Upper Spokane River Model in Idaho: Boundary Conditions and Model Setup and Calibration for 2001 and 2004

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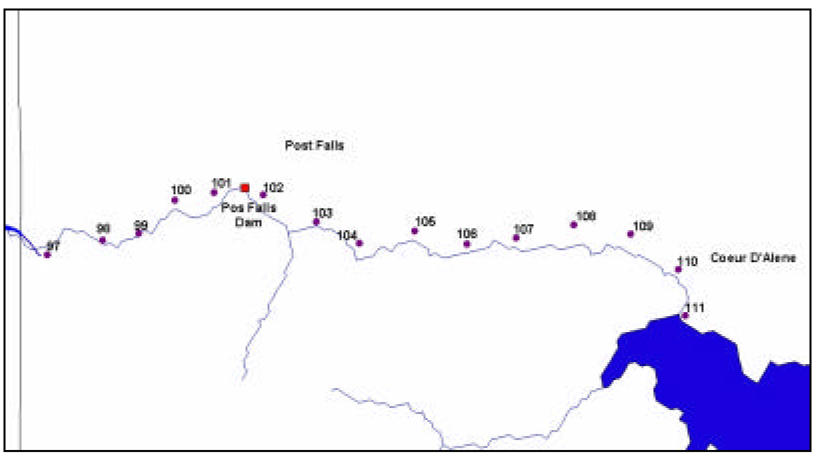

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Technical Report EWR-02-05

Prepared for the Washington Department of Ecology

July 2005

Table of Contents

List of Figures

List of Tables

Introduction

The Spokane River in Idaho originates in Coeur d'Alene Lake (Figure 1 and Figure 2). The section of the Spokane River from Coeur d'Alene Lake to the Washington state line is the subject of a water quality study for the US Environmental Protection Agency. The objective of this study is to create a water quality and hydrodynamic model of the Spokane River in Idaho using CE-QUAL-W2 Version 3.1 (Cole and Wells, 2002).

As a result of a Total Maximum Daily Load (TMDL) study of the Spokane River in Washington, a hydrodynamic and water quality model for the Spokane River was developed by Portland State University (PSU) for the Corps of Engineers and the Washington Department of Ecology from the Washington-Idaho state line to the outlet of Long Lake.

Prior reports prepared for the Spokane River modeling in Washington include:

- Annear et al. (2001) - Upper Spokane River Model: Boundary Conditions and Model Setup for 1991 and 2000
- Berger et al. (2002) - Upper Spokane River Model: Calibration for 1991 and 2000
- Slominski et al. (2002) - Upper Spokane River Model: Boundary Conditions and Model Setup for 2001
- Berger et al. (2003) - Upper Spokane River Model: Calibration for 2001

An earlier study of the Spokane River was undertaken by Limno-Tech (2001a, 2001b) for the domain shown in Figure 3. Limno-Tech used an earlier version of CE-QUAL-W2, Version 2, for the Reservoir portion of the Spokane River from Post Falls Dam to Coeur d'Alene Lake and a steady-state EPA model, QUAL2E, for the riverine section from Post Falls Dam to the Idaho-Washington State Line. The steady-state QUAL2E model was not adequate to deal with flow and water quality dynamics. Hence, the riverine portion of the model and the reservoir portion were both upgraded to CE-QUAL-W2 Version 3.1. PSU developed the CE-QUAL-W2 model, but did not have adequate data for model calibration. The set-up of this model was described in the following report:

- Wells et al. (2003) - Upper Spokane River Model in Idaho: Boundary Conditions and Model Setup for 2001

Because of the necessity of looking at the entire river basin, a model using CE-QUAL-W2 Version 3.1 of the Idaho portion of the Spokane River model was developed to assess water quality management strategies for the Idaho side of the Spokane River. The objective of this study was to use new field data from 2001 and 2004 to improve the model calibration for the Idaho portion of the Spokane River and re-evaluate the work done by Wells et al. (2003).

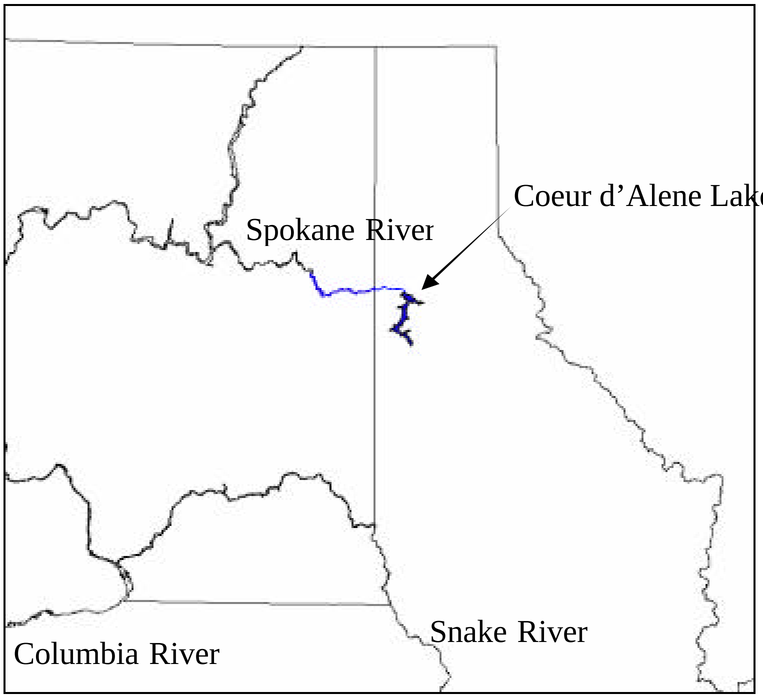


Figure 1: Spokane River study area in Idaho.

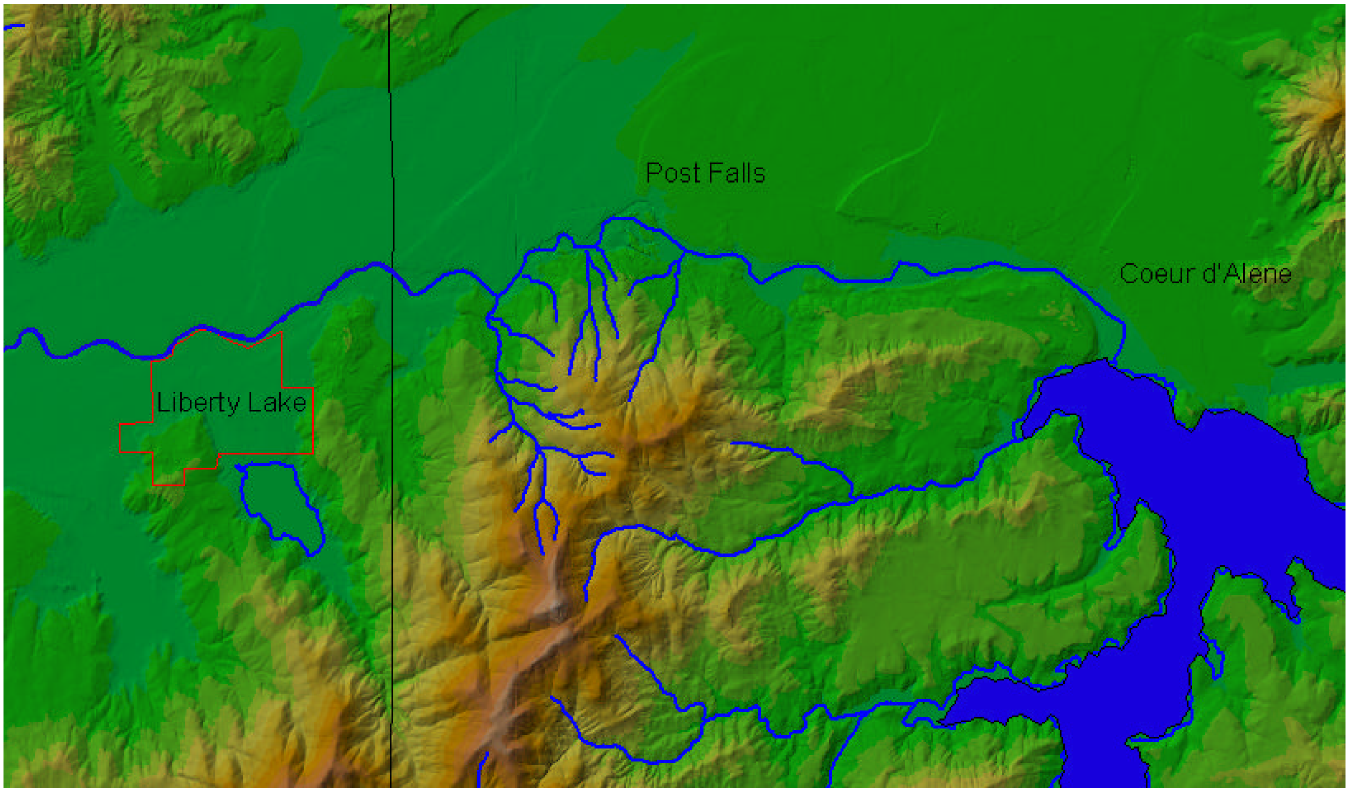


Figure 2: Spokane River from Coeur d'Alene Lake to the Washington-Idaho State Line.

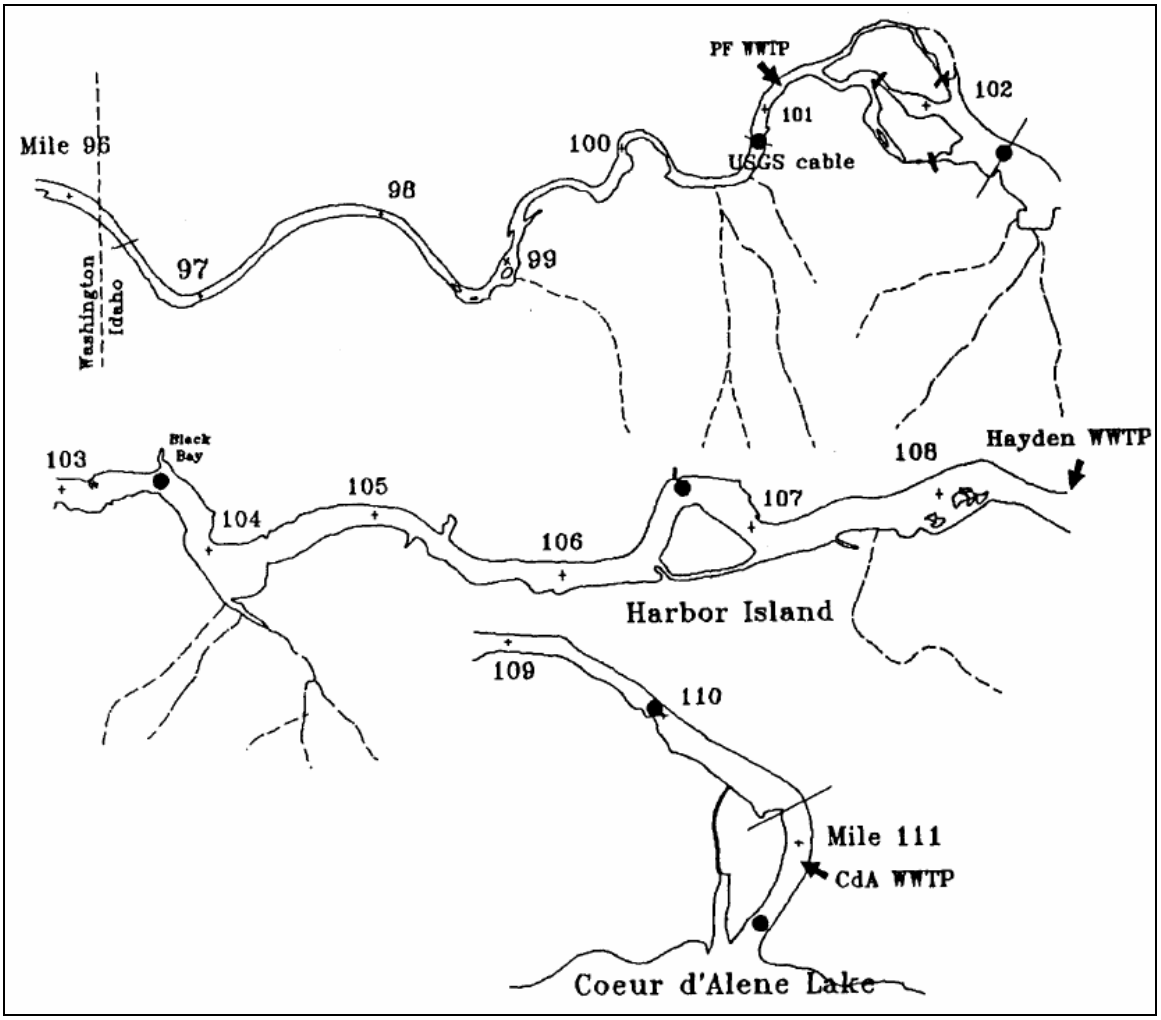


Figure 3: Map of study area from Limno-Tech, Inc. (2001a, 2001b).

Background

Washington Department of Ecology (Ecology) described the background of the Spokane River study area (Cusimano, 2002):

> The Spokane River upstream of Long Lake (Figure 4) drains over 6,000 square miles of land in Washington and Idaho. The Spokane River flows west from Lake Coeur d'Alene in Idaho, across the State Line to the City of Spokane. From Spokane, the river flows northwesterly to its confluence with the Columbia River at Lake Roosevelt. Most of the people in the watershed live in the Spokane metropolitan area. However, the incorporated area of Liberty Lake east of Spokane and the Cities of Coeur d'Alene and Post Falls in Idaho are growing in population.
>
> Ecology is concerned about the pollutant loading capacity of the Spokane River system, including the Long Lake impoundment, which has a long history of water quality problems. The Spokane River exhibits low dissolved oxygen levels during the summer months, in violation of Washington State water quality standards. Segments of the river are included on Ecology's 1998 303 (d) list of impaired water bodies for dissolved oxygen. A TMDL for this water body was

identified as a high priority during the water quality scoping process for the Spokane Water Quality Management Area.

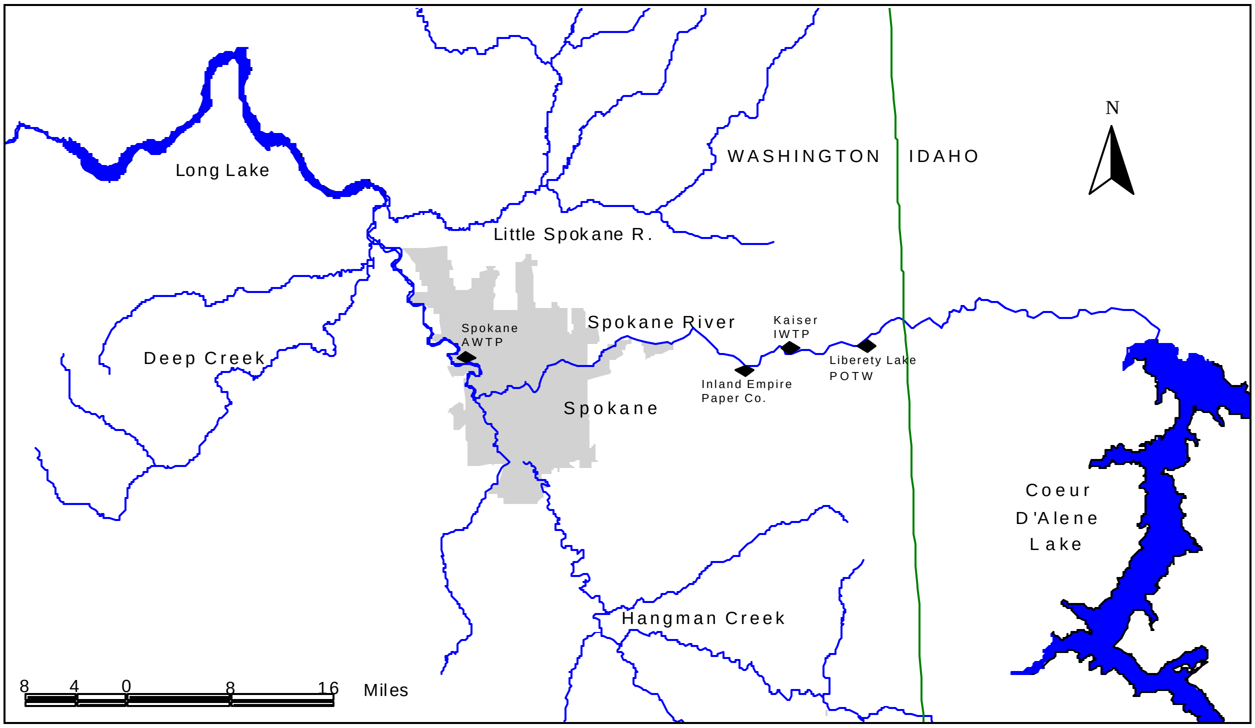


Figure 4: Current TMDL study area for the Spokane River.

