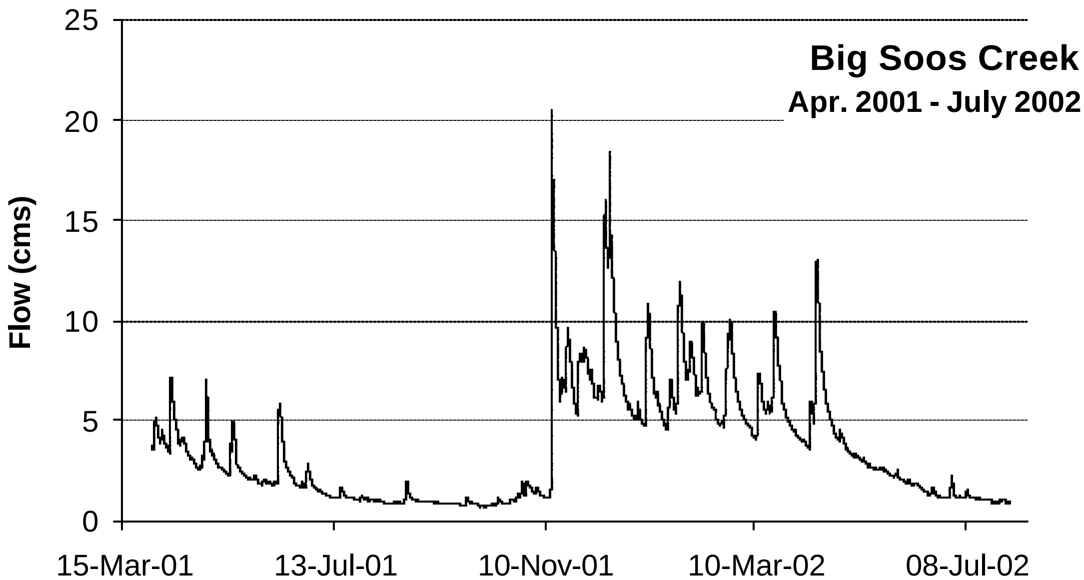


Figure 182: Big Soos Creek Flow: Apr 2001 – July 2002

Temperature

King County provided temperature data from a station at the mouth of Soos Creek from October 1, 1994 to August 1, 2002, in 15-minute intervals (Station 54a). Data for the model calibration period are shown in Figure 183.

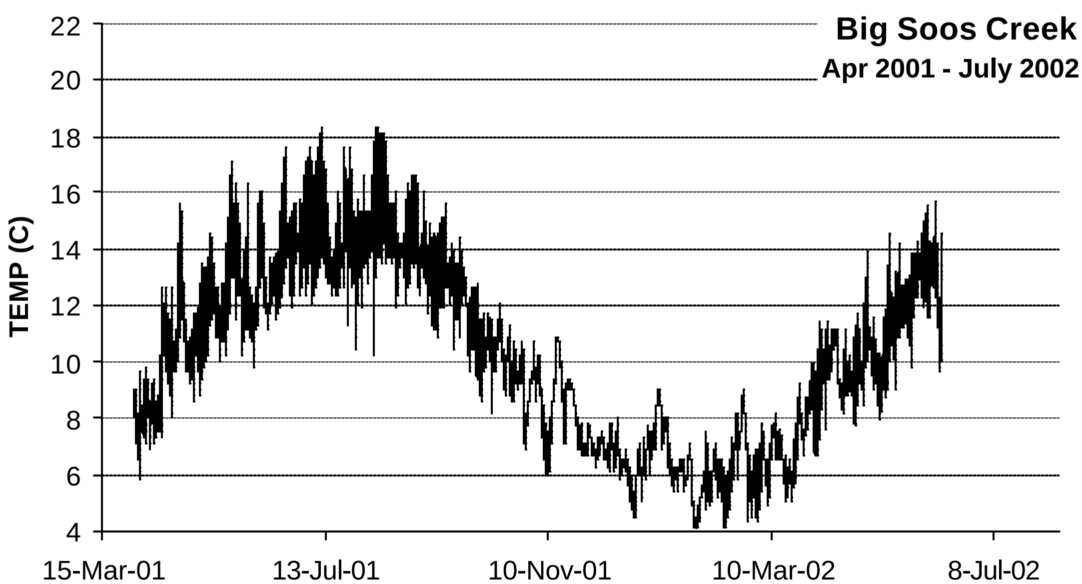


Figure 183: Big Soos Temperature: Apr 2001 – July 2002

Water Quality

King County has provided water quality data at the mouth of the Big Soos Creek from 1995 through 2002 (Station A320). Data are available for all constituents except chlorophyll a. Figure 184 through Figure 198 show graphs of the data for the model calibration period. Data from 1995-2002 are shown in Appendix A. See Appendix D for procedures used in assembling the water quality data, including estimates of missing data.

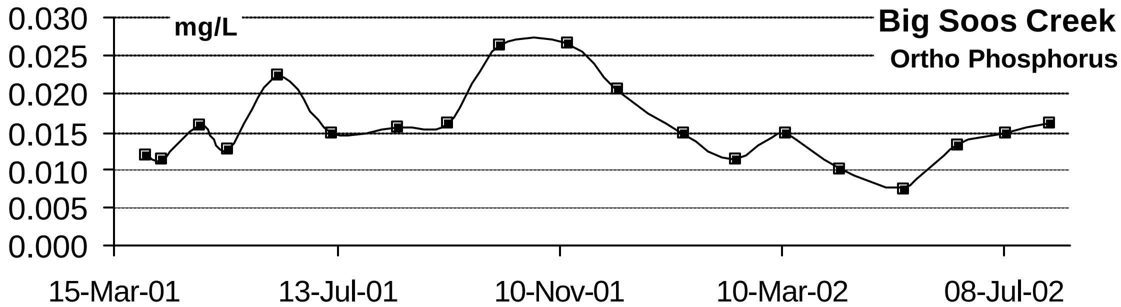


Figure 184: Ortho Phosphorus Big Soos: Apr 2001 – July 2002

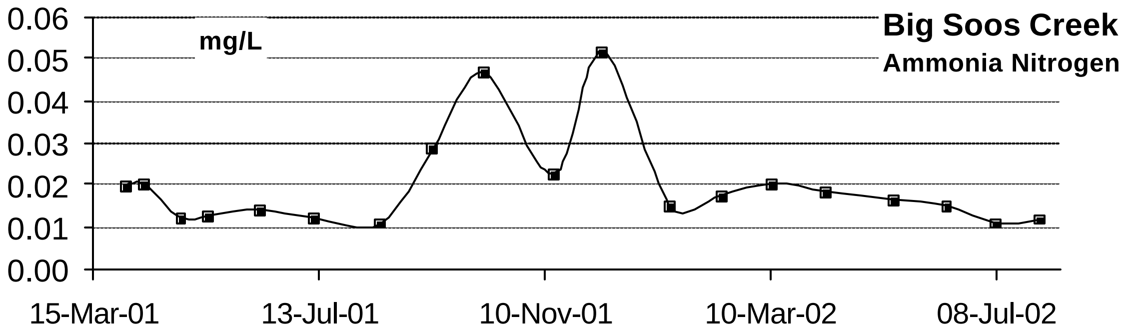


Figure 185: Ammonia Big Soos: Apr 2001 – July 2002

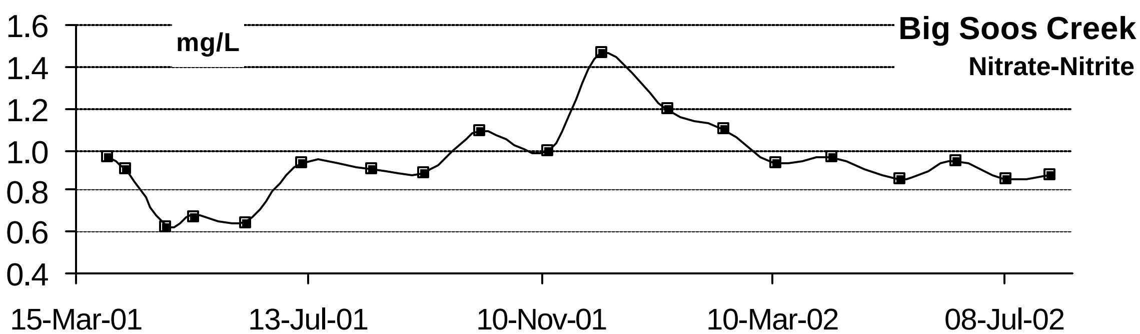


Figure 186: Nitrate-Nitrite Big Soos: Apr 2001 – July 2002

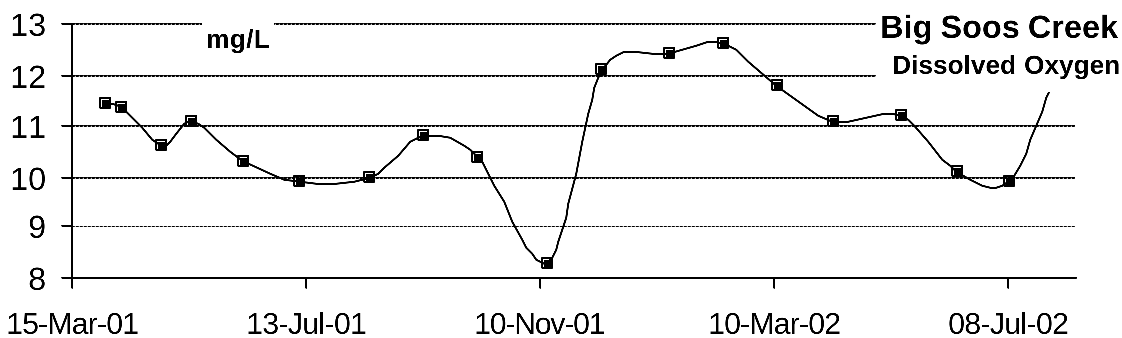


Figure 187: DO Big Soos: Apr 2001 – July 2002

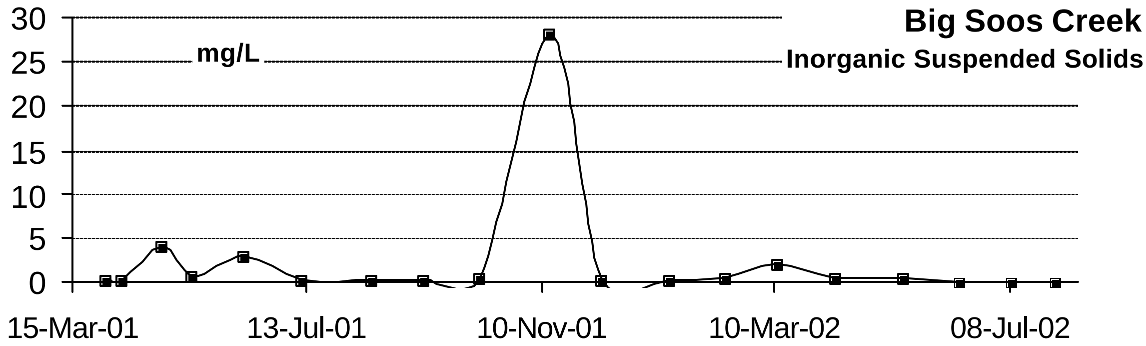


Figure 188: ISS Big Soos: Apr 2001 – July 2002

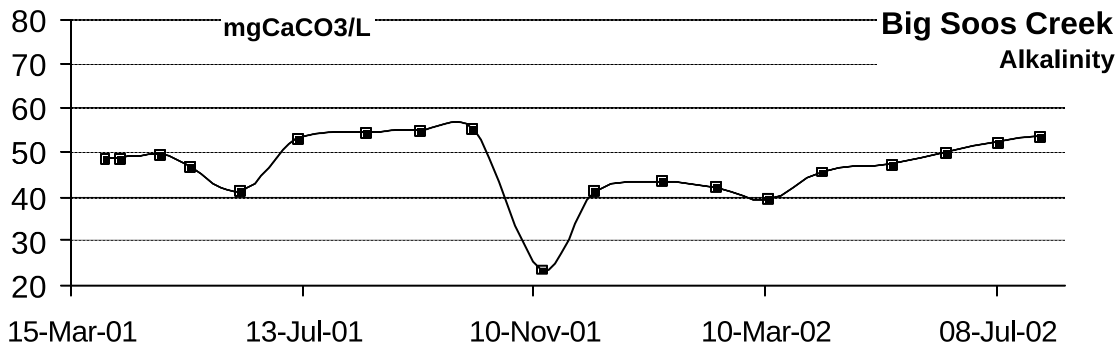


Figure 189: Alkalinity Big Soos: Apr 2001 – July 2002

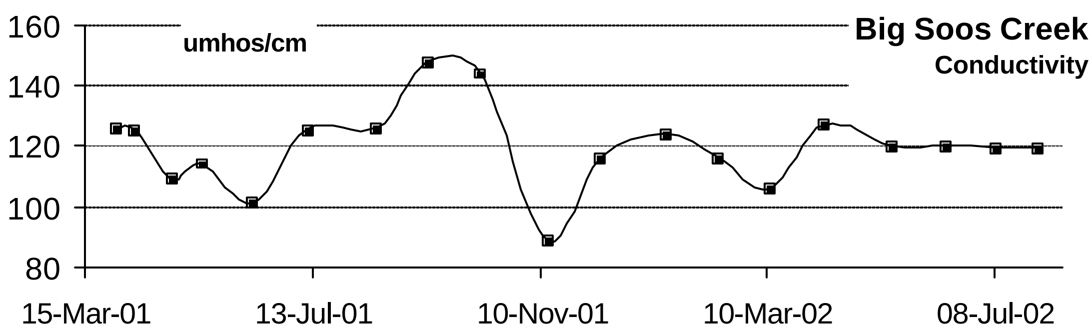


Figure 190: Conductivity Big Soos: Apr 2001 – July 2002

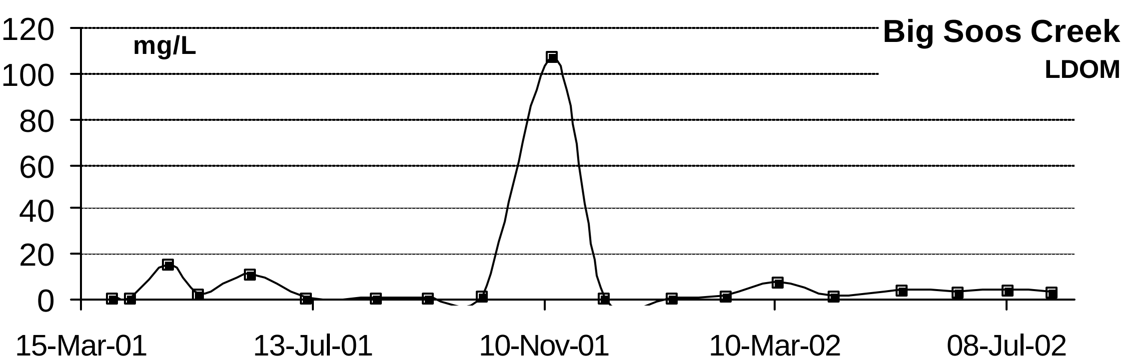


Figure 191: LDOM Big Soos: Apr 2001 – July 2002

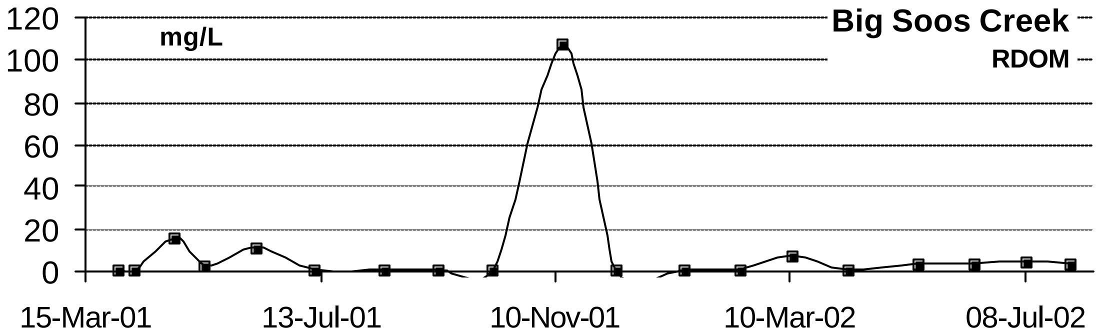


Figure 192: RDOM Big Soos: Apr 2001 – July 2002

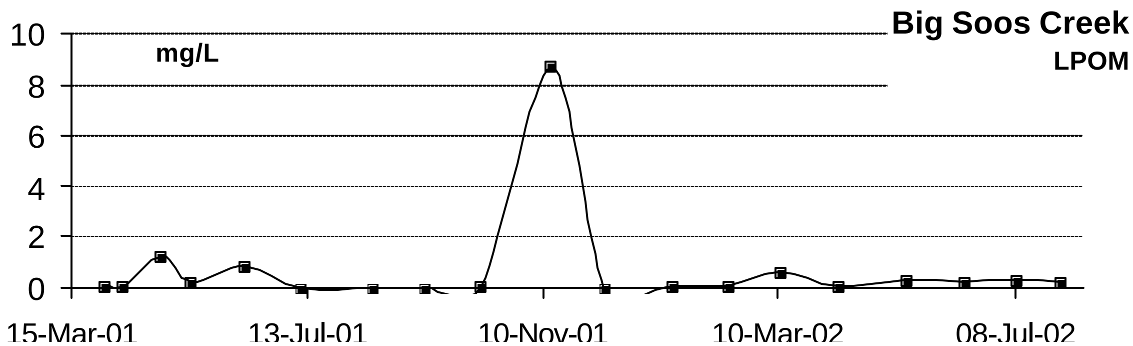


Figure 193: LPOM Big Soos: Apr 2001 – July 2002

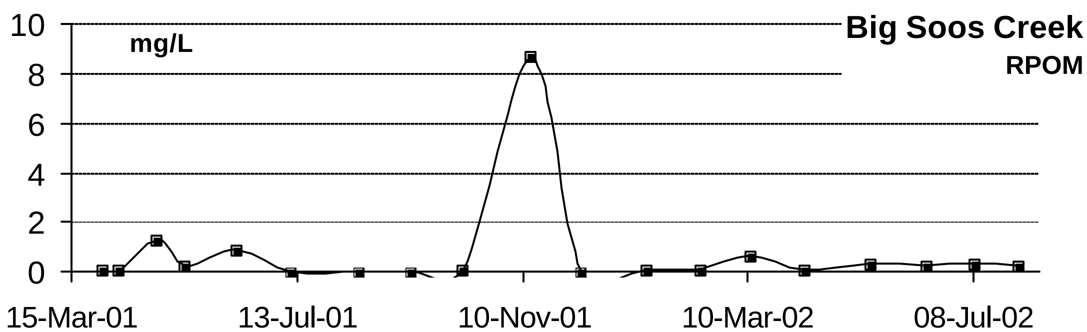


Figure 194: RPOM Big Soos: Apr 2001 – July 2002

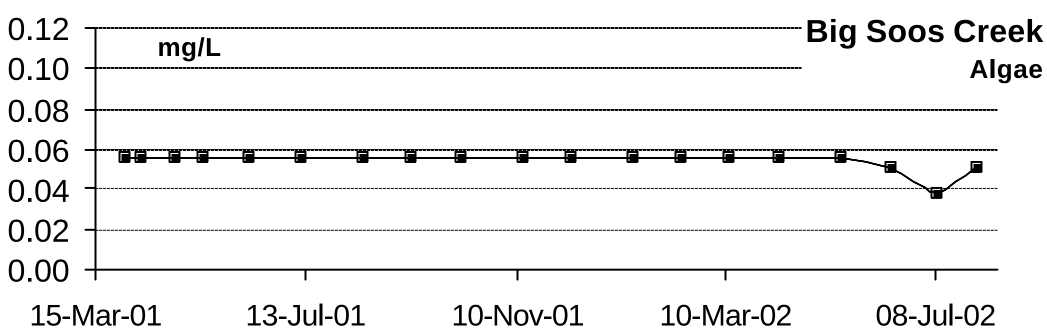


Figure 195: Algae Big Soos: Apr 2001 – July 2002

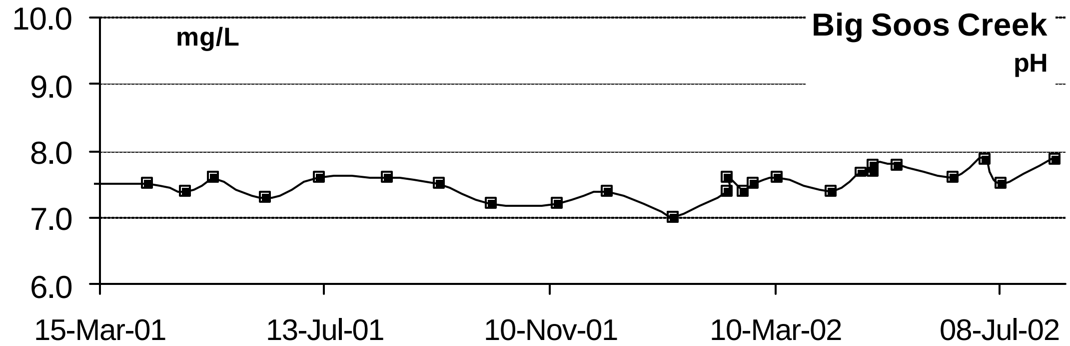


Figure 196: pH Big Soos: Apr 2001 - July 2002

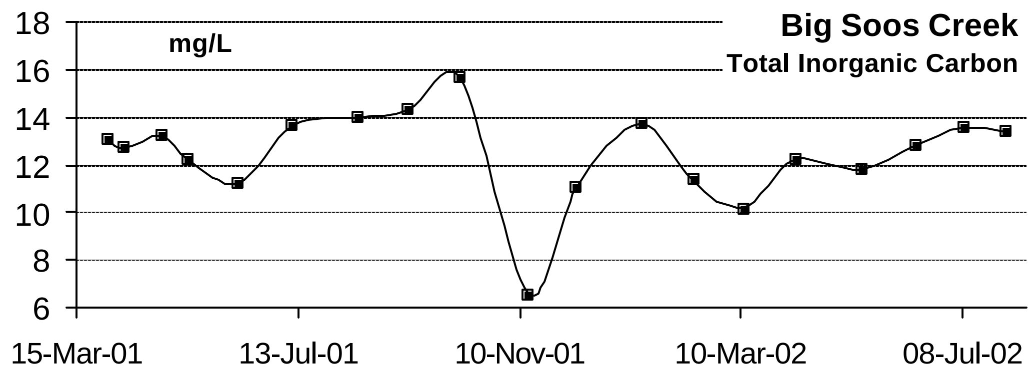


Figure 197: TIC Big Soos: Apr 2001 – July 2002

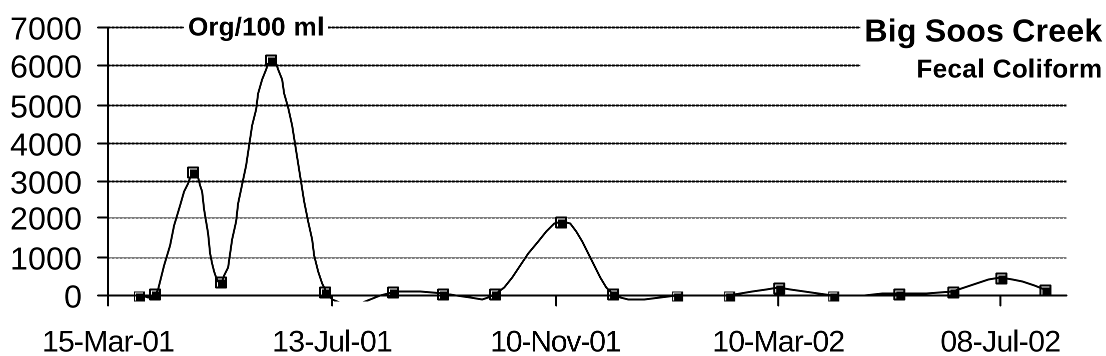


Figure 198: Fecal Coliform Big Soos: Apr 2001 - July 2002

2.5.4 Mill Creek

Mill Creek is another small tributary to Green River, with an approximate basin size of 3,950 hectares (9760 acres), which enters the Green River at River Mile 23.80.

May 25, 1995 – November 1996

Flow

King County maintained a flow gage on Mill Creek, but it was removed because the county believes backwater from the Green River made data from this gage unreliable (DeGasperi, 2003). Data were provided for this gage in 15-minute intervals from August 22, 1989 to April 6, 1996. These data are shown in Appendix A. Note the number of time periods where the gage data is at zero. These are time periods of "bad" data, possibly where flow is reversed in the creek.

King County also modeled the Mill Creek basin using HSPF from October 1948 to December 2002. Daily average flow data were provided from this model. Flow data from Station 41a were graphed against the HSPF data. Figure 199 shows the comparison. The highs and lows occur at the same time, but the HSPF data are consistently larger in magnitude. Because there is a question of the reliability of data from Station 41a, HSPF data will be used for both model calibration periods. Figure 200 shows the data for the model simulation period.

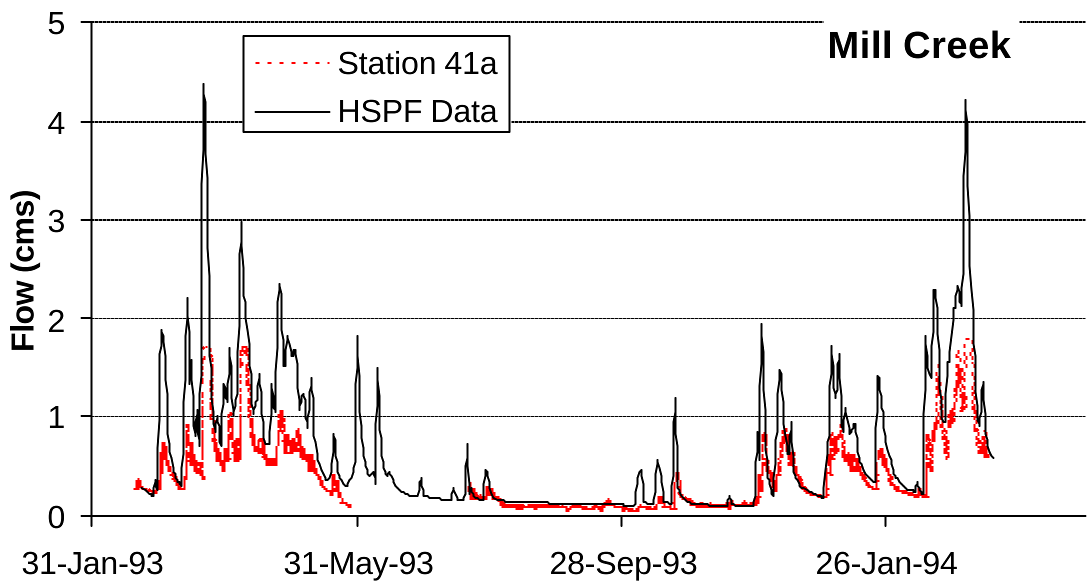


Figure 199: Mill Creek Flow Comparison

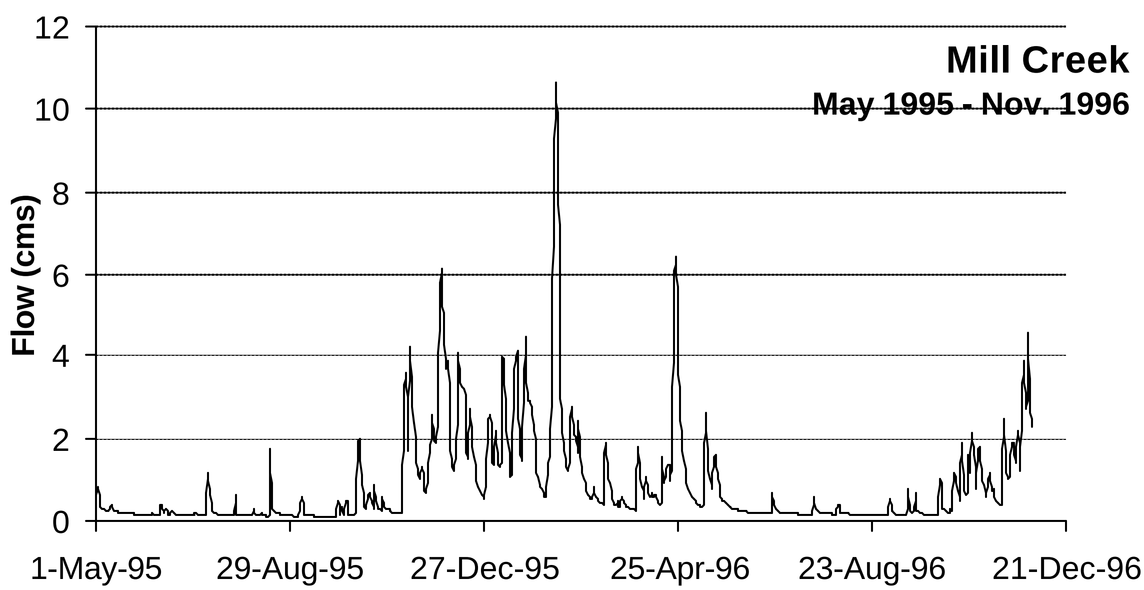


Figure 200: Mill Creek Flow: May 25, 1995 – Nov 1996

Temperature

Temperature monitoring data are not available until October 1999. Temperature data from Big Soos Creek will be used for this time period. Data from Big Soos Creek were chosen because it is the closest tributary to Mill Creek. See Figure 166 for temperature data.

Water Quality

King County has provided water quality data for the mouth of Mill Creek from 1990 to December 2002. Data are available for all constituents except chlorophyll a, and alkalinity. See Appendix A for water quality data for the entire time period, and Figure 201 through Figure 215 for data for the model calibration period. See Appendix D for procedures used in assembling the water quality data, including estimating missing data.

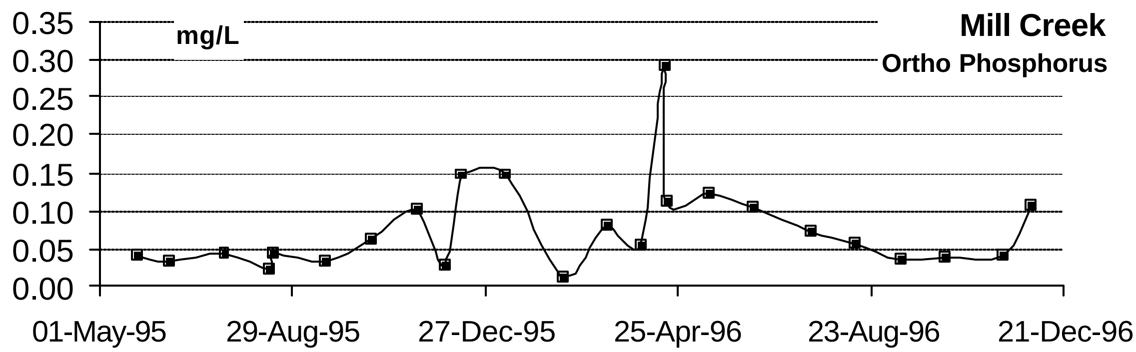


Figure 201: Ortho phosphorus Mill Creek: May 25, 1995 – Nov 1996

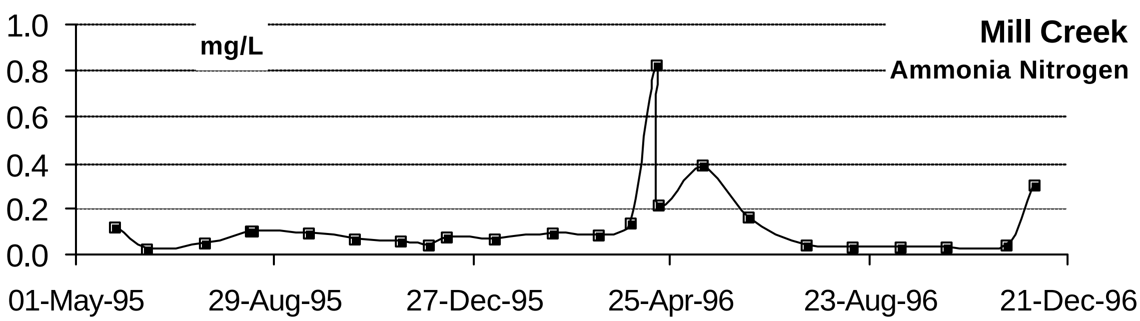


Figure 202: Ammonia Mill Creek: May 25, 1995 – Nov 1996

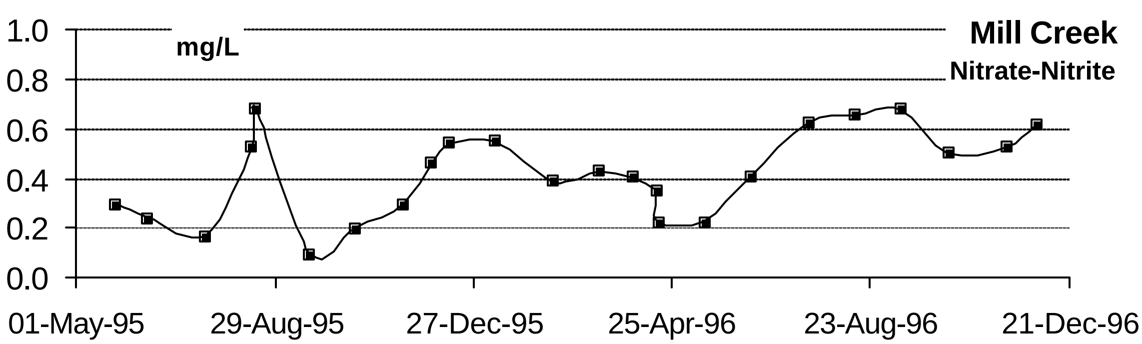


Figure 203: Nitrate-Nitrite Mill Creek: May 25, 1995 – Nov 1996

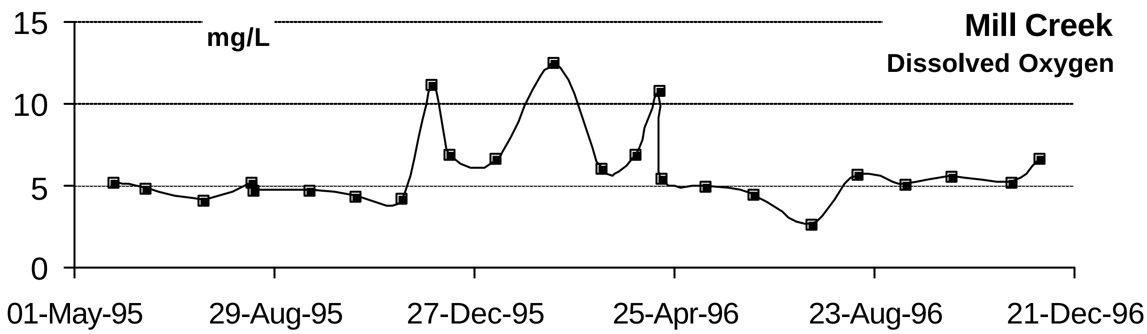


Figure 204: DO Mill Creek: May 25, 1995 – Nov 1996

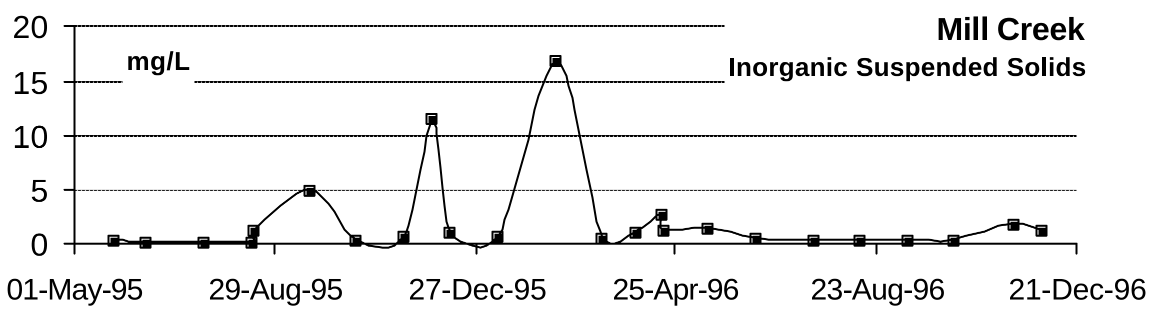


Figure 205: ISS Mill Creek: May 25, 1995 – Nov 1996

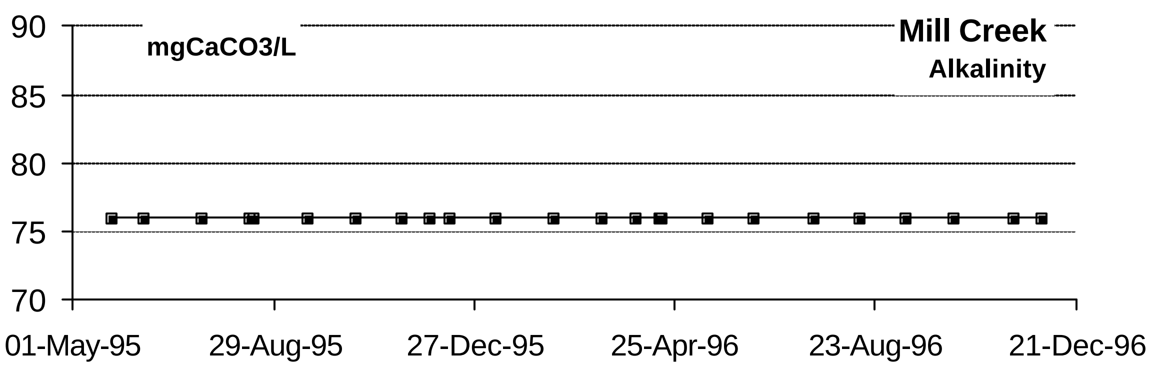


Figure 206: Alkalinity Mill Creek: May 25, 1995 – Nov 1996

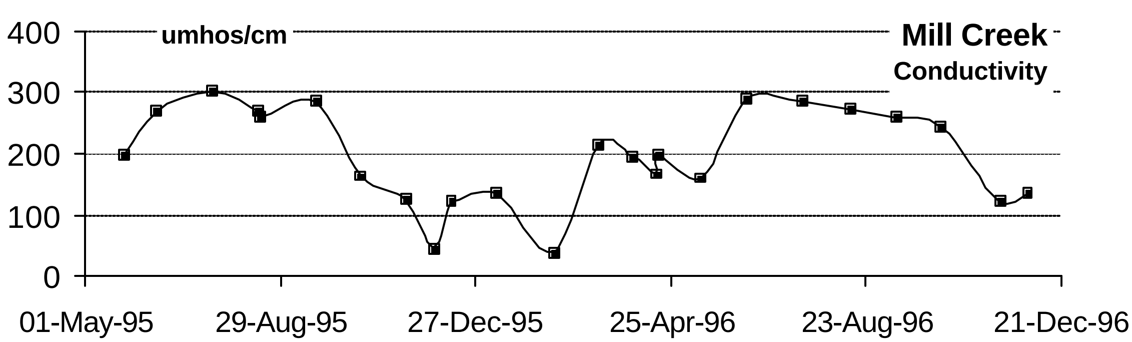


Figure 207: Conductivi ty Mill Creek: May 25, 1995 – Nov 1996

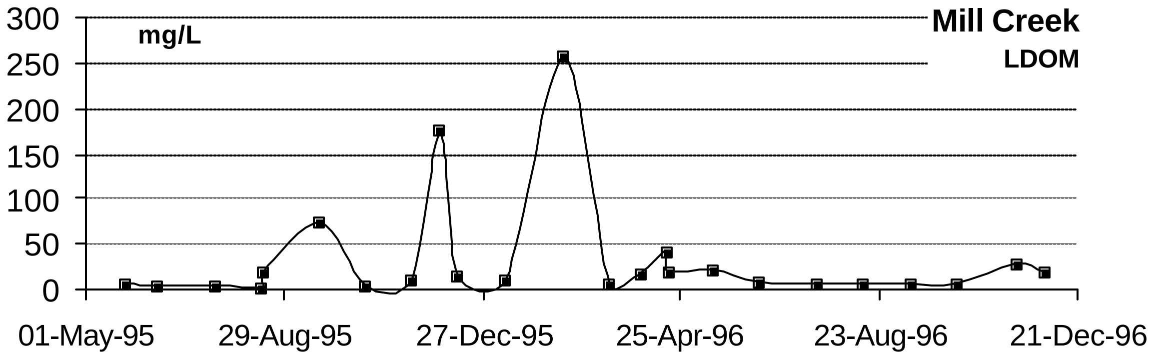


Figure 208: LDOM Mill Creek: May 25, 1995 – Nov 1996

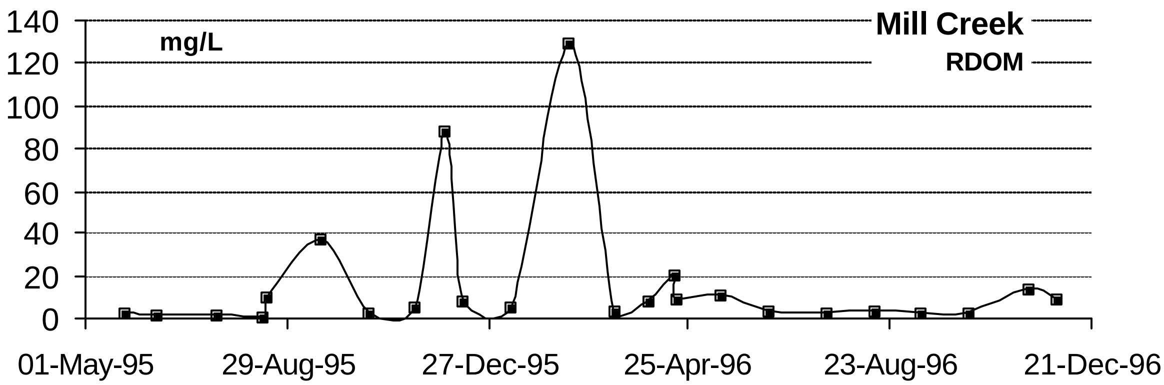


Figure 209: RDOM Mill Creek: May 25, 1995 – Nov 1996

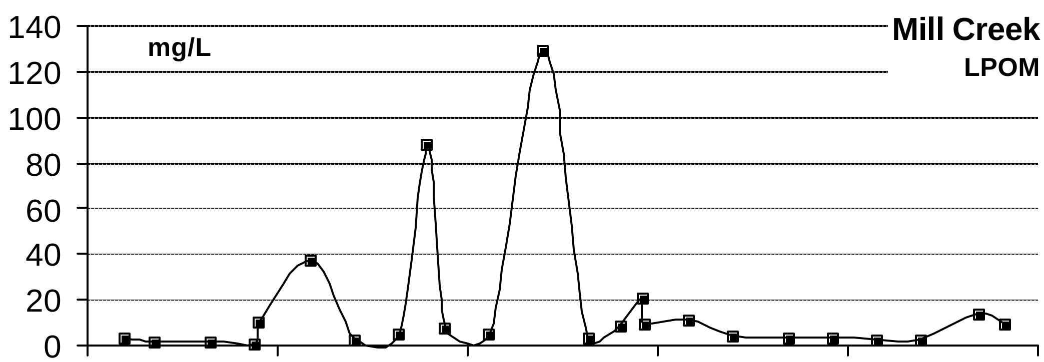


Figure 210: LPOM Mill Creek: May 25, 1995 – Nov 1996

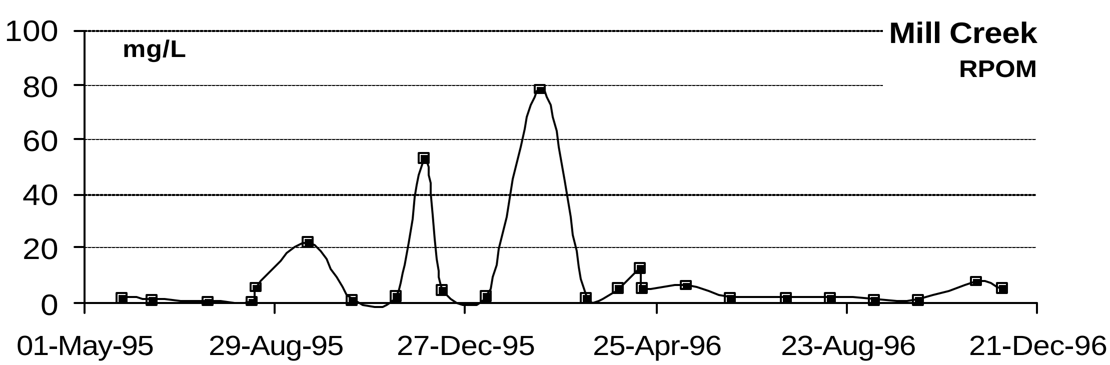


Figure 211: RPOM Mill Creek: May 25, 1995 – Nov 1996

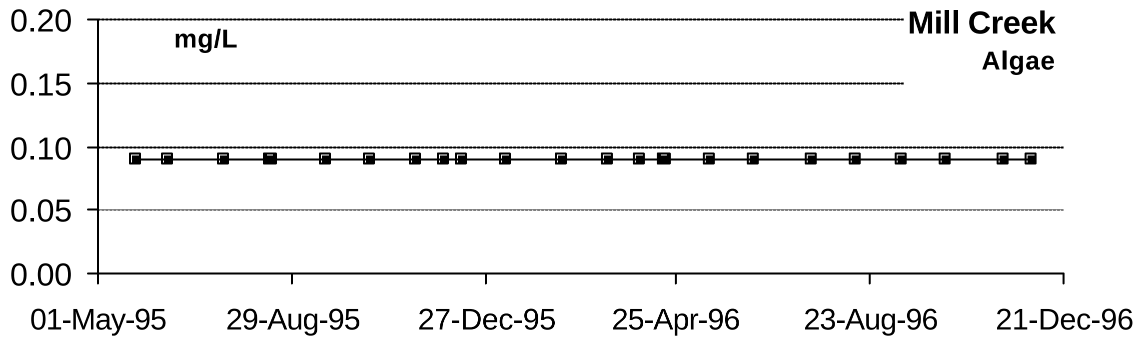


Figure 212: Algae Mill Creek: May 25, 1995 – Nov 1996

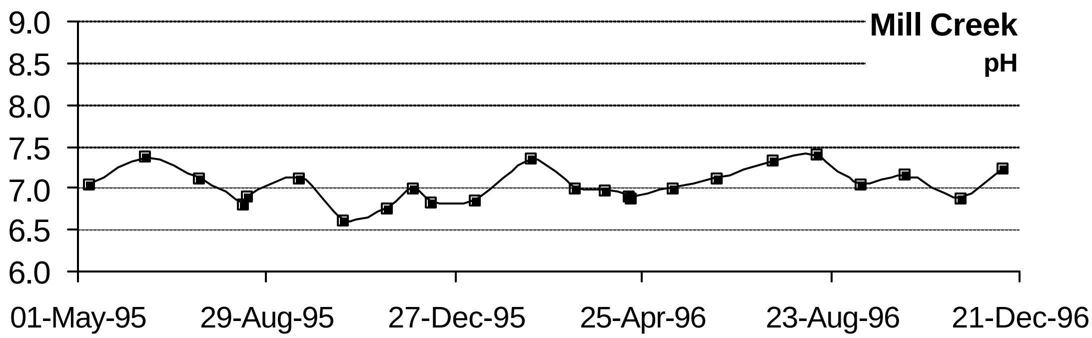


Figure 213: pH Mill Creek: May 25, 1995 - Nov 1996

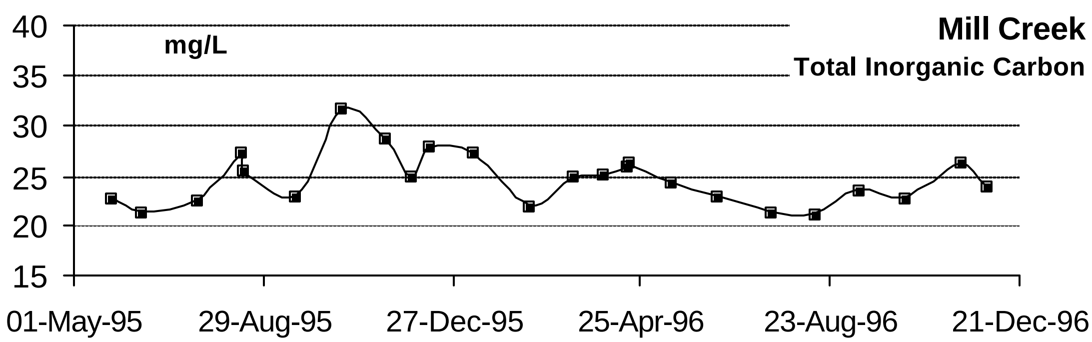


Figure 214: TIC Mill Creek: May 25, 1995 – Nov 1996

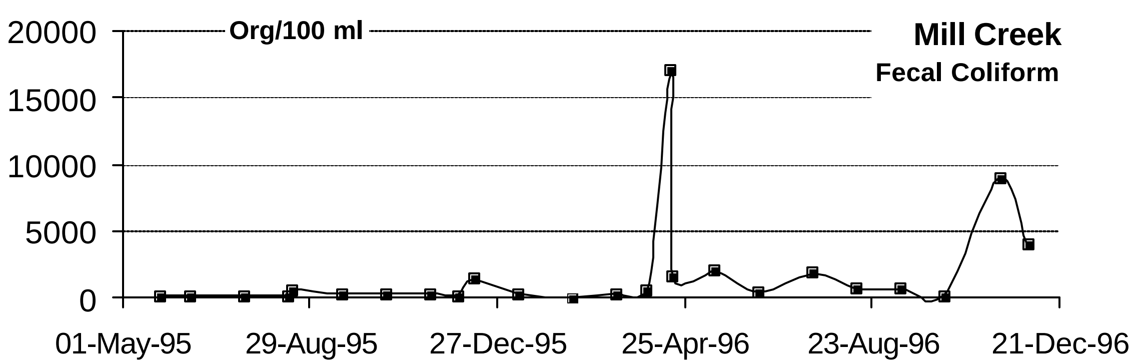


Figure 215: Fecal Coliform: May 25, 1995 - Nov 1996

April 2001 – July 2002

Flow

HSPF daily model output flows were used for this calibration period. Figure 216 shows the data for this model calibration period.

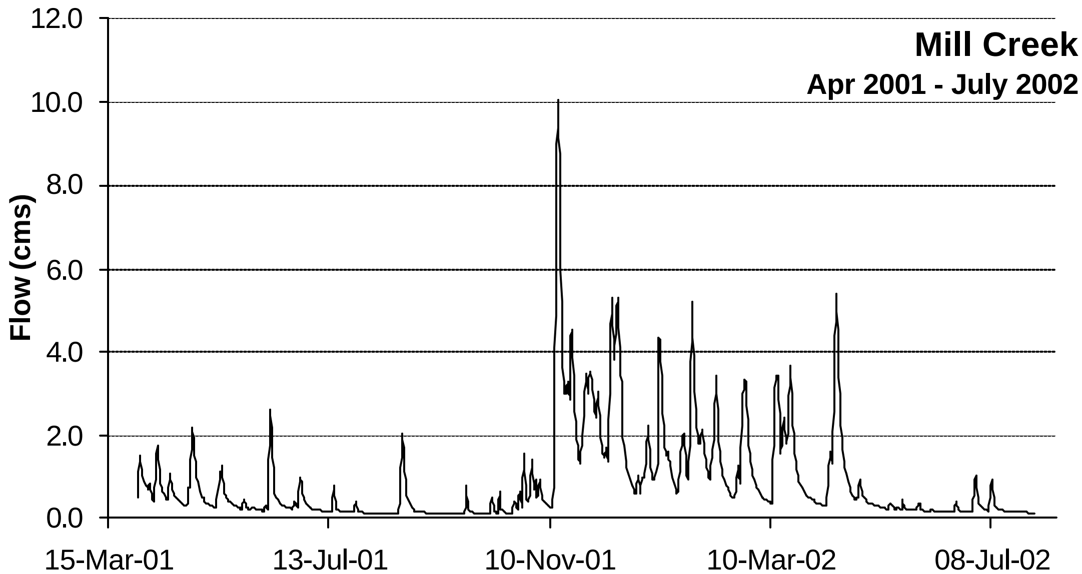


Figure 216: Mill Creek Flow: Apr 2001 – July 2002

Temperature

King County has also recorded temperature at the mouth of Mill Creek (Station 41a) beginning in October 1999 in 15-minute intervals. Figure 217 is a graph of temperature data for the model calibration period. Note that when backwater from the Green River enters Mill Creek the backwater would influence this temperature data also.

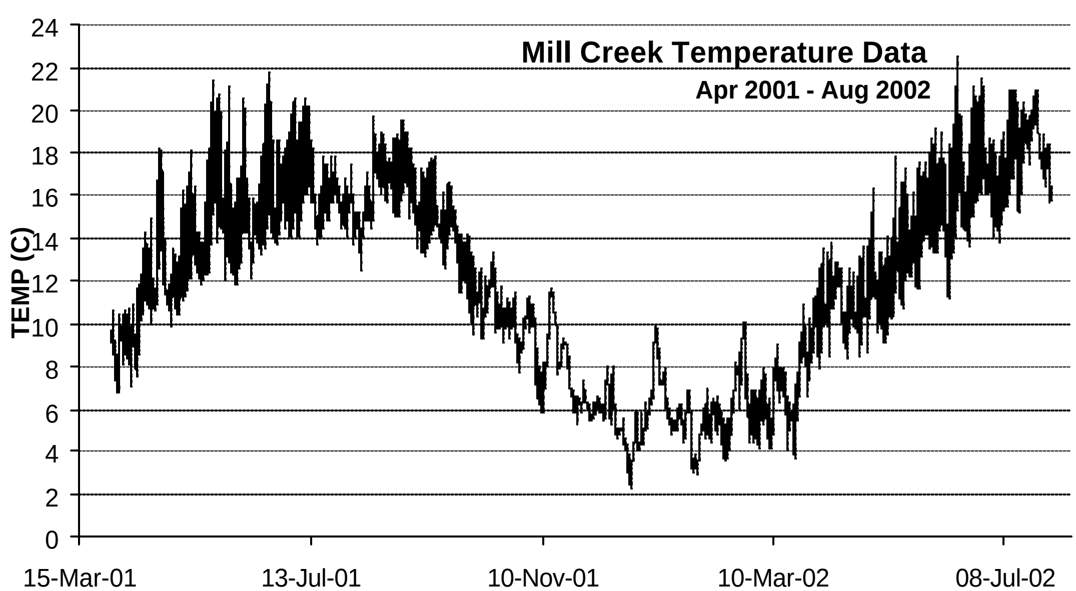


Figure 217: Mill Creek Temperature: Apr 2001 – July 2002

Water Quality

King County has provided water quality data at the mouth of Mill Creek from 1995 through 2002 (Station A315). Figure 218 through Figure 232 shows these data for the model calibration period. See Appendix D for procedures used in assembling the water quality data, including estimating missing data.

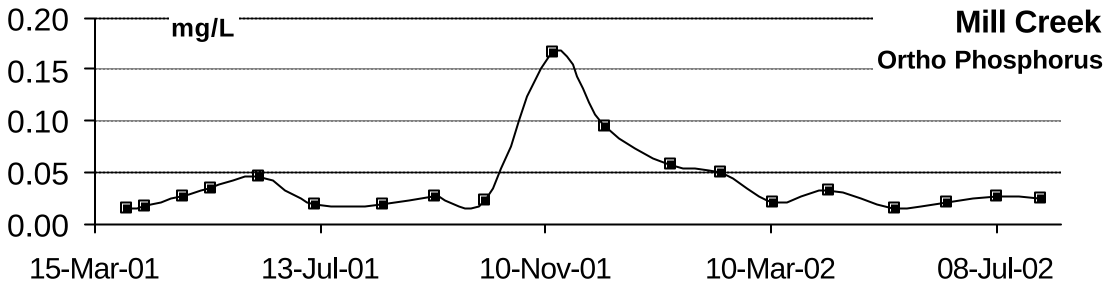


Figure 218: Ortho phosphorus Mill Creek: Apr 2001-July 2002

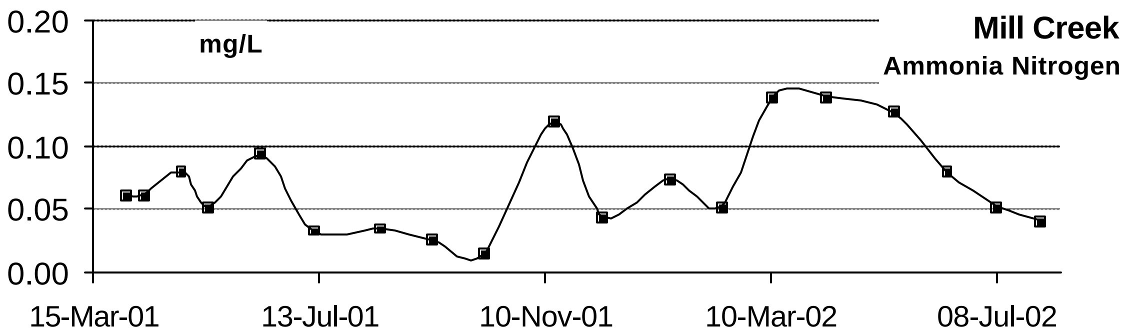


Figure 219: Ammonia Mill Creek: Apr 2001-July 2002

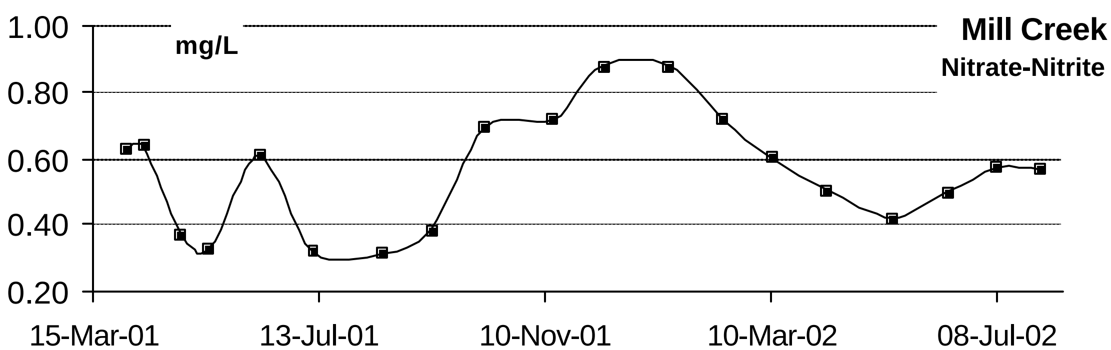


Figure 220: Nitrate-Nitrite Mill Creek: Apr 2001-July 2002

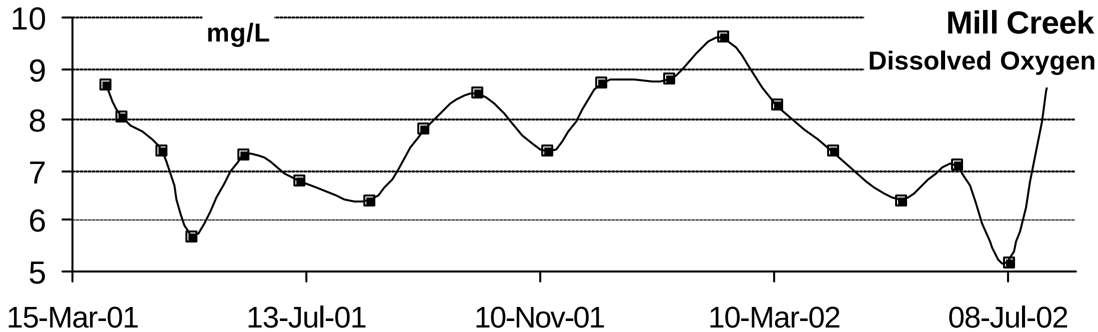


Figure 221: DO Mill Creek: Apr 2001-July 2002

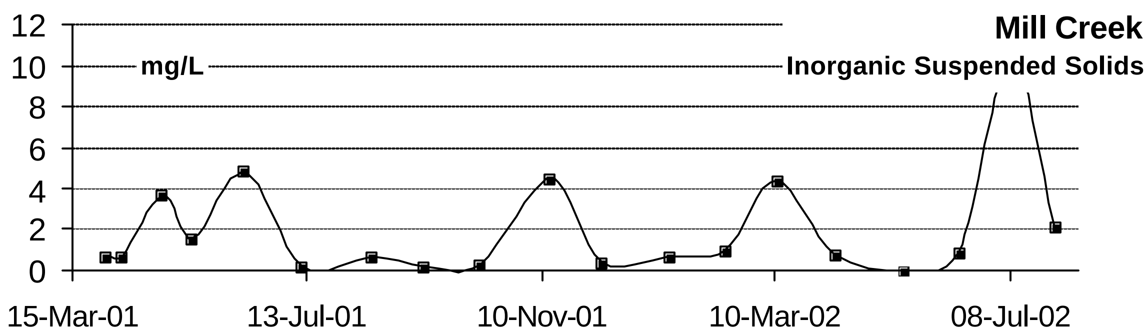


Figure 222: ISS Mill Creek: Apr 2001-July 2002

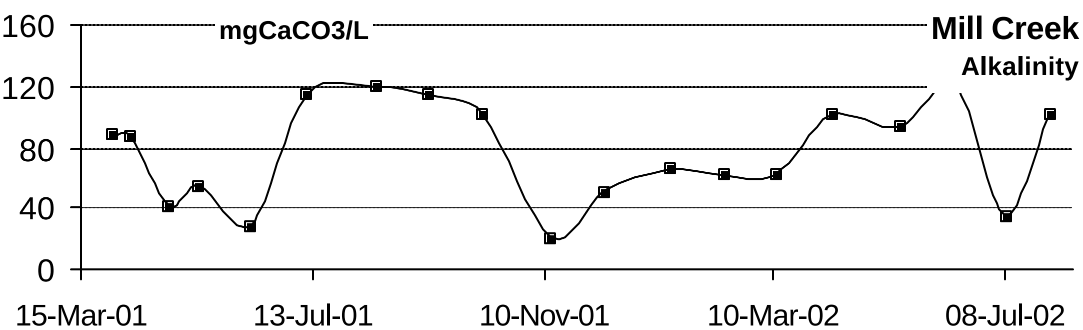


Figure 223: Alkalinity Mill Creek: Apr 2001-July 2002

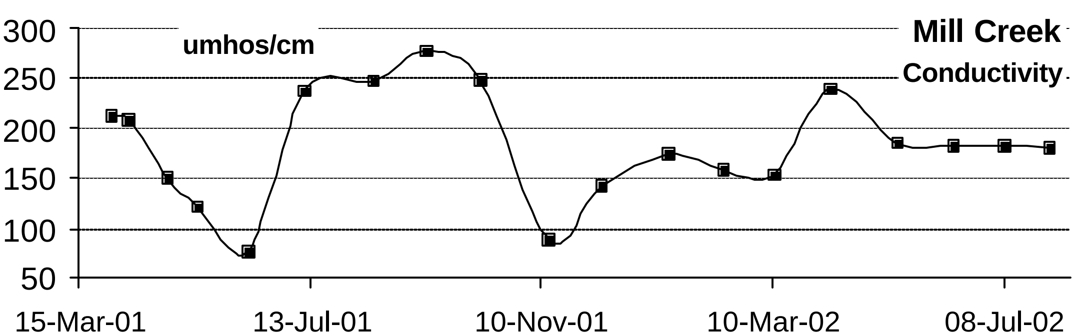


Figure 224: Conductivity Mill Creek: Apr 2001-July 2002

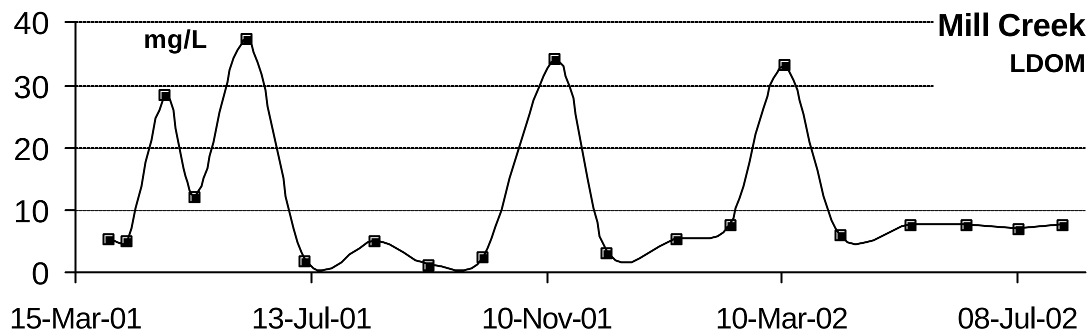


Figure 225: LDOM Mill Creek: Apr 2001-July 2002

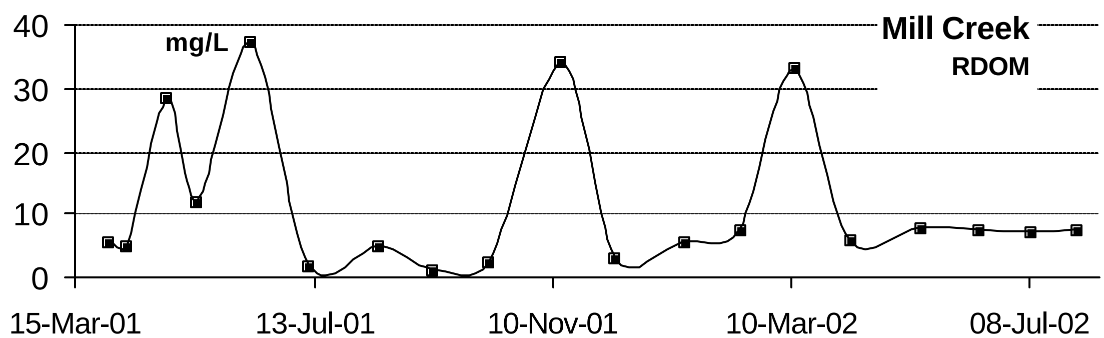


Figure 226: RDOM Mill Creek: Apr 2001-July 2002

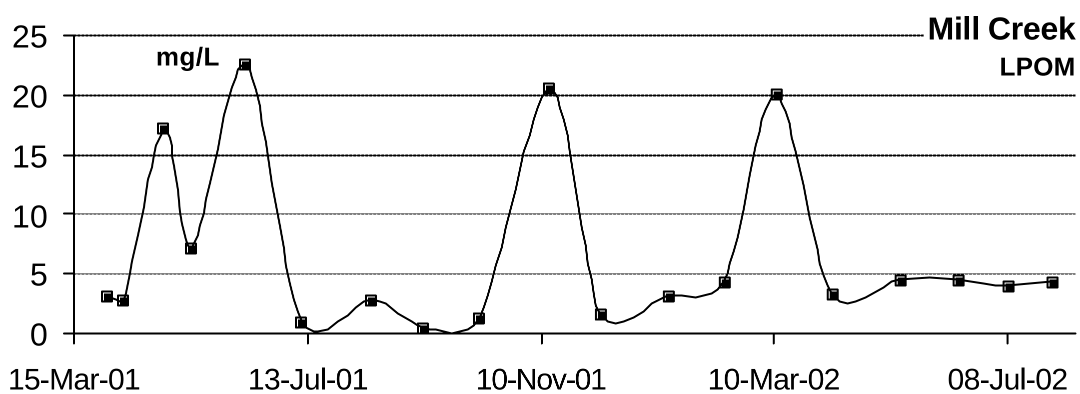


Figure 227: LPOM Mill Creek: Apr 2001-July 2002

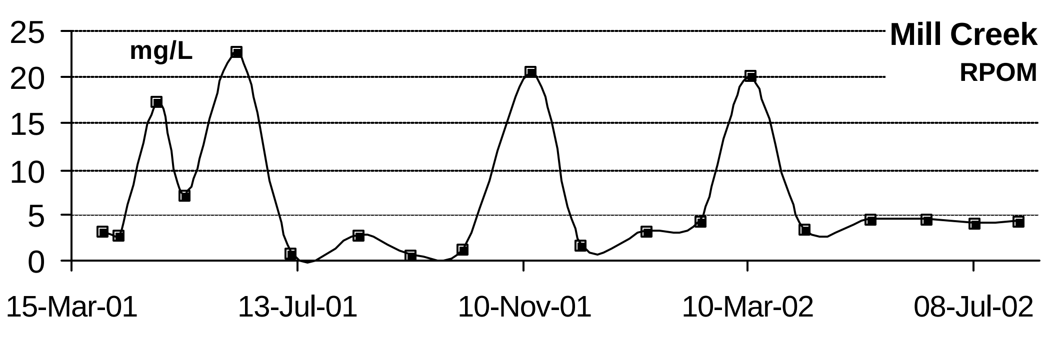


Figure 228: RPOM Mill Creek: Apr 2001-July 2002

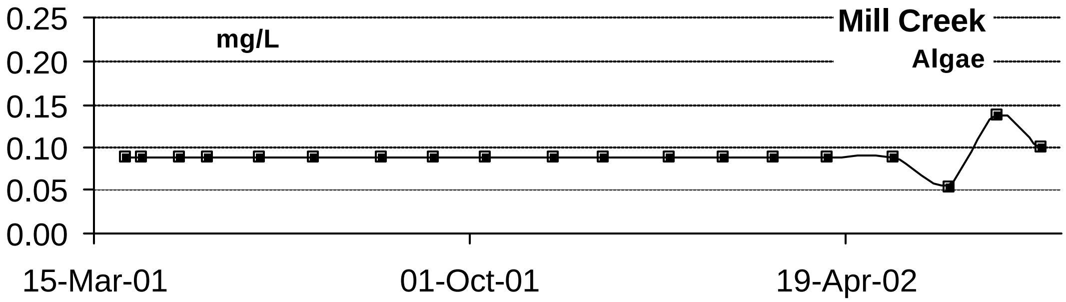


Figure 229: Algae Mill Creek: Apr 2001-July 2002

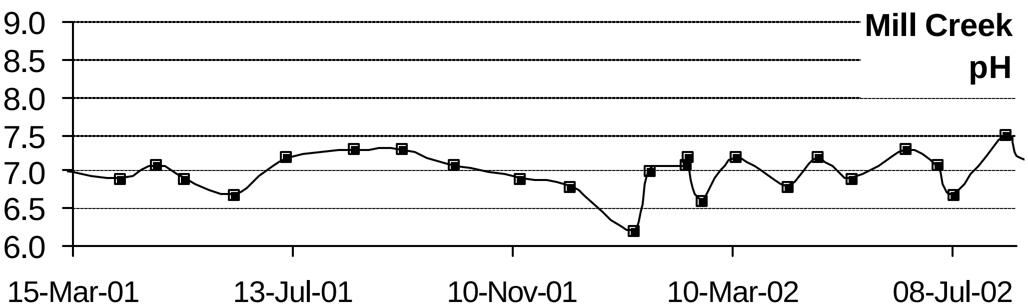


Figure 230: pH Mill Creek: Apr 2001 - July 2002

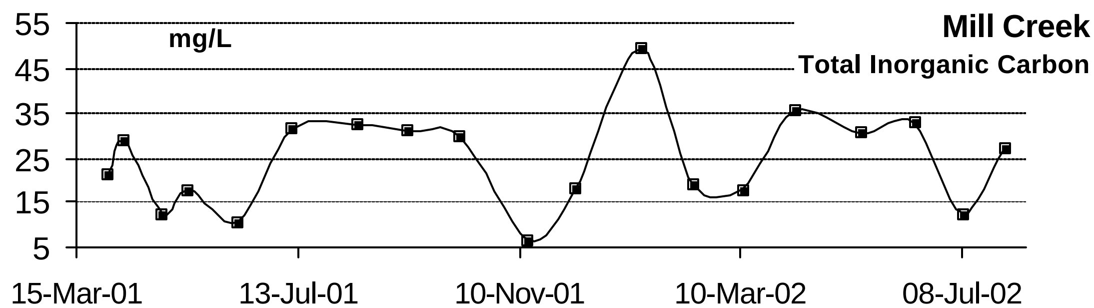


Figure 231: TIC Mill Creek: Apr 2001-July 2002

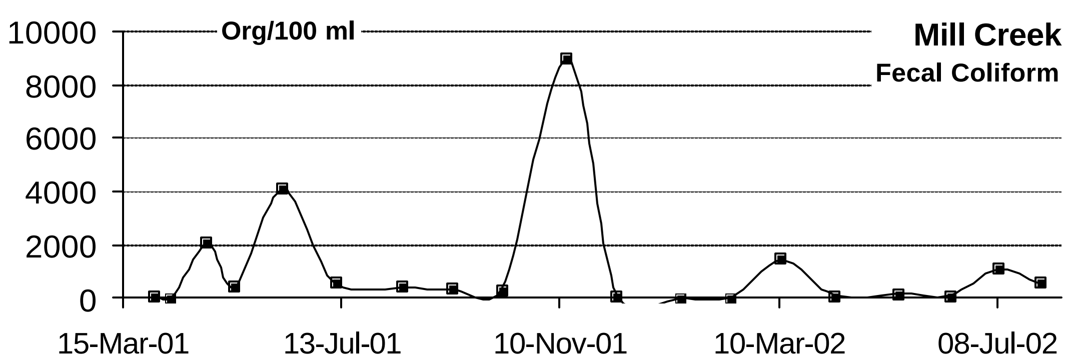


Figure 232: Fecal Coliform Mill Creek: Apr 2001 - July 2002

2.5.5 Auburn Creek, Mullen Slough, and Midway Creek

Auburn Creek, Mullen Slough, and Midway Creek are three of the smallest tributaries to the Green River. The only available data are a few water quality samples collected on Mullen Slough.

May 25, 1995 – November 1996

Flow

King County provided daily average flow from HSPF models of these three tributaries from 1948 to 2001. This information will be used in the model. Figure 233 through Figure 235 shows the flow data for the model simulation period.

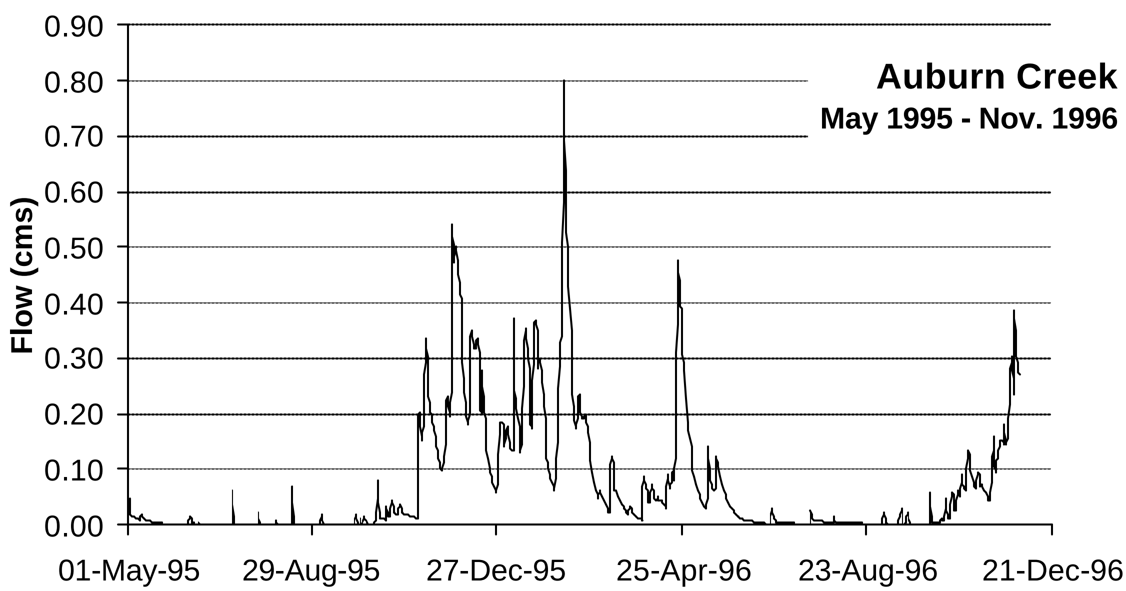


Figure 233: Auburn Creek Flow: May 25, 1995 – Nov 1996 (HSPF)

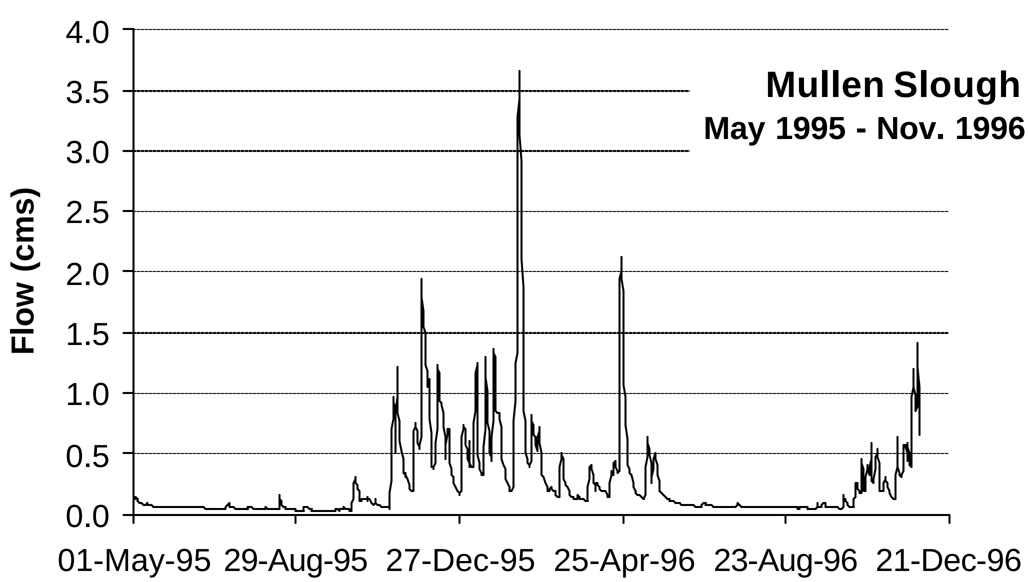


Figure 234: Mullen Slough Flow: May 25, 1995 – Nov 1996 (HSPF)

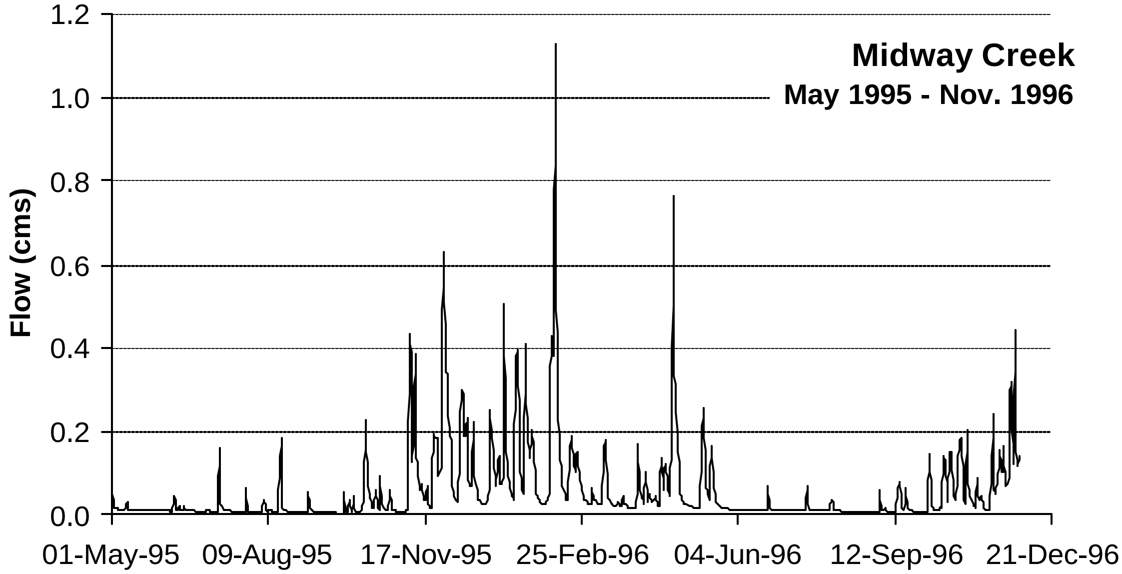


Figure 235: Midway Creek Flow: May 25, 1995 – Nov 1996 (HSPF)

Temperature

Water temperature has not been monitored on these creeks. Temperature data from Big Soos Creek will be used for this model calibration period. Figure 166 shows the temperature for the model simulation period. Big Soos Creek was chosen because it is the closest creek to these creeks with available data for this model run period.

Water Quality

Water quality constituents have not been sampled on these creeks for this model calibration period. Water quality data from Mill Creek will be used. See Figure 201 through Figure 214 for graphs of data for this model calibration period. Mill Creek was chosen because it is the closest creek with available data for this model run period.

April 2001 – Nov 2002

Flow

HSPF flow data will be used for these tributaries. Figure 236 through Figure 238 shows the flow data for the model calibration period.

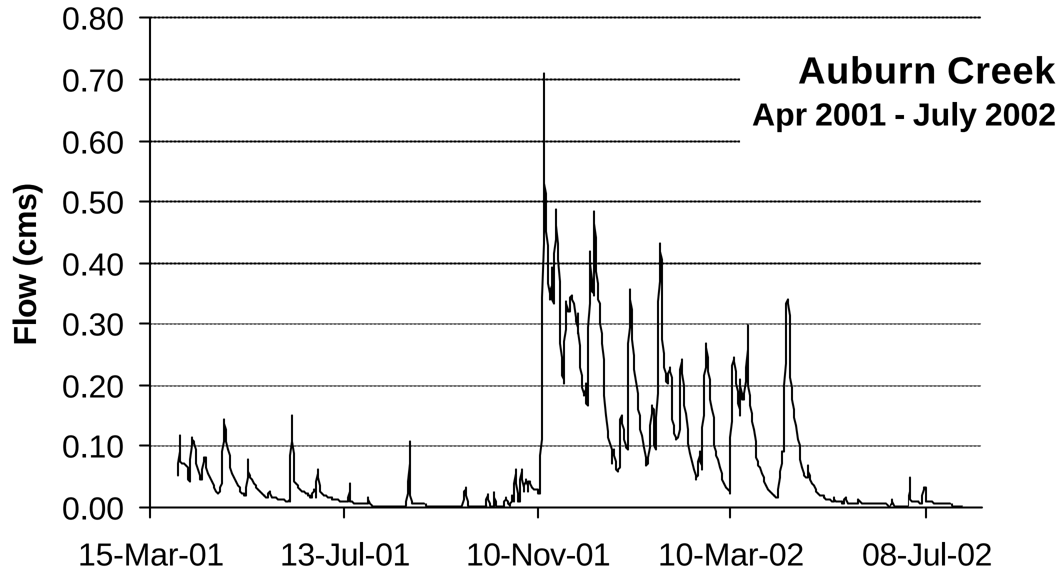


Figure 236: Auburn Creek Flow: Apr 2001 – July 2002

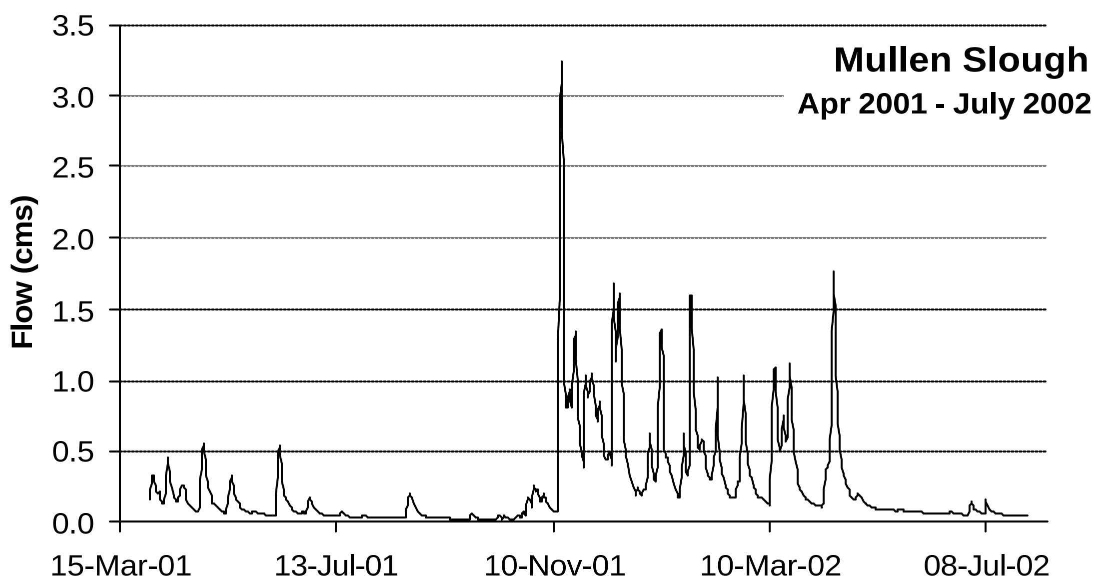


Figure 237: Mullen Slough Flow: Apr 2001 – July 2002

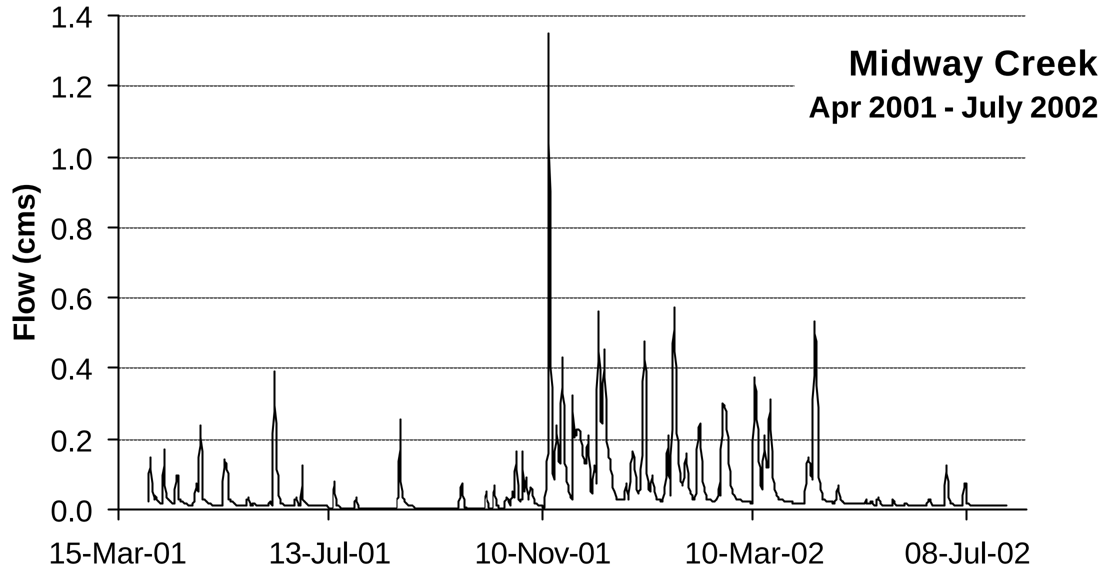


Figure 238: Midway Creek Flow: Apr 2001 – July 2002

Temperature

Water temperature has not been monitored on these creeks. Temperature data from Mill Creek, the closest tributary to these creeks will be used. Figure 217 shows the temperature for the model simulation period.

Water Quality

Water quality constituents have not been sampled on these creeks for this model calibration period. Water quality data from Mill Creek will be used. Mill Creek was chosen because it is the closest tributary with sampled data. See Figure 218 through Figure 231 for data for the model calibration period.

2.6 Groundwater

Groundwater contributes flow to the river along most of its length, and except for a stretch near Auburn, Green River gains more water from groundwater than it loses (Luzier 1969; Woodward et al. 1995). Luzier (1969) believes there are significant groundwater inflows south of Kent where the river traverses the valley, and this report also identifies numerous springs in the slopes of the Green River Gorge, which is east of Flaming Geyser State Park. Woodward et al. (1995) identifies 25 springs in the hill-slopes above the Green River between the upstream and downstream boundaries of this modeling project. The arrows in Figure 239 show the location of these springs.

There is little data available that quantifies inflow from groundwater, and Woodward et al., (1995) did not find adequate data to estimate baseflow in the Green River. The report does include an estimate of discharge from springs in the bluffs above the river. Table 8 lists the discharge per mile from these springs as estimated in Woodward et al (1995). The information is broken down into contributions to each branch of the model. The inflow rate from these springs is less than a tenth of a percent of the flow rate of the river.