The following facilities have National Pollutant Discharge Elimination System (NPDES) permits for discharging BOD, ammonia, and phosphorus to the Spokane River study area, in order of upstream to downstream:

Washington:

- Liberty Lake Publicly Owned Treatment Works (POTW)
- Kaiser Aluminum Industrial Wastewater Treatment Plant (IWTP)
- Inland Empire Paper Company IWTP
- City of Spokane AWTP

Idaho:

- Coeur d'Alene Wastewater Treatment Plant (WTP)
- Hayden Area Regional Sewer Board WTP (land discharge during the summer)
- Post Falls WTP

The following tributaries affect dissolved oxygen levels and nutrient concentrations in the Spokane River study area:

- Latah Creek (formerly Hangman Creek) (note – City of Cheney, Spangle, Rockford, Tekoa, and FairField all have small seasonal POTW discharges to creeks in the watershed.)
- Little Spokane River (note – Kaiser-Mead discharges to the Spokane River)
- Deep Creek (note – City of Medical Lake discharges to Deep Creek. In Knight, 1998 it was stated, "at current proposed design flows the discharge will probably not affect the Spokane

River. However, as the system is expanded there may be some winter hydraulic capacity issues in Deep Cr. and a potential for a new growing season P load to the Spokane River.")

The Spokane aquifer also potentially affects dissolved oxygen levels and nutrient concentrations in the river. The aquifer discharges to the river in some reaches, and is recharged by the river in other reaches.

The TMDL study area is currently from the Washington/Idaho State Line at river mile (RM) 96.0 to Long Lake Dam at RM 33.9. The [Portland State University] PSU group developed a CE-QUAL-W2 model of the river-lake system for 1991 and 2000 from the Washington State line to the outlet of Long Lake. This further work would extend the model into Idaho. Ecology will use the model developed by PSU to recommend TMDL pollutant allocations to protect the water quality of the Spokane River and Long Lake. However, there are interstate water quality issues with Idaho that are currently not being addressed since the model does not extend past the Washington-Idaho border.

Water quality at the State Line with Idaho is not meeting Washington State's dissolved oxygen criterion, and the upstream impacts of point sources (e.g., Lake Coeur d'Alene WTP and Post Falls WTP) of oxygen consuming substances on water quality in the river are unknown.

Model Boundary Condition and Forcing Data

Model Bathymetry

The model geometry was developed in two sections:

- Coeur d'Alene Lake to Post Falls Dam
- Post Falls Dam to the Washington-Idaho State Line

Existing information from both sections was used to develop the grid for CE-QUAL-W2.

Post Falls Dam to the Washington-Idaho Border

The river section from Post Falls Dam to the Washington-Idaho State Line was developed using Digital Elevation Models (DEMs) of the river channel topography, and two river cross-sections – one at the Post Falls USGS gage (12419000) and one at the Washington-Idaho State Line as shown in Figure 5. The two cross-sections are shown in Figure 6 and Figure 7. The cross-section at Washington-Idaho State Line (RM 96.401) was based on an older historical cross-section. The maximum elevations of the cross-section agreed with the DEM data of the river banks.

The cross-section elevations at Post Falls (RM 100.515) were obtained by adding the gage height to the datum and then subtracting off the water depths measured. The elevation datum at the Post Falls gage station was corrected in June, 2005 based on conversations with USGS staff at Post Falls, Idaho (Keith Hein). This correction affected the river cross section elevation and the water level elevation data recorded at this site. The river bathymetry, model grid and water level elevation data were all adjusted to correct for the datum change.

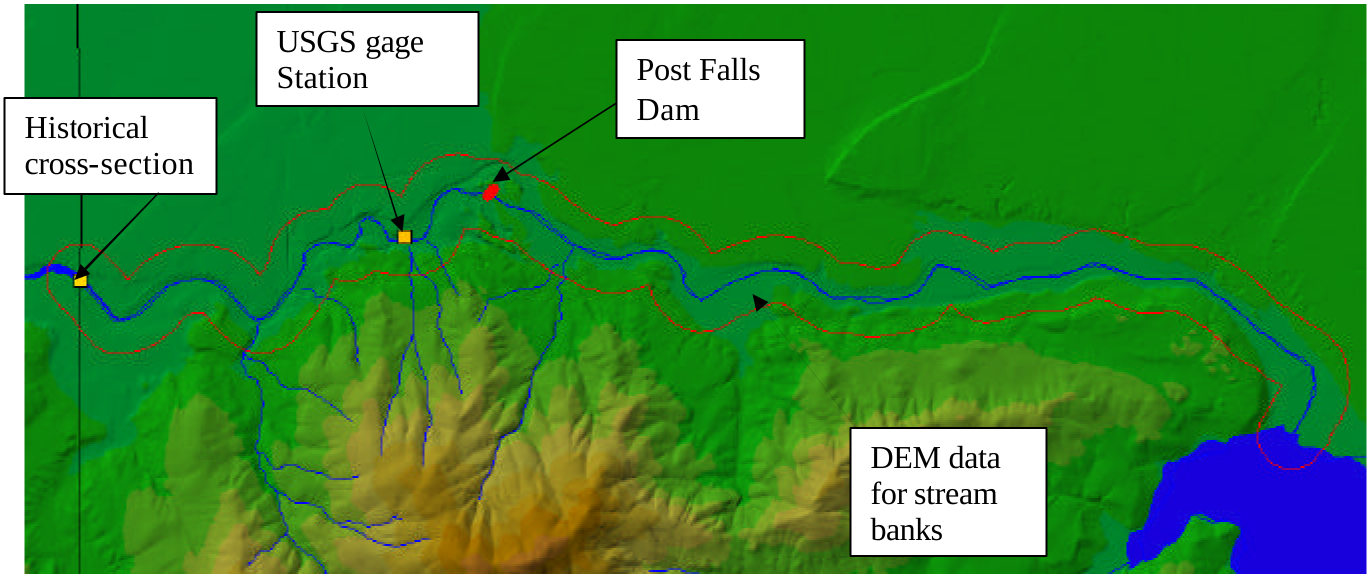


Figure 5: Spokane River study area showing DEM coverage and location of 2 cross-sections below Post Falls Dam.

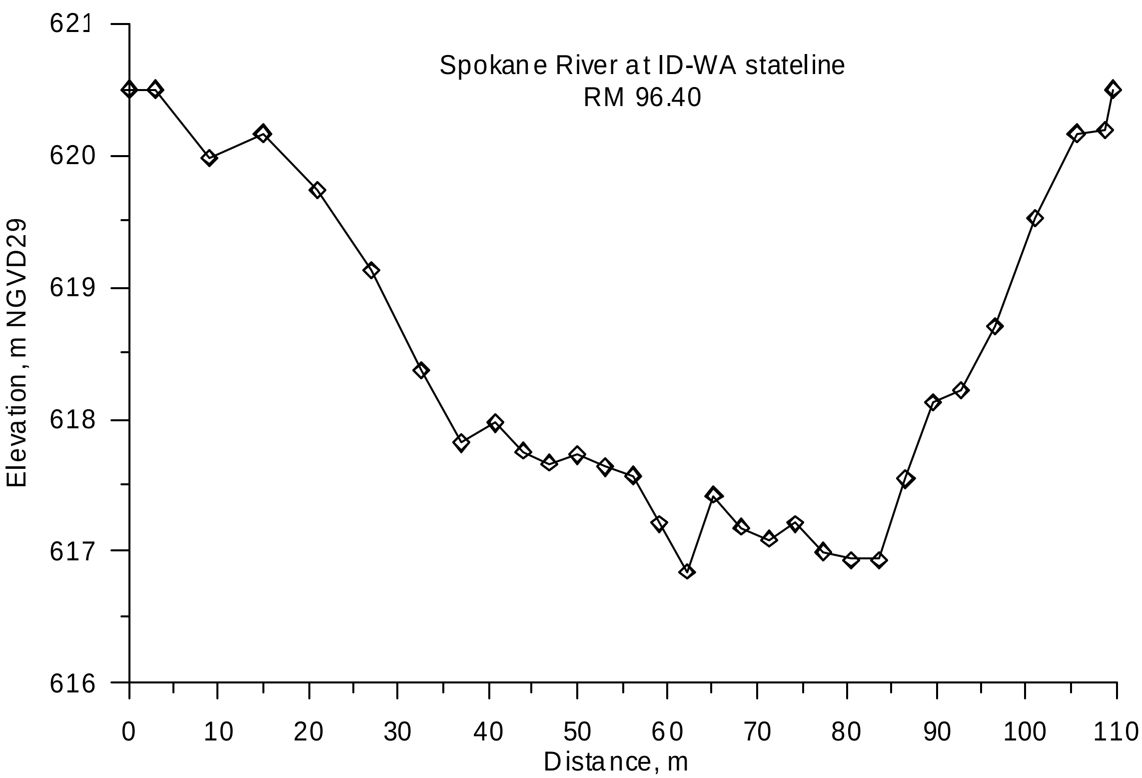


Figure 6: Spokane River cross-section at RM 96.4.

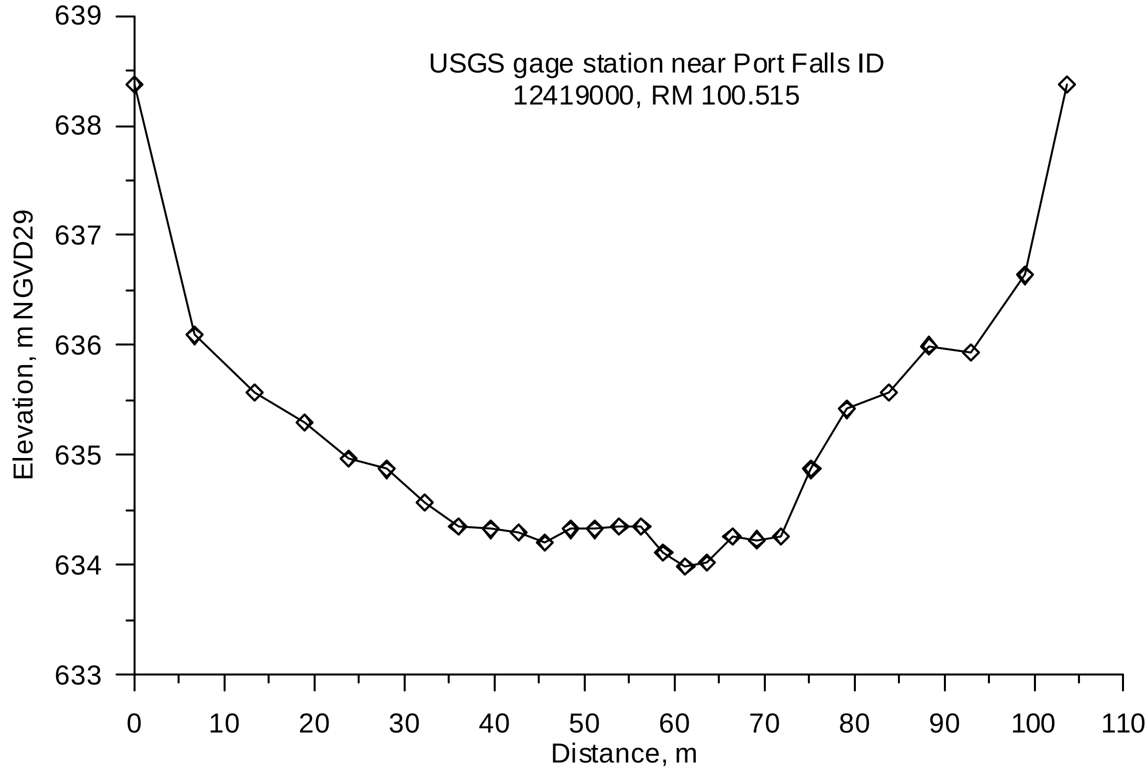


Figure 7: Spokane River cross-section at RM 100.515.

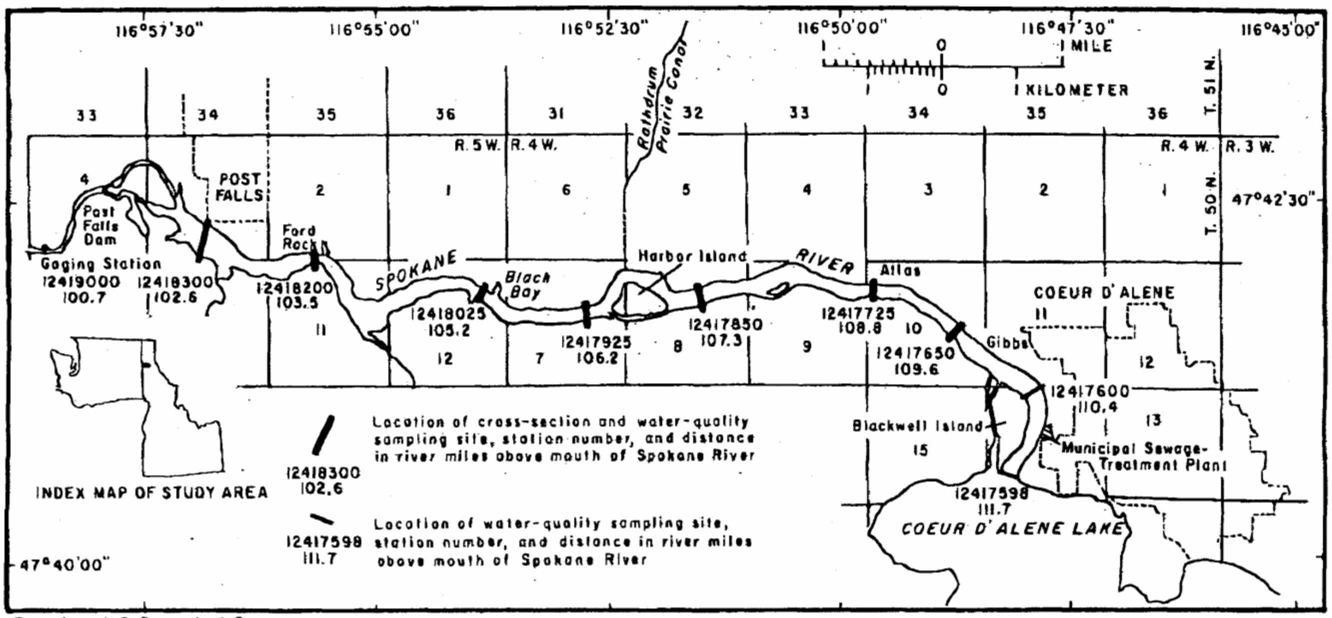
The first step in generating the river bathymetry was using the river centerline points every 30 m to generate river cross sections for the wetted channel. Elevations for these river cross section points were calculated by interpolating between the two cross sections at RM 96.401 and 100.515. If the cross sections were upstream or downstream of the two data cross sections then the nearest cross section was used with adjustments in the elevation using the stream gradient, which was developed using the elevation change over the ricer channel. The cross sections were then combined with the 10 m resolution DEM data (up to 500 m away from the stream channel) to interpolate a contour plot of the river channel. Using the slope computed in GIS (Geographic Information System) for the river resulted in river bottom elevations above the water surface. Hence, the GIS calculated slopes were not used. The slope of the river between the Washington-Idaho State Line and Post Falls Dam was 0.242%.

Coeur d'Alene Lake to Post Falls Dam

This section of the model was constructed based on an earlier W2 Version 2 model development by Limno-Tech, Inc. (2001). The section of the model developed by Limno-Tech, Inc. (2001) was based on a set of 8 cross-sections taken at locations noted in Figure 8 and Table 1 done in 1980 (Seitz and Jones, 1981). Individual cross-section data are shown in Figure 9, Figure 10, Figure 11, and Figure 12. Seitz and Jones (1981) also estimated the Manning's friction factors for this reach as shown in Table 1. Also, another 5 cross-sections were taken in 1991 by Falter and Riggers (Cusimano, 2002) above Post Falls Dam. These data are summarized in Table 2. Apparently, these data were also used by Limno-Tech (2001) to develop their model grid.

Table 1: Cross-sections surveyed by Seitz and Jones (1981) in 1980 at 8 locations above Post Falls Dam, as well as estimated friction factors.

Cross-section ID#	RM location	Estimated Manning's friction, n
12417600	110.4	0.027-0.028
12417650	109.6	0.026-0.027
12417725	108.8	0.027-0.028
12417850	107.3	0.027-0.028
12417925	106.2	0.029-0.030
12418025	105.2	0.030-0.032
12418200	103.5	0.034-0.036
12418300	102.6	0.029-0.030



Base from U.S. Geological Survey
Coeur d' Alene NE 1:24,000, 1975 and
Coeur d' Alene NW 1:24,000, 1975

Figure 8: Map showing survey locations for 1980 study of Seitz and Jones (1981).

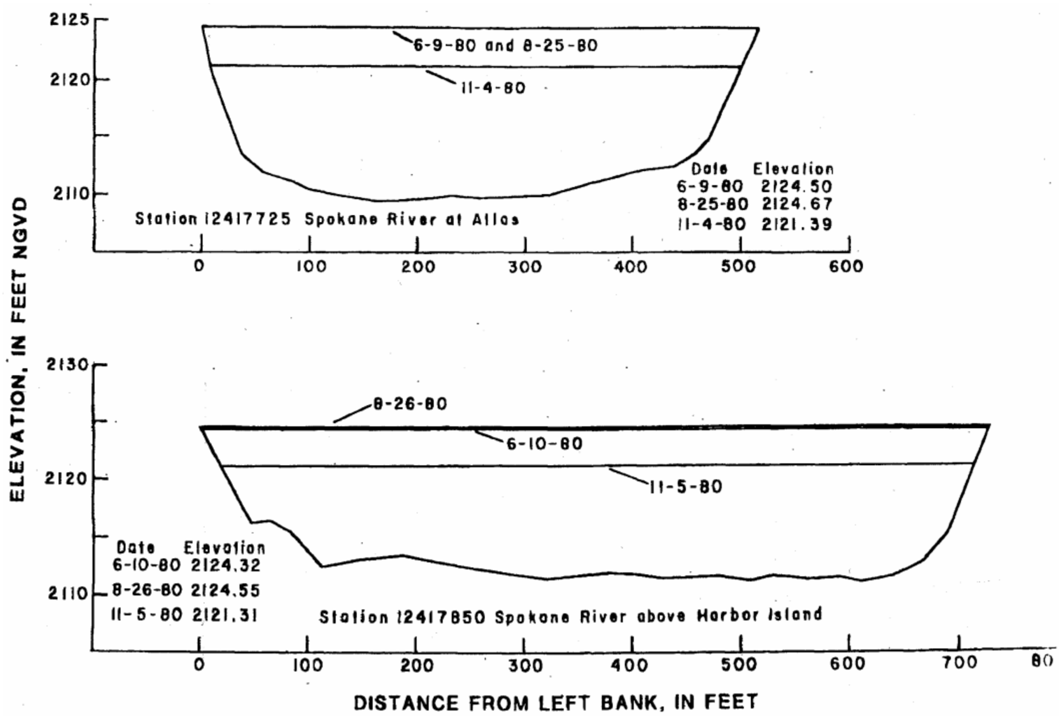


Figure 9: Survey information from Seitz and Jones (1981) for stations 12417725 and 12417850.

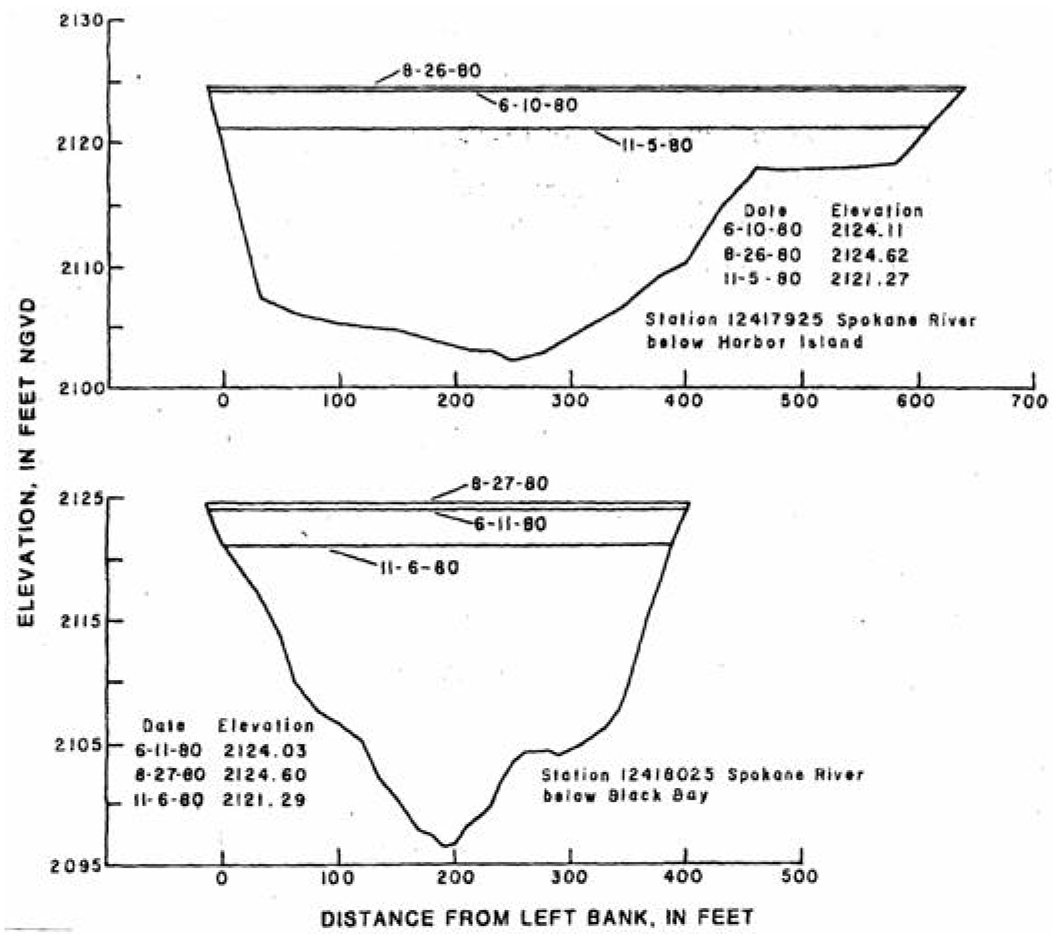


Figure 10: Survey information from Seitz and Jones (1981) for stations 12417925 and 12418025.

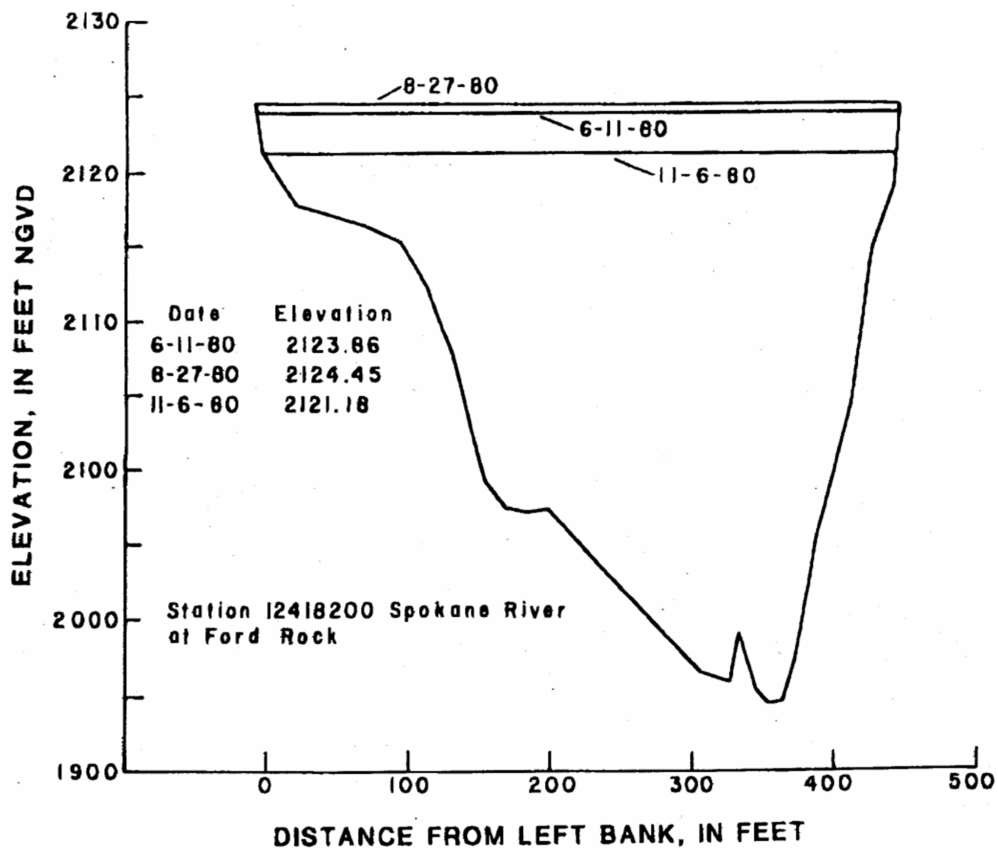


Figure 11: Survey information from Seitz and Jones (1981) for stations 12418200.

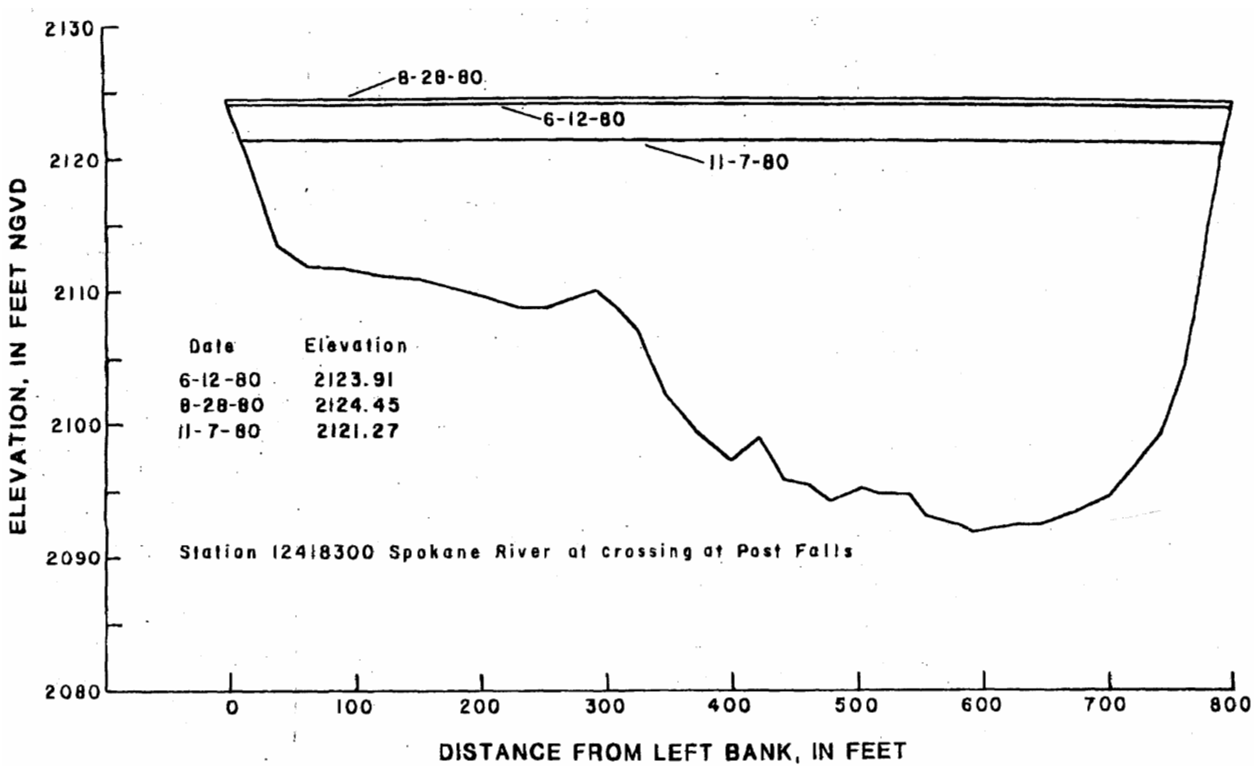


Figure 12: Survey information from Seitz and Jones (1981) for stations 12418300.

Table 2: Cross-section depths (ft) on August 13, 1991 when the water level elevation was 2128 ft.

Distance from Right bank, ft	Station 1, RM 111.1	Station 2, RM 108.8	Station 3, RM 106.2	Station 4, RM 103.5	Station 5, RM 102.5
0	0	0	0	0	0
19.0	1.9	4.7	5	14	15
38.1	3.8	5.3	5.6	16.9	20
57.1	5.8	8.9	8	19.1	23
76.1	6.7	11.2	17.1	19.4	24.5
95.5	7.5	12	19	27.9	26
114.5	8	12.6	20.1	28.8	27.2
133.5	8.9	13	21.2	34.9	28
152.6	8.6	13.6	21.7	32	29.2
171.6	9.3	14.4	22.1	31.8	29.6
190.6	9	15	22.2	31.9	28.6
209.7	9.7	15.3	22.1	30	28
228.7	10.2	16	21.7	27.5	26.2
247.7	10.7	16.8	20.8	24.7	24
267.1	11	15	20.5	22.4	19.5
286.1	10.9	11	20.4	13	16.2
305.1	10.4	10.2	19	11.1	14.2
324.2	10	9	16.9	10.7	15.9
343.5	10	2.7	15	10.7	16
362.2	9.8	0 (at 361 ft)	12.2	9.9	14.9
381.3	9.3		10.3	7	14.3
400.3	9.1		7.8	4.8	13.7
419.6	8.5		7.7	2.3	13.3
438.7	6.9		6.1	0 (at 440 ft)	12.9
457.7	5.2		4.9		12
476.7	4		3.2		12.2
495.8	2.9		2.1		11.7
514.8	0 (at 515 ft)		0 (at 515 ft)		10.8
533.8					10.5
552.8					10
571.9					0 (at 571 ft)
Mean depths	7.43	10.34	13.31	17.95	17.66

Model Grid

The model grid was divided into 2 separate water bodies: the Post Falls Dam to Coeur d'Alene reservoir-like section and the Post Falls Dam to the Washington-Idaho State Line riverine section. For the first water body, the existing grid developed by S. Wells for Limno Tech, Inc. (2001b) for the earlier CE-QUAL-W2 Version 2 model was used with minor file revisions. The segment numbers from Limno Tech, Inc. (2001b) are shown in Figure 13 with segment spacing of 643.7 m and no channel slope.

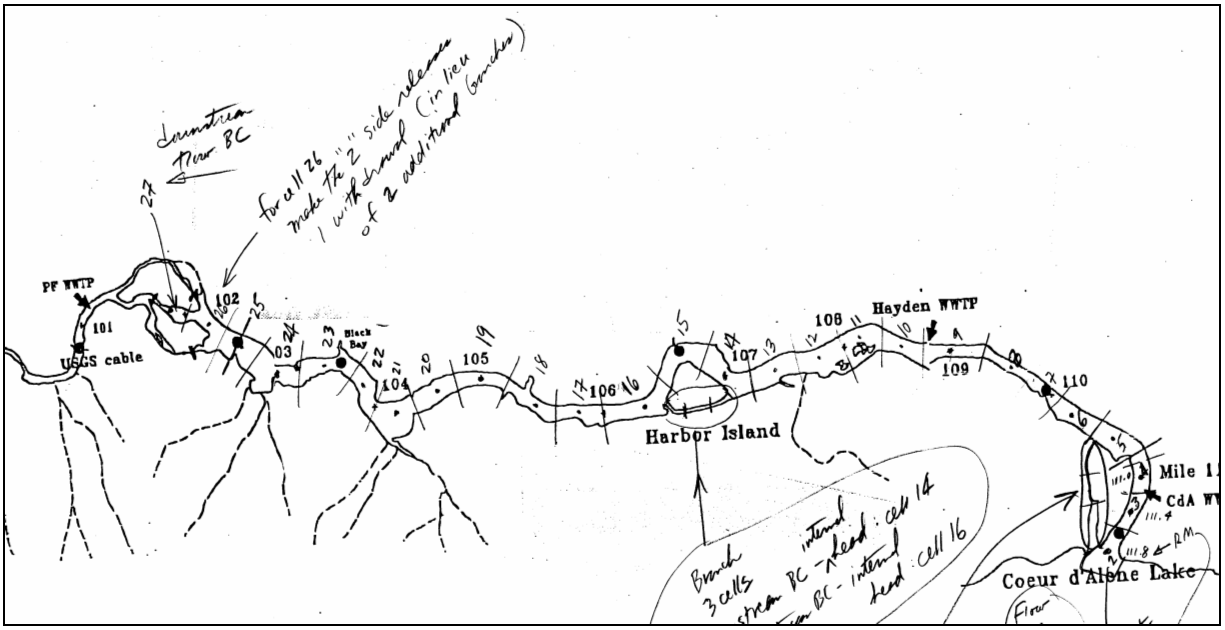


Figure 13: Model segment layout from Wells in work done for Limno-Tech, Inc. (2001).