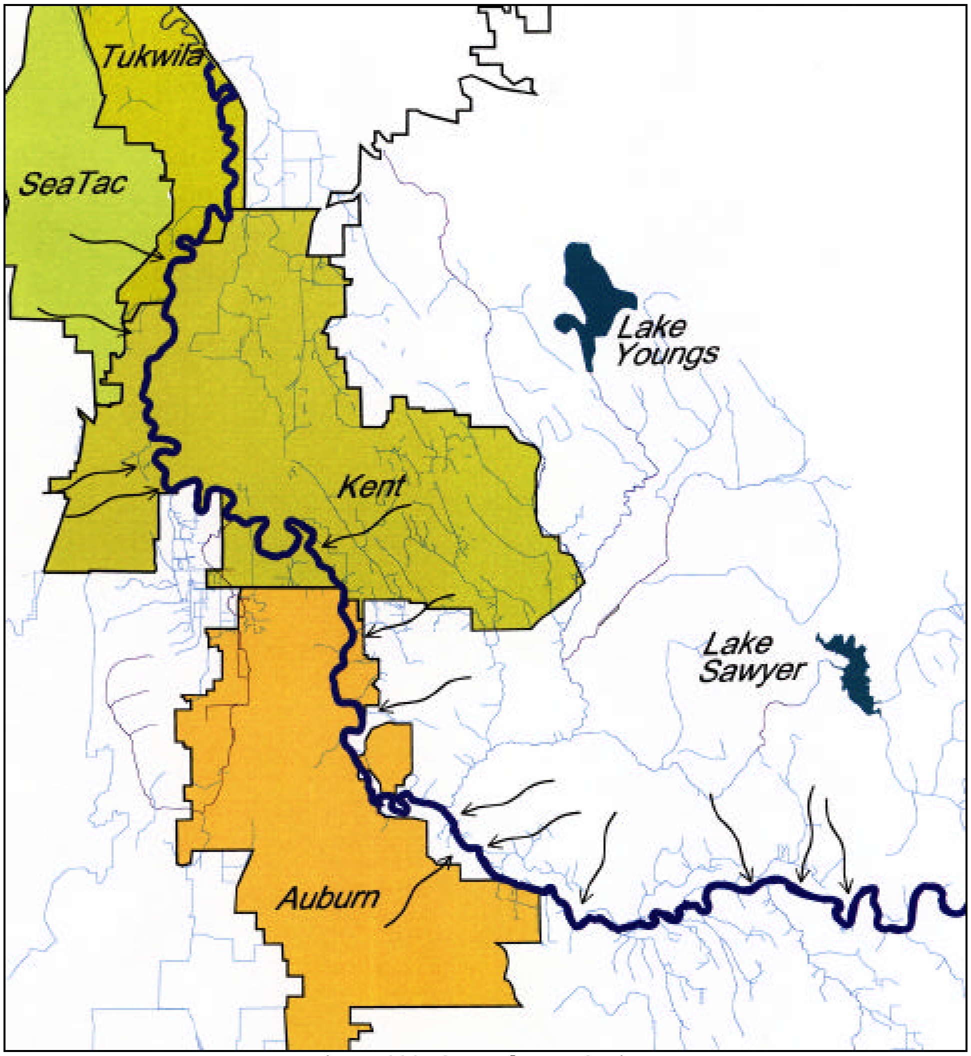


Figure 239: Groundwater Springs

Table 8: Groundwater Inflows per Branch

Branch	Discharge (cfs/mile)	Miles per branch	Discharge (cfs)
1	.01	3.90	.039
2	.01	3.40	.034
3	0.24	4.20	.042
4	0.24	7.0	1.0
5	0.27	15.50	4.20

Since the flow rates in Table 8 are not significant enough to be considered in the model, and no other reliable data are available for estimating groundwater and smaller tributaries downstream of Auburn, groundwater inflows will not be included in the Lower Green River. This will be reviewed during model calibration.

2.7 Distributed Tributaries

To address flow contributions from a series of smaller tributaries on the upper end of the Lower Green River and the lower end of the Middle Green River, King County hydrologists have simulated surface runoff using HSPF. Figure 240 shows the limits of Basin MG1. Basins MG2 and MG3 were added to the upstream boundary.

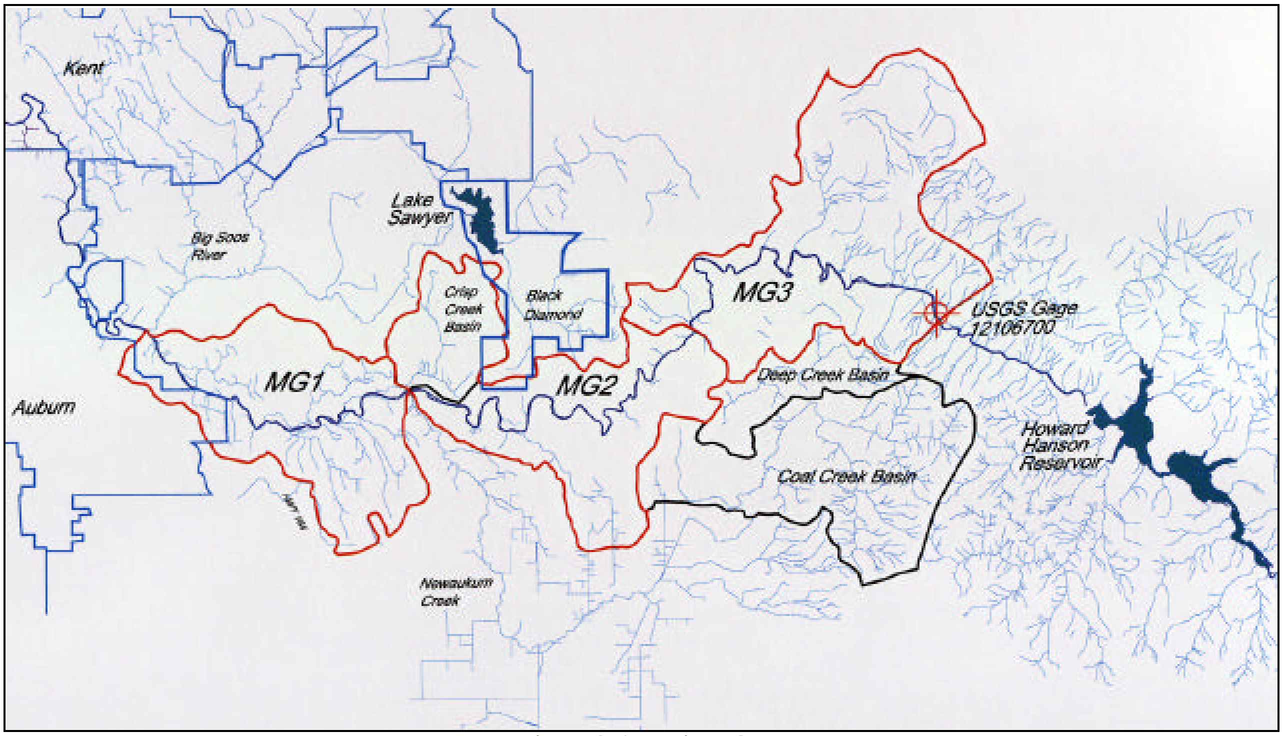


Figure 240: Basin MG1

Inflow from Basin MG1 will be added as a distributed tributary to Branches two and three. Table 9 shows the segments and percentage of the flow attributed to each branch.

Table 9: Basin MG1 Distributed Tributary

Branch	Number of Segments	Area (hectare)	% of Basin MG1
2	22	1,920	52
3	27	1,767	48
TOTAL	49	3,687	100

May 25, 1995 – Nov 1996

Flow

Daily average flow was provided for this basin (HSPF data). It was divided evenly among the segments in each branch, and split between the two branches based upon the percentage of area within MG1 in each branch. The distributed discharges for each branch are shown in Figure 241 and Figure 242 for the proposed model period.

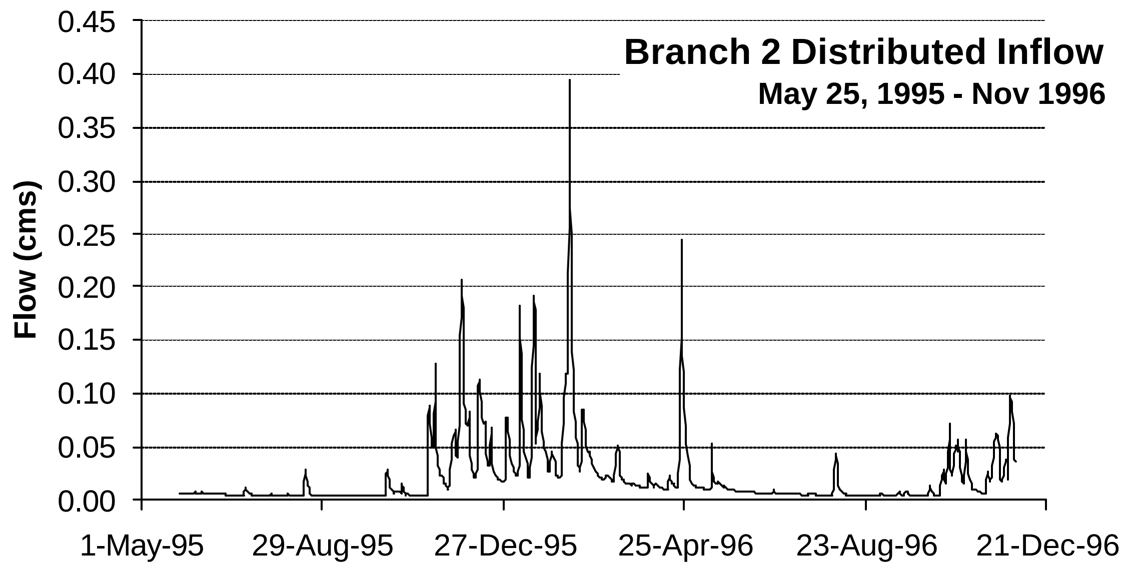


Figure 241: Branch 2 Distributed Flow: May 25, 1995 – Nov 1996

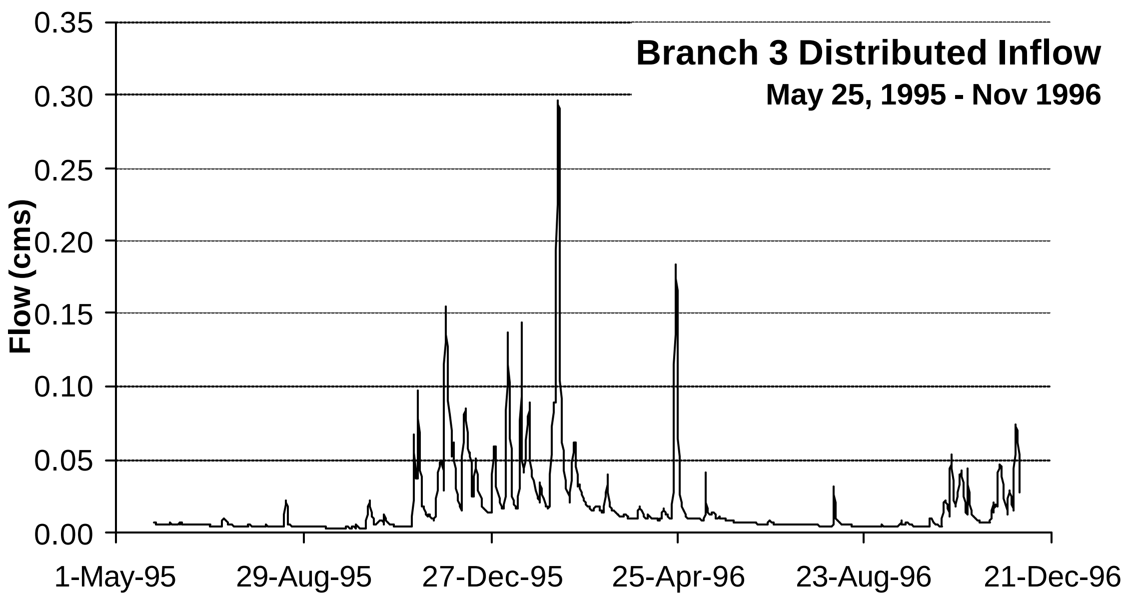


Figure 242: Branch 3 Distributed Flow: May 25, 1995 – Nov 1996

Temperature

A 1995-1996 temperature study conducted by King County recorded temperature at numerous locations at the downstream end of Basin MG1. None of these monitoring locations have complete data for the model calibration period. The station with the most complete data set, Station "NEE" was used for both distributed tributaries. There were three data gaps to be filled:

- The first 14 hours of May 25, 1995
- November 3, 1995 – June 7, 1996
- October 29, 1996 – November 30, 1996

To fill these data gaps, data from the upstream boundary was correlated with data from this monitoring location. Station "WHI" was used as the upstream temperature boundary for the May 25, 1995-November 1996 calibration period. Because it had missing data, the data from the upstream boundary, including filled gaps, was used in the correlation. The equation relating the two temperatures is as follows:

NEE temperature = 0.923*(WHI temperature) + 0.775

Figure 243 shows the correlation between the two stations, Figure 244 shows the correlated values and station data, and Figure 245 is the temperature data used in the model calibration period.

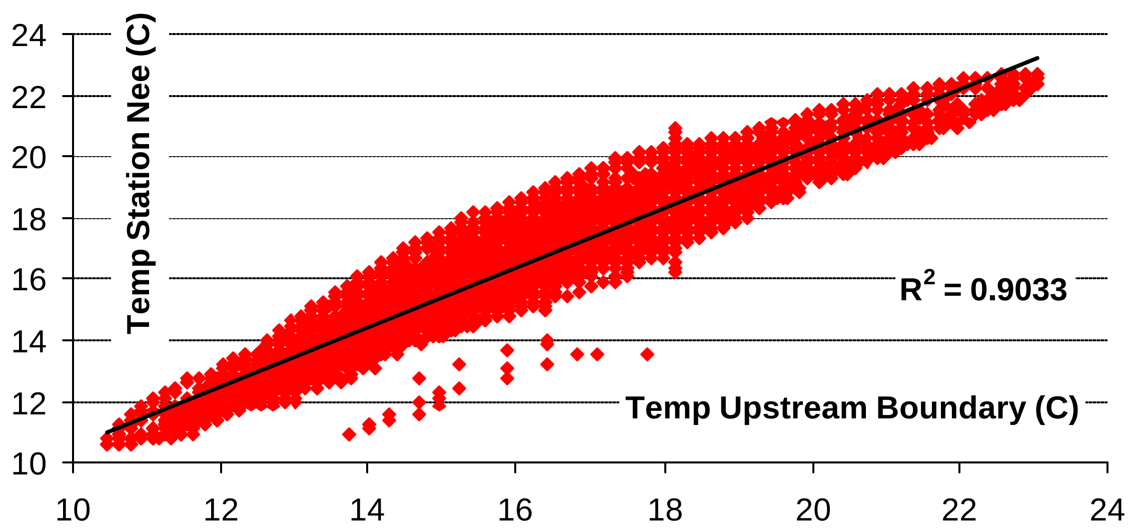


Figure 243: Correlation between upstream boundary temperature and station "nee"

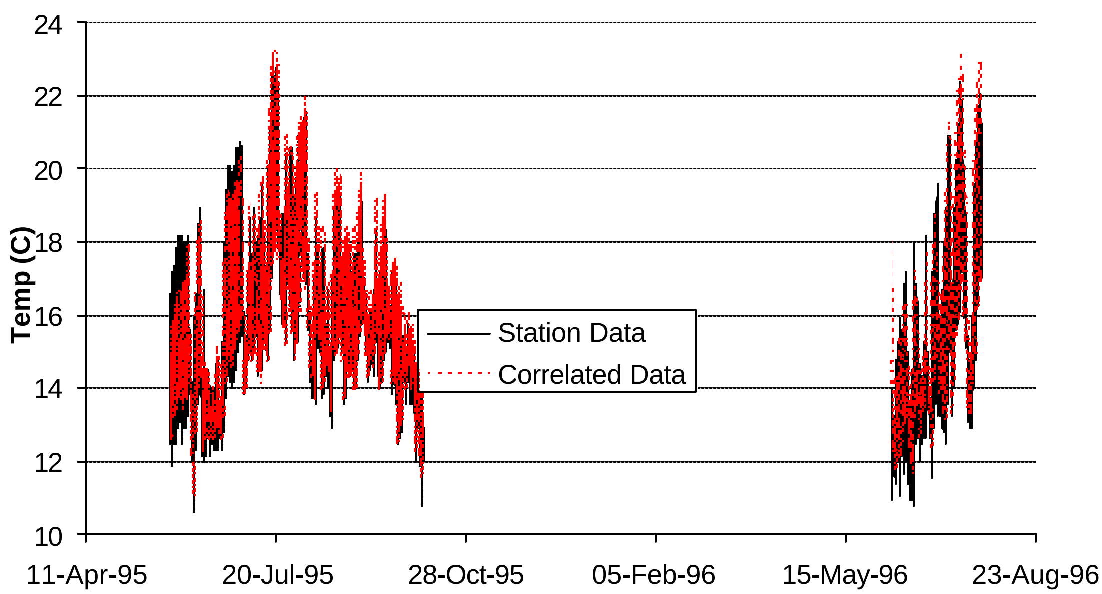


Figure 244: Distributed Tributary: Correlated versus station data 1995-1996

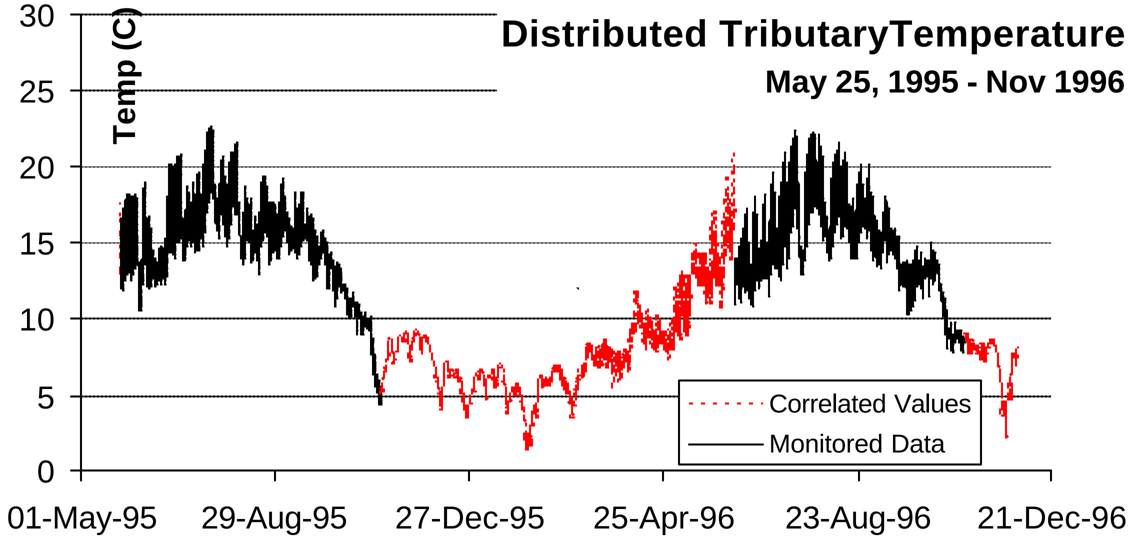


Figure 245: Distributed Tributary Temperature: May 25, 1995 – Nov 1996

Water Quality

Water quality data are not available for the distributed tributaries. Data from Big Soos Creek will be used. This is the closest tributary with monitored data. See Figure 167 through Figure 180.

April 2001 - July 2002

Flow

Daily average flow was provided for this basin (HSPF data). It was divided evenly among the segments in each branch, and split between the two branches based upon the percentage of area within MG1 in each branch. The distributed discharges for each branch are shown in Figure 246 and Figure 247 for the proposed model period.

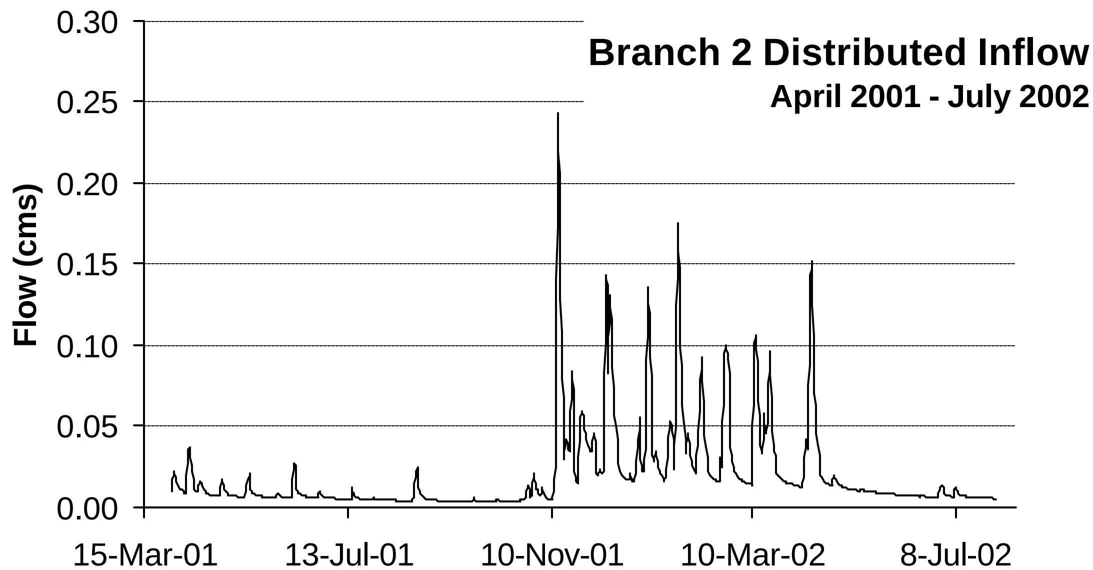


Figure 246: Branch 2 Distributed Inflow: Apr 2001 – July 2002

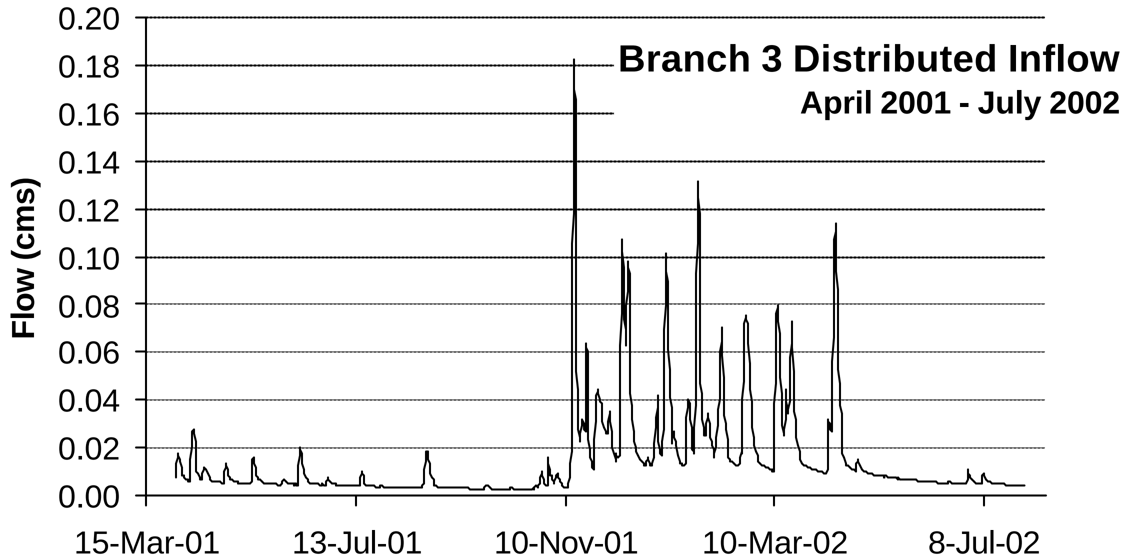


Figure 247: Branch 3 Distributed Inflow: Apr 2001 – July 2002

Temperature

King County monitors temperature on the Green River inside the downstream boundary of Branch two. Locator GRT04 has temperature data from July 2001 to the end of this model calibration period. About four km downstream of GRT04, a University of Washington monitoring station (GR1) has temperature data from April 2001 to July 2001. These data were correlated with data from GRT04 to fill this time period. The correlation equation is as follows:

$$GRT04 = (GR1)(0.894) + 1.7154$$

Figure 248 graphs the two stations and shows the linear regression line, Figure 249 shows correlated values and station data, and Figure 250 shows the temperature data for the model calibration period. These data will be used for both distributed tributaries.

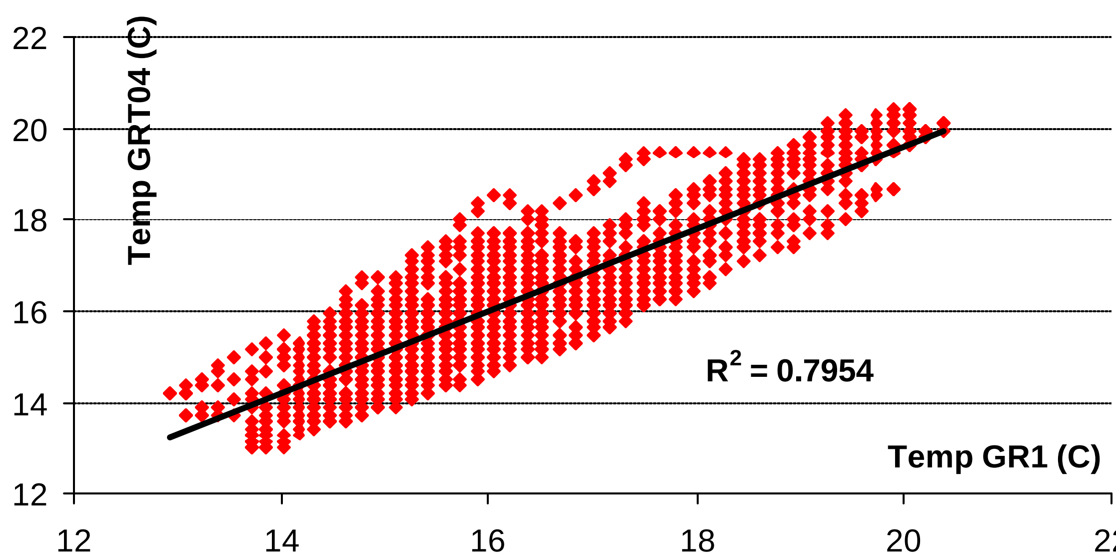


Figure 248: Correlation between station Gr1 and station GRT04

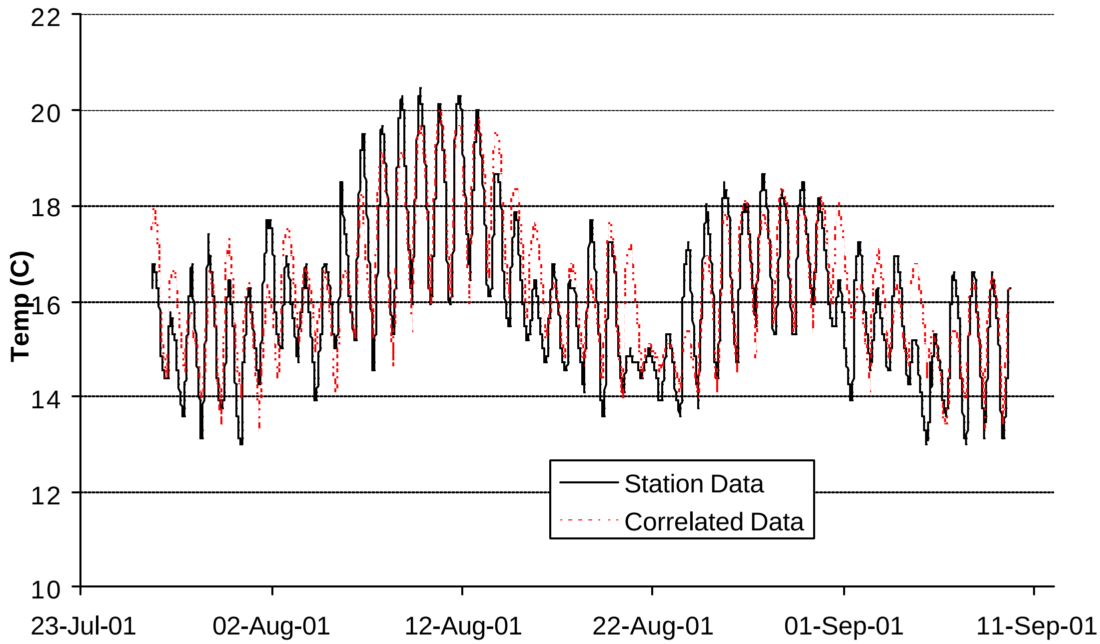


Figure 249: Distributed tributary: Correlated versus station data 2001-2002

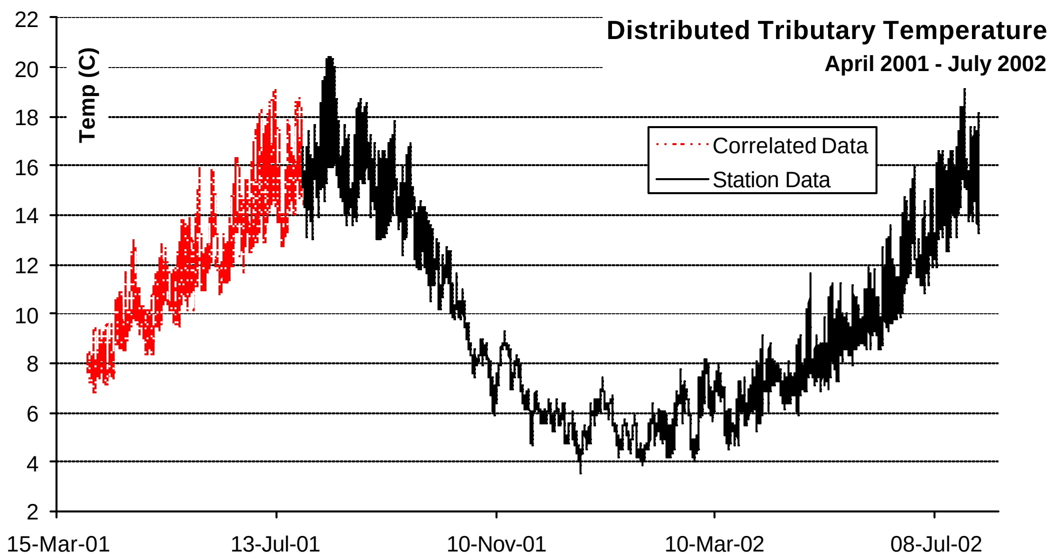


Figure 250: Distributed Tributary Temperature: Apr 2001 – July 2002

Water Quality

Water quality data are not available for the distributed tributaries. Data from Big Soos Creek will be used. See Figure 184 through Figure 197.

2.8 Meteorological Data

The Seattle-Tacoma (SeaTac) International Airport is less than a mile west of the downstream project boundary at Tukwila. The airport collects weather data including air temperature, dew point temperature, cloud cover, air pressure, wind speed, wind direction, and cloud cover. King County assembled this data in a database file for years 1995 through March 2000. Additional data for the remainder of 2000 and for years 2001 and 2002 were collected for use in the model. Data were obtained in hourly intervals.

May 25, 1995 - Nov 1996

Figure 251 shows air temperature, Figure 252 shows dew point temperature, and Figure 253 shows wind speed.

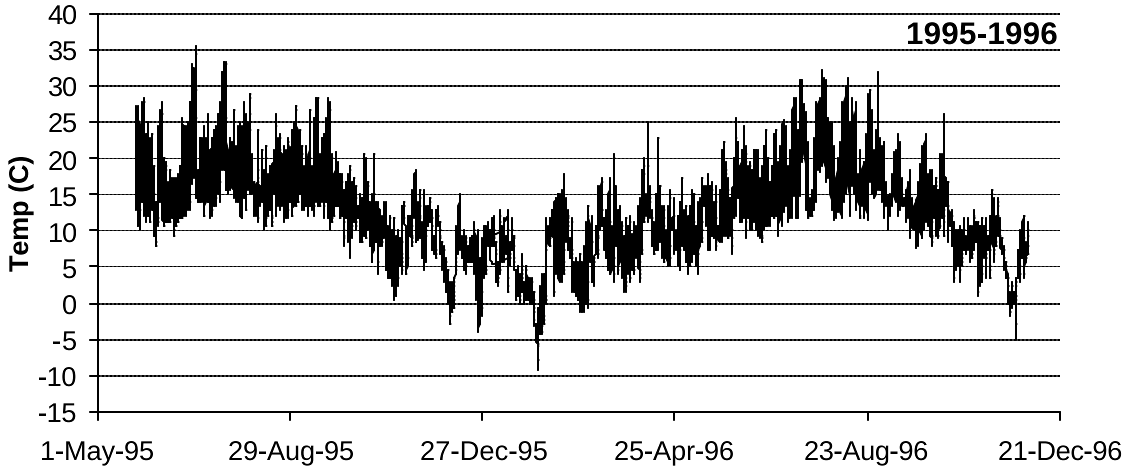


Figure 251: Air Temperature at Seattle-Tacoma International Airport

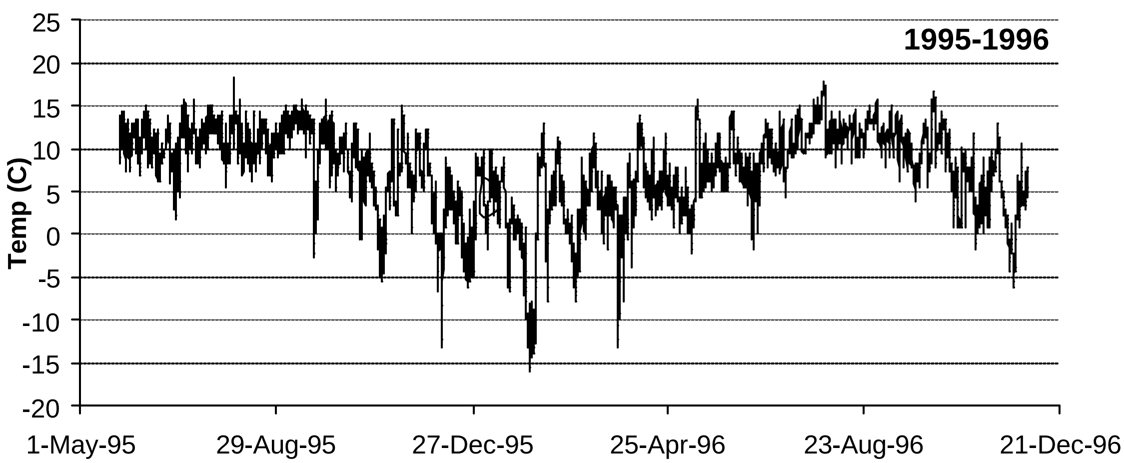


Figure 252: Dew Point Temperature at Seattle-Tacoma International Airport

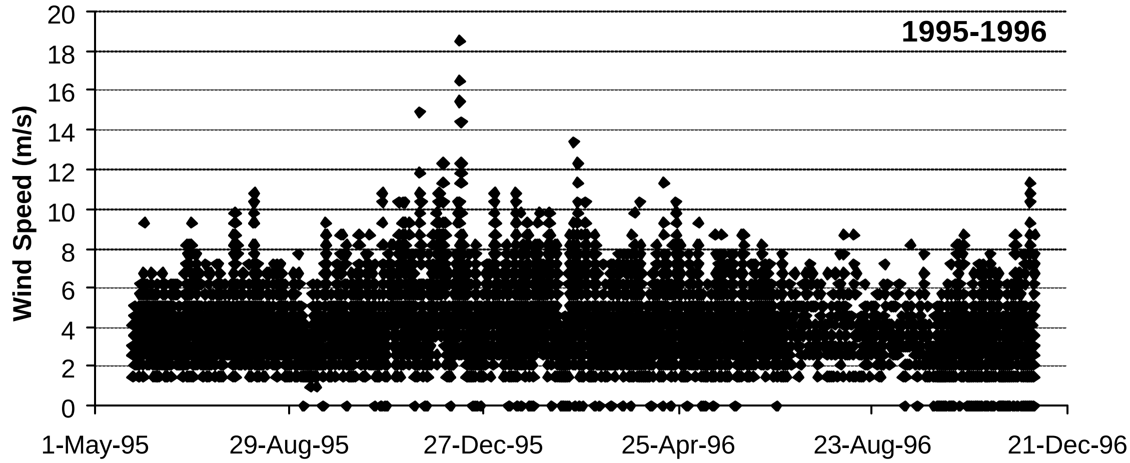


Figure 253: Wind Speed at Seattle-Tacoma International Airport

Note that in Figure 253 no wind values were recorded between 0 and 1.50 m/s.

Figure 254 shows the frequency of the direction of the wind. Note that in this figure the number on the bottom axis of the bar graph refers to the angle of the wind direction, and the number on top of the bar refers to the number of times wind speed was recorded between that angle and the next angle left. For example, at 360 degrees there were 1011 times the wind was recorded at an angle between 331 degrees and 360 degrees.

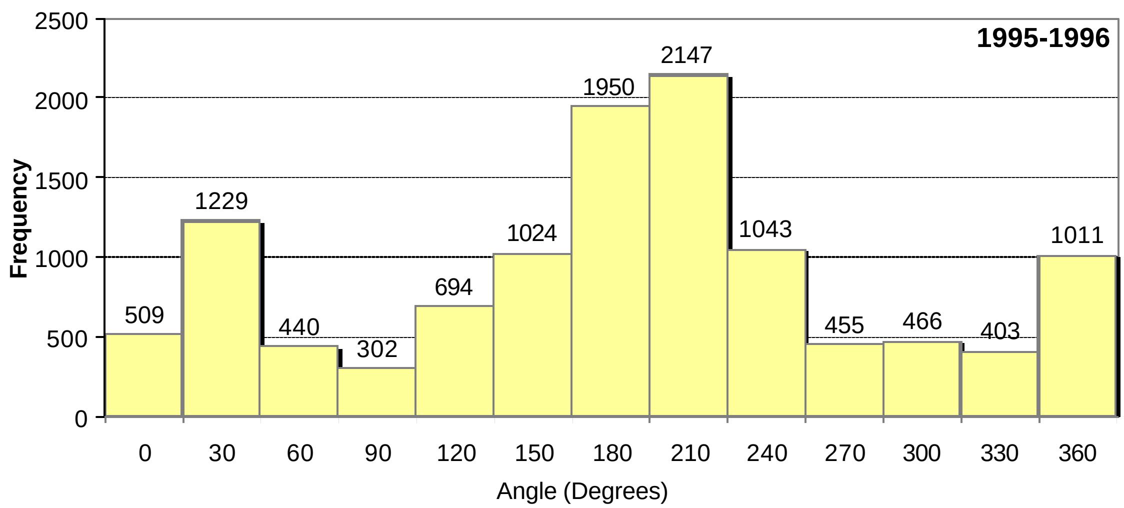


Figure 254: Frequency of Wind Direction at Seattle-Tacoma International Airport

In Figure 255 cloud cover varies on a scale of 0 to 10 with zero representing no cloud cover and ten representing full cloud cover. These were recorded to the nearest whole number.

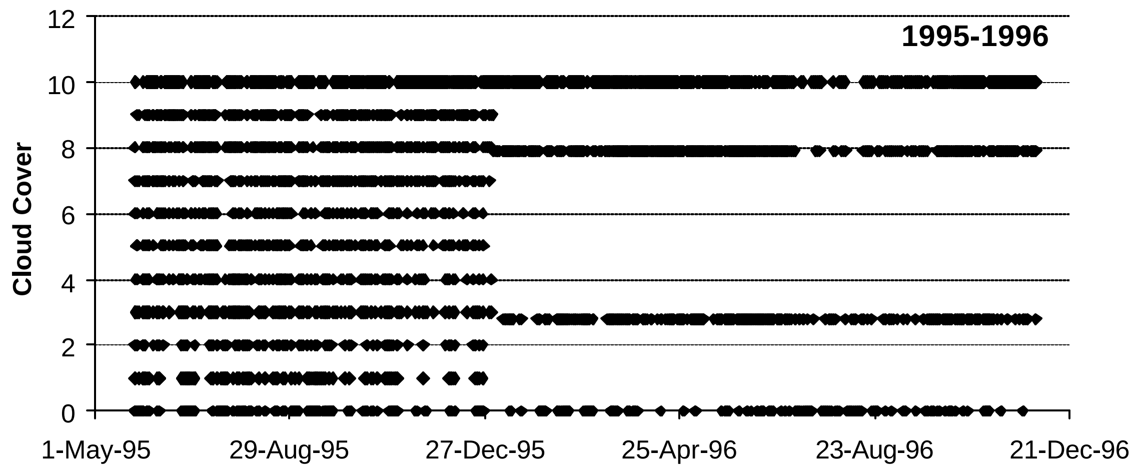


Figure 255: Cloud Cover at Seattle-Tacoma International Airport

The National Oceanic and Atmospheric Administration have a Level I ISIS (Integrated Surface Irradiance Study) station in Seattle which measures shortwave solar radiation data. These data are available from the NOAA web site in 15-minute intervals and was provided by King County for 1995 through 2000. Figure 256 is a graph of the shortwave solar radiation for the model simulation period.

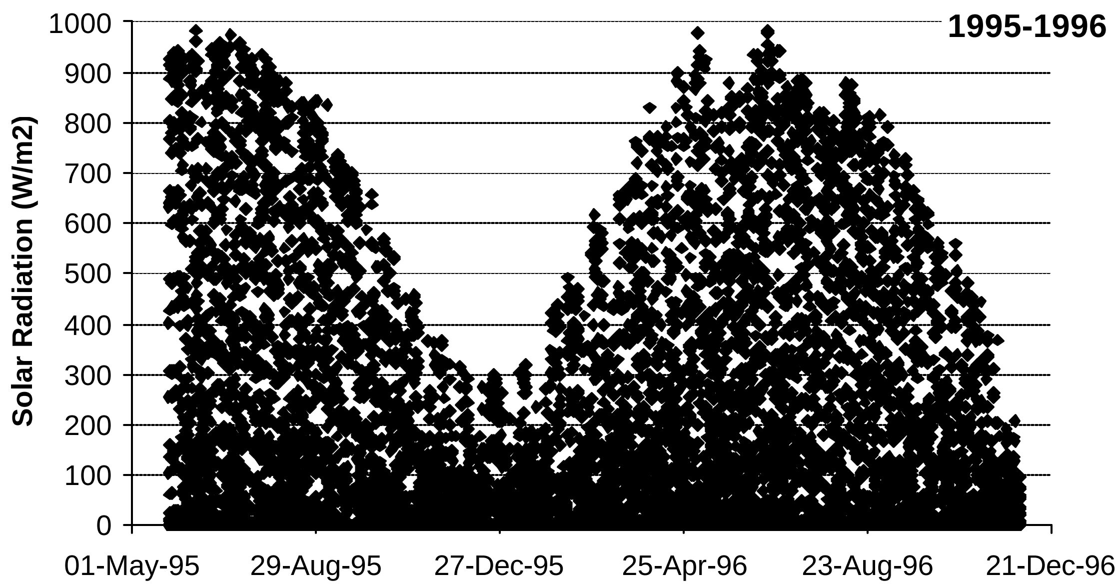


Figure 256: Shortwave Solar Radiation for model calibration period

April 2001 - July 2002

Figure 257 through Figure 262 are graphs of air temperature, dew point temperature, wind speed, wind direction, cloud cover, and shortwave solar radiation for this model calibration period.

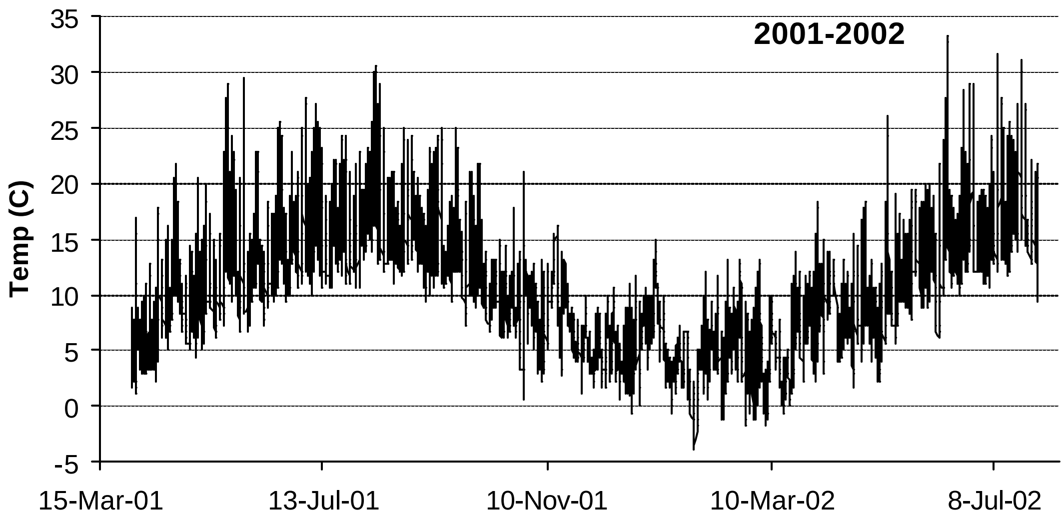


Figure 257: Air Temperature at Seattle-Tacoma International Airport

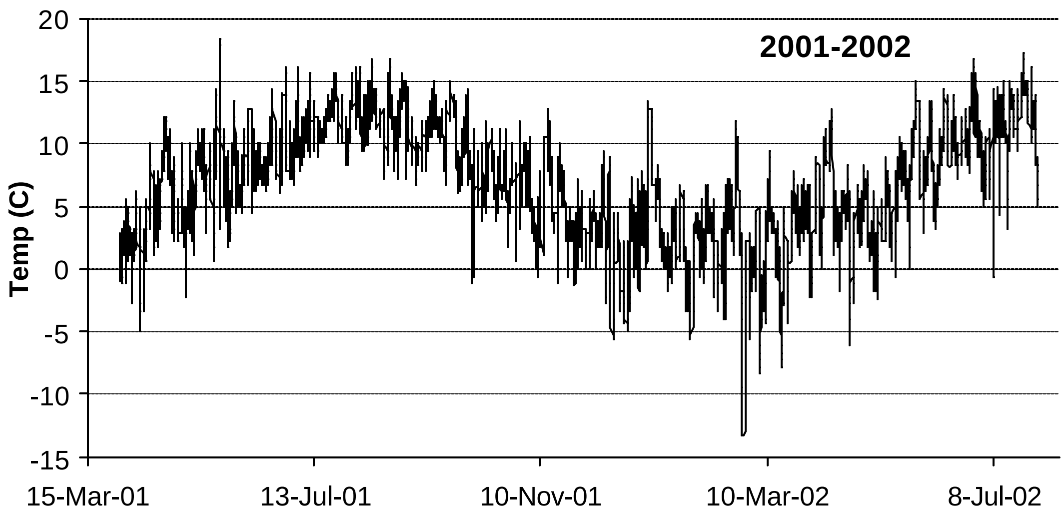


Figure 258: Dew Point Temperature at Seattle-Tacoma International Airport

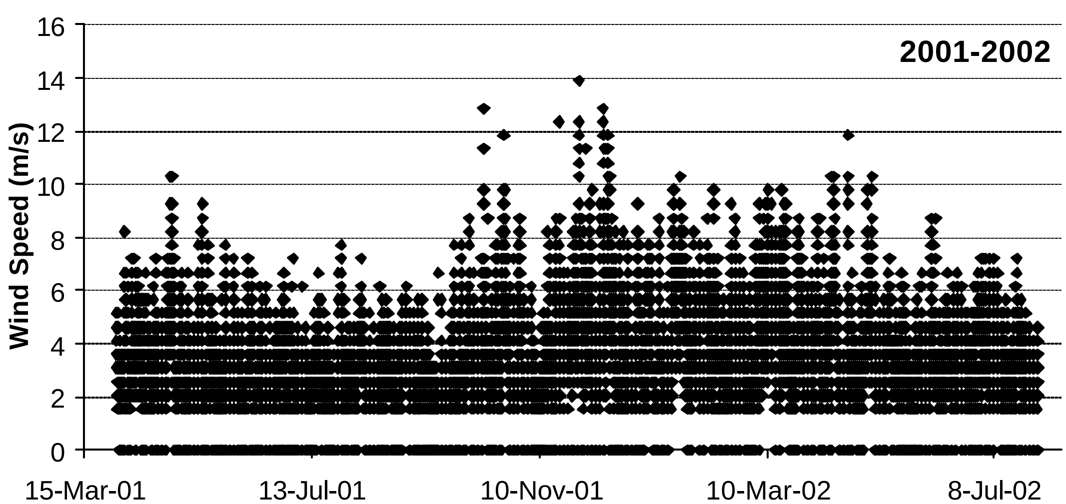


Figure 259: Wind Speed at Seattle-Tacoma International Airport

Note that in Figure 259 no wind values were recorded between 0 and 1.50 m/s.

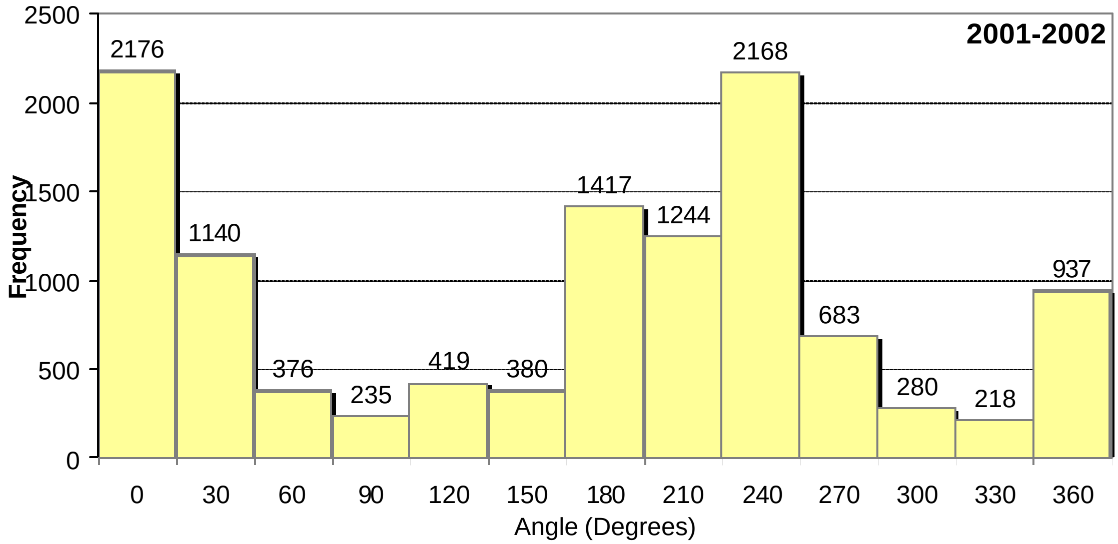


Figure 260: Frequency of Wind Direction at Seattle-Tacoma International Airport

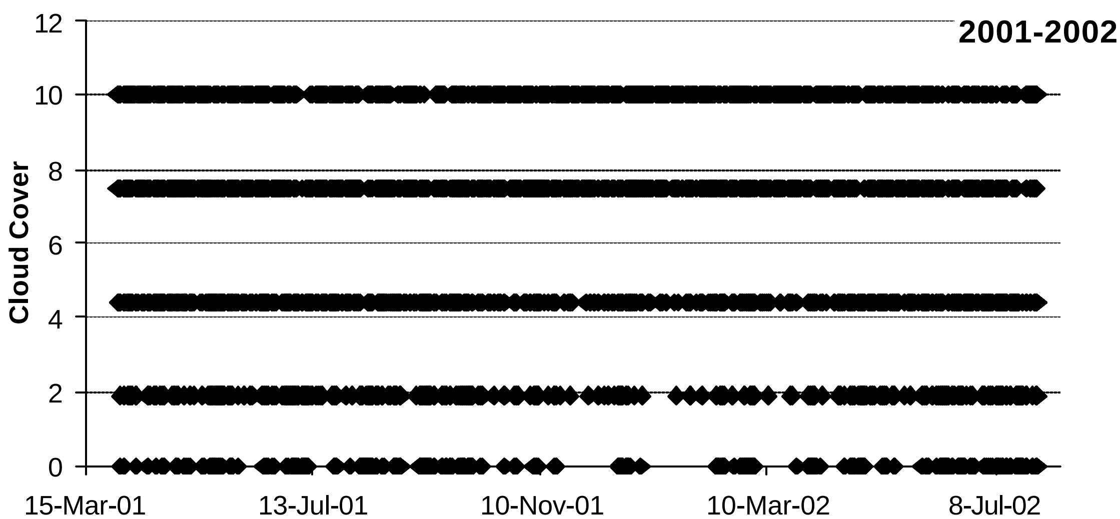


Figure 261: Cloud Cover at Seattle-Tacoma International Airport

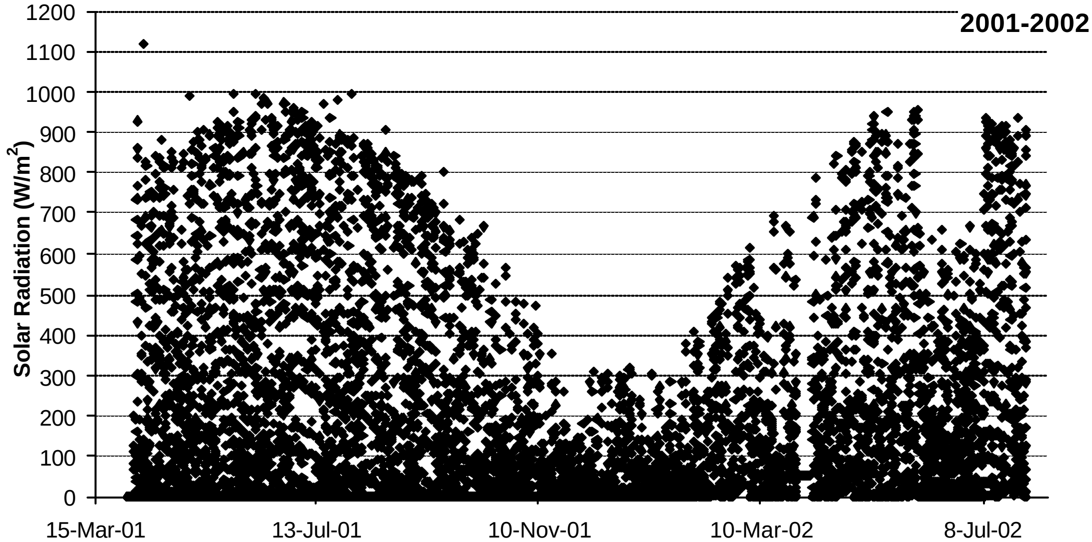


Figure 262: Shortwave solar Radiation from Seattle ISIS Station

The shortwave solar radiation for this model calibration period had a number of negative values during late evening and early morning hours. These values were set to zero.

2.9 Shading

Model input for the dynamic shading algorithm includes tree top elevations, distances from centerline to controlling vegetation from both stream banks, and a shade reduction factor for both streambanks (Cole, 2002).

King County assembled shade data and processed it using a Washington Department of Ecology spreadsheet program. This program is a modification of the Shade-a-lator program developed by Oregon's Department of Environmental Quality. Information from King County was further processed for the input file to CE-QUAL-W2.

3.0 MODEL CALIBRATION: 1995-1996 AND 2001-2002

This section of the report discusses issues relative to the calibration effort. Data input to the model as discussed in Section 2.0 is reviewed and revised as necessary during model calibration.

The calibration effort focused on model predictions of hydrodynamics (flow and water level), temperature, bacteria (fecal coliform), and eutrophication model parameters (such as nutrients, algae, dissolved oxygen, and organic matter). The model calibration periods were from May 25, 1995 to November 30, 1996 and April 1, 2001 to July 31, 2002.

3.1 Hydrodynamic Calibration

There is one flow and water level gage station along the sections of river being modeled. This is a USGS gage (12113000), located near Auburn at River Mile 31.30. Figure 263 shows the location of this station.

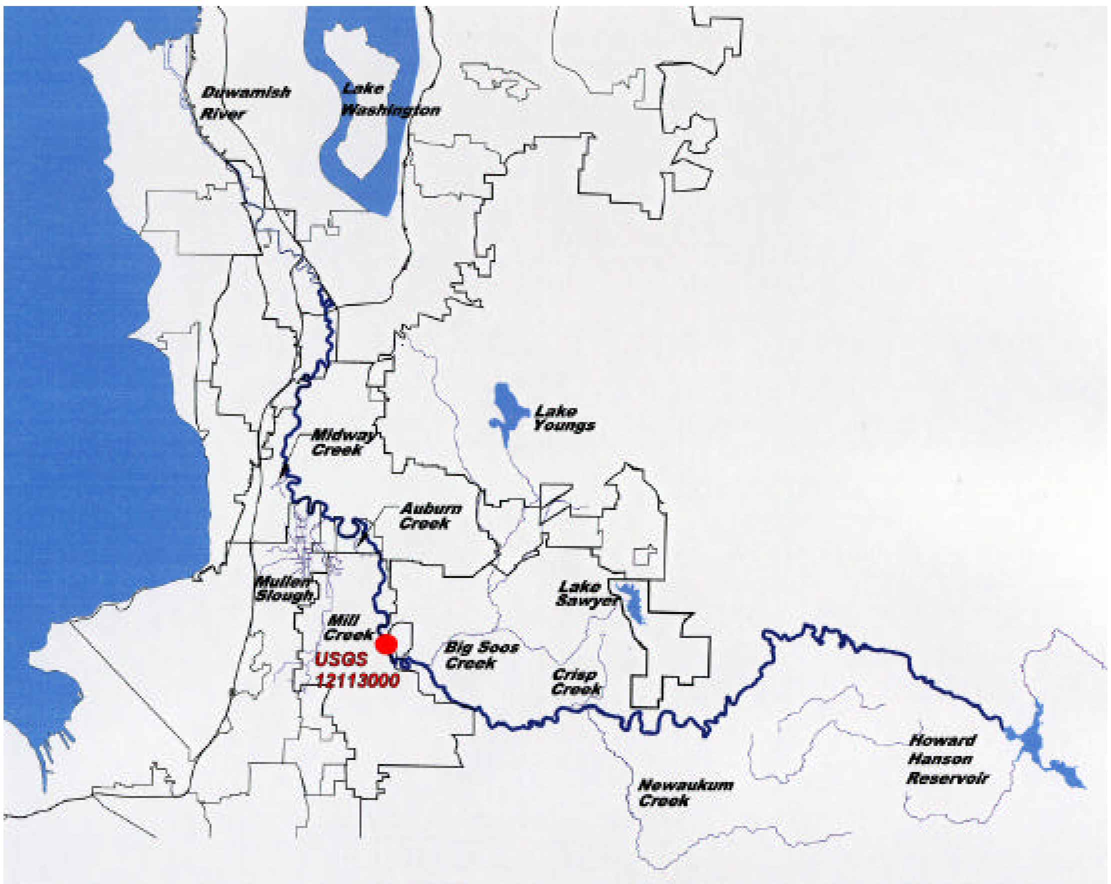


Figure 263: Flow and Water Level Calibration Station

3.1.1 2001-2002

A review of literature indicated there are many springs that contribute flow to the Green River, especially upstream of the upper project boundary (Luzier 1969, Woodward et. al. 1995). Luzier 1969 estimated average winter flow rates as 6.30 cms, and summer rates at 1.26 cms from flows in the Green River Gorge. To account for groundwater in the model, 6.30 cms was added to flow at the upstream boundary from October 1, 2001 to March 30, 2002, and 1.26 cms was added to the upstream flow from April 1, 2002 to July 31, 2002. Initial model results at Site 12113000 showed that flow was under-predicted during summer months and over-predicted during winter months.

Since groundwater contributions were approximated, it was assumed this was the source of the difference between model values and data. Flow data at the upstream boundary were adjusted to calibrate flow. Figure 264 shows the initial and revised flow added at the upstream boundary and shows the model values and data at Station 12113000. Table 10 shows the flow error statistics.

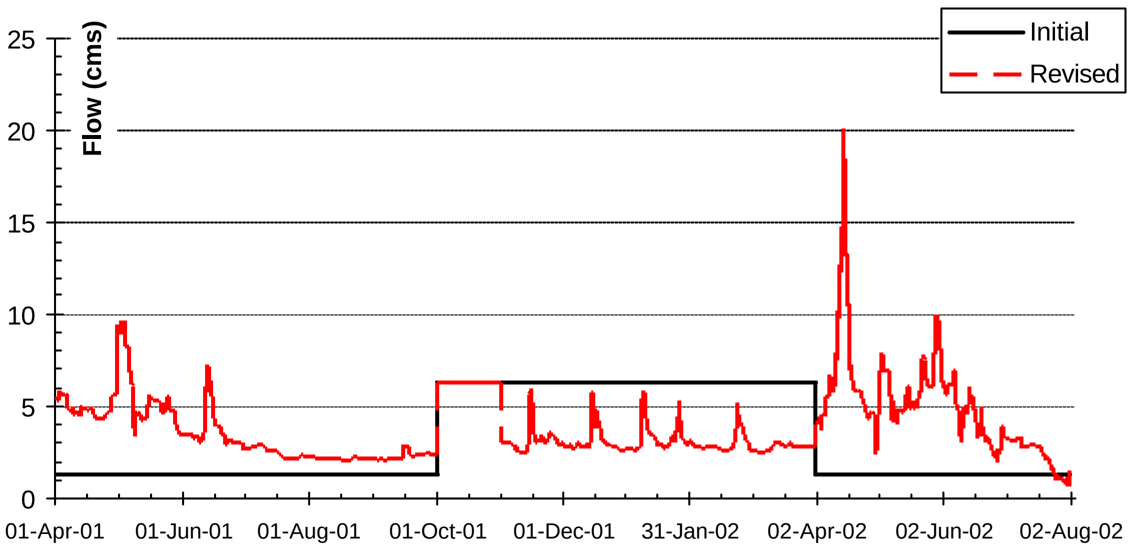


Figure 264: Initial and Revised Flow Additions at Upstream Boundary, 2001-2002

Table 10: Flow Error Statistics, 2001-2002 Model Run Period

No. of Data Comparisons	Mean Error (cms)	AME (cms)	RMS Error (cms)
11665	0.05	1.6	3.1

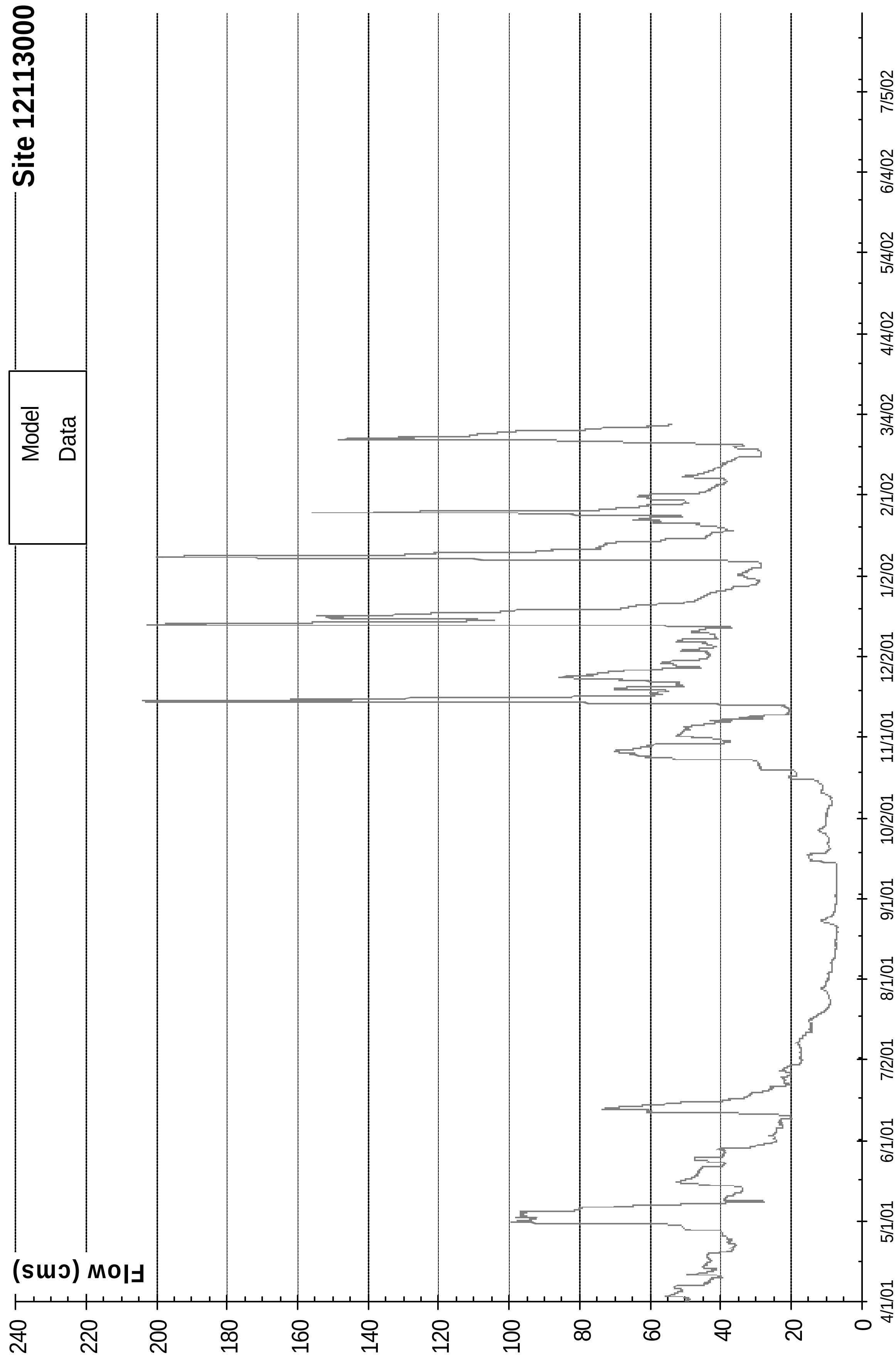


Figure 265: Flow Comparison - April 2001-July 2002

Water level was also monitored at the same location on the Green River (USGS 12113000). Calibrating water surface elevation at this location required adjustments to the bathymetry and friction factor. Figure 266 shows the water surface elevation for the model calibration period, and Table 11 shows the error statistics.

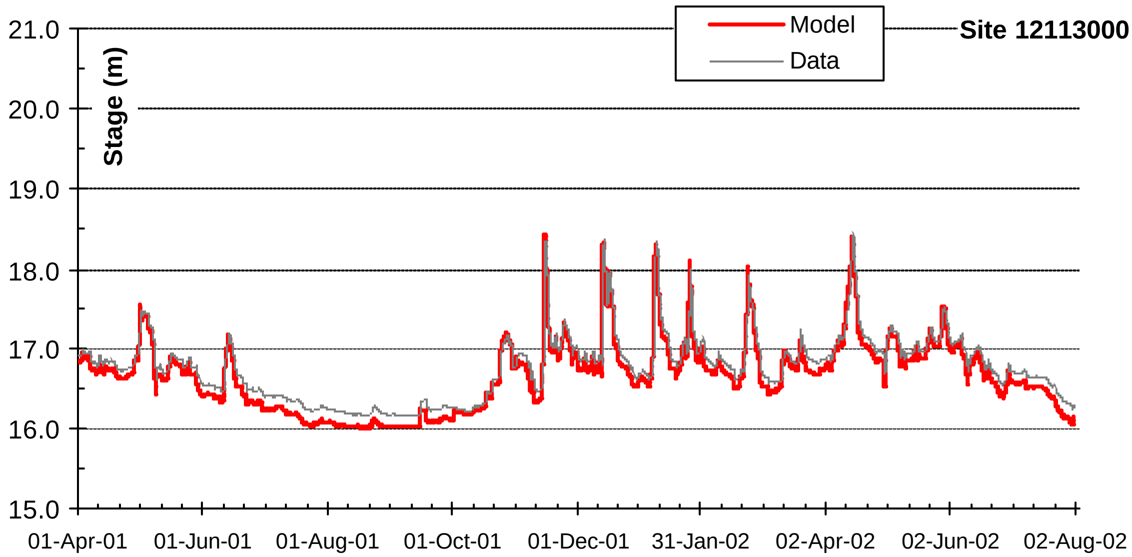


Figure 266: Water Surface Elevation Comparison - April 2001 - July 2002

Table 11: Water Surface Elevation Error Statistics, 2001-2002 Model Run Period

No. of Data Comparisons	Mean Error (m)	AME (m)	RMS Error (m)
11665	-0.11	0.11	0.12

3.1.2 1995-1996

As with the 2001-2002 model run period, water level and flow values were compared with data at USGS Station 12113000, near Auburn, Washington. Since groundwater inflows were approximated at the upstream boundary, these values were adjusted to calibrate model values with data at the USGS station. Figure 267 shows the initial and revised flow added at the upstream boundary,

Figure **268** shows the model results and data for flow, Figure 269 shows water surface elevation data and model results, and Table 12 shows the error statistics for this model calibration period.

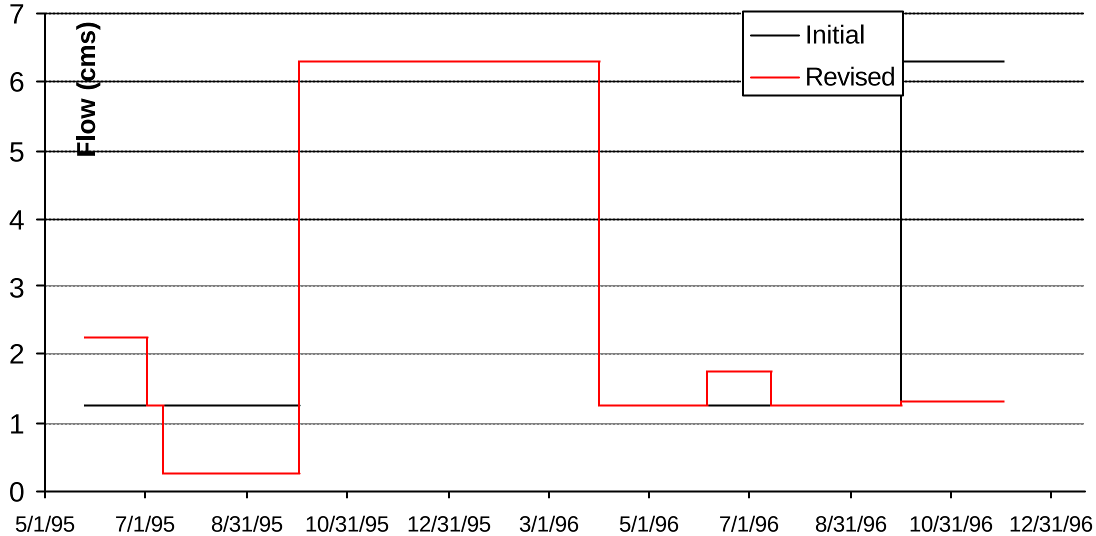


Figure 267: Initial and Revised Flow Additions at Upstream Boundary, May 25, 1995-Nov 1996

Table 12: Flow Error Statistics, 1995-1996 Model Run Period

No. of Data Comparisons	Mean Error (cms)	AME (cms)	RMS Error (cms)
13312	0.13	2.5	5.6

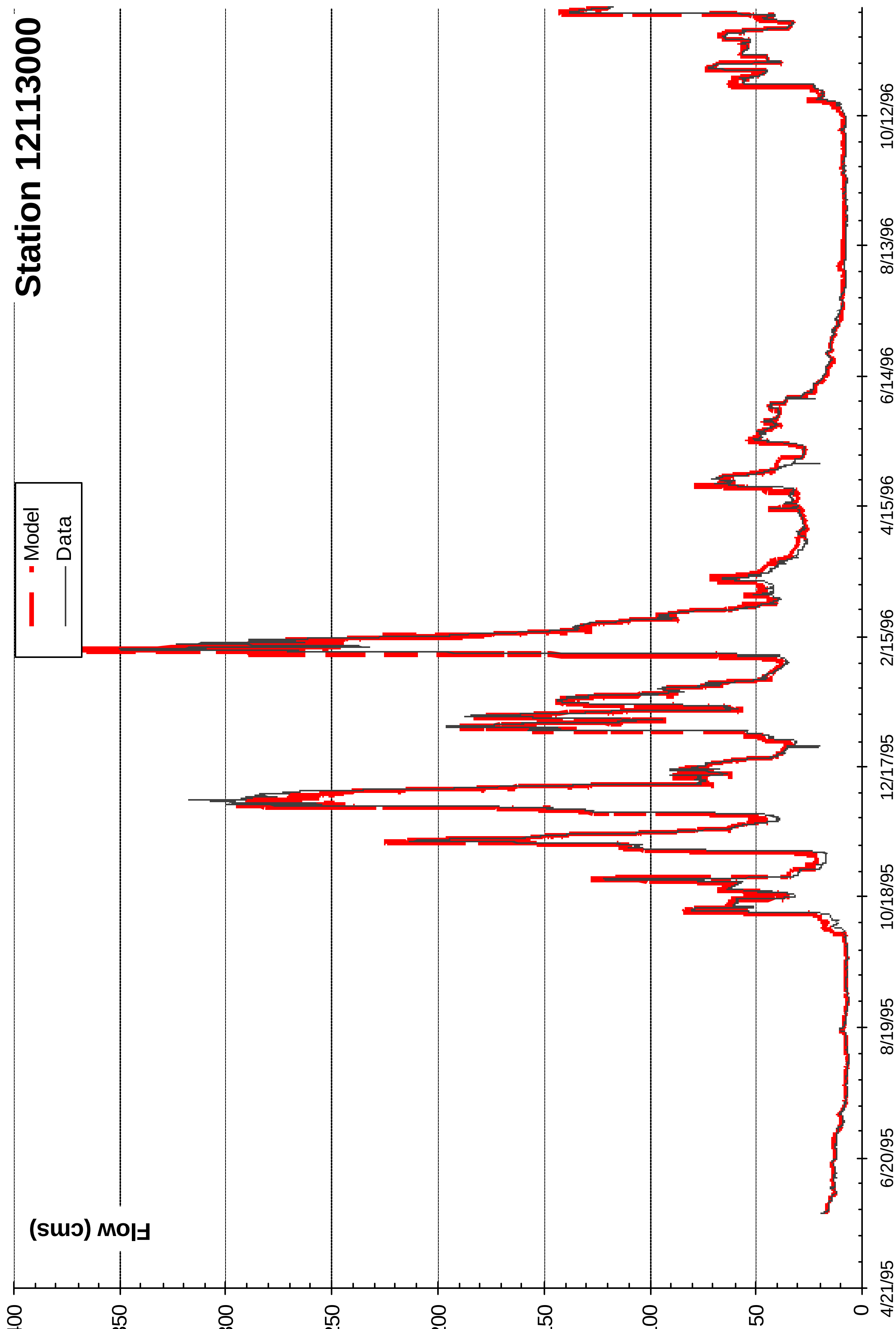


Figure 268: Flow Comparison - May 25, 1995 to November 1996

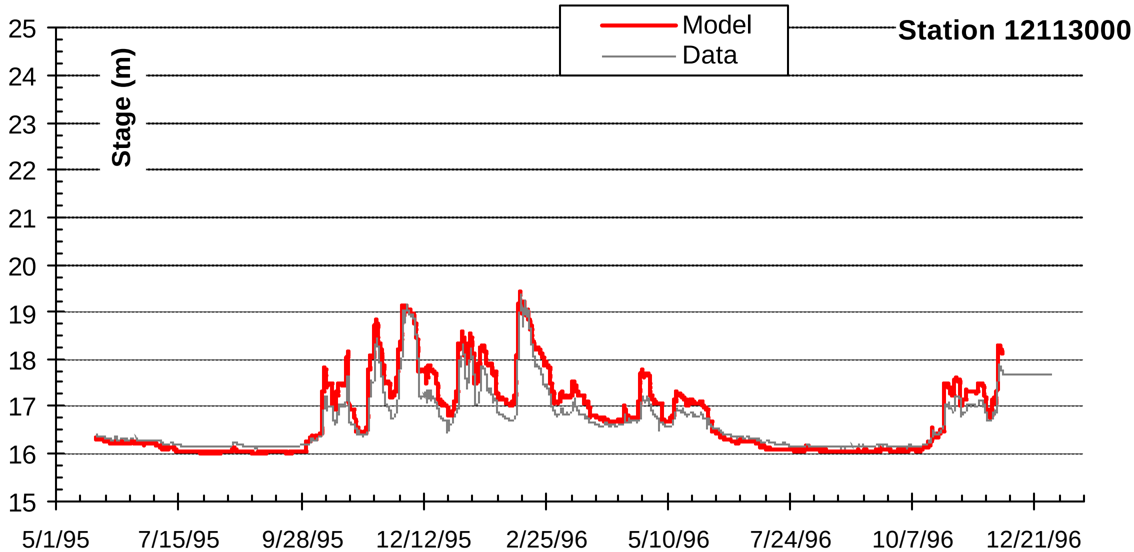


Figure 269: Water Surface Elevation Comparison - 1995-1996 Model Run Period

Table 13: Water Surface Elevation Error Statistics, 1995-1996 Model Run Period

No. of Data Comparisons	Mean Error (m)	AME (m)	RMS Error (m
13312	0.10	0.21	0.26

3.2 Temperature Calibration

3.2.1 2001-2002

Monitoring Sites

There were four locations available for temperature calibration during this run period. Figure 270 shows the site locations, and Table 14 lists the time periods of data sampling and the river mile of the sampling site.

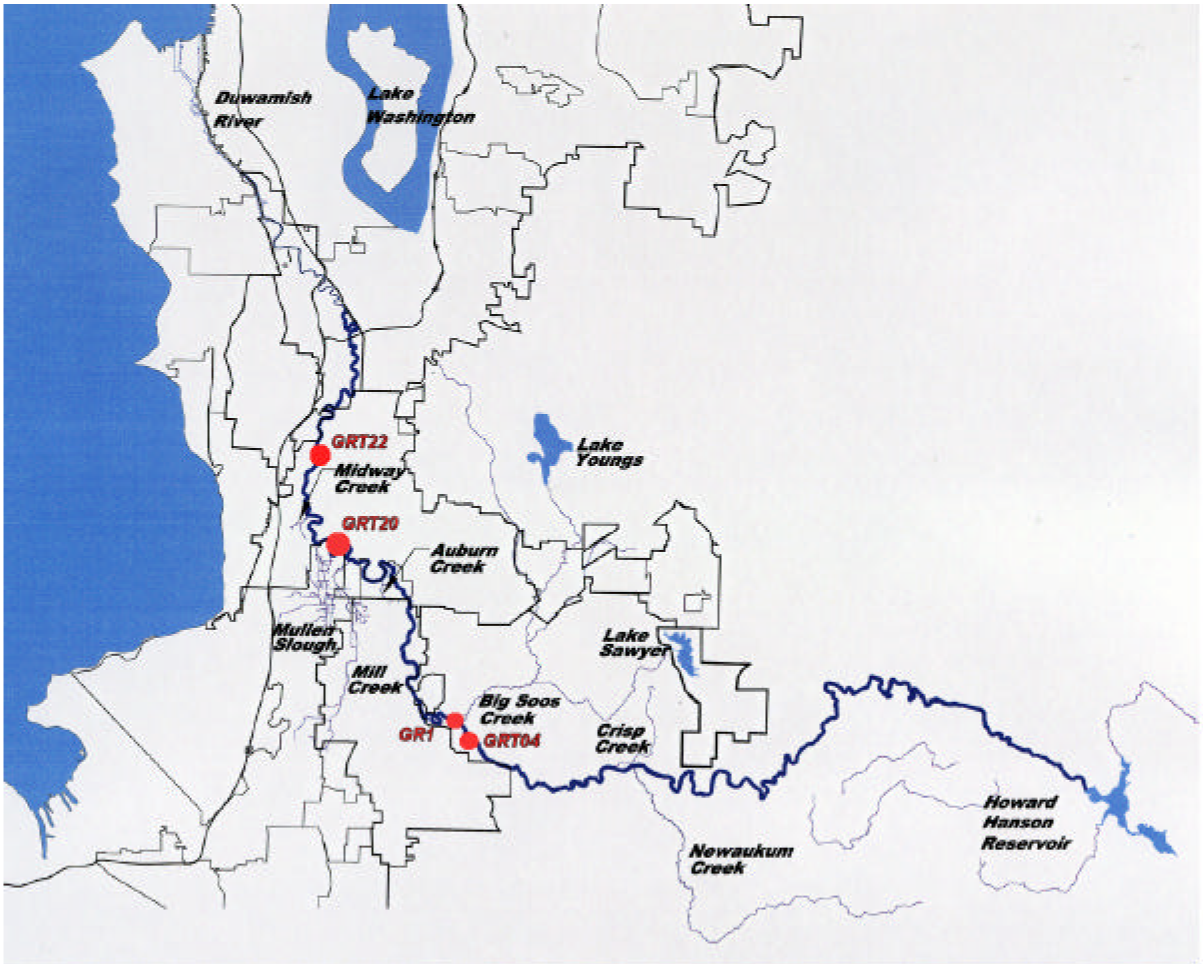


Figure 270: 2001-2002 Temperature Calibration Sites

Table 14: 2001-2002 Temperature Calibration Sites

Locator Station	Description	River Mile	Time Period of Data
GRT22	Van Doren's Landing	18.60	7/9/2002 – 7/31/2002
GRT20	Near Mill Creek	23.20	7/9/2002 – 7/31/2002
GR1	Near Big Soos Creek	33.80	4/1/2001 – 9/10/01 11/09/01 – 9/12/2002
GRT04	Porter Levee	34.40	7/27/2001 – 11/09/2001

Temperature adjustments were made by reviewing which model layers contained water during the summer months and adjusting the width of these layers at and upstream of the calibration segments. By decreasing segment widths, the depth was increased, and the area exposed to solar radiation was decreased, thus decreasing solar heating.

Figure 271 and Figure 272 shows model value and data temperature comparisons for Site GRT04, and Figure 273 and Figure 274 shows the same comparison for Site GR1 (See Figure 270 for site locations). Error statistics can be found in Table 15

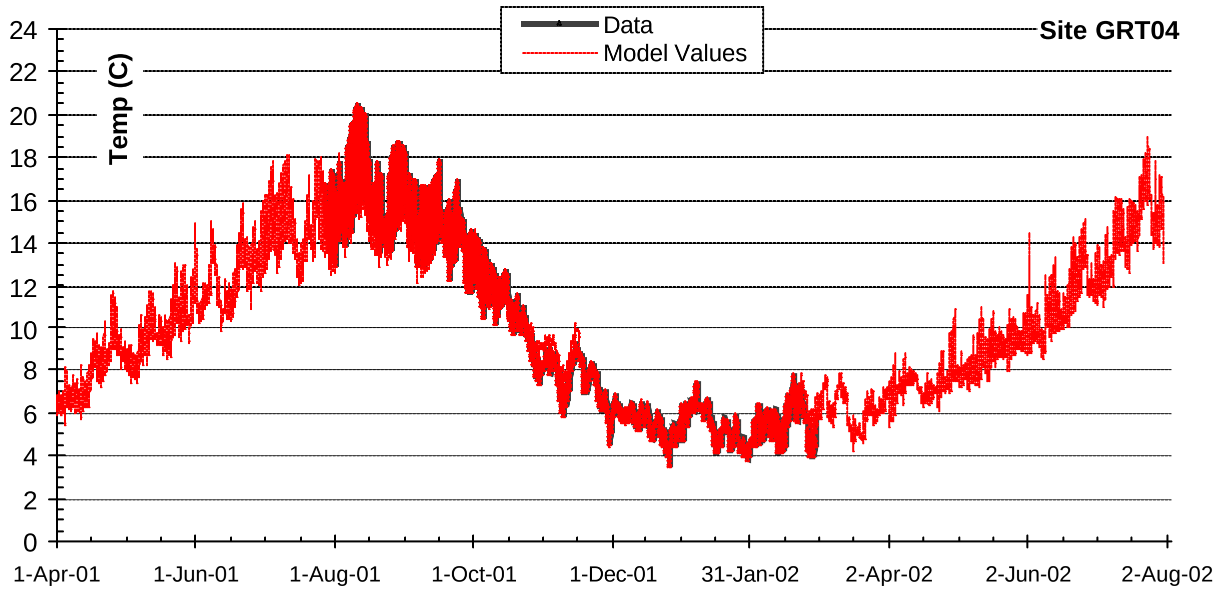


Figure 271: Temperature comparison at Site GRT04, 2001-2002 Model Run Period

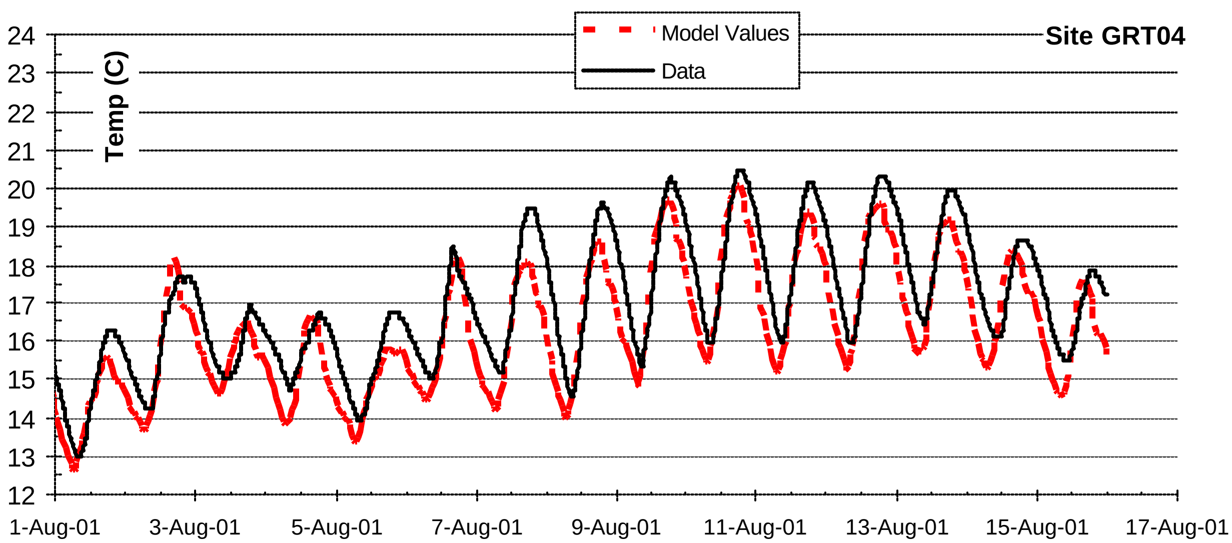


Figure 272: Temperature Comparison at Site GRT04, Aug 1-Aug 16, 2001

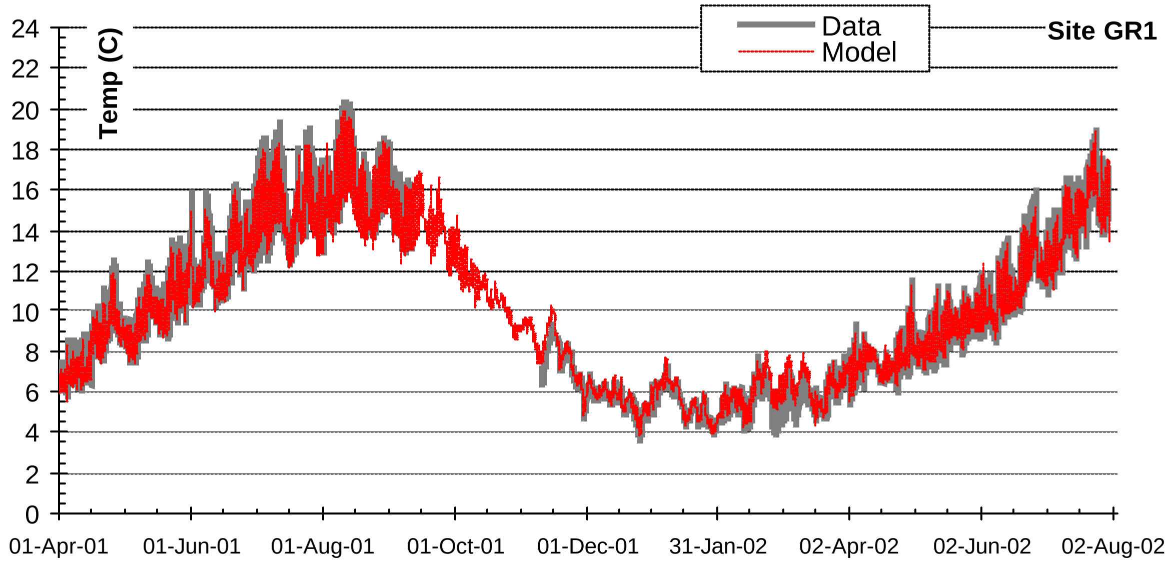


Figure 273: Temperature comparison at Site GR1, 2001-2002 Model Run Period

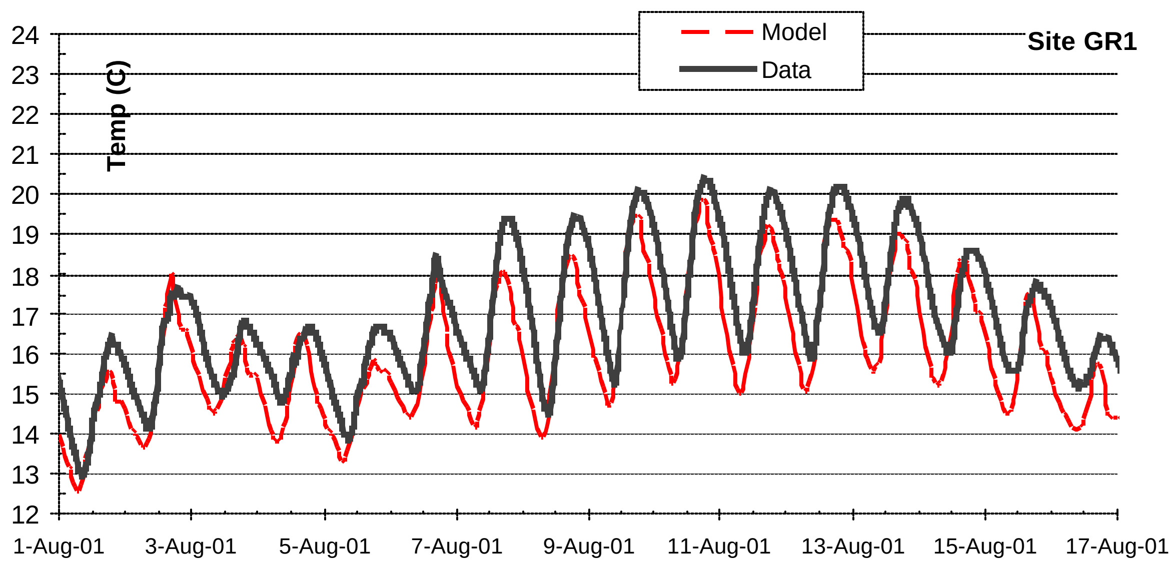


Figure 274: Temperature Comparison at Site GR1, Aug 1-Aug 16, 2001

Temperature was sampled in July 2002 at Sites GRT22 and GRT20 (See Figure 270 for site locations). Figure 275 and Figure 276 show the comparisons, and Table 15 shows the error statistics for all four sites.