For the riverine section the grid was developed using data from the 2 cross-sections mentioned above. The process of developing the river grid consisted of the following steps:

- Creation of a topographic map of the river channel using x, y, z information from the 2 cross-sections, DEMs and interpolated points
- Dividing the river channel into model segments (consisting of polygons)
- Creating for each segment a model volume versus elevation relationship
- Computing the segment widths from the volume versus elevation relationship for each segment
- Constructing a model file compatible with CE-QUAL-W2

This procedure is also detailed in the CE-QUAL-W2 user's manual (Cole and Wells, 2002). The slope of the riverine section is shown in Figure 14. Figure 15 shows the segment layout using a segment length of 252 m with a channel slope of 0.00198.

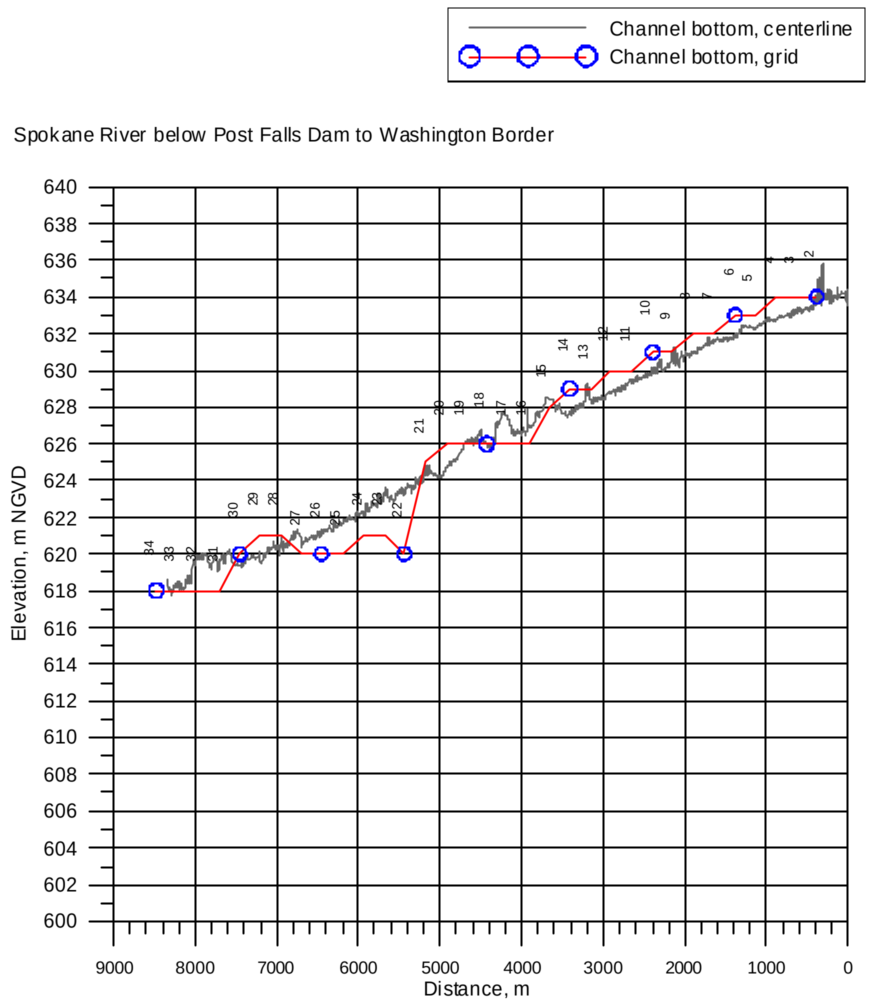


Figure 14: Channel bottom elevations from Post Falls Dam to Idaho-Washington State Line.

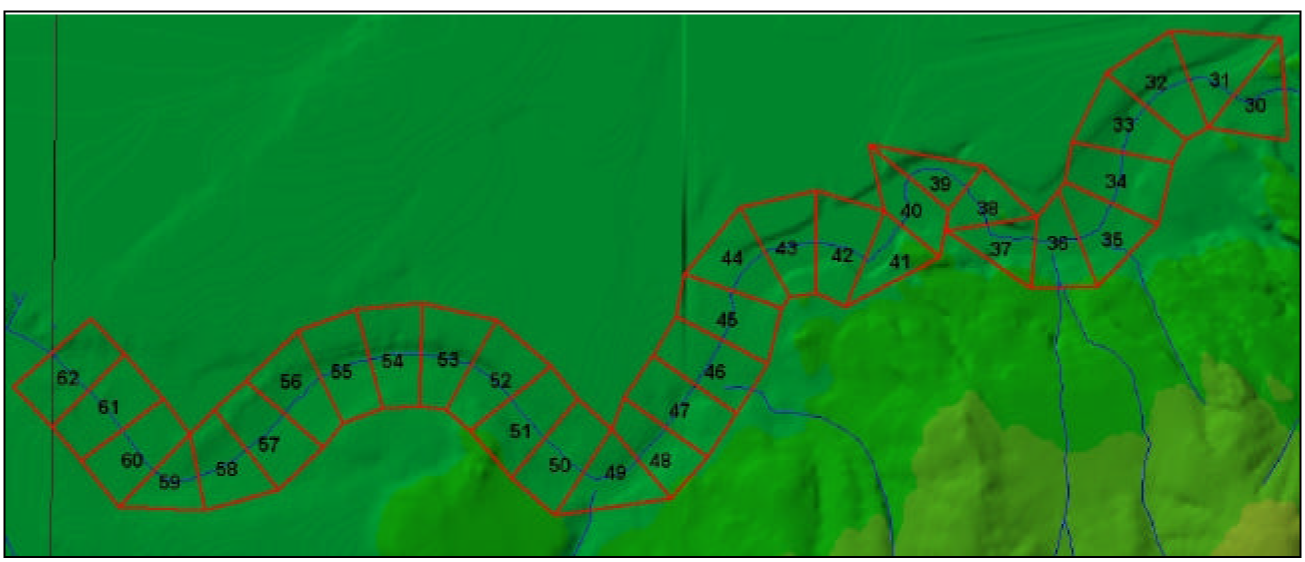


Figure 15: Segment number layout for model segments below Post Falls Dam.

The overall segment numbering and grid characteristics are shown in Figure 16 and Table 3. The side view of the grid for Branch 1 (also water body 1) and for Branch 2 (also water body 2) is shown in Figure 17 and Figure 18, respectively. Representative cross-sections of segments in each branch are shown in Figure 19 and Figure 20 for Branch 1 and 2, respectively. A listing of the segment numbers and their corresponding river miles is shown in Appendix A.

Table 3: Model grid characteristics

Branch #	Up stream cell #	Down stream cell #	Cell longitudinal spacing, m	Slope [-]	Vertical layer spacing, m	Elevation of bottom of grid, m NGVD	Up stream BC	Down stream BC
1	2	27	643.75	0.0	0.6 to 1.2	636.73	Flow or head	Flow
2	30	62	252.82	0.00242	1.0	618.00	Flow	Flow (weir)

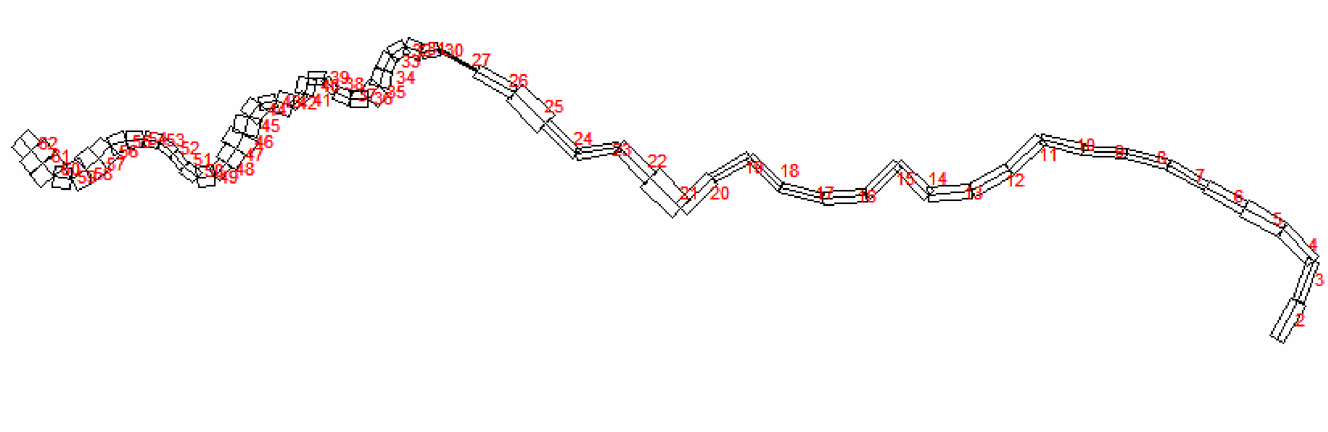


Figure 16: Model segment layout for W2 model.

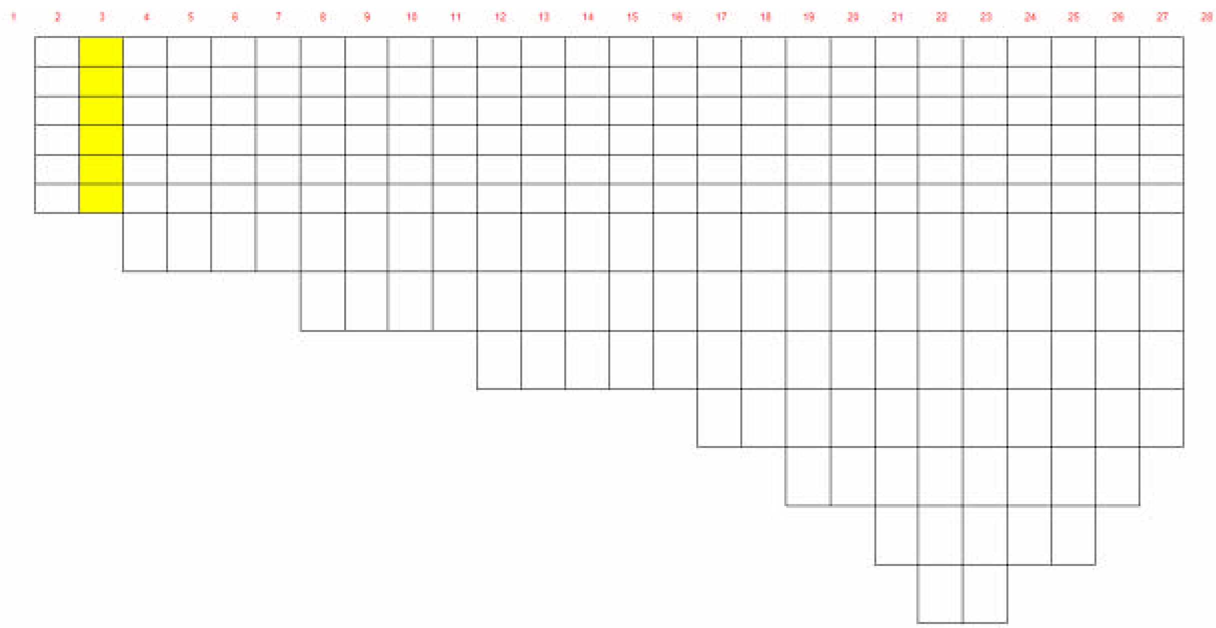


Figure 17: Side view of bathymetry grid for Branch 1 to Post Falls Dam.

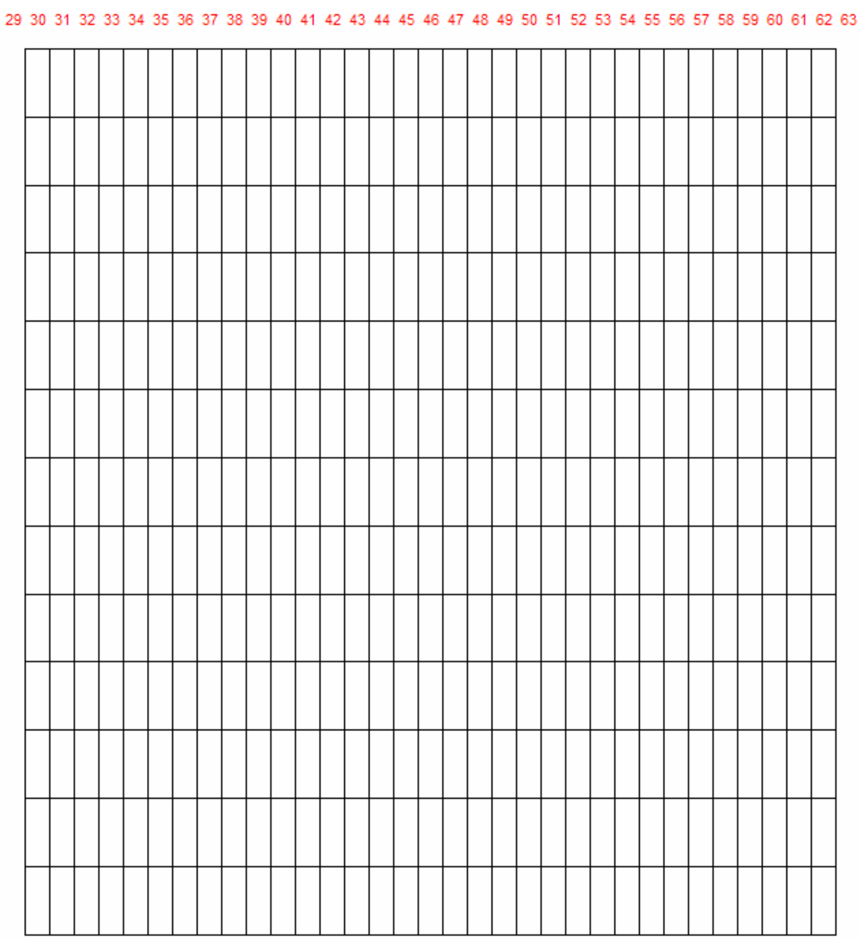


Figure 18: Side view of grid for Branch 2, river section.