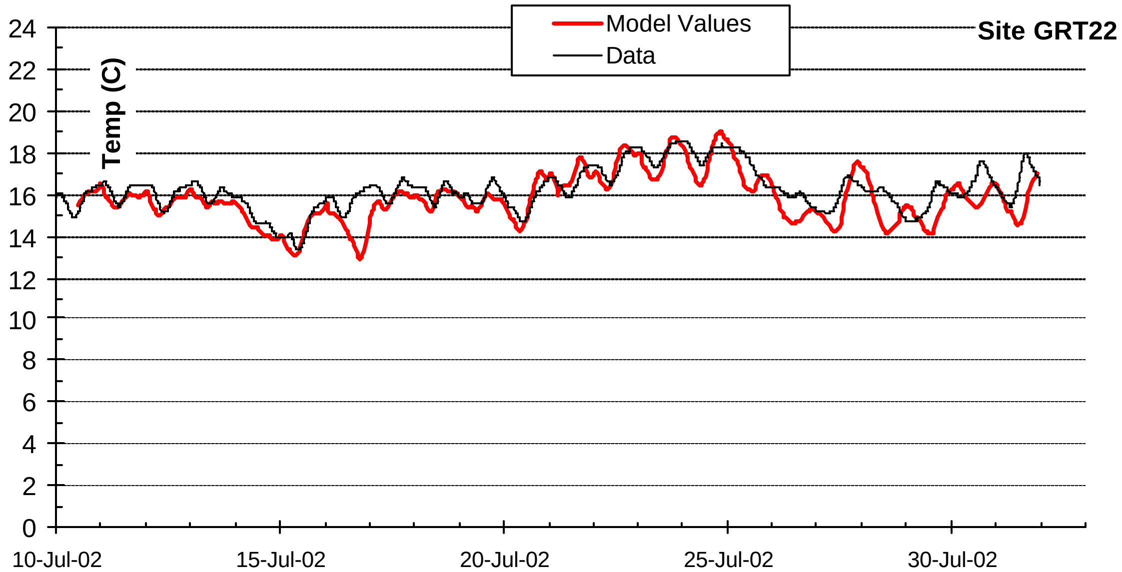


Figure 275: Temperature Comparison at Site GRT22, 2001-2002 Model Run Period

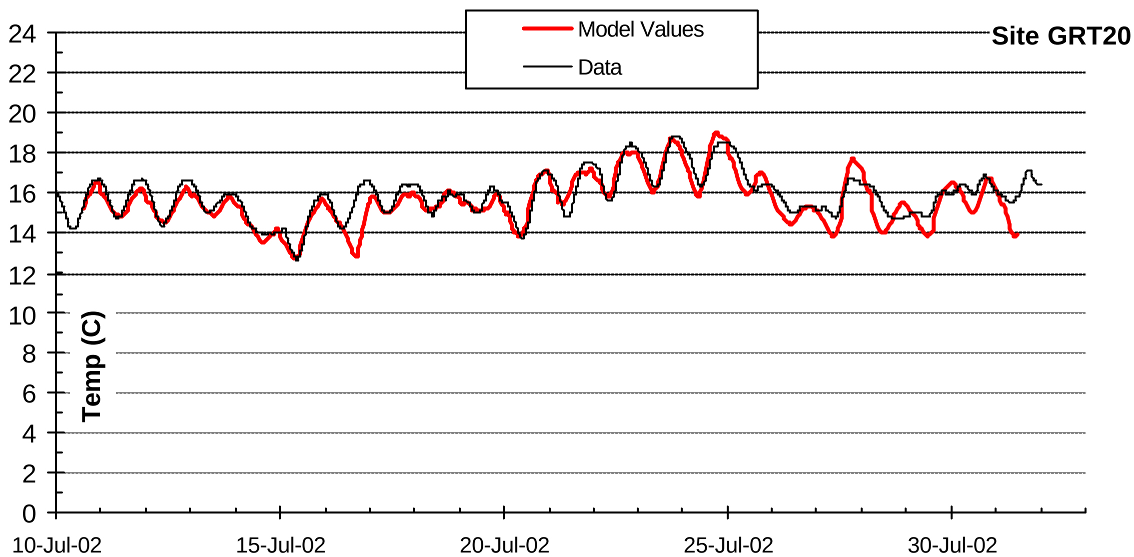


Figure 276: Temperature Comparison at Site GRT20, 2001-2002 Model Run Period

Table 15: Temperature Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (ºC)	AME (ºC)	RMS Error (ºC)
GRT04	8517	0.009	0.4	0.6
GR1	10209	-0.3	0.4	0.6
GRT20	510	-0.2	0.5	0.6
GRT22	510	-0.4	0.6	0.8

3.2.2 1995-1996

Monitoring Sites

Figure 277 shows the temperature monitoring locations for the May 25, 1995 to November 30, 1996 calibration period and Table 16 lists the sites, including time period of available data and river mile location of the site.

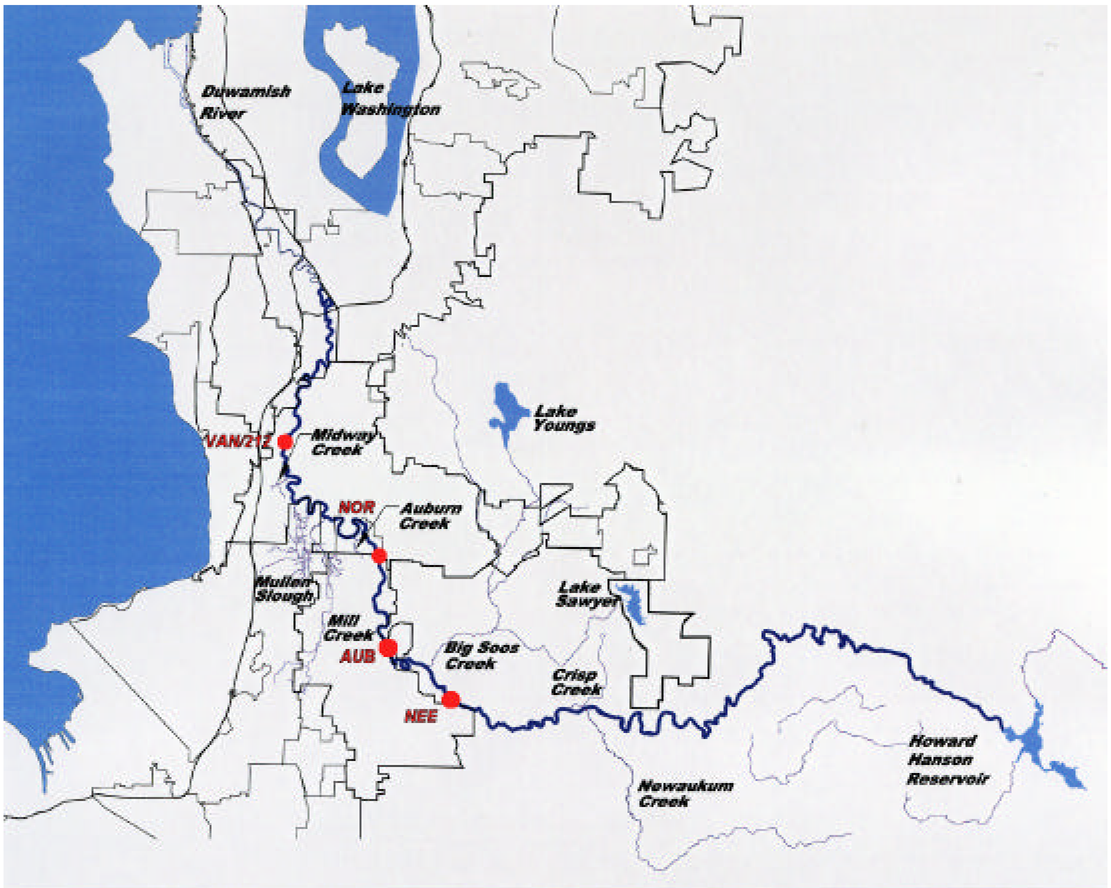


Figure 277: 1995-1996 Temperature Calibration Sites

Table 16: 1995-1996 Temperature Calibration Sites

Locator Statior	Description	River Mile	Time Period of Data
VAN/212	Van Doren's Landing/ S. 212th Street	18.60	5/24/1995 – 11/2/1995 6/7/1996 – 11/2/1996
NOR	North Green River Park	27.50	5/25/1995 – 11/3/1995 6/7/1996 – 11/2/1996
AUB/2ND	Below Big Soos Creek/ NE 2nd Street	31.30	7/21/1995 – 10/17/1995 7/2/1996 – 9/5/1996
NEE	Neely Bridge	34.40	5/25/1995 – 11/3/1995 6/7/1996 – 10/29/1996

Figure 278 through Figure 281 show the comparison of model temperature values and data for the full model period, and Table 17 shows the model error statistics. As with the 2001-2002 model run period, bathymetry adjustments were used to calibrate temperature.

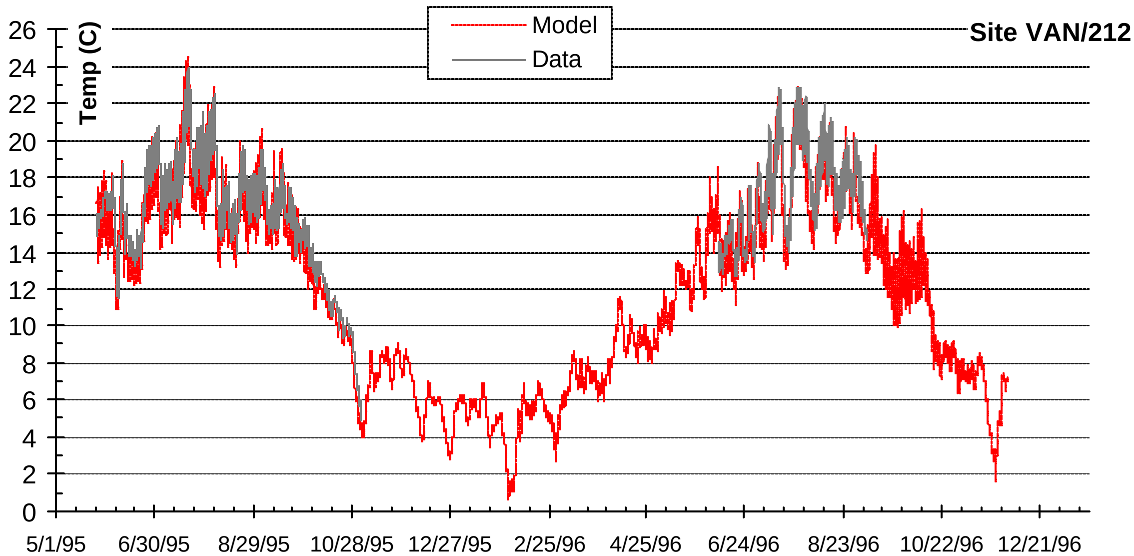


Figure 278: Temperature Comparison at Site VAN/212, May 25, 1995 - Nov 1996

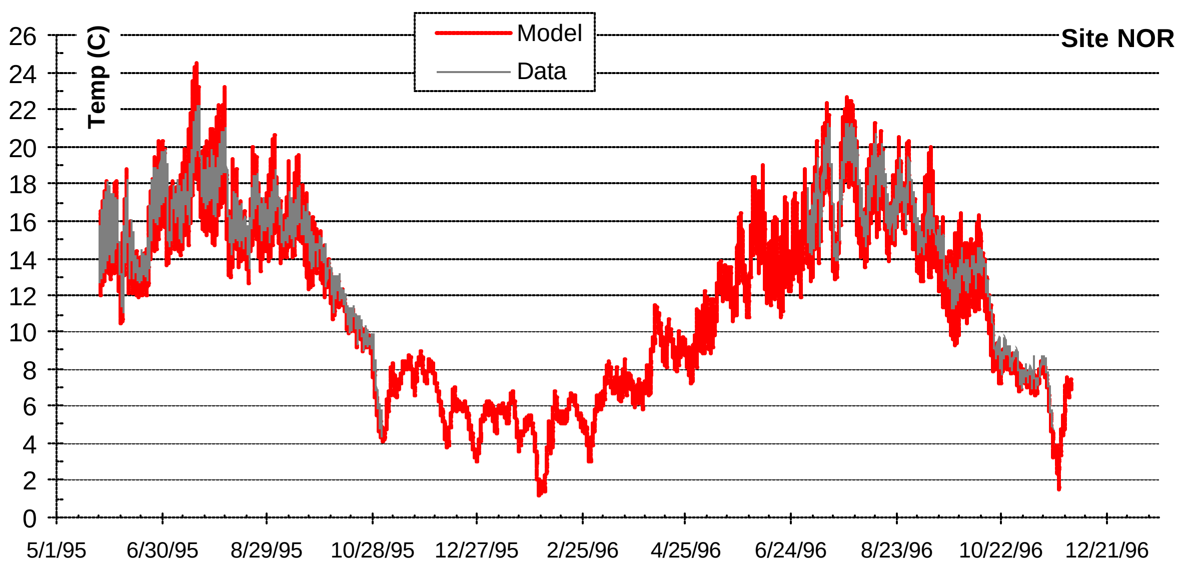


Figure 279: Temperature Comparison at Site NOR, May 25, 1995 - Nov 1996

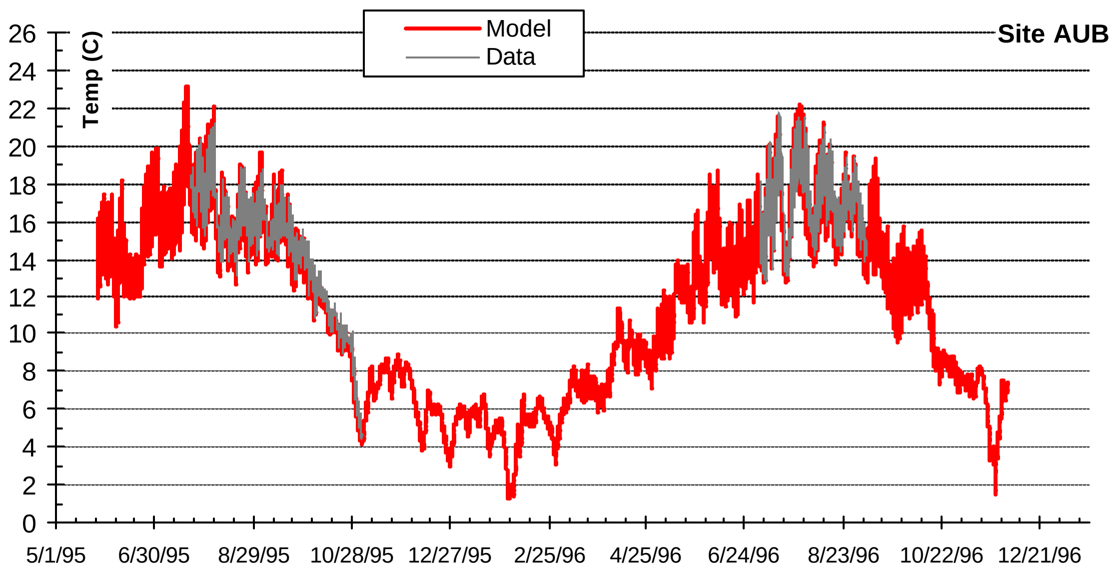


Figure 280: Temperature Comparison at Site AUB - May 25, 1995 - Nov. 1996

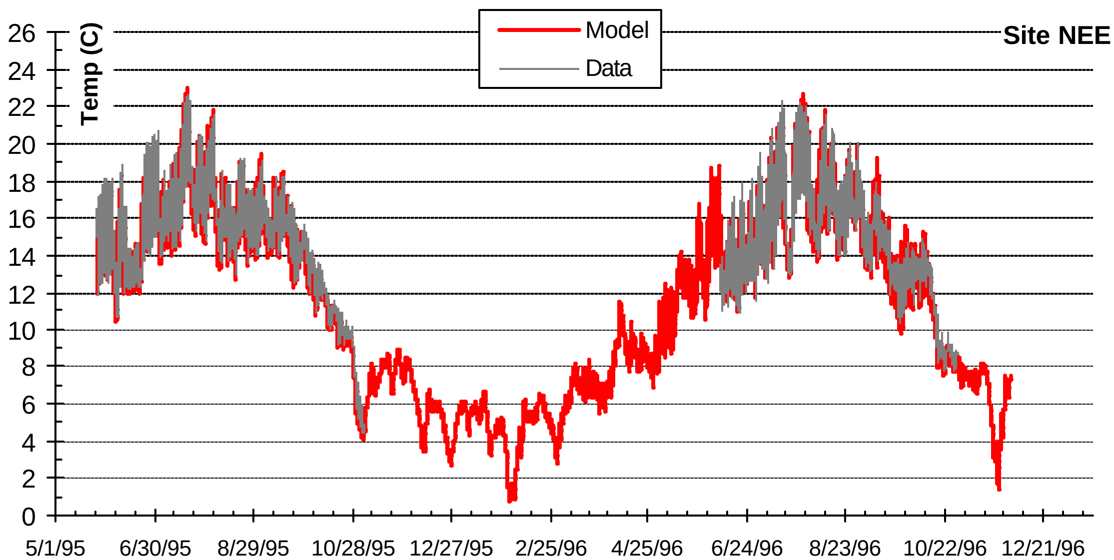


Figure 281: Temperature Comparison at Site NEE - May 25, 1995 - Nov. 1996

Figure 282 shows model and data temperature comparisons at Site NEE for August 1995, Figure 283 shows the same comparison for Site AUB, and Figure 284 shows the comparison at Site AUB for August 1996.

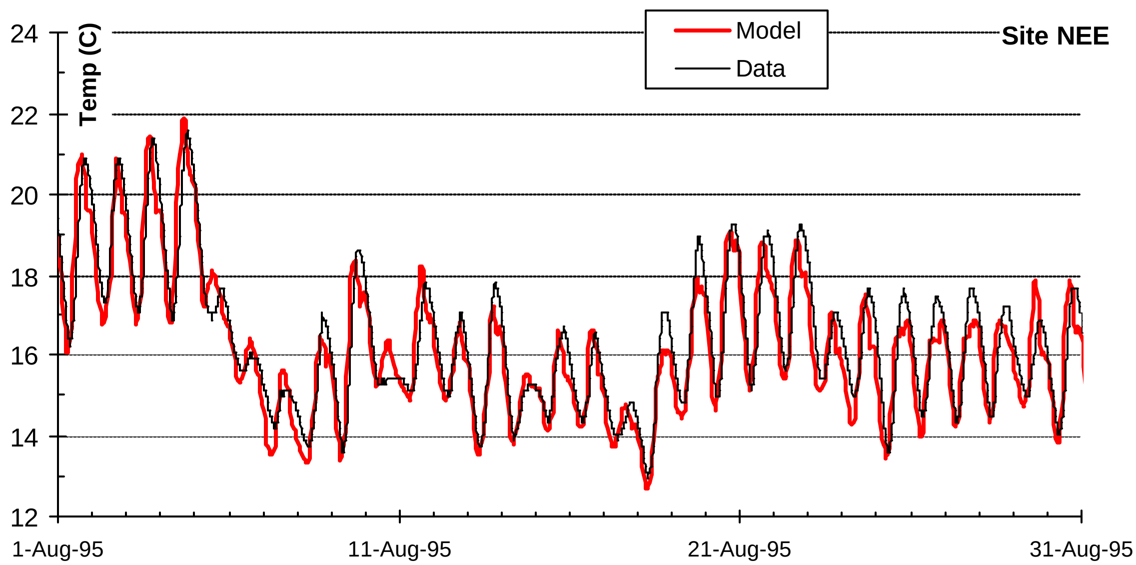


Figure 282: Temperature Comparison at Site NEE - August 1995

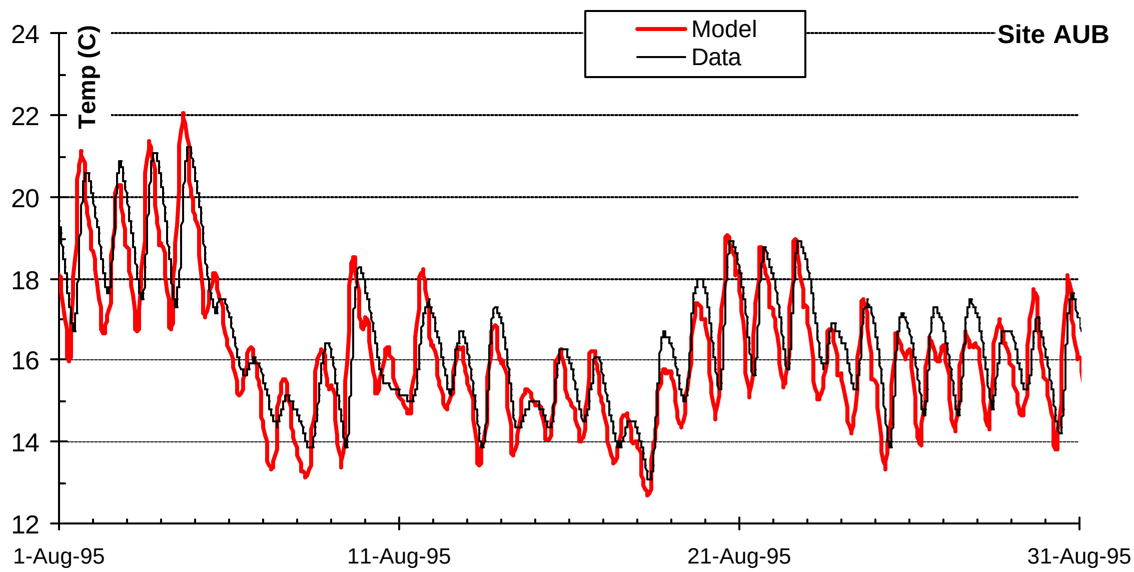


Figure 283: Temperature Comparison at Site AUB - August 1995

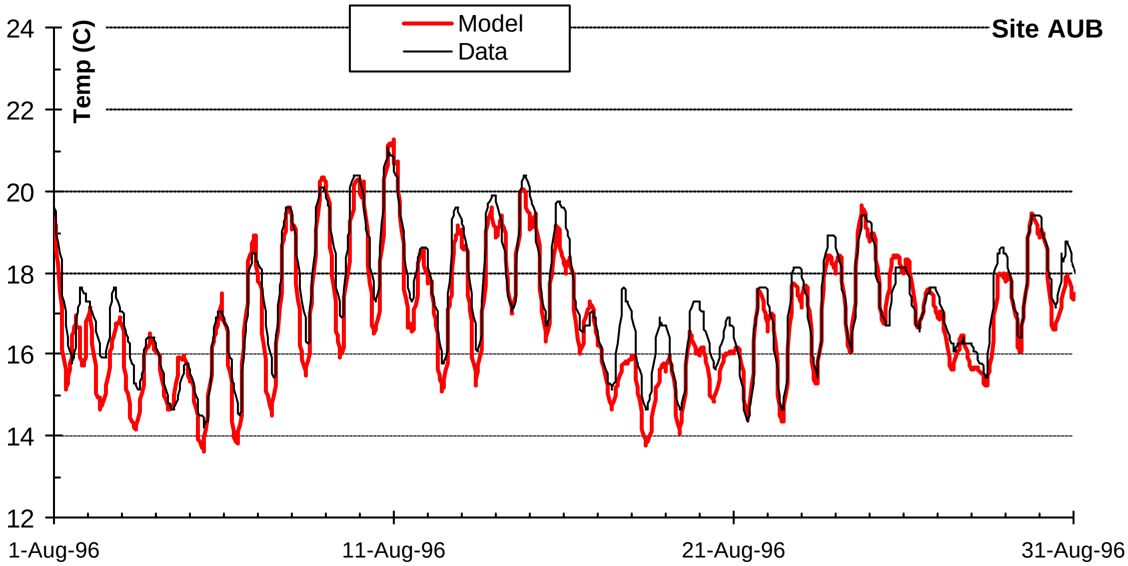


Figure 284: Temperature Comparison at Site AUB - August 1996

Table 17: Temperature Error Statistics, 1995-1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (ºC)	AME (ºC)	RMS Error (ºC)
NEE	5599	0.1	0.7	0.9
AUB	3681	0.2	0.6	0.8
NOR	3584	0.2	0.9	1.0
VAN/212	3855	-0.7	0.9	1.1

3.3 Water Quality Calibration

Figure 285 shows the locations of the water quality monitoring sites on the river. Table 18 lists the sites, along with the periods of available data and river mile. Sites 0311 and A319 have data for both model run periods, and Site G319 has data beginning in January of 2002.

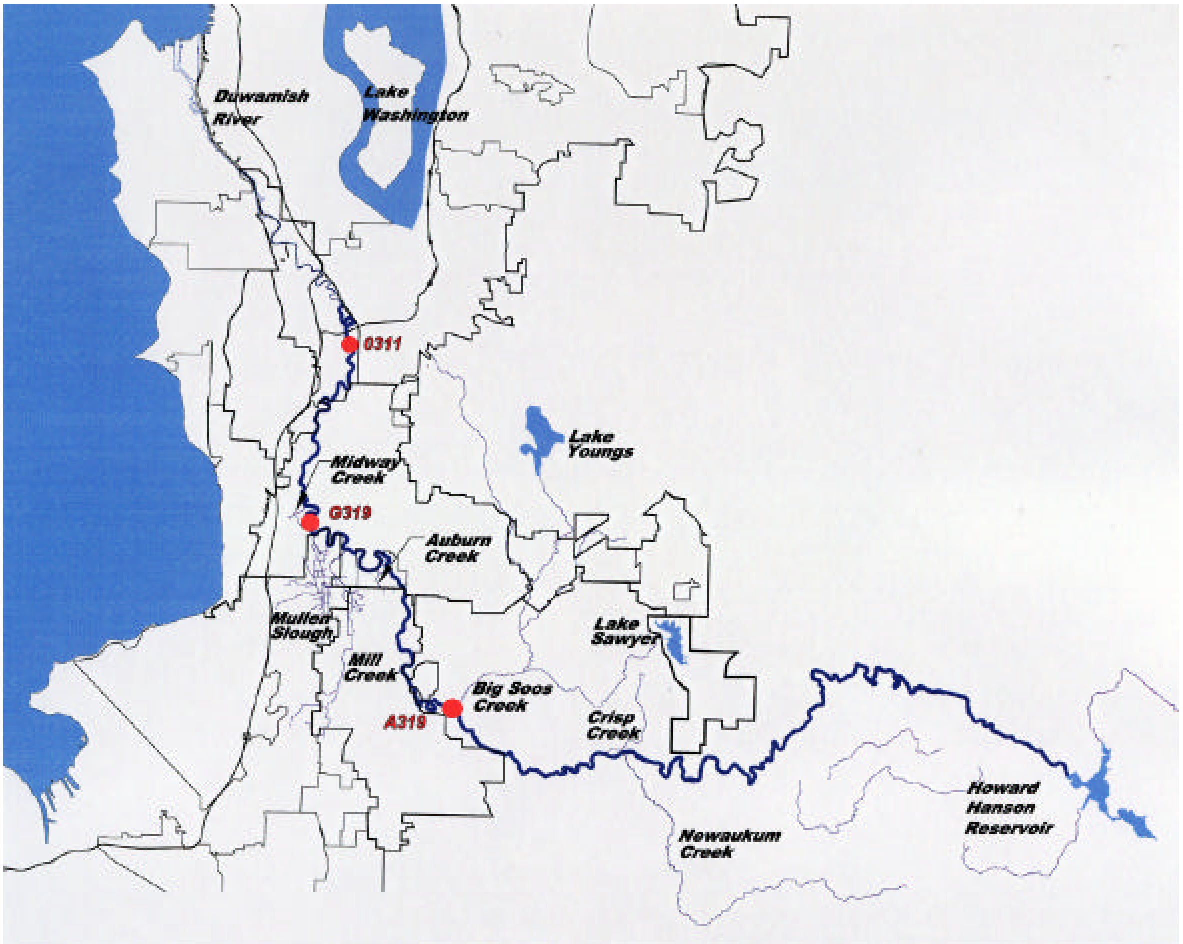


Figure 285: Water Quality Calibration Sites

Table 18: Water Quality Calibration Sites

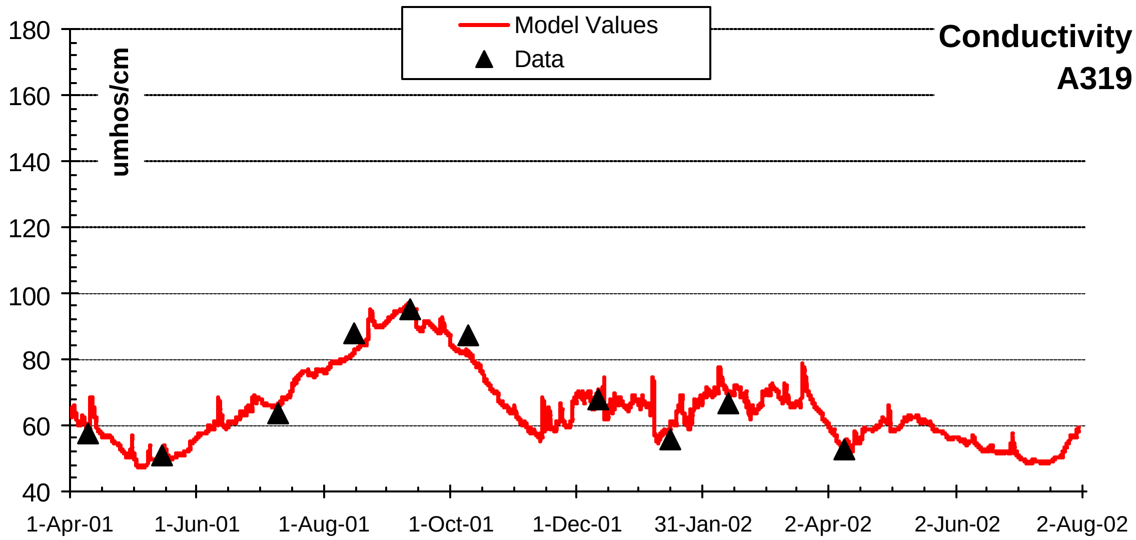
Locator Station	Description	River Mile
0311	Interurban Avenue	13.20
G319	Near Mullen Slough	21.30
A319	Auburn-Black Diamond Road	33.80

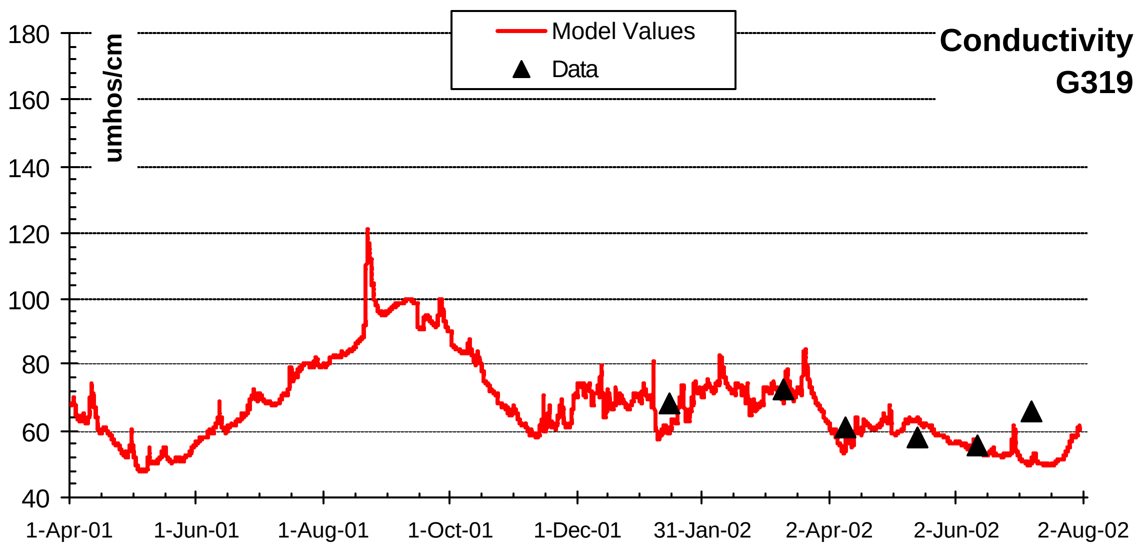
The water quality calibration section shows a comparison between model values and sampled data, and discusses calibration measures used to match model values with the sampled data. Each model run period is discussed separately.

3.3.1 2001-2002

Conductivity

Conductivity is modeled as a conservative constituent, with all rate terms set to zero. Figure 286 shows the comparison between sampled data and model results and Table 19 shows the model error statistics.





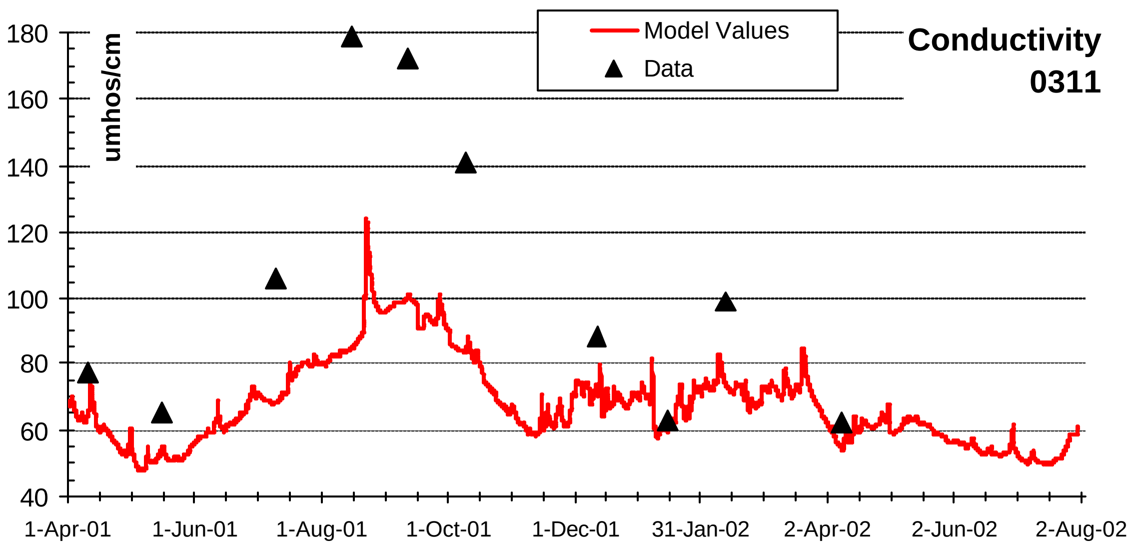


Figure 286: Conductivity comparison, 2001-2002 Model Run Period

Table 19: Conductivity Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (umhos/cm)	AME (umhos/cm)	RMS Error (umhos/cm)
A319	10	0.26	2.48	3.04
G319	6	-4.22	6.15	7.62
0311	10	-33.40	33.40	44.4

Model values and data compare well at Site A319, the farthest upstream site, and at Site G319, which is farther downstream, but do not compare well at the farthest downstream calibration site, Site 0311, during late summer and fall of 2001. Note that data were not available for comparison at Site G319 during the summer and fall of 2001.

Since conductivity is a conservative constituent, the difference between model values and data is an issue with model data - there is a source of flow and conductivity missing from the model. This issue is discussed in more detail in the Summary and Conclusions section. An additional distributed tributary was added to the last branch of the model to simulate conditions needed to match the data at this location. This is discussed in the Sensitivity Analysis section.

Alkalinity

Alkalinity is a conservative constituent in the model and is used to calculate pH. Model values match well at Sites A319 and G319 for this model run period, but as with other constituents, model values do not compare as well at Site 0311 in the summer and fall of 2001. See the Summary and Conclusions section for a discussion, and the Sensitivity Analysis section for additional alkalinity added to the model to match data.

Figure 287 shows the comparisons for the three locations, and Table 20 shows the model error statistics.

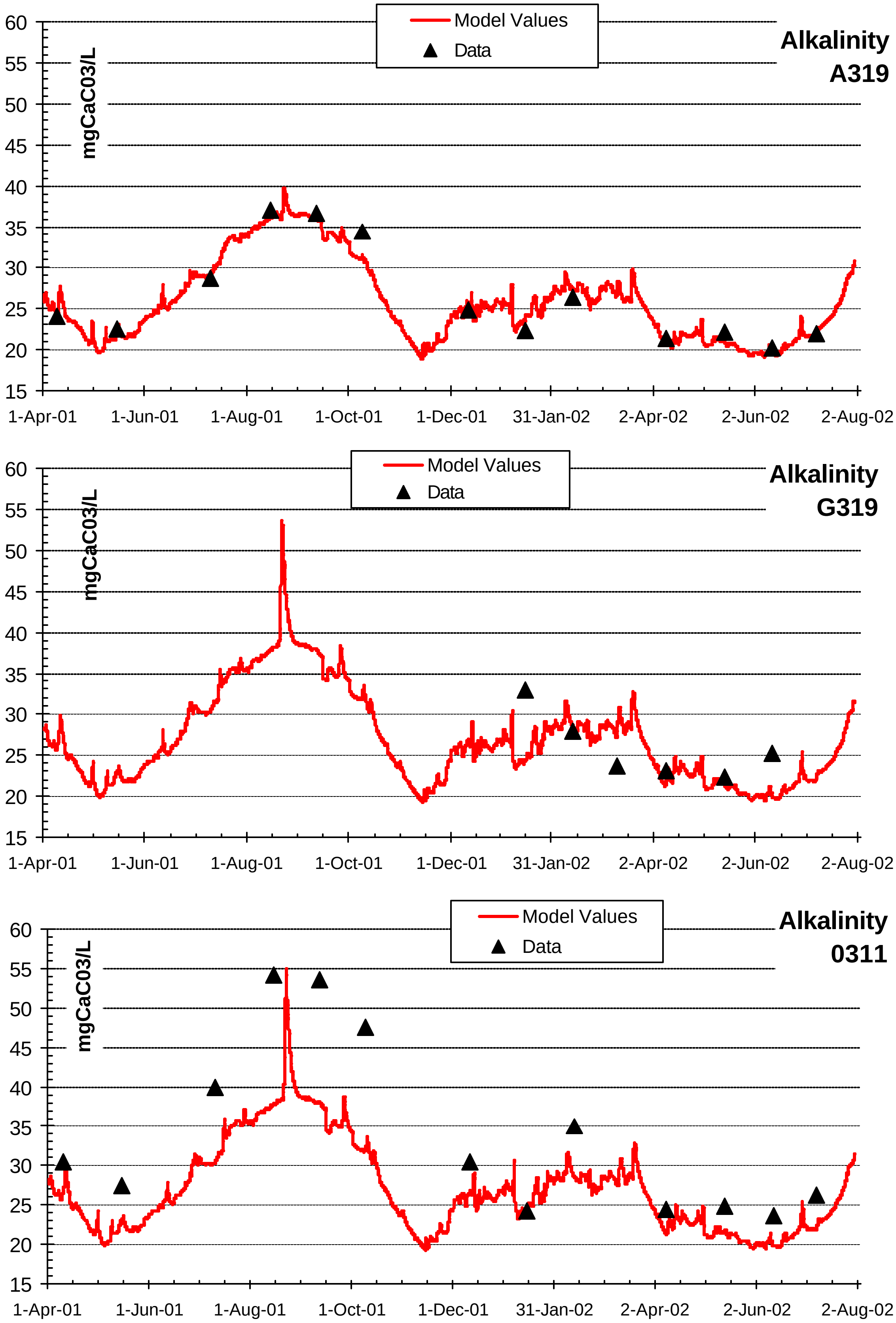


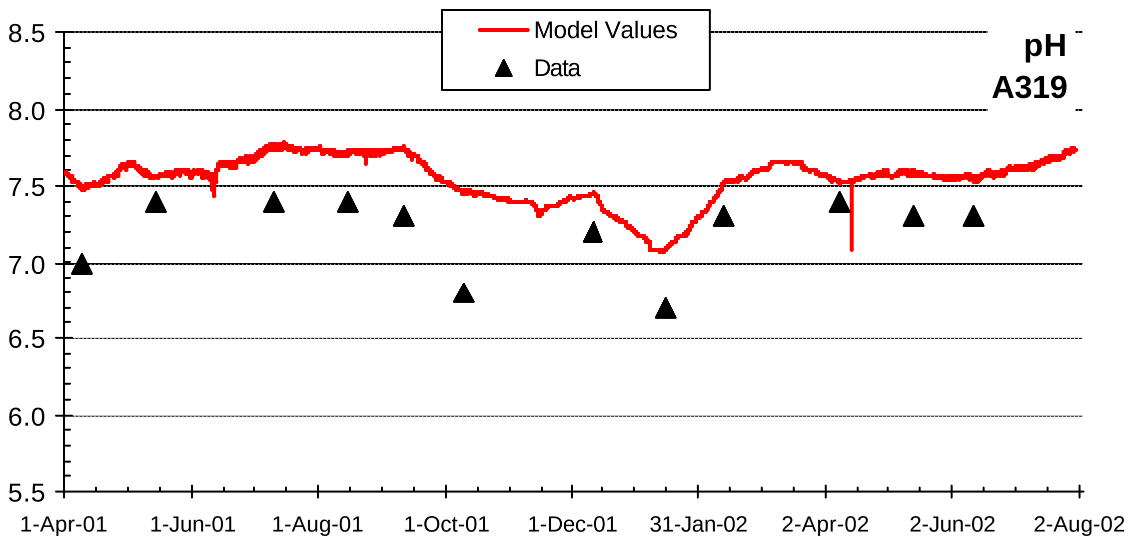
Figure 287: Alkalinity Comparison, 2001-2002 Model Run Period

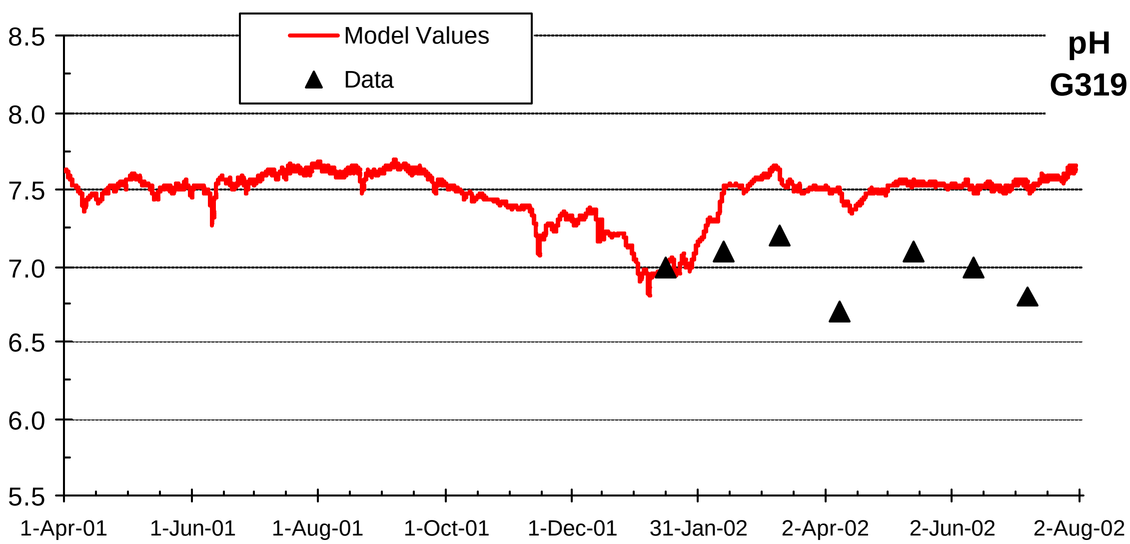
Site	No. of Data Comparisons	Mean Error (mgCaCO3/L)	AME (mgCaCO3/L)	RMS Error (mgCaCO3/L)
A319	13	-0.23	0.86	1.11
G319	6	-2.1	3.03	3.97
0311	13	-6.83	6.87	8.65

Table 20: Alkalinity Error Statistics, 2001-2002 Model Run Period

pH

pH is calculated in the model from total inorganic carbon (TIC), alkalinity, and temperature model values. Figure 288 shows the comparison between model values and sampled data for all three sites, and Table 21 shows the mean, AME and RMS model error statistics for each calibration site.





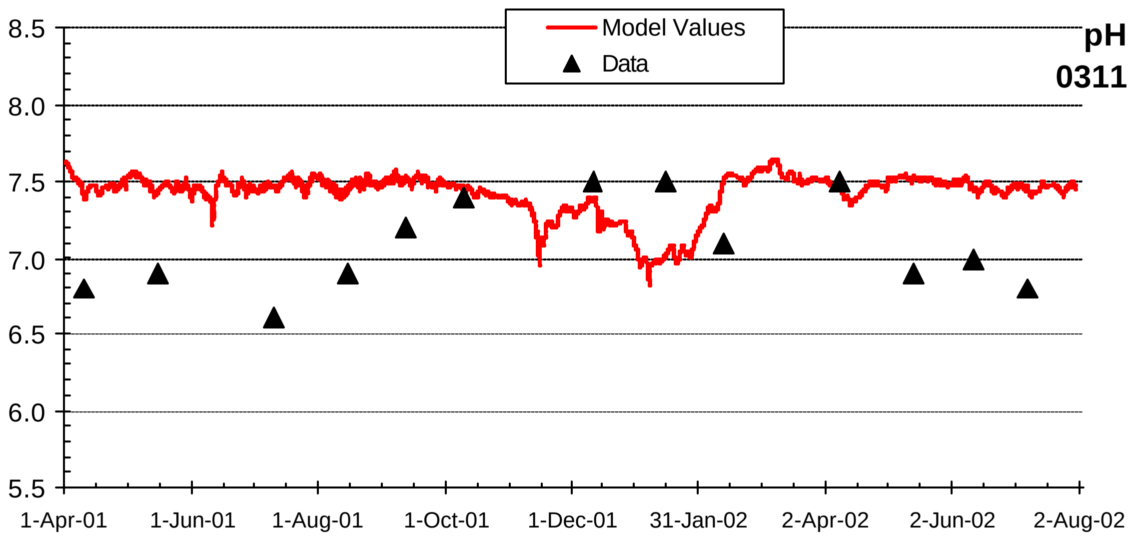


Figure 288: pH comparison, 2001-2002 Model Run Period

Table 21: pH Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
A319	7	0.33	0.33	0.31
G319	7	0.46	0.46	0.52
0311	13	0.35	0.44	0.50

pH model values do not compare well at at all three calibration sites. Model predictions of alkalinity match well with field data at Site A319, so TIC was calculated from temperature, alkalinity, and pH data at this site to compare with TIC values from the model. A graph comparing TIC from field data with model predictions is shown in Figure 289. A comparison of Figure 288 and Figure 289 shows that the model is under-predicting TIC at the same time it's over-predicting pH. This shows that TIC is under-predicted in the model during the low flow end-of-summer months. The TIC model values in Figure 289 compare very closely with the TIC data used in the upstream boundary condition, therefore there is a source of high TIC below the upstream boundary, possibly in a groundwater source. This is reviewed in more detail in the Sensitivity Analysis Section. Please see Section 4.2 for more information.

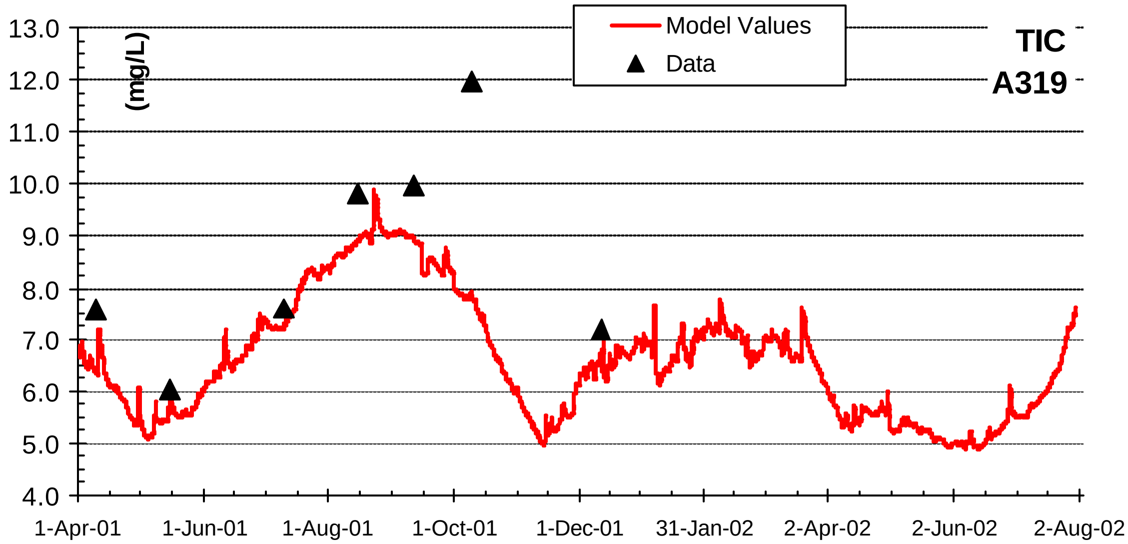


Figure 289: TIC Comparison, 2001-2002 Model Run Period

Total Suspended Solids

Total Suspended Solids is a derived constituent in CE-QUAL-W2, calculated by adding particulate organic matter, inorganic suspended solids, and algae. The model data for TSS consisted of monthly grab samples. CE-QUAL-W2 uses linear interpolation for values between the monthly data points. When a monthly sample with low TSS values is followed by a monthly sample with high values of TSS, the model predictions are affected by the interpolation between the low and high TSS values. Figure 290 shows model results using monthly data input. Although the values match close with data, the peaks in TSS are spread out over three months due to the linear interpolation of values.

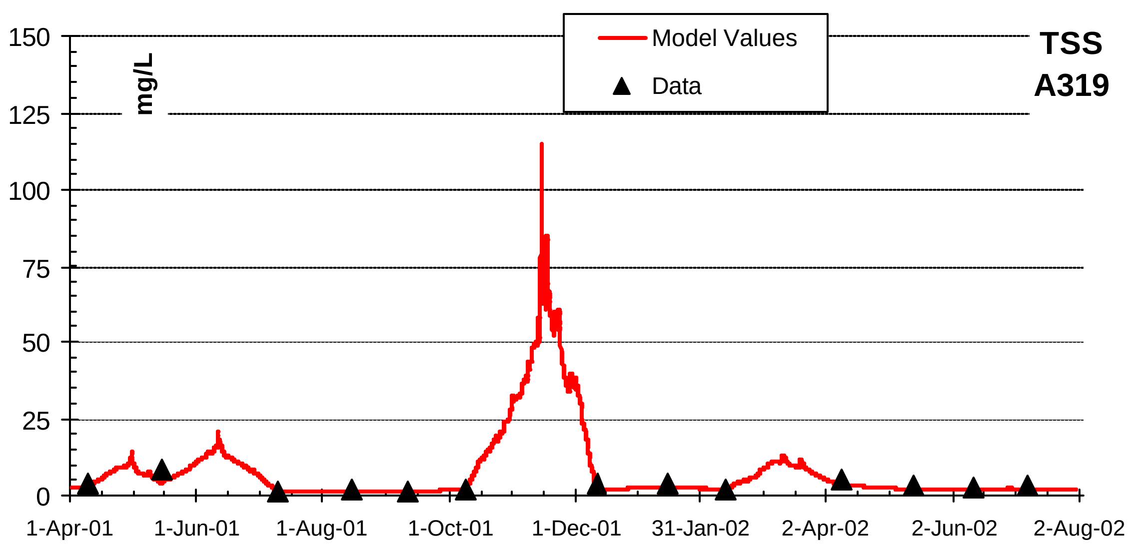
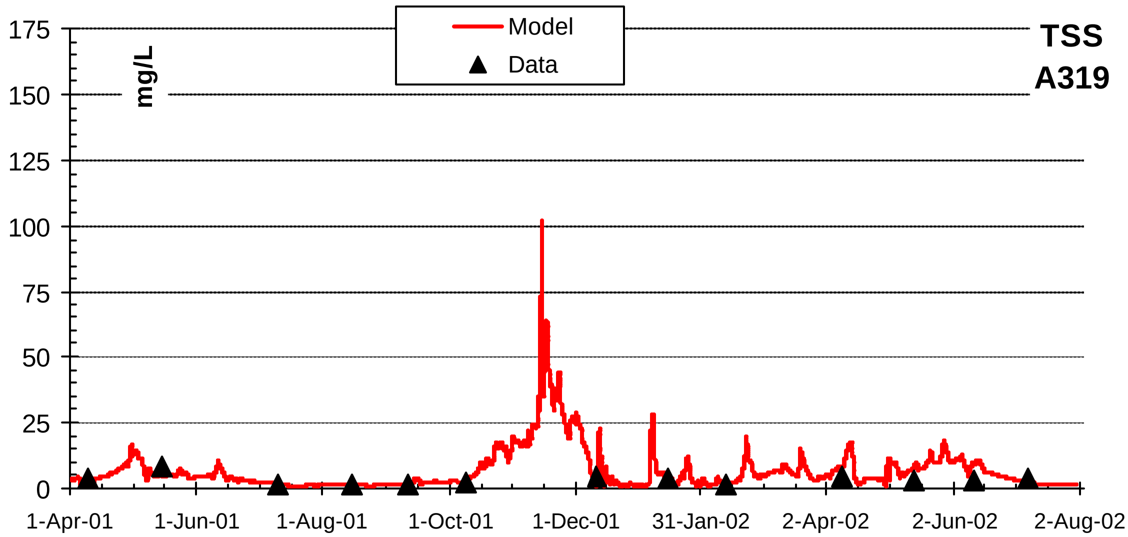


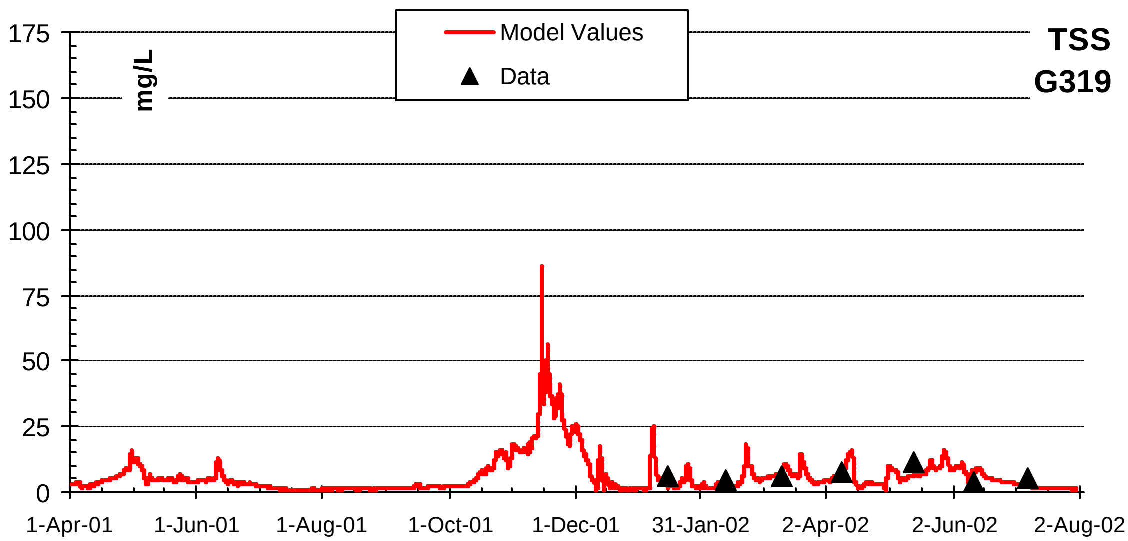
Figure 290: TSS Comparison with monthly grab samples, 2001-2002 Model Run Period

To address this, a regression equation was used to estimate model input between the monthly sampled data. Daily average TSS model data were estimated using flow data from the USGS gage at Palmer (Station No. 12108700), from flow data at the USGS gage near Auburn (12113000), and the Julian date. The following correlation was developed for the 2001-2002 model run period (R^2 = 0.88):

TSS = ABS[0.90*(Palmer flow) + 0.045*Log(Palmer flow) - 0.61*AUB flow-0.0007*Julian date - 265.62]

Model input at the upstream boundary was adjusted using this equation. The resulting graph of model values and data are shown in Figure 291, and the error statistics can be found in Table 22.





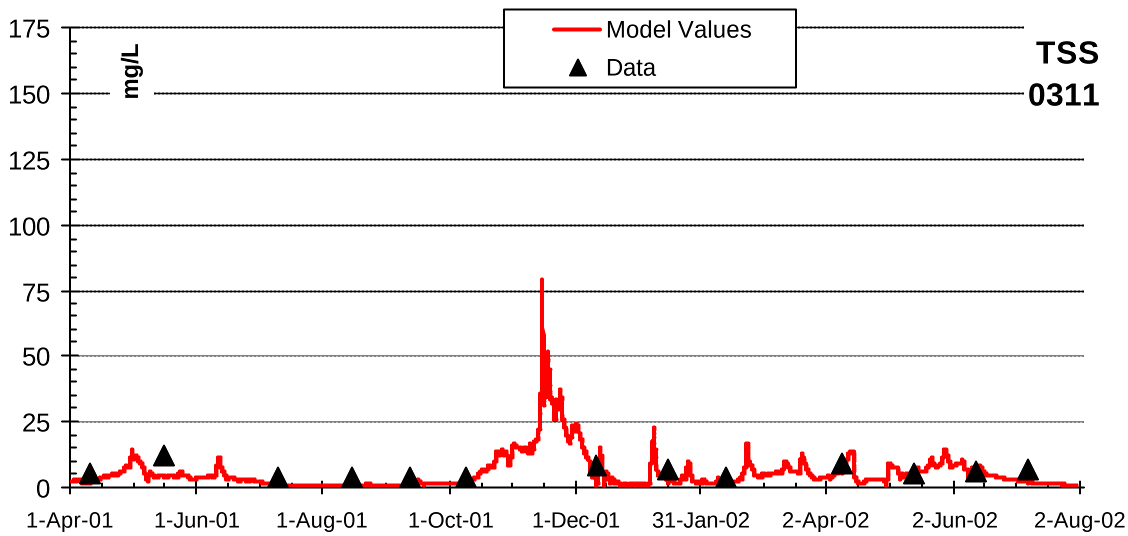


Figure 291: TSS Comparison using regression equation, 2001-2002 Model Run Period

Table 22: Total Suspended Solids Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	13	0.36	2.21	2.97
G319	7	-1.55	3.26	3.41
0311	13	-3.21	3.64	4.12

Dissolved Oxygen

CE-QUAL-W2 has nine separate reaeration formulations that can be used for river systems. The Melching and Flores (1999) equation applicable for channel control streams was used in both model runs. Zero order sediment oxygen demands were set at 1.0 g m^{-2} d^{-1} for the first two water bodies, and 3 g m^{-2} d^{-1} for Water Body three. Figure 292 shows the time series comparison of data and model values, and Table 23 shows the mean, AME, and RMS error statistics.

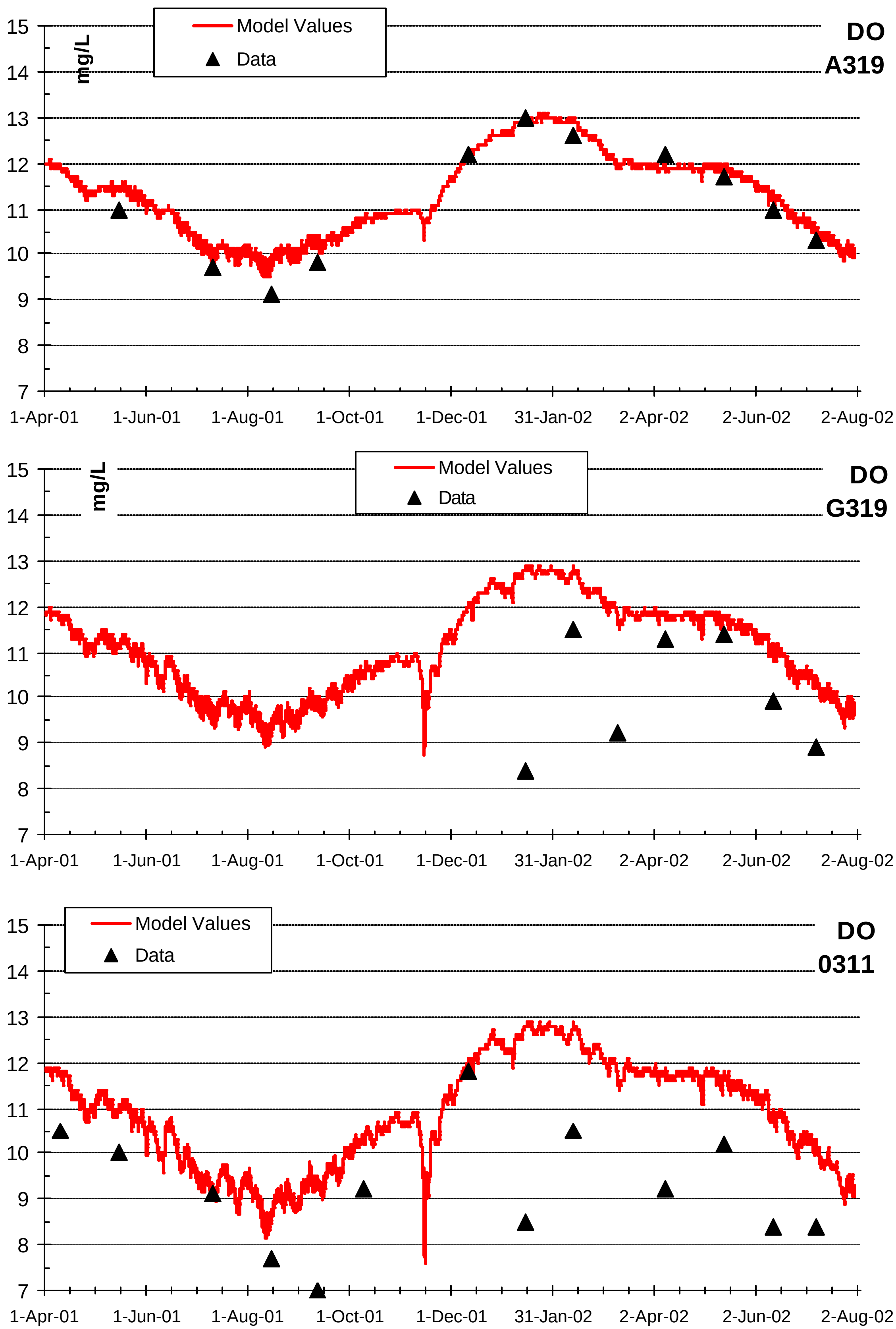


Figure 292: DO comparison, 2001-2002 Model Run Period

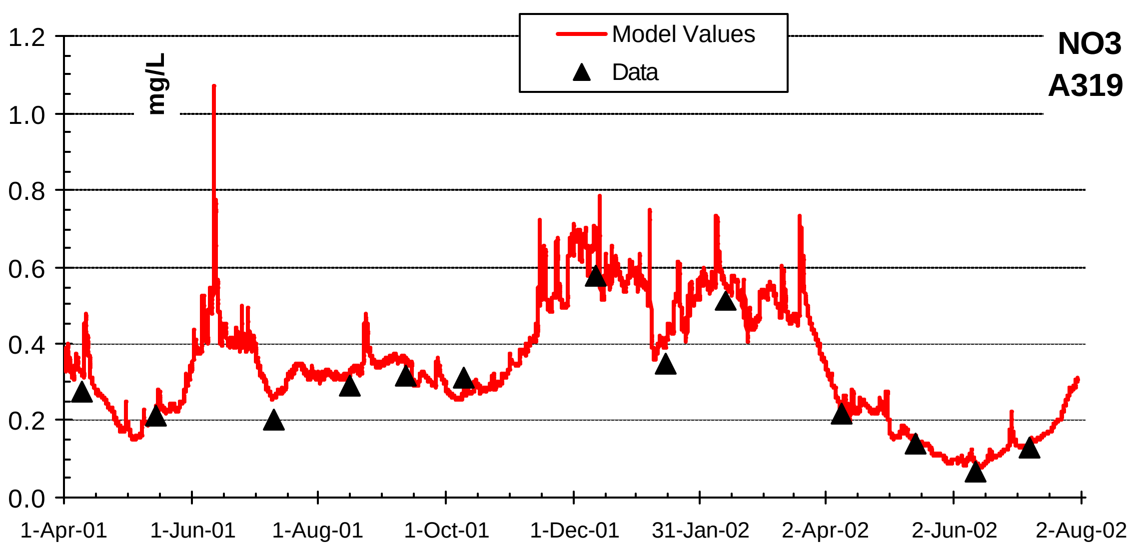
Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	11	0.30	0.36	0.42
G319	7	1.67	1.67	2.13
0311	13	1.66	1.66	1.98

Table 23: Dissolved Oxygen Error Statistics, 2001-2002 Model Run Period

With dissolved oxygen, model values compare well at Site A319, but do not compare well at Site G319 and Site 0311. The model is predicting mostly saturated values, but data indicates lower DO for much of the model run period. The Summary and Conclusions section discusses possible reasons for the difference, and the Sensitivity Analysis section discusses model runs performed with additional data added to the Lower Green River to replicate sampled data.

Nitrite-Nitrate Nitrogen

Nitrite-Nitrate data were available for comparison with model-predicted values for all three sampling sites. Figure 293 compares field data to model values, and Table 24 shows the model error statistics.



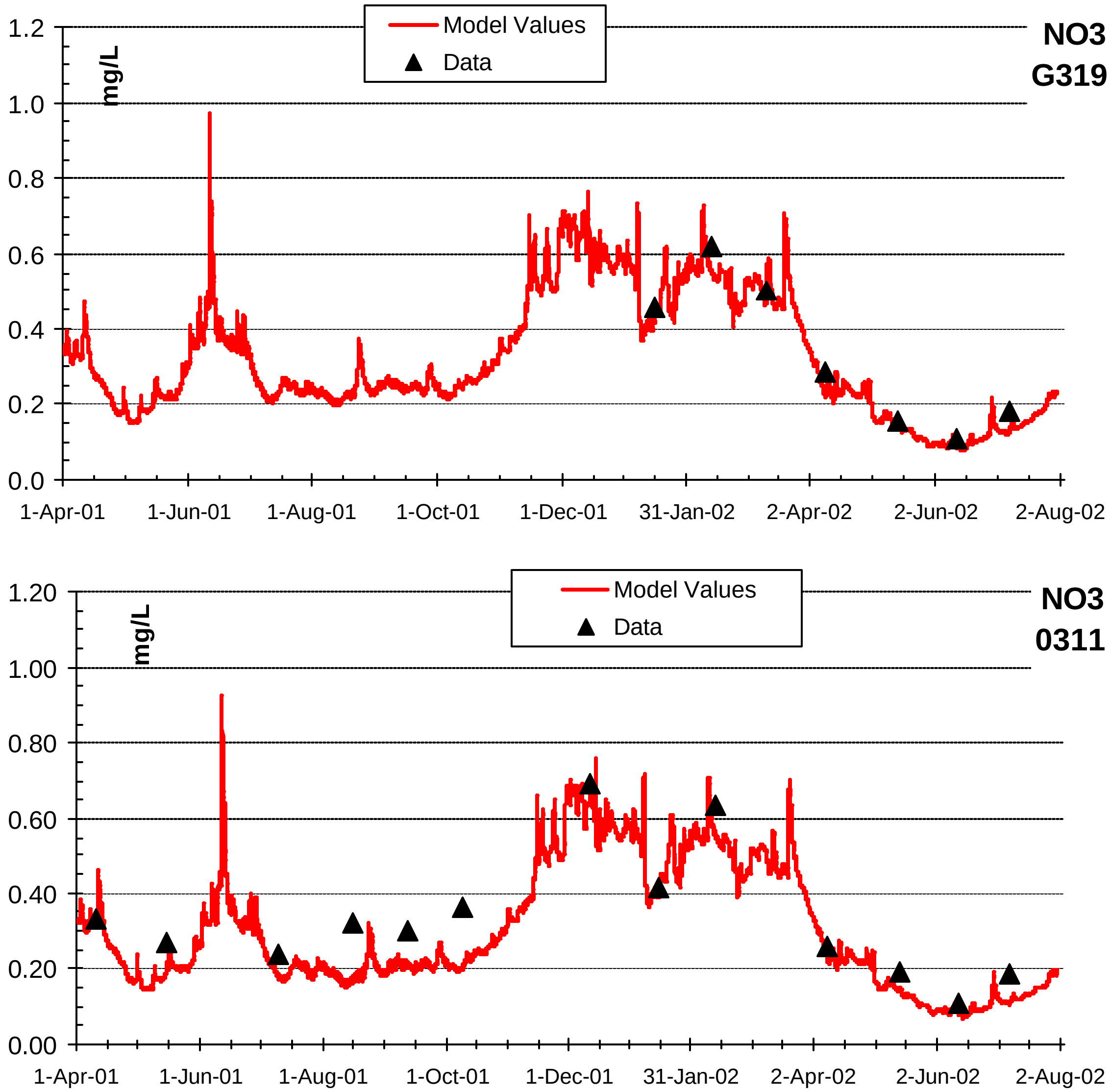


Figure 293: Nitrite-Nitrate comparison, 2001-2002 Model Run Period

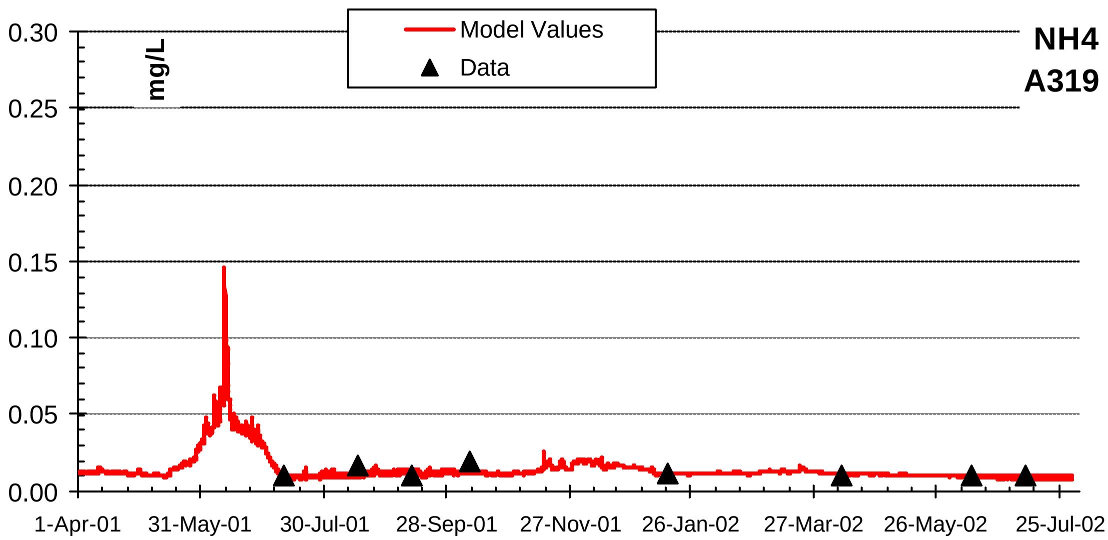
Table 24: Nitrite-Nitrate Nitrogen Error Statistics, 2001-2002 Model Run Period

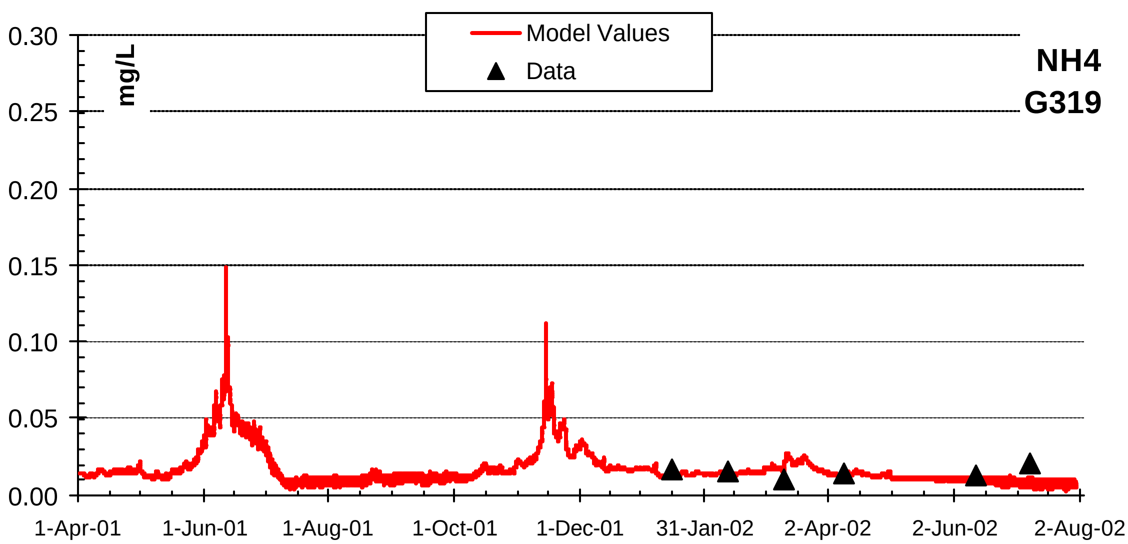
Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	13	0.032	0.039	0.046
G319	7	-0.039	0.039	0.044
0311	13	-0.064	0.064	0.080

Model values compare very well with data for Sites A319 and G319, and compare relatively well at Site 0311, except during late summer and early fall of 2001. It is assumed this discrepancy can also be attributed to missing inflows near the downstream boundary.

Ammonia Nitrogen

Ammonia Nitrogen data were available for comparison through most of this model run period for Sites A319 and G319, and for the entire run period for Site 0311. Figure 294 shows the comparison of sampled data and model values, and Figure 295 shows a comparison of values over a small time period at Site A319 to show the diurnal fluctuations predicted by the model. Table 25 shows the error statistics for all three sampling sites.





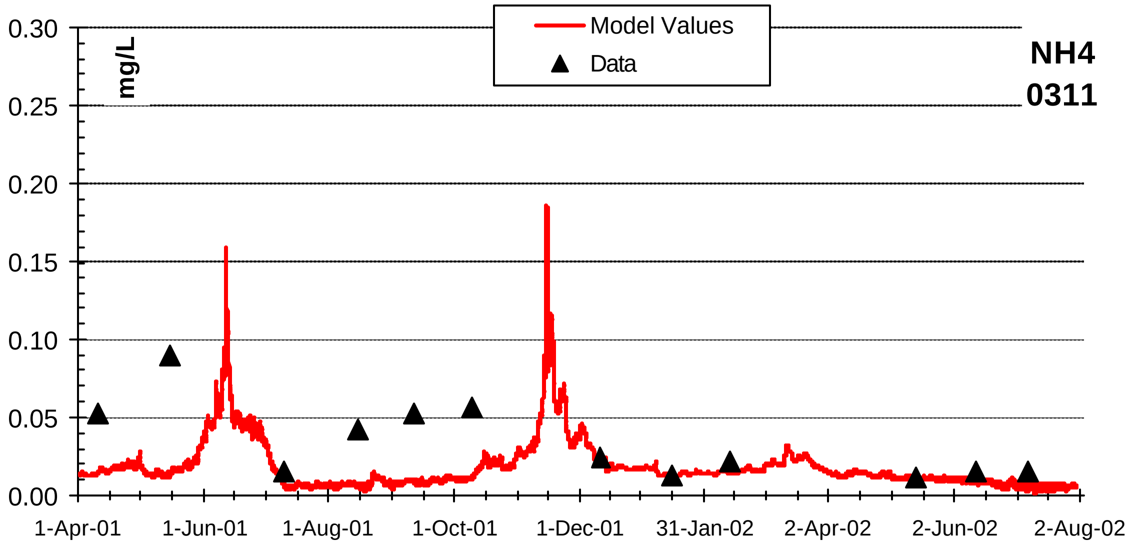


Figure 294: Ammonia Nitrogen Comparison, 2001-2002 Model Run Period

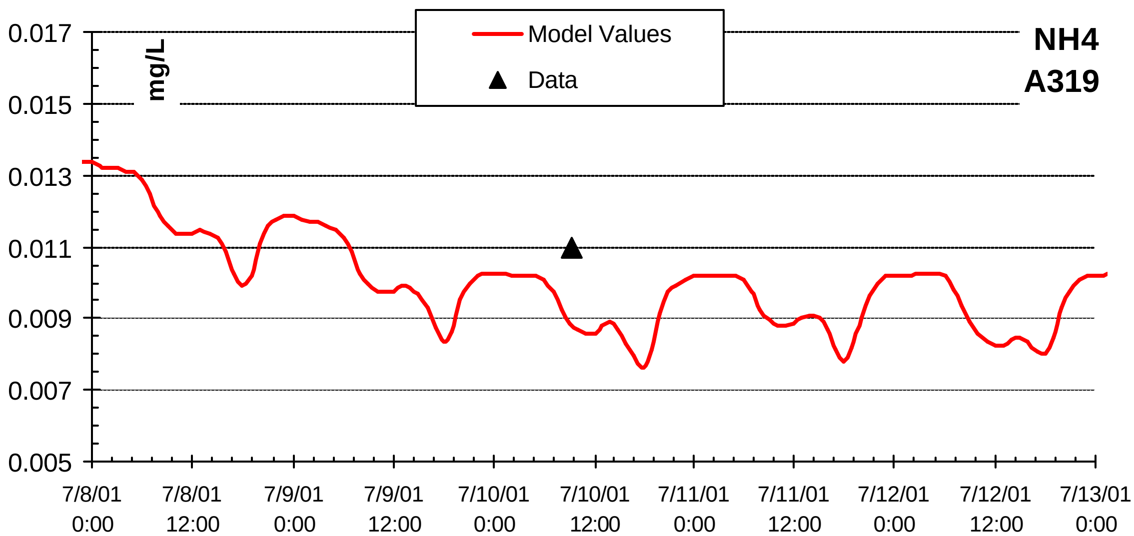


Figure 295: Diurnal Fluctuations in Ammonia Nitrogen

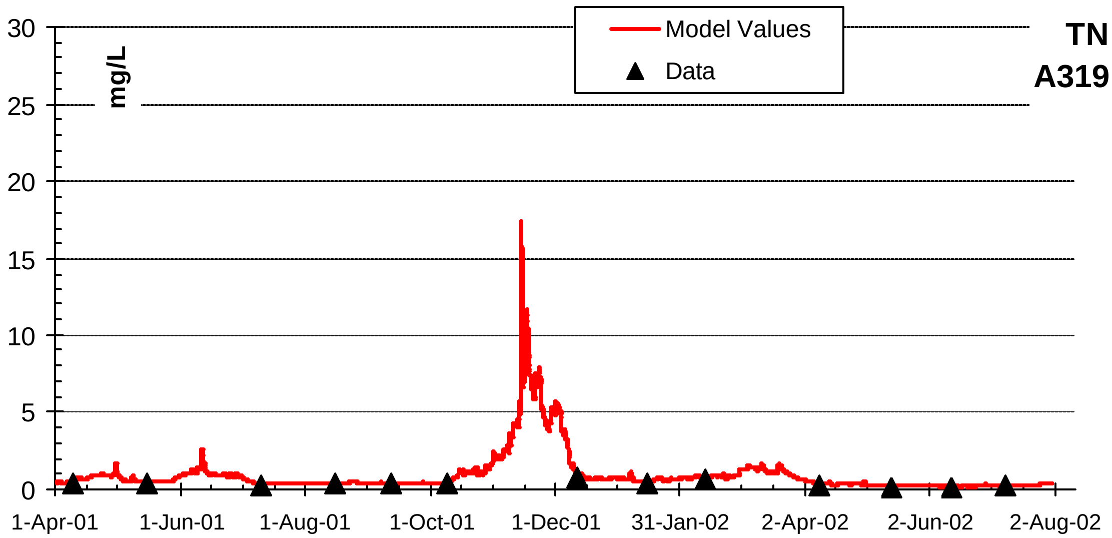
Table 25: Ammonia Nitrogen Error Statistics, 2001-2002 Model Run Period

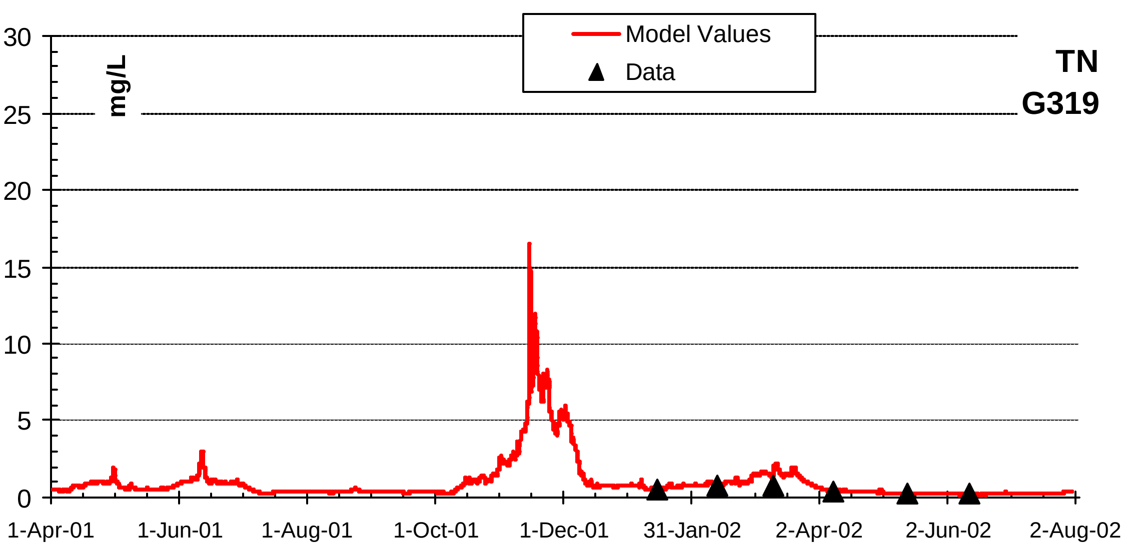
Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	8	-0.0020	0.0023	0.0034
G319	6	0.0017	0.0052	0.0065
0311	12	-0.023	0.023	0.032

Total Nitrogen

Total nitrogen data were available for comparison with model values for the entire model run period, and for all three sampling sites. Total Nitrogen values are calculated using ammonia nitrogen, nitrite-nitrate, and organic matter values. To calibrate Total Nitrogen to sampled data, the procedures for establishing organic matter model input were reviewed and revised. For the 2001-2002 model run period initial organic matter model inputs were determined by estimation from two Total Organic Carbon samples from the summer of 2002. During model calibration the amount of organic matter in the system was calculated from its contribution to ammonia nitrogen (See Appendix F for more information on the calculation of these values). From these values the percentage of TSS that is organic matter was calculated. This percentage was then used to estimate organic matter input from the regression values of TSS used in the model (See TSS section above for more information on the regression). These estimates were revised during calibration to match data.

Figure 296 shows the comparison of field data with model values for all three sites, and Figure 297 shows the same time period, without the peak of large concentration from a mid-November storm to better show model value comparison with the field data. Table 26 shows the error statistics for the model run period.





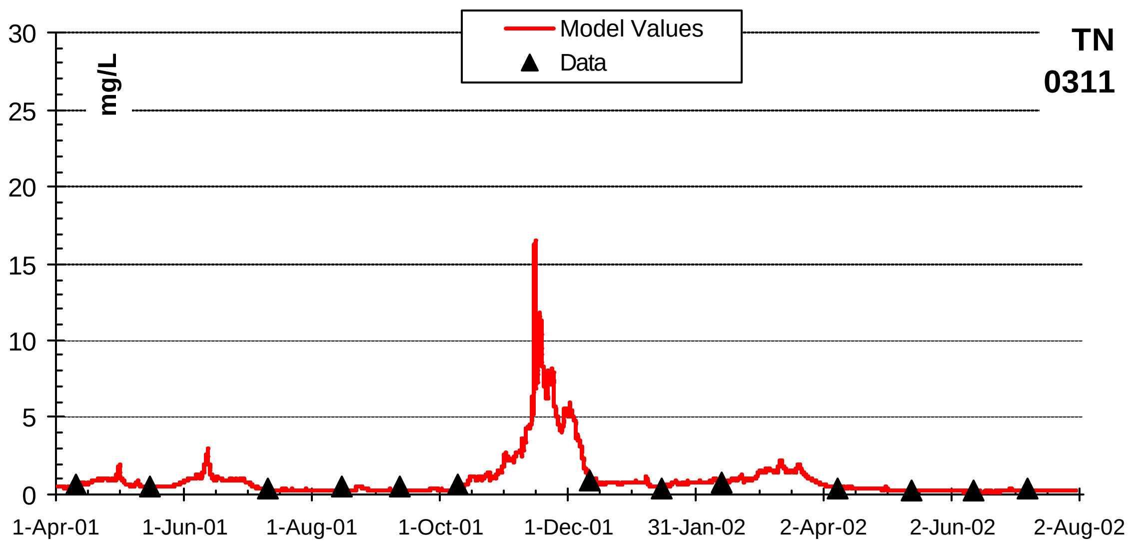
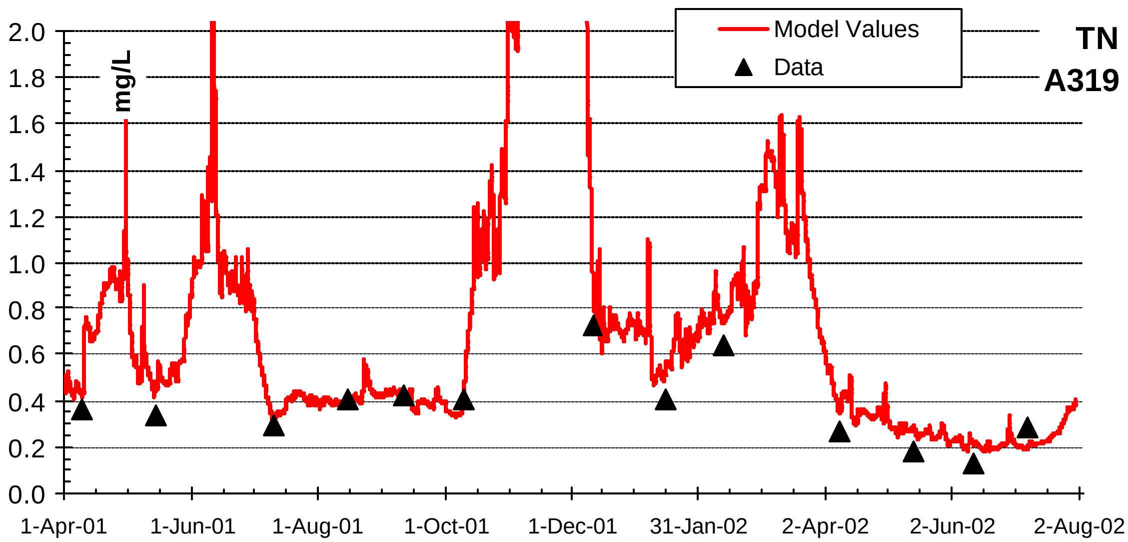
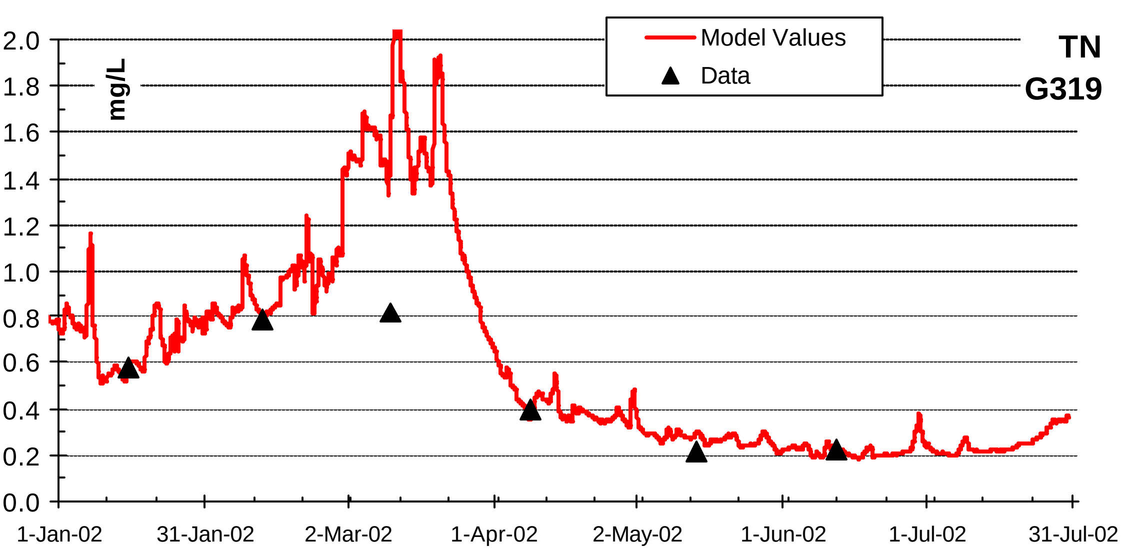


Figure 296: Total Nitrogen Comparison, 2001-2002 Model Run Period





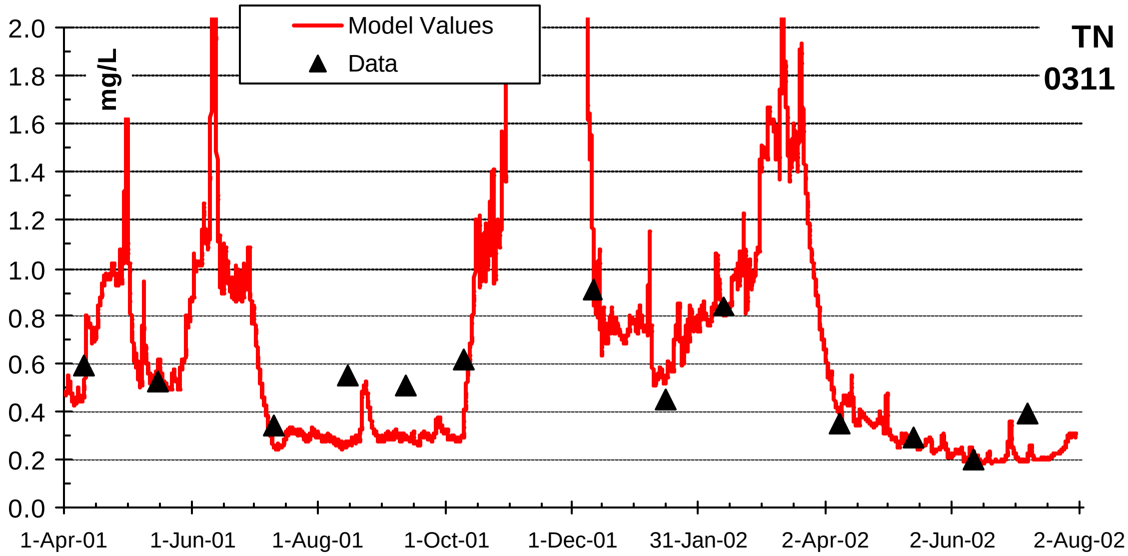


Figure 297: Reduced Scale Total Nitrogen Comparison, 2001-2002 Model Run Period

Table 26: Total Nitrogen Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	13	0.055	0.070	0.080
G319	6	0.10	0.18	0.33
0311	13	-0.090	0.11	0.15

Total Nitrogen values compare well with data at all three locations.

Ortho Phosphorus

Ortho phosphorus is a primary nutrient for algal growth, and is considered the limiting growth factor in many systems (Chapra, 1997). Data in Green River were sampled as Ortho Phosphorus, and this data were input in the model. Model values compare very closely with sampled data at all three locations. Figure 298 shows the data and model comparisons for all three locations, and Table 27 shows the error statistics.

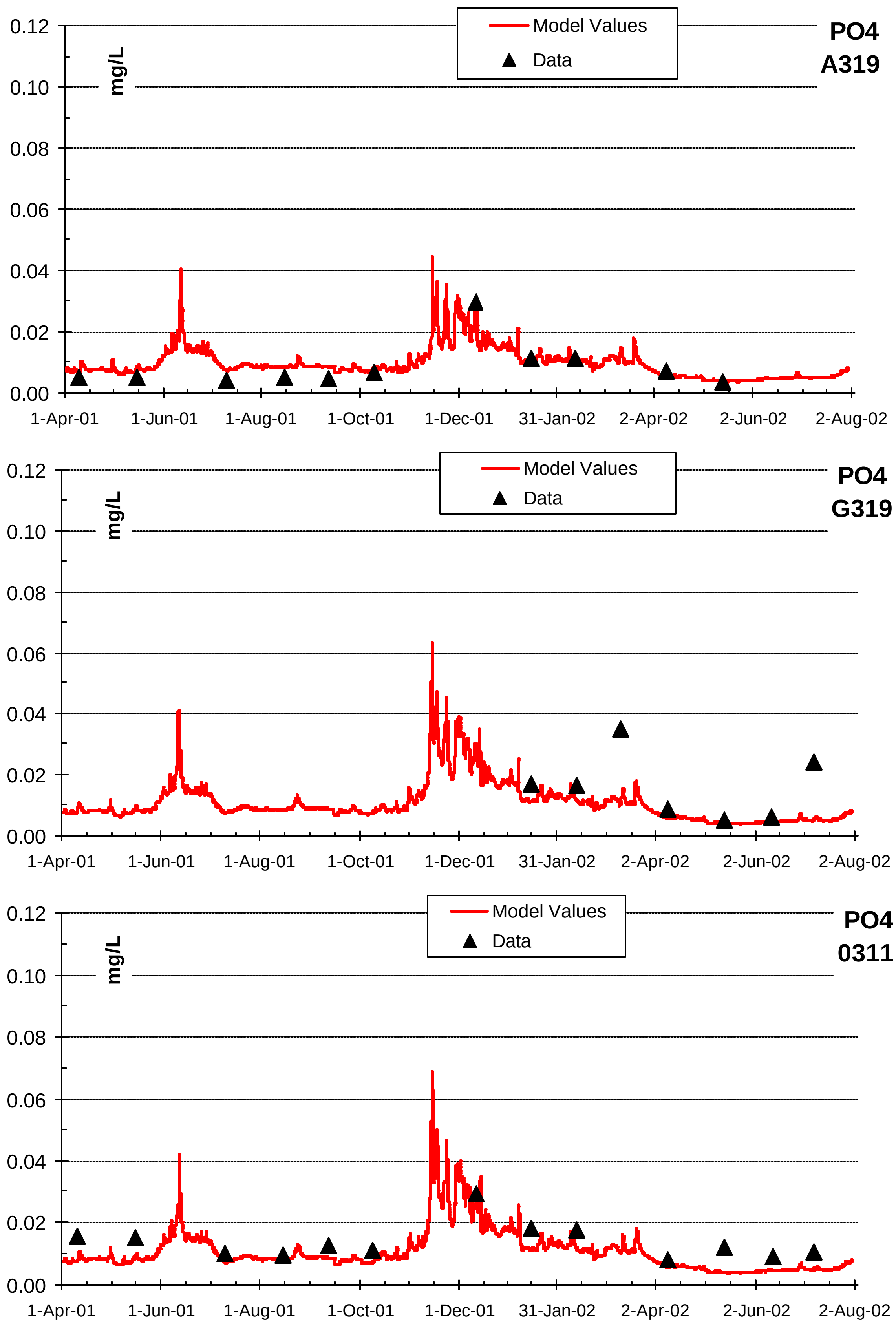


Figure 298: Ortho Phosphorus Comparison, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	7	0.0006	0.0021	0.0025
G319	7	-0.0085	0.0085	0.012
0311	13	-0.0045	0.0045	0.0051

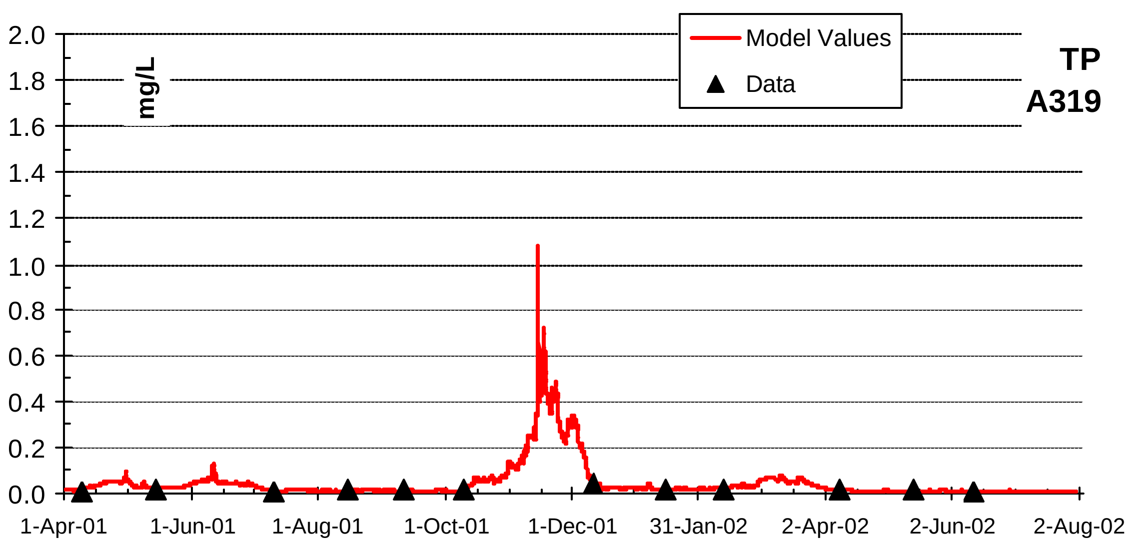
Table 27: Ortho Phosphorus Error Statistics, 2001-2002 Model Run Period

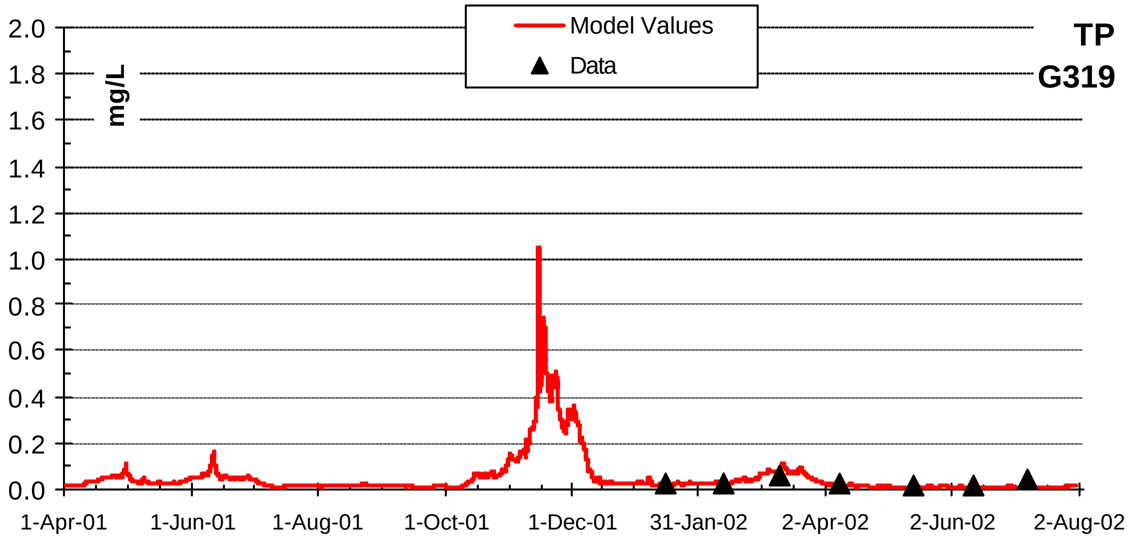
Total Phosphorus

Total Phosphorus is calculated by the model as the sum of all phosphorus compartments. Field data were available at all three sites, but only at Site 0311 for the entire model run period.

Total Phosphorus values are calculated using ortho phosphorus and organic matter. To calibrate Total Phosphorus to sampled data, the procedures for estimating organic matter input were reviewed and revised. For the 2001-2002 model run period initial organic matter model inputs were determined by estimation from two Total Organic Carbon samples from the summer of 2002. During model calibration the amount of organic matter in the system was calculated from its contribution to ammonia nitrogen (See Appendix F for more information on the calculation of these values). From these values the percentage of TSS that is organic matter was estimated. This percentage was then used to estimate organic matter input from the regression values of TSS used in the model (See TSS section above for more information on the regression). This percentage of organic matter was then adjusted to calibrate Total Phosphorus.

Figure 299 shows the data and model comparison for the model run period, and Table 28 shows the model error statistics.





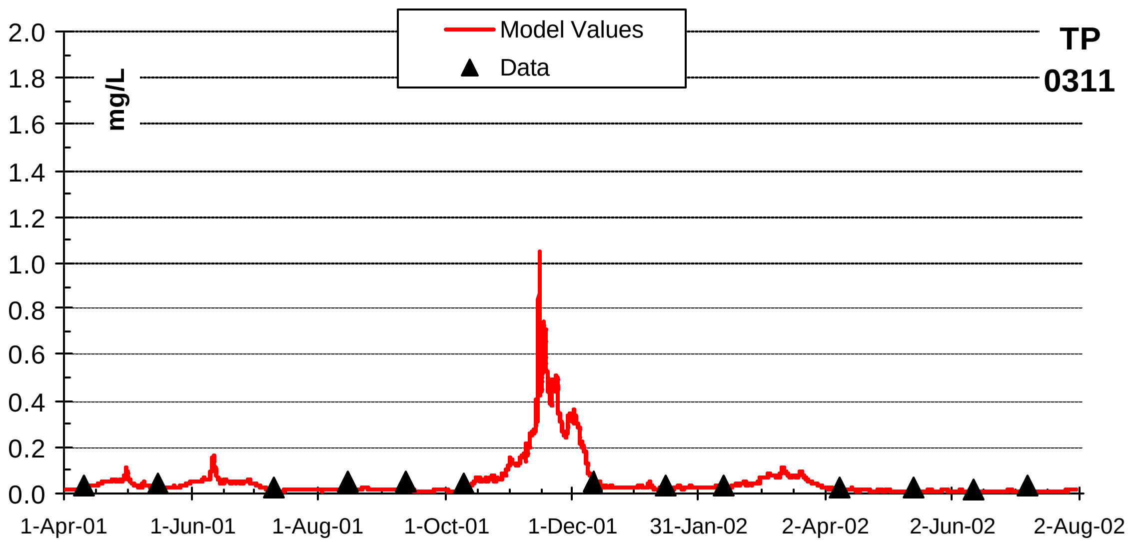


Figure 299: Total Phosphorus Comparison, 2001-2002 Model Run Period

Table 28: Total Phosphorus Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	7	-0.0035	0.0041	0.0042
G319	7	-0.006	0.012	0.016
0311	13	-0.018	0.018	0.021

Chlorophyll A

There were only two data points at Site A319 to compare to for this model period, in June and July of 2002. Figure 300 shows the model data for the model run period, and the sampled data points, and Figure 301 shows the model and data comparison for June and July of 2002.

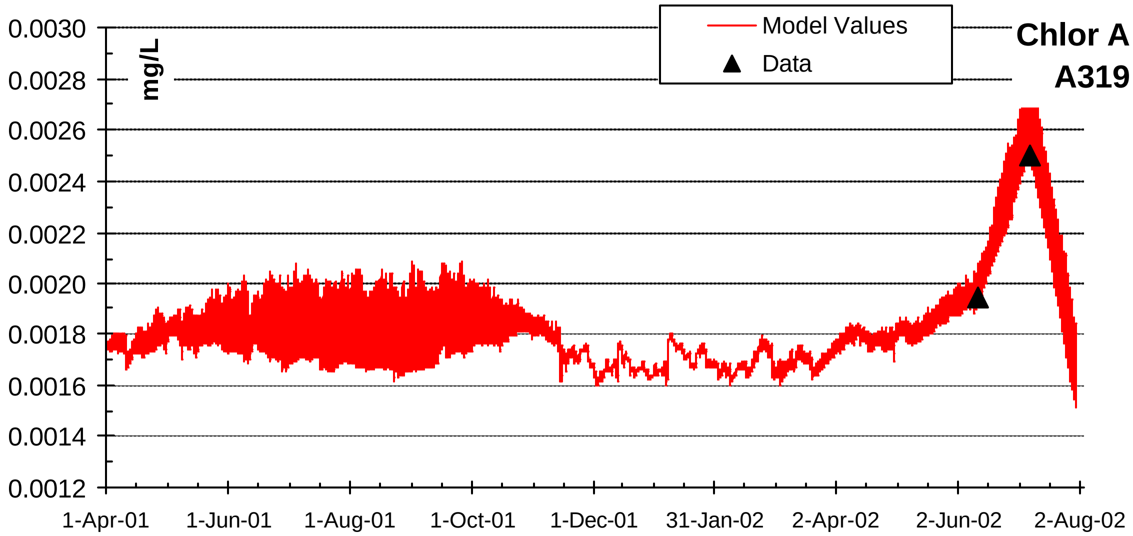


Figure 300: Chlorophyll a Comparison, 2001-2002 Model Run Period

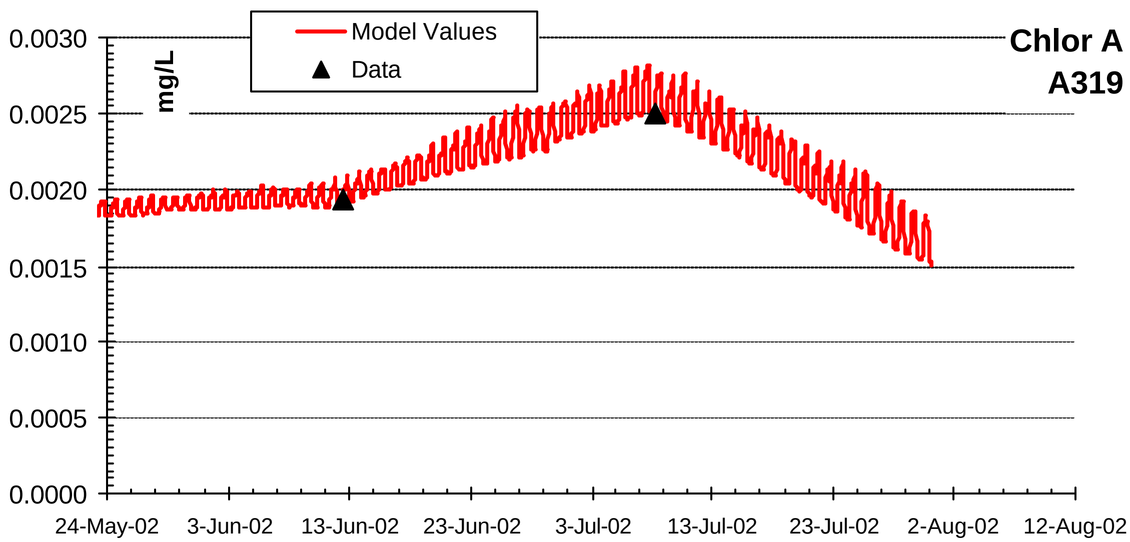


Figure 301: Chlorophyll a Comparison, June 10, 2002 to July 10, 2002

Table 29: Chlorophyll A Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (ug/L)	AME (ug/L)	RMS Error (ug/L)
A319	2	0.065	0.065	0.05

The algae biomass to chlorophyll a ratio was used to calibrate the model to the sampled data. An algal to biomass ratio of 100 was used in the model, along with an algae growth rate of 2 d^{-1}.

Total Organic Carbon

Three data samples were available for comparison during the summer of 2002 at Site A319. Figure 302 shows the model values and data comparison, and Table 30 shows the error statistics.

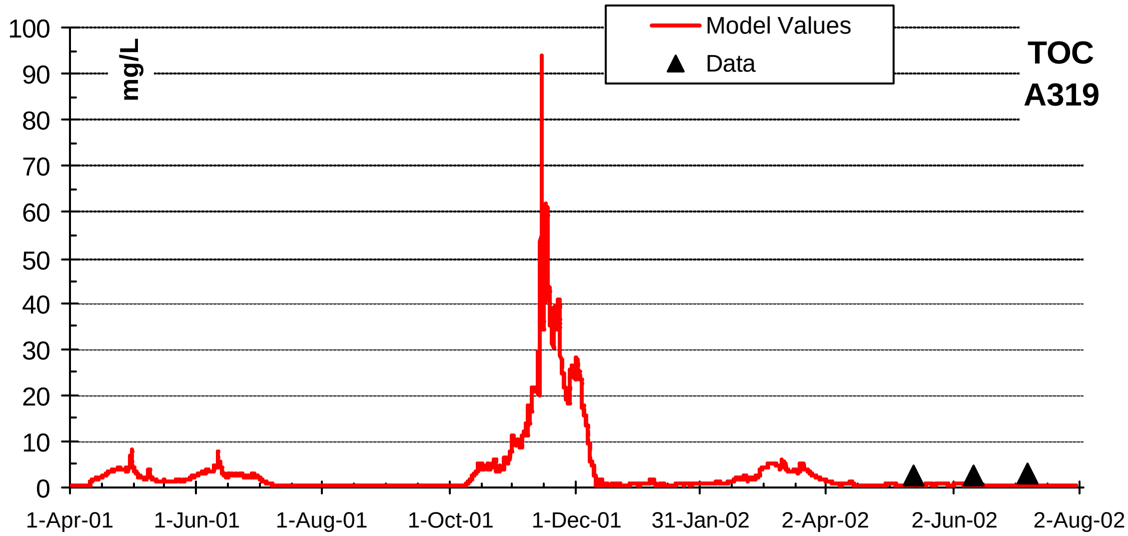


Figure 302: TOC Comparison, 2001-2002 Model Run Period

Table 30: Total Organic Carbon Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	3	-2.25	2.25	2.29

Dissolved Organic Carbon

Three data samples were available for comparison during the summer of 2002 at Site A319. Figure 303 shows the model values and data comparison, and Table 31 shows the error statistics.

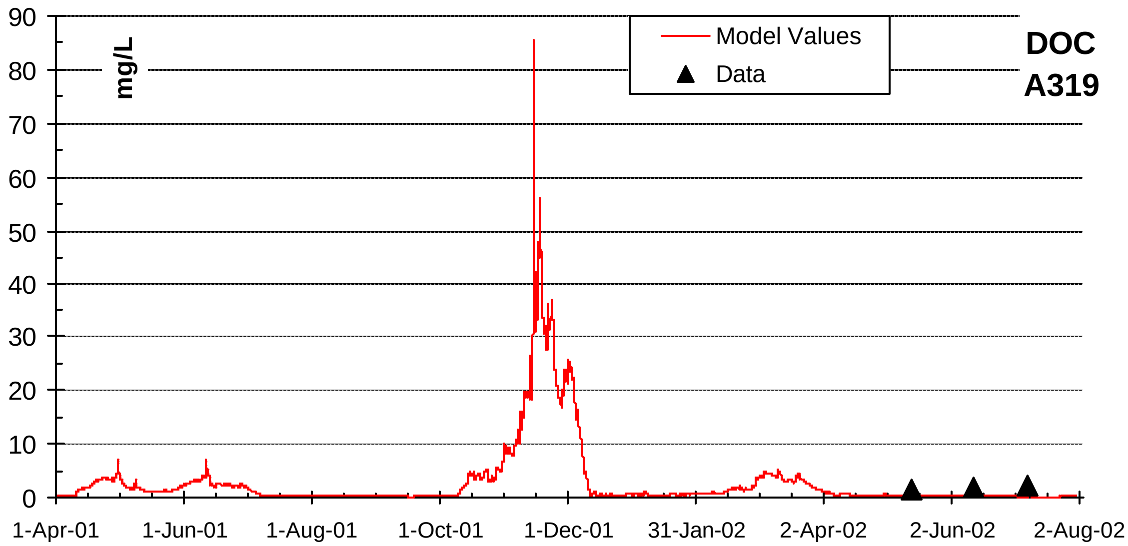


Figure 303: DOC Comparison, 2001-2002 Model Run Period

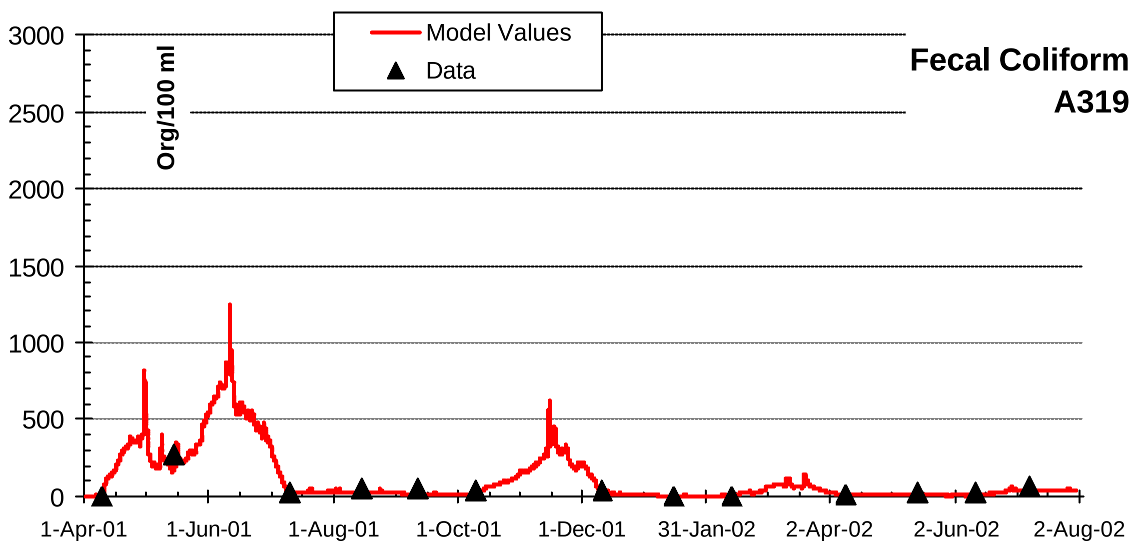
Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	3	-1.59	1.59	1.62

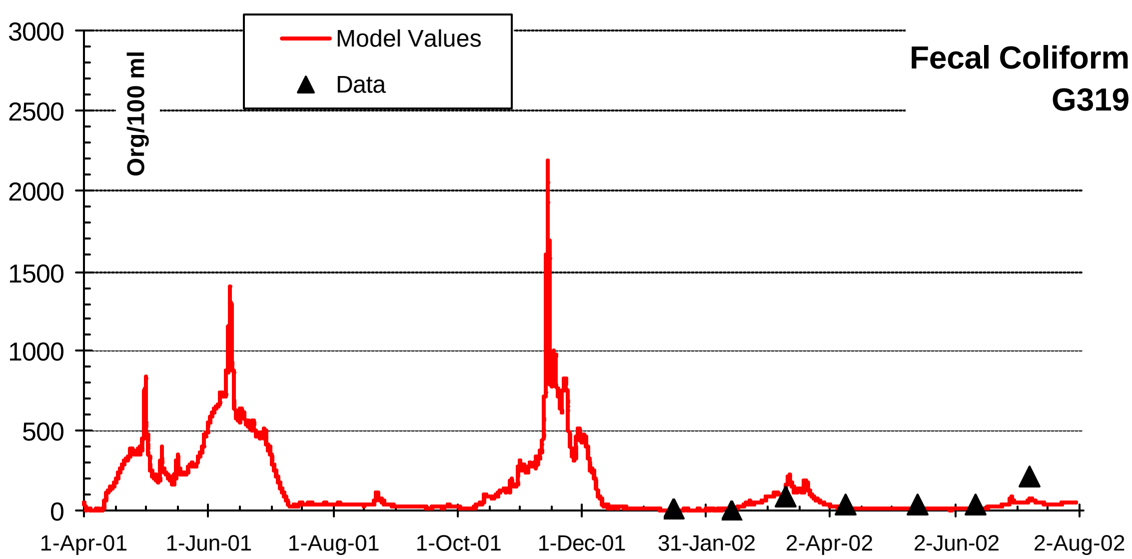
Table 31: Dissolved Organic Carbon Error Statistics, 2001-2002 Model Run Period

Fecal Coliform

Fecal Coliform is modeled using a generic constituent. In CE QUAL-W2, decay rate and temperature multipliers can be individually set for generic constituents, but they do not interact with other constituents. The default variables of 1.04 for the Arrhenius Temperature Multiplier, and 0.20 d^{-1} for the first order decay rate were used in the model for Fecal Coliform.

Figure 304 shows the model value and data comparison, and Figure 305 shows the same time period, but does not include the high peak produced during a storm event of middle June 2001. The model values match well with field data.





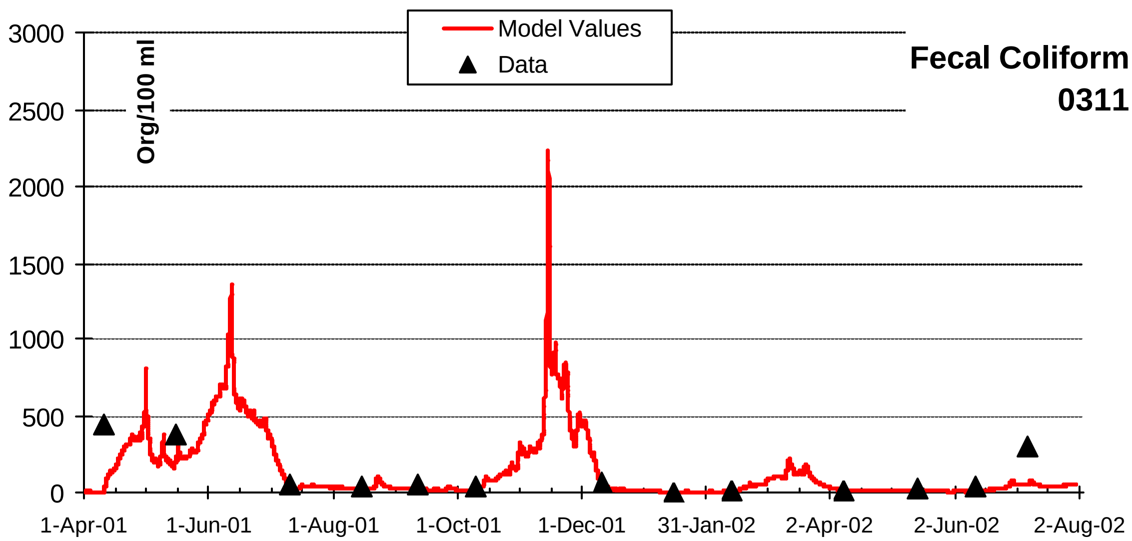
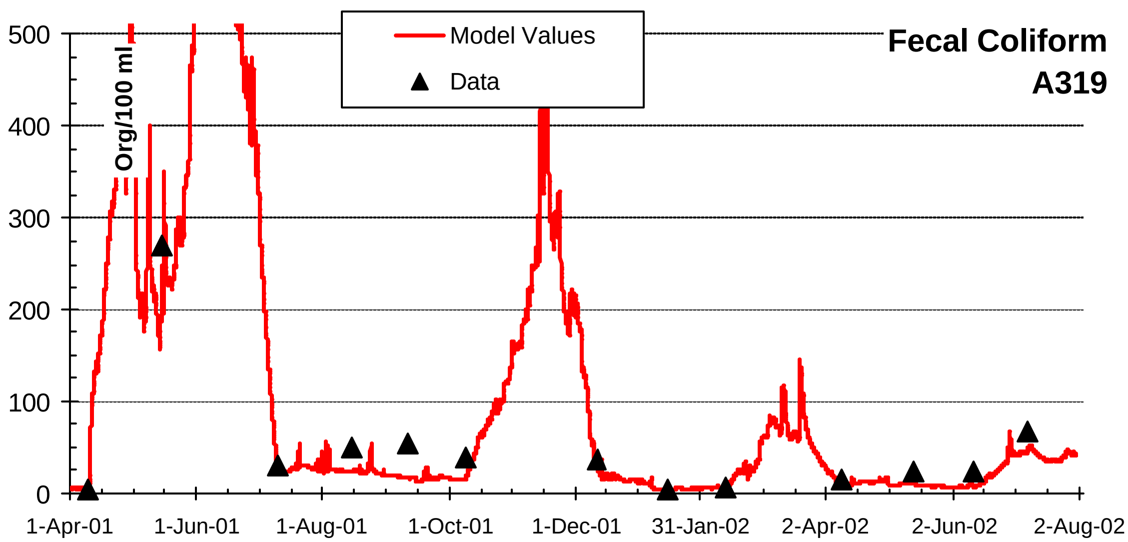
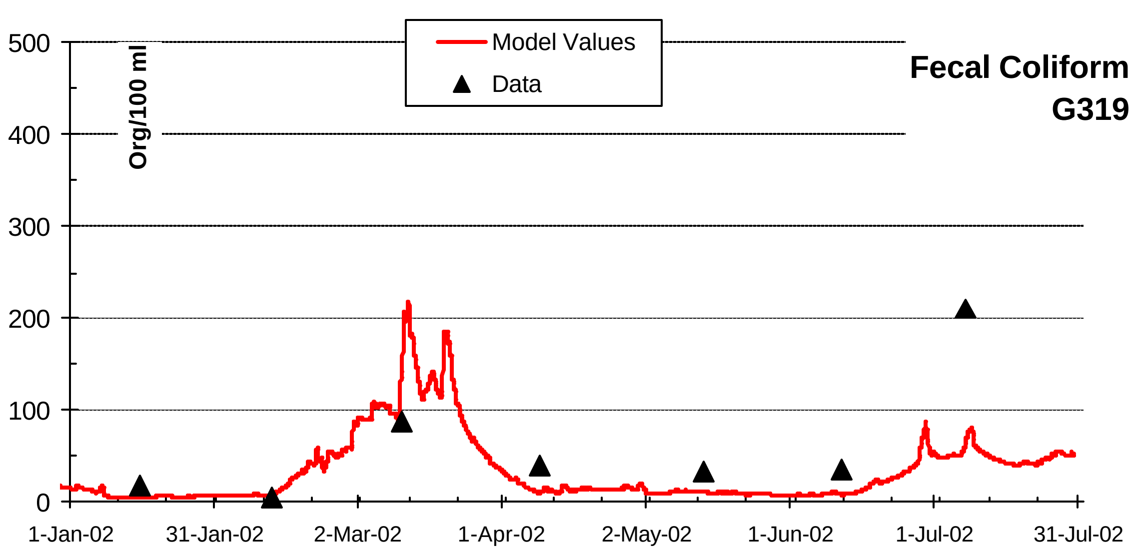


Figure 304: Fecal Coliform Comparison, 2001-2002 Model Run Period





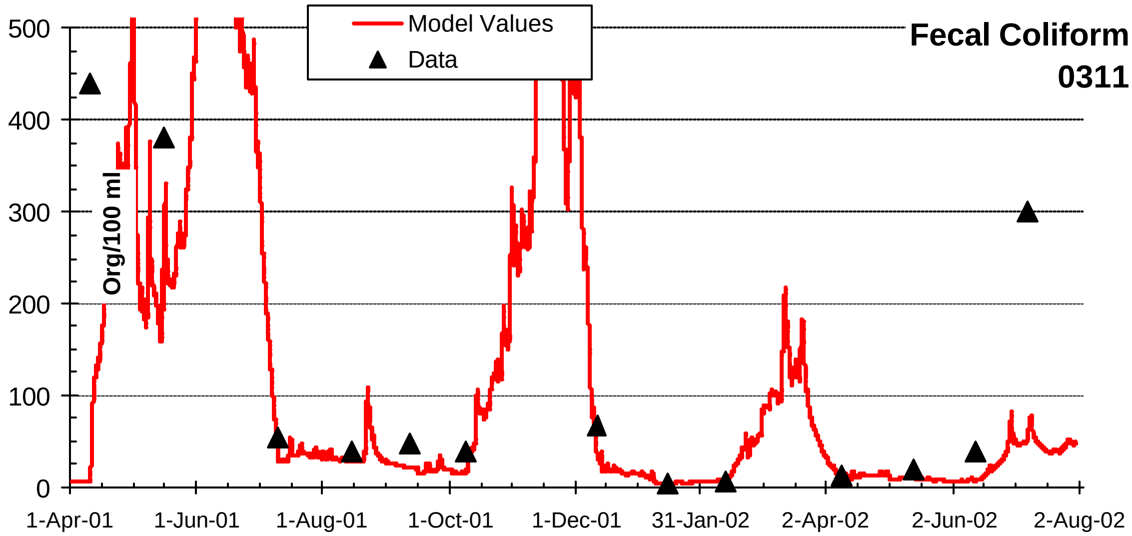


Figure 305: Reduced Scale Fecal Coliform Comparison, 2001-2002 Model Run Period

Table 32: Fecal Coliform Error Statistics, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error (ORG/100mL)	AME (Org/100 ml)	RMS Error (Org/100 ml)
A319	13	-13.85	14.01	18.00
G319	7	-26.70	40.00	59.60
0311	13	-75.80	75.80	145.4

3.3.2 1995-1996

Model data were compared with field values at two sites for this model run period: Site A319, which is about 18 km below the upstream project boundary at River Mile 33.8, and Site 0311, which is near the downstream boundary at River Mile 13.20. The model run period is from May 25, 1995 to November 30, 1996.

Conductivity

Conductivity is modeled as a conservative constituent, with all rate terms set to zero. Figure 306 shows the comparison between sampled data and model results and Table 33 shows the model error statistics. Note that the model values compare very well at Site A319, but, as with the 2001-2002 model run period, summer conductivity model values are lower than the data at Site 0311. Since conductivity is a conservative constituent, the most likely possibility is that a source of high conductivity flow in the Lower Green River is not represented in the model. This issue is discussed in more detail in the Summary and Conclusions analysis section. An additional distributed tributary was added to the last branch of the model to simulate conditions needed to match the data at this location. This is discussed in the Sensitivity Analysis section.

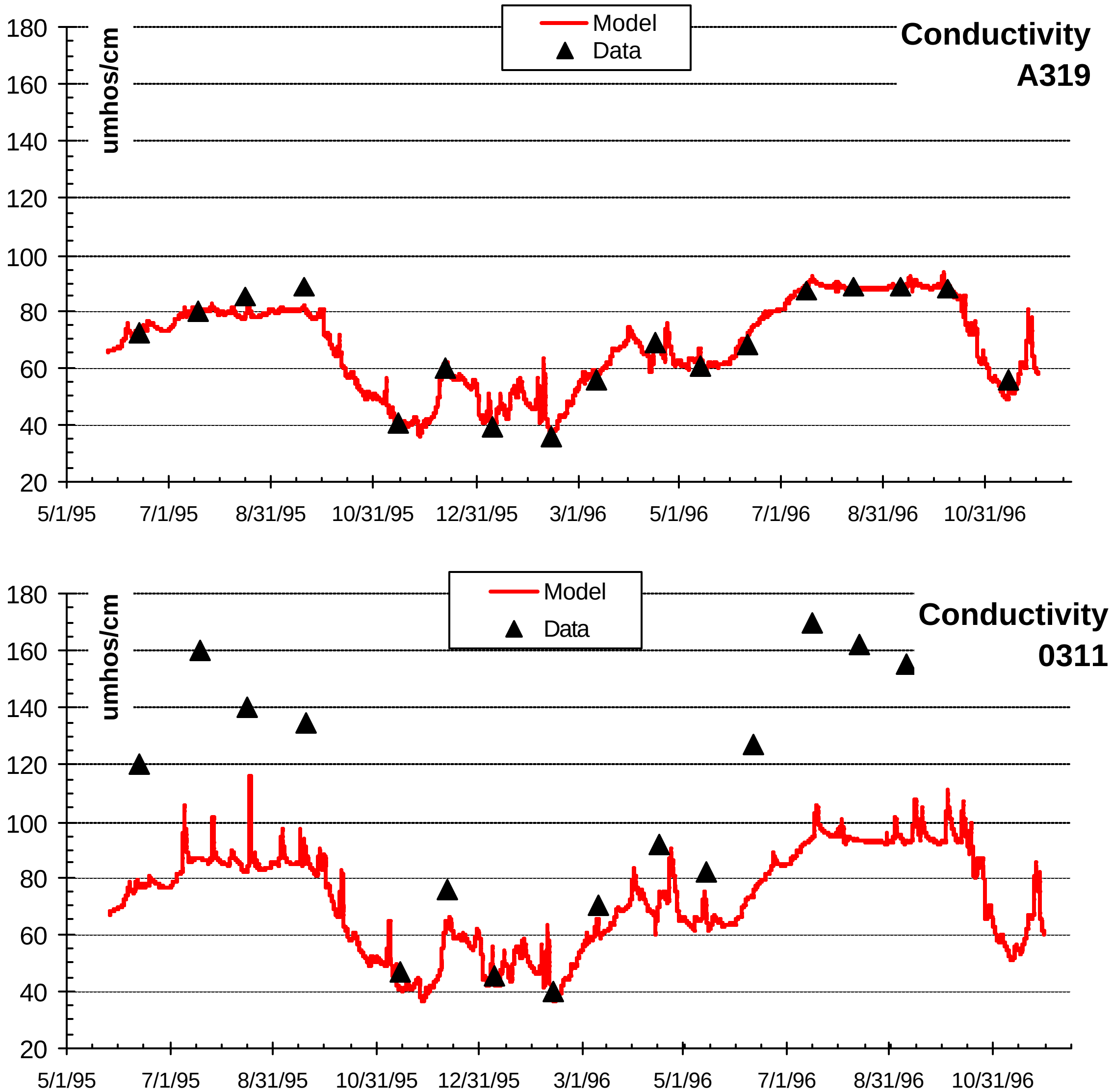


Figure 306: Conductivity Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 33: Conductivity Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (umhos/cm)	AME (umhos/cm)	RMS Error (umhos/cm)
A319	17	-0.32	2.02	2.87
0311	16	-37.73	37.73	46.21

pH

pH is computed in the model from total inorganic carbon, alkalinity, and temperature model values. Figure 307 shows the comparison between model values and data for both sites, and Table 34 shows AME and RMS error statistics at each sampling site.

Alkalinity data were not available for the boundary conditions during this model run period, and an average from periods where data were available was used in the model. Since alkalinity is unknown, this was used as a calibration factor to match model values of pH with data.

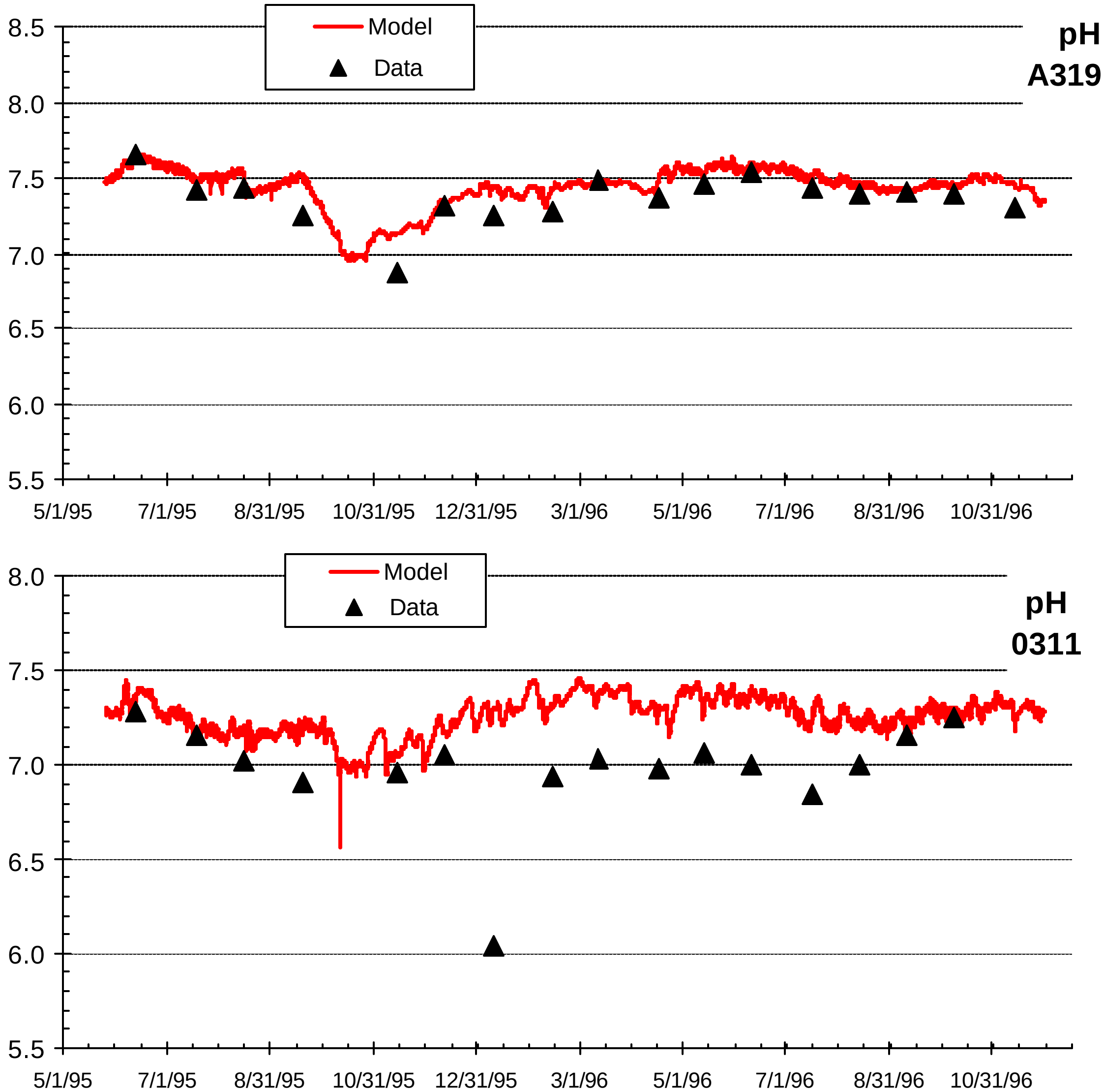


Figure 307: pH Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 34: pH Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
A319	17	0.10	0.10	0.13
0311	16	0.28	0.29	0.41

Total Suspended Solids

Total Suspended Solids is a derived constituent in CE-QUAL-W2, found by adding particulate organic matter, inorganic suspended solids, and algae. As with the 2001-2002 model run period regression was used to establish an equation that estimates model input between monthly sampling periods. Figure 308 shows the model results and data without the regression equation.

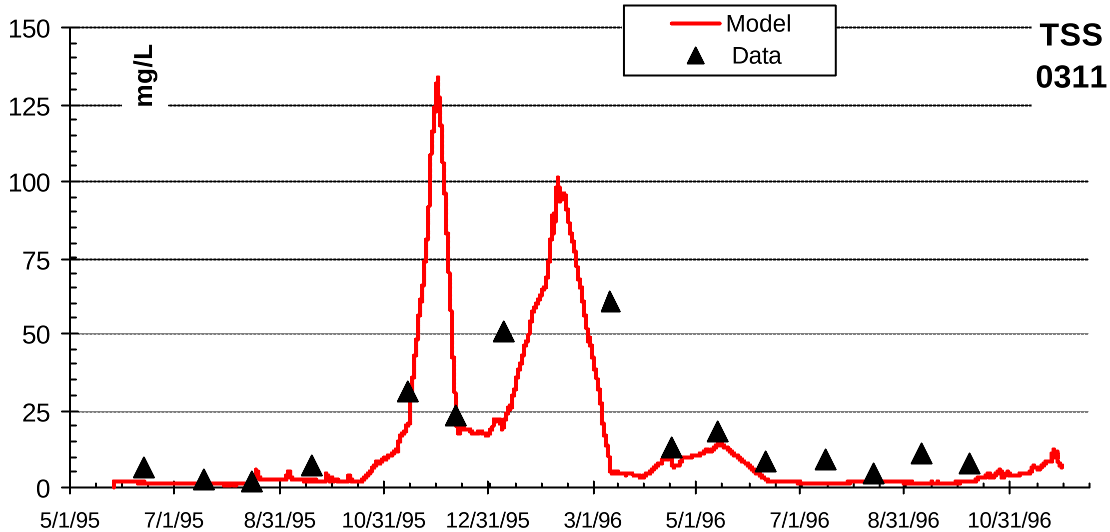
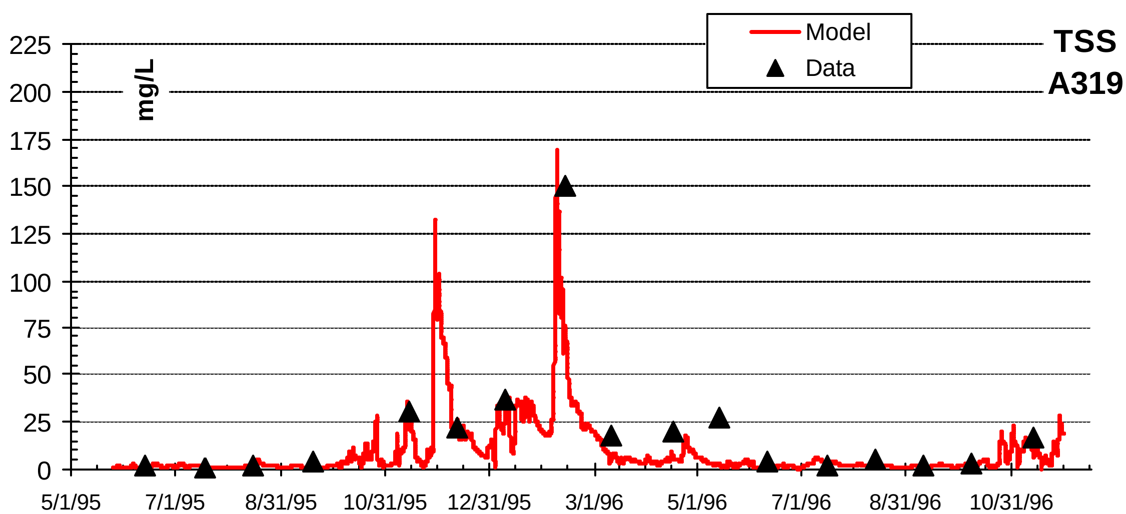


Figure 308: TSS Comparison with monthly grab samples, 1995-1996

Daily average TSS model values were estimated using flow data from the USGS gage at Palmer (Station No. 12108700), from flow data at the USGS gage near Auburn (12113000), and the Julian date. The following correlation was developed for the 2001-2002 model run period ($R^2 = 0.94$):

TSS = ABS[5.82 - 1.24*(Palmer flow) - 26.58*Log(Palmer flow) + 1.50*AUB flow-0.032*Julian date]

Model input at the upstream boundary was adjusted using this equation. The resulting graph of model values and data are shown in Figure 309, and the error statistics can be found in Table 35.



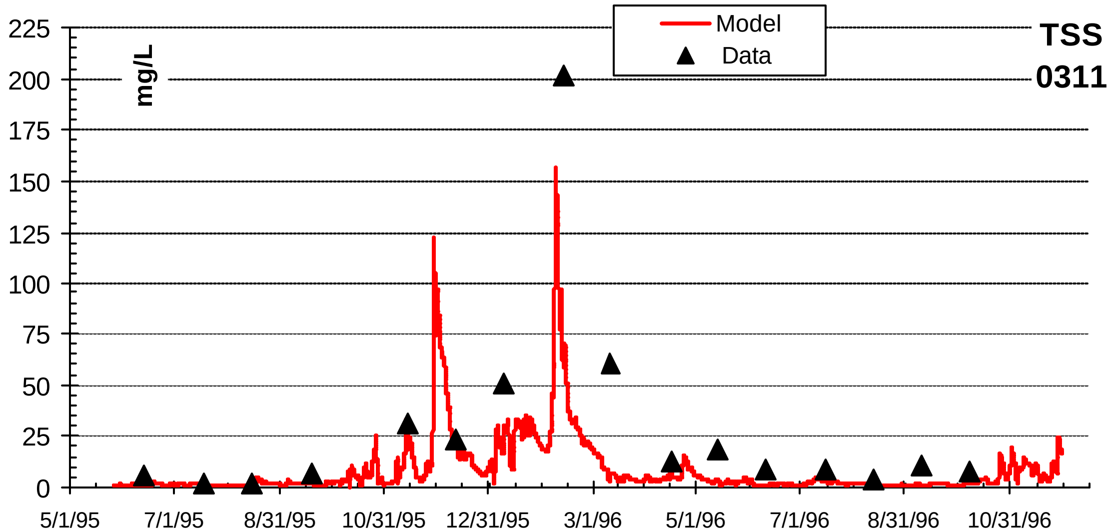


Figure 309: TSS Comparison, May 25, 1995 - Nov 1996 Model Run Period

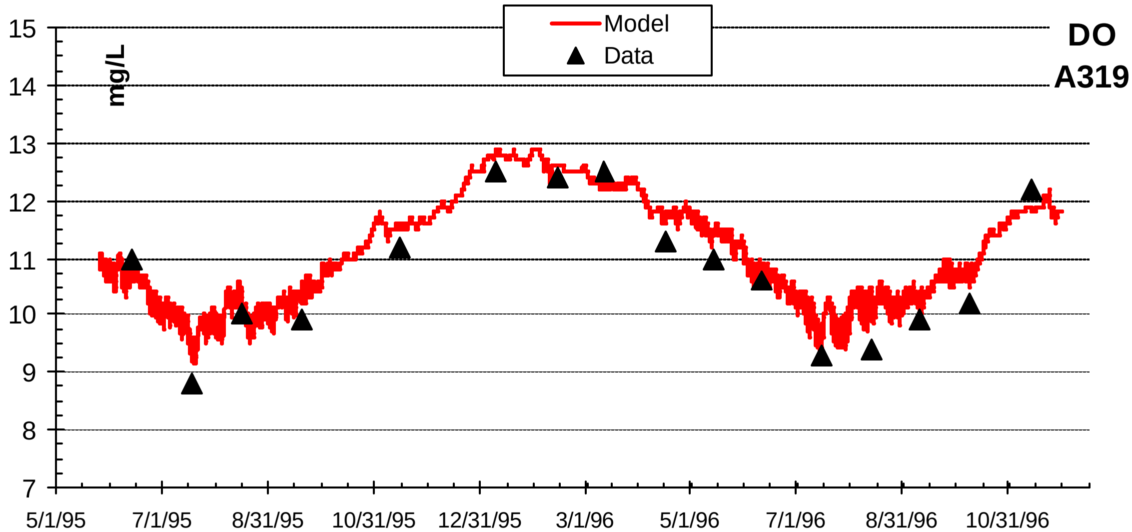
Table 35: Total Suspended Solids Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	17	-9.30	9.81	20.8
0311	16	-18.11	18.11	36.9

Dissolved Oxygen

CE-QUAL-W2 has nine separate reaeration formulations that can be used for river systems. The Melching and Flores (1999) equation applicable for channel control streams was used. Zero order sediment oxygen demands were set at 1.0 g m^{-2} d^{-1} for Waterbody One and two, and 2 g m^{-2} d^{-1} for Water Body three. Figure 310 shows the time series comparison of data and model values, and Table 36 shows the AME and RMS error statistics.

As with conductivity, the model values compare very closely at Site A319, but do not compare as well at Site 0311. The Summary and Conclusions section discusses possible reasons for the difference, and the Sensitivity Analysis section discusses model runs made with additional data added to the Lower Green River to replicate sampled data.



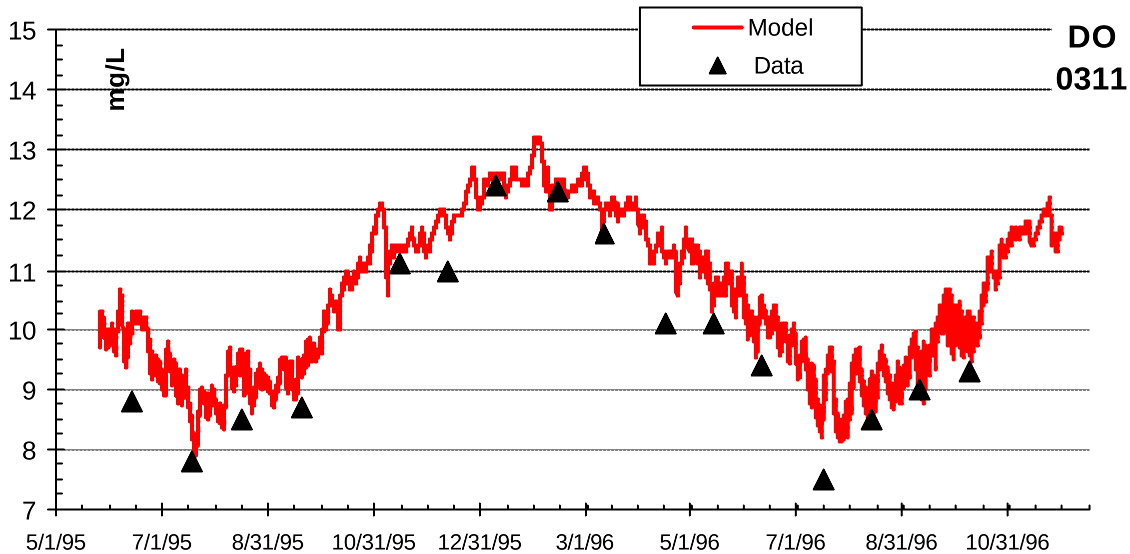


Figure 310: DO Comparison, May 25, 1995-Nov 1996 Model Run Period

Table 36: Dissolved Oxygen Error Statistics, May 25, 1995-Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	16	0.36	0.45	0.50
0311	16	0.59	0.59	0.68

Nitrite-Nitrate Nitrogen

Nitrite-Nitrate data were available for comparison with model-predicted values for both sampling sites. Figure 311 compares data to model values at both sampling sites, and Table 37 shows the model error statistics.

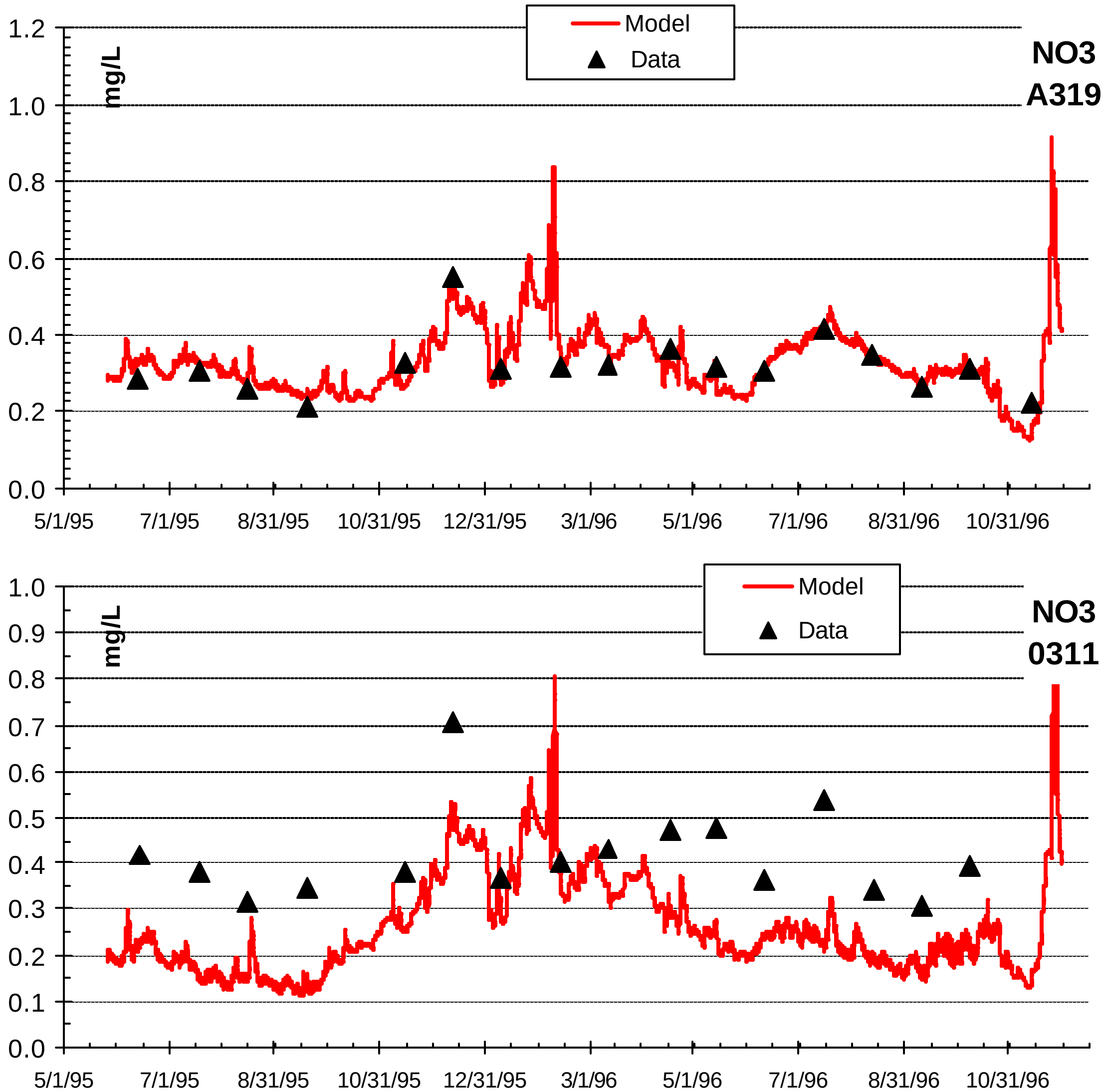


Figure 311: Nitrite -Nitrate Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 37: Nitrite -Nitrate Nitrogen Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	17	-0.005	0.026	0.031
0311	16	-0.17	0.17	0.18

As with the 2001-2002 model run period, nitrite-nitrate model values are under-predicted during summer periods at Site 0311. See the Sensitivity Analysis section for more information.

Ammonia Nitrogen

Ammonia Nitrogen data were available for comparison through the last half of this model run period for Site A319, and for the entire run period for Site 0311. Figure 312 shows the comparison of sampled data and model values, and Table 38 shows the error statistics for both sampling sites.

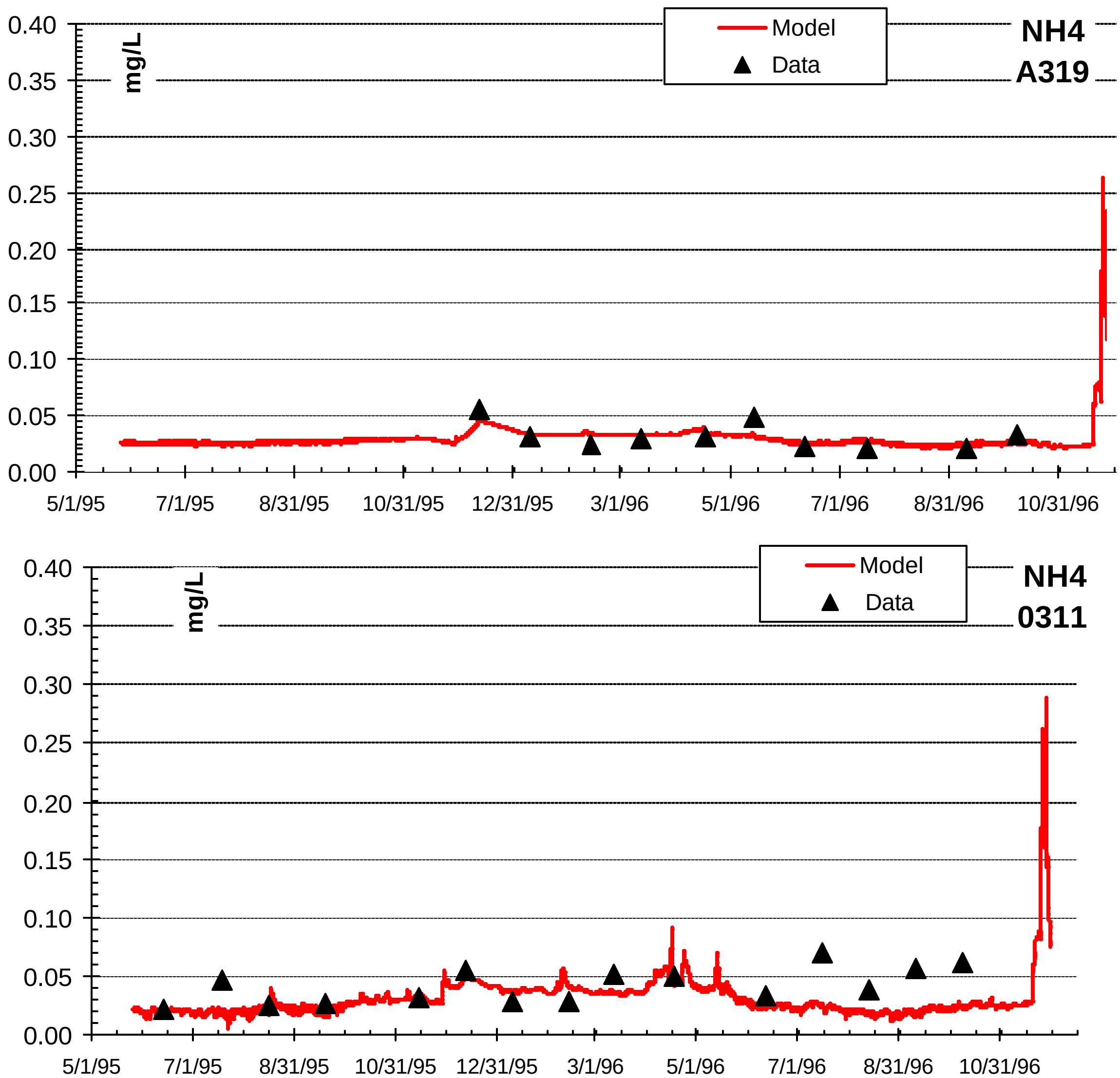


Figure 312: Ammonia Nitrogen Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 38: Ammonia Nitrogen Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L
A319	10	0.000	0.006	0.008
0311	15	-0.012	0.015	0.25

Total Nitrogen

Total nitrogen data were available for comparison with model values for the entire model run period, and for both sampling sites. Total Nitrogen values are calculated from nitrite-nitrate, ammonia nitrogen, and organic matter. To calibrate Total Nitrogen, the procedures for establishing organic matter input were reviewed and revised. For the 1995-1996 model run period initial organic matter model inputs were determined as a percentage of Total Suspended Solids. During model calibration the amount of organic matter in the system was calculated from its contribution to ammonia nitrogen (See Appendix F for more information on the calculation of these values). From these values the percentage of TSS that is organic matter was calculated. This value was used to calculate organic matter input from the regression values of TSS used in the model (See TSS section above for more information on the regression). This percentage of TSS was then adjusted to calibrate Total Phosphorus.

Figure 313 shows the comparison of data with model values for both sites, and Figure 314 shows the same time period, without the peak of large concentration from two winter storms. Table 39 shows the error statistics for the model run period.

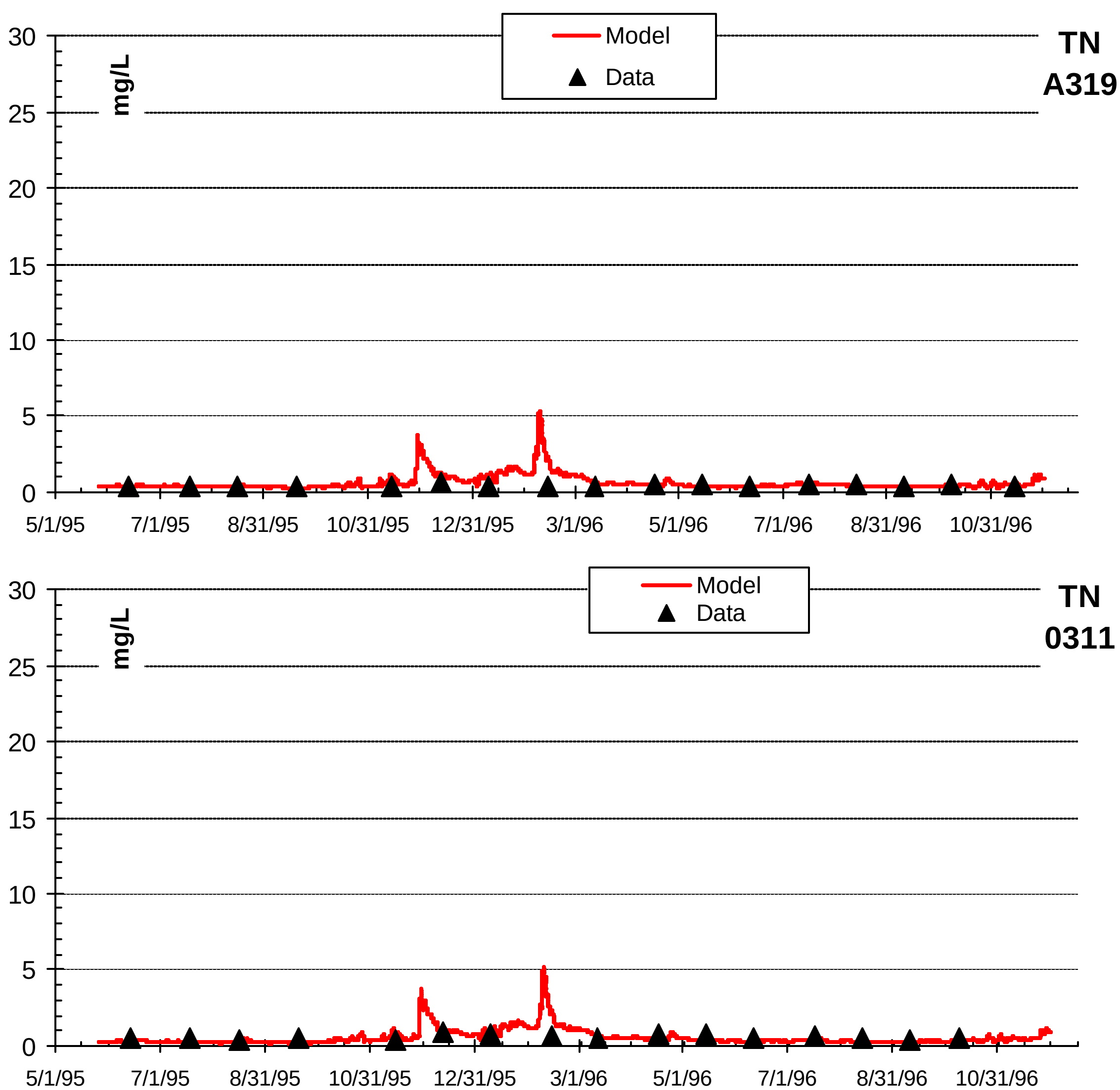


Figure 313: Total Nitrogen Comparison, May 25, 1995 - Nov 1996 Model Run Period

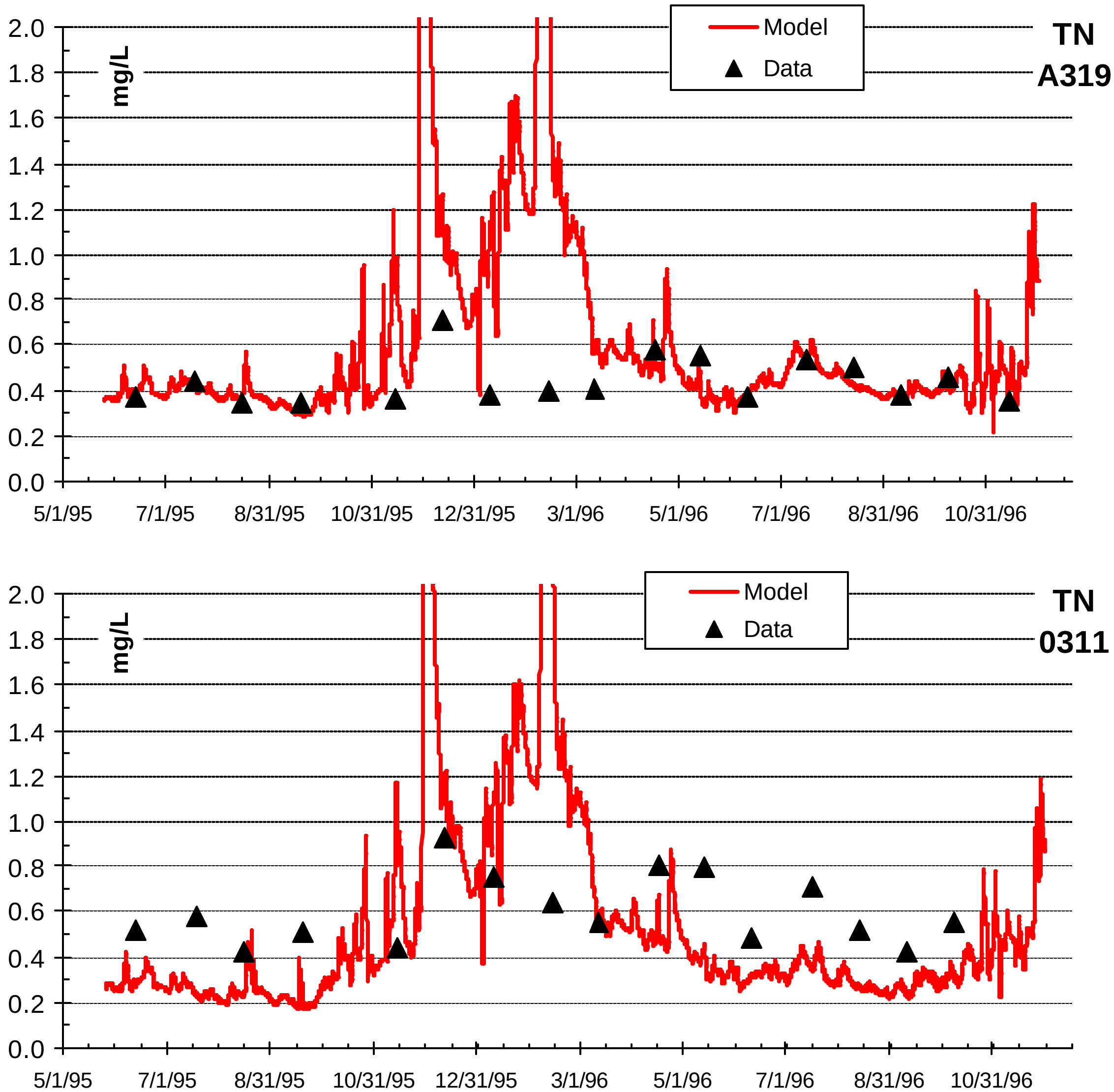


Figure 314: Reduced Scale Total Nitrogen Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 39: Total Nitrogen Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	17	0.21	0.26	0.53
0311	16	-0.013	0.35	0.50

Ortho Phosphorus

Ortho-phosphorus model values compare closely with sampled data at both locations. Figure 315 shows the data and model comparisons for all three locations, and Table 40 shows the error statistics.

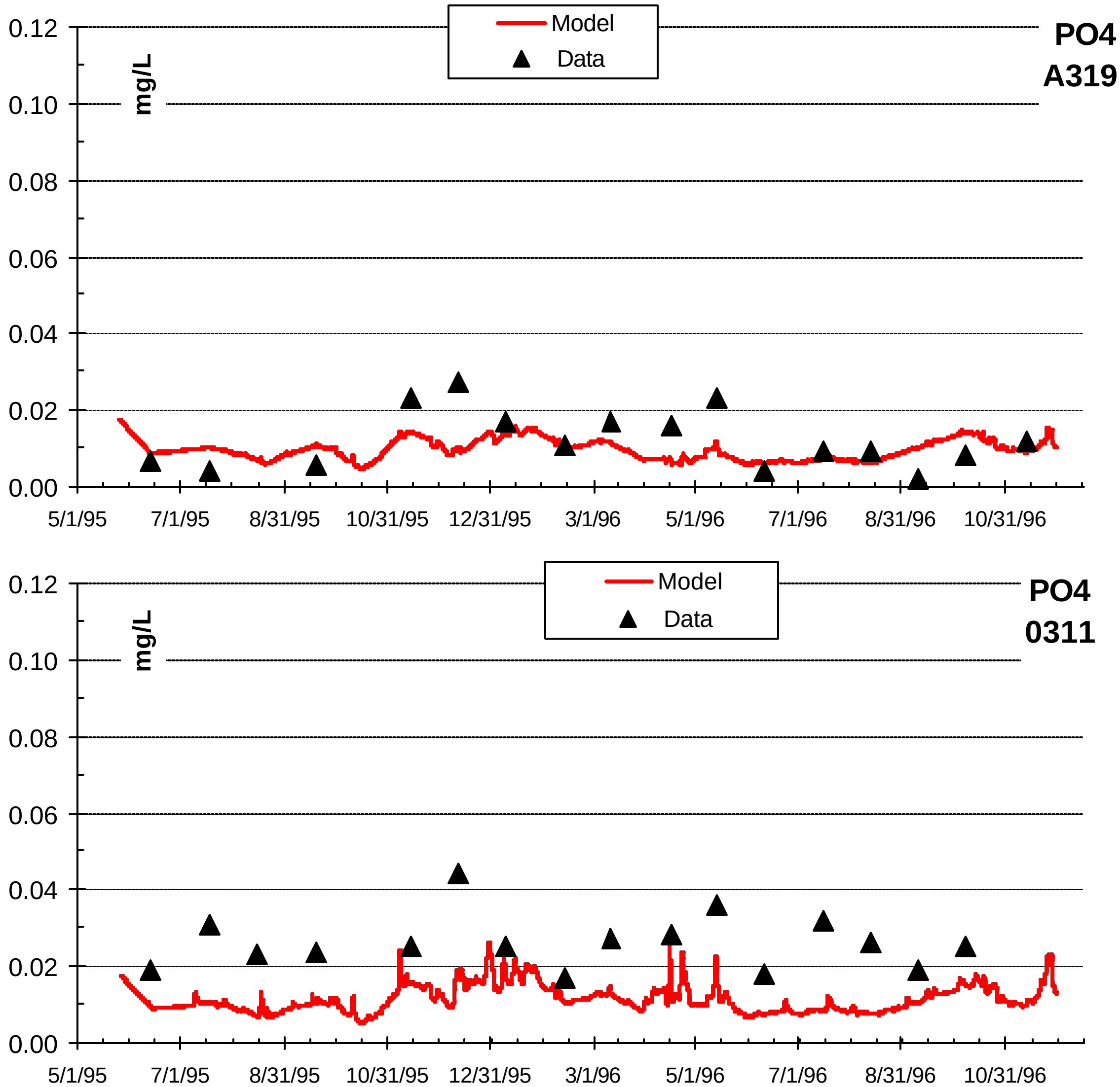


Figure 315: Ortho Phosphorus Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 40: Ortho Phosphorus Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L	RMS Error (mg/L
A319	16	-0.002	0.006	0.007
0311	16	-0.014	0.014	0.015

Total Phosphorus

Total Phosphorus is calculated by the model as the sum of all phosphorus compartments. Total Phosphorus values are calculated using ortho-phosphorus and organic matter. To calibrate Total Phosphorus, the procedures for establishing organic matter input were reviewed and revised. For the 1995-1996 model run period initial organic matter model inputs were estimated as a percentage of Total Suspended Solids. During model calibration this percentage was revised as described

previously and in Appendix F. Note that a regression equation has been established to determine average daily values of TSS. A percentage of these values were used as input for organic matter.
Figure 316 shows the data and model comparison for the model run period. Figure 317 shows the same comparison at both sites, without the large peaks from winter storms. Table 41 shows the model error statistics.

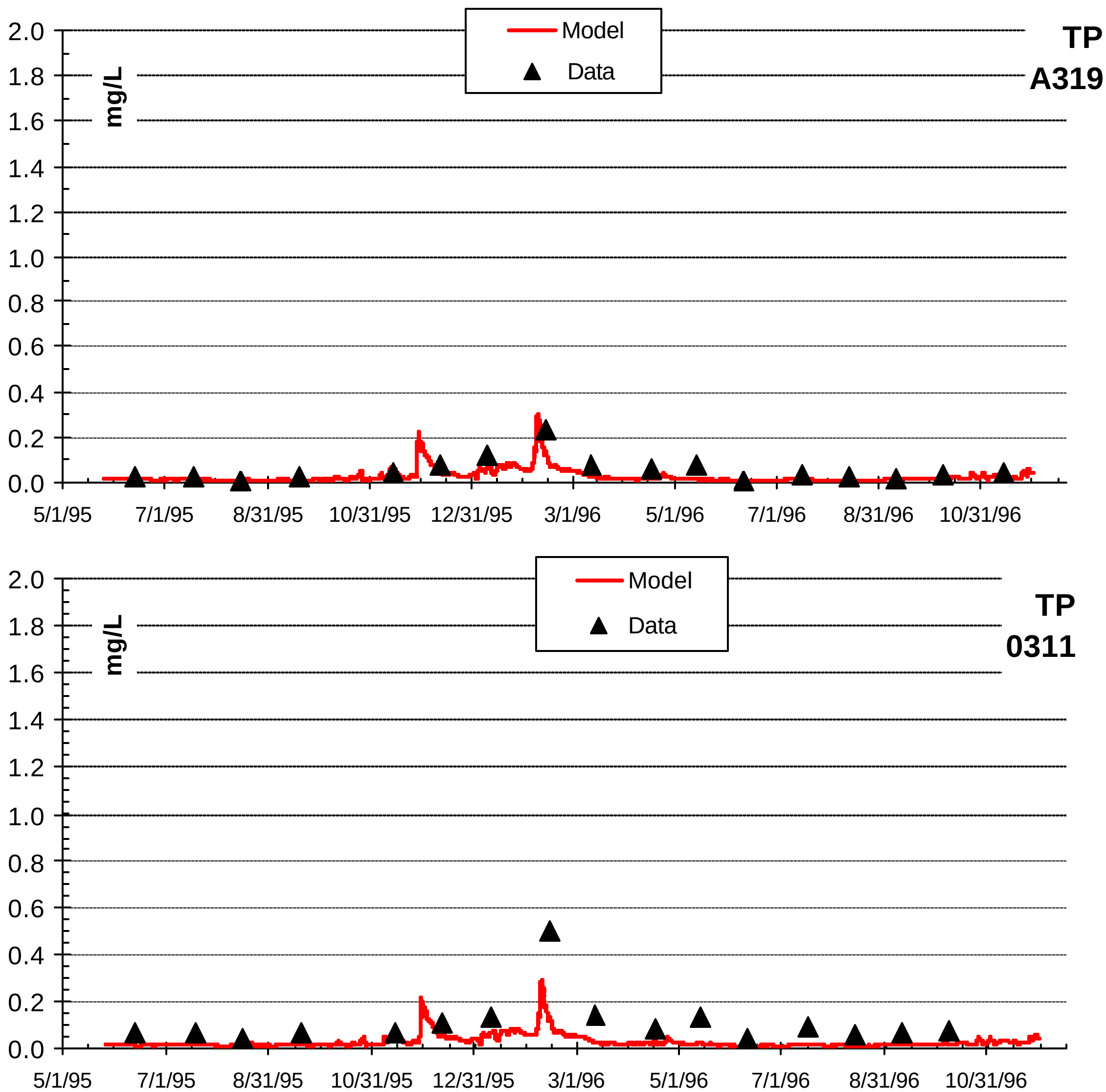


Figure 316: Total Phosphorus Comparison, May 25, 1995 - Nov 1996 Model Run Period

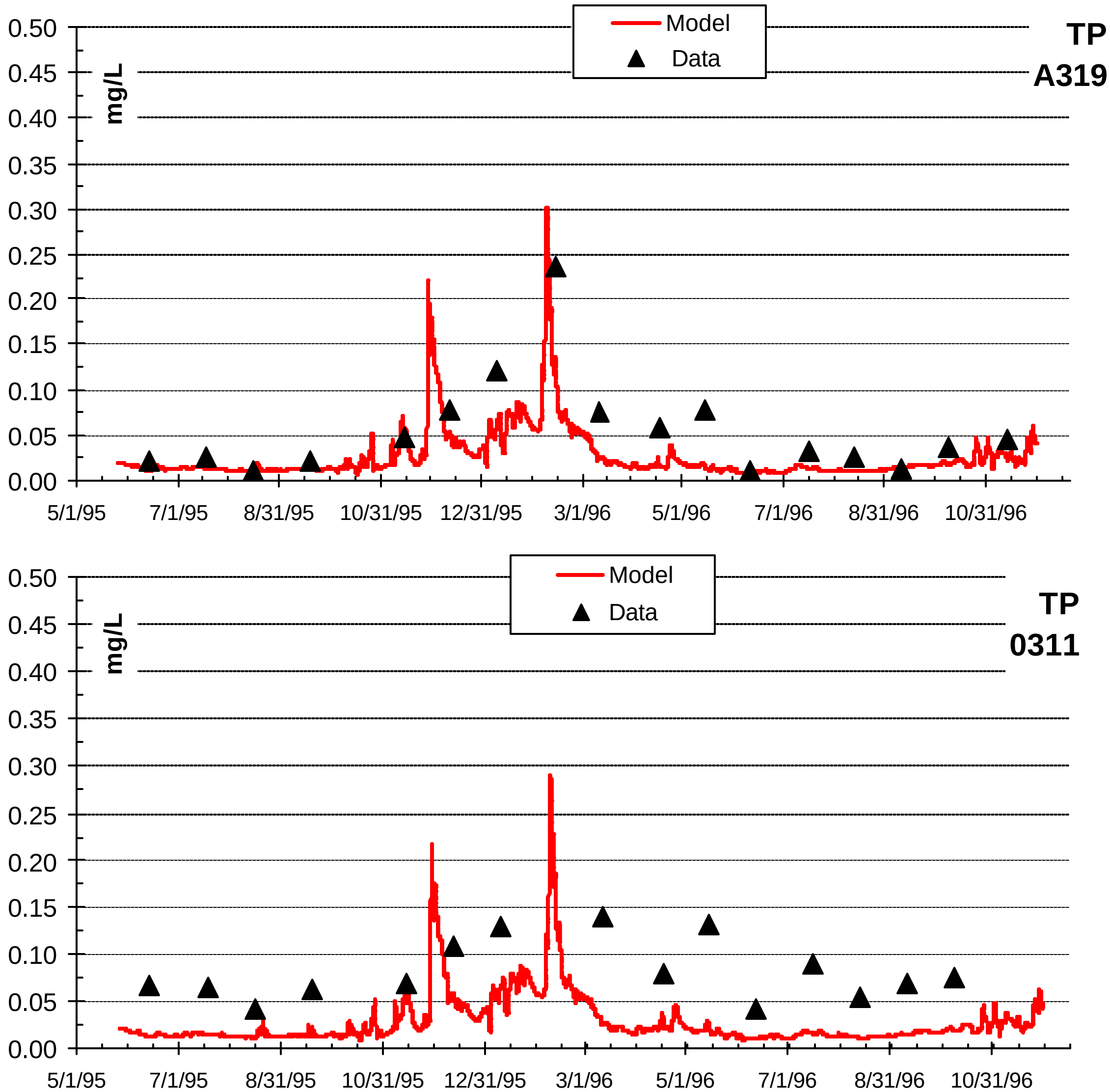


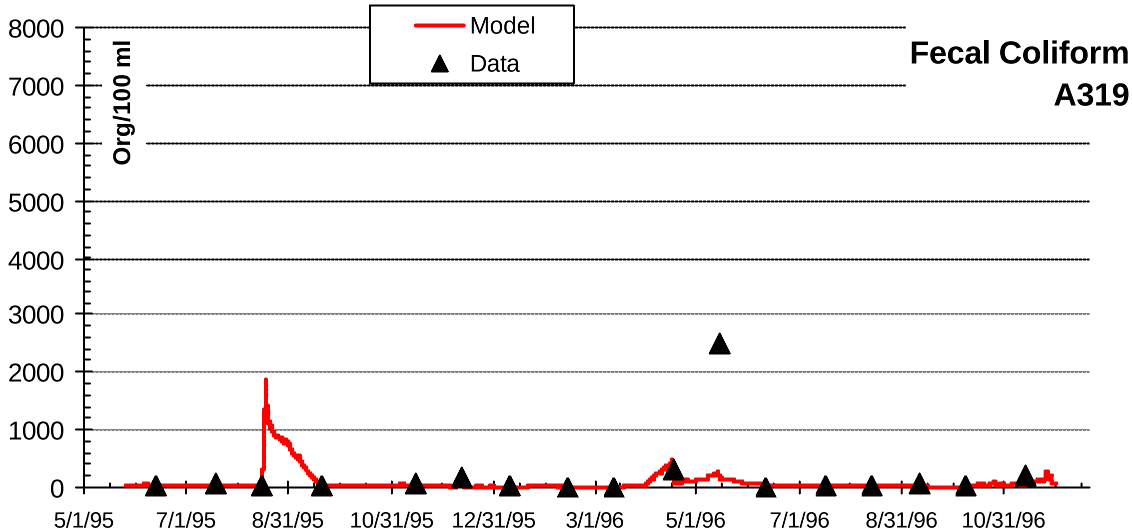
Figure 317: Reduced Scale Total Phosphorus Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 41: Total Phosphorus Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (mg/L)	AME (mg/L)	RMS Error (mg/L)
A319	17	-0.026	0.027	0.039
0311	16	-0.076	0.076	0.108

Fecal Coliform

Fecal Coliform is set up as a generic constituent in the model. In CE QUAL-W2, decay rate and temperature multipliers can be individually set for generic constituents, but the constituents do not interact with other constituents. The default variables of 1.04 for the Arrhenius Temperature Multiplier, and 0.20 d^{-1} for the first order decay rate were used in the model for Fecal Coliform. Figure 318 shows the model value and data comparison, and Table 42 shows the error statistics.