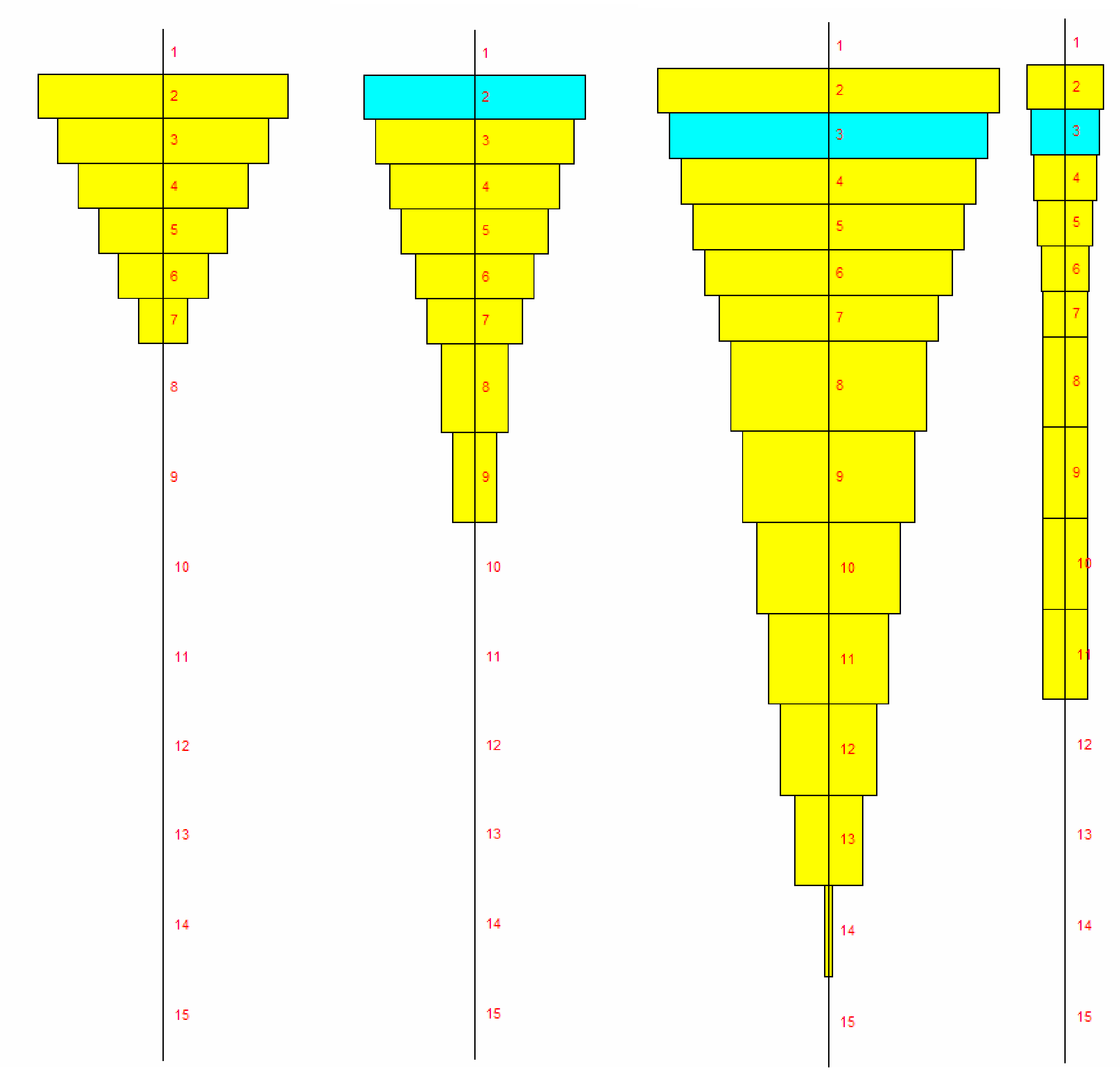


Figure 19: Segment 2, 9, 22, and 27 width versus layer for Branch 1.

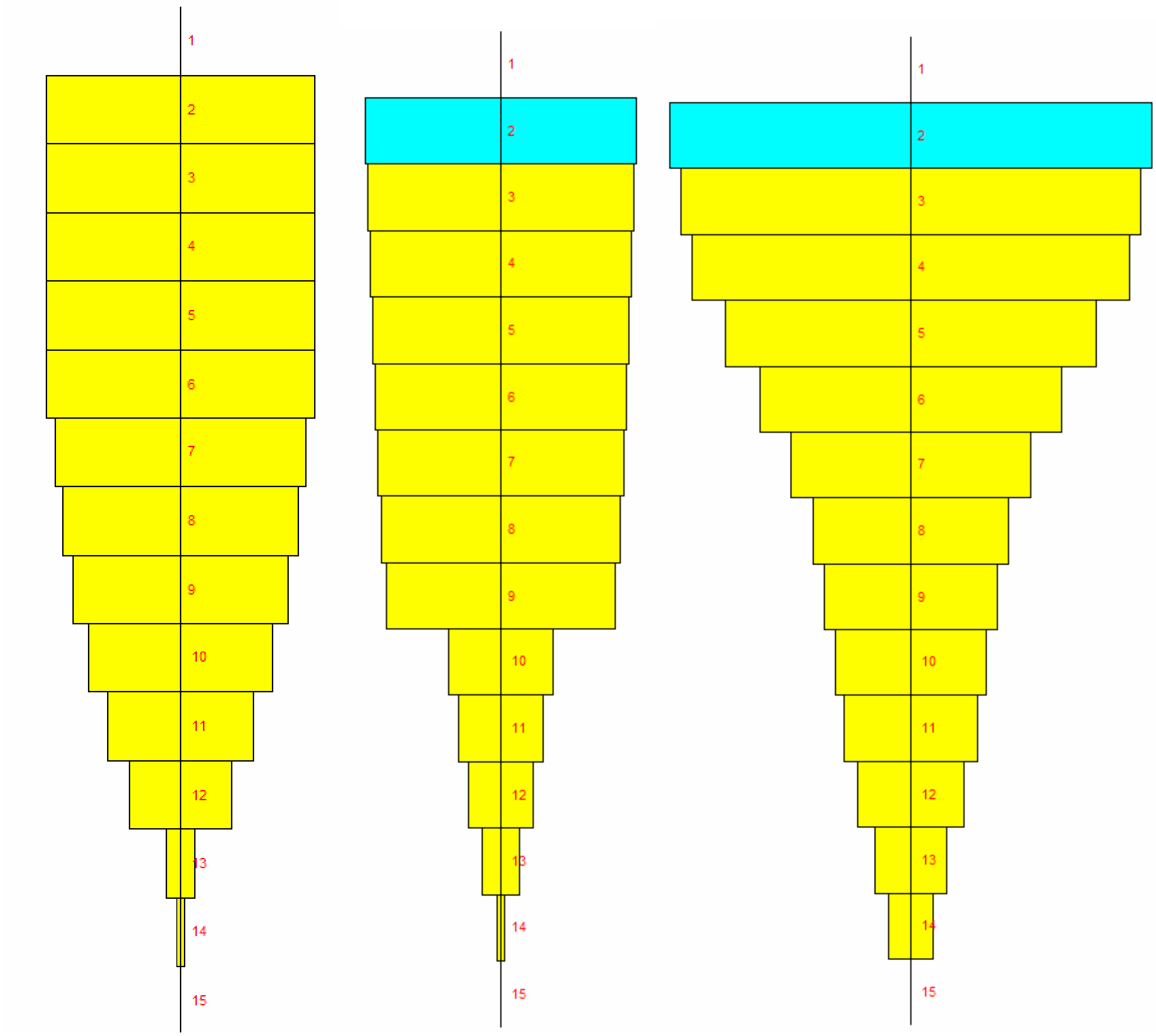


Figure 20: Segments 30, 39, and 62 width vs. layer for Branch 2. Note that the upper layers are never used; the river channel is defined by the lowest layers, for example 14, 13, and 12.

Boundary Conditions

The upstream boundary condition on the Spokane River was set at the outlet of Lake Coeur d'Alene. The model simulation time periods were from January through December, 2001 and from January through September, 2004.

Hydrodynamic, temperature and water quality data in 2001 and 2004 were compiled from WA Department of Ecology, ID Department of Environmental Quality and the U.S. Geological Survey. Figure 21 shows the location of monitoring sites in 2001 and 2004. Table 4 lists the hydrodynamic monitoring sites for 2001 and 2004 and Table 5 lists the temperature and water quality monitoring sites for both years.

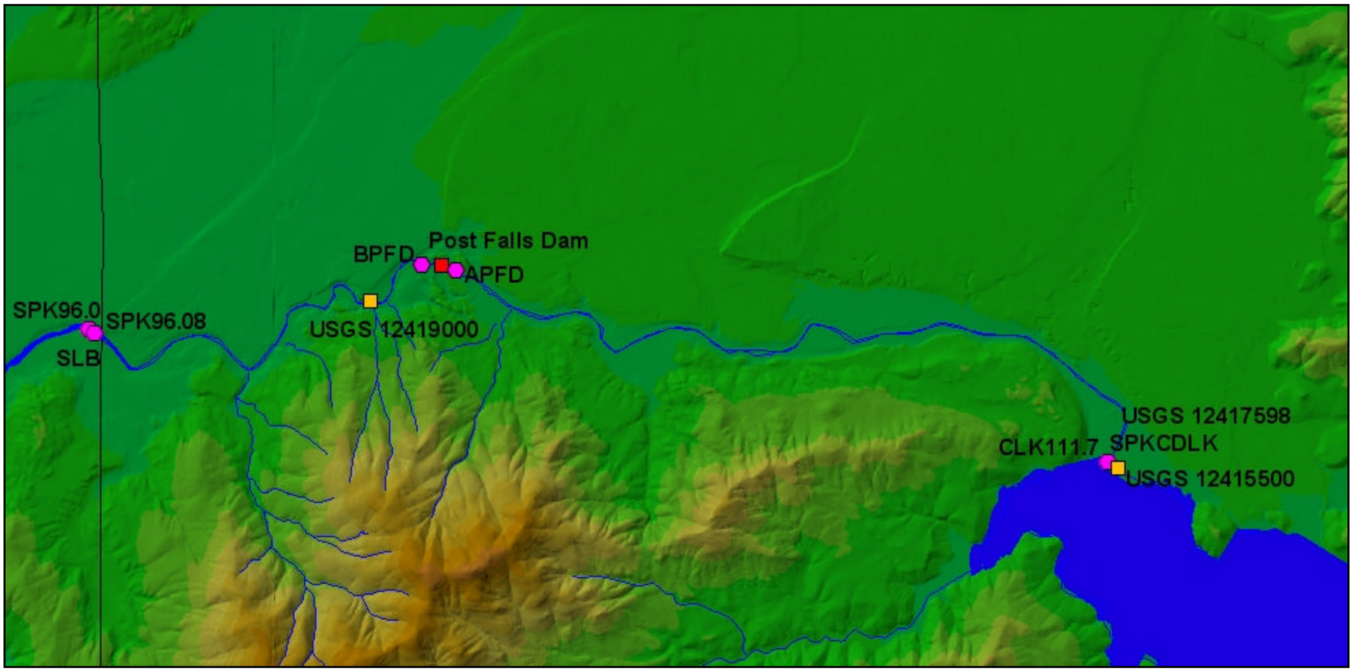


Figure 21: Hydrodynamic, temperature and water quality monitoring sites, 2001 and 2004.

Table 4: Flow and water level elevation monitoring sites, 2001 and 2004.

Site	Description	Agency	RM	Data	Model Segment	Years
12415500	Coeur D'Alene Lake at Coeur D'Alene ID	USGS	111.05	WL	2	2001 & 2004
12419000	Spokane River near Post Falls, ID	USGS	100.52	Q & WL	36	2001 & 2004
SPK96.0	Grab samples	WADOE	96.00	Q	62	2001
Stateline	flow estimate based on groundwater gain and loss and USGS at Post Falls	Est.	96.00	Q	62	2001 & 2004

Table 5: Temperature and water quality monitoring sites, 2001 and 2004.

Site	Description	Agency	RM	Data	Model Segment	Years
CLK111.7	Lake Coeur d'Alene outlet	WADOE	111.05	WQ	2	2001
12417598	Spokane River at Lake Outlet at Coeur D'Alene ID	USGS	111.05	Temp & WQ	2	2004
SPKCDLK	Spokane River at Lake Coeur d'Alene Outlet,	IDEQ	111.05	WQ	2	2004
APFD	Above Post Falls Dam	IDEQ	101.30	WQ	27	2004
12419000	Post Falls Gage Station	USGS	100.52	Temp	36	2001
BPFD	Below Post Falls Dam	IDEQ	101.14	WQ	30	2004
SPK96.08	Spokane River near the Stateline	WADOE	96.10	Temp & WQ	62	2001
SLB95.8	Stateline Bridge	IDEQ	96.00	WQ	62	2004
SPK96.0	Spokane River at the Stateline Bridge, 400 ft upstream of Stateline Bridge.	WADOE	96.00	Temp & WQ	62	2001 & 2004

Year 2001

The boundary conditions consisted of flow, water temperature and water quality characteristics. The model used linear interpolation to fill in the boundary conditions between data measurements.

Flow

The flow rates used for the upstream boundary condition are shown in Figure 22. Lake Coeur d'Alene outflows are based on using the Post Falls USGS gage station flow data, and tributary inflow data. There were no groundwater losses from Coeur d'Alene Lake to the Post Falls Dam (Seitz and Jones, 1981). This section of the model had water loss from evaporation implicitly included in the water balance and hence was not turned on for water body 1.

Note that a recommendation for further analysis is to integrate the Coeur d'Alene Lake CE-QUAL-W2 model with the Spokane River since this flow would then be calculated internally in the model rather than being set a priori. This model (Golder, 2004) was developed by AVISTA in their relicensing effort.

Temperature

There were little temperature and water quality data available in 2001 to characterize the upstream boundary condition. Historical data were utilized in developing the upstream boundary conditions.

The only temperature data collected in 2001 consisted of several grab samples in August. Monthly averages of historical data (Spokane River at the Lake outlet (RM 111.0) and the Spokane River 50 meters above Coeur d'Alene WWTP outflow (RM 110.6)) were used for model input over the year. The upstream boundary condition temperature record was improved by using the hourly temperature data recorded at the USGS gage station near Post Falls, ID. Figure 23 shows a plot of the upstream boundary condition temperatures. The data gap from October 1 to November 26th was filled in by linearly interpolating between the data.

Water Quality

Water quality of the upstream boundary condition was described using pH, conductivity, dissolved oxygen, total dissolved solids, nitrite-nitrate nitrogen, ammonia nitrogen, chloride, soluble reactive phosphorus, alkalinity, chlorophyll a and carbonaceous BOD ultimate ($CBOD_u$) data. These data were measured at sampling site CLK111.7 located near the outflow of Lake Coeur d'Alene into the Spokane River. Data were sparse and existed only during August 2001.

Monthly averages of historical data from 1992 to 2004 were used for temperature, pH and alkalinity. Gaps in the alkalinity monthly averages were filled in by interpolation. Data collected in August 2001 was used for these three constituents as well.

Alkalinity, pH and temperature data were used to estimate inorganic carbon concentration by applying equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981).

Algae concentrations were estimated first by filling in data gaps in the chlorophyll a data using interpolation and then assuming a ratio of 130 mg algae to 1 µg chlorophyll a.

Organic matter was primarily simulated using a CBOD compartment. $CBOD_u$ data were used with gaps filled in by linear interpolation. To characterize the CBOD concentrations, the CBODu concentrations were adjusted by subtracting out the oxygen demand from decaying algae by multiplying the algae concentration by the oxygen demand (1.4 mg/L O_2 consumed per 1 mg/L of algae).

A refractory dissolved organic matter (RDOM) compartment was added with a constant concentration set at 1.0 mg/L at the Coeur d'Alene entrance to the Spokane River. The refractory DOM was added to better match TOC data at the Washington/Idaho State Line. The RDOM had little effect on the pH. The RDOM was very, very slow decaying organic matter that did not affect dissolved oxygen or release nutrients for algae/periphyton growth. It should be noted that the source of this organic matter could also have been the WWTPs. The point sources were assumed to have an RDOM of 0 mg/l.

There was limited dissolved oxygen data in 2001 so the monthly average water temperature values calculated from the historical data were used to calculate the dissolved oxygen saturation concentration from Mortimer's (1981) formulation:

$$\Phi_{O2sat} = P_{alt} e^{\left(7.7117 - 1.3140\left[\ln\{T + 45.93\}\right]\right)}$$

where T is the water temperature, ^{o}C, and P_{alt} is the altitude correction factor. The altitude correction factor can be calculated from Mortimer (1981) using

$$P_{alt} = \left(1.0 - \left(\frac{EL/1000.0}{44.3}\right)\right)^{5.25}$$

where EL is the elevation of the water body in meters.

Constituent concentrations of LDOM (labile dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero. Inorganic suspended solids concentrations were assumed to be 0.1 mg/l.

Conductivity, total dissolved solids, chloride, ammonia nitrogen, and soluble reactive phosphorus were based on limited data collected in 2001 and interpolated for the rest of the model time period.

Nitrite-nitrate nitrogen was estimated using the same method of filling in the data gaps using linear interpolation, resulting in a concentration of 0.010 mg/l NO_3-N+NO_2-N over the simulation period in 2001. Table 6 shows a list of the nitrate data collected in 2001 and shows all of the data was at the detection limit and was limited to August and September. Table 7 lists the nitrate data collected by IDEQ for 2004 and shows again the concentration at the detection limit of 0.02 mg/L. Table 8 lists the data collected by the USGS in 2004 and shows values above the detection limit with some variability.