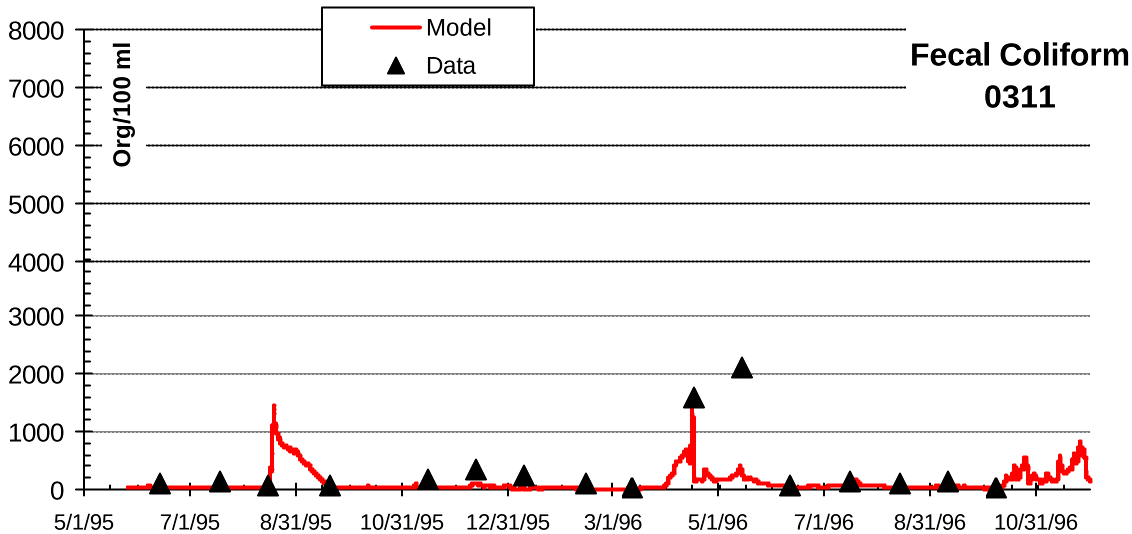
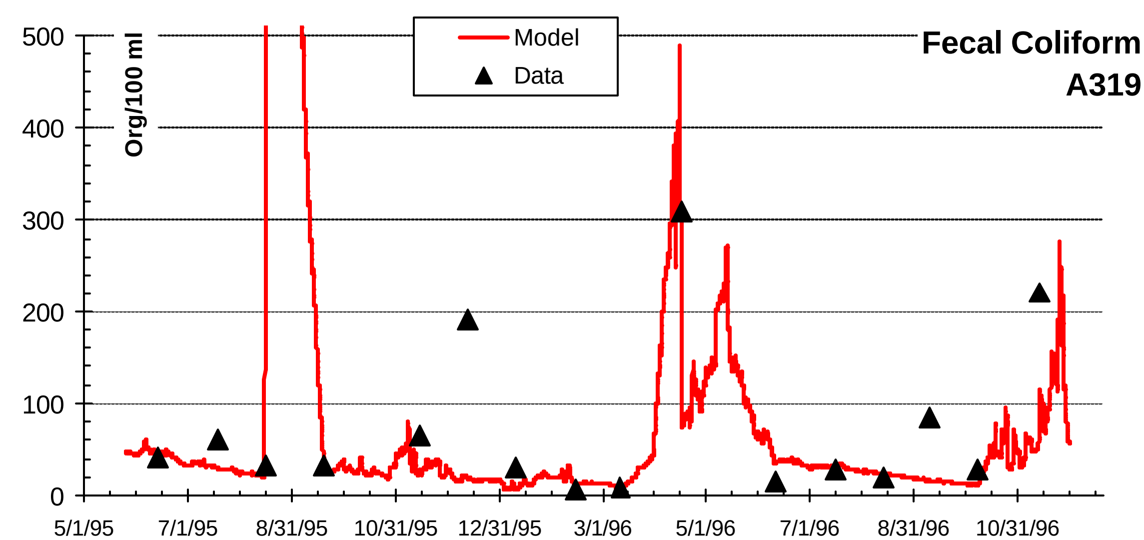


Figure 318: Fecal Coliform Comparison, May 25, 1995 - Nov 1996 Model Run Period



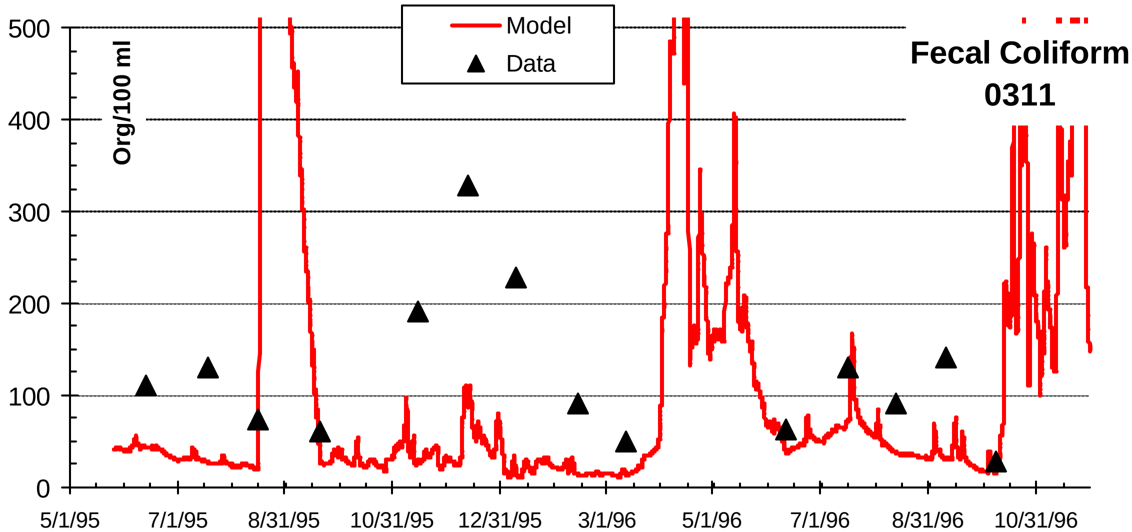


Figure 319: Reduced Scale Fecal Coliform Comparison, May 25, 1995 - Nov 1996 Model Run Period

Table 42: Fecal Coliform Error Statistics, May 25, 1995 - Nov 1996 Model Run Period

Site	No. of Data Comparisons	Mean Error (Org/100 ml)	AME (Org/100 ml)	RMS Error (Org/100 ml)
A319	17	-162	190.80	565.3
0311	16	-272.3	272.3	570

4.0 SENSITIVITY ANALYSES

4.1 Analysis of New Channel on Model Flow, Temperature, and Water Quality

In the winter of 1996 flooding created new channels in three locations on the river, with the most significant change located at River Mile 32.40 (See Figure 320). When assembling the model bathymetry this channel was to be included in the model; however there was no topographical information available. Since the topography is not known, and the effect of this new channel on the model is unknown, it was decided to leave it out of the model and perform separate model runs comparing results with and without the new channel.

For this model run a new branch was added to the model with two segments, connected upstream and downstream to the main river channel. Channel widths and bottom elevation were taken from model segments directly adjacent to the upstream and downstream end of the new channel. A spillway was used to spill water into the new channel. The model results were compared to each other and with field data. Flow data were compared at the downstream end of the new channel, and at Site 12113000, which is about 1.25 km downstream of the new channel. Model values for temperature were compared with each other at Site 12113000, and at the downstream end of the new channel. Temperature data were not collected at Site 12113000, but the only data collection sites downstream are GRT20 and GRT22, which is a long way downstream and only has data for July 2002. Water quality data were compared at the downstream end of the new channel, and at King County's water quality sampling site G319, which is approximately 20 km downstream of the new channel.

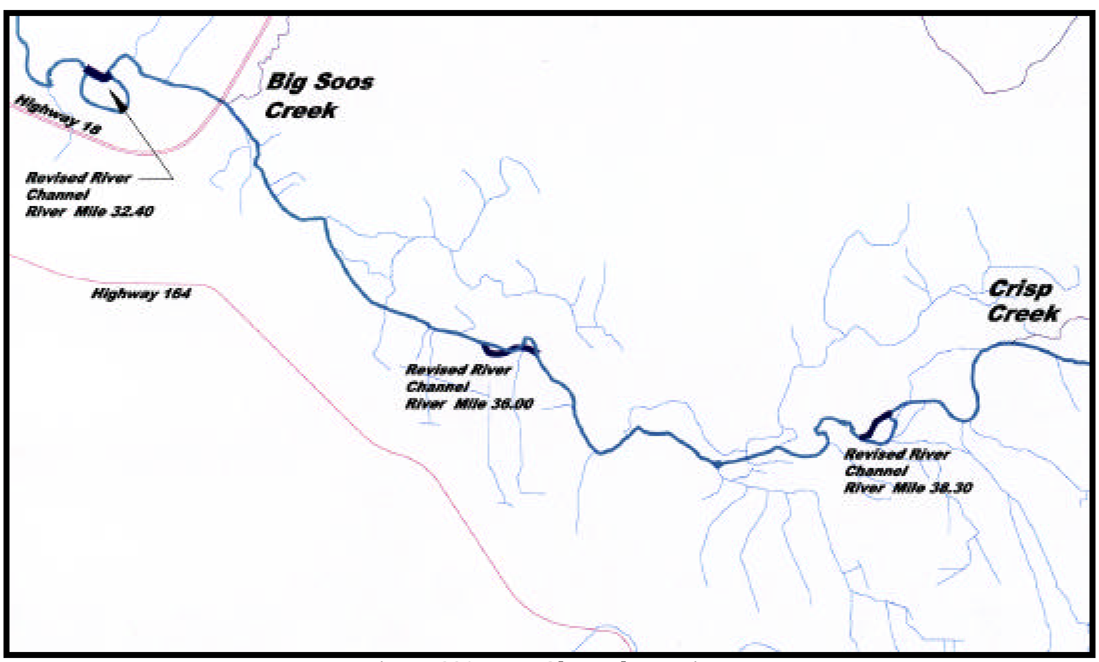


Figure 320: New Channel Locations

Figure 321 shows the comparison between model values of flow one segment downstream from where the new channel enters the main channel, and Figure 322 shows flow comparisons at Site 12113000. Model values for flow are the same with and without the channel at both locations.

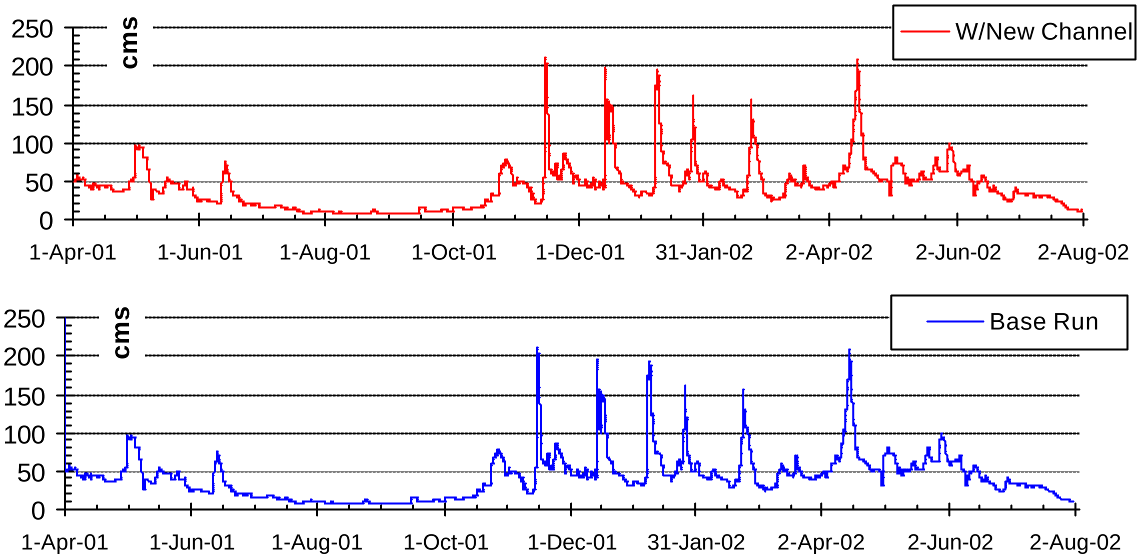


Figure 321: Flow Comparison at downstream end of new channel

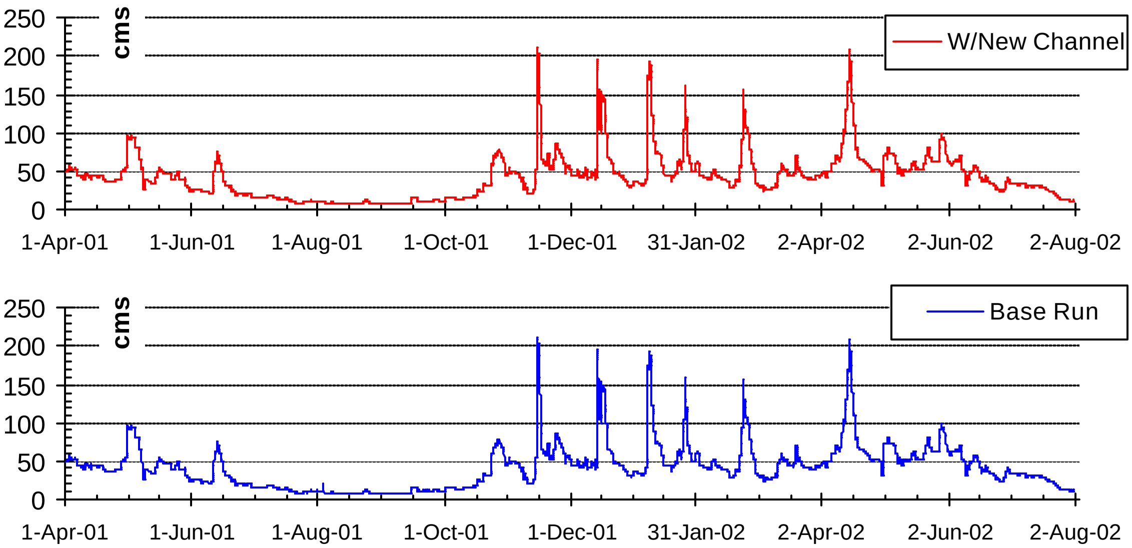


Figure 322: Flow Comparison at Site 12113000

Table 43 lists the error statistics between the model run without the side channel and the model run with the side channel.

Table 43: Flow Error Statistics with and without side channel

Site	Mean Error (cms)	AME (cms)	RMS (cms)
Downstream End (RM 34.0)	-0.0003	0.11	0.34
USGS Site 12113000 (RM 31.3)	0.0067	0.26	0.78

Figure 323 compares temperature model values at the first segment in the main channel downstream of the new channel, and Figure 324 compares temperature model values at Site 12113000.

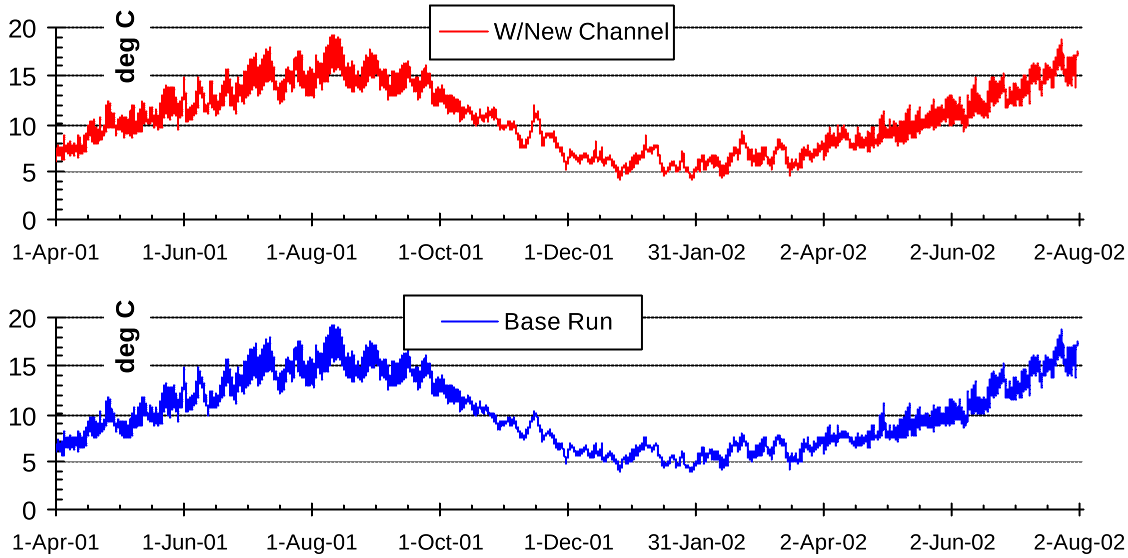


Figure 323: Temperature Comparison at downstream end of new channel

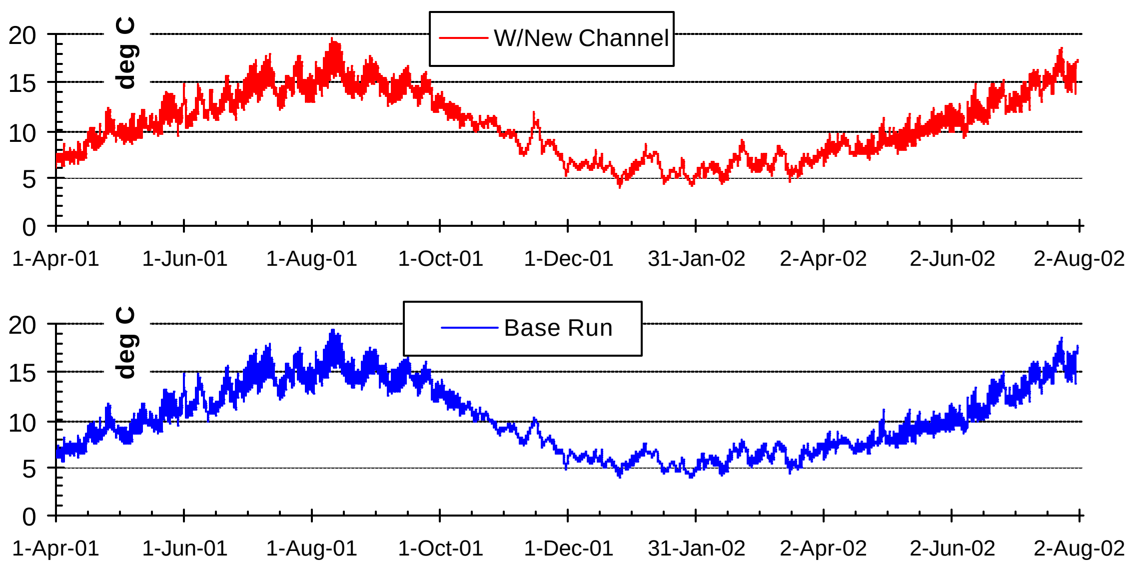


Figure 324: Temperature Comparison at Site 12113000

Figure 325 shows a comparison at the downstream end of the new channel for both model runs from mid-October 2001 through August of 2002. The run with the new channel has higher temperatures during this time period.

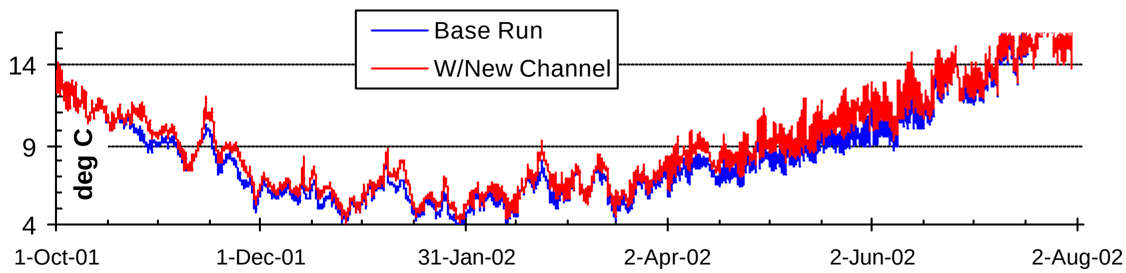


Figure 325: Side-by-side Temperature Comparison at downstream end of new channel

Temperature values with the new channel also ran higher during April and May of 2001. During other time periods model values match very closely with both runs. Table 44 lists the error statistics between the model run without the side channel and the model run with the side channel.

Table 44: Temperature Error Statistics with and without side channel

Site	Mean Error (C)	AME (C)	RMS (C)
Downstream End (RM 34.0)	0.43	0.43	0.61
USGS Site 12113000 (RM 31.3)	0.42	0.44	0.58

The median value of temperature for the base run is 9.56 C. The 95% confidence interval around this median is between 9.47 and 9.67 C. The median value of temperature for the model run with the additional channel is 10.38 C, and is outside the confidence interval for the median value.

Figure 326 through Figure 329 compares conductivity, pH, dissolved oxygen, and total suspended solids at Site G319, and Figure 330 through Figure 333 compares the same constituents at the downstream end of the new channel with and without the new channel included in the model.

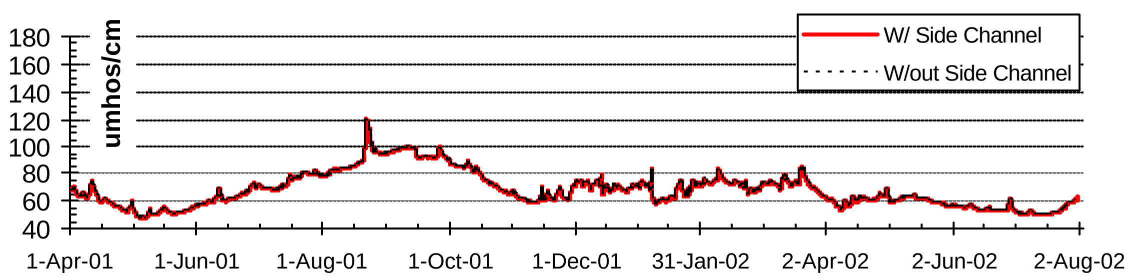


Figure 326: Conductivity Comparison at Site G319

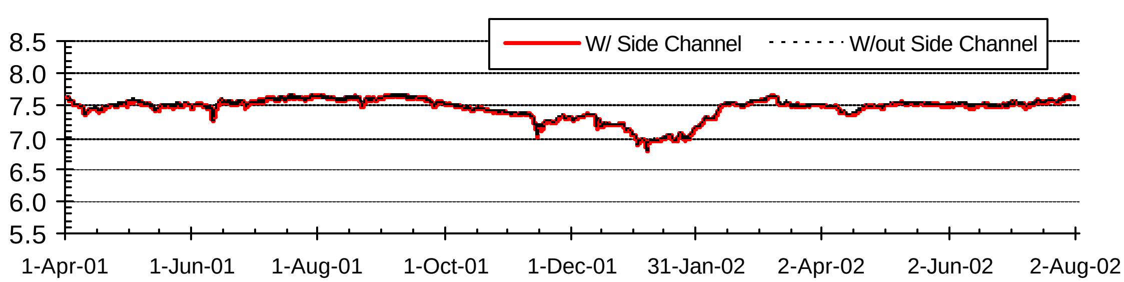


Figure 327: pH Comparison at Site G319

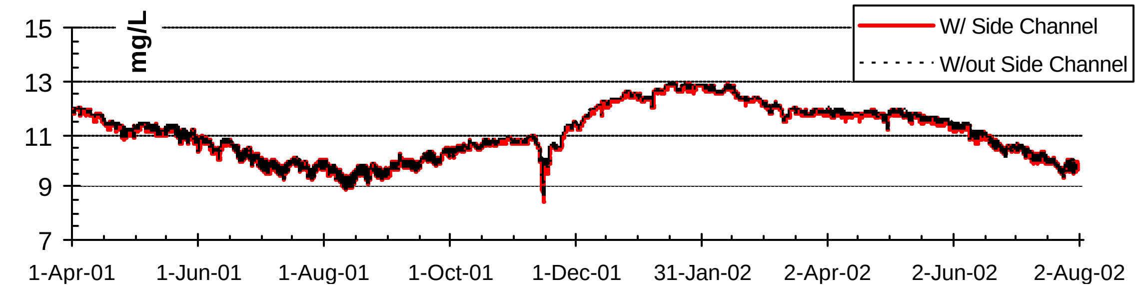


Figure 328: DO Comparison at Site G319

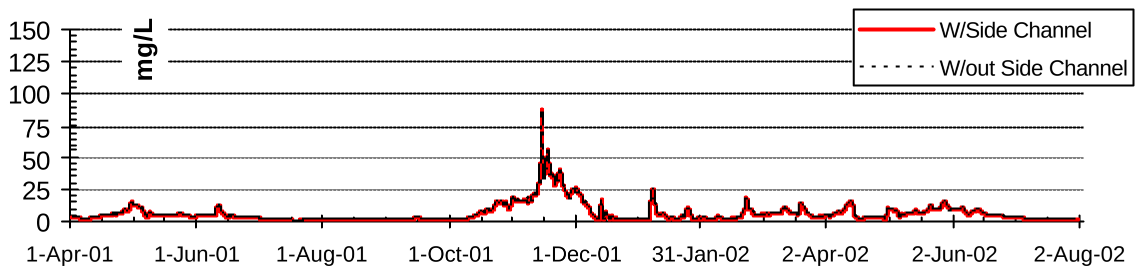


Figure 329: TSS Comparison at Site G319

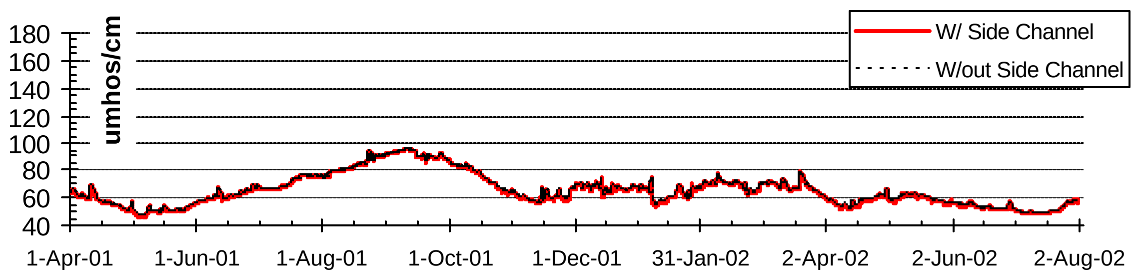


Figure 330: Conductivity Comparison Downstream of New channel

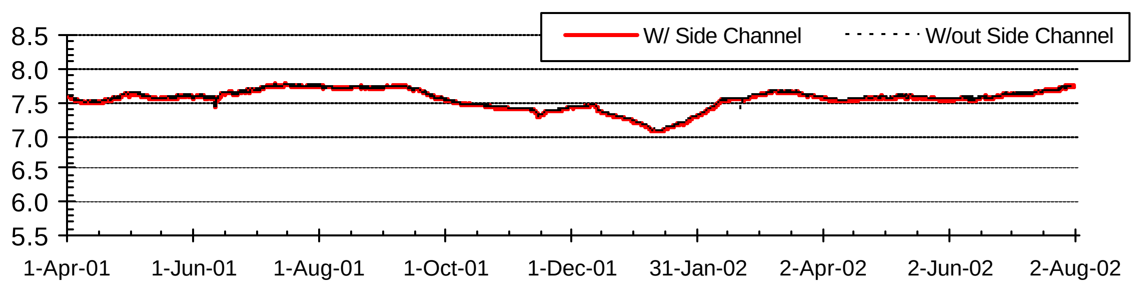


Figure 331: pH Comparison Downstream of New channel

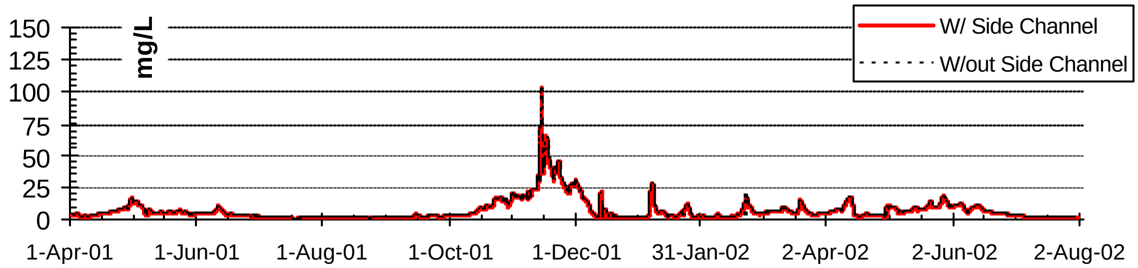


Figure 332: TSS Comparison Downstream of New channel

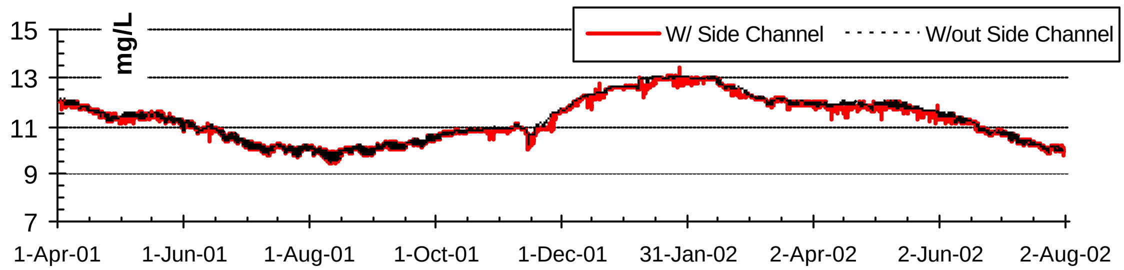


Figure 333: DO Comparison Downstream of New channel

Table 45 lists the error statistics between the model run without the side channel and the model run with the side channel.

Table 45:Water Quality Error Statistics with and without side channel

	Site	Mean Error (mg/L)	AME (mg/L)	RMS (mg/L)
CONDUCTIVITY	Downstream End (RM 34.0)	-0.16	0.24	0.43
	Site G319 (RM 21.3)	-0.027	0.058	0.15
pH	Downstream End (RM 34.0)	-0.0039	0.004	0.008
	Site G319 (RM 21.3)	-0.0038	0.0047	0.0077
DO	Downstream End (RM 34.0)	-0.039	0.046	0.094
	Site G319 (RM 21.3)	-0.027	0.029	0.054
TSS	Downstream End (RM 34.0)	-0.033	0.051	0.34
	Site G319 (RM 21.3)	0.0093	0.022	0.082

4.2 pH Calibration

pH model values differed from sampled data during late summer and early fall at all three water quality calibration sites and during both model run periods. For the 1995-1996 model run period alkalinity data were not available, so adjusting model input values of alkalinity was used to calibrate pH. Sample alkalinity data were available for the 2001-2002 model run period, so alkalinity values were not adjusted.

Figure 334 shows the field sampled pH data at the upstream boundary, field sampled pH data at Site A319, which is 20 km downriver from the upstream boundary, and model values of pH at Site A319. This graph shows that model values at Site A319 were close to the sampled data at the upstream boundary - even higher during some time periods, whereas sampled data at the downstream sampling site shows that pH values have dropped at this location. Model runs were performed varying data in an attempt to reproduce the sampled data at the downstream sampling site.

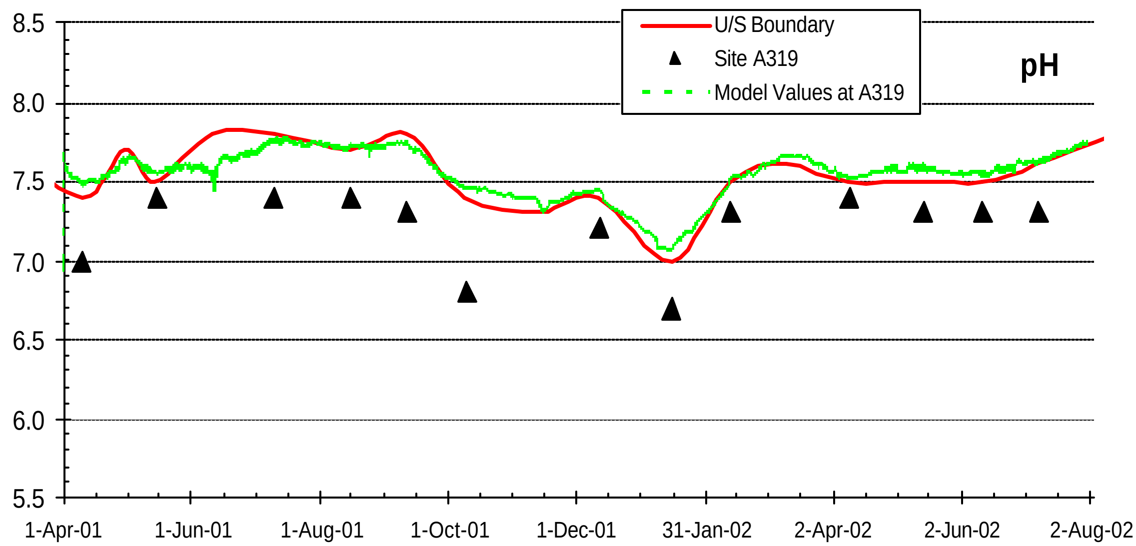
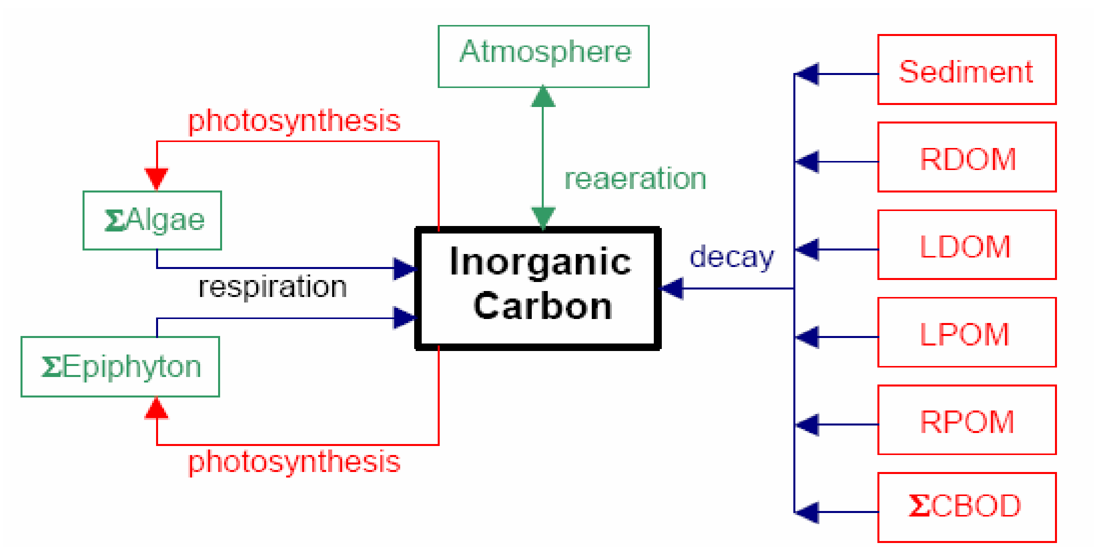


Figure 334: pH Comparison

pH is calculated in the model using temperature, alkalinity, and total inorganic carbon (TIC). Model temperature values and alkalinity values matched well with data when sampled data were available, so TIC values were reviewed. Low TIC values will result in higher calculated values for pH.

Figure 335 is a diagram from Cole (2002) which shows the sources and sinks for TIC. This figure shows how TIC is accumulated and lost in the model and provides a guideline for determining where additional sources of TIC might be produced.



SOURCE: Cole (2002)

Figure 335: CE-QUAL-W2 TIC MODEL

The following analyses were performed in an attempt to calibrate pH levels through adjusting the sources and sinks to TIC. Model runs were performed for August 2001 with the changes noted. This is a period of low-flow where pH values were noted to be different from sampled data.

- Adjusting SOD values. CE-QUAL-W2 allows different SOD values to be specified for each segment of the river. Adjusting these values was effective in reducing pH, but only by using very high SOD values. Using a SOD value of 5.0 g m^{-2} d^{-1} reduced model pH values very close to the sampled data at the calibration points.

- Reducing the algae growth rate. Algae growth consumes TIC, so reducing the growth rate of algae would reduce the amount of TIC consumed. This had little effect, mainly because of the small amounts of algae present in the river, especially in the upper reaches of the modeled section.

- Increasing the amount of organic matter in the system, and adjusting the percentage of labile and refractory organic matter. Total suspended solids data at boundaries and tributaries are divided between inorganic suspended solids and organic matter for input into the model. The percentage of organic matter was increased. Also, organic matter introduces TIC into the system when decaying, and labile organic matter has a higher decay factor than refractory organic matter. The percentage of labile organic matter was increased. However, these changes did not produce a significant increase in TIC.

- Turning on the first-order sediment compartment, which accumulates sediment and releases TIC based upon a 1st-order process. This change exhibited no effect on pH values.

- Changing the oxygen reaeration coefficient. The CO2 reaeration coefficient is determined as a percentage of the oxygen reaeration coefficient, so changing the oxygen reaeration coefficient will also change the reaeration of CO2 to the system. Oxygen reaeration values of 0.50, 1, 5, and 10 were used. Model runs showed improvement in pH model values with the reaeration coefficient set to 0.50.

- TIC values for the distributed tributaries were increased. Branches two and three have distributed tributaries. There were no water quality data available for these tributaries, so data from the Big Soos River was used. The amount of TIC input into the model for these distributed branches was increased. The amount of TIC need to be up over 200 mg /L to produce pH values close to sampled data at Site A319.

- Along with looking for sources of TIC, alkalinity changes were also tried. Alkalinity data for the distributed tributaries ranged from 41 to 55 mgCACO3/L. These model input values were reduced by 30 points for both tributaries. This had a small effect on lowering pH.

There is one other possible source of TIC that was not pursued. Increasing TIC and decreasing alkalinity values in the distributed tributaries had little affect because the flow rates used in the distributed tributaries are very low. When calibrating flow, additions or reductions were made to the upstream boundary when necessary, assuming the flow difference came from unknown flow contributions from springs above the upstream boundary. If the flow additions came from groundwater inflows below the upstream boundary, this would mean more flow added to the distributed tributaries. With additional flow, the changes in TIC and alkalinity would have a greater affect on model values of pH. The Summary and Conclusions section discusses recommendations for future model development. One recommendation is to move the upstream boundary of the model. Moving the boundary condition upstream and adding additional calibration points on the

Middle Green River would allow better characterization of groundwater inflows, and may provide better information on how groundwater inflows affect pH.

4.3 Lower Green River Model Calibration

Model values provided good comparisons with sampled data for most constituents at Site A319 (RM 33.80) matching data with model values was not as consistent at Site G319 (RM 21.30) and Site 0311 (RM 13.2) during the 2001-2002 model run period, and at Site 0311 for the 1995-1996 model run period.

Conductivity and alkalinity model values differ significantly from data at Site 0311 during summer months for both model run periods. These are conservative constituents, so this indicates a missing source with either significant flow or high concentrations.

Model values at Site G319 and Site 0311 showed significant differences from sampled data for dissolved oxygen throughout the 2001-2002 model run period. Model values for dissolved oxygen also differed significantly from data at Site 0311 during the 1995-1996 model run period.

pH model values differed from data at these sites for both model run periods.

To estimate missing data, a distributed tributary was added to a downstream branch of the model, and constituent data were added to replicate sampled data at the two sampling sites (G319 and 0311). The data and methods used differed for the two model run periods, so the two periods are addressed separately.

4.3.1 2001-2002 Model Run Period

A distributed inflow was added to Branch four, which extends approximately from RM 27 to RM 34. Flow values were set, and constituent input values to the model were adjusted to match data at both calibration sites. A BOD source was added to this distributed tributary to reduce dissolved oxygen values to match data. TIC data were adjusted to match pH values, and alkalinity and conductivity values were adjusted until model results produced values closer to data at both sites.

The distributed inflow was first added to Branch five, which is the branch that both Site G319 and Site 0311 are located in. However, the dissolved oxygen values did not respond to the BOD when used in Branch five. This distributed tributary was removed from Branch five and added to Branch four. This produced better results for dissolved oxygen, and did not affect results for the other constituents.

Figure 336 shows the flow used in the distributed tributary and Figure 337 through Figure 340 shows the combined flow/constituent values that were added to the model for the 2001-2002 model run period.

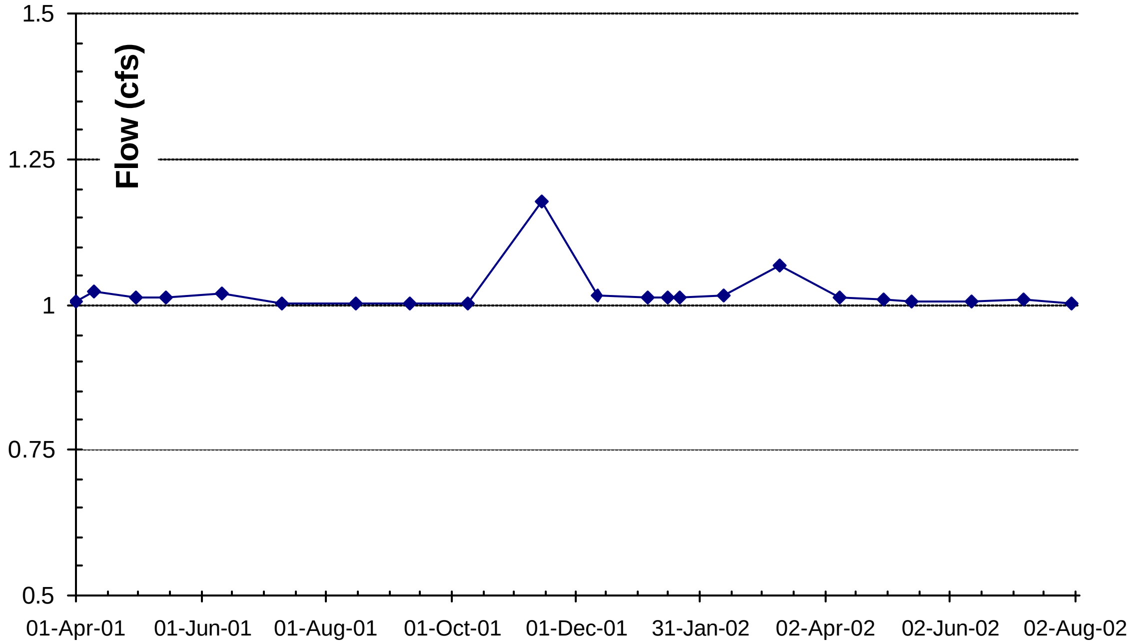


Figure 336: Flow Data for 2001-2002 Model Run Period - Branch 4 Distributed Tributary

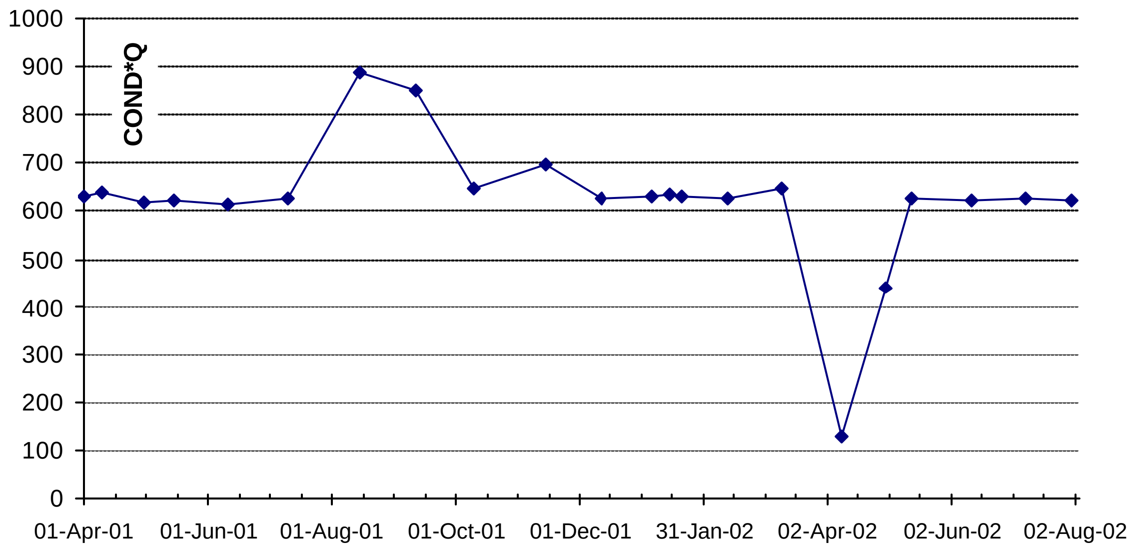


Figure 337: Flow and Conductivity Data for 2001-2002 Model Run Period - Branch 4 Distributed Tributary

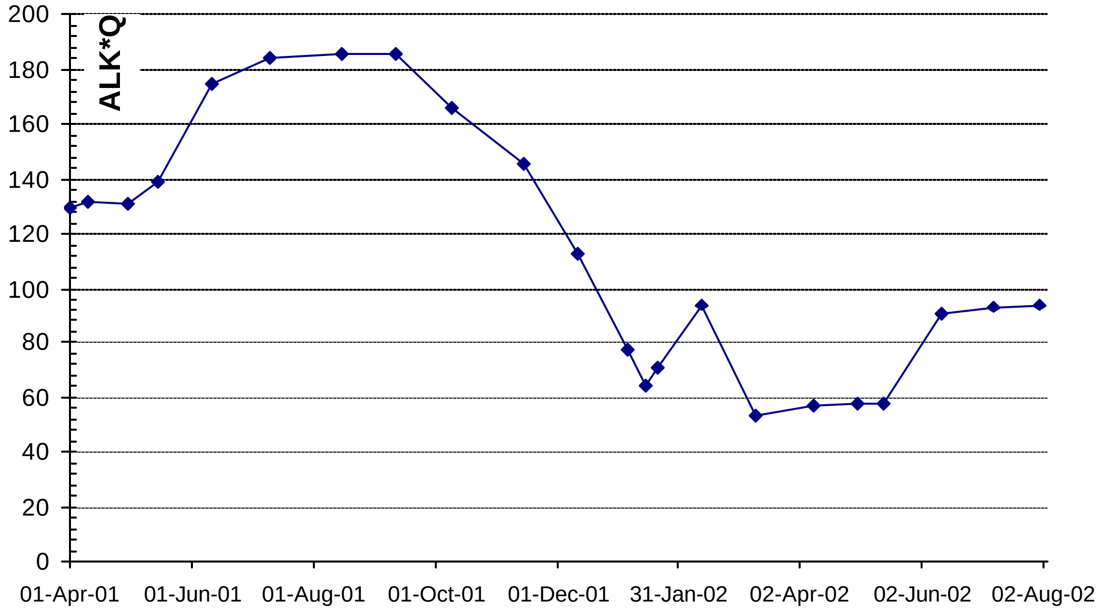


Figure 338: Flow and Alkalinity Data for 2001-2002 Model Run Period - Branch 4 Distributed Tributary

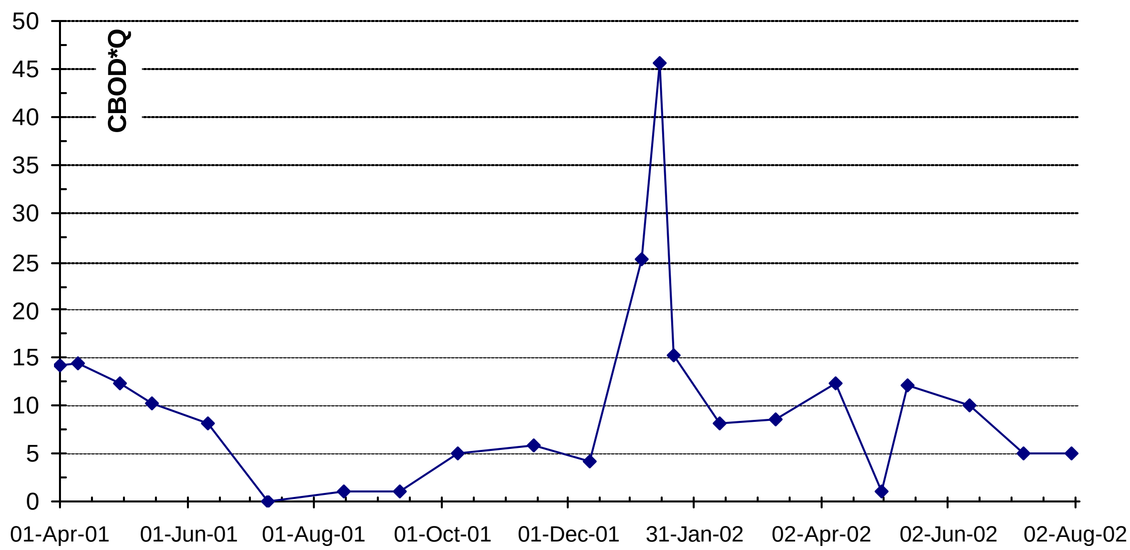


Figure 339: Flow and CBOD Data for 2001-2002 Model Run Period - Branch 4 Distributed Tributary

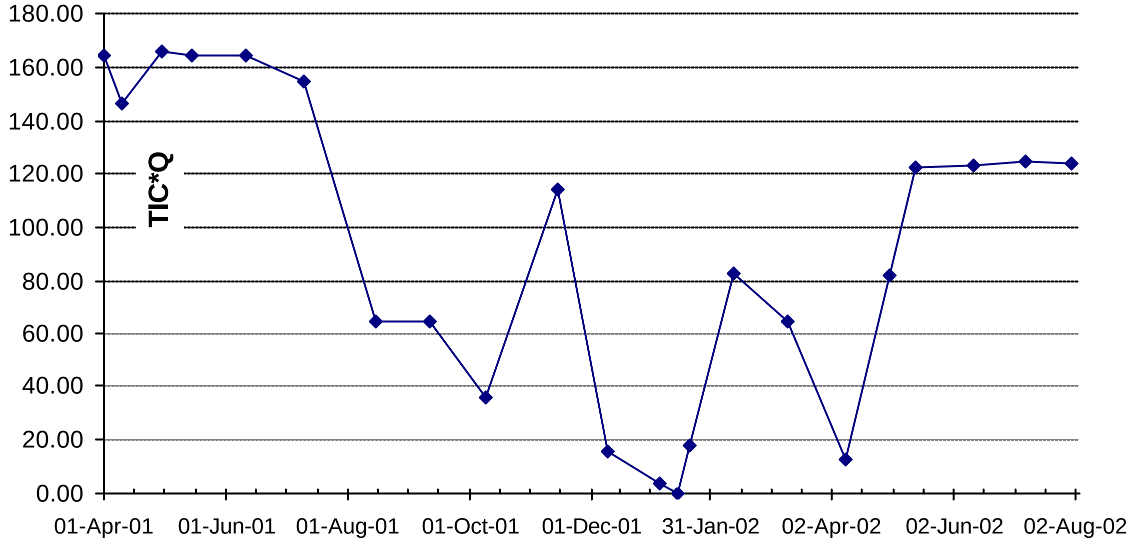


Figure 340: Flow and TIC Data for 2001-2002 Model Run Period - Branch 4 Distributed Tributary

Figure 341 through Figure 348 shows the model values and data with the distributed tributary for Sites 0311 and G319, and Table 46 through Table 49 shows the error statistics. The tables also show the error statistics without the additional data for comparison purposes.

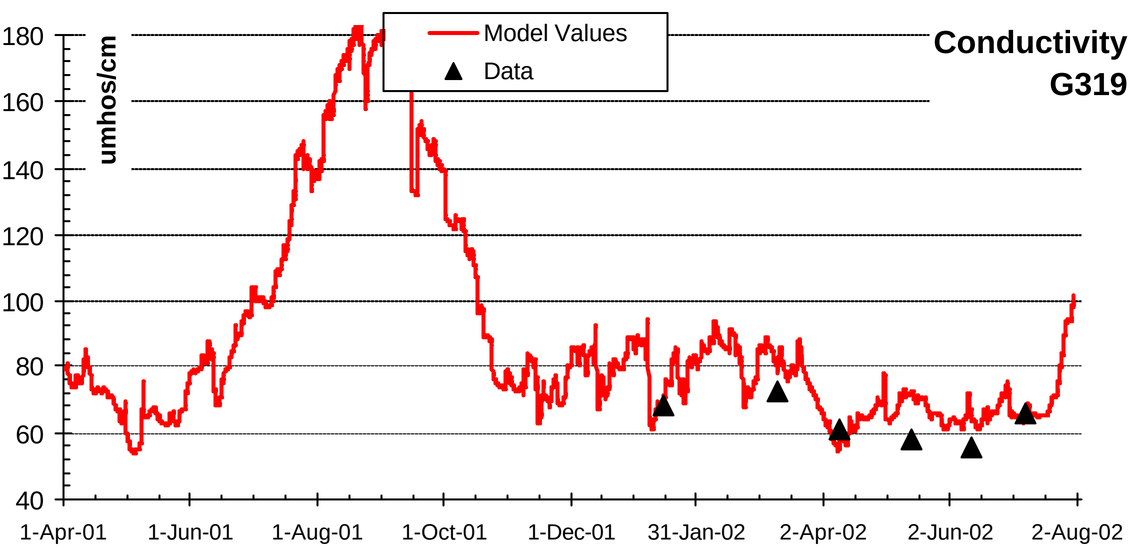


Figure 341: Conductivity Comparison with distributed tributary at Site G319 - 2001-2002 Model Run Period

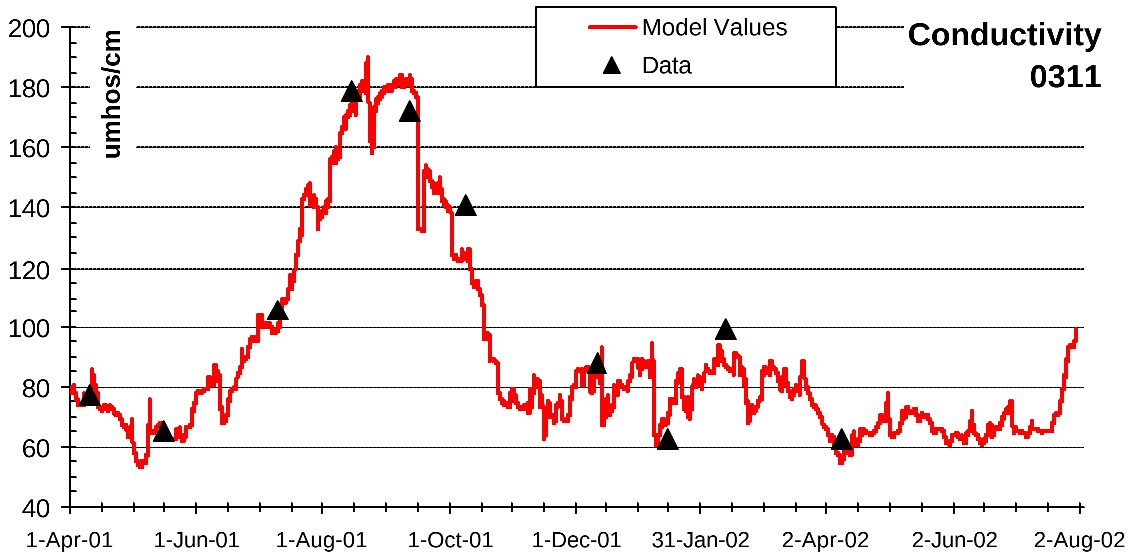


Figure 342: Conductivity Comparison with distributed tributary at Site 0311 - 2001-2002 Model Run Period

Table 46: Conductivity Error Statistics with distributed tributary, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
G319	6	4.51	6.88	8.33
0311	13	-3.58	7.34	8.79
Conductivity Error Statistics without distributed tributary, 2001-2002 Model Run Period				
G319	6	-4.22	6.15	7.6
0311	13	-33.4	33.4	44.4

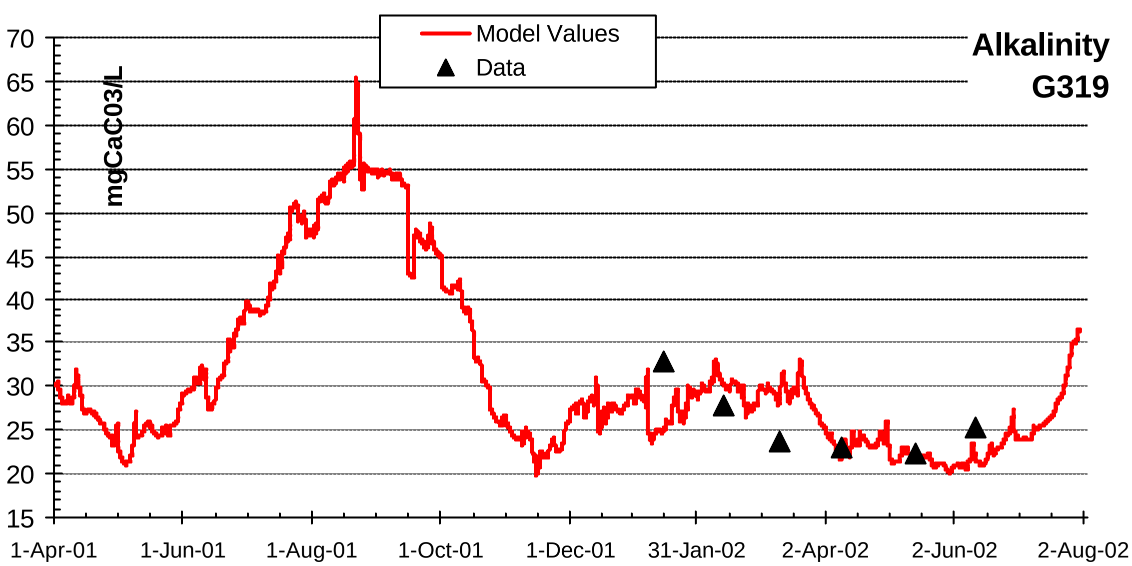


Figure 343: AlkalinityComparison with distributed tributary at Site G319 - 2001-2002 Model Run Period

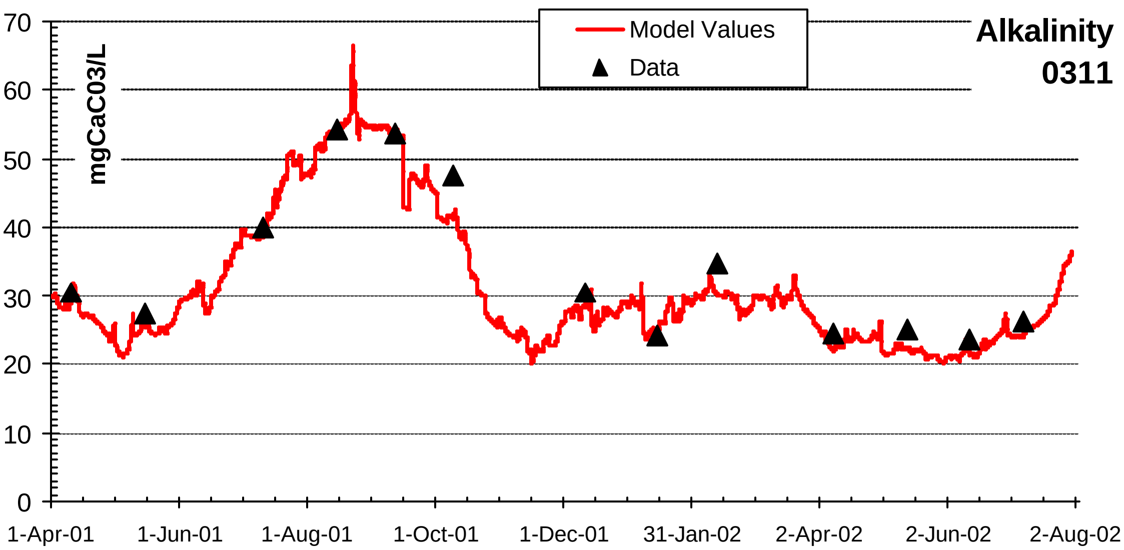


Figure 344: Alkalinity Comparison with distributed tributary at Site 0311 - 2001-2002 Model Run Period

Table 47: Alkalinity Error Statistics with distributed tributary, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
G319	6	-0.967	2.28	3.41
0311	13	-1.96	2.19	2.69
Alkalinity Error Statistics without distributed tributary, 2001-2002 Model Run Period				
G319	6	-2.1	3.0	4.0
0311	13	-6.83	6.87	8.65

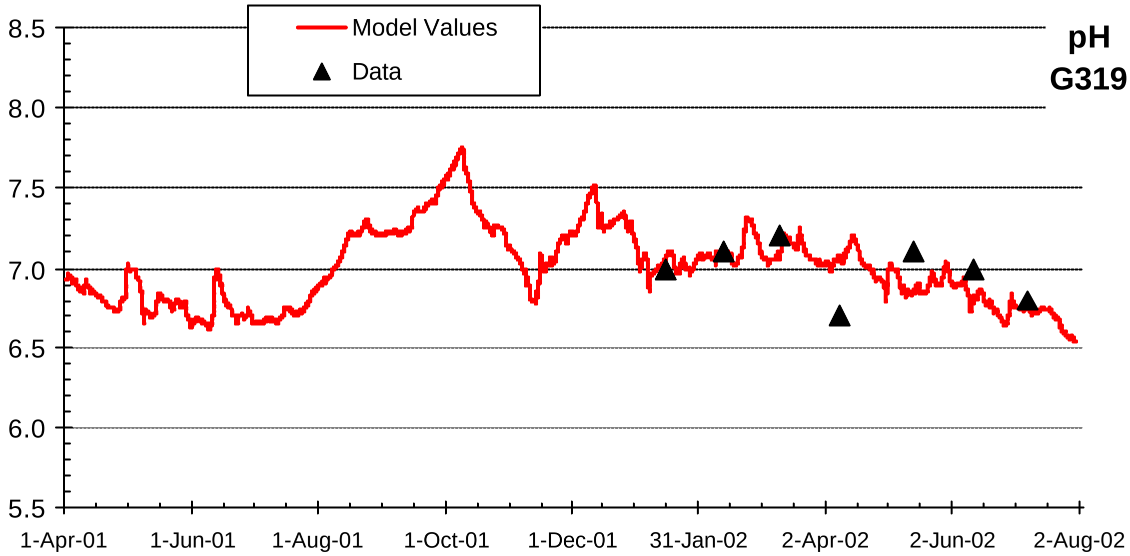


Figure 345: pH Comparison with distributed tributary at Site G319 - 2001-2002 Model Run Period

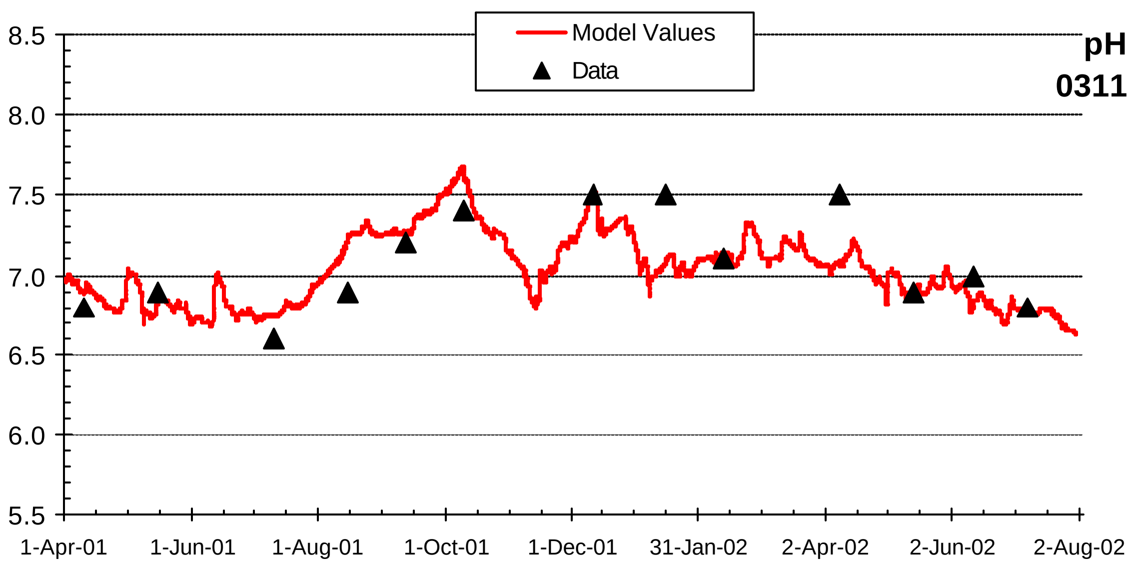


Figure 346: pH Comparison with distributed tributary at Site 0311 - 2001-2002 Model Run Period

Table 48: pH Error Statistics with distributed tributary, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
G319	7	-0.024	0.14	0.18
0311	13	-0.0062	0.16	0.21

pH Error Statistics without distributed tributary, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
G319	7	0.46	0.46	0.52
0311	13	0.35	0.44	0.50

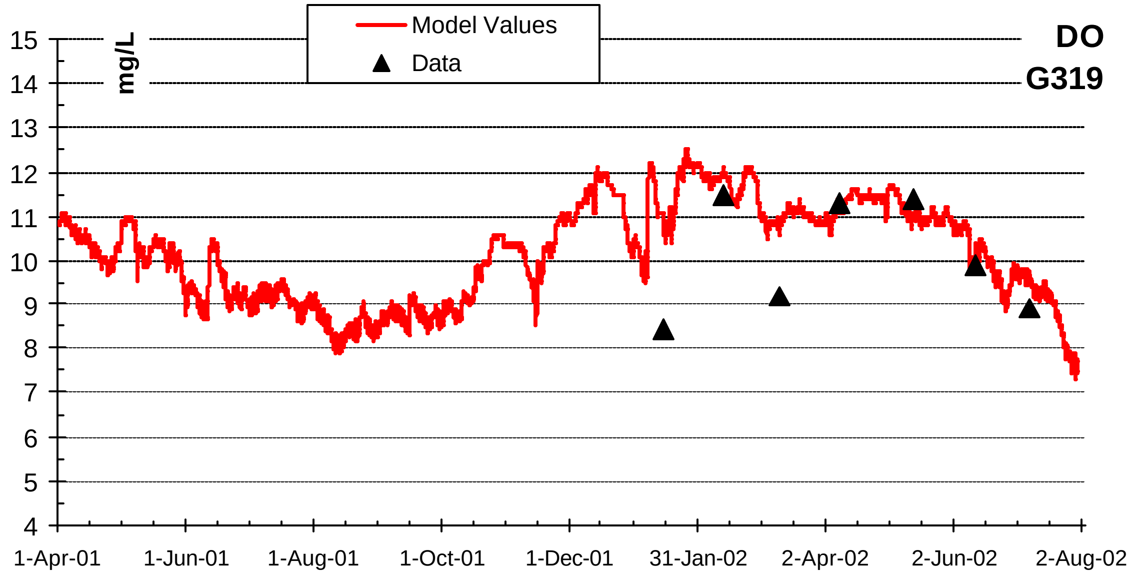


Figure 347: Dissolved Oxygen Comparison with distributed tributary at Site G319 - 2001-2002 Model Run Period

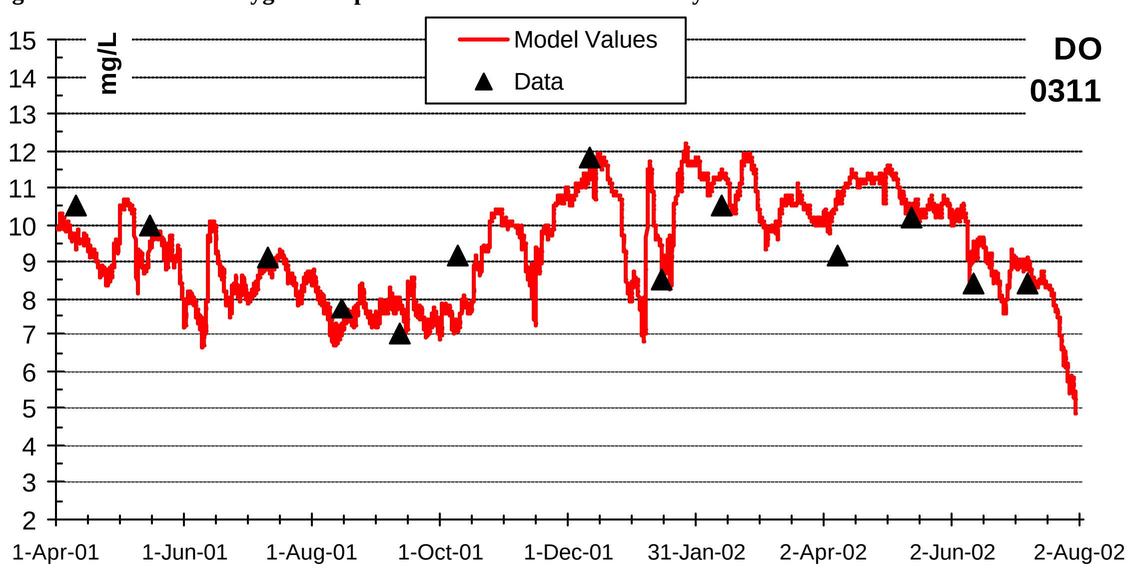


Figure 348: Dissolved Oxygen Comparison with distributed tributary at Site 0311 - 2001-2002 Model Run Period

Table 49: DO Error Statistics with distributed tributary, 2001-2002 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
G319	7	0.71	0.83	1.14
0311	13	0.07	0.80	0.96
DO Error Statistics without distributed tributary, 2001-2002 Model Run Period				
G319	7	1.67	1.67	2.13
0311	13	1.66	1.66	8.65

This analysis was meant to show that the model could reproduce the characteristics of the river, and to provide an estimate of the magnitude of the data missing from the model in the Lower Green River.

4.3.2 1995-1996 Model Run Period

A distributed inflow was added to Branch five. Flow values were set, and constituent values were adjusted to match data at Site 0311. A BOD source was not added during this model run because the large differences between model values and data were not seen at Site 0311 for this model run perod. TIC and alkalinity data were adjusted to match pH values, and conductivity values were adjusted until they matched data at Site 0311.

Figure 349 shows the flow used in the distributed tributary and Figure 350 through Figure 351 shows the combined flow/constituent values that were added to the model for the 2001-2002 model run period.

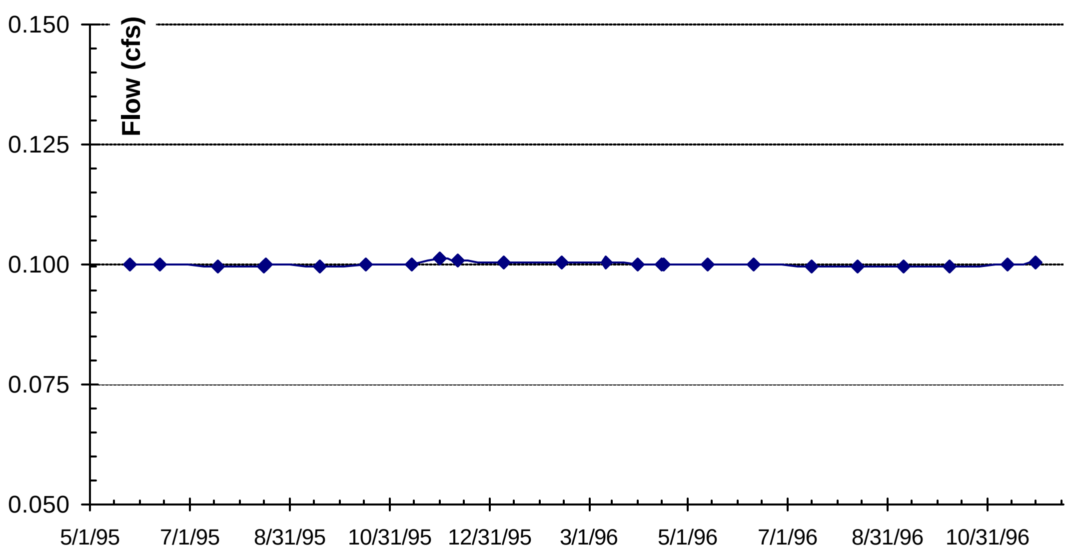


Figure 349: Flow Data for 1995-1996 Model Run Period - Branch 4 Distributed Tributary

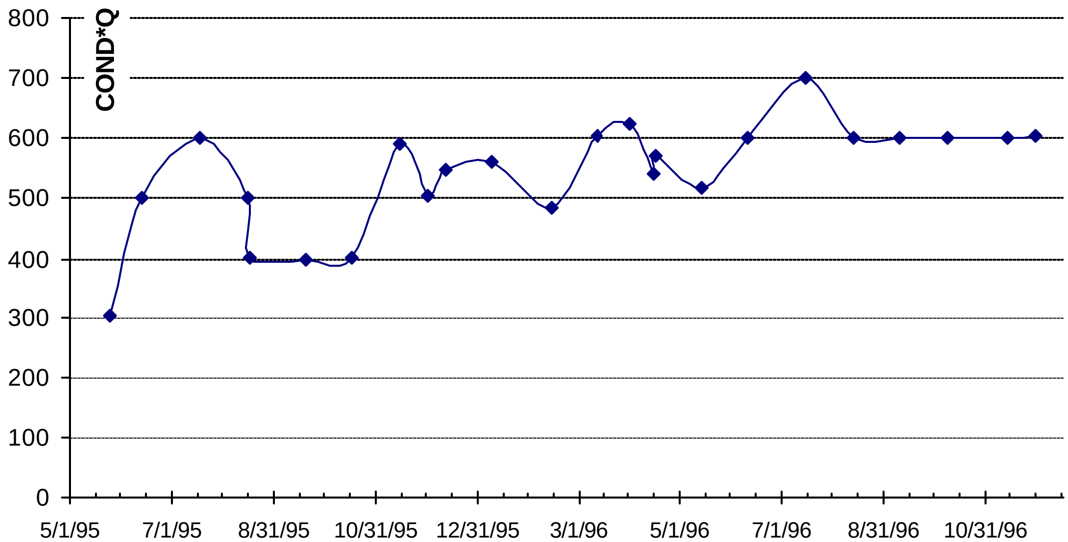


Figure 350: Flow and Conductivity Data for 2001-2002 Model Run Period - Branch 4 Distributed Tributary

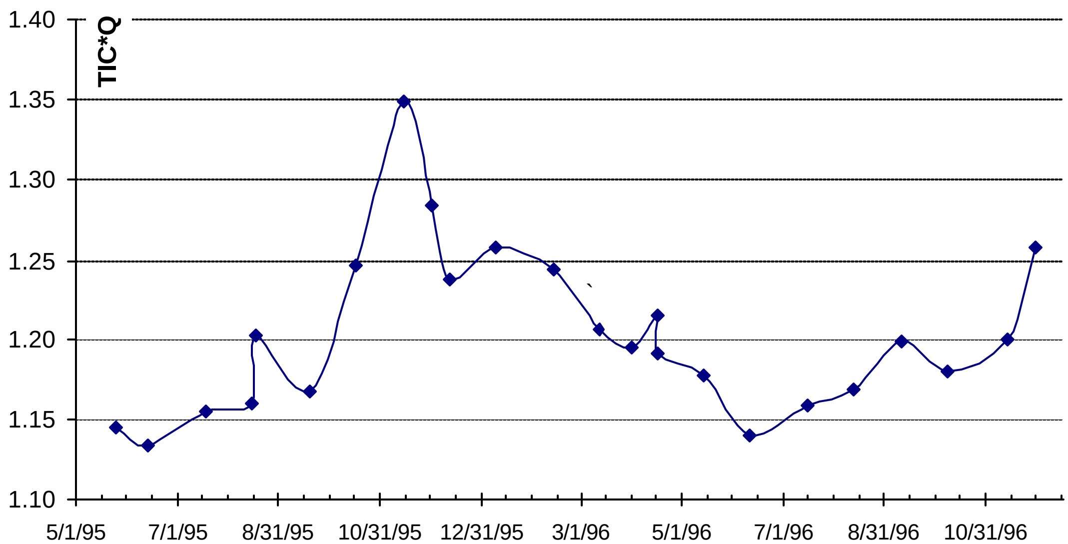


Figure 351 Flow and TIC Data for 2001-2002 Model Run Period - Branch 4 Distributed Tributary

Figure 352 through Figure 353 shows comparisons of data with model values with the distributed tributary, and Table 50 through Table 51 shows the error statistics. The tables also show the error statistics without the additional data for comparison purposes.

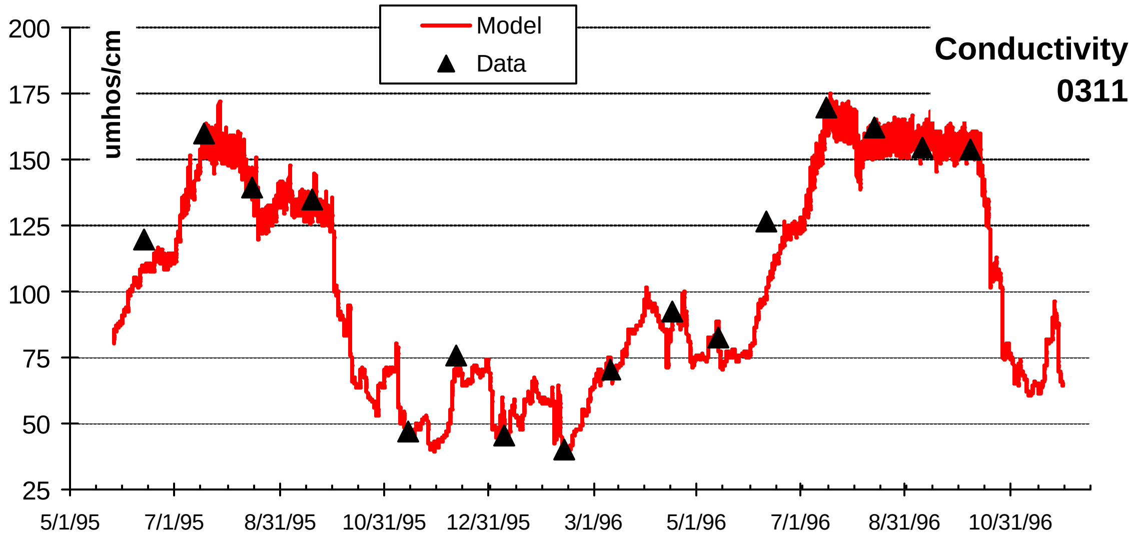


Figure 352: Conductivity Comparison with distributed tributary - 1995-1996 Model Run Period

Table 50: Conductivity Error Statistics with distributed tributary, 1995-1996 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
0311	13	-7.24	9.84	12.79
Conductivity Error Statistics without distributed tributary, 1995-1996 Model Run Period				
0311	13	-37.73	37.73	46.21

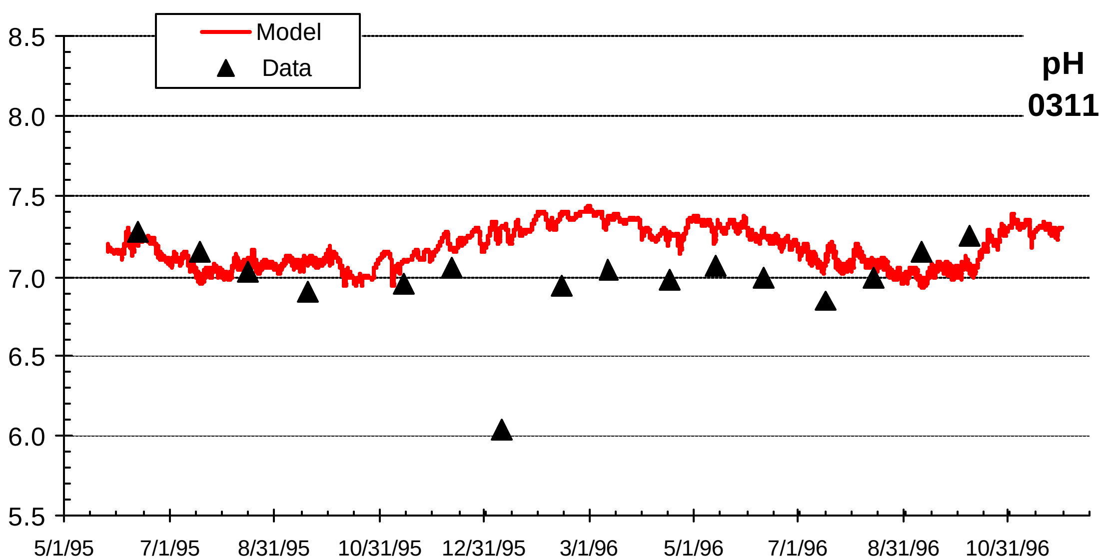


Figure 353: pH Comparison with distributed tributary - 1995-1996 Model Run Period

Table 51: pH Error Statistics with distributed tributary, 1995-1996 Model Run Period

Site	No. of Data Comparisons	Mean Error	AME	RMS Error
0311	13	0.045	0.21	0.24
pH Error Statistics without distributed tributary, 1995-1996 Model Run Period				
0311	13	0.28	0.29	0.41

5.0 SUMMARY AND CONCLUSIONS

5.1 Model Summary

The water quality and hydrodynamic model CE-QUAL-W2, Version 3.1 (Cole and Wells, 2001), was applied to the Middle and Lower Green River from River Mile 45.0, near Flaming Geyser State Park to River Mile 11.20 in Tukwila, Washington. This model was calibrated to field data from May 25, 1995 to November 30, 1996, and from April 1, 2001 to July 31, 2002. A description of field data used in the model and the model set-up is described in Section 2.0 of this report, and the calibration of hydrodynamic, temperature and water quality constituents is discussed in Section 3.0. A sensitivity analysis examined model responses to various data input and is discussed in Section 4.0.

Flow and water level model results were compared to field data at one location on the river, and temperature model results were compared with data at four locations. Grab-sample water quality data were compared with model results at three locations for the 2001-2002 model run period, and at two locations for the 1995-1996 model run period. Table 52 lists the constituents that were compared with field data for each model run period, and Table 53 shows the locations of the water quality model-data comparison sites.

Table 52: Water Quality Constituents

2001-2002 Constituents	1995-1996 Constituents
Conductivity	Conductivity
pH	pH
Nitrite-Nitrate	Nitrite-Nitrate
Ammonia Nitrogen	Ammonia Nitrogen
Total Nitrogen	Total Nitrogen
Ortho Phosphorus	Ortho Phosphorus
Total Phosphorus	Total Phosphorus
Alkalinity	
Chlorophyll A	
Total Organic Carbon	
Dissolved Organic Carbon	
Fecal Coliform	Fecal Coliform
Total Suspended Solids	Total Suspended Solids

Table 53: Water Quality Calibration Sites

Locator Station	Description	River Mile
0311	Interurban Avenue	13.20
G319	Near Mullen Slough	21.30
A319	Auburn-Black Diamond Road	33.80

Data were available for model-data comparisons at all sites for the 2001-2002 model run period, but not at Site G319 during the 1995-1996 model run period. Table 54 shows the overall model-data statistics for both model run periods.

Table 54: Overall Error Statistics

	Overall Mean Error	Overall AME	Overall RMS Error
Water Level (m)	0.10	0.21	0.23
Flow (cms)	0.12	2.1	4.5
Temperature (ºC)	-0.14	0.63	0.80
Conductivity (umhos/cm)	-15.8	17.0	21.5
Alkalinity (mgCaCO3/L)	-3.05	3.6	4.6
pH	0.29	0.31	0.36
TSS (mg/L)	-7.6	8.5	16.2
DO (mg/L)	0.84	0.88	1.05
NO2-NO3 (mg/L)	-0.054	0.075	0.085
NH4 (mg/L)	-0.007	0.01	0.014
TN (mg/L)	0.061	0.22	0.36
PO4 (mg/L)	-0.0061	0.0075	0.0088
TP (mg/L)	-0.03	0.031	0.044
Chlor A (ug/L)	0.065	0.065	0.05
TOC (ug/L)	-2.25	2.25	2.29
DOC (ug/L)	-1.59	1.59	1.62
FC (Org/100 ml)	89.2	137.5	321.0

Model-data comparisons show that the model reproduced the river responses to known boundary conditions at Site A319 (excluding pH), but comparisons at Site 0311, and to a lesser extent at Site G319, indicate conditions in the river that are not represented in the model. The model results indicate that data for conservative constituents such as conductivity, are not represented correctly in the model for the Lower Green River. This is most likely due to a source of flow missing from the model in the Lower Green River. There was one location available for comparing flow data with model values. It is at USGS Gaging Station 12113000, which is 36 km above the downstream boundary.

One possible source of missing flow could be groundwater inflows in the Lower Green River not included in the model. Luzier (1969) and Woodward et al (1995) discussed groundwater inflows in the Lower Green River, but the estimated values were so small they were not considered in the model. Since groundwater inflows are small relative to the instream flows, constituent concentrations would need to be very high to reproduce the constituent data sampled at Site 0311.

A second possibility for missing model data could be tidal inflows from downstream. As river levels drop during summer months, there is more possibility of tidal flows pushing up to site 0311. The volume of water moving upstream with a tidal inflow would be closer to the same magnitude as flows coming down the river, so the constituent concentrations would not need to be nearly as high to produce the values field-sampled from the river. This option was considered, but discounted for the following reasons:

- A review of flow data recorded at the downstream project boundary (USGS Site 12113350) between 1960 and 1987 did not show flow reversal.
- Two dye studies conducted in August and September of 1965 on the Lower Green River showed that dye did not flow upstream on the incoming tides (Santos 1972).
- Dye studies performed in 1968 (Fisher, 1968) showed that the tidal influence does not extend into the Lower Green River.
- Model results did not show flow reversals in the Lower Green River. The model was run with a new branch containing the last 10 segments of the model. The slope of the river was set to zero for this branch, and the bottom elevation of each model segment was set equal to the river elevation at the downstream boundary. The model results did not show flow reversal during these runs. Note that these model runs are reflective of the bathymetry used in the model. Both slope averaging the river bottom and the limitations of the bathymetry data available affect the ability of the model to reproduce river responses at the downstream boundary.

A sensitivity analysis was performed to determine the magnitude of constituent concentrations and flow necessary to produce the river response indicated by field data. A distributed tributary was added to the Lower Green River, and input data was adjusted until the model results produced values that matched closer with sampled data. The results of these model runs are discussed in the Sensitivity Analysis section.

The bathymetry for the Middle Green River came from a field survey of the river in 1995, supplemented with aerial photogrammetry. River channel cross-sections were surveyed approximately every 650 feet. Survey data for the Lower Green River was taken from a HEC2 river study originally done in the 1980s. This bathymetry was used for both model run periods. As was noted in this study, there were significant changes to the river channel during the 1996 floods. There have most likely been other changes to the river bathymetry since the 1980s, when the Lower Green River bathymetry was surveyed, and there have most likely been changes to the river between the two model run periods. Potential bathymetric changes may be large enough to influence model results.

5.2 Recommendations for further work

The following items have been identified where further work could improve model predictions.

- Additional gage stations measuring stage and discharge along the Lower Green River would provide more model calibration points and identify where groundwater is entering the system. It would also provide a better understanding of the flows and tidal influences at the downstream model boundary.

- Additional systematic data collection of BOD_5, COD, TOC, and Chl a could be used to determine if there is a source of oxygen depletion in the Lower Green River. Additional algae data will determine the significance of algal blooms in the lower reaches of the river.
- A dye study would verify model travel times and dispersion characteristics. This would allow a better check on the model predictive ability than currently exists. This study should be conducted at both high and low flows. Dye studies performed in 1965 (Santos 1975) and in 1968 (Fisher 1968) do not cover the section of the river in this model domain.
- Moving the upstream boundary to the gage station just below the Howard Hanson Reservoir (USGS: 12106700) would provide a more accurate boundary condition with flow, temperature and water quality data. Additionally, it would allow model development and calibration to better characterize groundwater inflows to the river. Water quality, temperature, and flow data are available at this location, but bathymetry data would need to be aquired.

REFERENCES

Chapra, S.C. (1997). "Surface Water Quality Modeling," McGraw-Hill.

Cole, T.M., and S.A. Wells (2002). "CE-QUAL-W2: A two-dimensional, laterally averaged, Hydrodynamic and Water Quality Model, Version 3.1," Instruction Report EL-2002-1, US Army Engineering and Research Development Center, Vicksburg, MS.

Fisher, Hugo B, (1968). "Methods for Predicting Dispersion Coefficients in Natural Streams, with Applications to Lower Reaches of the Green and Duwamish Rivers Washington," Geological Survey paper 582-A, United States Government Printing Office, Washington.

Luzier, J.E. (1969). "Geology and Ground-Water Resources of Southwestern King County, Washington," Water Supply Bulletin No. 28, U.S. Geological Survey, Water Resources Division.

Melching, C. and Flores, H. (1999) "Reaeration Equations Derived from USGS Database," Journal of Environmental Engineering, American Society of Civil Engineers, 125(5), 407-414.

Santos, J.F., and Stoner, J.D. (1972). "Physical, Chemical, and Biological Apects of the Duwamish River Estuary King County, Washington 1963-67." Geological Survey Water-Supply Paper 1873-C. United States Printing Office.

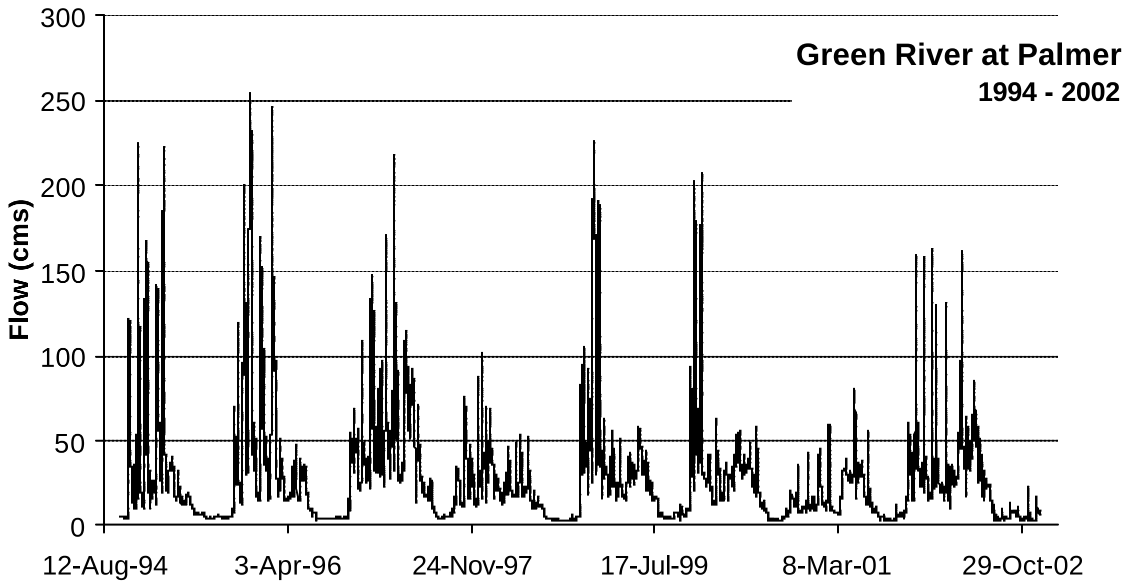
Wells, S. A. (1997) "Theoretical Basis for the CE-QUAL-W2 River Basin Model," Technical Report EWR-6-97, Department of Civil Engineering, Portland State University, Portland, Oregon.

Woodward, D.G., Packard, N.P. Dion, and Sumioka, S.S., (1995) "Occurrence and Quality of Ground Water in Southwestern King County, Washington," Water-Resources Investigations Report 92-4098, U.S. Department of the Interior, U.S. Geological Survey, Denver, Colorado.

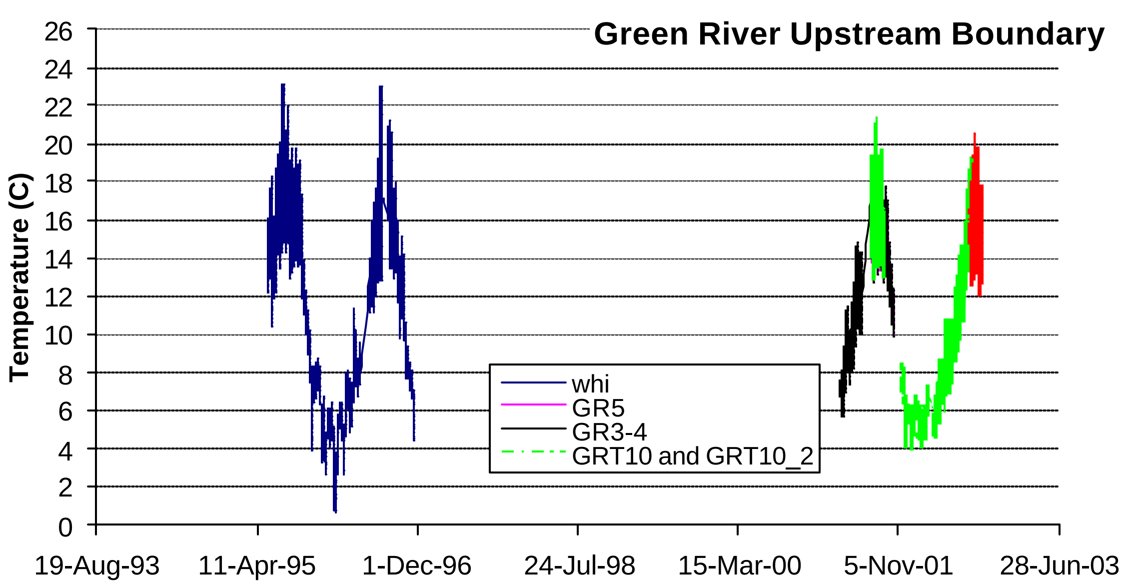
Appendix A: Boundary Condition and Tributary Flow, Temperature, and Water Quality Data

Upstream Boundary Data

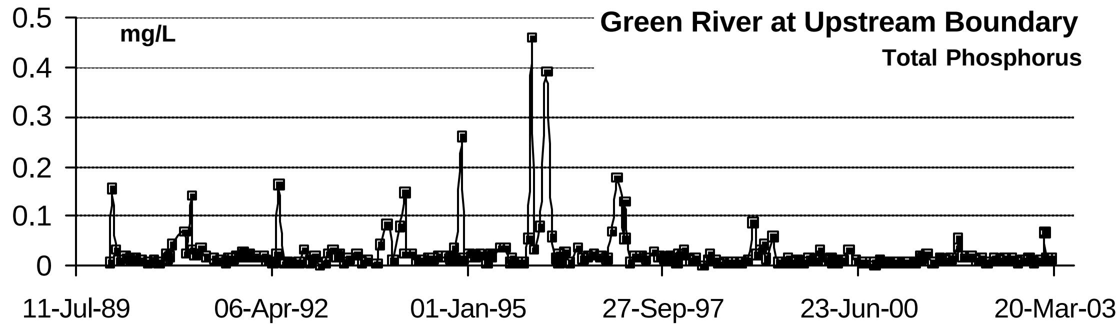
Flow data were obtained on the Green River near Palmer (USGS Gage 12106700) in 15-minute intervals from October 1994 through December 2002.

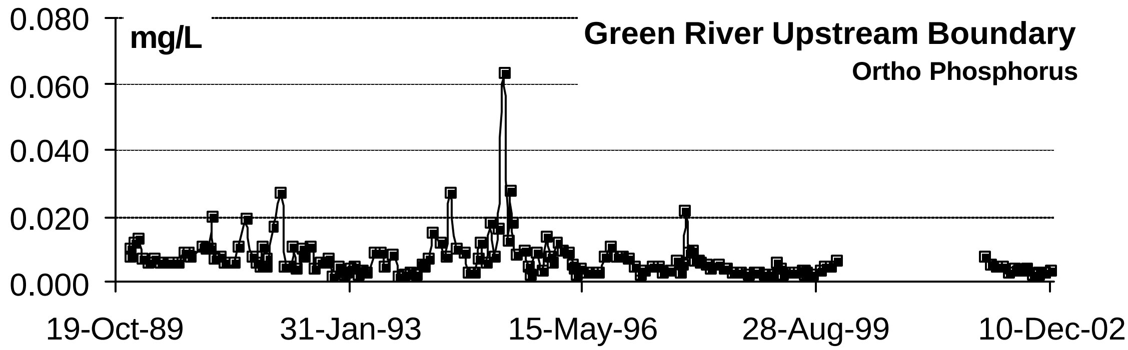


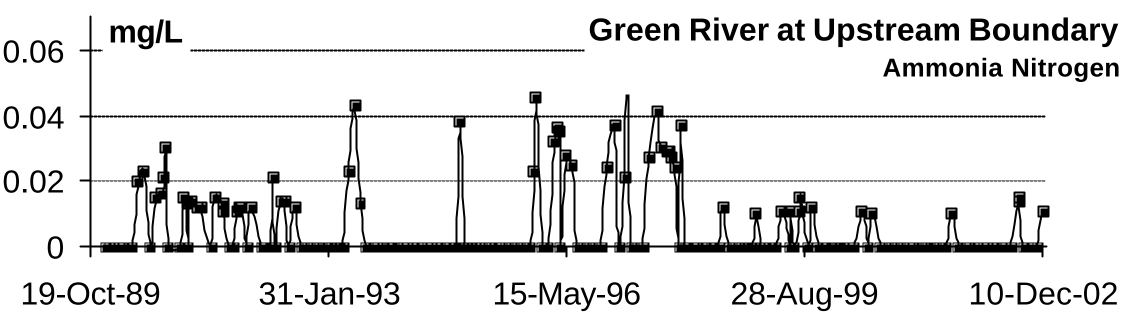
There have been a number of different temperature studies on the Green River near the upstream boundary - including two by the University of Washington (GR3-4 and GR5) and three by King County (WHI, GRT10, and GRT10_2). The data for all stations are shown below.

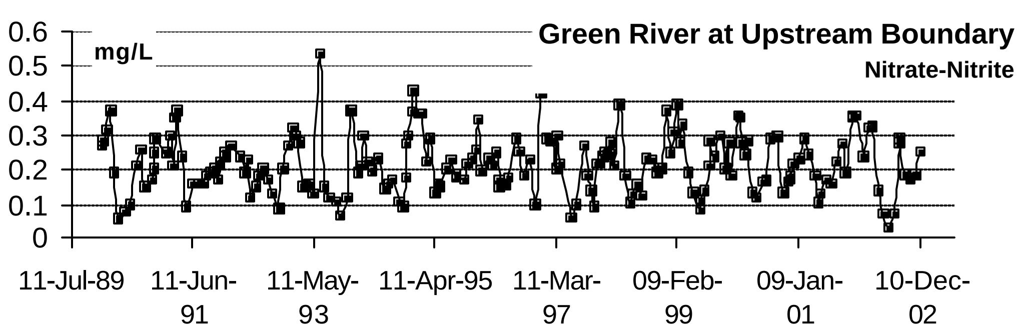


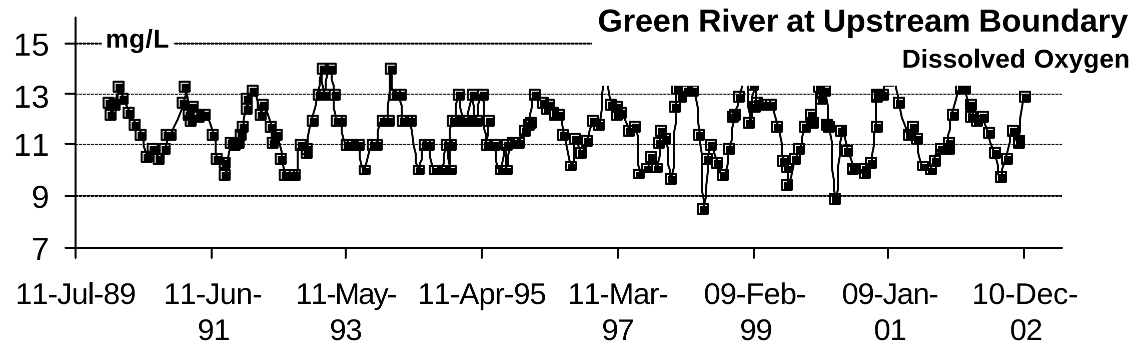
Monthly sampling of water quality constituents was provided from 1990 to 2002.

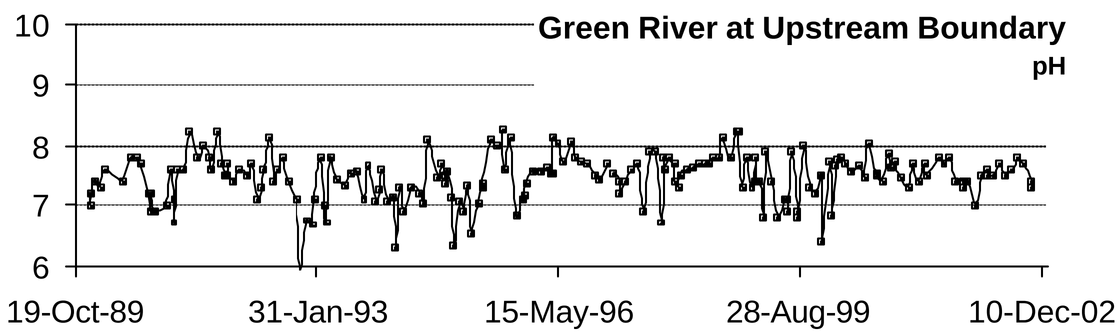


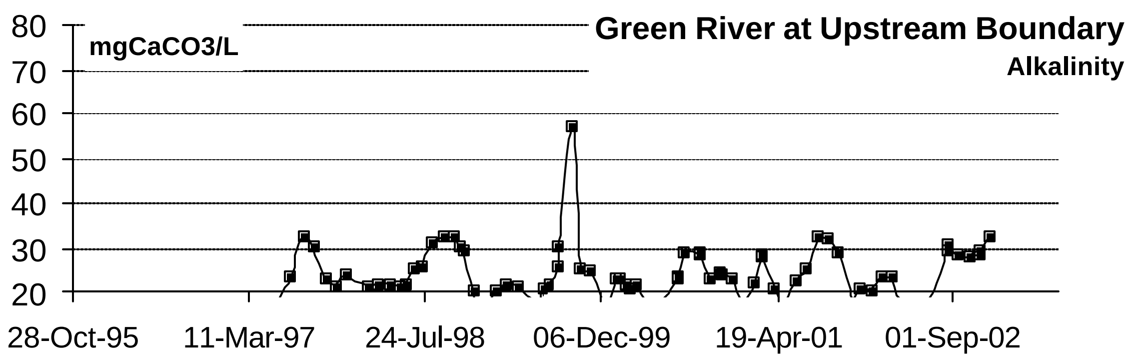


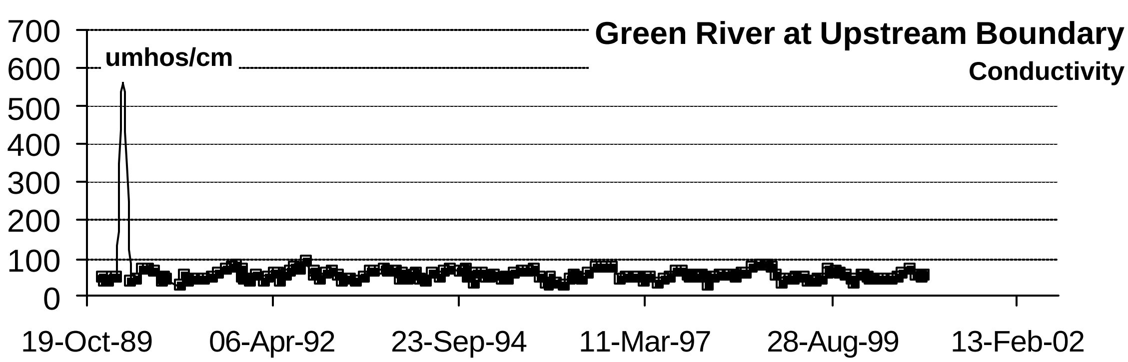


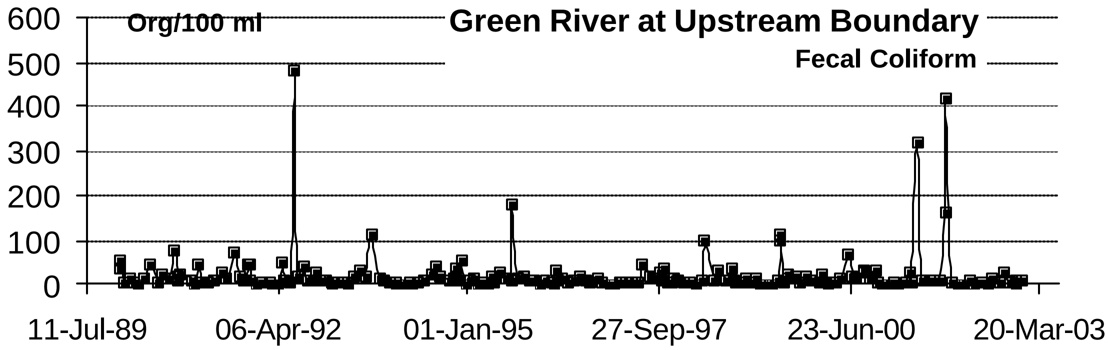



Green River at Upstream Boundary
Dissolved Oxygen
mg/L
15
13
11
9
7
11-Jul-89
11-Jun-91
11-May-93
11-Apr-95
11-Mar-97
09-Feb-99
09-Jan-01
10-Dec-02

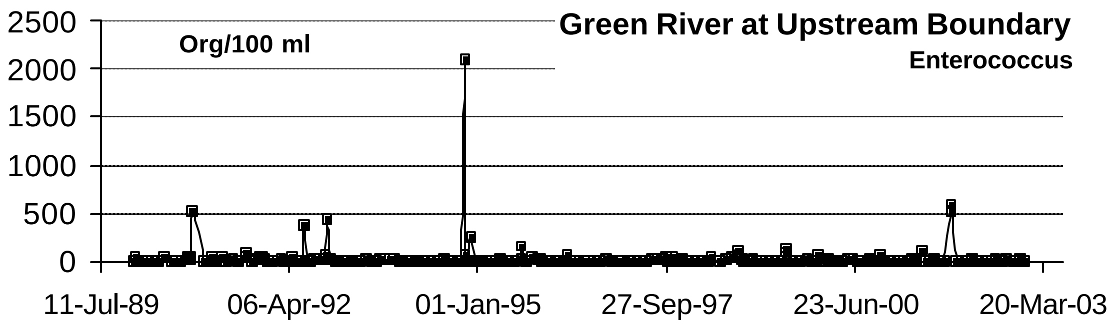

Green River at Upstream Boundary
pH
10
9
8
7
6
19-Oct-89
31-Jan-93
15-May-96
28-Aug-99
10-Dec-02


Green River at Upstream Boundary
Alkalinity
mgCaCO3/L
80
70
60
50
40
30
20
28-Oct-95
11-Mar-97
24-Jul-98
06-Dec-99
19-Apr-01
01-Sep-02

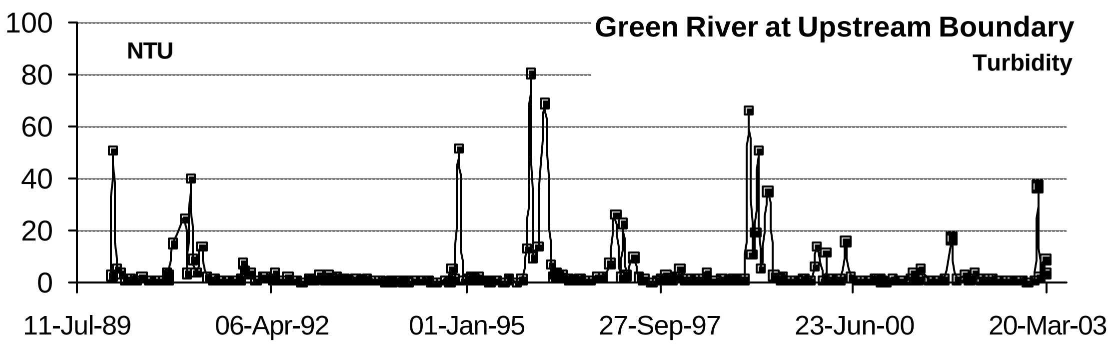

Green River at Upstream Boundary
Conductivity
umhos/cm
700
600
500
400
300
200
100
0
19-Oct-89
06-Apr-92
23-Sep-94
11-Mar-97
28-Aug-99
13-Feb-02



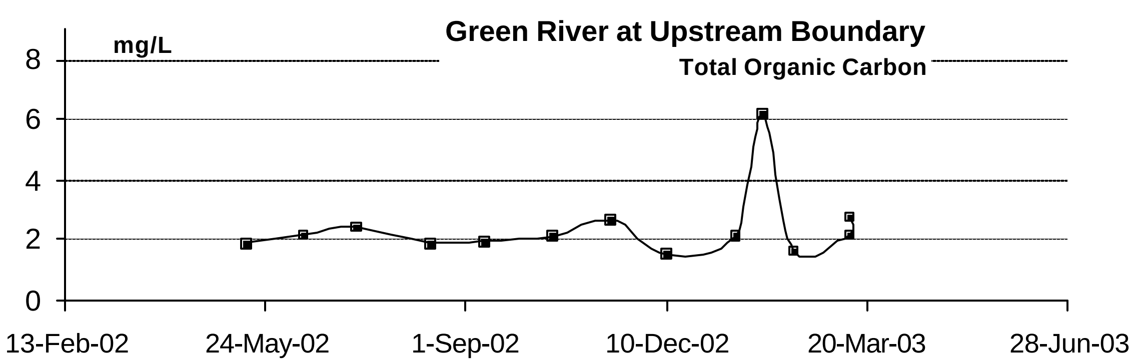
Green River at Upstream Boundary
Fecal Coliform
Org/100 ml
600
500
400
300
200
100
0
11-Jul-89
06-Apr-92
01-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03



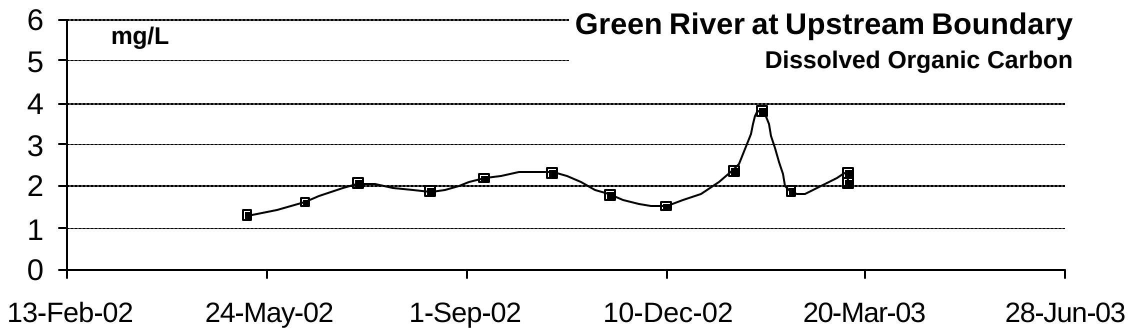
Green River at Upstream Boundary
Enterococcus
Org/100 ml
2500
2000
1500
1000
500
0
11-Jul-89
06-Apr-92
01-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03

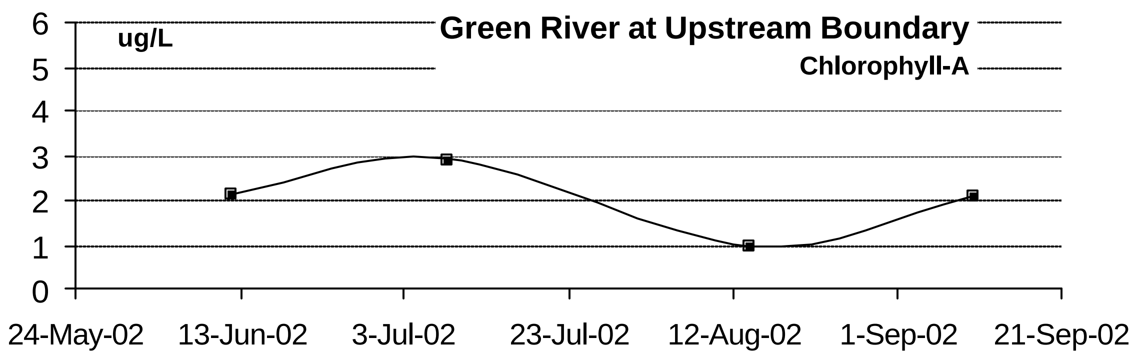


Green River at Upstream Boundary
Turbidity
NTU
100
80
60
40
20
0
11-Jul-89
06-Apr-92
01-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03



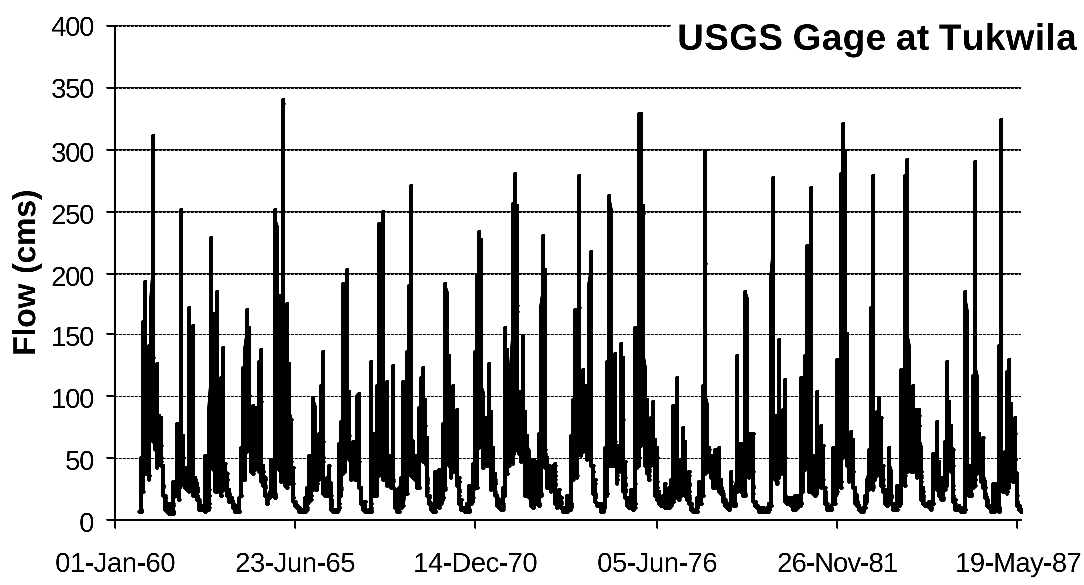
Green River at Upstream Boundary
Total Organic Carbon
mg/L
8
6
4
2
0
13-Feb-02
24-May-02
1-Sep-02
10-Dec-02
20-Mar-03
28-Jun-03



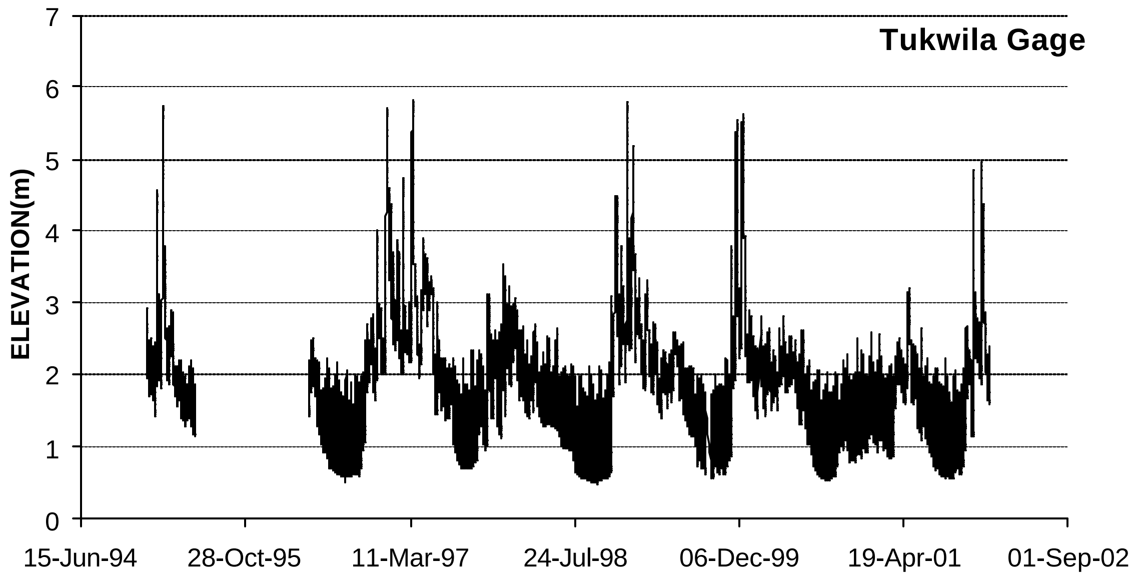


Downstream Boundary Data

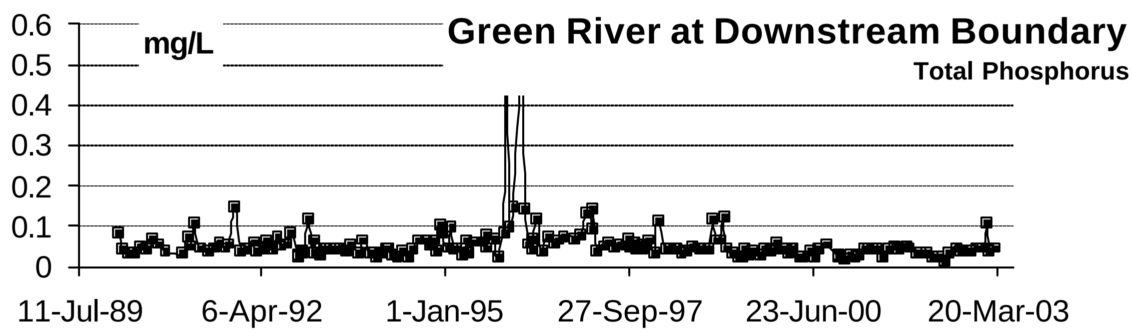
USGS (Gage No.12113350) recorded flow at Tukwila through 1987. Daily average data were provided by King County from 1960 through August 1987.

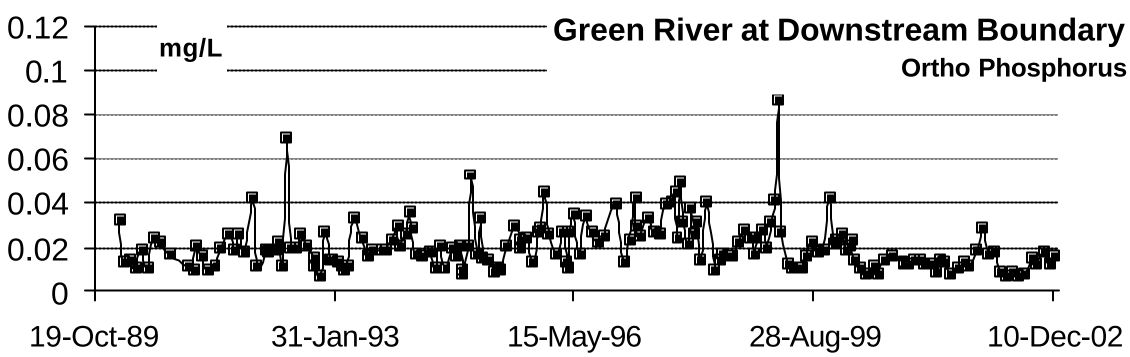


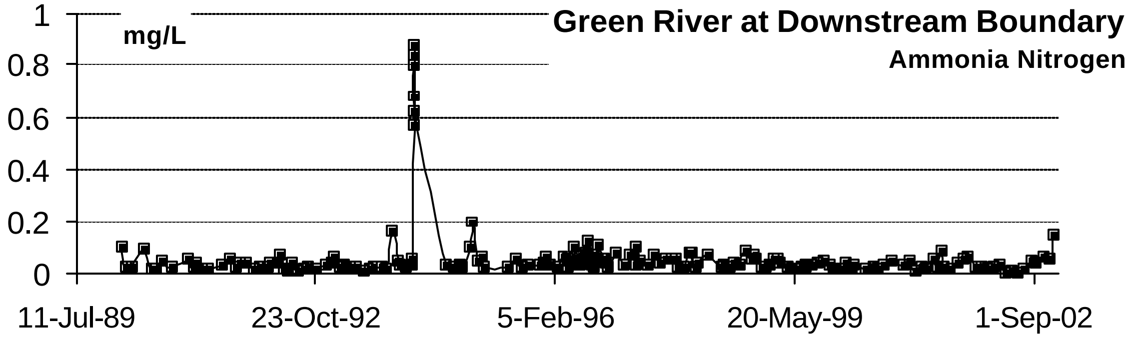
Stage data were obtained on the Green River at Tukwila (USGS Gage 12113500) in hourly intervals from 1995 through June of 2002.

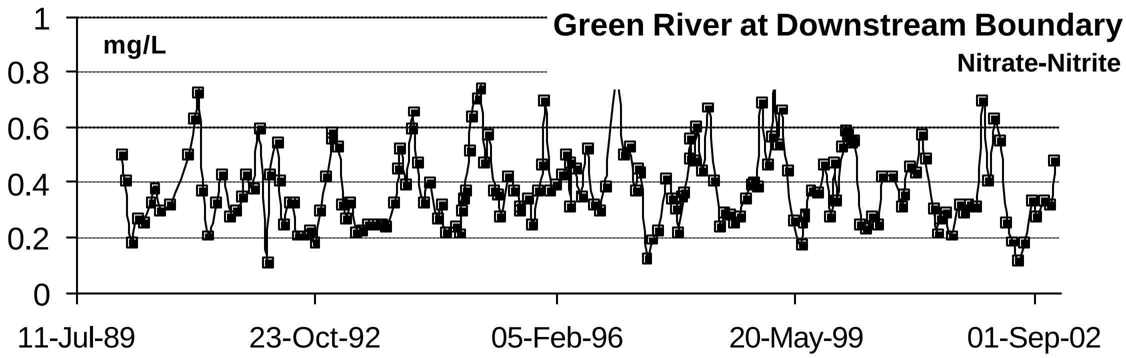


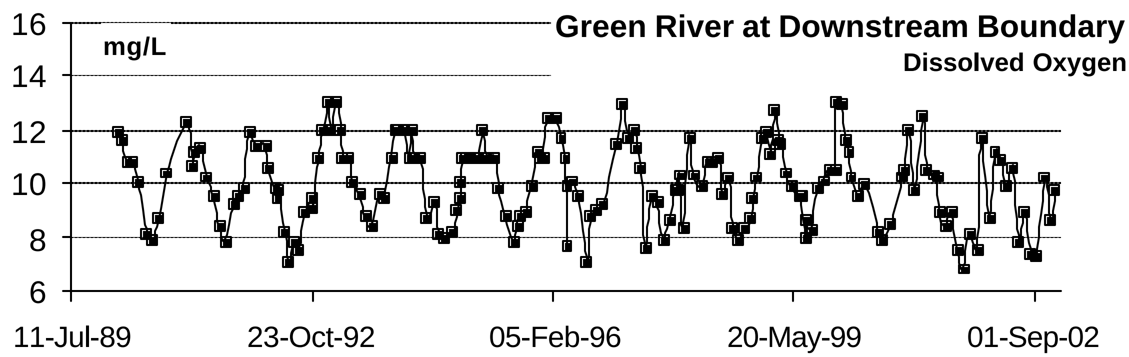
Water quality data were provided from 1990 to 2002.

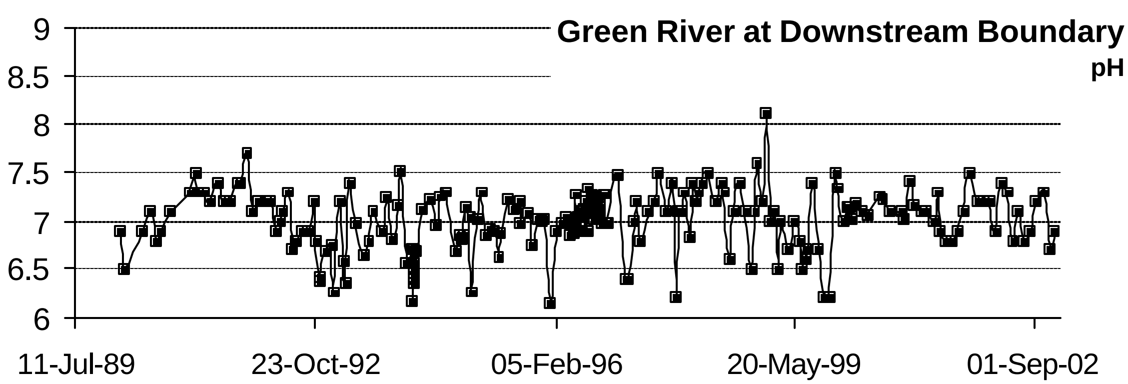


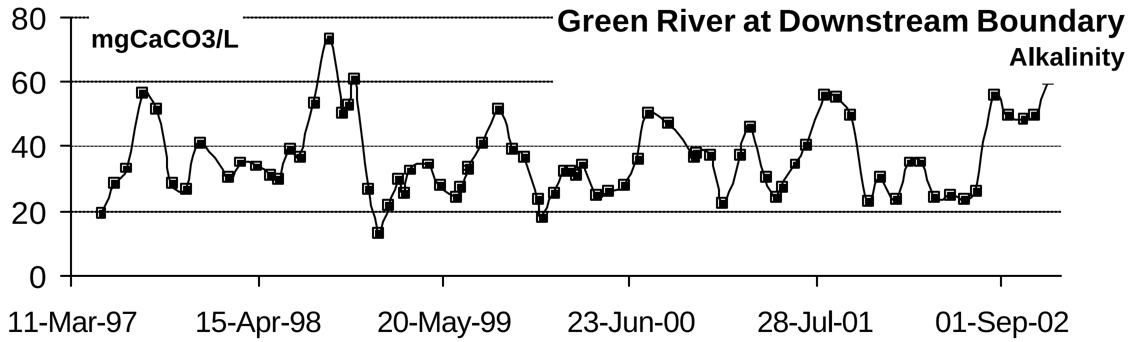


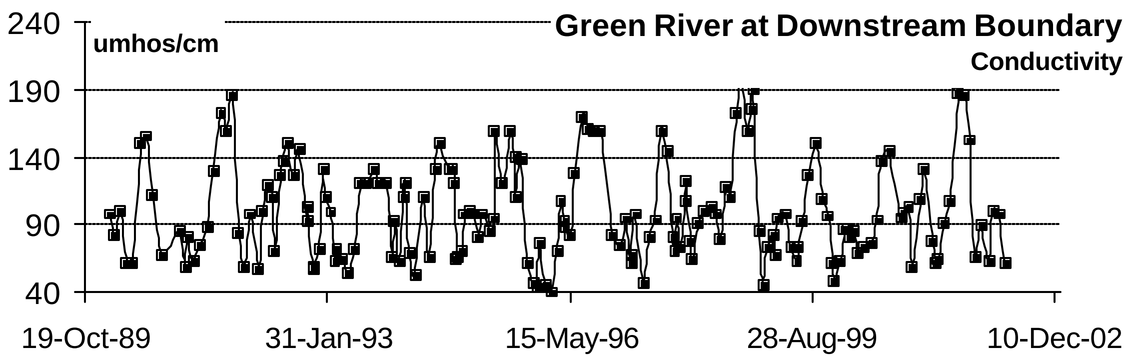

Green River at Downstream Boundary
Ammonia Nitrogen
mg/L
1
0.8
0.6
0.4
0.2
0
11-Jul-89
23-Oct-92
5-Feb-96
20-May-99
1-Sep-02

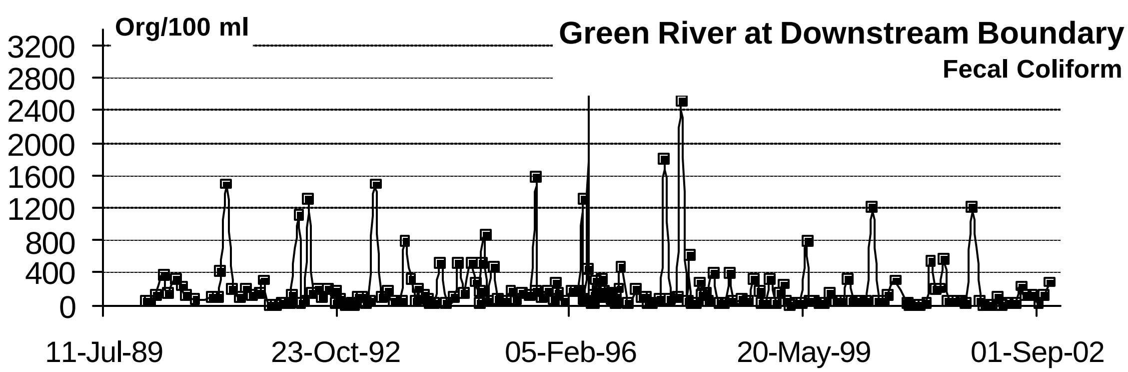

Green River at Downstream Boundary
Nitrate-Nitrite
mg/L
1
0.8
0.6
0.4
0.2
0
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

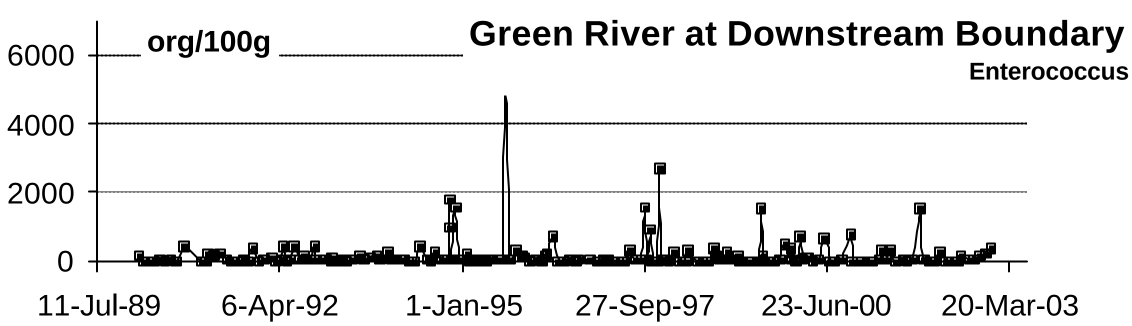

Green River at Downstream Boundary
Dissolved Oxygen
mg/L
16
14
12
10
8
6
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

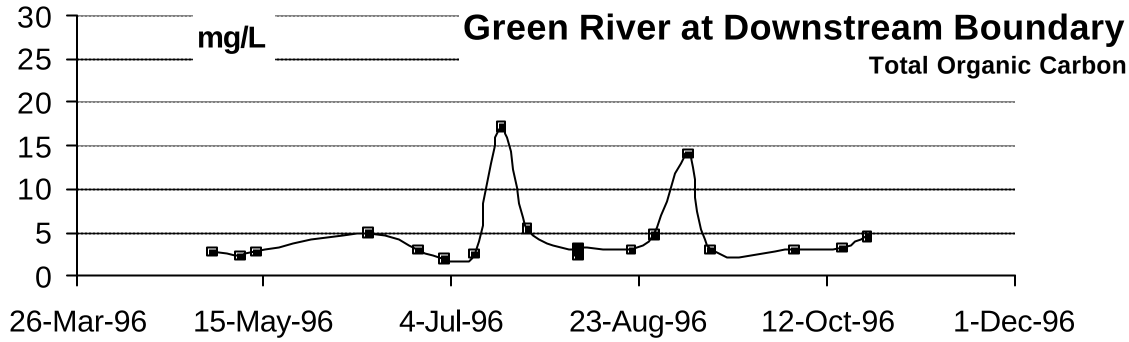

Green River at Downstream Boundary
pH
9
8.5
8
7.5
7
6.5
6
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

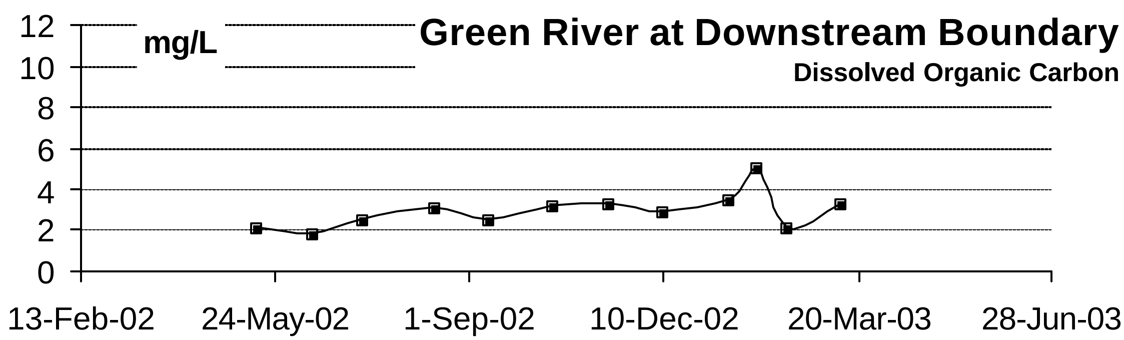

Green River at Downstream Boundary
Alkalinity
mgCaCO3/L
80
60
40
20
0
11-Mar-97
15-Apr-98
20-May-99
23-Jun-00
28-Jul-01
01-Sep-02

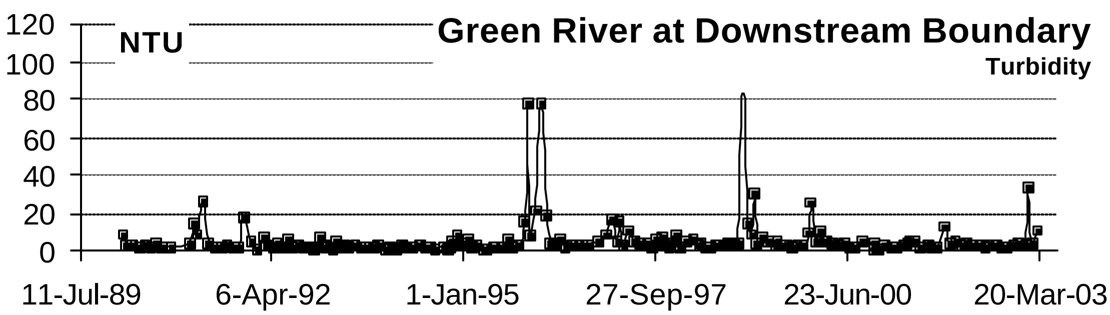

Green River at Downstream Boundary
Conductivity
umhos/cm
240
190
140
90
40
19-Oct-89
31-Jan-93
15-May-96
28-Aug-99
10-Dec-02


Green River at Downstream Boundary
Fecal Coliform
Org/100 ml
3200
2800
2400
2000
1600
1200
800
400
0
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02


Green River at Downstream Boundary
Enterococcus
org/100g
6000
4000
2000
0
11-Jul-89
6-Apr-92
1-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03

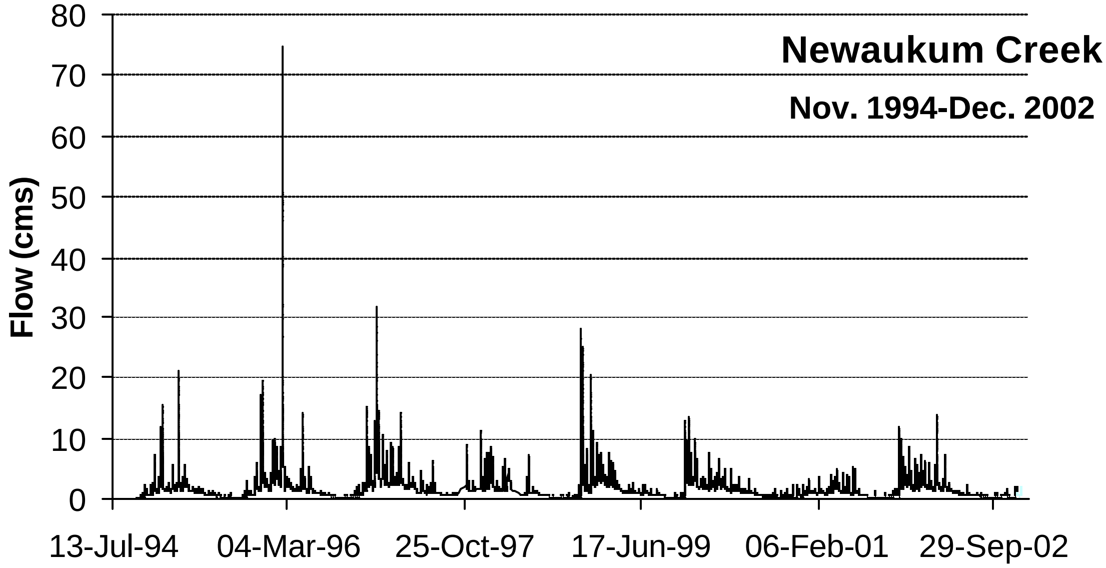




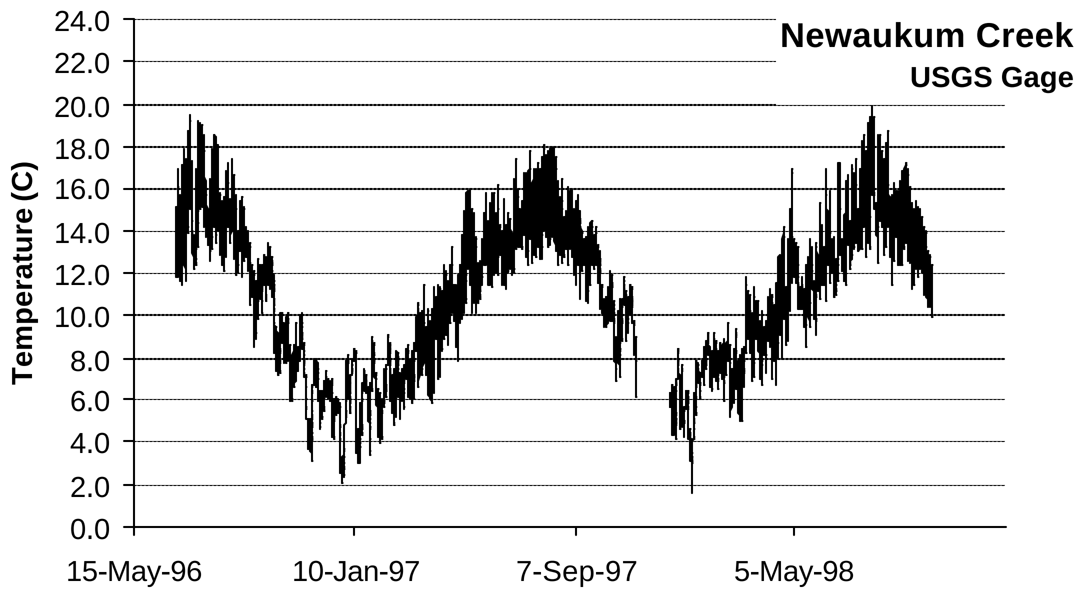


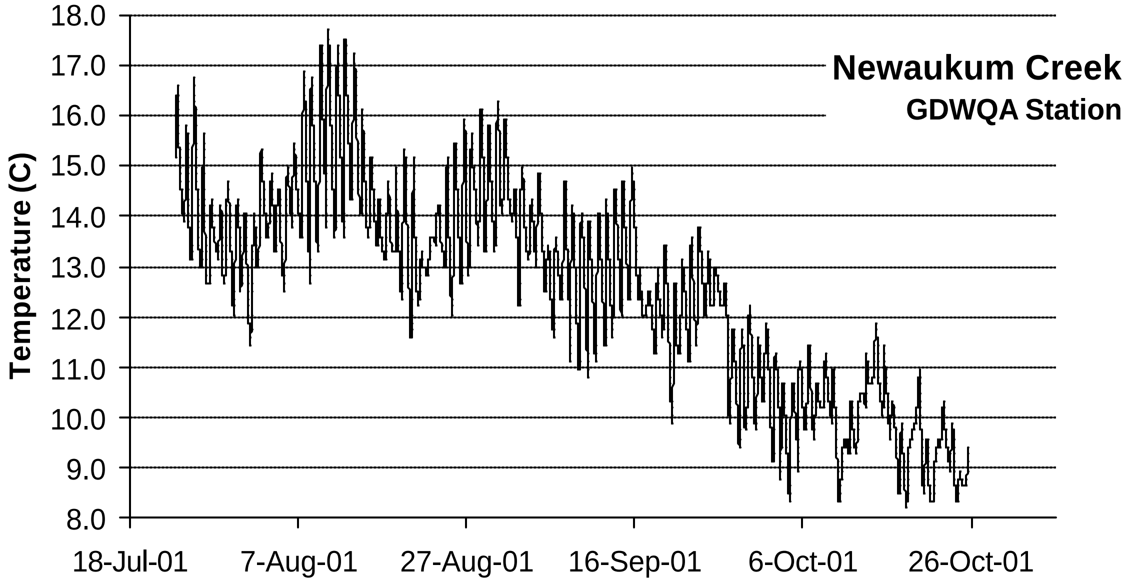
Newaukum Creek Data

Flow data were obtained on Newaukum Creek (USGS Gage 12108500) from November 1994 through December 2002.

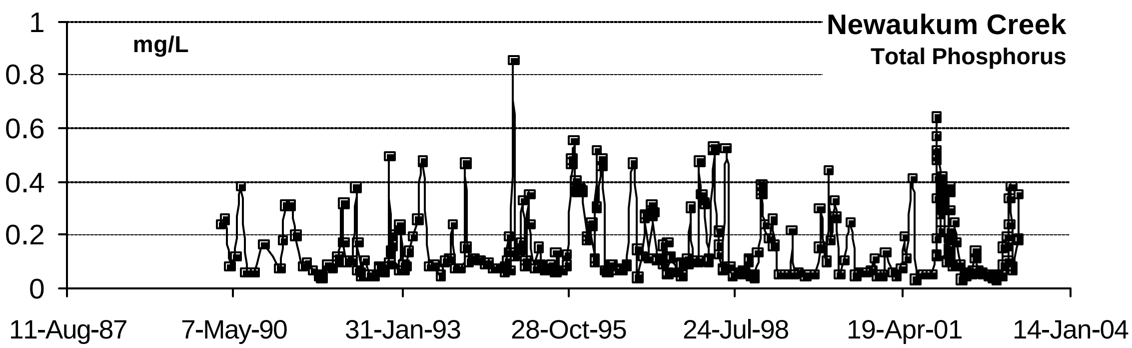


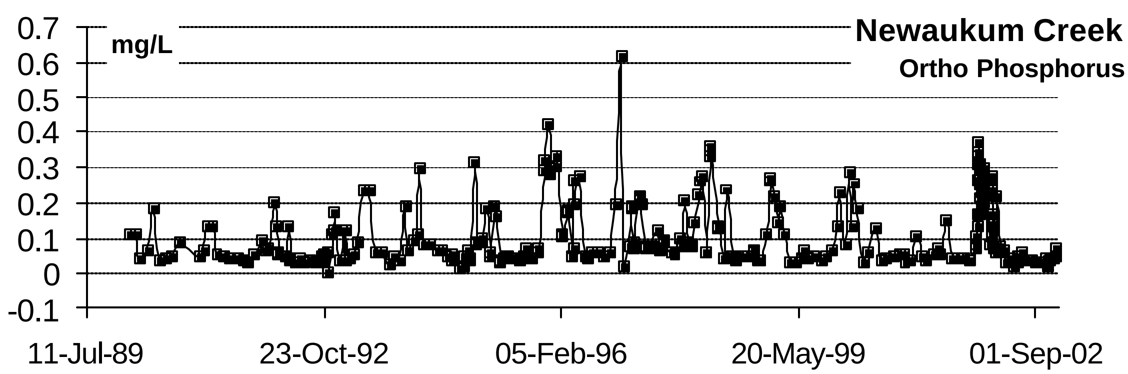
Both King County and the USGS recorded temperature on Newaukum Creek at different times. USGS recorded hourly temperature data from June 1996 to October 1998, and King County recorded temperature at the same location from July 2001 to the present. These data were provided in hourly intervals.

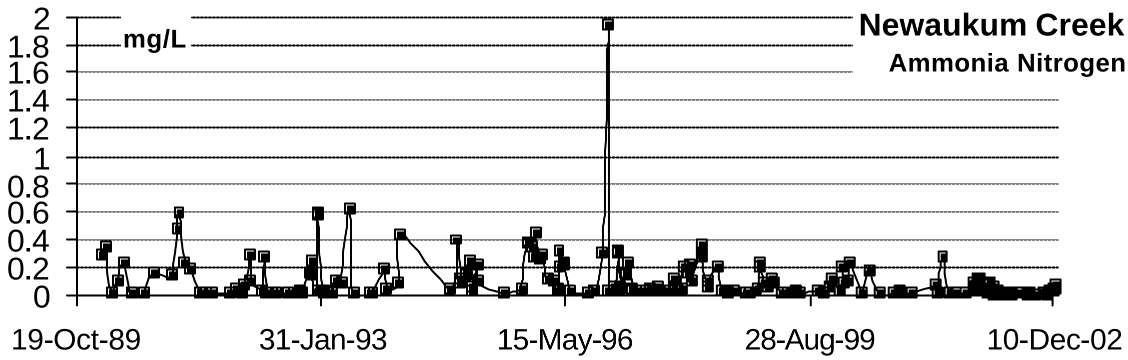


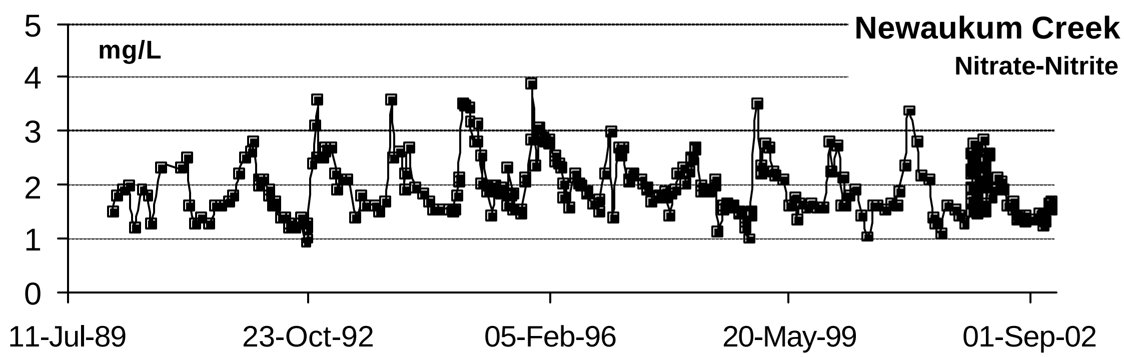


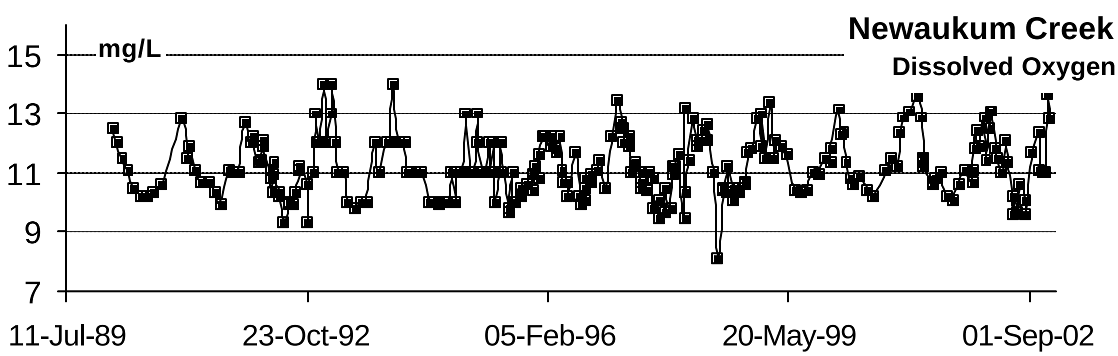
Water quality constituent data have been provided from 1990 to 2002.

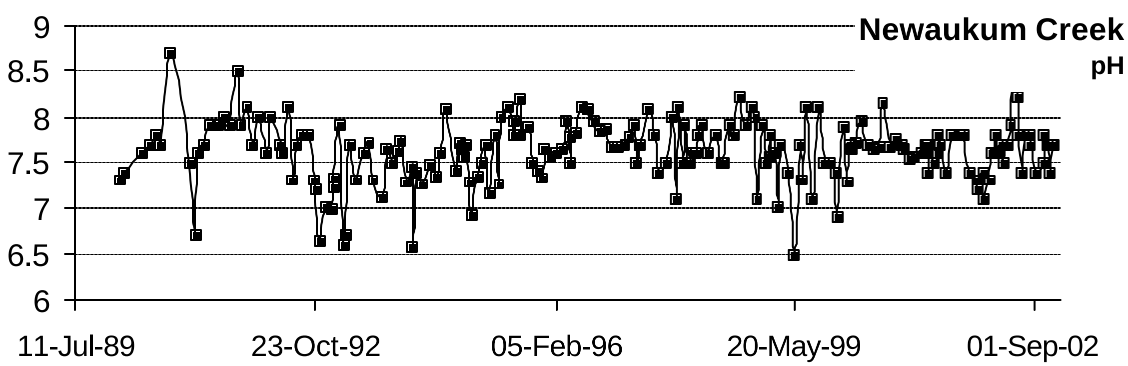


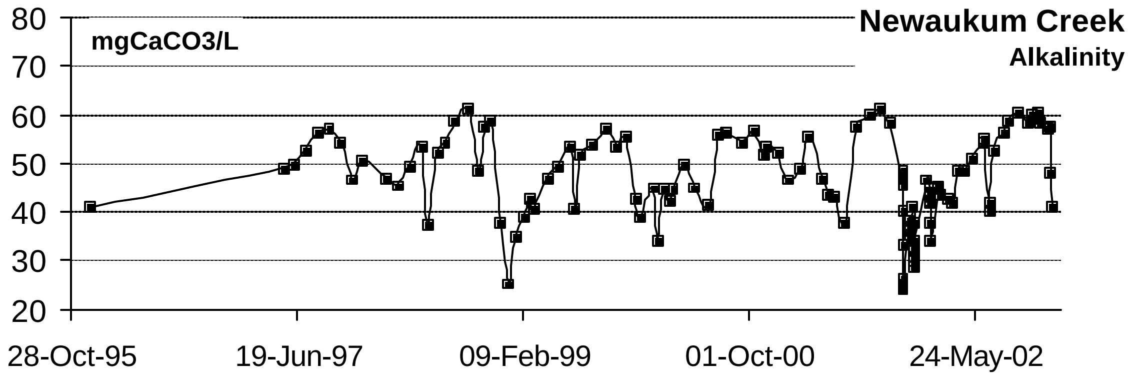


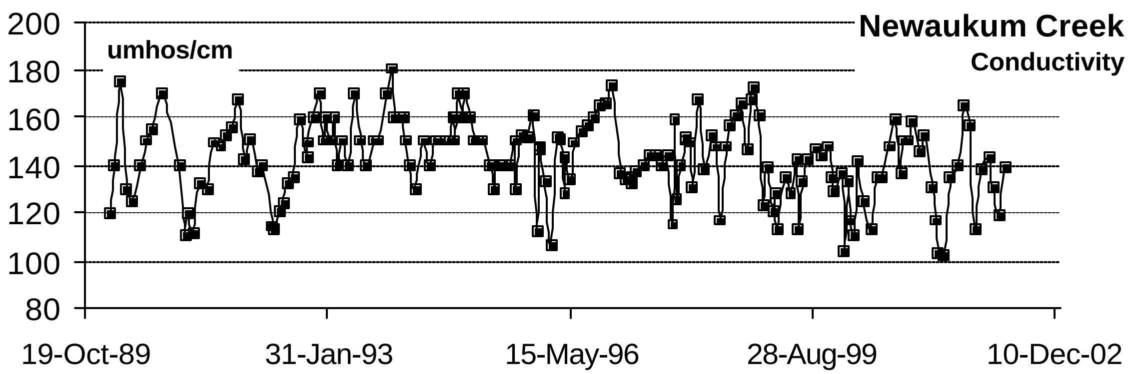

Newaukum Creek
Ammonia Nitrogen
mg/L
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
19-Oct-89
31-Jan-93
15-May-96
28-Aug-99
10-Dec-02

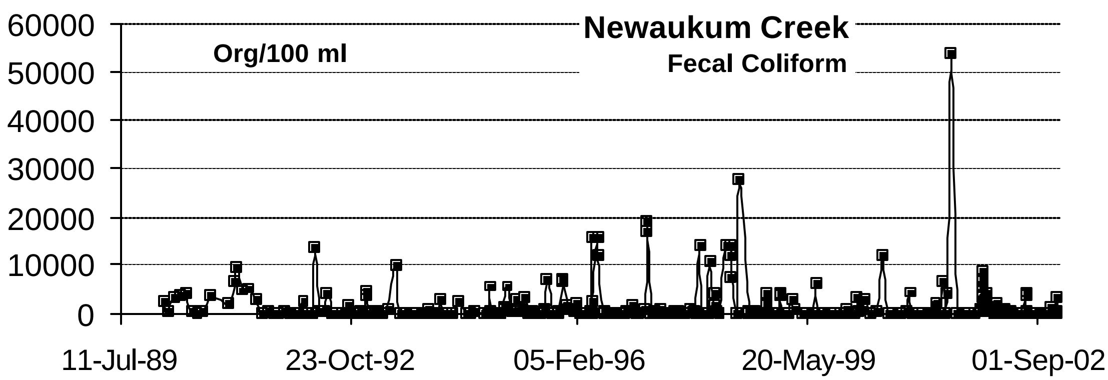

Newaukum Creek
Nitrate-Nitrite
mg/L
5
4
3
2
1
0
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

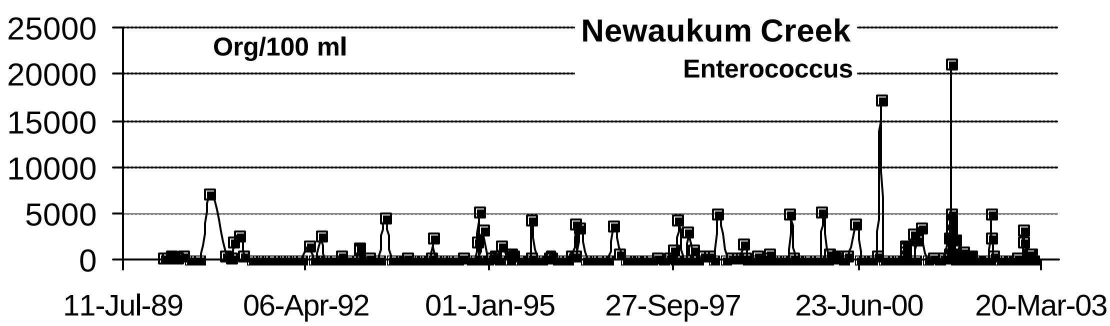

Newaukum Creek
Dissolved Oxygen
mg/L
15
13
11
9
7
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

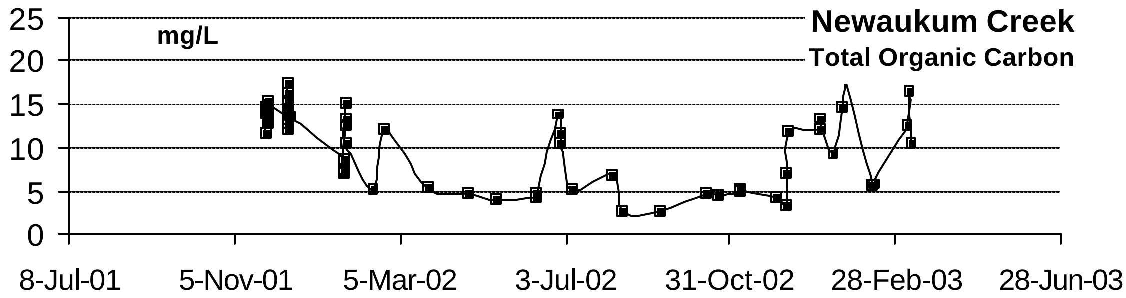

Newaukum Creek
pH
9
8.5
8
7.5
7
6.5
6
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

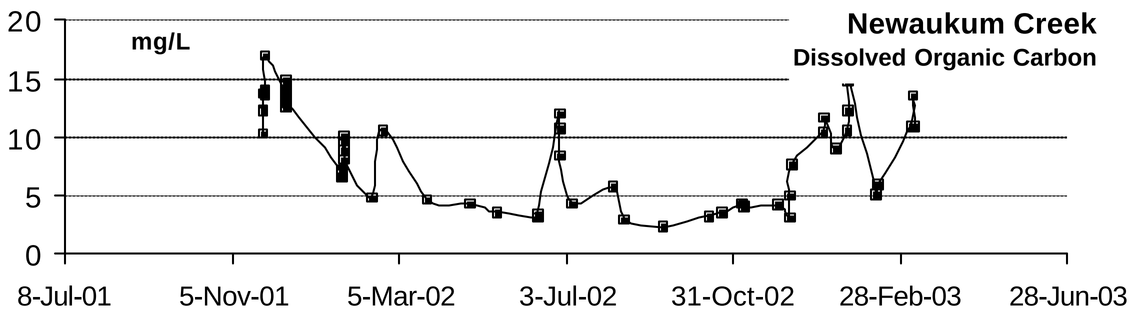

Newaukum Creek
Alkalinity
mgCaCO3/L
80
70
60
50
40
30
20
28-Oct-95
19-Jun-97
09-Feb-99
01-Oct-00
24-May-02

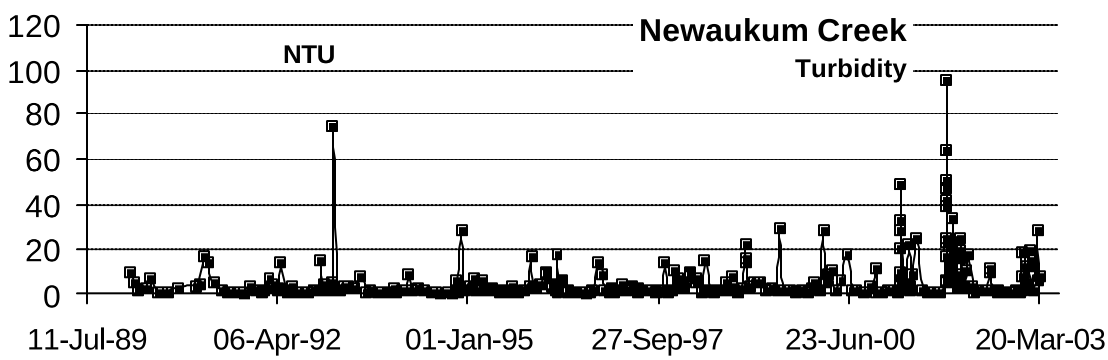

Newaukum Creek
Conductivity
umhos/cm
200
180
160
140
120
100
80
19-Oct-89
31-Jan-93
15-May-96
28-Aug-99
10-Dec-02


Newaukum Creek
Fecal Coliform
Org/100 ml
60000
50000
40000
30000
20000
10000
0
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02


Newaukum Creek
Enterococcus
Org/100 ml
25000
20000
15000
10000
5000
0
11-Jul-89
06-Apr-92
01-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03

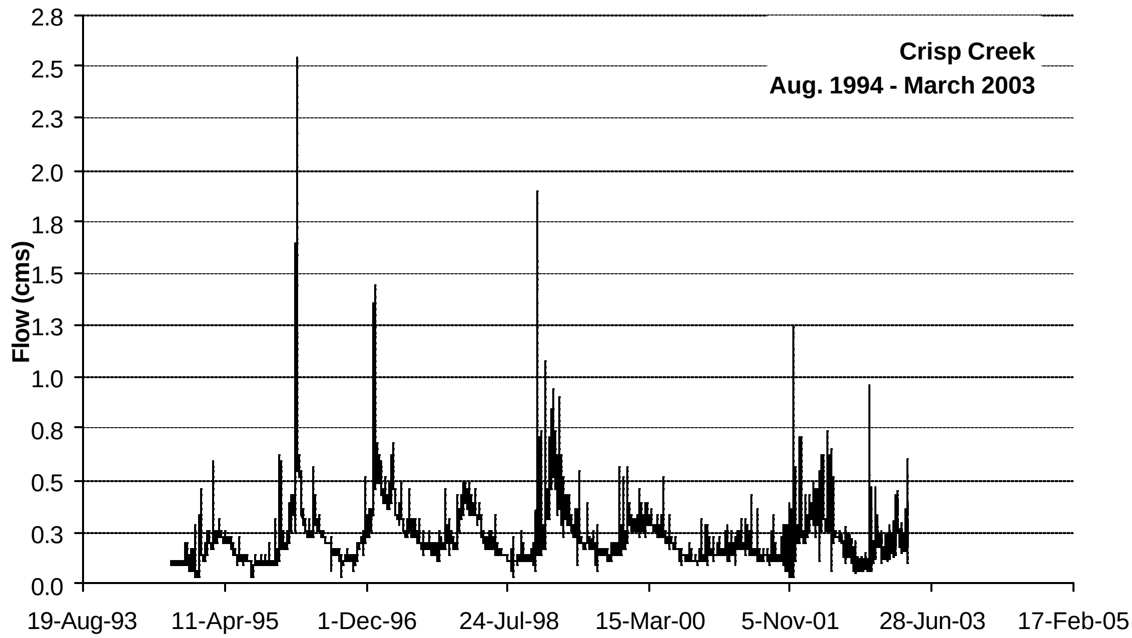

Newaukum Creek
Total Organic Carbon
mg/L
25
20
15
10
5
0
8-Jul-01
5-Nov-01
5-Mar-02
3-Jul-02
31-Oct-02
28-Feb-03
28-Jun-03


Newaukum Creek
Dissolved Organic Carbon
mg/L
20
15
10
5
0
8-Jul-01
5-Nov-01
5-Mar-02
3-Jul-02
31-Oct-02
28-Feb-03
28-Jun-03

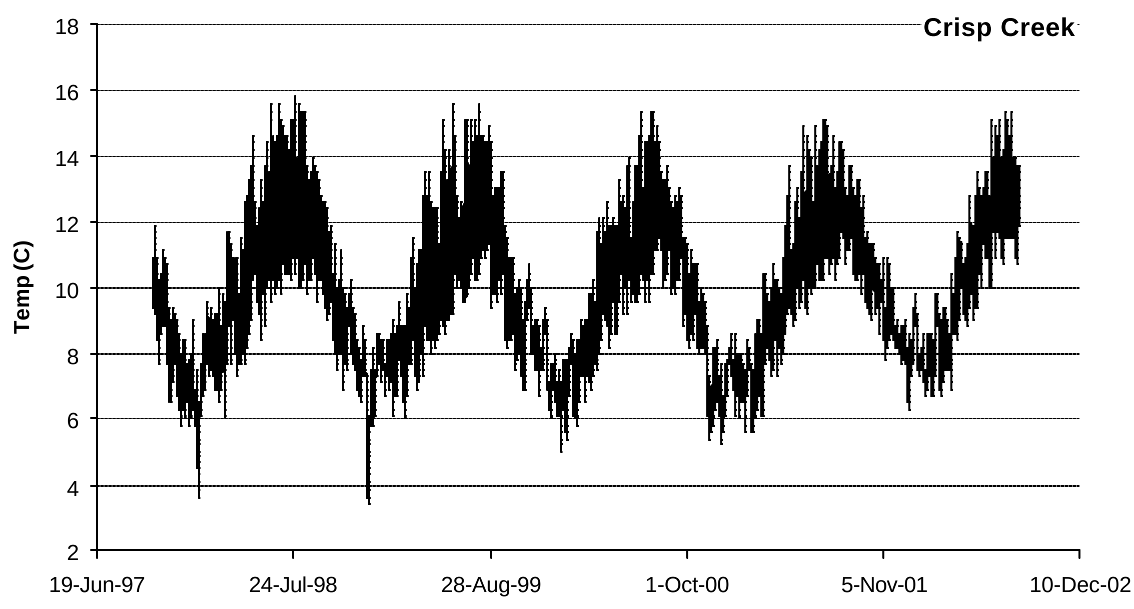

Newaukum Creek
Turbidity
NTU
120
100
80
60
40
20
0
11-Jul-89
06-Apr-92
01-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03

Crisp Creek Data

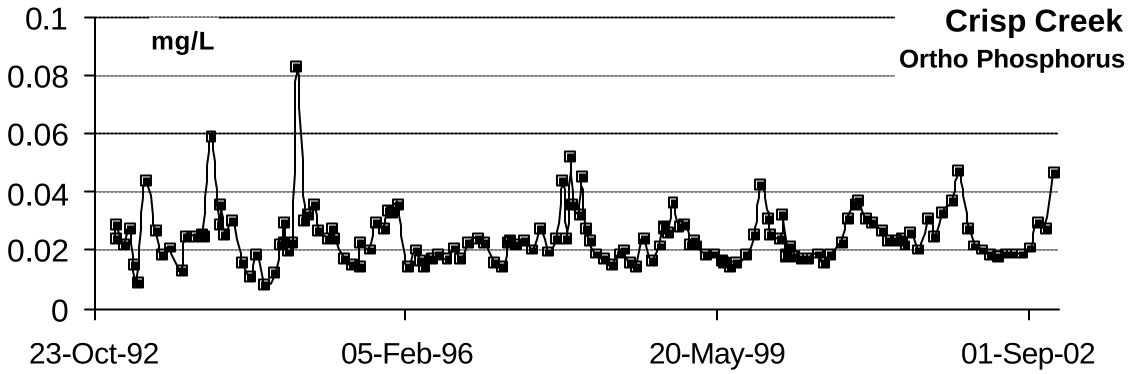
King County has a flow gage (#40d) on Crisp Creek. Data were obtained in 15-minute intervals from August 1994 through March 2003.

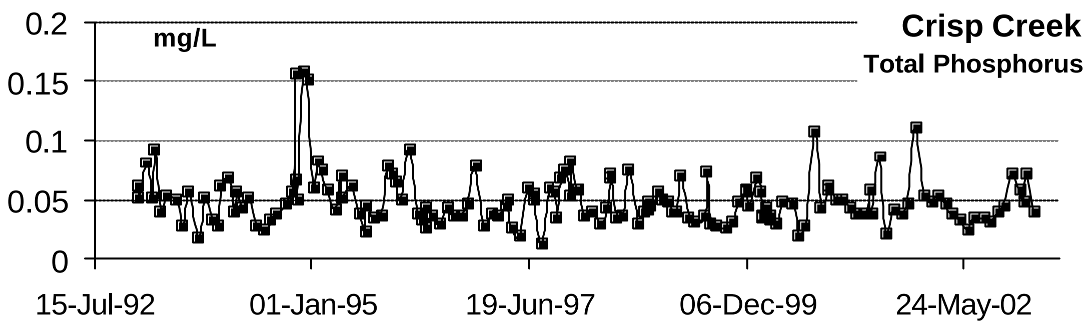


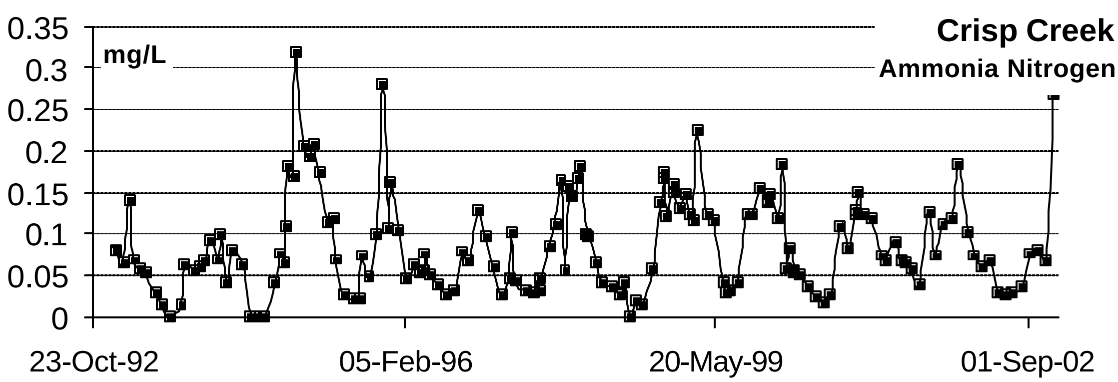
Temperature data for Crisp Creek were recorded by King County (#40d) in 15-minute intervals. Data were provided from October 1997 to August 2002.

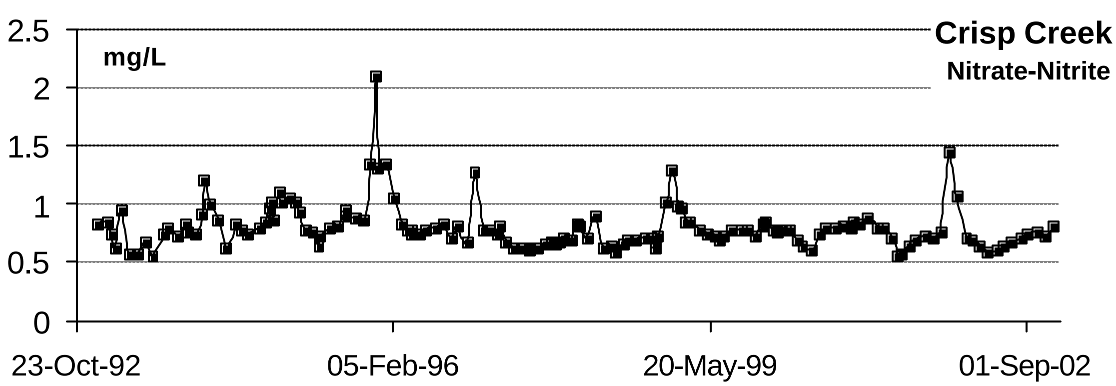


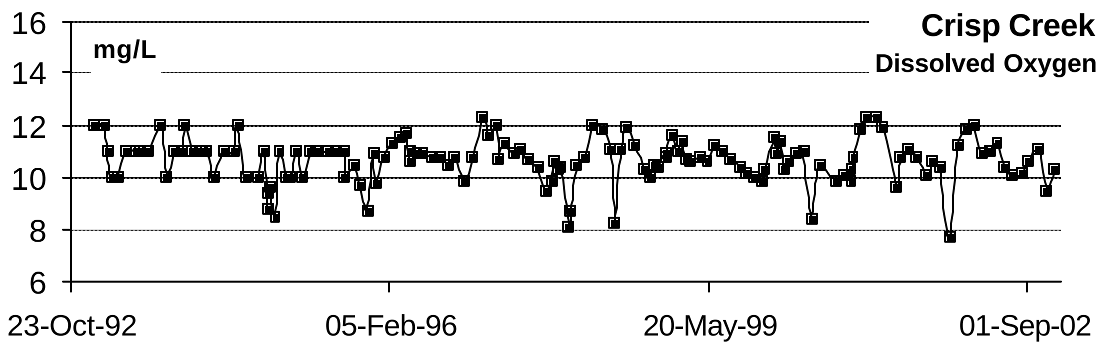
Water quality constituent data were provided from 1990 to 2002.

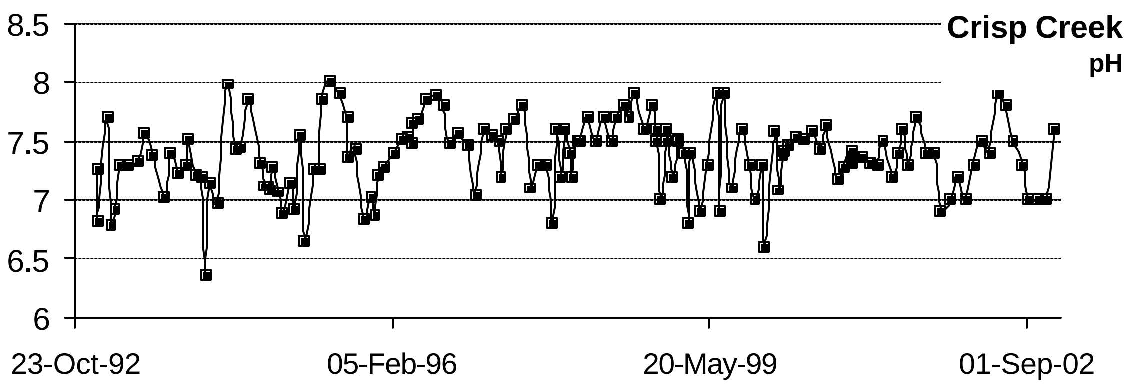

Crisp Creek
Ortho Phosphorus
mg/L
0.1
0.08
0.06
0.04
0.02
0
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

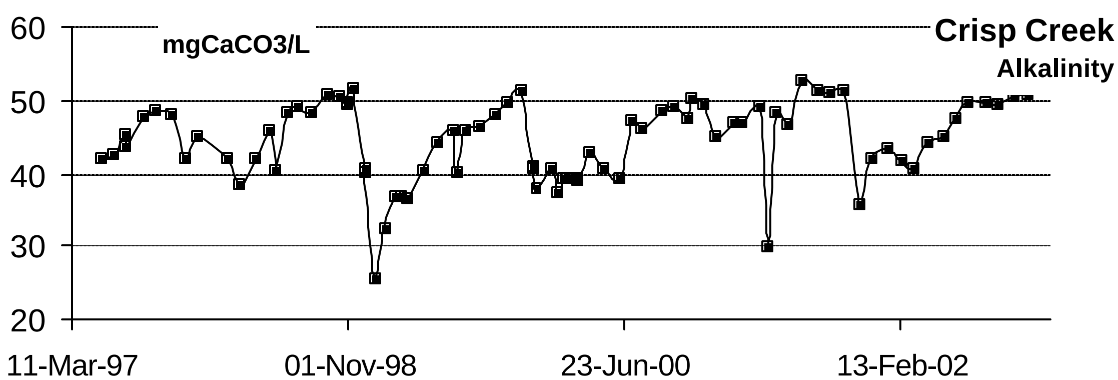

Crisp Creek
Total Phosphorus
mg/L
0.2
0.15
0.1
0.05
0
15-Jul-92
01-Jan-95
19-Jun-97
06-Dec-99
24-May-02

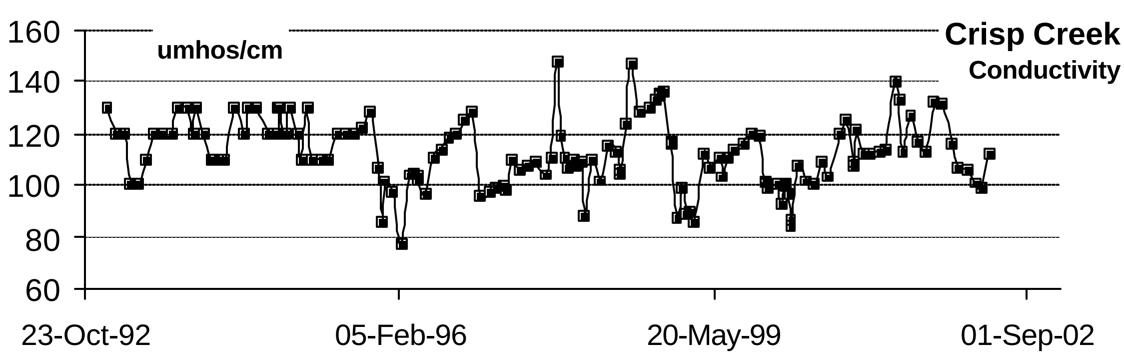

Crisp Creek
Ammonia Nitrogen
mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

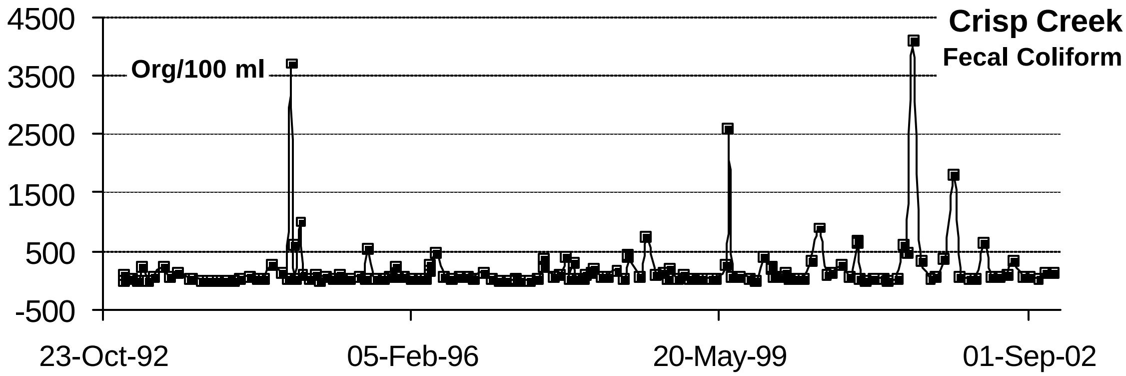

Crisp Creek
Nitrate-Nitrite
mg/L
2.5
2
1.5
1
0.5
0
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

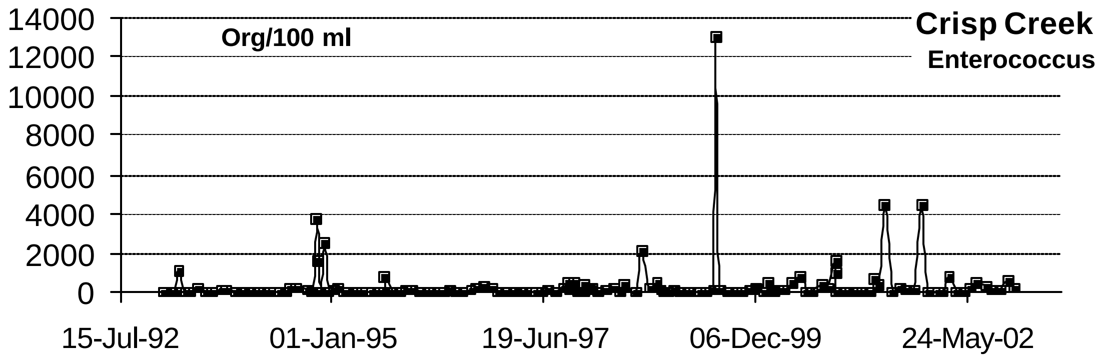

Crisp Creek
Dissolved Oxygen
mg/L
16
14
12
10
8
6
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

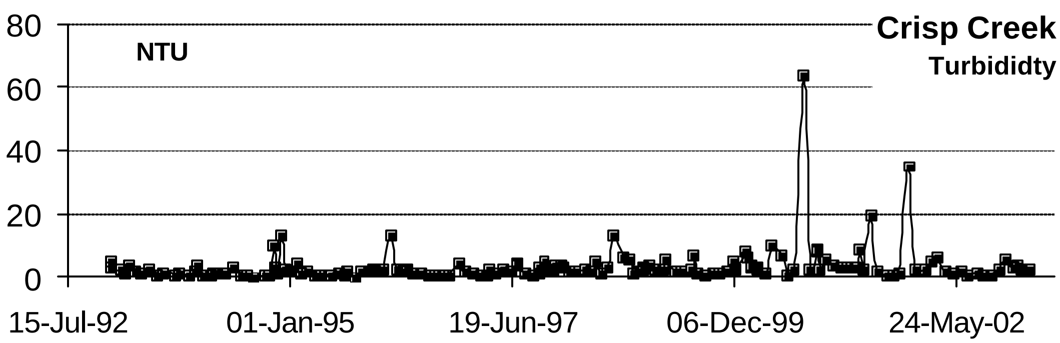

Crisp Creek
pH
8.5
8
7.5
7
6.5
6
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02


Crisp Creek
Alkalinity
mgCaCO3/L
60
50
40
30
20
11-Mar-97
01-Nov-98
23-Jun-00
13-Feb-02


Crisp Creek
Conductivity
umhos/cm
160
140
120
100
80
60
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

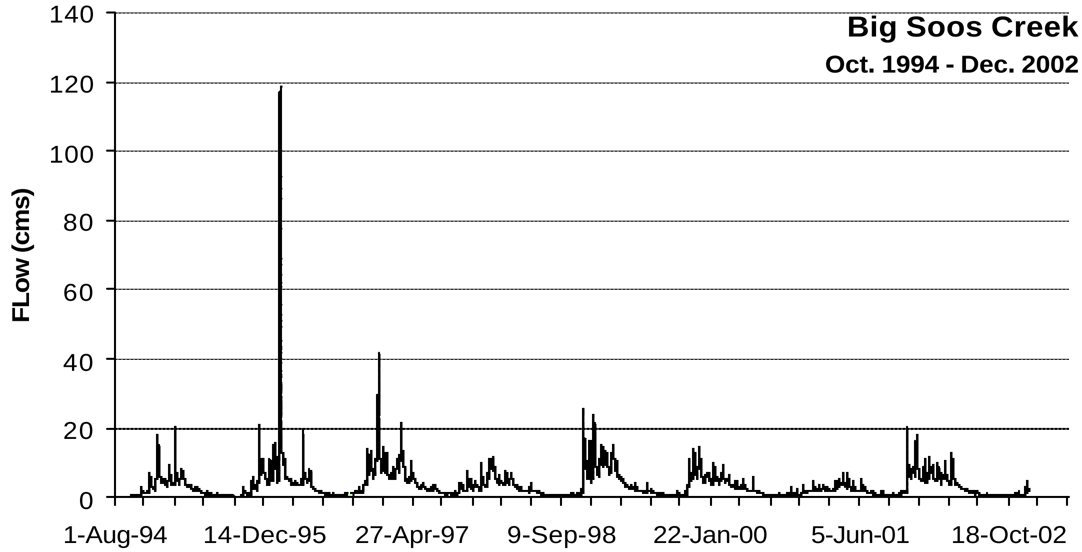




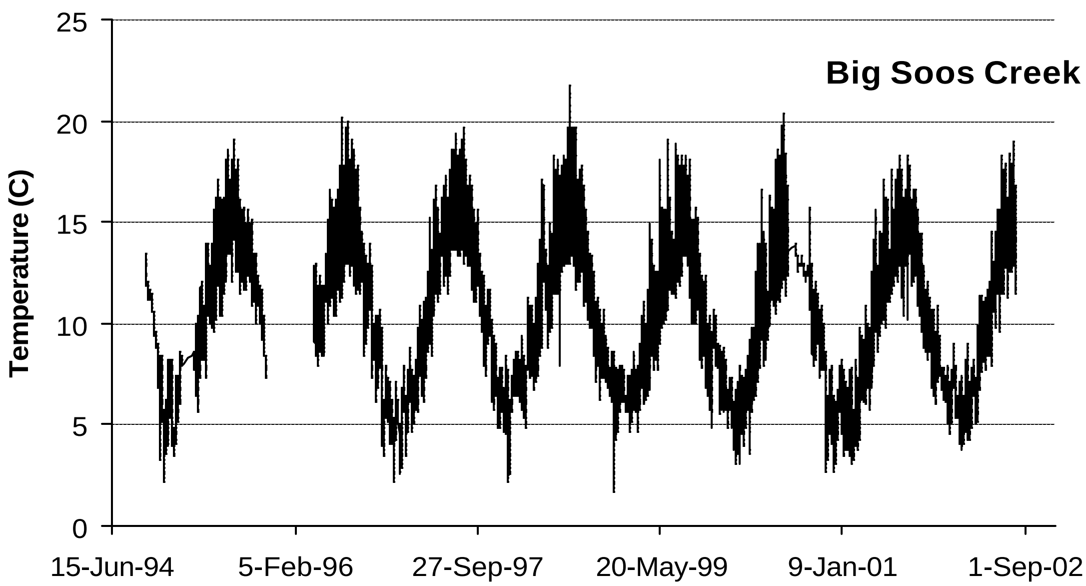


Big Soos Creek Data

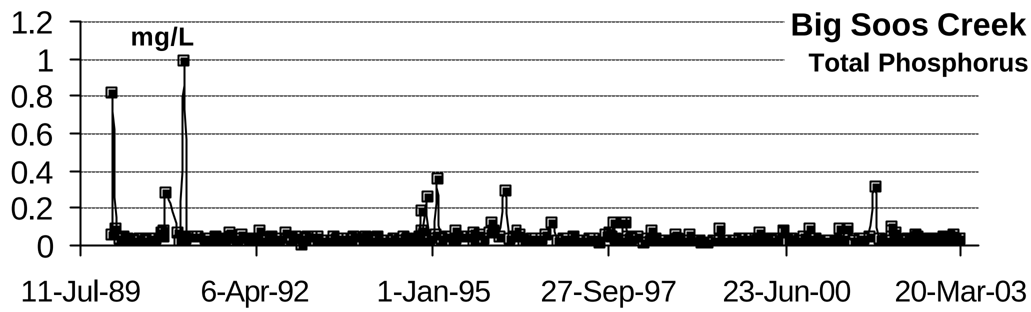
USGS has a flow gage (#12112600) on Big Soos Creek. Data were obtained in 15-minute intervals from October 1994 through December 2002.