Table 6: Nitrate-nitrite concentration data collected in 2001 by the Washing Department of Ecology (site: CLK 111.7, Lake Coeur d'Alene outlet)

Date	Time	NO2-NO3, mg/L
08/09/2001		0.01
08/30/2001	7:00:00 AM	0.01
	Average	0.01

Table 7: Nitrate-nitrite concentration data collected in 2004 by the Idaho Department of Environmental Quality (site: Lake Coeur d'Alene outlet)

Date	Sample Type	NO2-NO3, mg/L	Date	Sample Type	NO2-NO3, mg/L
04/29/2004	Depth Integrated	0.02	07/13/2004	Depth Integrated	0.02
04/29/2004	Discrete 2-4	0.02	07/29/2004	Depth Integrated	0.02
04/29/2004	Discrete 3-5	0.02	07/29/2004	Discrete 2-4	0.02
04/29/2004	Discrete 4-6	0.02	07/29/2004	Discrete 4-6	0.02
04/29/2004	Discrete 5-7	0.02	07/29/2004	Discrete 6-8	0.02
04/29/2004	Discrete Surface	0.02	07/29/2004	Discrete 8-10	0.02
05/17/2004	Depth Integrated	0.02	07/29/2004	Discrete Surface	0.02
06/02/2004	Depth Integrated	0.02	08/11/2004	Depth Integrated	0.02
06/02/2004	Discrete 2-4	0.02	08/25/2004	Depth Integrated	0.02
06/02/2004	Discrete 3-5	0.02	08/25/2004	Discrete 2-4	0.02
06/02/2004	Discrete 4-6	0.02	08/25/2004	Discrete 4-6	0.02
06/02/2004	Discrete 5-7	0.02	08/25/2004	Discrete 6-8	0.02
06/02/2004	Discrete Surface	0.02	08/25/2004	Discrete Surface	0.02
06/15/2004	Depth Integrated	0.02	09/08/2004	Depth Integrated	0.02
06/29/2004	Depth Integrated	0.02	09/21/2004	Depth Integrated	0.02
06/29/2004	Discrete 2-4	0.02	09/21/2004	Discrete 2-4	0.02
06/29/2004	Discrete 4-6	0.02	09/21/2004	Discrete 4-6	0.02
06/29/2004	Discrete 6-8	0.02	09/21/2004	Discrete 6-8	0.02
06/29/2004	Discrete 8-10	0.02	09/21/2004	Discrete 8-10	0.02
06/29/2004	Discrete Surface	0.02	09/21/2004	Discrete Surface	0.02
				Average	0.02

Table 8: Nitrate-nitrite concentration data collected in 2004 by the U.S. Geological Survey (site: 12417598, Lake Coeur d'Alene outlet)

Date	Time	NO2-NO3, mg/L
01/20/2004	12:50:00 PM	0.026
04/08/2004	9:00:00 AM	0.040
05/03/2004	10:45:00 AM	0.031
06/08/2004	7:35:00 AM	0.016
07/26/2004	8:15:00 AM	0.031
09/08/2004	2:30:00 PM	0.075
	Average	0.036

The tracer and coliform concentration were set to zero. Figure 24, Figure 25, and Figure 26 show the water quality concentrations used in the model for the upstream boundary condition for 2001.

Note that Limno-Tech, Inc. (2001b) used the following water quality parameter values based on September 1998 data: Temperature = 21.7^{o}C, SS=1.2 mg/l, LDOM=0.455 mg/l; RDOM=0 mg/l; Algae=0.070 mg/l (using a chlorophyll a/algae ratio of 11 μg chlorophyll a/mg algae); LPOM=0 mg/l; PO_4-P=0.001 mg/l; NH_4-N=0.003 mg/l; NO_3-N=0.005 mg/l; DO=7.66 mg/l; $CBOD_5$=1.0 mg/l.

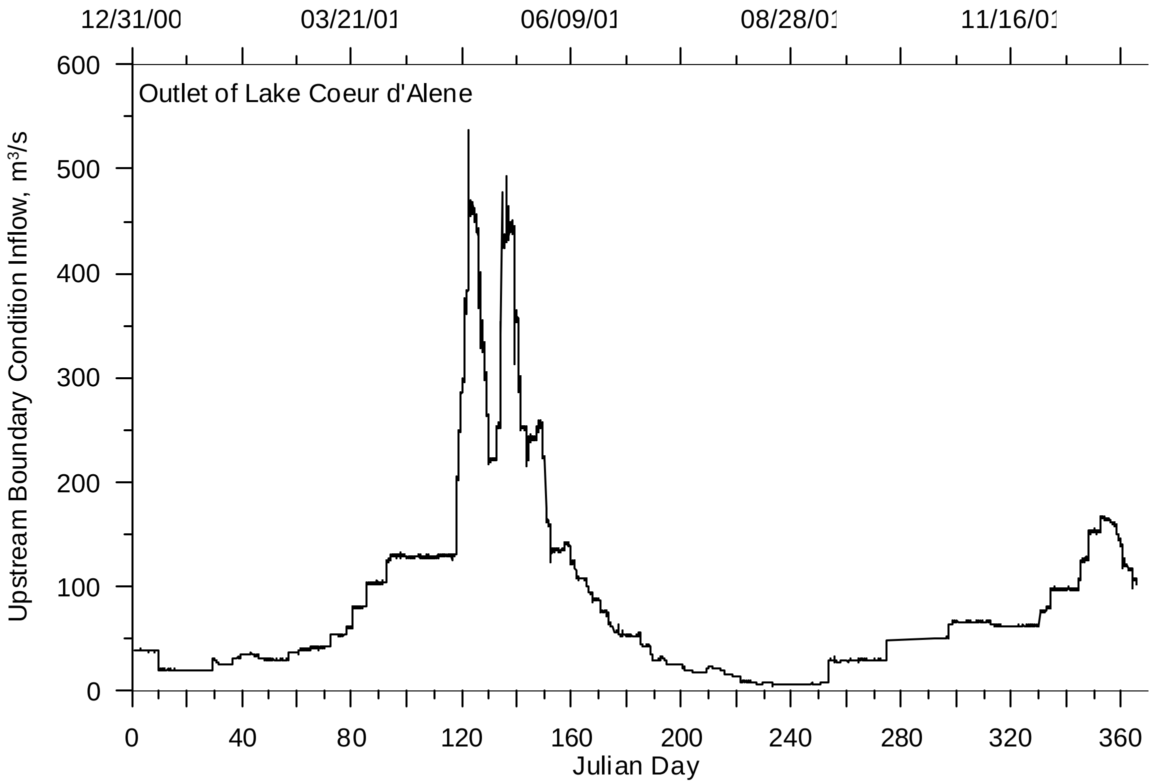


Figure 22: Upstream boundary condition flows at outlet of Lake Coeur d'Alene, 2001.

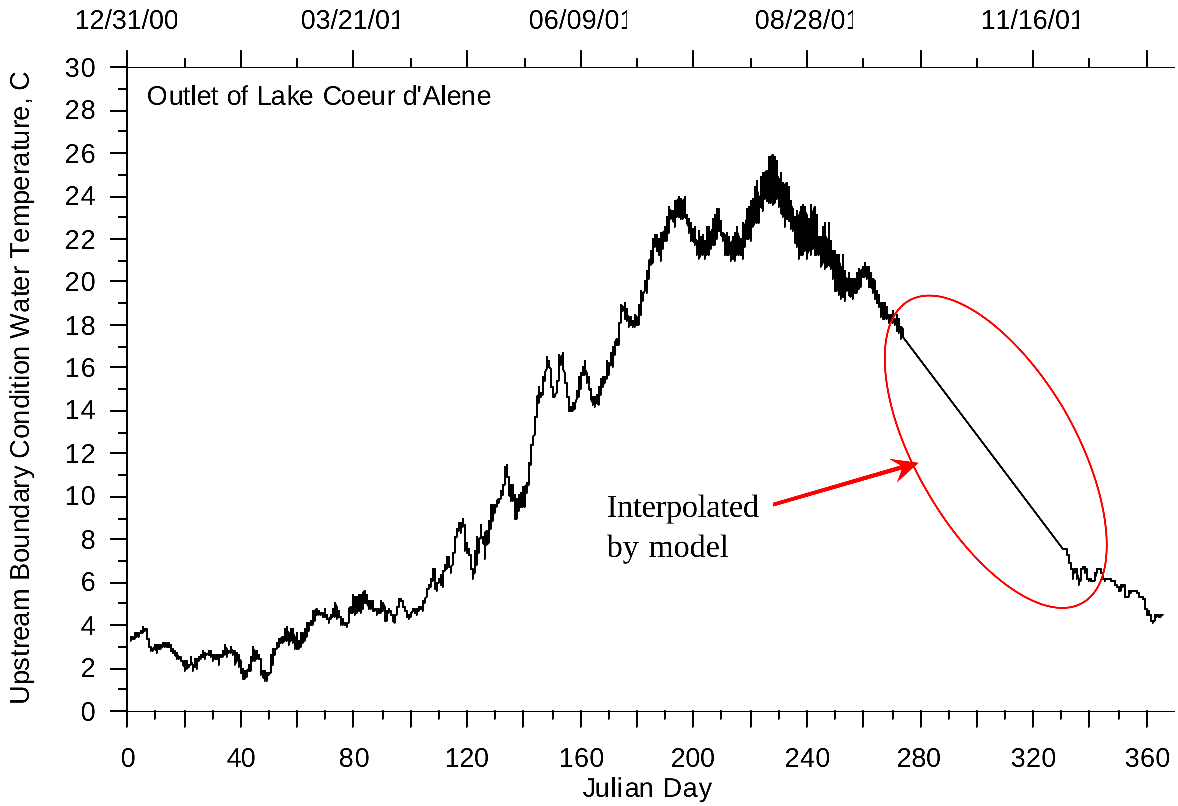


Figure 23: Upstream boundary condition temperature at outlet of Lake Coeur d'Alene, 2001.

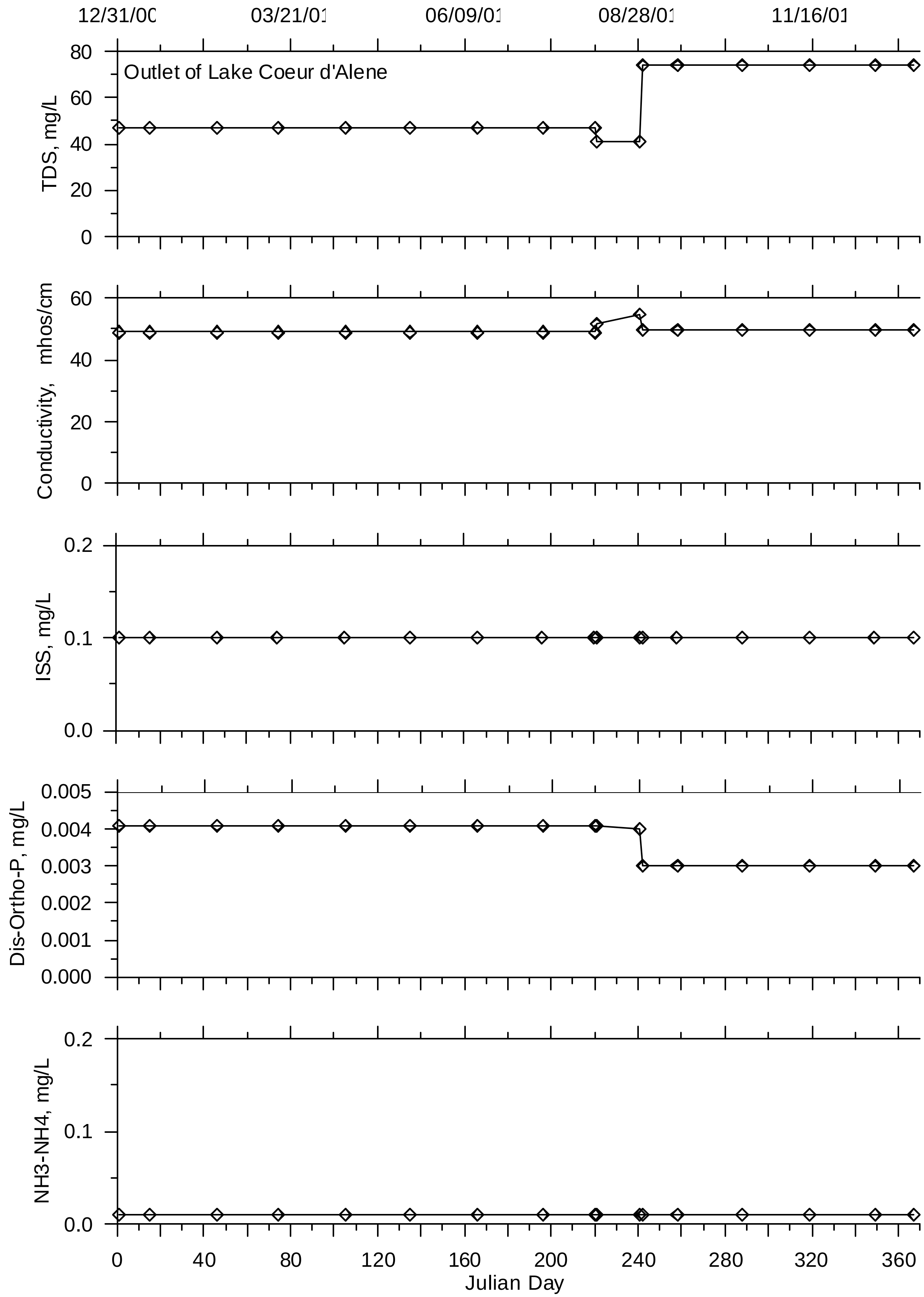


Figure 24: Upstream boundary water quality conditions, 2001 (Part 1).

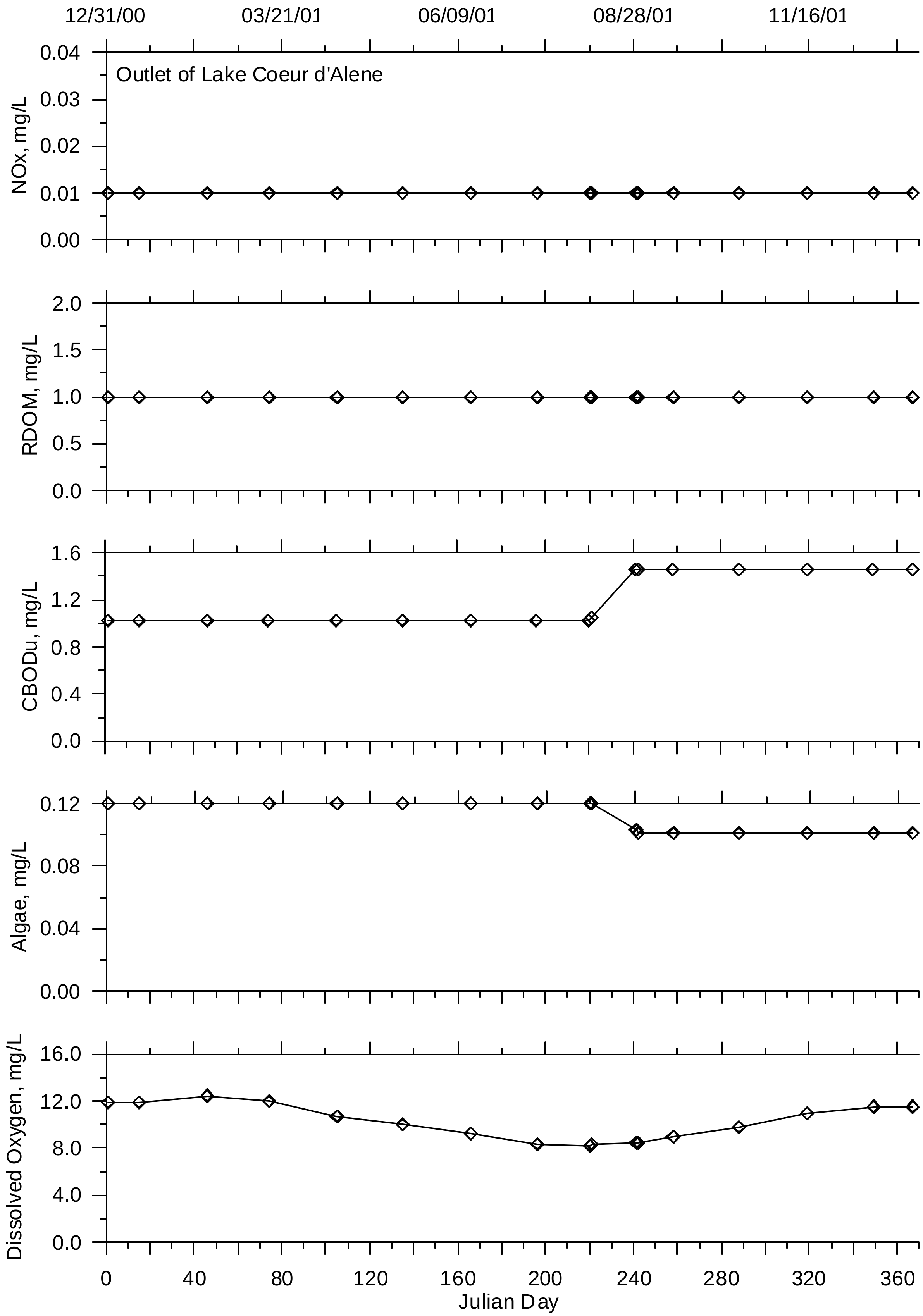


Figure 25: Upstream boundary water quality conditions, 2001 (Part 2)