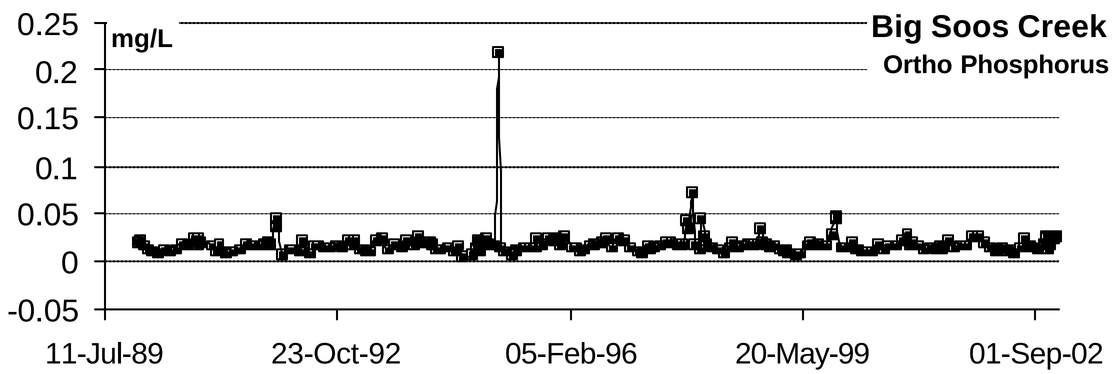


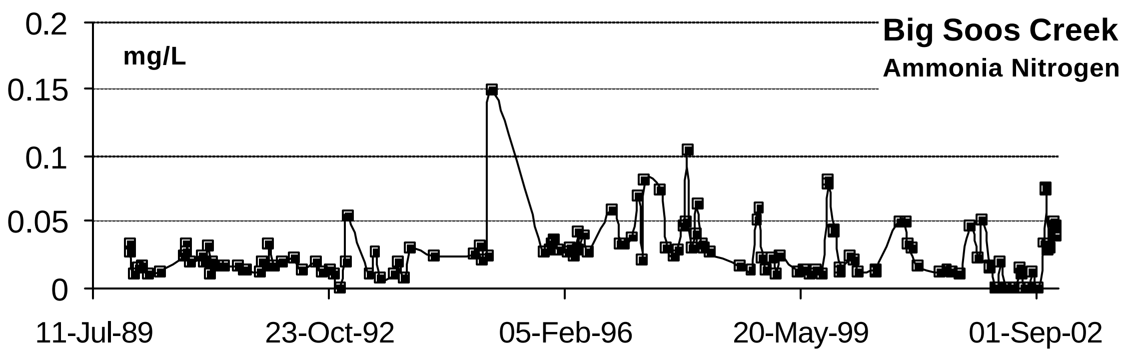
Temperature was recorded by King County (#54a) at the mouth of Big Soos Creek in 15-minute intervals. Data were provided from October 1994 to August 2002.

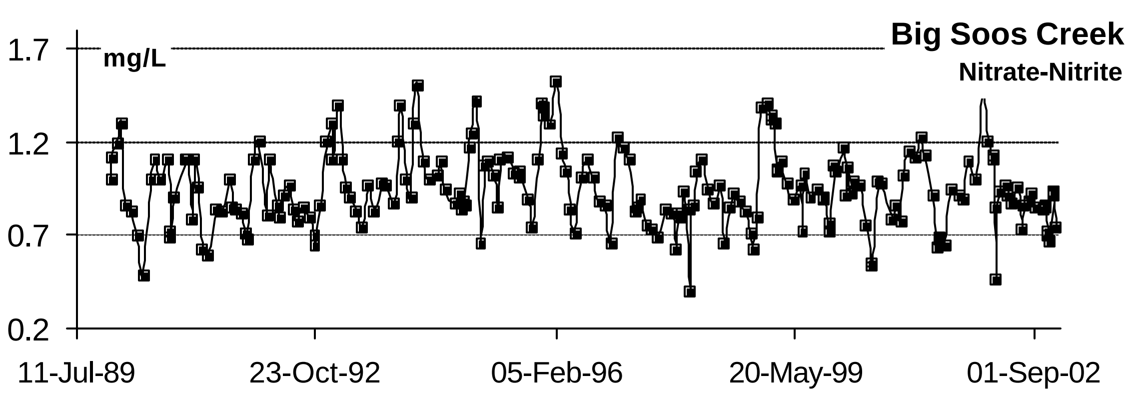


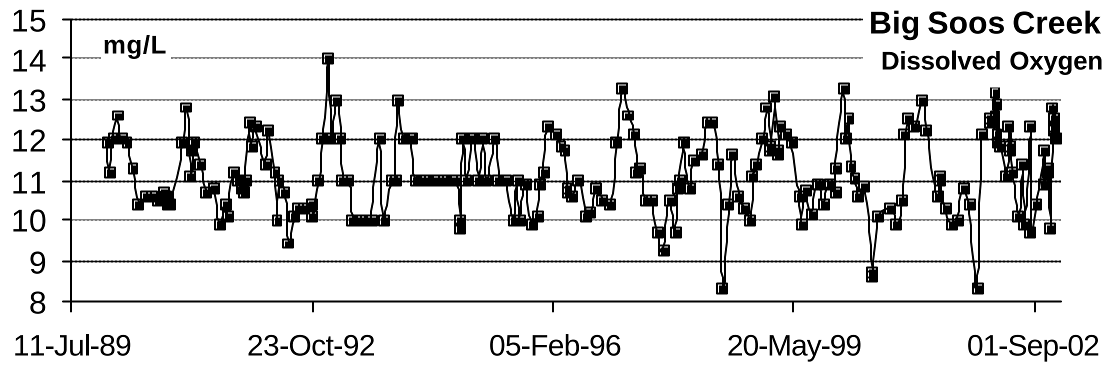
Water quality constituent data were provided from 1990 to 2002.

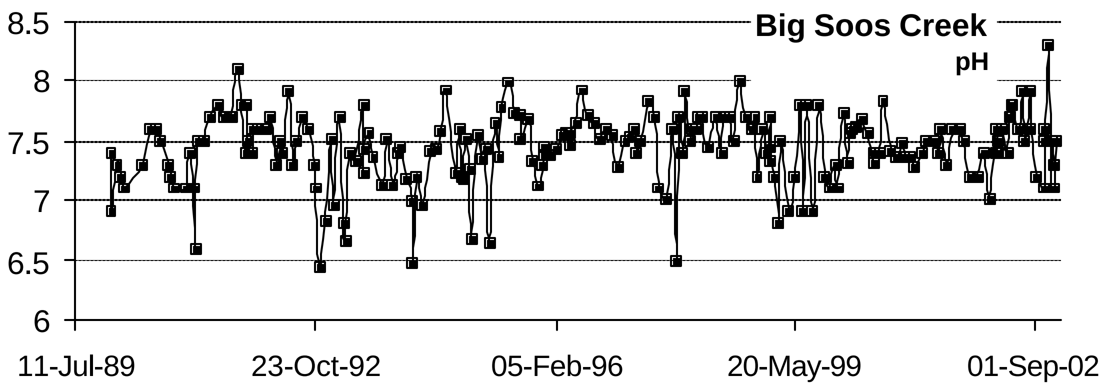


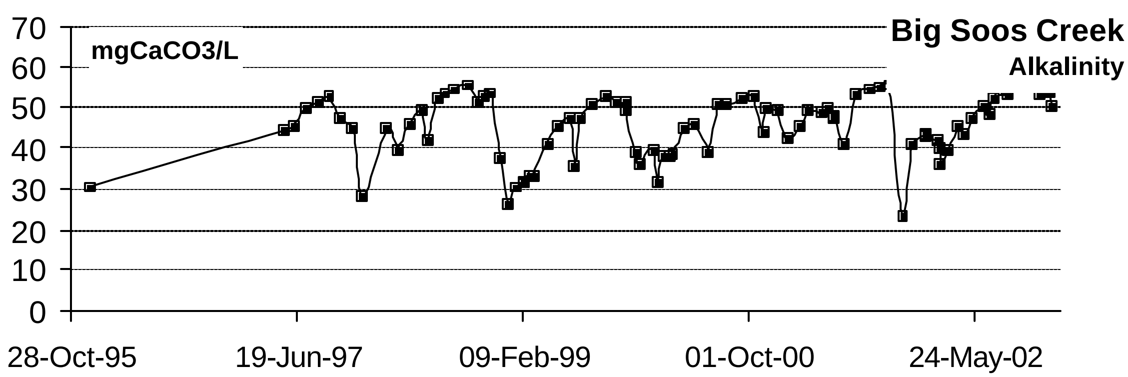


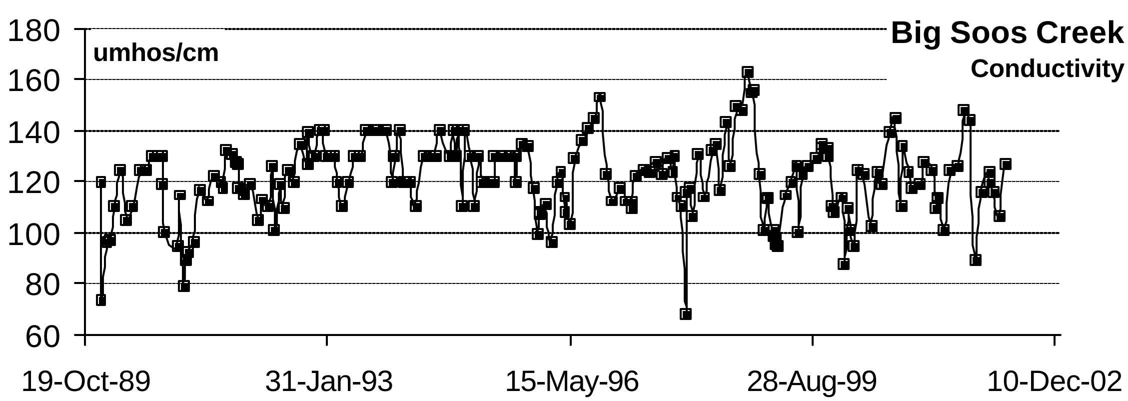


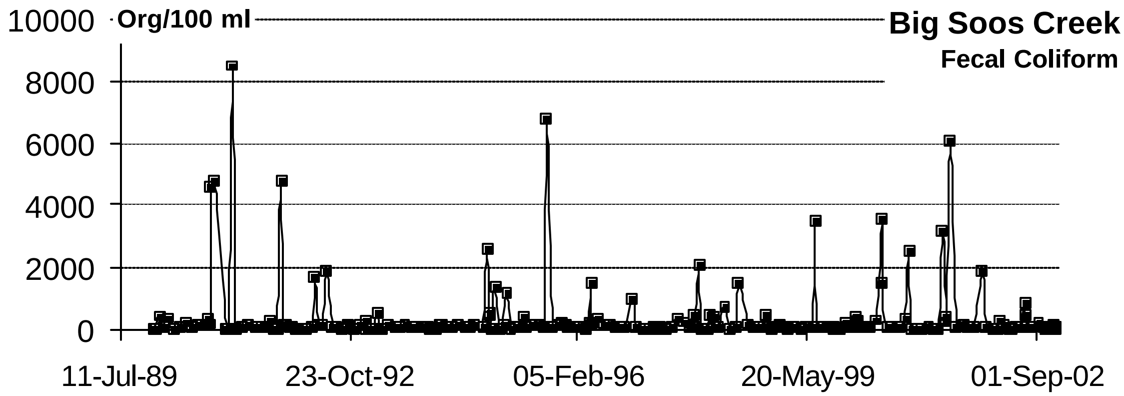


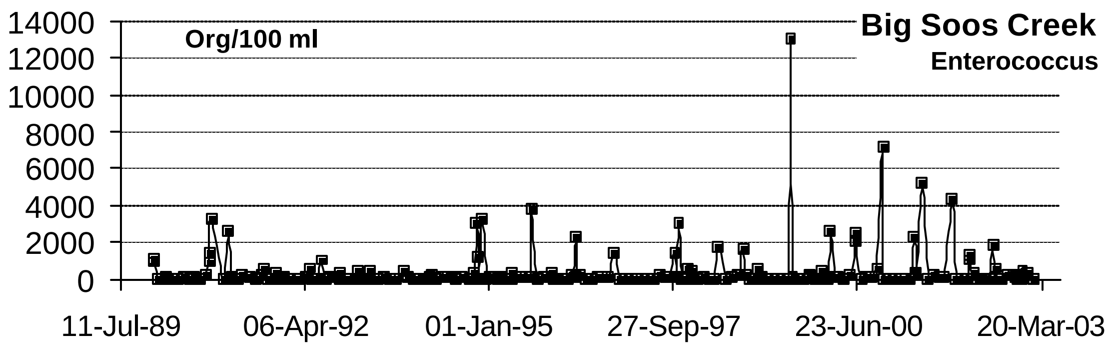

Big Soos Creek
Dissolved Oxygen
mg/L
15
14
13
12
11
10
9
8
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

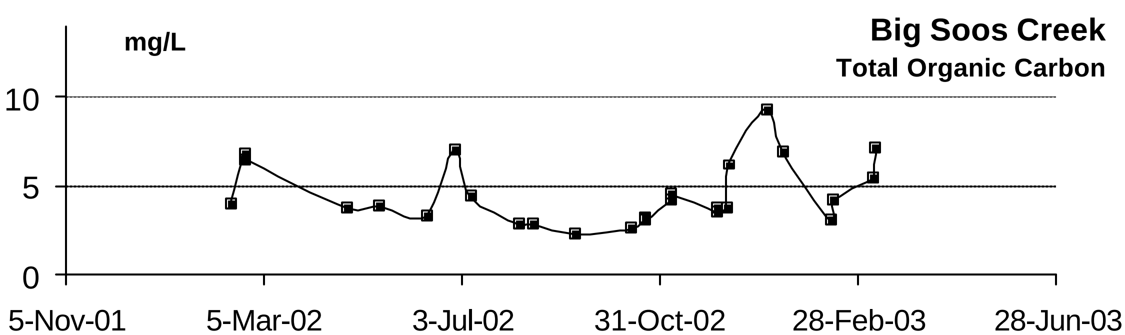

Big Soos Creek
pH
8.5
8
7.5
7
6.5
6
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

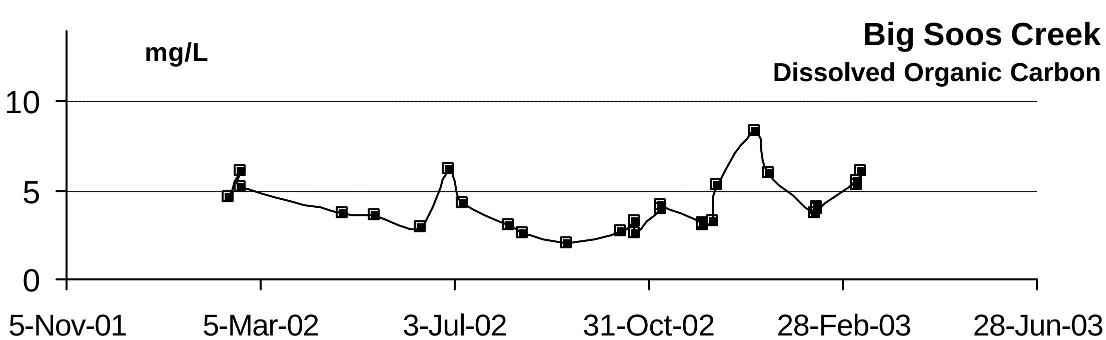

Big Soos Creek
Alkalinity
mgCaCO3/L
70
60
50
40
30
20
10
0
28-Oct-95
19-Jun-97
09-Feb-99
01-Oct-00
24-May-02

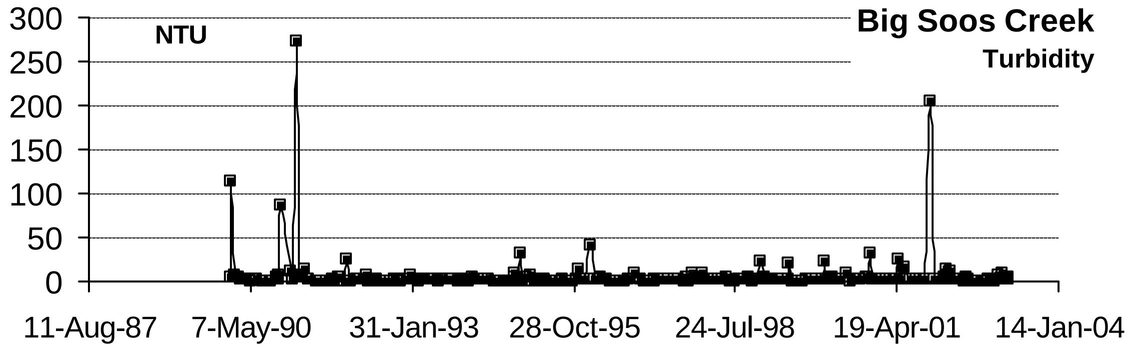

Big Soos Creek
Conductivity
umhos/cm
180
160
140
120
100
80
60
19-Oct-89
31-Jan-93
15-May-96
28-Aug-99
10-Dec-02


Big Soos Creek
Fecal Coliform
Org/100 ml
10000
8000
6000
4000
2000
0
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02


Big Soos Creek
Enterococcus
Org/100 ml
14000
12000
10000
8000
6000
4000
2000
0
11-Jul-89
06-Apr-92
01-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03

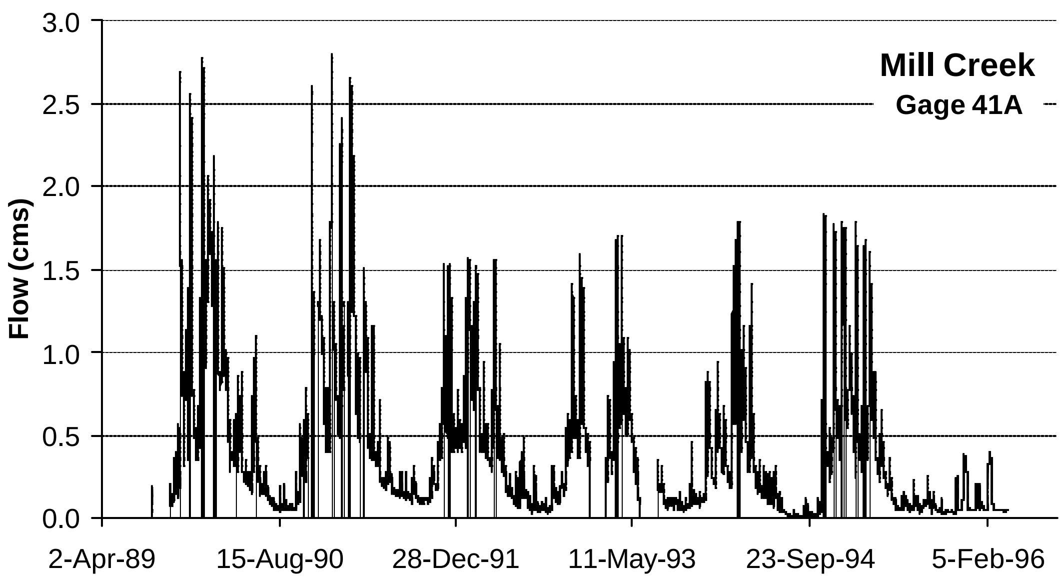

Big Soos Creek
Total Organic Carbon
mg/L
10
5
0
5-Nov-01
5-Mar-02
3-Jul-02
31-Oct-02
28-Feb-03
28-Jun-03


Big Soos Creek
Dissolved Organic Carbon
mg/L
10
5
0
5-Nov-01
5-Mar-02
3-Jul-02
31-Oct-02
28-Feb-03
28-Jun-03

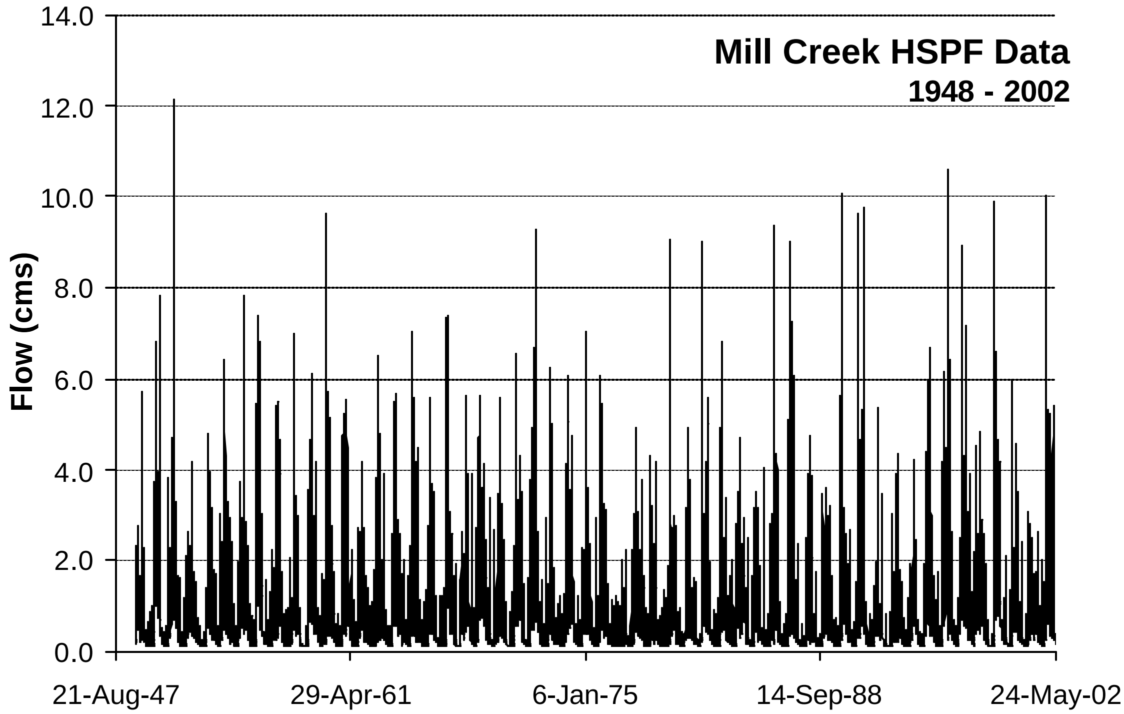


Mill Creek Data

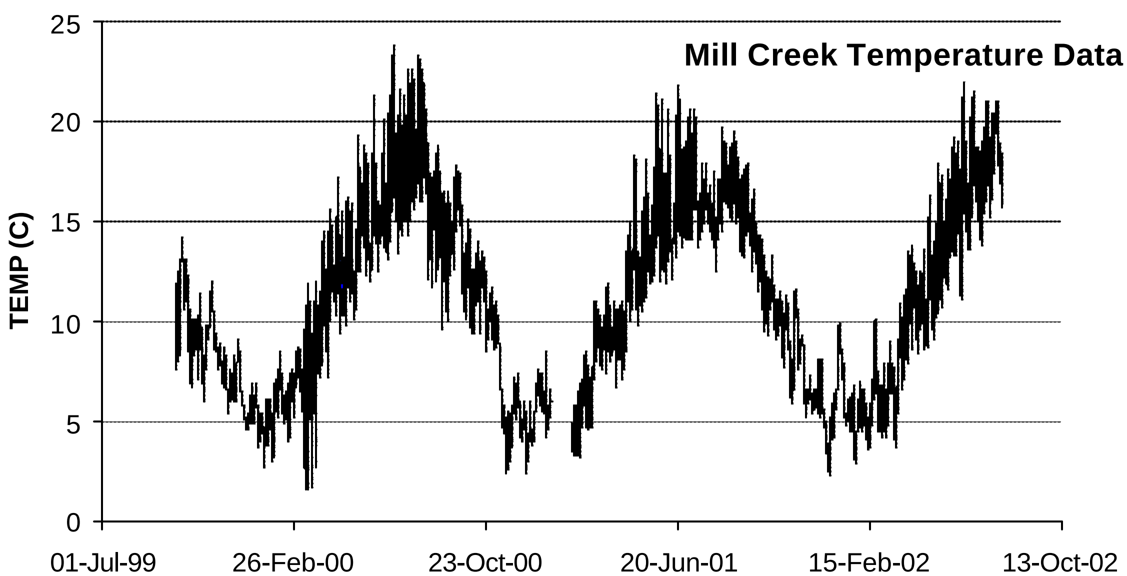
King County has a flow gage (#41a) on Mill Creek that recorded data through March 1996. Data from this gage has been determined to be unreliable because of backwater from Green River (DeGasperi 2003).



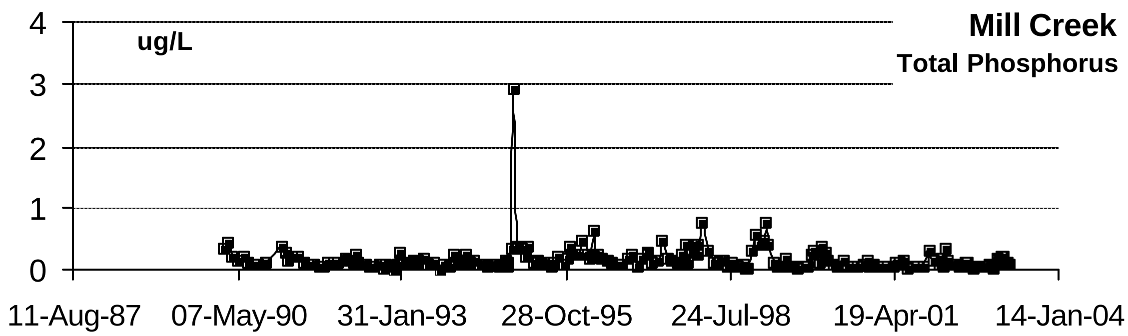
King County has modeled the Mill Creek drainage and provided daily average flow data from 1948 to 2002.

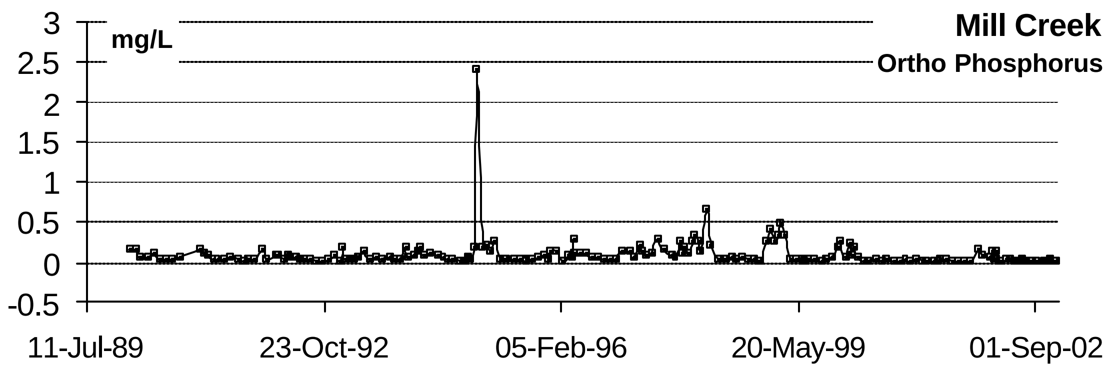


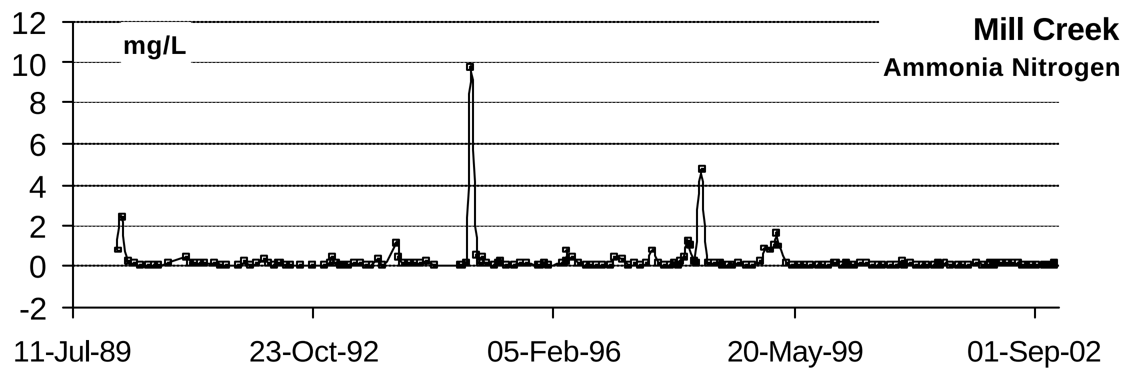
Mill Creek Temperature was recorded in 15-minute intervals by King County (41a), and data were provided from October 1999 to August 2002.

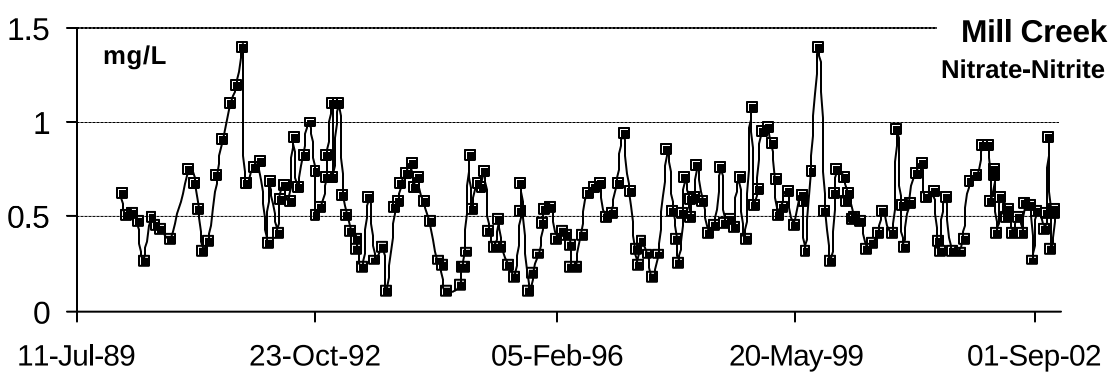


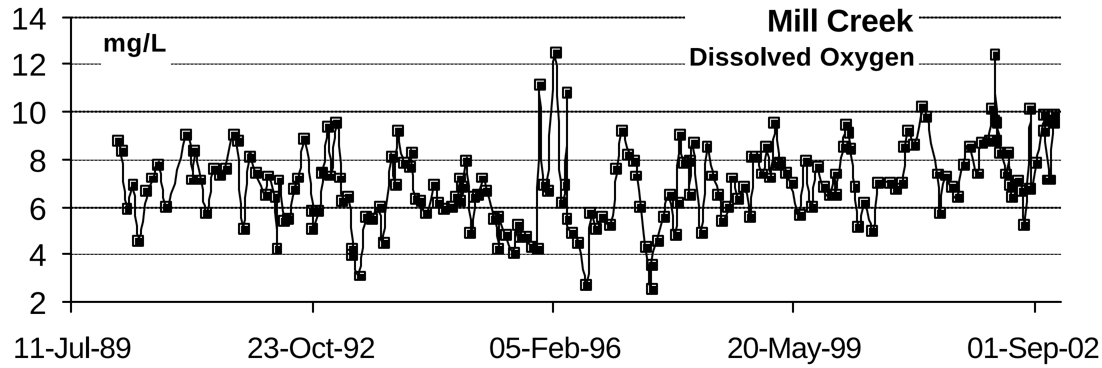
Water quality constituent data were provided from 1990 to 2002.

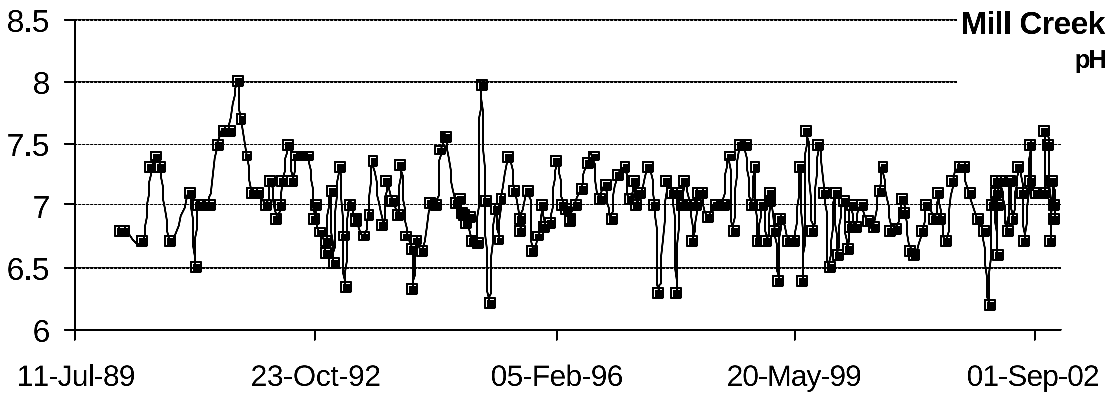

Mill Creek
Total Phosphorus
ug/L
4
3
2
1
0
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04

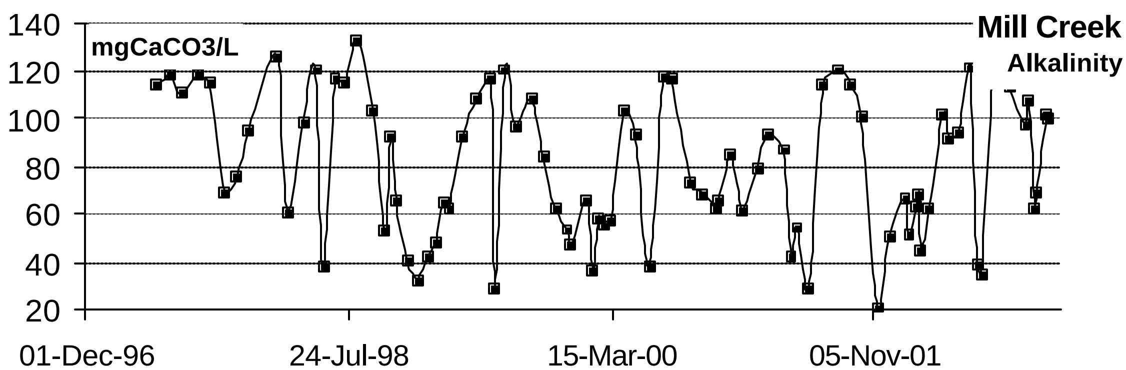

Mill Creek
Ortho Phosphorus
mg/L
3
2.5
2
1.5
1
0.5
0
-0.5
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

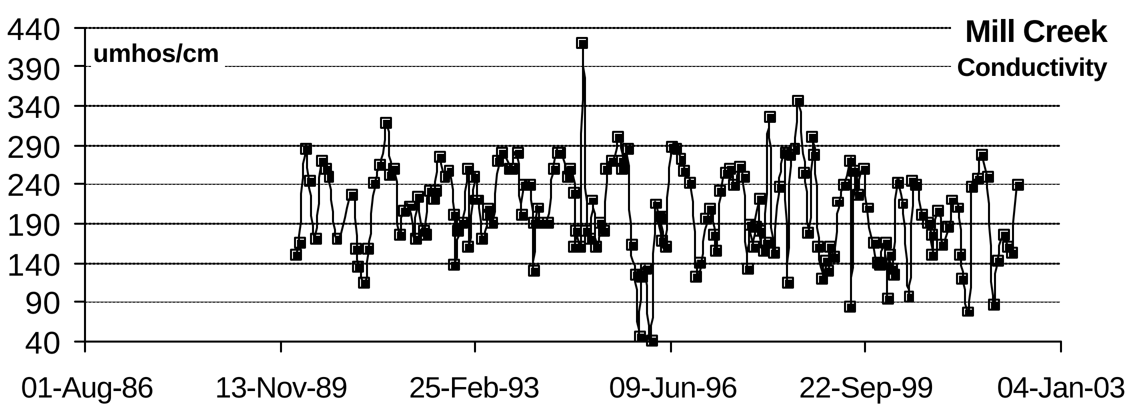

Mill Creek
Ammonia Nitrogen
mg/L
12
10
8
6
4
2
0
-2
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

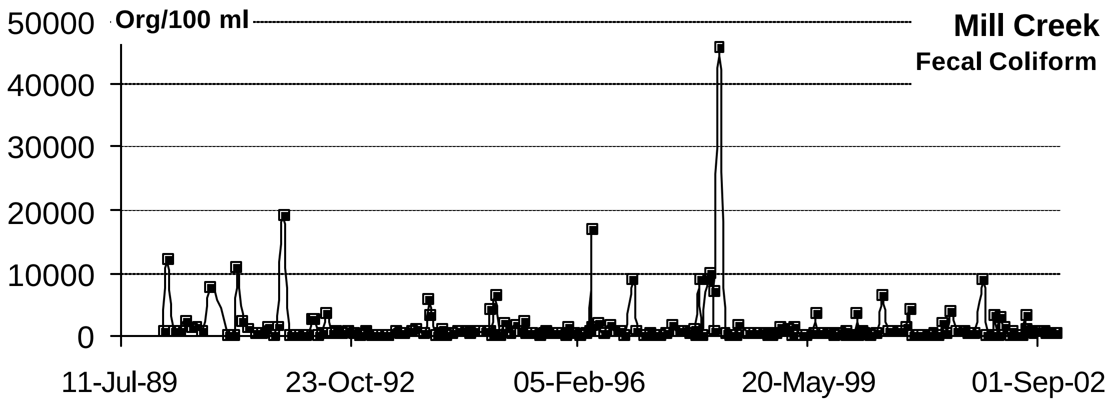

Mill Creek
Nitrate-Nitrite
mg/L
1.5
1
0.5
0
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

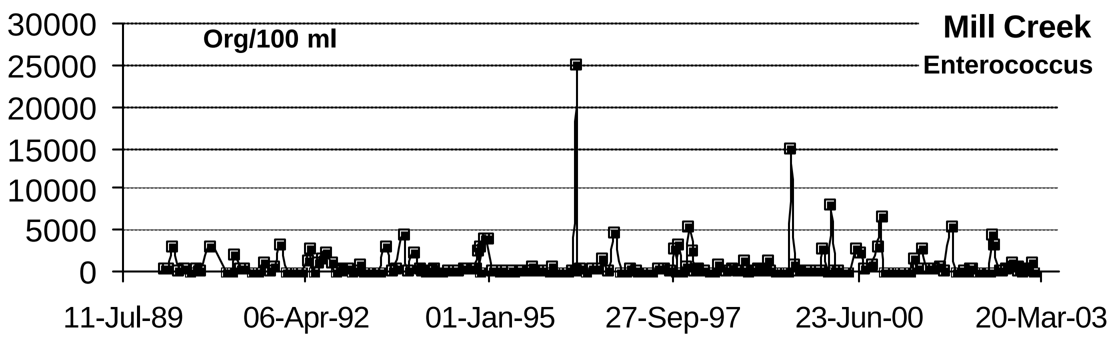

Mill Creek
Dissolved Oxygen
mg/L
14
12
10
8
6
4
2
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

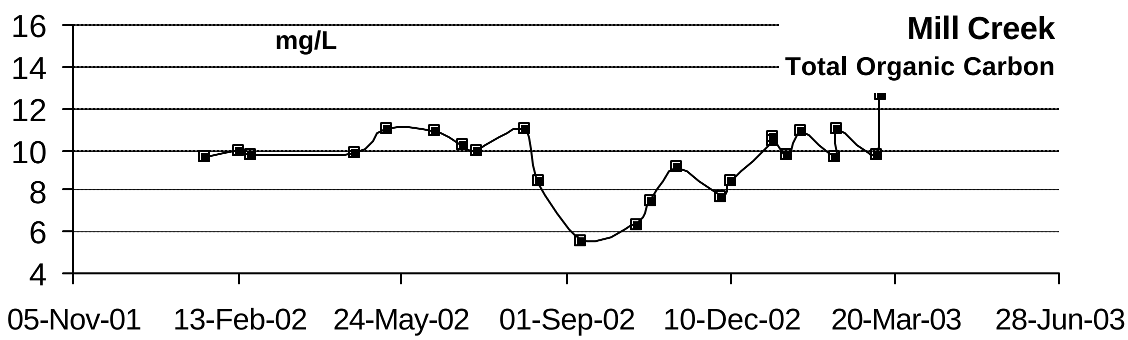

Mill Creek
pH
8.5
8
7.5
7
6.5
6
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02

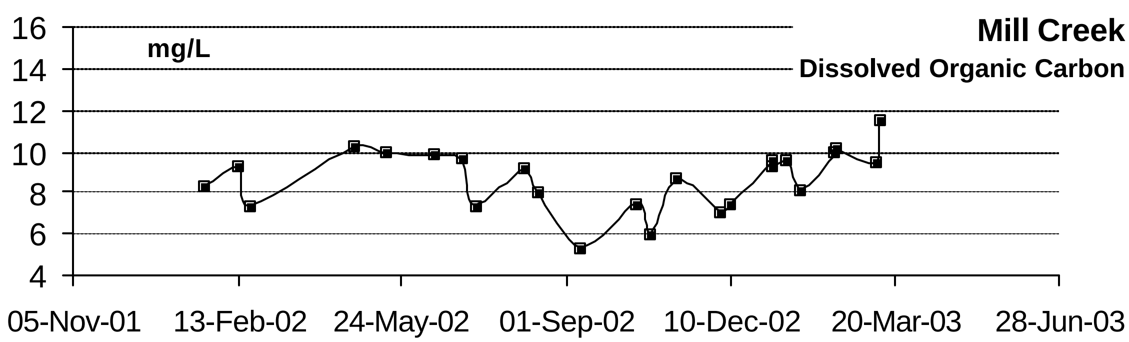

Mill Creek
Alkalinity
mgCaCO3/L
140
120
100
80
60
40
20
01-Dec-96
24-Jul-98
15-Mar-00
05-Nov-01

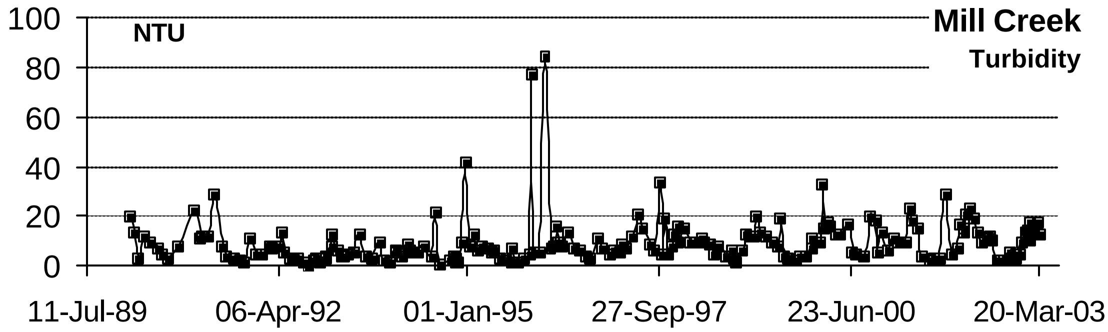

Mill Creek
Conductivity
umhos/cm
440
390
340
290
240
190
140
90
40
01-Aug-86
13-Nov-89
25-Feb-93
09-Jun-96
22-Sep-99
04-Jan-03


Org/100 ml
Mill Creek
Fecal Coliform
50000
40000
30000
20000
10000
0
11-Jul-89
23-Oct-92
05-Feb-96
20-May-99
01-Sep-02


Org/100 ml
Mill Creek
Enterococcus
30000
25000
20000
15000
10000
5000
0
11-Jul-89
06-Apr-92
01-Jan-95
27-Sep-97
23-Jun-00
20-Mar-03

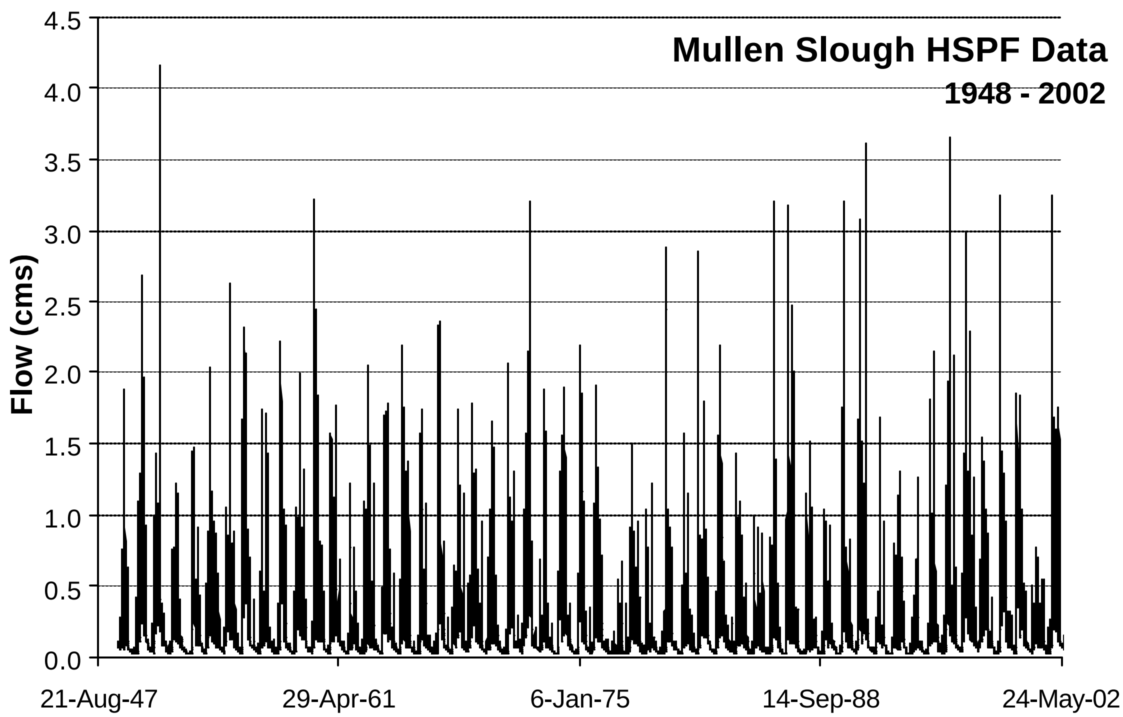

mg/L
Mill Creek
Total Organic Carbon
16
14
12
10
8
6
4
05-Nov-01
13-Feb-02
24-May-02
01-Sep-02
10-Dec-02
20-Mar-03
28-Jun-03

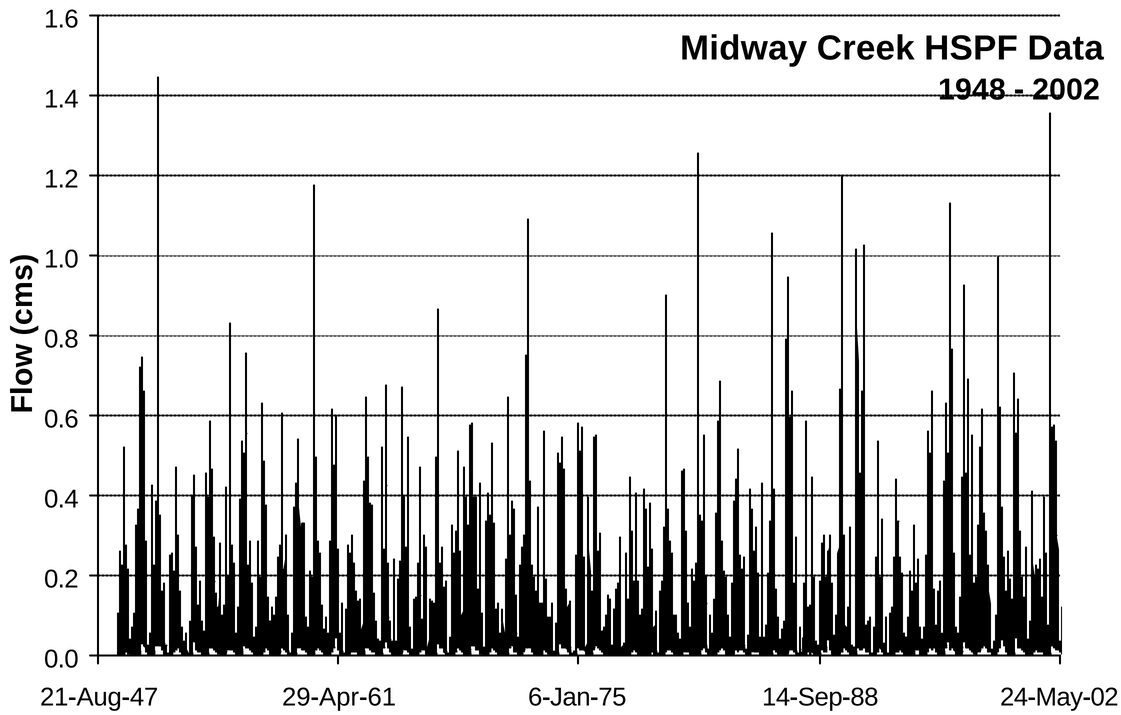

mg/L
Mill Creek
Dissolved Organic Carbon
16
14
12
10
8
6
4
05-Nov-01
13-Feb-02
24-May-02
01-Sep-02
10-Dec-02
20-Mar-03
28-Jun-03



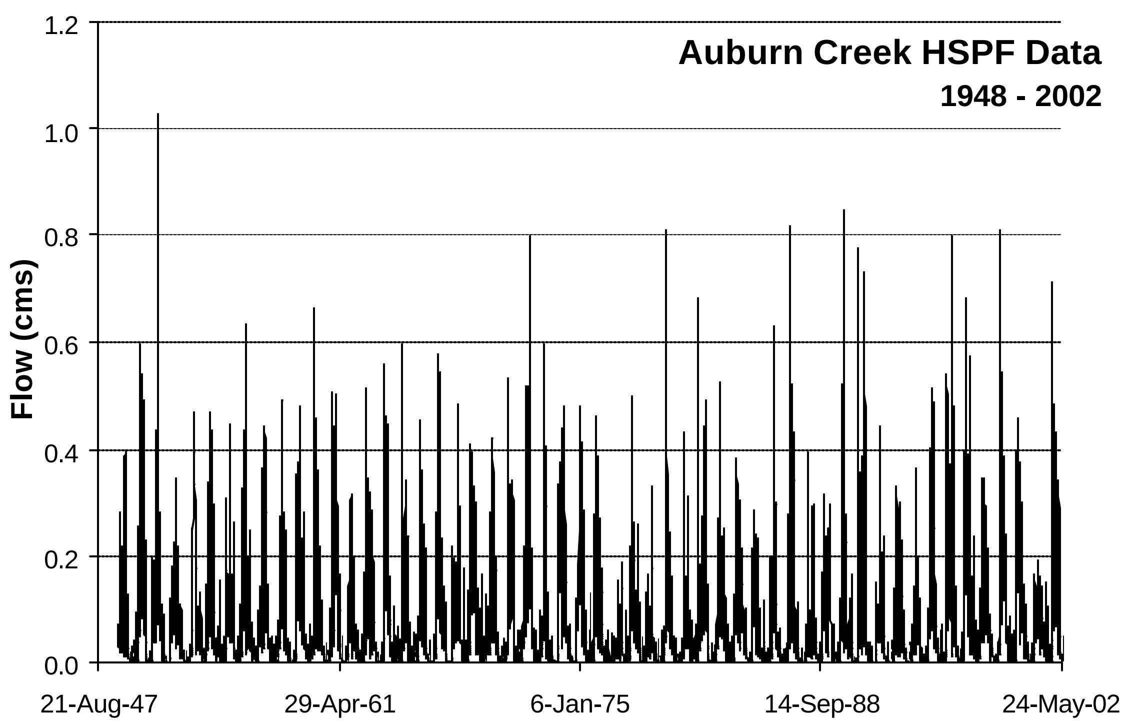
Mullen Slough, Midway Creek, and Auburn Creek

King County provided HSPF data for Mullen Slough, Midway Creek, and Auburn Creek from 1948 to 2002.



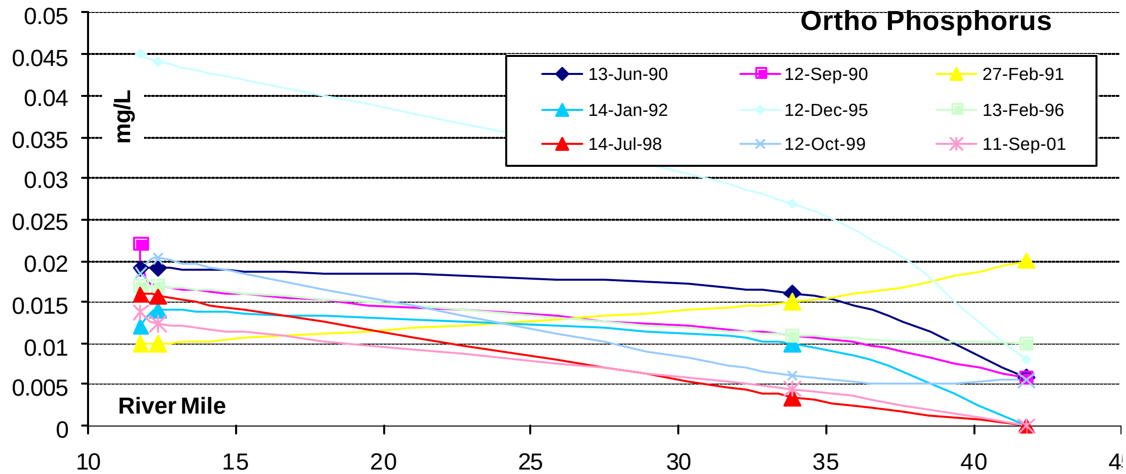


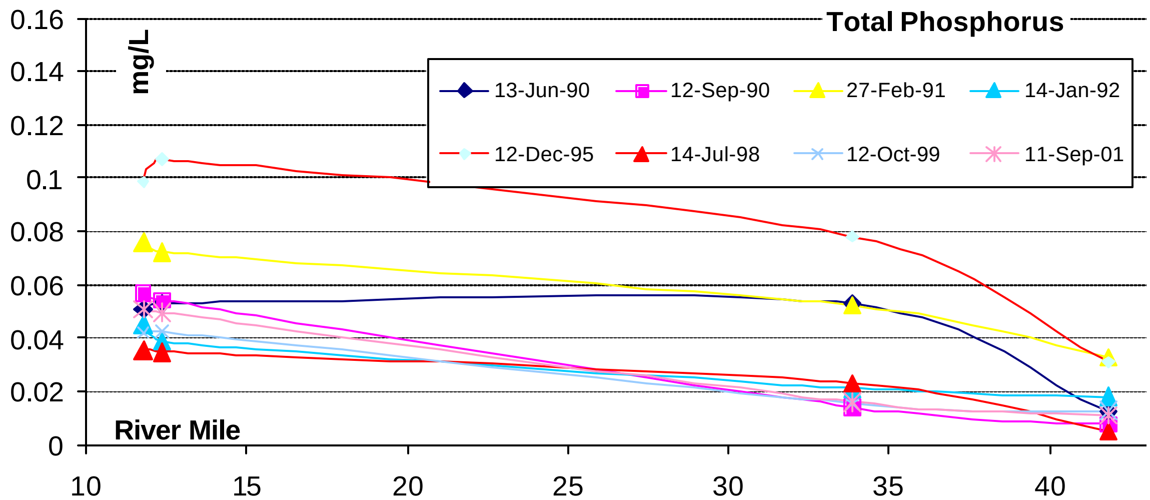
Midway Creek HSPF Data
1948 - 2002
Flow (cms)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
21-Aug-47
29-Apr-61
6-Jan-75
14-Sep-88
24-May-02

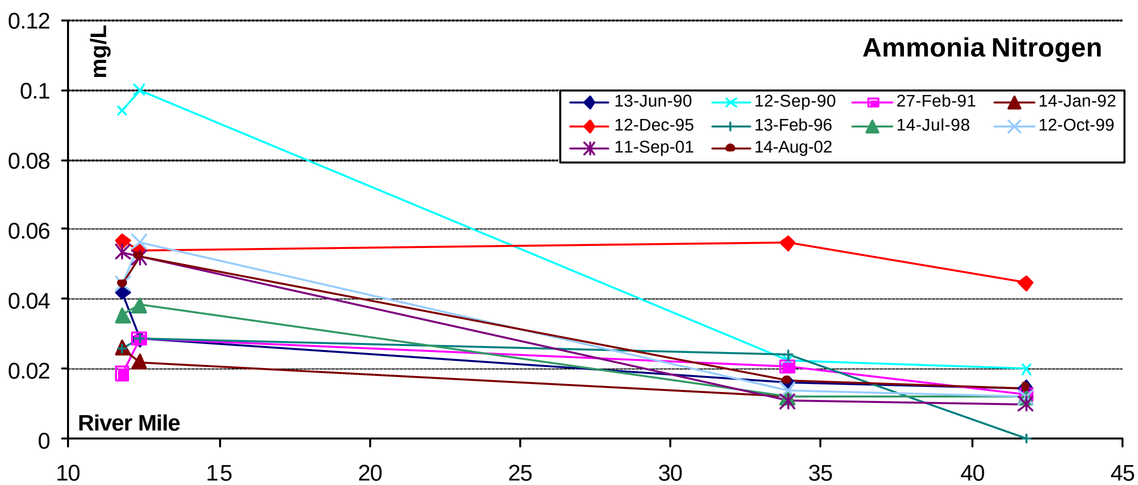


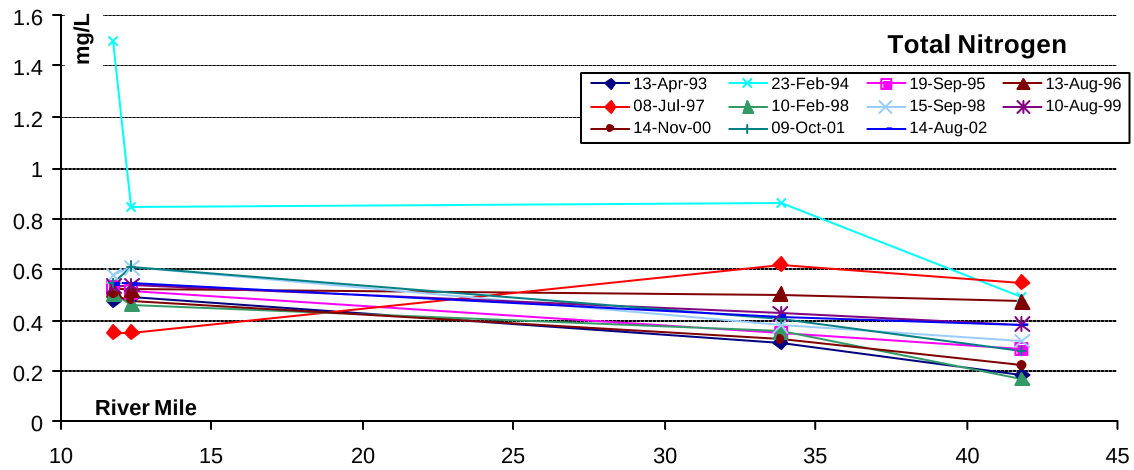
Auburn Creek HSPF Data
1948 - 2002
Flow (cms)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
21-Aug-47
29-Apr-61
6-Jan-75
14-Sep-88
24-May-02

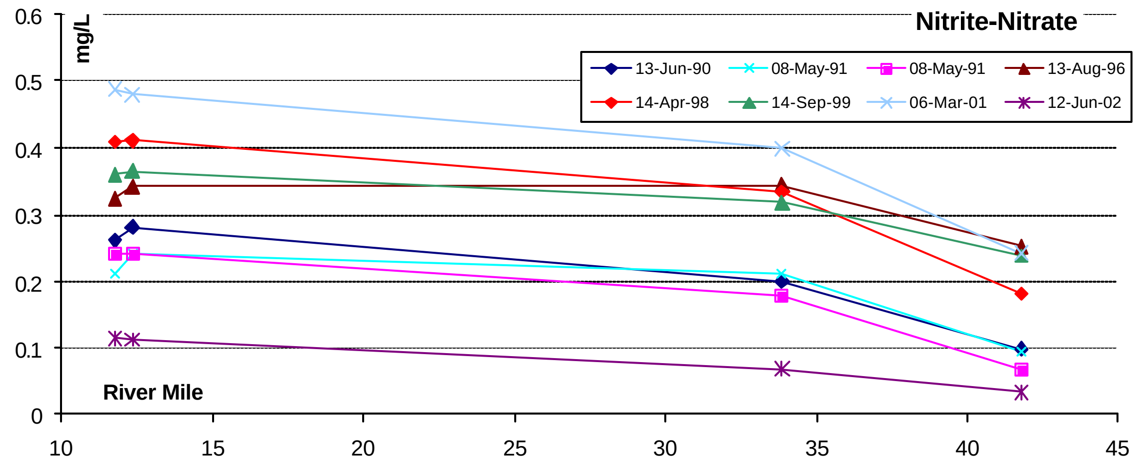
Appendix B: Water Quality Longitudinal Profiles

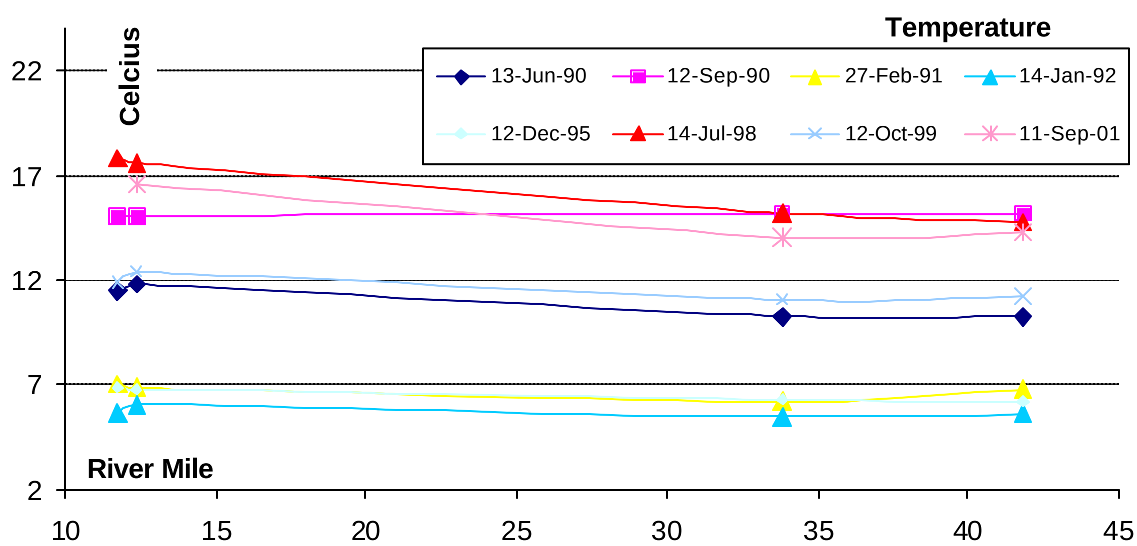


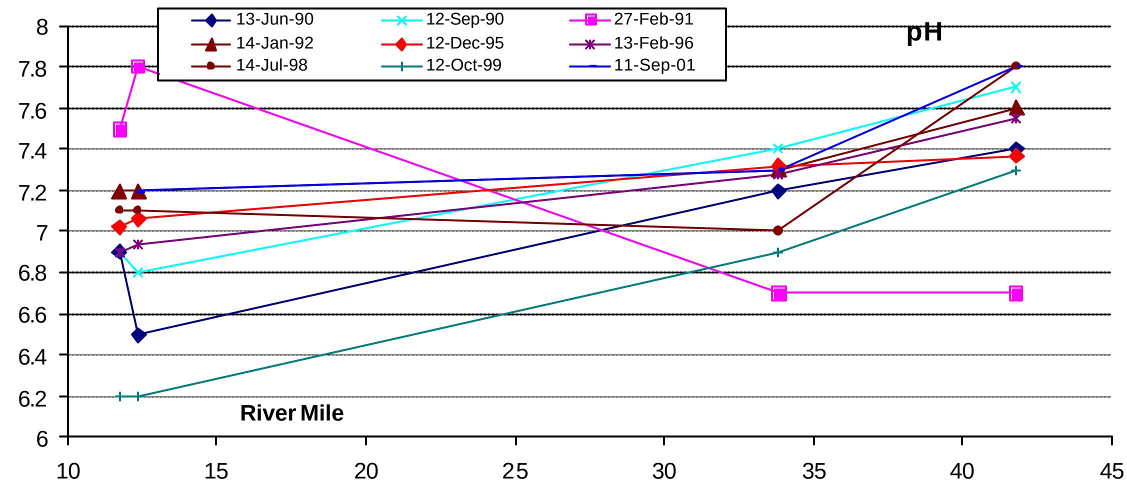


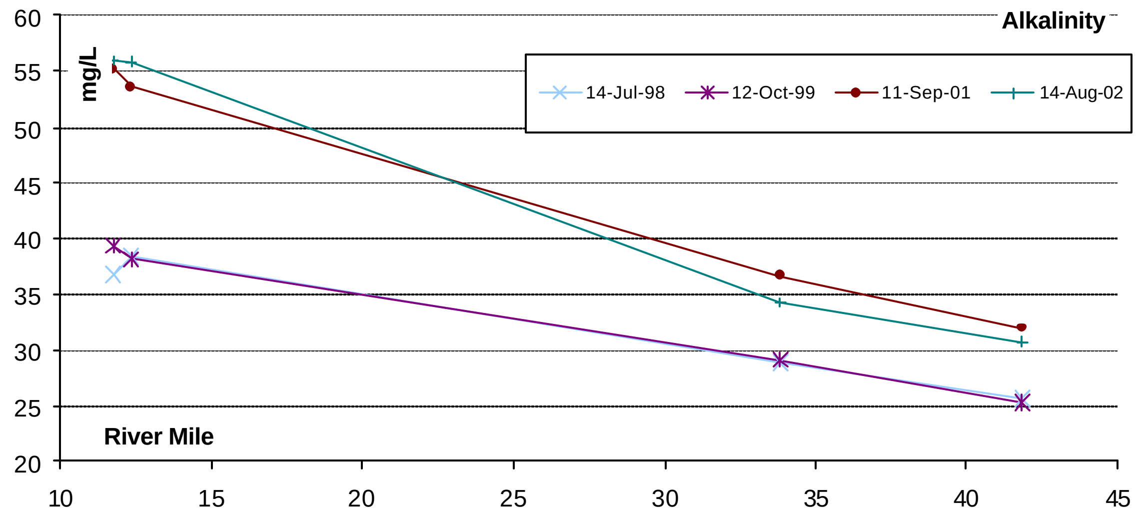


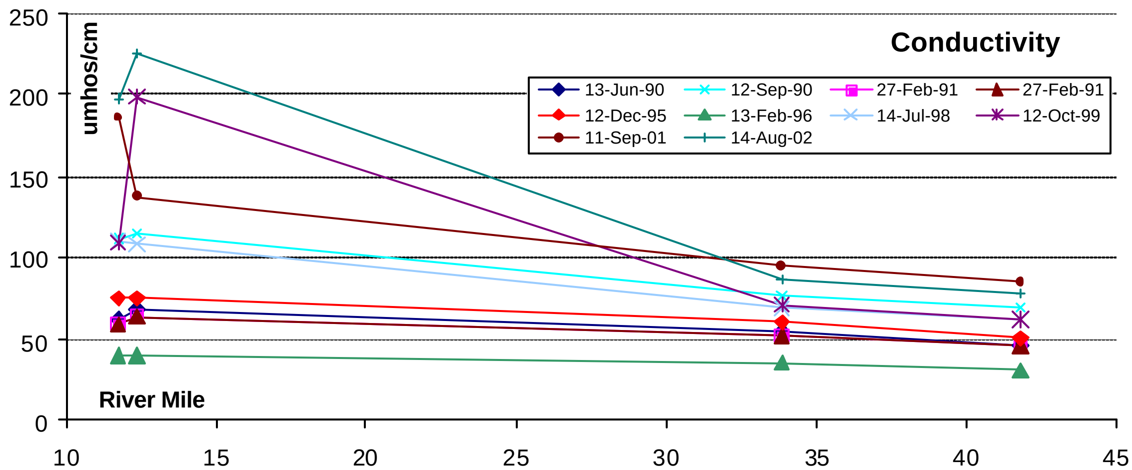

Total Nitrogen
mg/L
13-Apr-93
23-Feb-94
19-Sep-95
13-Aug-96
08-Jul-97
10-Feb-98
15-Sep-98
10-Aug-99
14-Nov-00
09-Oct-01
14-Aug-02
River Mile
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
15
20
25
30
35
40
45

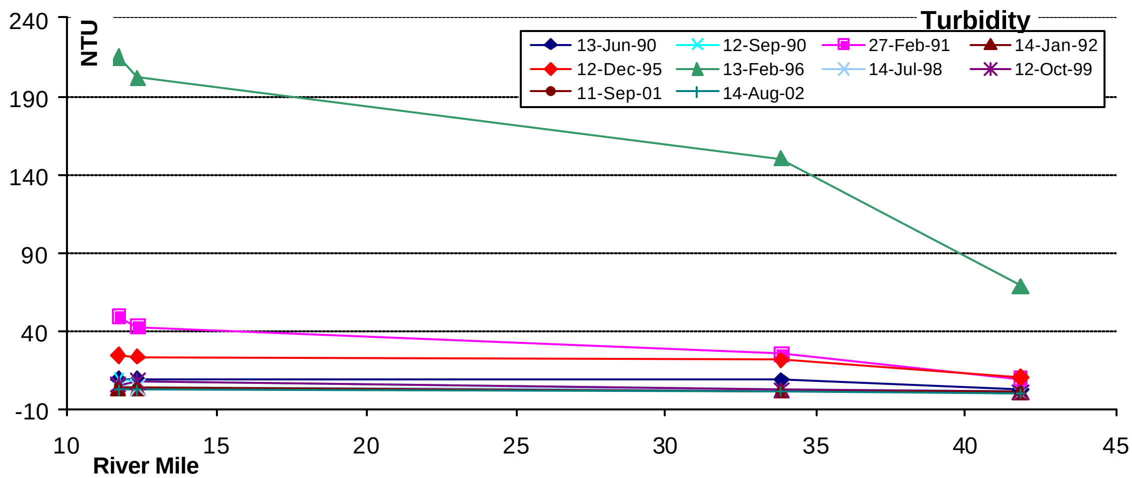

Nitrite-Nitrate
mg/L
13-Jun-90
08-May-91
08-May-91
13-Aug-96
14-Apr-98
14-Sep-99
06-Mar-01
12-Jun-02
River Mile
0.6
0.5
0.4
0.3
0.2
0.1
0
10
15
20
25
30
35
40
45

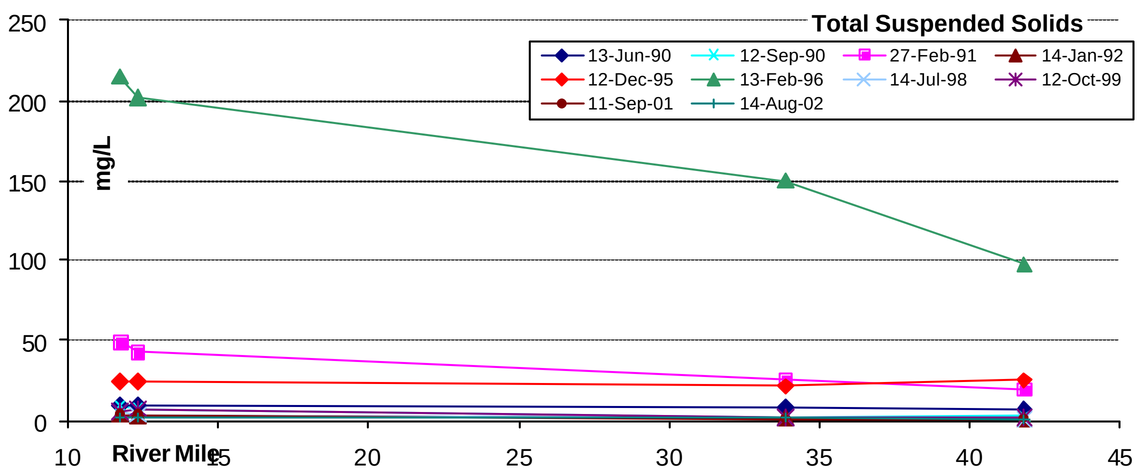

Temperature
Celcius
13-Jun-90
12-Sep-90
27-Feb-91
14-Jan-92
12-Dec-95
14-Jul-98
12-Oct-99
11-Sep-01
River Mile
22
17
12
7
2
10
15
20
25
30
35
40
45

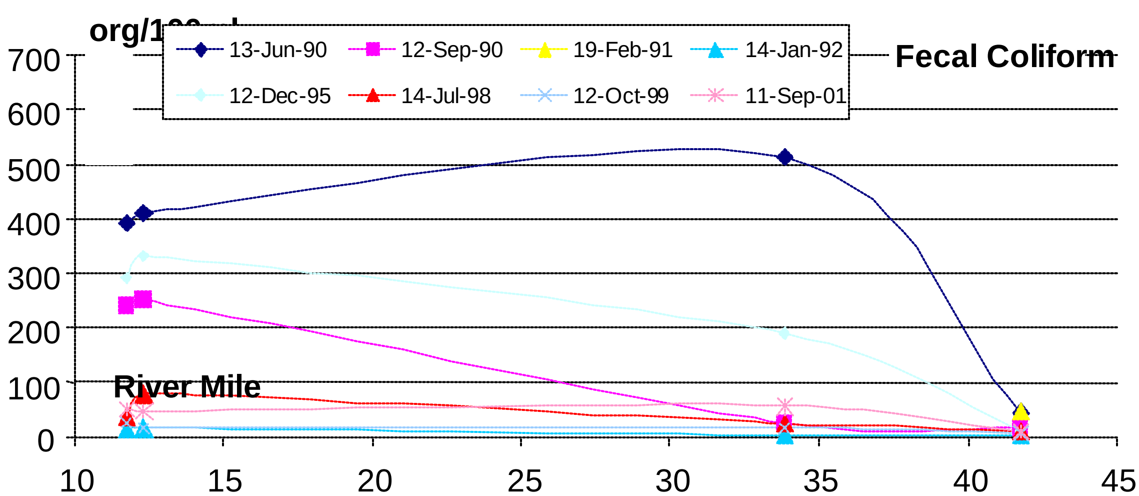

pH
13-Jun-90
12-Sep-90
27-Feb-91
14-Jan-92
12-Dec-95
13-Feb-96
14-Jul-98
12-Oct-99
11-Sep-01
River Mile
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
10
15
20
25
30
35
40
45

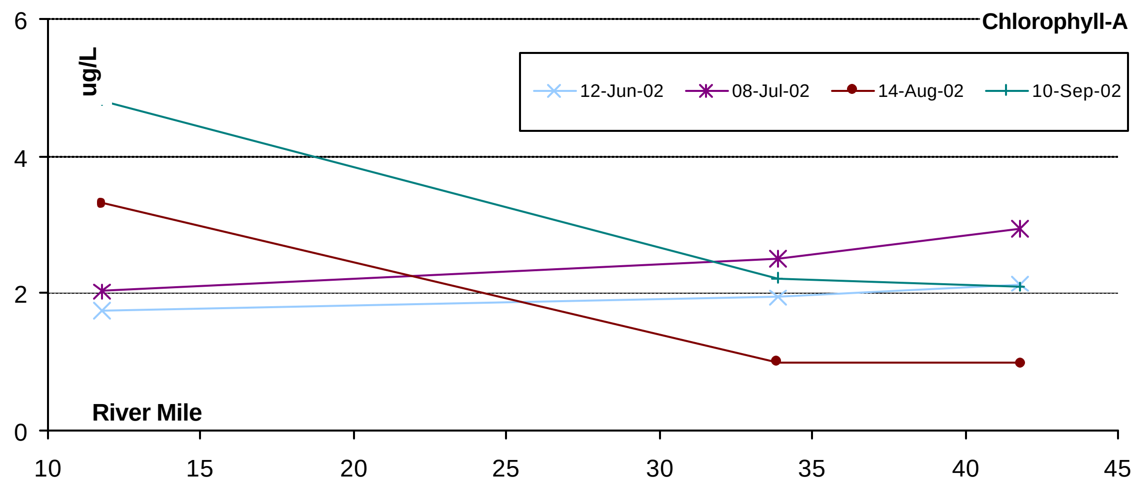

Alkalinity
mg/L
14-Jul-98
12-Oct-99
11-Sep-01
14-Aug-02
River Mile
60
55
50
45
40
35
30
25
20
10
15
20
25
30
35
40
45


Conductivity
umhos/cm
13-Jun-90
12-Sep-90
27-Feb-91
27-Feb-91
12-Dec-95
13-Feb-96
14-Jul-98
12-Oct-99
11-Sep-01
14-Aug-02
River Mile
250
200
150
100
50
0
10
15
20
25
30
35
40
45

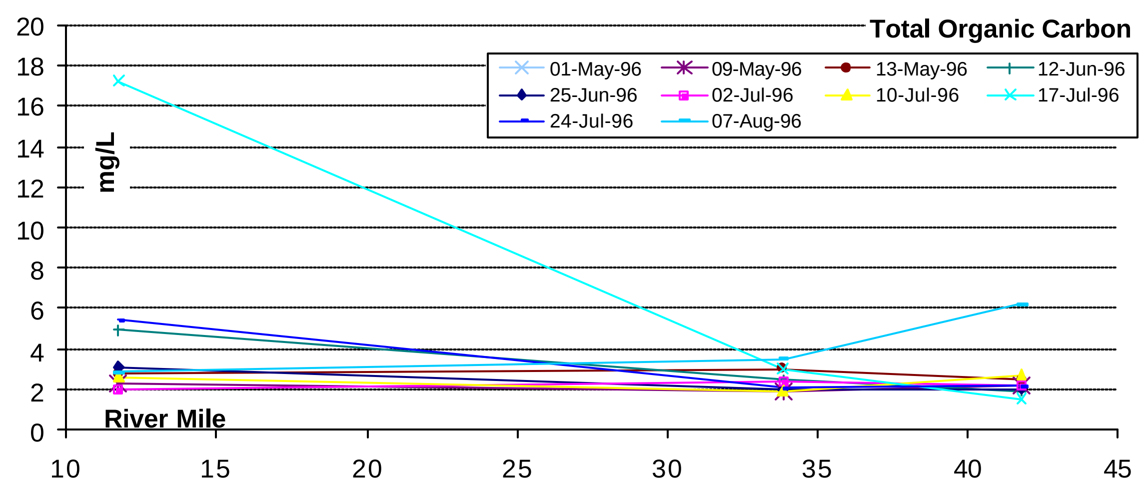

Turbidity
NTU
240
190
140
90
40
-10
10
15
20
25
30
35
40
45
River Mile
13-Jun-90
12-Sep-90
27-Feb-91
14-Jan-92
12-Dec-95
13-Feb-96
14-Jul-98
12-Oct-99
11-Sep-01
14-Aug-02


Total Suspended Solids
mg/L
250
200
150
100
50
0
10
15
20
25
30
35
40
45
River Mile
13-Jun-90
12-Sep-90
27-Feb-91
14-Jan-92
12-Dec-95
13-Feb-96
14-Jul-98
12-Oct-99
11-Sep-01
14-Aug-02

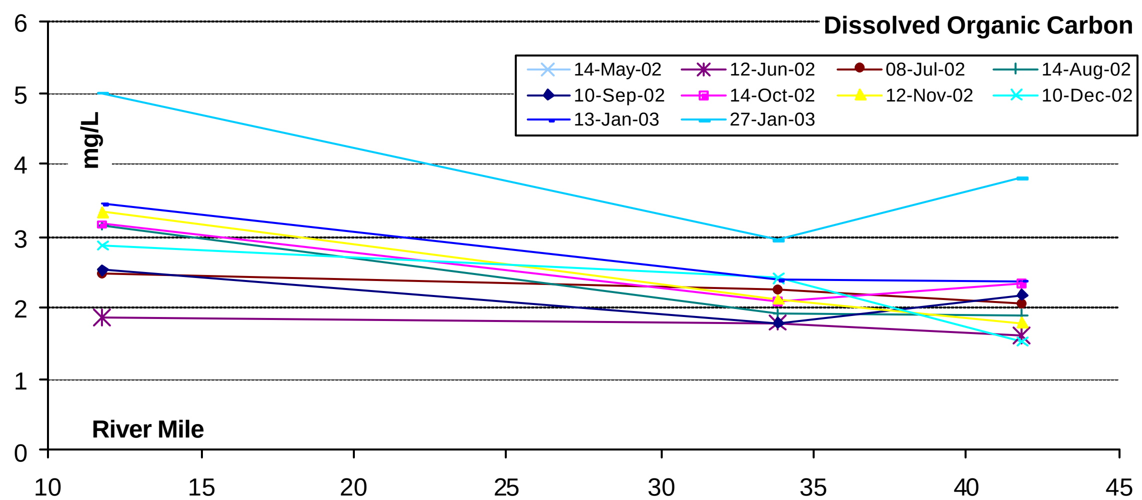

Fecal Coliform
700
600
500
400
300
200
100
0
10
15
20
25
30
35
40
45
River Mile
13-Jun-90
12-Sep-90
19-Feb-91
14-Jan-92
12-Dec-95
14-Jul-98
12-Oct-99
11-Sep-01



Chlorophyll-A
ug/L
12-Jun-02
08-Jul-02
14-Aug-02
10-Sep-02
River Mile
0
2
4
6
10
15
20
25
30
35
40
45



Total Organic Carbon
mg/L
01-May-96
09-May-96
13-May-96
12-Jun-96
25-Jun-96
02-Jul-96
10-Jul-96
17-Jul-96
24-Jul-96
07-Aug-96
River Mile
0
2
4
6
8
10
12
14
16
18
20
10
15
20
25
30
35
40
45



Dissolved Organic Carbon
mg/L
14-May-02
12-Jun-02
08-Jul-02
14-Aug-02
10-Sep-02
14-Oct-02
12-Nov-02
10-Dec-02
13-Jan-03
27-Jan-03
River Mile
0
1
2
3
4
5
6
10
15
20
25
30
35
40
45

Appendix C: Travel Time Analysis

Flow data for the upstream boundary comes from a gage located 26 km upstream (USGS Gage 126700, near Palmer). To account for flow between the gage at Palmer and the upstream project boundary, King County hydrologists have prepared HSPF simulations of runoff from the basins tributary to the Green River between these two points. Basin MG3 and a portion of MG2 will be added to flow from the Palmer gage for a better estimate of the flow at the upstream boundary.

The flow from the Palmer gage takes time to travel down to the upstream project boundary. To estimate this time period, flow data were compared at Palmer Gage and at a USGS gage at Auburn (Gage 12113300) for two separate time periods. Figure 354 shows data from the two gages for the month of August 2002, and Figure 355 shows data for the same month, with the Palmer gage shifted ahead by 12 hours. Figure 356 and Figure 357 compares data from the same time and data shifted 12 hours for May, 2002

The distance from the Palmer gage to the Auburn gage is 47 km, and the distance from the Palmer gage to the upstream boundary is 26 km, a little over half the distance to the Auburn gage. To account for this travel time, data from the Palmer gage will be shifted by six hours when used at the upstream boundary.

The distance from the Palmer gage to the Auburn gage is 47 km, and the distance from the Palmer gage to the downstream end of Basin MG3 is 15 km, one-third of the distance to the Auburn gage. Therefore, when adding flows from Basin MG3, Flow from MG3 will be shifted by four hours.

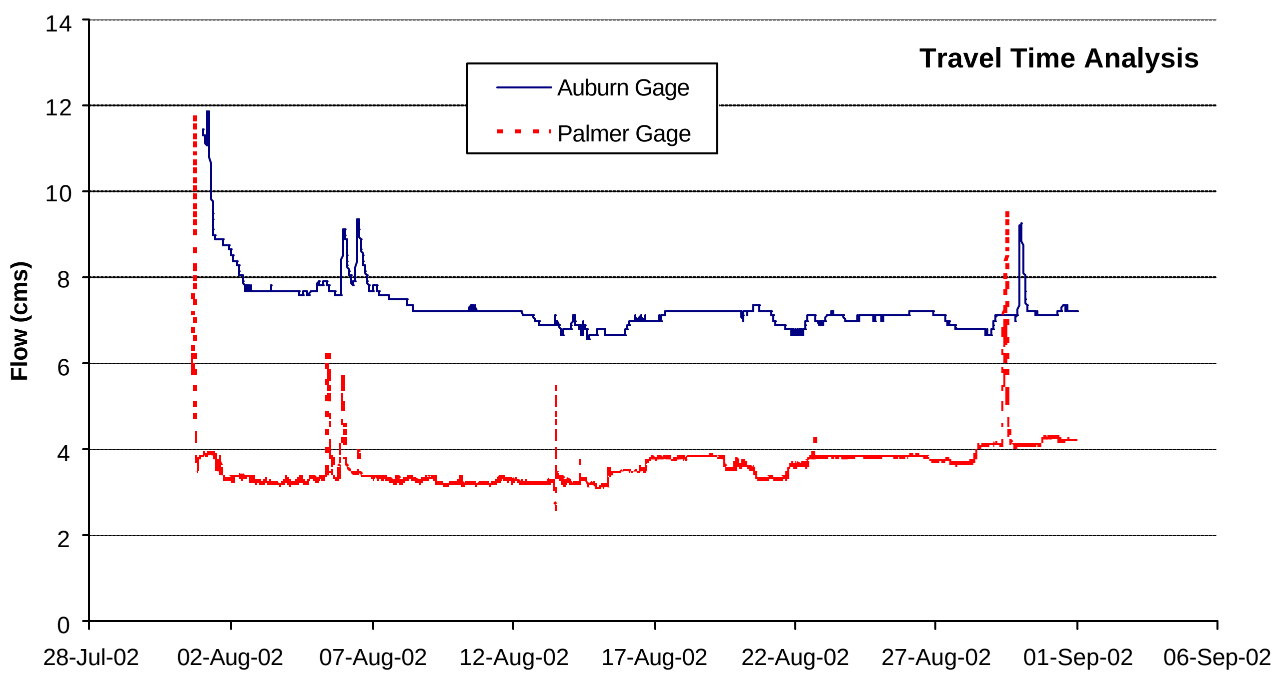


Figure 354: August 2002 flow data without travel time shift

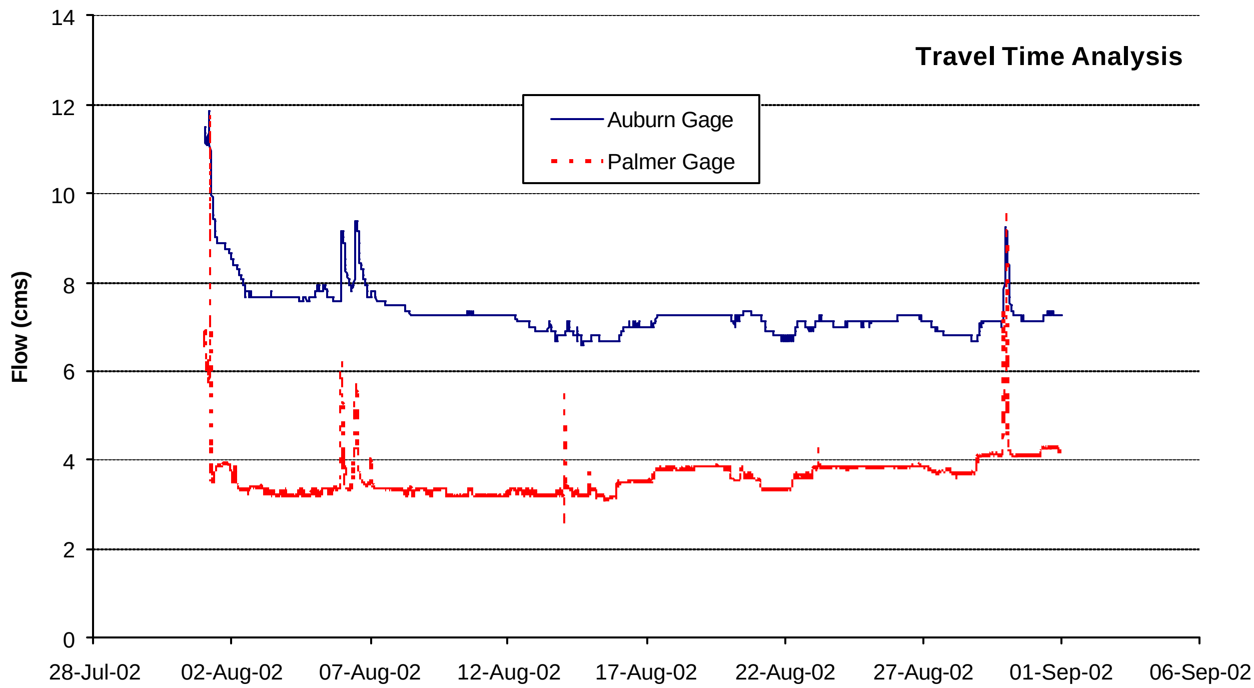


Figure 355: August 2002 flow data shifted by 12 hours

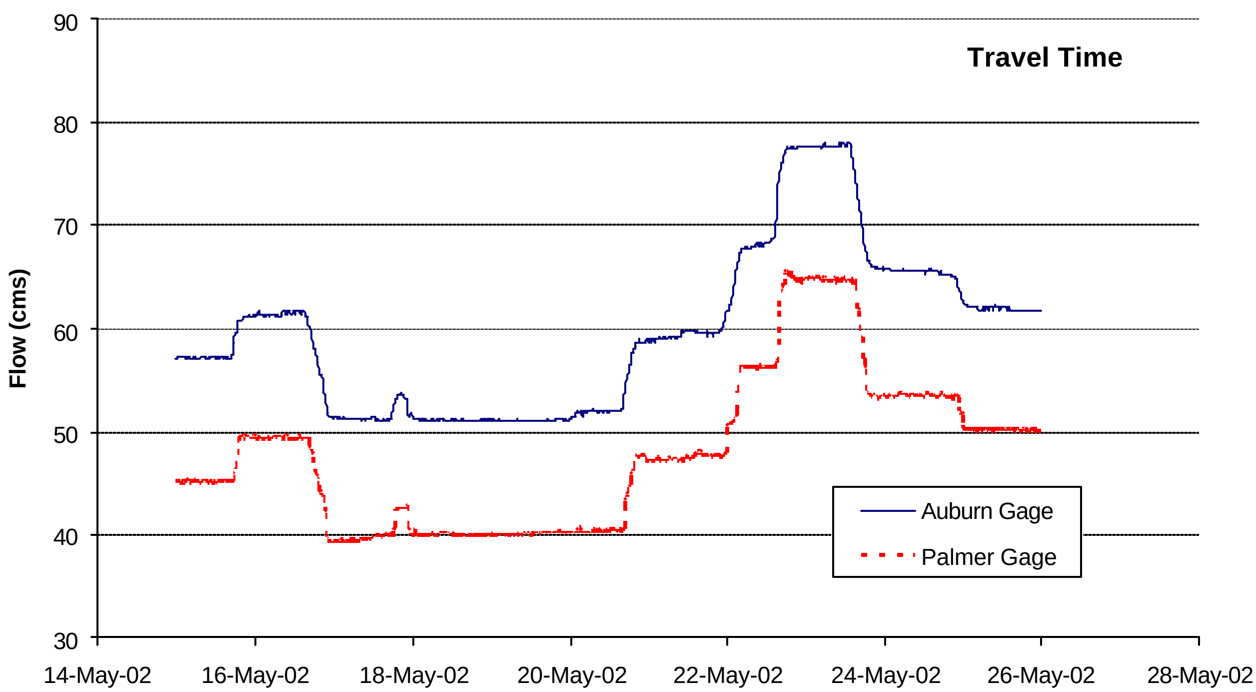


Figure 356: May 2002 flow data without travel time shift

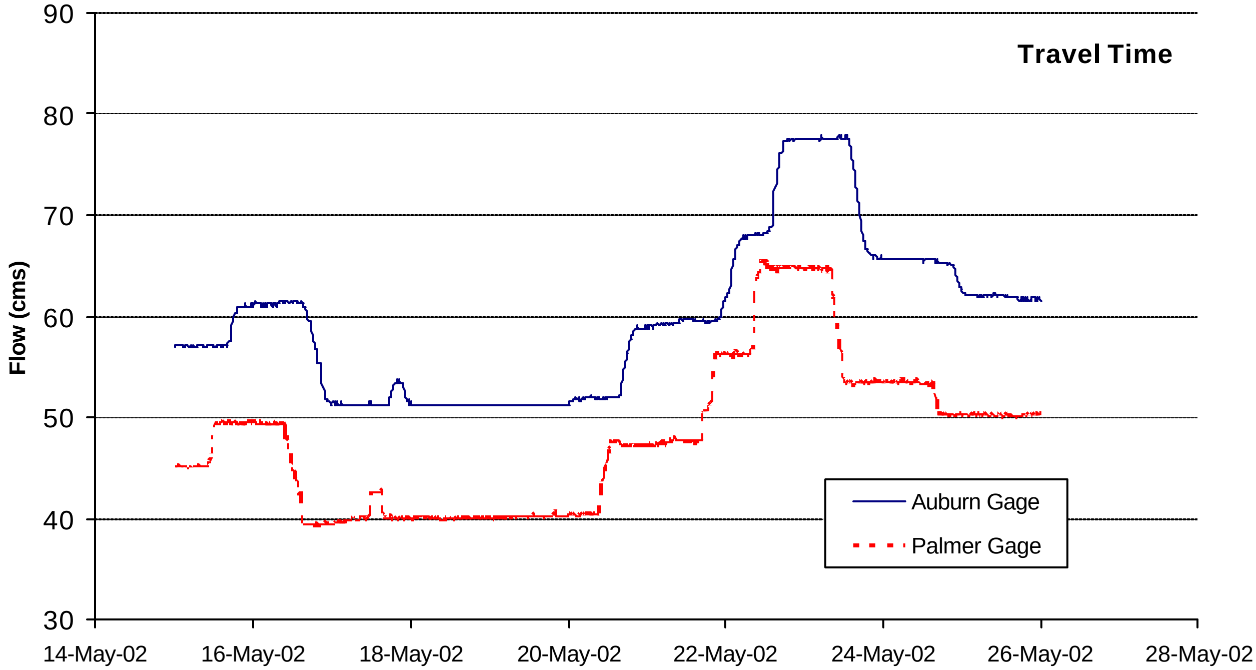


Figure 357: May 2002 flow data shifted by 12 hours

Appendix D: Water Quality Procedures

These water quality procedures were used in initial data setup and were revised as necessary during model calibration. Please see Section 4.0 for additional information.

Algae:

If data are available:

$$\sum \Phi_{a\lg ae} = \Phi_{a\lg ae(total)} = \Phi_{Chl\_a(total)} \Big/ Chla\_to\_A\lg ae\_ratio \tag{1}$$

Chla_to_Algae_Ratio = 11 and $\Phi_{Chl\_a(total)} = data$ If missing data for both model run periods, use 0.19 (Average from other stations). If some data are available, use average to fill missing data.

Total Organic Matter

If Total Organic Carbon (TOC) data were available, then:

$$\Phi_{TOM} = \frac{\Phi_{TOC}}{d_O} \tag{2}$$

$d_O = 0.45$

If TOC data were not available, then:

$$\Phi_{TOM} = \frac{\Phi_{POM} + \Phi_{a\lg ae}}{fraction} \tag{3}$$

Where fraction = 0.45

Detritus:

If Total Organic Carbon (TOC) data were available, then:

$$\Phi_{POM} = frac(\Phi_{TOM}) - \sum \Phi_{a\lg ae} \tag{4}$$

$$f = \frac{\Phi_{POM} + \sum \Phi_{a\lg ae}}{\Phi_{TSS}} \tag{5}$$

If TOC data were not available, then:

$$\Phi_{POM} = f(\Phi_{TSS}) - \sum \Phi_{a\lg ae} \tag{6}$$

Where TOC was not available, an average f was used from dates where TOC was available.

ISS:

$$\Phi_{ISS} = \left(\Phi_{TSS} - \sum \Phi_{a\lg ae} - \Phi_{POM}\right) \text{ or } \Phi_{ISS} = (1 - f)(\Phi_{TSS}) \qquad \textbf{(7)}$$

Dissolved Organic Matter (DOM)

$$\Phi_{DOM} = \Phi_{TOM} - \Phi_{POM} \qquad \textbf{(8)}$$

Labile DOM

$$\Phi_{LDOM} = f_{LDOM}\Phi_{DOM} \qquad \textbf{(9)}$$

$$f_{LDOM} = 0.50$$

Refractory DOM

$$\Phi_{RDOM} = (1 - f_{LDOM})\Phi_{DOM} \qquad \textbf{(10)}$$

Labile POM

$$\Phi_{LPOM} = f_{LPOM}\Phi_{POM} \qquad \textbf{(11)}$$

$$f_{LPOM} = 0.5$$

Refractory POM

$$\Phi_{RPOM} = (1 - f_{LPOM})\Phi_{POM} \qquad \textbf{(12)}$$

Total Organic Phosphorus

$$\Phi_{PO4-P} = \Phi_{PO4} \qquad \textbf{(13)}$$

If no data then $\Phi_{PO4} = \frac{\sum_{j=1}^{n} \Phi_{PO4-data}}{n}$ for all n data points. PO4 represents Dissolved Ortho Phosphorus. If not available then Ortho Phosphorus.

Nitrogen

$$\Phi_{TKN} = \Phi_{NH4} \qquad \textbf{(14)}$$

If no data exists for that time then $\Phi_{NH4} = \frac{\sum_{j=1}^{n} \Phi_{NH4-data}}{n}$ for all n data points. NH4 represents NH3-N Dissolved, if available, if not then NH3-N total.

Nitrite-Nitrate

$\Phi_{NO3+NO2} = data$, if missing interpolate with nearest two points

Total Inorganic Carbon

$\Phi_{TIC} = function(\Phi_{alk} + pH + Temp)$ and is solved from the following equation:

$\Phi_{Alk} = TIC(a_1 + 2a_2) + [OH^-] - [H^+]$

where a_1 and a_2 vary and are dependent upon temperature.

Alkalinity

$\Phi_{alk} = data$, if missing interpolate with nearest two points. No data were available for 1995-1996 model run period, so the average from the 2001-2002 run period was used.

Dissolved Oxygen

$\Phi_{DO} = data$, if missing interpolate with nearest two points

Conductivity

$\Phi_{arbitray\_constituent} = Conductivity = data$, if missing interpolate with nearest two points

Fecal Coliform

$\Phi_{arbitray\_constituent} = FecalColiform = data$, if missing interpolate with nearest two points

Appendix E: Station and Gage Locations

Table 55 and Table 56 list the stations used for model boundary condition and tributary data. Figure 358, on the following page, shows where each station is located.

Table 55: Flow/Temperature/Water Quality Stations Used; May 1995 - Nov 1996

Boundary Condition/Tributary	Flow/ Stage	Temperature	Water Quality
Upstream Boundary	USGS 12106700	WHI	B319
Downstream Boundary	USGS 12113350	BIC	3106
Newaukum Creek	USGS 12108500	12108500	322
Crisp Creek	KC 40d	KC 40d	321
Big Soos Creek	USGS 12112600	KC 54a	A320
Auburn Creek	HSPF	Mill Creek	Mill Creek
Mill Creek	HSPF	KC 41a	A315
Mullen Slough	HSPF	Mill Creek	Mill Creek
Midway Creek	HSPF	Mill Creek	Mill Creek
Distributed Inflows	HSPF	NEE	Big Soos Creek

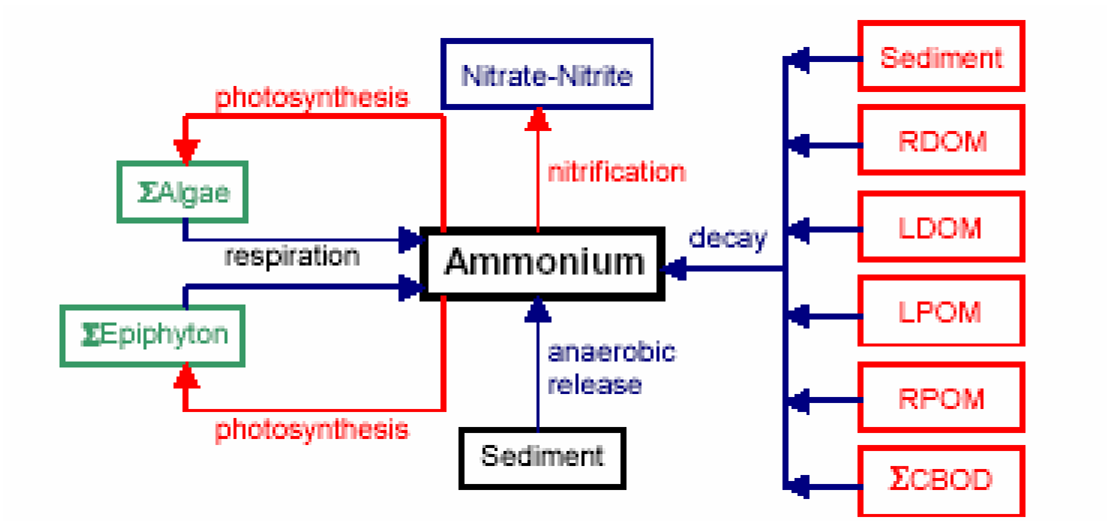
Table 56: Flow/Temperature/Water Quality Stations Used; April 2001 - July 2002

Boundary Condition/Tributary	Flow/ Stage	Temperature	Water Quality
Upstream Boundary	USGS 12106700	GR5, GR3-4, GR10	B319
Downstream Boundary	USGS 12113350	GRT18	3106
Newaukum Creek	USGS 12108500	GDWQA GRT-09	322
Crisp Creek	KC 40d	KC 40d	321
Big Soos Creek	USGS 12112600	KC 54a	A320
Auburn Creek	HSPF	Mill Creek	Mill Creek
Mill Creek	HSPF	KC 41a	A315
Mullen Slough	HSPF	Mill Creek	Mill Creek
Midway Creek	HSPF	Mill Creek	Mill Creek
Distributed Inflows	HSPF	GRT04	Big Soos Creek

Figure 358: Data Monitoring Stations

Appendix F: Organic Matter Contributions Calculated from Ammonia Nitrogen

For the 2001-2002 model run period initial organic matter model inputs were determined by estimation from two Total Organic Carbon samples from the summer of 2002 (See Appendix D). During model calibration the amount of organic matter in the system was calculated from its contribution to ammonia nitrogen. Figure 359 shows the sources and sinks to Ammonium. CE-QUAL-W2 will output the contributions from each source/sink to a time-series output file. To estimate the amount of organic matter in the system, all values were output except organic matter values. These outputs were subtracted from the total ammonium to estimate the organic matter. This calculation was performed at each date that sampled data were available for input into the model. It was then partitioned between dissolved and particulate organic matter, and used as data input at the upstream boundary.



SOURCE: Cole (2002)

Figure 359: Ammonium Sources and Sinks

Appendix G: W2 Control File For 2001-2002 Model Run Period

```
W2 Model Version 3.1

TITLE C ..............................TITLE.....................................
        Green River - April 1, 2001 through July 31, 2002
        River with 5 branches and 3 water bodies
        Default hydraulic and kinetic coefficients
        Scott Wells, Chris Berger, Rob Annear, PSU
        Tom Cole, WES




GRID         NWB     NBR     IMX     KMX
               3       5     227      22

IN/OUTFL     NTR     NST     NIW     NWD     NGT     NSP     NPI     NPU
               7       0       0       0       0       0       0       0

CONSTITU     NGC     NSS     NAL     NEP    NBOD
               2       1       1       0       0

MISCELL     NDAY

             100

TIME CON  TMSTRT   TMEND    YEAR
          91.000 578.000    2001

DLT CON      NDT  DLTMIN
               1 1.00000

DLT DATE    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD
         91.0000

DLT MAX   DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX
         200.000

DLT FRN     DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF
         0.80000

DLT LIMI    VISC    CELC
WB 1          ON      ON
WB 2          ON      ON
WB 3          ON      ON

BRANCH G      US      DS     UHS     DHS     UQB     DQB   NLMIN   SLOPE
BR1            2      26       0      29       0       0       1 0.00300
BR2           29      50      26      53       0       0       1 0.00300
BR3           53      77      50      80       0       0       1 0.00150
BR4           80     124      77     127       0       0       1 0.00120
BR5          127     226     124      -1       0       0       1 0.00034

LOCATION     LAT    LONG    EBOT      BS      BE    JBDN
WB 1     47.2000 122.100 29.2000       1       2       2
WB 2     47.2000 122.100 6.60000       3       4       4
```

```
WB 3     47.2000 122.100 -2.5000       5       5       5

INIT CND   TEMPI    ICEI  WTYPEC
WB 1     6.00000 0.00000   FRESH
WB 2     6.00000 0.00000   FRESH
WB 3     6.00000 0.00000   FRESH

CALCULAT     VBC     EBC     MBC     PQC     EVC     PRC
WB 1         OFF     OFF     OFF     OFF      ON     OFF
WB 2         OFF     OFF     OFF     OFF      ON     OFF
WB 3         OFF     OFF     OFF     OFF      ON     OFF

DEAD SEA   WINDC    QINC   QOUTC   HEATC
WB 1          ON      ON      ON      ON
WB 2          ON      ON      ON      ON
WB 3          ON      ON      ON      ON

INTERPOL   QINIC   DTRIC    HDIC
BR1           ON      ON      ON
BR2           ON      ON      ON
BR3           ON      ON      ON
BR4           ON      ON      ON
BR5           ON      ON      ON

HEAT EXCH  SLHTC    SROC  RHEVAP   METIC  FETCHC     AFW     BFW     CFW   WINDH
WB 1        TERM     OFF     OFF      ON     OFF 9.20000 0.46000 2.00000 2.00000
WB 2        TERM     OFF     OFF      ON     OFF 9.20000 0.46000 2.00000 2.00000
WB 3        TERM     OFF     OFF      ON     OFF 9.20000 0.46000 2.00000 2.00000

ICE COVE    ICEC  SLICEC  ALBEDO   HWICE    BICE    GICE  ICEMIN   ICET2
WB 1         OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000
WB 2         OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000
WB 3         OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000

TRANSPOR   SLTRC   THETA
WB 1    ULTIMATE 0.55000
WB 2    ULTIMATE 0.55000
WB 3    ULTIMATE 0.55000

HYD COEF      AX      DX    CBHE    TSED      FI   TSEDF   FRICC
WB 1     1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN
WB 2     1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN
WB 3     1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN

EDDY VISC    AZC   AZSLC   AZMAX
WB 1        NICK     IMP 1.00000
WB 2        NICK     IMP 1.00000
WB 3        NICK     IMP 1.00000

N STRUC     NSTR
BR1            0
BR2            0
BR3            0
BR4            0
BR5            0

STR INT    STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC
BR 1
```

```
BR 2
BR 3
BR 4
BR 5

STR TOP    KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR
BR1
BR2
BR3
BR4
BR5

STR BOT    KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR
BR1
BR2
BR3
BR4
BR5

STR SINK   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC
BR1
BR2
BR3
BR4
BR5

STR ELEV    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR
BR1
BR2
BR3
BR4
BR5

STR WIDT    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR
BR1
BR2
BR3
BR4
BR5

PIPES       IUPI    IDPI    EUPI    EDPI     WPI   DLXPI     FPI  FMINPI   WTHLC


PIPE UP    PUPIC   ETUPI   EBUPI   KTUPI   KBUPI


PIPE DOWN  PDPIC   ETDPI   EBDPI   KTDPI   KBDPI


SPILLWAY    IUSP    IDSP     ESP    A1SP    B1SP    A2SP    B2SP   WTHLC


SPILL UP   PUSPC   ETUSP   EBUSP   KTUSP   KBUSP


SPILL DOWN PDSPC   ETUSP   EBUSP   KTDSP   KBDSP
```

SPILL GAS	GASSPC	EQSP	AGASSP	BGASSP	CGASSP				
GATES	IUGT	IDGT	EGT	A1GT	B1GT	G1GT	A2GT	B2GT	G2GT
WTHLC									
GATE WEIR	GTA1	GTB1	GTA2	GTB2	DYNVAR				
GATE UP	PUGTC	ETUGT	EBUGT	KTUGT	KBUGT				
GATE DOWN	PDGTC	ETDGT	EBDGT	KTDGT	KBDGT				
GATE GAS	GASGTC	EQGT	AGASGT	BGASGT	CGASGT				
PUMPS 1	IUPU	IDPU	EPU	STRTPU	ENDPU	EONPU	EOFFPU	QPU	WTHLC
PUMPS 2	PPUC	ETPU	EBPU	KTPU	KBPU				
WEIR SEG	IWR	IWR	IWR	IWR	IWR	IWR	IWR	IWR	IWR
WEIR TOP	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR
WEIR BOT	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR
WD INT	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC
WD SEG	IWD	IWD	IWD	IWD	IWD	IWD	IWD	IWD	IWD
WD ELEV	EWD	EWD	EWD	EWD	EWD	EWD	EWD	EWD	EWD
WD TOP	KTWD	KTWD	KTWD	KTWD	KTWD	KTWD	KTWD	KTWD	KTWD
WD BOT	KBWD	KBWD	KBWD	KBWD	KBWD	KBWD	KBWD	KBWD	KBWD
TRIB PLA	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC
	DISTR	DISTR	DISTR	DISTR	DISTR	DISTR	DISTR		
TRIB INT	TRIC	TRIC	TRIC	TRIC	TRIC	TRIC	TRIC	TRIC	TRIC
	ON	ON	ON	ON	ON	ON	ON		
TRIB SEG	ITR	ITR	ITR	ITR	ITR	ITR	ITR	ITR	ITR
	26	32	76	134	145	159	171		

TRIB TOP	KTTR	KTTR	KTTR	KTTR	KTTR	KTTR	KTTR	KTTR	KTTR
	0	0	0	0	0	0	0		
TRIB BOT	KBTR	KBTR	KBTR	KBTR	KBTR	KBTR	KBTR	KBTR	KBTR
	0	0	0	0	0	0	0		
DST TRIB	DTRC	DTRC	DTRC	DTRC	DTRC	DTRC	DTRC	DTRC	DTRC
BR 1	OFF								
BR 2	ON								
BR 3	ON								
BR 4	OFF								
BR 5	OFF								
PUMPBACK	JBG	KTG	KBG	JBP	KTP	KBP			
	0	0	0	0	0	0			
PRINTER	LJC								
	IV								
HYD PRIN	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC
NVIOL	ON	ON	ON						
U	ON	ON	ON						
W	ON	ON	ON						
T	ON	ON	ON						
RHO	OFF	OFF	OFF						
AZ	OFF	OFF	OFF						
SHEAR	OFF	OFF	OFF						
ST	OFF	OFF	OFF						
SB	OFF	OFF	OFF						
ADMX	OFF	OFF	OFF						
DM	OFF	OFF	OFF						
HDG	OFF	OFF	OFF						
ADMZ	OFF	OFF	OFF						
HPG	OFF	OFF	OFF						
GRAV	OFF	OFF	OFF						
SNP PRINT	SNPC	NSNP	NISNP						
WB 1	ON	1	9						
WB 2	ON	1	5						
WB 3	ON	1	7						
SNP DATE	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD
WB 1	91.0000								
WB 2	91.0000								
WB 3	91.0000								
SNP FREQ	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF
WB 1	10.0000								
WB 2	10.0000								
WB 3	10.0000								
SNP SEG	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP
WB 1	2	5	10	15	20	24	32	38	47
WB 2	60	72	76	94	112				
WB 3	148	160	178	195	205	218	225		
SCR PRINT	SCRC	NSCR							

```
WB 1         OFF       1
WB 2         OFF       1
WB 3          ON       1

SCR DATE    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD
WB 1     91.0000
WB 2     91.0000
WB 3     91.0000

SCR FREQ    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF
WB 1     0.10000
WB 2     0.10000
WB 3     0.10000

PRF PLOT    PRFC    NPRF   NIPRF
WB 1         OFF       0       0
WB 2         OFF       0       0
WB 3         OFF       0       0

PRF DATE    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD
WB 1
WB 2
WB 3

PRF FREQ    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF
WB 1
WB 2
WB 3

PRF SEG     IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF
WB 1
WB 2
WB 3

SPR PLOT    SPRC    NSPR   NISPR
WB 1         OFF       0       0
WB 2         OFF       0       0
WB 3         OFF       0       0

SPR DATE    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD
WB 1
WB 2
WB 3

SPR FREQ    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF
WB 1
WB 2
WB 3

SPR SEG     ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR
WB 1
WB 2
WB 3

VPL PLOT    VPLC    NVPL
WB 1         OFF       0
WB 2         OFF       0
WB 3         OFF       0
```

```
VPL DATE     VPLD     VPLD     VPLD     VPLD     VPLD     VPLD     VPLD     VPLD     VPLD
WB 1
WB 2
WB 3

VPL FREQ     VPLF     VPLF     VPLF     VPLF     VPLF     VPLF     VPLF     VPLF     VPLF
WB 1
WB 2
WB 3

CPL PLOT     CPLC     NCPL
WB 1          OFF        0
WB 2          OFF        0
WB 3          OFF        0

CPL DATE     CPLD     CPLD     CPLD     CPLD     CPLD     CPLD     CPLD     CPLD     CPLD
WB 1
WB 2
WB 3

CPL FREQ     CPLF     CPLF     CPLF     CPLF     CPLF     CPLF     CPLF     CPLF     CPLF
WB 1
WB 2
WB 3

FLUXES       FLXC     NFLX
WB 1          OFF       19
WB 2          OFF       19
WB 3          OFF       19

FLX DATE     FLXD     FLXD     FLXD     FLXD     FLXD     FLXD     FLXD     FLXD     FLXD

WB 1      91.0000  100.000  120.000  135.000  162.000  191.000  227.000  254.000  282.000
          318.000  345.000  380.000  408.000  435.000  464.000  499.000  528.000  554.000
          578.000
WB 2      91.0000  100.000  120.000  135.000  162.000  191.000  227.000  254.000  282.000
          318.000  345.000  380.000  408.000  435.000  464.000  499.000  528.000  554.000
          578.000
WB 3      91.0000  100.000  120.000  135.000  162.000  191.000  227.000  254.000  282.000
          318.000  345.000  380.000  408.000  435.000  464.000  499.000  528.000  554.000
          578.000

FLX FREQ     FLXF     FLXF     FLXF     FLXF     FLXF     FLXF     FLXF     FLXF     FLXF
WB 1      76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000
          76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000
          76.0000
WB 2      76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000
          76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000
          76.0000
WB 3      76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000
          76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000  76.0000
          76.0000

TSR PLOT     TSRC     NTSR    NITSR
               ON        1        9

TSR DATE     TSRD     TSRD     TSRD     TSRD     TSRD     TSRD     TSRD     TSRD     TSRD
```

```
         91.0000

TSR FREQ    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF
         0.04170

TSR SEG     ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR
             178     148     112      94      76      72     164     218      88

TSR LAYE    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

WITH OUT    WDOC    NWDO   NIWDO
             OFF       1       1

WITH DAT    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD
         63.5000

WITH FRE    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF
         0.01000

WITH SEG    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO
              30

RESTART     RSOC    NRSO    RSIC
             OFF       0     OFF

RSO DATE    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD


RSO FREQ    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF


CST COMP     CCC    LIMC     CUF
              ON     OFF      10

CST ACTIVE   CAC
TDS          OFF
Gen1          ON
Gen2          ON
ISS1          ON
PO4           ON
NH4           ON
NO3           ON
DSI          OFF
PSI          OFF
FE           OFF
LDOM          ON
RDOM          ON
LPOM          ON
RPOM          ON
ALG1          ON
DO            ON
TIC           ON
ALK           ON

CST DERI   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC
DOC           ON      ON      ON
POC          OFF     OFF     OFF
```

```
TOC             ON      ON      ON
DON            OFF     OFF     OFF
PON            OFF     OFF     OFF
TON            OFF     OFF     OFF
TKN            OFF     OFF     OFF
TN              ON      ON      ON
DOP            OFF     OFF     OFF
POP            OFF     OFF     OFF
TOP            OFF     OFF     OFF
TP              ON      ON      ON
APR            OFF     OFF     OFF
CHLA            ON      ON      ON
ATOT           OFF     OFF     OFF
%DO            OFF     OFF     OFF
TSS             ON      ON      ON
TISS           OFF     OFF     OFF
CBOD           OFF     OFF     OFF
pH              ON      ON      ON
CO2            OFF     OFF     OFF
HCO3           OFF     OFF     OFF
CO3            OFF     OFF     OFF

CST FLUX     CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC
TISSIN         OFF     OFF     OFF
TISSOUT        OFF     OFF     OFF
PO4AR          OFF     OFF     OFF
PO4AG          OFF     OFF     OFF
PO4AP          OFF     OFF     OFF
PO4ER          OFF     OFF     OFF
PO4EG          OFF     OFF     OFF
PO4EP          OFF     OFF     OFF
PO4POM         OFF     OFF     OFF
PO4DOM         OFF     OFF     OFF
PO4OM          OFF     OFF     OFF
PO4SED         OFF     OFF     OFF
PO4SOD         OFF     OFF     OFF
PO4SET         OFF     OFF     OFF
NH4NITR        OFF     OFF     OFF
NH4AR          OFF     OFF     OFF
NH4AG          OFF     OFF     OFF
NH4AP          OFF     OFF     OFF
NH4ER          OFF     OFF     OFF
NH4EG          OFF     OFF     OFF
NH4EP          OFF     OFF     OFF
NH4POM         OFF     OFF     OFF
NH4DOM         OFF     OFF     OFF
NH4OM          OFF     OFF     OFF
NH4SED         OFF     OFF     OFF
NH4SOD         OFF     OFF     OFF
NO3DEN         OFF     OFF     OFF
NO3AG          OFF     OFF     OFF
NO3EG          OFF     OFF     OFF
NO3SED         OFF     OFF     OFF
DSIAG          OFF     OFF     OFF
DSIEG          OFF     OFF     OFF
DSIPIS         OFF     OFF     OFF
DSISED         OFF     OFF     OFF
DSISOD         OFF     OFF     OFF
```

```
DSISET        OFF     OFF     OFF
PSIAM         OFF     OFF     OFF
PSINET        OFF     OFF     OFF
PSIDK         OFF     OFF     OFF
FESET         OFF     OFF     OFF
FESED         OFF     OFF     OFF
LDOMDK        OFF     OFF     OFF
LRDOM         OFF     OFF     OFF
RDOMDK        OFF     OFF     OFF
LDOMAP        OFF     OFF     OFF
LDOMEP        OFF     OFF     OFF
LPOMDK        OFF     OFF     OFF
LRPOM         OFF     OFF     OFF
RPOMDK        OFF     OFF     OFF
LPOMAP        OFF     OFF     OFF
LPOMEP        OFF     OFF     OFF
LPOMSET       OFF     OFF     OFF
RPOMSET       OFF     OFF     OFF
CBODDK        OFF     OFF     OFF
DOAP          OFF     OFF     OFF
DOAR          OFF     OFF     OFF
DOEP          OFF     OFF     OFF
DOER          OFF     OFF     OFF
DOPOM         OFF     OFF     OFF
DODOM         OFF     OFF     OFF
DOOM          OFF     OFF     OFF
DONITR        OFF     OFF     OFF
DOCBOD        OFF     OFF     OFF
DOREAR        OFF     OFF     OFF
DOSED         OFF     OFF     OFF
DOSOD         OFF     OFF     OFF
TICAG         OFF     OFF     OFF
TICEG         OFF     OFF     OFF
SEDDK         OFF     OFF     OFF
SEDAS         OFF     OFF     OFF
SEDLPOM       OFF     OFF     OFF
SEDSET        OFF     OFF     OFF
SODDK         OFF     OFF     OFF

CST ICON    C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB
TDS       1.00000 1.00000 1.00000
Gen1      100.000 100.000 100.000
Gen2      45.0000 45.0000 45.0000
ISS1      3.00000 3.00000 3.00000
PO4       0.20000 0.20000 0.20000
NH4       0.30000 0.30000 0.30000
NO3       0.15000 0.15000 0.15000
DSI       0.00000 0.00000 0.00000
PSI       0.00000 0.00000 0.00000
FE        0.00000 0.00000 0.00000
LDOM      0.50000 0.50000 0.50000
RDOM      0.50000 0.50000 0.50000
LPOM      0.50000 0.50000 0.50000
RPOM      0.50000 0.50000 0.50000
ALG1      0.00006 0.00006 0.00006
DO        8.00000 8.00000 8.00000
TIC       8.00000 8.00000 8.00000
ALK       24.0000 24.0000 24.0000
```

CST PRIN	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC
TDS	OFF	OFF	OFF						
Gen1	ON	ON	ON						
Gen2	ON	ON	ON						
ISS1	ON	ON	ON						
PO4	ON	ON	ON						
NH4	ON	ON	ON						
NO3	ON	ON	ON						
DSI	OFF	OFF	OFF						
PSI	OFF	OFF	OFF						
FE	OFF	OFF	OFF						
LDOM	ON	ON	ON						
RDOM	ON	ON	ON						
LPOM	ON	ON	ON						
RPOM	ON	ON	ON						
ALG1	ON	ON	ON						
DO	ON	ON	ON						
TIC	ON	ON	ON						
ALK	ON	ON	ON						

CIN CON	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC
TDS	OFF	OFF	OFF	OFF	OFF				
Gen1	ON	ON	ON	ON	ON				
Gen2	ON	ON	ON	ON	ON				
ISS1	ON	ON	ON	ON	ON				
PO4	ON	ON	ON	ON	ON				
NH4	ON	ON	ON	ON	ON				
NO3	ON	ON	ON	ON	ON				
DSI	OFF	OFF	OFF	OFF	OFF				
PSI	OFF	OFF	OFF	OFF	OFF				
FE	OFF	OFF	OFF	OFF	OFF				
LDOM	ON	ON	ON	ON	ON				
RDOM	ON	ON	ON	ON	ON				
LPOM	ON	ON	ON	ON	ON				
RPOM	ON	ON	ON	ON	ON				
ALG1	ON	ON	ON	ON	ON				
DO	ON	ON	ON	ON	ON				
TIC	ON	ON	ON	ON	ON				
ALK	ON	ON	ON	ON	ON				

CTR CON	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC
TDS	OFF	OFF	OFF	OFF	OFF	OFF	OFF		
Gen1	ON	ON	ON	ON	ON	ON	ON		
Gen2	ON	ON	ON	ON	ON	ON	ON		
ISS1	ON	ON	ON	ON	ON	ON	ON		
PO4	ON	ON	ON	ON	ON	ON	ON		
NH4	ON	ON	ON	ON	ON	ON	ON		
NO3	ON	ON	ON	ON	ON	ON	ON		
DSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF		
PSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF		
FE	OFF	OFF	OFF	OFF	OFF	OFF	OFF		
LDOM	ON	ON	ON	ON	ON	ON	ON		
RDOM	ON	ON	ON	ON	ON	ON	ON		
LPOM	ON	ON	ON	ON	ON	ON	ON		
RPOM	ON	ON	ON	ON	ON	ON	ON		
ALG1	ON	ON	ON	ON	ON	ON	ON		
DO	ON	ON	ON	ON	ON	ON	ON		

TIC	ON	ON	ON	ON	ON	ON	ON
ALK	ON	ON	ON	ON	ON	ON	ON

CDT CON	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC
TDS	OFF	OFF	OFF	OFF	OFF				
Gen1	OFF	ON	ON	ON	ON				
Gen2	OFF	ON	ON	ON	ON				
ISS1	OFF	ON	ON	ON	ON				
PO4	OFF	ON	ON	ON	ON				
NH4	OFF	ON	ON	ON	ON				
NO3	OFF	ON	ON	ON	ON				
DSI	OFF	OFF	OFF	OFF	OFF				
PSI	OFF	OFF	OFF	OFF	OFF				
FE	OFF	OFF	OFF	OFF	OFF				
LDOM	OFF	ON	ON	ON	ON				
RDOM	OFF	ON	ON	ON	ON				
LPOM	OFF	ON	ON	ON	ON				
RPOM	OFF	ON	ON	ON	ON				
ALG1	OFF	ON	ON	ON	ON				
DO	OFF	ON	ON	ON	ON				
TIC	OFF	ON	ON	ON	ON				
ALK	OFF	ON	ON	ON	ON				

CPR CON	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC
TDS	OFF	OFF	OFF	OFF	OFF				
Gen1	OFF	OFF	OFF	OFF	OFF				
Gen2	OFF	OFF	OFF	OFF	OFF				
ISS1	OFF	OFF	OFF	OFF	OFF				
PO4	OFF	OFF	OFF	OFF	OFF				
NH4	OFF	OFF	OFF	OFF	OFF				
NO3	OFF	OFF	OFF	OFF	OFF				
DSI	OFF	OFF	OFF	OFF	OFF				
PSI	OFF	OFF	OFF	OFF	OFF				
FE	OFF	OFF	OFF	OFF	OFF				
LDOM	OFF	OFF	OFF	OFF	OFF				
RDOM	OFF	OFF	OFF	OFF	OFF				
LPOM	OFF	OFF	OFF	OFF	OFF				
RPOM	OFF	OFF	OFF	OFF	OFF				
ALG1	OFF	OFF	OFF	OFF	OFF				
DO	OFF	OFF	OFF	OFF	OFF				
TIC	OFF	OFF	OFF	OFF	OFF				
ALK	OFF	OFF	OFF	OFF	OFF				

EX COEF	EXH2O	EXSS	EXOM	BETA	EXC	EXIC
WB 1	0.45000	0.01000	0.01000	0.45000	OFF	OFF
WB 2	0.45000	0.01000	0.01000	0.45000	OFF	OFF
WB 3	0.45000	0.01000	0.01000	0.45000	OFF	OFF

ALG EX	EXA	EXA	EXA	EXA	EXA	EXA
	0.20000					

GENERIC	CGQ10	CG0DK	CG1DK	CGS
CG 1	0.00000	0.00000	0.00000	0.00000
CG 2	1.04000	0.00000	0.20000	0.00000

S SOLIDS	SSS	SSS	SSS	SSS	SSS	SSS	SSS	SSS	SSS
	1.00000								

```
ALGAL RATE    AG      AR      AE      AM      AS    AHSP    AHSN   AHSSI    ASAT
ALG1     2.00000 0.04000 0.04000 0.10000 0.10000 0.00300 0.01400 0.00000 75.0000

ALGAL TEMP   AT1     AT2     AT3     AT4     AK1     AK2     AK3     AK4
ALG1     5.00000 25.0000 35.0000 40.0000 0.10000 0.99000 0.99000 0.10000

ALG STOI    ALGP    ALGN    ALGC   ALGSI   ACHLA   ALPOM   ANEQN    ANPR
ALG1     0.00500 0.08000 0.45000 0.18000 100.000 0.80000       2 0.00100

EPIPHYTE    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC
EPI1         OFF     OFF     OFF

EPI PRIN    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC
EPI1         OFF     OFF     OFF

EPI INIT   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI
EPI1     0.00000 0.00000 0.00000

EPI RATE      EG      ER      EE      EM      EB    EHSP    EHSN   EHSSI
EPI1     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

EPI HALF    ESAT     EHS   ENEQN    ENPR
EPI1     0.10000 0.00000       0 0.00000

EPI TEMP     ET1     ET2     ET3     ET4     EK1     EK2     EK3     EK4
EPI1     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

EPI STOI      EP      EN      EC     ESI   ECHLA    EPOM
EPI1     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

DOM       LDOMDK  RDOMDK   LRDDK
WB 1     0.10000 0.00100 0.01000
WB 2     0.10000 0.00100 0.01000
WB 3     0.10000 0.00100 0.01000

POM       LPOMDK  RPOMDK   LRPDK    POMS
WB 1     0.08000 0.00100 0.01000 0.10000
WB 2     0.08000 0.00100 0.01000 0.10000
WB 3     0.08000 0.00100 0.01000 0.10000

OM STOIC    ORGP    ORGN    ORGC   ORGSI
WB 1     0.00500 0.08000 0.45000 0.18000
WB 2     0.00500 0.08000 0.45000 0.18000
WB 3     0.00500 0.08000 0.45000 0.18000

OM RATE     OMT1    OMT2    OMK1    OMK2
WB 1     4.00000 25.0000 0.10000 0.99000
WB 2     4.00000 25.0000 0.10000 0.99000
WB 3     4.00000 25.0000 0.10000 0.99000

CBOD        KBOD    TBOD    RBOD
BOD 1    0.25000 1.01400 71.8500

CBOD STOIC  BODP    BODN    BODC
BOD 1    0.00400 0.06000 0.32000

PHOSPHOR    PO4R   PARTP
WB 1     0.00100 0.00000
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WB 2      0.00100 0.00000
WB 3      0.00100 0.00000

AMMONIUM     NH4R   NH4DK
WB 1      0.00100 0.12000
WB 2      0.00100 0.12000
WB 3      0.00100 0.12000

NH4 RATE   NH4T1   NH4T2   NH4K1   NH4K2
WB 1      5.00000 25.0000 0.10000 0.99000
WB 2      5.00000 25.0000 0.10000 0.99000
WB 3      5.00000 25.0000 0.10000 0.99000

NITRATE    NO3DK    NO3S
WB 1      0.03000 1.00000
WB 2      0.03000 1.00000
WB 3      0.03000 1.00000

NO3 RATE   NO3T1   NO3T2   NO3K1   NO3K2
WB 1      5.00000 25.0000 0.10000 0.99000
WB 2      5.00000 25.0000 0.10000 0.99000
WB 3      5.00000 25.0000 0.10000 0.99000

SILICA       DSIR    PSIS   PSIDK  PARTSI
WB 1      5.00000 20.0000 0.05000 0.99000
WB 2      5.00000 20.0000 0.05000 0.99000
WB 3      5.00000 20.0000 0.05000 0.99000

IRON          FER     FES
WB 1      0.00000 0.00000
WB 2      0.00000 0.00000
WB 3      0.00000 0.00000

SED CO2      CO2R
WB 1      0.50000
WB 2      0.50000
WB 3      0.50000

STOICH 1   O2NH4    O2OM
WB 1      4.57000 1.40000
WB 2      4.57000 1.40000
WB 3      4.57000 1.40000

STOICH 2    O2AR    O2AG
ALG1      1.10000 1.40000

STOICH 3    O2ER    O2EG
EPI1      0.00000 0.00000

O2 LIMIT   O2LIM
          0.10000

SEDIMENT     SEDC  SEDPRC   SEDCI    SEDK    FSOD    FSED
WB 1          OFF      ON 0.00000 0.10000 1.00000 1.00000
WB 2          OFF      ON 0.00000 0.10000 1.00000 1.00000
WB 3          OFF      ON 0.00000 0.10000 1.00000 1.00000

SOD RATE   SODT1   SODT2   SODK1   SODK2
```

```
WB 1      4.00000 30.0000 0.10000 0.99000
WB 2      4.00000 30.0000 0.10000 0.99000
WB 3      4.00000 30.0000 0.10000 0.99000

S DEMAND      SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000 3.00000
          3.00000 3.00000

REAERATION  TYPE    EQN#   COEF1   COEF2   COEF3   COEF4
WB 1       RIVER       8 0.00000 0.00000 0.00000 0.00000
WB 2       RIVER       8 0.00000 0.00000 0.00000 0.00000
WB 3       RIVER       8 0.00000 0.00000 0.00000 0.00000

RSI FILE.................................RSIFN................................
        rsi.npt

QWD FILE.................................QWDFN................................
        qwd.npt

QGT FILE.................................QGTFN................................
        qgt.npt

WSC FILE.................................WSCFN................................
        wsc.npt

SHD FILE.................................SHDFN................................
        shade.npt

BTH FILE.................................BTHFN................................
WB 1    bth_wb1.npt
WB 2    bth_wb2.npt
WB 3    bth_wb3.npt

MET FILE.................................METFN................................
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```
WB 1    met_wb1.npt
WB 2    met_wb2.npt
WB 3    met_wb3.npt

EXT FILE.................................EXTFN................................
WB 1    ext_wb1.npt - not used
WB 2    ext_wb2.npt - not used
WB 3    ext_wb3.npt - not used

VPR FILE.................................VPRFN................................
WB 1    vpr00wb1.npt
WB 2    vpr00wb2.npt
WB 3    vpr00wb3.npt

LPR FILE.................................LPRFN................................
WB 1    lpr_1.npt
WB 2    lpr_2.npt
WB 3    lpr_3.npt

QIN FILE.................................QINFN................................
BR1     qin_br1.npt
BR2     qin_br2.npt
BR3     qin_br3.npt
BR4     qin_br4.npt
BR5     qin_br5.npt

TIN FILE.................................TINFN................................
BR1     Tin_br1.npt
BR2     tin_br2.npt
BR3     tin_br3.npt
BR4     tin_br4.npt
BR5     tin_br5.npt

CIN FILE.................................CINFN................................
BR1     Cin_br1.npt
BR2     cin_br2.npt
BR3     cin_br3.npt
BR4     cin_br4.npt
BR5     cin_br5.npt

QOT FILE.................................QOTFN................................
BR1     qll_00.npt
BR2     qot_br2.npt
BR3     qot_br3.npt
BR4     qot_br4.npt
BR5     qot_br5.npt

QTR FILE.................................QTRFN................................
TR1     qtr_tr1.npt
TR2     qtr_tr2.npt
TR3     qtr_tr3.npt
TR4     qtr_tr4.npt
TR5     qtr_tr5.npt
TR6     qtr_tr6.npt
TR7     qtr_tr7.npt

TTR FILE.................................TTRFN................................
TR1     ttr_tr1.npt
```

```
TR2     ttr_tr2.npt
TR3     ttr_tr3.npt
TR4     ttr_tr4.npt
TR5     ttr_tr5.npt
TR6     ttr_tr6.npt
TR7     ttr_tr7.npt

CTR FILE..................................CTRFN.................................
TR1     ctr_tr1.npt
TR2     ctr_tr2.npt
TR3     ctr_tr3.npt
TR4     ctr_tr4.npt
TR5     ctr_tr5.npt
TR6     ctr_tr6.npt
TR7     ctr_tr7.npt

QDT FILE..................................QDTFN.................................
BR1     qdt_br1.npt
BR2     qdt_br2.npt
BR3     qdt_br3.npt
BR4     qdt_br4.npt
BR5     qdt_br5.npt

TDT FILE..................................TDTFN.................................
BR1     tdt_br1.npt
BR2     tdt_br2.npt
BR3     tdt_br3.npt
BR4     tdt_br4.npt
BR5     tdt_br5.npt

CDT FILE..................................CDTFN.................................
BR1     cdt_br1.npt
BR2     cdt_br2.npt
BR3     cdt_br3.npt
BR4     cdt_br4.npt
BR5     cdt_br5.npt

PRE FILE..................................PREFN.................................
BR1     pre_br1.npt
BR2     pre_br2.npt
BR3     pre_br3.npt
BR4     pre_br4.npt
BR5     pre_br5.npt

TPR FILE..................................TPRFN.................................
BR1     tpr_br1.npt
BR2     tpr_br2.npt
BR3     tpr_br3.npt
BR4     tpr_br4.npt
BR5     tpr_br5.npt

CPR FILE..................................CPRFN.................................
BR1     cpr_br1.npt
BR2     cpr_br2.npt
BR3     cpr_br3.npt
BR4     cpr_br4.npt
BR5     cpr_br5.npt
```

```
EUH FILE..................................EUHFN.................................

BR1     euh_br1.npt
BR2     euh_br2.npt
BR3     euh_br3.npt
BR4     euh_br4.npt
BR5     euh_br5.npt

TUH FILE..................................TUHFN.................................
BR1     tuh_br1.npt
BR2     tuh_br2.npt
BR3     tuh_br3.npt
BR4     tuh_br4.npt
BR5     tuh_br5.npt

CUH FILE..................................CUHFN.................................
BR1     cuh_br1.npt
BR2     cuh_br2.npt
BR3     cuh_br3.npt
BR4     cuh_br4.npt
BR5     cuh_br5.npt

EDH FILE..................................EDHFN.................................
BR1     edh_br1.npt
BR2     edh_br2.npt
BR3     edh_br3.npt
BR4     edh_br4.npt
BR5     edh_br5.npt

TDH FILE..................................TDHFN.................................
BR1     tdh_br1.npt
BR2     tdh_br2.npt
BR3     tdh_br3.npt
BR4     tdh_br4.npt
BR5     tdh_br5.npt

CDH FILE..................................CDHFN.................................
BR1     cdh_br1.npt
BR2     cdh_br2.npt
BR3     cdh_br3.npt
BR4     cdh_br4.npt
BR5     cdh_br5.npt

SNP FILE..................................SNPFN.................................
WB 1    snp1.opt
WB 2    snp2.opt
WB 3    snp3.opt

PRF FILE..................................PRFFN.................................
WB 1    prf1.opt
WB 2    prf2.opt
WB 3    prf3.opt

VPL FILE..................................VPLFN.................................
WB 1    vpl1.opt
WB 2    vpl2.opt
WB 3    vpl3.opt
```

```
CPL FILE..................................CPLFN.................................
WB 1    cpl1.opt
WB 2    cpl2.opt
WB 3    cpl3.opt

SPR FILE..................................SPRFN.................................
WB 1    spr1.opt
WB 2    spr2.opt
WB 3    spr3.opt

FLX FILE..................................FLXFN.................................
WB 1    kfl1.opt
WB 2    kfl2.opt
WB 3    kfl3.opt

TSR FILE..................................TSRFN.................................
        tsr.opt

WDO FILE..................................WDOFN.................................
        wdo.opt
```

Appendix H: W2 Control File For 1995-1996 Model Run Period

```
  W2 Model Version 3.1

TITLE C ...............................TITLE....................................
        Green River - MAY 25, 1995 through November 30, 1996
        June 2003
        River with 5 branches and 3 water bodies
        Default hydraulic and kinetic coefficients
        Scott Wells, Chris Berger, Rob Annear, PSU
        Tom Cole, WES




GRID         NWB     NBR     IMX     KMX
               3       5     227      22

IN/OUTFL     NTR     NST     NIW     NWD     NGT     NSP     NPI     NPU
               7       0       0       0       0       0       0       0

CONSTITU     NGC     NSS     NAL     NEP    NBOD
               2       1       1       0       0

MISCELL     NDAY
             100

TIME CON  TMSTRT   TMEND    YEAR
         145.000 701.000    1995

DLT CON      NDT  DLTMIN
               1 1.00000

DLT DATE    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD
         145.000

DLT MAX   DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX
         200.000

DLT FRN     DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF
         0.70000

DLT LIMI    VISC    CELC
WB 1          ON      ON
WB 2          ON      ON
WB 3          ON      ON

BRANCH G      US      DS     UHS     DHS     UQB     DQB   NLMIN   SLOPE
BR1            2      26       0      29       0       0       1 0.00310
BR2           29      50      26      53       0       0       1 0.00310
BR3           53      77      50      80       0       0       1 0.00150
BR4           80     124      77     127       0       0       1 0.00120
BR5          127     226     124      -1       0       0       1 0.00034

LOCATION     LAT    LONG    EBOT      BS      BE    JBDN
WB 1     47.2000 122.100 29.2000       1       2       2
```

```
WB 2     47.2000 122.100 6.60000       3       4       4
WB 3     47.2000 122.100 -2.5000       5       5       5

INIT CND   TEMPI    ICEI  WTYPEC
WB 1     15.0000 0.00000   FRESH
WB 2     15.0000 0.00000   FRESH
WB 3     15.0000 0.00000   FRESH

CALCULAT     VBC     EBC     MBC     PQC     EVC     PRC
WB 1         OFF     OFF     OFF     OFF      ON     OFF
WB 2         OFF     OFF     OFF     OFF      ON     OFF
WB 3         OFF     OFF     OFF     OFF      ON     OFF

DEAD SEA   WINDC    QINC   QOUTC   HEATC
WB 1          ON      ON      ON      ON
WB 2          ON      ON      ON      ON
WB 3          ON      ON      ON      ON

INTERPOL   QINIC   DTRIC    HDIC
BR1           ON      ON      ON
BR2           ON      ON      ON
BR3           ON      ON      ON
BR4           ON      ON      ON
BR5           ON      ON      ON

HEAT EXCH  SLHTC    SROC  RHEVAP   METIC  FETCHC     AFW     BFW     CFW   WINDH
WB 1        TERM     OFF     OFF      ON     OFF 9.20000 0.46000 2.00000 2.00000
WB 2        TERM     OFF     OFF      ON     OFF 9.20000 0.46000 2.00000 2.00000
WB 3        TERM     OFF     OFF      ON     OFF 9.20000 0.46000 2.00000 2.00000

ICE COVE    ICEC  SLICEC  ALBEDO   HWICE    BICE    GICE  ICEMIN   ICET2
WB 1         OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000
WB 2         OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000
WB 3         OFF  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000

TRANSPOR   SLTRC   THETA
WB 1    ULTIMATE 0.55000
WB 2    ULTIMATE 0.55000
WB 3    ULTIMATE 0.55000

HYD COEF      AX      DX    CBHE    TSED      FI   TSEDF   FRICC
WB 1     1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN
WB 2     1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN
WB 3     1.00000 1.00000   7E-08 11.5000 0.01000 1.00000    MANN

EDDY VISC    AZC   AZSLC   AZMAX
WB 1        NICK     IMP 1.00000
WB 2        NICK     IMP 1.00000
WB 3        NICK     IMP 1.00000

N STRUC     NSTR
BR1            0
BR2            0
BR3            0
BR4            0
BR5            0

STR INT    STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC
```

```
BR 1
BR 2
BR 3
BR 4
BR 5

STR TOP    KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR
BR1
BR2
BR3
BR4
BR5

STR BOT    KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR
BR1
BR2
BR3
BR4
BR5

STR SINK   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC
BR1
BR2
BR3
BR4
BR5

STR ELEV    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR
BR1
BR2
BR3
BR4
BR5

STR WIDT    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR
BR1
BR2
BR3
BR4
BR5

PIPES       IUPI    IDPI    EUPI    EDPI     WPI   DLXPI     FPI  FMINPI   WTHLC


PIPE UP    PUPIC   ETUPI   EBUPI   KTUPI   KBUPI


PIPE DOWN  PDPIC   ETDPI   EBDPI   KTDPI   KBDPI


SPILLWAY    IUSP    IDSP     ESP    A1SP    B1SP    A2SP    B2SP   WTHLC


SPILL UP   PUSPC   ETUSP   EBUSP   KTUSP   KBUSP


SPILL DOWN PDSPC   ETUSP   EBUSP   KTDSP   KBDSP
```

```
SPILL GAS GASSPC    EQSP  AGASSP  BGASSP  CGASSP

GATES       IUGT    IDGT     EGT    A1GT    B1GT    G1GT    A2GT    B2GT    G2GT
WTHLC

GATE WEIR   GTA1    GTB1    GTA2    GTB2  DYNVAR

GATE UP    PUGTC   ETUGT   EBUGT   KTUGT   KBUGT

GATE DOWN  PDGTC   ETDGT   EBDGT   KTDGT   KBDGT

GATE GAS  GASGTC    EQGT  AGASGT  BGASGT  CGASGT

PUMPS 1     IUPU    IDPU     EPU  STRTPU   ENDPU   EONPU  EOFFPU     QPU   WTHLC

PUMPS 2     PPUC    ETPU    EBPU    KTPU    KBPU

WEIR SEG     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR

WEIR TOP    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR

WEIR BOT    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR

WD INT      WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC

WD SEG       IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD

WD ELEV      EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD

WD TOP      KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD

WD BOT      KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD

TRIB PLA    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC
           DISTR   DISTR   DISTR   DISTR   DISTR   DISTR   DISTR

TRIB INT    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC
              ON      ON      ON      ON      ON      ON      ON

TRIB SEG     ITR     ITR     ITR     ITR     ITR     ITR     ITR     ITR     ITR
              26      32      76     134     145     159     171
```

```
TRIB TOP    KTTR    KTTR    KTTR    KTTR    KTTR    KTTR    KTTR    KTTR    KTTR
               0       0       0       0       0       0       0

TRIB BOT    KBTR    KBTR    KBTR    KBTR    KBTR    KBTR    KBTR    KBTR    KBTR
               0       0       0       0       0       0       0

DST TRIB    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC
BR 1         OFF
BR 2          ON
BR 3          ON
BR 4         OFF
BR 5         OFF

PUMPBACK     JBG     KTG     KBG     JBP     KTP     KBP
               0       0       0       0       0       0

PRINTER      LJC
              IV

HYD PRIN  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC
NVIOL         ON      ON      ON
U             ON      ON      ON
W             ON      ON      ON
T             ON      ON      ON
RHO          OFF     OFF     OFF
AZ           OFF     OFF     OFF
SHEAR        OFF     OFF     OFF
ST           OFF     OFF     OFF
SB           OFF     OFF     OFF
ADMX         OFF     OFF     OFF
DM           OFF     OFF     OFF
HDG          OFF     OFF     OFF
ADMZ         OFF     OFF     OFF
HPG          OFF     OFF     OFF
GRAV         OFF     OFF     OFF

SNP PRINT   SNPC    NSNP   NISNP
WB 1          ON       1       1
WB 2          ON       1       1
WB 3          ON       1       1

SNP DATE    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD
WB 1     145.000
WB 2     145.000
WB 3     145.000

SNP FREQ    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF
WB 1     10.0000
WB 2     10.0000
WB 3     10.0000

SNP SEG     ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP
WB 1           2
WB 2          94
WB 3         226

SCR PRINT   SCRC    NSCR
```

```
WB 1          OFF        1
WB 2          OFF        1
WB 3           ON        1

SCR DATE     SCRD     SCRD     SCRD     SCRD     SCRD     SCRD     SCRD     SCRD     SCRD
WB 1      145.000
WB 2      145.000
WB 3      145.000

SCR FREQ     SCRF     SCRF     SCRF     SCRF     SCRF     SCRF     SCRF     SCRF     SCRF
WB 1      0.10000
WB 2      0.10000
WB 3      0.15000

PRF PLOT     PRFC     NPRF    NIPRF
WB 1          OFF        0        0
WB 2          OFF        0        0
WB 3          OFF        0        0

PRF DATE     PRFD     PRFD     PRFD     PRFD     PRFD     PRFD     PRFD     PRFD     PRFD
WB 1
WB 2
WB 3

PRF FREQ     PRFF     PRFF     PRFF     PRFF     PRFF     PRFF     PRFF     PRFF     PRFF
WB 1
WB 2
WB 3

PRF SEG      IPRF     IPRF     IPRF     IPRF     IPRF     IPRF     IPRF     IPRF     IPRF
WB 1
WB 2
WB 3

SPR PLOT     SPRC     NSPR    NISPR
WB 1          OFF        0        0
WB 2          OFF        0        0
WB 3          OFF        0        0

SPR DATE     SPRD     SPRD     SPRD     SPRD     SPRD     SPRD     SPRD     SPRD     SPRD
WB 1
WB 2
WB 3

SPR FREQ     SPRF     SPRF     SPRF     SPRF     SPRF     SPRF     SPRF     SPRF     SPRF
WB 1
WB 2
WB 3

SPR SEG      ISPR     ISPR     ISPR     ISPR     ISPR     ISPR     ISPR     ISPR     ISPR
WB 1
WB 2
WB 3

VPL PLOT     VPLC     NVPL
WB 1          OFF        0
WB 2          OFF        0
WB 3          OFF        0
```

```
VPL DATE    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD
WB 1
WB 2
WB 3

VPL FREQ    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF
WB 1
WB 2
WB 3

CPL PLOT    CPLC    NCPL
WB 1         OFF      32
WB 2         OFF      32
WB 3         OFF      32

CPL DATE    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD
WB 1       400.0   401.0   402.0   403.0   404.0   405.0   406.0   407.0   408.0
           409.0   410.0   411.0   412.0   413.0   414.0   415.0   416.0   417.0
           418.0   419.0   420.0   421.0   422.0   423.0   424.0   425.0   426.0
           427.0   428.0   429.0   430.0   431.0
WB 2       400.0   401.0   402.0   403.0   404.0   405.0   406.0   407.0   408.0
           409.0   410.0   411.0   412.0   413.0   414.0   415.0   416.0   417.0
           418.0   419.0   420.0   421.0   422.0   423.0   424.0   425.0   426.0
           427.0   428.0   429.0   430.0   431.0
WB 3       400.0   401.0   402.0   403.0   404.0   405.0   406.0   407.0   408.0
           409.0   410.0   411.0   412.0   413.0   414.0   415.0   416.0   417.0
           418.0   419.0   420.0   421.0   422.0   423.0   424.0   425.0   426.0
           427.0   428.0   429.0   430.0   431.0

CPL FREQ    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF
WB 1      0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  400.00
WB 2      0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  400.00
WB 3      0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668  0.1668
          0.1668  0.1668  0.1668  0.1668  400.00

FLUXES      FLXC    NFLX
WB 1         OFF      18
WB 2         OFF      18
WB 3         OFF      18

FLX DATE    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD
WB 1     145.000 164.000 199.000 227.000 262.000 318.000 346.000 374.000 409.000
         437.000 473.000 500.000 528.000 563.000 591.000 619.000 647.000 683.000
WB 2     145.000 164.000 199.000 227.000 262.000 318.000 346.000 374.000 409.000
         437.000 473.000 500.000 528.000 563.000 591.000 619.000 647.000 683.000
WB 3     145.000 164.000 199.000 227.000 262.000 318.000 346.000 374.000 409.000
         437.000 473.000 500.000 528.000 563.000 591.000 619.000 647.000 683.000

FLX FREQ    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF
```

```
WB 1      76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000
          76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000
WB 2      76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000
          76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000
WB 3      76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000
          76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000 76.0000

TSR PLOT     TSRC    NTSR   NITSR
               ON       1       9

TSR DATE     TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD
          145.000

TSR FREQ     TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF
          0.04170

TSR SEG      ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR
              178     148     112      94      76      72     160     218     226

TSR LAYE     ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR
          0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

WITH OUT     WDOC    NWDO   NIWDO
              OFF       1       1

WITH DAT     WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD
          63.5000

WITH FRE     WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF
          0.10000

WITH SEG     IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO
               30

RESTART      RSOC    NRSO    RSIC
              OFF       0     OFF

RSO DATE     RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD


RSO FREQ     RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF


CST COMP      CCC    LIMC     CUF
               ON     OFF      10

CST ACTIVE    CAC
TDS           OFF
Gen1           ON
Gen2           ON
ISS1           ON
PO4            ON
NH4            ON
NO3            ON
DSI           OFF
PSI           OFF
FE            OFF
LDOM           ON
```

RDOM	ON
LPOM	ON
RPOM	ON
ALG1	ON
DO	ON
TIC	ON
ALK	ON

CST DERI	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC
DOC	ON	ON	ON						
POC	OFF	OFF	OFF						
TOC	ON	ON	ON						
DON	OFF	OFF	OFF						
PON	OFF	OFF	OFF						
TON	OFF	OFF	OFF						
TKN	OFF	OFF	OFF						
TN	ON	ON	ON						
DOP	OFF	OFF	OFF						
POP	OFF	OFF	OFF						
TOP	OFF	OFF	OFF						
TP	ON	ON	ON						
APR	OFF	OFF	OFF						
CHLA	ON	ON	ON						
ATOT	OFF	OFF	OFF						
%DO	OFF	OFF	OFF						
TSS	ON	ON	ON						
TISS	OFF	OFF	OFF						
CBOD	OFF	OFF	OFF						
pH	ON	ON	ON						
CO2	OFF	OFF	OFF						
HCO3	OFF	OFF	OFF						
CO3	OFF	OFF	OFF						

CST FLUX	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC
TISSIN	OFF	OFF	OFF						
TISSOUT	OFF	OFF	OFF						
PO4AR	OFF	OFF	OFF						
PO4AG	OFF	OFF	OFF						
PO4AP	OFF	OFF	OFF						
PO4ER	OFF	OFF	OFF						
PO4EG	OFF	OFF	OFF						
PO4EP	OFF	OFF	OFF						
PO4POM	OFF	OFF	OFF						
PO4DOM	OFF	OFF	OFF						
PO4OM	OFF	OFF	OFF						
PO4SED	OFF	OFF	OFF						
PO4SOD	OFF	OFF	OFF						
PO4SET	OFF	OFF	OFF						
NH4NITR	OFF	OFF	OFF						
NH4AR	OFF	OFF	OFF						
NH4AG	OFF	OFF	OFF						
NH4AP	OFF	ON	OFF						
NH4ER	OFF	OFF	OFF						
NH4EG	OFF	OFF	OFF						
NH4EP	OFF	OFF	OFF						
NH4POM	OFF	OFF	OFF						
NH4DOM	OFF	OFF	OFF						
NH4OM	OFF	OFF	OFF						

```
NH4SED        OFF      ON     OFF
NH4SOD        OFF      ON     OFF
NO3DEN        OFF     OFF     OFF
NO3AG         OFF     OFF     OFF
NO3EG         OFF     OFF     OFF
NO3SED        OFF     OFF     OFF
DSIAG         OFF     OFF     OFF
DSIEG         OFF     OFF     OFF
DSIPIS        OFF     OFF     OFF
DSISED        OFF     OFF     OFF
DSISOD        OFF     OFF     OFF
DSISET        OFF     OFF     OFF
PSIAM         OFF     OFF     OFF
PSINET        OFF     OFF     OFF
PSIDK         OFF     OFF     OFF
FESET         OFF     OFF     OFF
FESED         OFF     OFF     OFF
LDOMDK        OFF     OFF     OFF
LRDOM         OFF     OFF     OFF
RDOMDK        OFF     OFF     OFF
LDOMAP        OFF     OFF     OFF
LDOMEP        OFF     OFF     OFF
LPOMDK        OFF     OFF     OFF
LRPOM         OFF     OFF     OFF
RPOMDK        OFF     OFF     OFF
LPOMAP        OFF     OFF     OFF
LPOMEP        OFF     OFF     OFF
LPOMSET       OFF     OFF     OFF
RPOMSET       OFF     OFF     OFF
CBODDK        OFF     OFF     OFF
DOAP          OFF     OFF      ON
DOAR          OFF     OFF      ON
DOEP          OFF     OFF      ON
DOER          OFF     OFF      ON
DOPOM         OFF     OFF      ON
DODOM         OFF     OFF      ON
DOOM          OFF     OFF      ON
DONITR        OFF     OFF      ON
DOCBOD        OFF     OFF      ON

DOREAR        OFF     OFF      ON
DOSED         OFF     OFF      ON
DOSOD         OFF     OFF      ON
TICAG         OFF     OFF      ON
TICEG         OFF     OFF      ON
SEDDK         OFF     OFF      ON
SEDAS         OFF     OFF      ON
SEDLPOM       OFF     OFF      ON
SEDSET        OFF     OFF      ON
SODDK         OFF     OFF      ON

CST ICON    C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB
TDS       1.00000 1.00000 1.00000
Gen1      100.000 100.000 100.000
Gen2      45.0000 45.0000 45.0000
ISS1      3.00000 3.00000 3.00000
PO4       0.02000 0.02000 0.02000
NH4       0.03000 0.03000 0.03000
```

NO3	0.25000	0.25000	0.25000
DSI	0.00000	0.00000	0.00000
PSI	0.00000	0.00000	0.00000
FE	0.00000	0.00000	0.00000
LDOM	0.50000	0.50000	0.50000
RDOM	0.50000	0.50000	0.50000
LPOM	0.50000	0.50000	0.50000
RPOM	0.50000	0.50000	0.50000
ALG1	0.00006	0.00006	0.00006
DO	11.0000	11.0000	11.0000
TIC	12.0000	12.0000	12.0000
ALK	24.0000	24.0000	24.0000

CST PRIN	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC
TDS	OFF	OFF	OFF						
Gen1	ON	ON	ON						
Gen2	ON	ON	ON						
ISS1	ON	ON	ON						
PO4	ON	ON	ON						
NH4	ON	ON	ON						
NO3	ON	ON	ON						
DSI	OFF	OFF	OFF						
PSI	OFF	OFF	OFF						
FE	OFF	OFF	OFF						
LDOM	ON	ON	ON						
RDOM	ON	ON	ON						
LPOM	ON	ON	ON						
RPOM	ON	ON	ON						
ALG1	ON	ON	ON						
DO	ON	ON	ON						
TIC	ON	ON	ON						
ALK	ON	ON	ON						

CIN CON	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC
TDS	OFF	OFF	OFF	OFF	OFF				
Gen1	ON	ON	ON	ON	ON				
Gen2	ON	ON	ON	ON	ON				
ISS1	ON	ON	ON	ON	ON				
PO4	ON	ON	ON	ON	ON				
NH4	ON	ON	ON	ON	ON				
NO3	ON	ON	ON	ON	ON				
DSI	OFF	OFF	OFF	OFF	OFF				
PSI	OFF	OFF	OFF	OFF	OFF				
FE	OFF	OFF	OFF	OFF	OFF				
LDOM	ON	ON	ON	ON	ON				
RDOM	ON	ON	ON	ON	ON				
LPOM	ON	ON	ON	ON	ON				
RPOM	ON	ON	ON	ON	ON				
ALG1	ON	ON	ON	ON	ON				
DO	ON	ON	ON	ON	ON				
TIC	ON	ON	ON	ON	ON				
ALK	ON	ON	ON	ON	ON				

CTR CON	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC
TDS	OFF	OFF	OFF	OFF	OFF	OFF	OFF		
Gen1	ON	ON	ON	ON	ON	ON	ON		
Gen2	ON	ON	ON	ON	ON	ON	ON		
ISS1	ON	ON	ON	ON	ON	ON	ON		

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PO4           ON      ON      ON      ON      ON      ON      ON
NH4           ON      ON      ON      ON      ON      ON      ON
NO3           ON      ON      ON      ON      ON      ON      ON
DSI          OFF     OFF     OFF     OFF     OFF     OFF     OFF

PSI          OFF     OFF     OFF     OFF     OFF     OFF     OFF
FE           OFF     OFF     OFF     OFF     OFF     OFF     OFF
LDOM          ON      ON      ON      ON      ON      ON      ON
RDOM          ON      ON      ON      ON      ON      ON      ON
LPOM          ON      ON      ON      ON      ON      ON      ON
RPOM          ON      ON      ON      ON      ON      ON      ON
ALG1          ON      ON      ON      ON      ON      ON      ON
DO            ON      ON      ON      ON      ON      ON      ON
TIC           ON      ON      ON      ON      ON      ON      ON
ALK           ON      ON      ON      ON      ON      ON      ON

CDT CON   CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC
TDS          OFF     OFF     OFF     OFF     OFF
Gen1         OFF      ON      ON     OFF      ON
Gen2         OFF      ON      ON     OFF      ON
ISS1         OFF      ON      ON     OFF      ON
PO4          OFF      ON      ON     OFF      ON
NH4          OFF      ON      ON     OFF      ON
NO3          OFF      ON      ON     OFF      ON
DSI          OFF     OFF     OFF     OFF     OFF
PSI          OFF     OFF     OFF     OFF     OFF
FE           OFF     OFF     OFF     OFF     OFF
LDOM         OFF      ON      ON     OFF      ON
RDOM         OFF      ON      ON     OFF      ON
LPOM         OFF      ON      ON     OFF      ON
RPOM         OFF      ON      ON     OFF      ON
ALG1         OFF      ON      ON     OFF      ON
DO           OFF      ON      ON     OFF      ON
TIC          OFF      ON      ON     OFF      ON
ALK          OFF      ON      ON     OFF      ON

CPR CON   CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC
TDS          OFF     OFF     OFF     OFF     OFF
Gen1         OFF     OFF     OFF     OFF     OFF
Gen2         OFF     OFF     OFF     OFF     OFF
ISS1         OFF     OFF     OFF     OFF     OFF
PO4          OFF     OFF     OFF     OFF     OFF
NH4          OFF     OFF     OFF     OFF     OFF
NO3          OFF     OFF     OFF     OFF     OFF
DSI          OFF     OFF     OFF     OFF     OFF
PSI          OFF     OFF     OFF     OFF     OFF
FE           OFF     OFF     OFF     OFF     OFF
LDOM         OFF     OFF     OFF     OFF     OFF
RDOM         OFF     OFF     OFF     OFF     OFF
LPOM         OFF     OFF     OFF     OFF     OFF
RPOM         OFF     OFF     OFF     OFF     OFF
ALG1         OFF     OFF     OFF     OFF     OFF
DO           OFF     OFF     OFF     OFF     OFF
TIC          OFF     OFF     OFF     OFF     OFF
ALK          OFF     OFF     OFF     OFF     OFF

EX COEF    EXH2O    EXSS    EXOM    BETA     EXC    EXIC
WB 1     0.45000 0.01000 0.01000 0.45000     OFF     OFF
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WB 2     0.45000 0.01000 0.01000 0.45000     OFF     OFF
WB 3     0.45000 0.01000 0.01000 0.45000     OFF     OFF

ALG EX       EXA     EXA     EXA     EXA     EXA     EXA
         0.20000

GENERIC    CGQ10   CG0DK   CG1DK     CGS
CG 1     0.00000 0.00000 0.00000 0.00000
CG 2     1.04000 0.00000 0.20000 0.00000

S SOLIDS     SSS     SSS     SSS     SSS     SSS     SSS     SSS     SSS     SSS
         0.50000

ALGAL RATE    AG      AR      AE      AM      AS    AHSP    AHSN   AHSSI    ASAT
ALG1     2.00000 0.04000 0.04000 0.10000 0.10000 0.00300 0.01400 0.00000 75.0000

ALGAL TEMP   AT1     AT2     AT3     AT4     AK1     AK2     AK3     AK4
ALG1     5.00000 25.0000 35.0000 40.0000 0.10000 0.99000 0.99000 0.10000

ALG STOI    ALGP    ALGN    ALGC   ALGSI   ACHLA   ALPOM   ANEQN    ANPR
ALG1     0.00500 0.08000 0.45000 0.18000 100.000 0.80000       2 0.00100

EPIPHYTE    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC
EPI1         OFF     OFF     OFF

EPI PRIN    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC
EPI1         OFF     OFF     OFF

EPI INIT   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI
EPI1     0.00000 0.00000 0.00000

EPI RATE      EG      ER      EE      EM      EB    EHSP    EHSN   EHSSI
EPI1     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

EPI HALF    ESAT     EHS   ENEQN    ENPR
EPI1     0.10000 0.00000       0 0.00000

EPI TEMP     ET1     ET2     ET3     ET4     EK1     EK2     EK3     EK4
EPI1     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

EPI STOI      EP      EN      EC     ESI   ECHLA    EPOM
EPI1     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

DOM       LDOMDK  RDOMDK   LRDDK
WB 1     0.10000 0.00100 0.01000
WB 2     0.10000 0.00100 0.01000
WB 3     0.10000 0.00100 0.01000

POM       LPOMDK  RPOMDK   LRPDK    POMS
WB 1     0.08000 0.00100 0.01000 0.10000
WB 2     0.08000 0.00100 0.01000 0.10000
WB 3     0.08000 0.00100 0.01000 0.10000

OM STOIC    ORGP    ORGN    ORGC   ORGSI
WB 1     0.00500 0.08000 0.45000 0.18000
WB 2     0.00500 0.08000 0.45000 0.18000
WB 3     0.00500 0.08000 0.45000 0.18000
```

OM RATE	OMT1	OMT2	OMK1	OMK2
WB 1	4.00000	25.0000	0.10000	0.99000
WB 2	4.00000	25.0000	0.10000	0.99000
WB 3	4.00000	25.0000	0.10000	0.99000

CBOD	KBOD	TBOD	RBOD
BOD 1	0.01000	0.01000	0.01000

CBOD STOIC	BODP	BODN	BODC
BOD 1	0.00000	0.00000	0.00000

PHOSPHOR	PO4R	PARTP
WB 1	0.0300	0.00000
WB 2	0.0300	0.00000
WB 3	0.0300	0.00000

AMMONIUM	NH4R	NH4DK
WB 1	0.00100	0.12000
WB 2	0.00100	0.12000
WB 3	0.00100	0.12000

NH4 RATE	NH4T1	NH4T2	NH4K1	NH4K2
WB 1	5.00000	25.0000	0.10000	0.99000
WB 2	5.00000	25.0000	0.10000	0.99000
WB 3	5.00000	25.0000	0.10000	0.99000

NITRATE	NO3DK	NO3S
WB 1	0.03000	1.00000
WB 2	0.03000	1.00000
WB 3	0.03000	1.00000

NO3 RATE	NO3T1	NO3T2	NO3K1	NO3K2
WB 1	5.00000	25.0000	0.10000	0.99000
WB 2	5.00000	25.0000	0.10000	0.99000
WB 3	5.00000	25.0000	0.10000	0.99000

SILICA	DSIR	PSIS	PSIDK	PARTSI
WB 1	5.00000	20.0000	0.05000	0.99000
WB 2	5.00000	20.0000	0.05000	0.99000
WB 3	5.00000	20.0000	0.05000	0.99000

IRON	FER	FES
WB 1	0.00000	0.00000
WB 2	0.00000	0.00000
WB 3	0.00000	0.00000

SED CO2	CO2R
WB 1	0.50000
WB 2	0.50000
WB 3	0.50000

STOICH 1	O2NH4	O2OM
WB 1	4.57000	1.40000
WB 2	4.57000	1.40000
WB 3	4.57000	1.40000

STOICH 2	O2AR	O2AG
ALG1	1.10000	1.40000

```
STOICH 3    O2ER    O2EG
EPI1     0.00000 0.00000

O2 LIMIT   O2LIM
         0.10000

SEDIMENT    SEDC  SEDPRC   SEDCI    SEDK    FSOD    FSED
WB 1          ON     OFF 0.00000 0.10000 1.00000 1.00000
WB 2          ON     OFF 0.00000 0.10000 1.00000 1.00000
WB 3          ON     OFF 0.00000 0.10000 1.00000 1.00000

SOD RATE   SODT1   SODT2   SODK1   SODK2
WB 1     4.00000 30.0000 0.10000 0.99000
WB 2     4.00000 30.0000 0.10000 0.99000
WB 3     4.00000 30.0000 0.10000 0.99000

S DEMAND     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
         1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
          2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
'wb3
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000 2.00000
         2.00000 2.00000

REAERATION  TYPE    EQN#   COEF1   COEF2   COEF3   COEF4
WB 1       RIVER       8 0.00000 0.00000 0.00000 0.00000
WB 2       RIVER       8 0.00000 0.00000 0.00000 0.00000
WB 3       RIVER       8 0.00000 0.00000 0.00000 0.00000

RSI FILE..................................RSIFN................................
        rsi.npt

QWD FILE..................................QWDFN................................
        qwd.npt

QGT FILE..................................QGTFN................................
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        qgt.npt

WSC FILE.................................WSCFN................................
        wsc.npt

SHD FILE.................................SHDFN................................
        shade.npt

BTH FILE.................................BTHFN................................
WB 1    bth_wb1.npt
WB 2    bth_wb2.npt
WB 3    bth_wb3.npt

MET FILE.................................METFN................................
WB 1    met_wb1.npt
WB 2    met_wb2.npt
WB 3    met_wb3.npt

EXT FILE.................................EXTFN................................
WB 1    ext_wb1.npt - not used
WB 2    ext_wb2.npt - not used
WB 3    ext_wb3.npt - not used

VPR FILE.................................VPRFN................................
WB 1    vpr00wb1.npt
WB 2    vpr00wb2.npt
WB 3    vpr00wb3.npt

LPR FILE.................................LPRFN................................
WB 1    lpr_1.npt
WB 2    lpr_2.npt
WB 3    lpr_3.npt

QIN FILE.................................QINFN................................
BR1     qin_br1.npt
BR2     qin_br2.npt
BR3     qin_br3.npt
BR4     qin_br4.npt
BR5     qin_br5.npt

TIN FILE.................................TINFN................................
BR1     Tin_br1.npt
BR2     tin_br2.npt
BR3     tin_br3.npt
BR4     tin_br4.npt
BR5     tin_br5.npt

CIN FILE.................................CINFN................................
BR1     Cin_br1.npt
BR2     cin_br2.npt
BR3     cin_br3.npt
BR4     cin_br4.npt
BR5     cin_br5.npt

QOT FILE.................................QOTFN................................
BR1     qll_00.npt
BR2     qot_br2.npt
BR3     qot_br3.npt
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BR4     qot_br4.npt
BR5     qot_br5.npt

QTR FILE.................................QTRFN................................
TR1     qtr_tr1.npt
TR2     qtr_tr2.npt
TR3     qtr_tr3.npt
TR4     qtr_tr4.npt
TR5     qtr_tr5.npt
TR6     qtr_tr6.npt
TR7     qtr_tr7.npt

TTR FILE.................................TTRFN................................
TR1     ttr_tr1.npt
TR2     ttr_tr2.npt
TR3     ttr_tr3.npt
TR4     ttr_tr4.npt
TR5     ttr_tr5.npt
TR6     ttr_tr6.npt
TR7     ttr_tr7.npt

CTR FILE.................................CTRFN................................
TR1     ctr_tr1.npt
TR2     ctr_tr2.npt
TR3     ctr_tr3.npt
TR4     ctr_tr4.npt
TR5     ctr_tr5.npt
TR6     ctr_tr6.npt
TR7     ctr_tr7.npt

QDT FILE.................................QDTFN................................
BR1     qdt_br1.npt
BR2     qdt_br2.npt
BR3     qdt_br3.npt
BR4     qdt_br4.npt
BR5     qdt_br5.npt

TDT FILE.................................TDTFN................................
BR1     tdt_br1.npt
BR2     tdt_br2.npt
BR3     tdt_br3.npt
BR4     tdt_br4.npt
BR5     tdt_br5.npt

CDT FILE.................................CDTFN................................
BR1     cdt_br1.npt
BR2     cdt_br2.npt
BR3     cdt_br3.npt
BR4     cdt_br4.npt
BR5     cdt_br5.npt

PRE FILE.................................PREFN................................
BR1     pre_br1.npt
BR2     pre_br2.npt
BR3     pre_br3.npt
BR4     pre_br4.npt

BR5     pre_br5.npt
```

```
TPR FILE..................................TPRFN.................................
BR1     tpr_br1.npt
BR2     tpr_br2.npt
BR3     tpr_br3.npt
BR4     tpr_br4.npt
BR5     tpr_br5.npt

CPR FILE..................................CPRFN.................................
BR1     cpr_br1.npt
BR2     cpr_br2.npt
BR3     cpr_br3.npt
BR4     cpr_br4.npt
BR5     cpr_br5.npt

EUH FILE..................................EUHFN.................................
BR1     euh_br1.npt
BR2     euh_br2.npt
BR3     euh_br3.npt
BR4     euh_br4.npt
BR5     euh_br5.npt

TUH FILE..................................TUHFN.................................
BR1     tuh_br1.npt
BR2     tuh_br2.npt
BR3     tuh_br3.npt
BR4     tuh_br4.npt
BR5     tuh_br5.npt

CUH FILE..................................CUHFN.................................
BR1     cuh_br1.npt
BR2     cuh_br2.npt
BR3     cuh_br3.npt
BR4     cuh_br4.npt
BR5     cuh_br5.npt

EDH FILE..................................EDHFN.................................
BR1     edh_br1.npt
BR2     edh_br2.npt
BR3     edh_br3.npt
BR4     edh_br4.npt
BR5     edh_br5.npt

TDH FILE..................................TDHFN.................................
BR1     tdh_br1.npt
BR2     tdh_br2.npt
BR3     tdh_br3.npt
BR4     tdh_br4.npt
BR5     tdh_br5.npt

CDH FILE..................................CDHFN.................................
BR1     cdh_br1.npt
BR2     cdh_br2.npt
BR3     cdh_br3.npt
BR4     cdh_br4.npt
BR5     cdh_br5.npt

SNP FILE..................................SNPFN.................................
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```
WB 1    snp1.opt
WB 2    snp2.opt
WB 3    snp3.opt

PRF FILE.................................PRFFN................................
WB 1    prf1.opt
WB 2    prf2.opt
WB 3    prf3.opt

VPL FILE.................................VPLFN................................
WB 1    vpl1.opt
WB 2    vpl2.opt
WB 3    vpl3.opt

CPL FILE.................................CPLFN................................
WB 1    cpl1.opt
WB 2    cpl2.opt
WB 3    cpl3.opt

SPR FILE.................................SPRFN................................
WB 1    spr1.opt
WB 2    spr2.opt
WB 3    spr3.opt

FLX FILE.................................FLXFN................................
WB 1    kfl1.opt
WB 2    kfl2.opt
WB 3    kfl3.opt

TSR FILE.................................TSRFN................................
        tsr.opt

WDO FILE.................................WDOFN................................
        wdo.opt
```