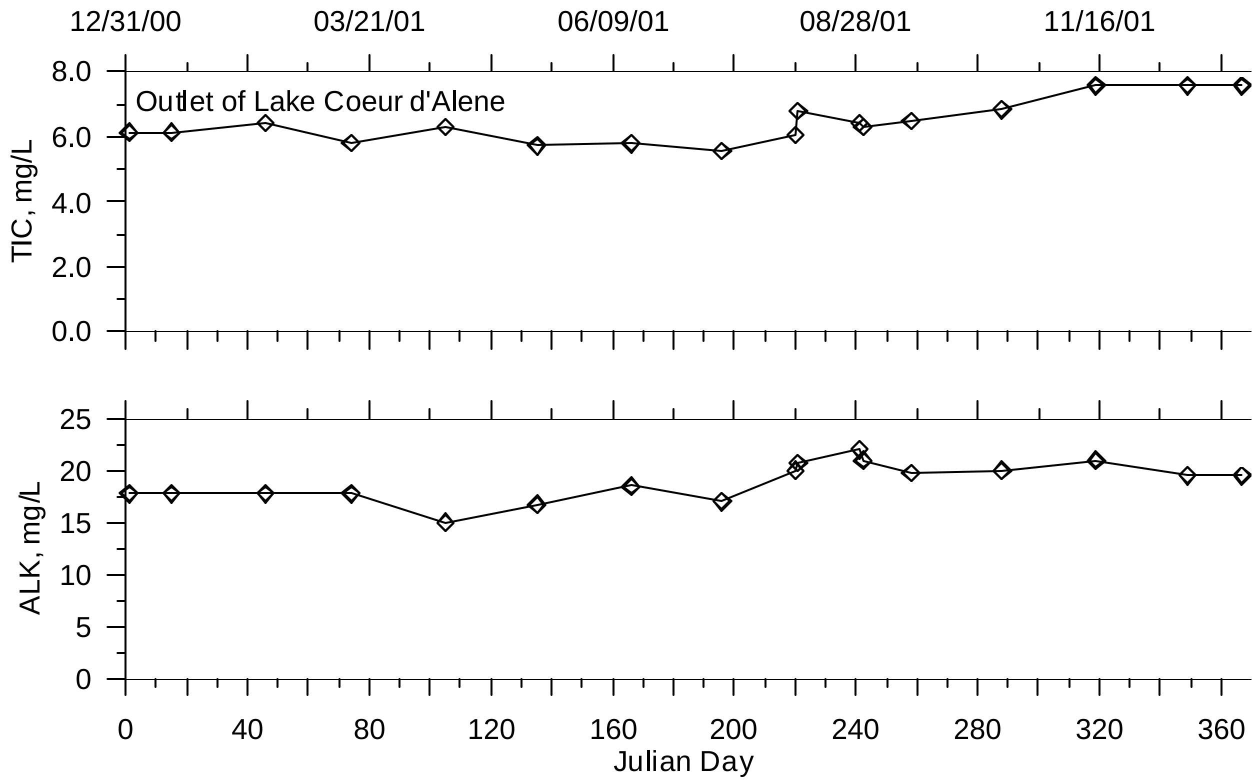


Figure 26: Upstream boundary water quality conditions, 2001 (Part 3).

Year 2004

The boundary conditions consisted of flow, water temperature and water quality characteristics. The model used linear interpolation to fill in the boundary conditions between the data.

Flow

The flow rates used for the upstream boundary condition are shown in Figure 27. Lake Coeur d'Alene outflows are based on using the Post Falls USGS gage station flow data and tributary inflow data. There were no groundwater losses from Coeur d'Alene Lake to the Post Falls Dam. This section of the model had water loss from evaporation implicitly included in the water balance and hence was not turned on for water body 1.

Temperature

The upstream boundary condition for temperature consists of grab sample data collected by the USGS (12417598, Coeur d'Alene Lake at Coeur d'Alene, ID), depth average of grab samples and periodic Hydrolab temperature time series data collected by Idaho Department of Environmental Quality (IDEQ, Spokane River at Lake Coeur d'Alene outlet), and monthly averaged temperature from historical data from 1992 to 2004. The historical data (monthly averages) were used for January 1 and from October 15 to December 31. Figure 28 shows a plot of the upstream boundary condition temperatures.

Water Quality

Water quality of the upstream boundary condition was described using pH, conductivity, dissolved oxygen, total dissolved solids, nitrite-nitrate nitrogen, ammonia nitrogen, chloride, soluble reactive phosphorus, alkalinity, chlorophyll a and carbonaceous BOD ultimate ($CBOD_u$) data. These data were measured at sampling sites near the outlet of Lake Coeur d'Alene into the Spokane River and were collected by the USGS and IDEQ.

There were no alkalinity data collected in 2004 so depth averaged temperature and pH data were used with a fixed alkalinity (20.74 mg/L) to estimate inorganic carbon concentration by applying equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981).

Algae concentrations were estimated first by filling in data gaps in the chlorophyll a data using interpolation and then assuming a ratio of 130 mg/l algae to 1 µg/l chlorophyll a.

Organic matter was primarily simulated using a CBOD compartment. $CBOD_u$ data were used with gaps filled in by linear interpolation. To characterize the CBOD concentrations, CBODu concentrations were adjusted by subtracting out the oxygen demand from decaying algae by multiplying the algae concentration by the oxygen demand (1.4 mg/L O_2 consumed per 1 mg/L of algae). In addition to the CBOD compartment a refractory dissolved organic matter (RDOM) compartment was added with a constant concentration set at 0.5 mg/L. This was added to match TOC data at the Washington-Idaho state line.

There was limited dissolved oxygen data in 2004 so the grab sample data from IDEQ and USGS were used to calculate the dissolved oxygen saturation concentration using the equation from Mortimer (1981).

Constituent concentrations of LDOM (labile dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero. Total dissolved solids were set at the annual average of 2001 data at 47.60 mg/L. The chloride concentration was set fixed at 0.64 mg/L based on 2001 data.

Inorganic suspended solids, conductivity, ammonia nitrogen, nitrite-nitrate nitrogen, and soluble reactive phosphorus were based on data collected in 2004 and interpolated for the rest of the model time period. Several values of the soluble reactive phosphorus collected by the USGS were removed from the data set since these values were larger than the total phosphorus measurements from the same grab sample. Two values of the ammonia nitrogen from the grab samples collected by IDEQ were also removed for having values larger than total persulfate nitrogen. The tracer and coliform concentration were set to zero. Figure 29, Figure 30, and Figure 31 show the water quality concentrations used in the model for the upstream boundary condition for 2004.

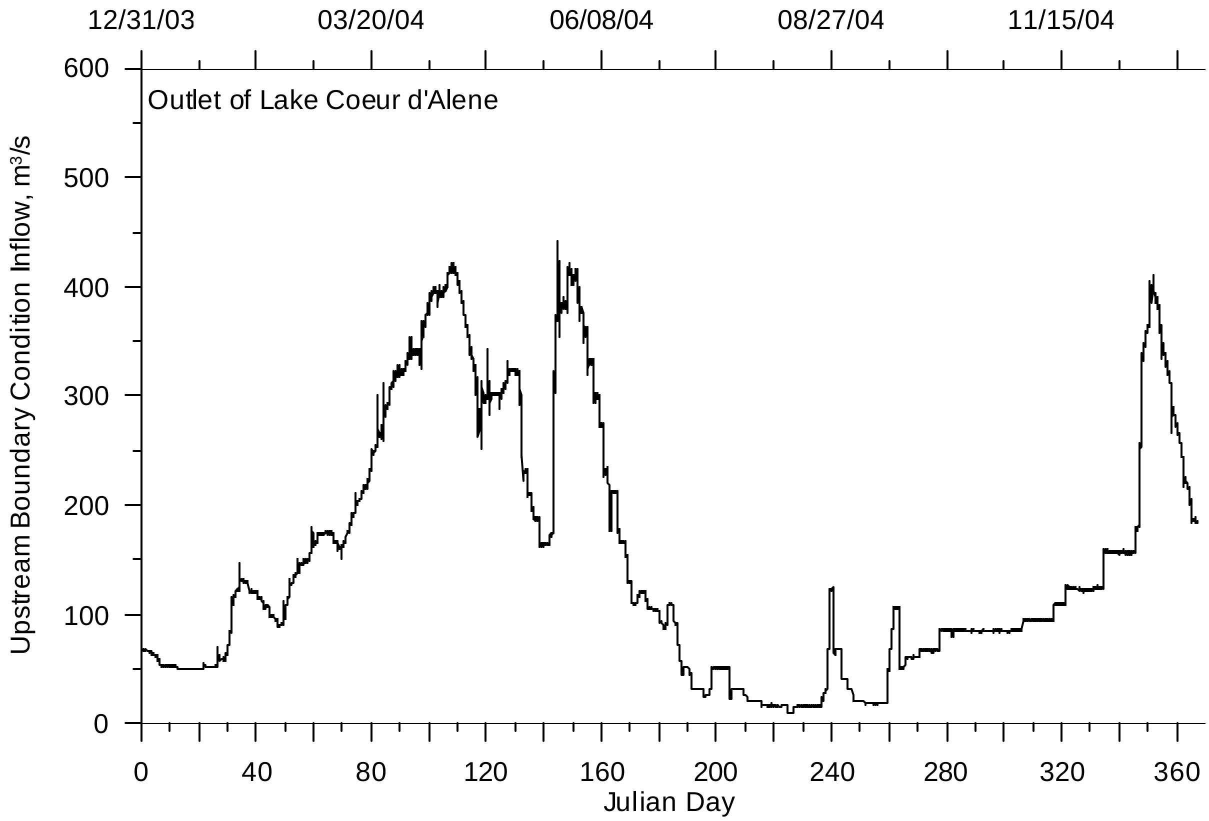


Figure 27: Upstream boundary condition flows at outlet of Lake Coeur d'Alene, 2004.

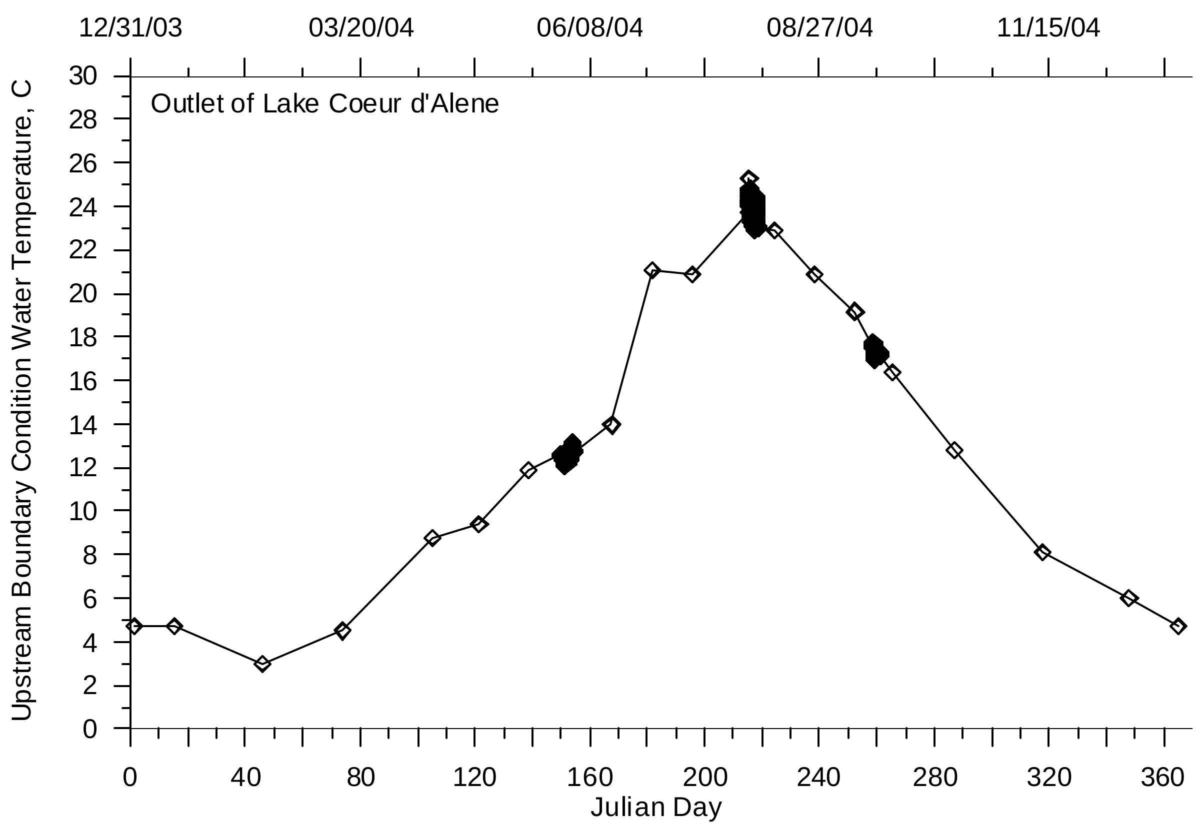


Figure 28: Upstream boundary condition temperature at outlet of Lake Coeur d'Alene, 2004.

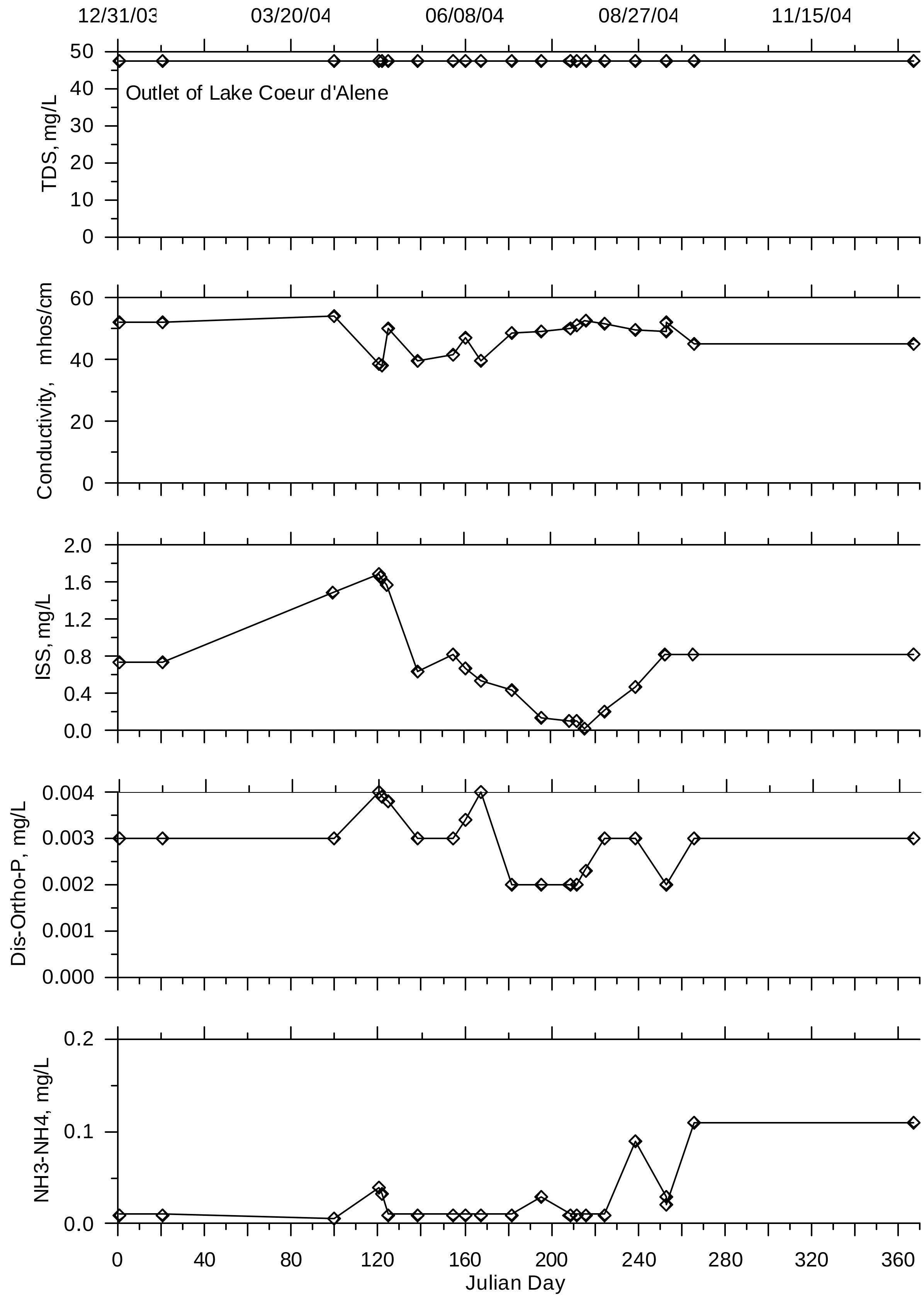


Figure 29: Upstream boundary water quality conditions, 2004 (Part 1).

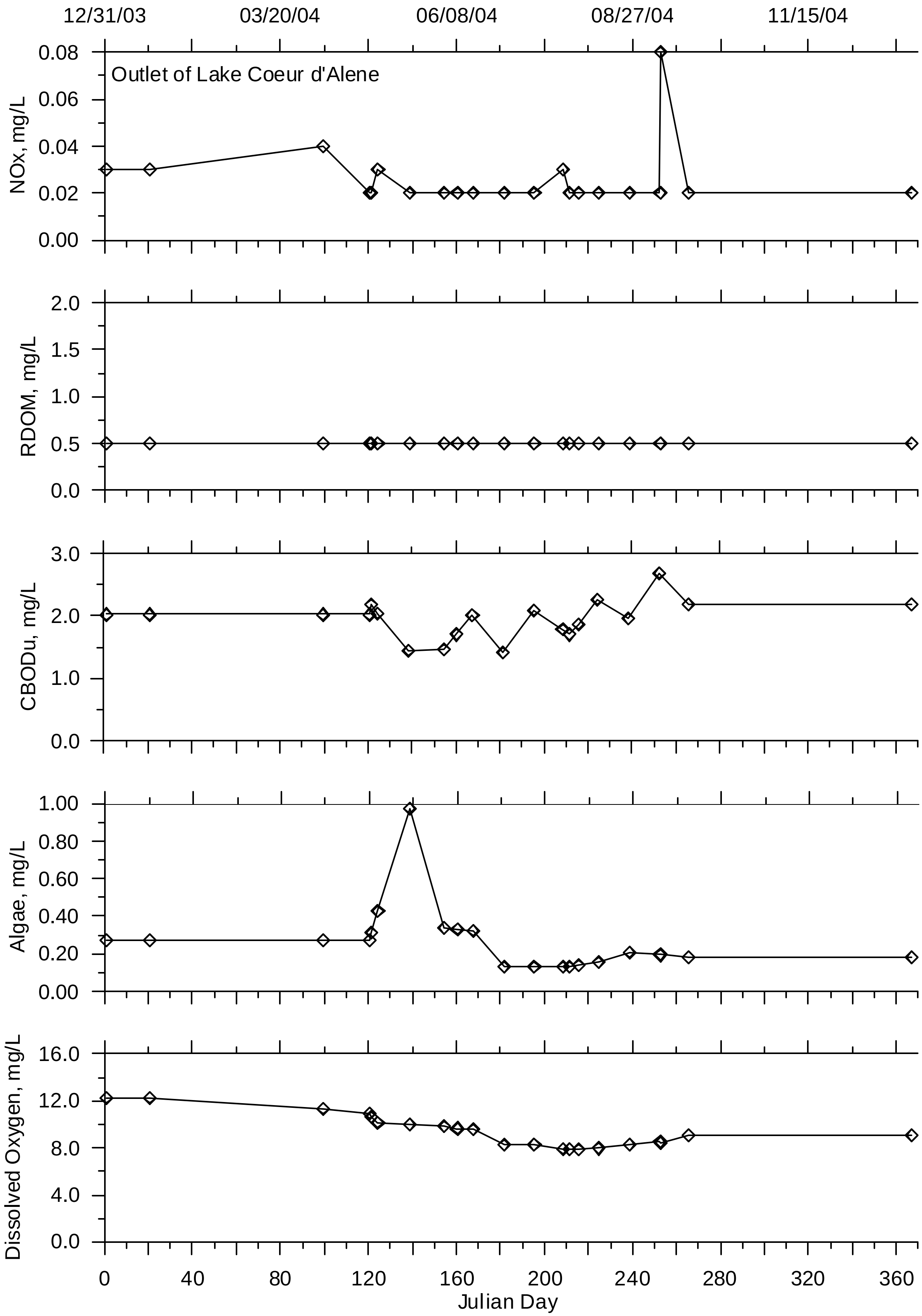


Figure 30: Upstream boundary water quality conditions, 2004 (Part 2).

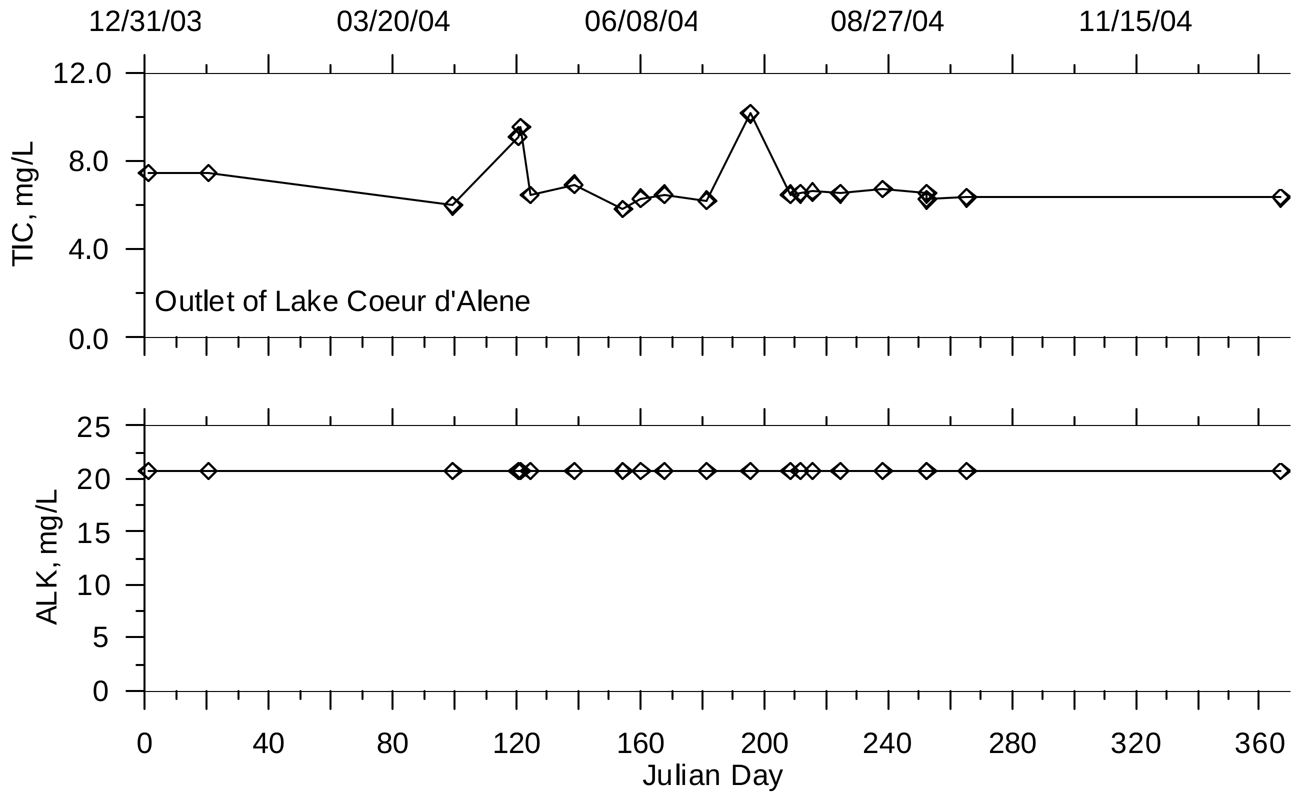


Figure 31: Upstream boundary water quality conditions, 2004 (Part 3).

Tributaries and Point Dischargers

There are three point source discharges to the Spokane River between Coeur d'Alene and the ID-WA state line. There are several small tributaries and one larger tributary called Skalan Creek. Table 9 lists the locations of the point sources and the tributary inflow. Several of the dischargers had limited nutrient, inorganic and organic carbon data in 2001 and 2004. More comprehensive data collected by the dischargers would better characterize their inflows in the model.

Skalan Creek was not expected to contribute much flow to Spokane River model. There has been no data collected on the creek to assess its flow contribution. The flow was expected to be negligible compared to the groundwater gain and loss in this reach of the river. Although the model incorporates the creek as a tributary inflow, the flow has been set to zero and could be used at a future time once flow data are available.

Table 9: Tributaries to the Spokane River in Idaho.

Tributaries	Segment Number	River Mile
Post Falls WWTP	32	101.186
Skalan Creek	49	98.465
Coeur D'Alene WWTP	4	110.563
Hayden Area POTW	9	109.500 (other maps show RM 108.5)

Organic matter in the upstream boundary condition, tributaries, and point sources were simulated using $CBOD_u$ data and multiple CBOD compartments in CE-QUAL-W2. Each point source and the upstream boundary condition were represented by separate CBOD compartments and decay rates. The tributary BOD compartments were grouped into a single CBOD compartment. These CBOD compartments are summarized in Table 10. CBOD compartments 1 to 4 correspond to dischargers that do not exist in the Idaho section of the model, but have been included to facilitate model linkage to the rest of the Upper Spokane River model. The first-order decay rates of the CBOD compartments were developed from laboratory data supplied by the Washington Department of Ecology and the Idaho Department of Environmental Quality.

Table 10 also lists the stoichiometry of CBOD in terms of N (nitrogen), P (phosphorus), and C (carbon). The stoichiometric values listed in the table are based on either model default values (carbon) or calculated from data (phosphorus and nitrogen). The organic matter concentration, $\Phi_{a\lg ae(OM)}$ from algae was calculated as

$$\Phi_{a\lg ae(OM)} = \Phi_{Chl\_a}\left(OM / Chla\_ratio\right)$$

where the *OM/Chl a_ratio* is the ratio of organic matter, mg/L, to chlorophyll a concentration, µg/L, which was 130, and Φ_{Chla_a} is the chlorophyll a concentration. The point source dischargers had a chlorophyll a concentration of zero. The total organic matter Φ_{TOM}, mg/L, was then calculated as

$$\Phi_{TOM} \approx \frac{BOD_u}{d_O}$$

where d_o is the ratio of O_2 consumed, mg/L, per BOD_u, mg/L, which was 1.4, and BOD_u is the concentration of ultimate biochemical oxygen demand from data, mg/L. The organic matter from the CBOD was then calculated as

$$\Phi_{CBOD} = \Phi_{TOM} - \Phi_{a\lg ae(OM)}$$

The phosphorus in the organic matter from algae, $\Phi_{a\lg aeP}$, mg/L of P, was calculated as

$$\Phi_{alageP} = 0.004\Phi_{a\lg a(OM)}$$

where 0.004 is the ratio of phosphorus, mg/L, to organic matter from algae, mg/L. The phosphorus from the CBOD, Φ_{CBODP}, was then calculated as

$$\Phi_{CBODP} = \Phi_{TP} - \Phi_{OP4-P} - \Phi_{alagaeP}$$

where Φ_{TP} is the total phosphorus concentration from data and Φ_{OP4-P} is the ortho-phosphorus concentration from data. The fraction of phosphorus to the CBOD concentration was then calculated as

$$Pfraction_{CBOD} = \frac{\Phi_{CBODP}}{\Phi_{CBOD}}$$

The nitrogen in the organic matter from algae, $\Phi_{a\lg aeN}$, mg/L of N, was calculated as

$$\Phi_{alageN} = 0.08\Phi_{a\lg a(OM)}$$

where 0.08 is the ratio of nitrogen, mg/L to organic matter from algae, mg/L. The nitrogen from the CBOD, Φ_{CBODN}, was then calculated as

$$\Phi_{CBODN} = \Phi_{TN} - \Phi_{NH3} - \Phi_{NO3-NO2} - \Phi_{alagaeN}$$

where Φ_{TN} is the total nitrogen concentration, Φ_{NH3} is the ammonia concentration, and $\Phi_{NO3-NO2}$ is the nitrite-nitrate concentration, all from data. The fraction of nitrogen to the CBOD concentration was then calculated as

$$Nfraction_{CBOD} = \frac{\Phi_{CBODN}}{\Phi_{CBOD}}$$

Table 10: CBOD compartments, decay rates, and stoichiometry used in model.

CBOD compartment	Description	Decay rate, day^{-1}	Phosphorus fraction of CBOD	Nitrogen Fraction of CBOD	Carbon Fraction of CBOD
1	Liberty WTP	0.0456	0.020	0.08	0.45
2	Kaiser Aluminum	0.1275	0.002	0.08	0.45
3	Inland Empire Paper	0.0186	0.002	0.08	0.45
4	Spokane WTP	0.0736	0.016	0.08	0.45
5	Compartment simulating organic matter from tributaries; Includes Coulee Creek, Hangman Creek, Little Spokane River	0.0660	0.011	0.08	0.45
6	Coeur d'Alene WWTP	0.0792	0.003	0.08	0.45
7	Hayden POTW	0.0838	0.005	0.08	0.45
8	Post Falls	0.0660	0.005	0.08	0.45
9	Lake Coeur d'Alene (Upstream Boundary Condition)	0.1300	0.003	0.06	0.45

Coeur d'Alene WWTP

Year 2001

The City of Coeur d'Alene wastewater treatment plant discharge daily flow is shown in Figure 32. Figure 33 shows the discharge temperature for 2001 and shows a general seasonal warming trend into August and then decreasing temperatures from September through the end of the year.

The water quality constituent file for Coeur d'Alene WWTP was developed from pH, dissolved oxygen, CBODu, total phosphorus, ammonia nitrogen, chloride, conductivity, alkalinity, nitrite-nitrate nitrogen, soluble reactive phosphorus, total dissolved solids, and total non-volatile suspended solids data.

Water temperature, pH and alkalinity data were linearly interpolated to fill in data gaps and used to estimate inorganic carbon concentration by applying equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981).

Algae concentrations were set to zero. Constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were also set to zero.

Organic matter was simulated using a CBOD compartment. $CBOD_u$ data were used with gaps filled in by linear interpolation.

Because total phosphorus data were more frequent than soluble reactive phosphorus (SRP) data, for time periods when SRP data were sparse, total phosphorus data were used to estimate SRP concentrations by assuming a ratio of 0.629 mg/l SRP per 1 mg/l Total Phosphorus from 2001 data. This ratio was the average of coincidental SRP and total phosphorus Coeur d'Alene WWTP data.

Fecal coliform data did not exist and concentrations were set to zero. Tracer concentrations were also set to zero.

Dissolved oxygen, ammonia nitrogen, chloride, conductivity, nitrite-nitrate nitrogen, total dissolved solids, and inorganic suspended solids (non-volatile suspended solids) concentrations were all determined using data with gaps filled in by linear interpolation. The nitrite-nitrate concentrations for 2001 were derived from CAS Analytical Results, Spokane River TMDL Study Summer 2001 and provided to Portland State University by the Washington Department of Ecology. Table 11 lists the nitrite-nitrate concentration data provided for the City of Coeur d'Alene WWTP.

Table 11: Nitrite-nitrate concentrations for the City of Coeur d'Alene WWTP from the CAS Analytical Results, Spokane River TMDL Study Summer 2001 (data provided by Washington Department of Ecology)

Date	CAS ID#	AWTP ID #	Nitrate + Nitrite as Nitrogen (353.2)		
			mg/L	MDL	MRL
06/28/2001	K2104612-001	01-05660	13.8	0.2	1.0
07/12/2001	K2104964-001	01-06131	15.9	0.1	1.0

Date	CAS ID#	AWTP ID #	Nitrate + Nitrite as Nitrogen (353.2)		
			mg/L	MDL	MRL
07/26/2001	K2105327-009	01-06499	13.4	NR	1.0
08/08/2001	K2105704-001	01-06909	13.0	NR	1.0
08/09/2001	K2105747-001	01-06928	13.2	0.2	1.0
08/23/2001	K2106187-004	01-07556	16.5	0.2	1.0
08/29/2001	K2106326-024	01-07805	14.7	0.2	1.0
08/30/2001	K2106374-022	01-07824	14.7	0.2	1.0
09/26/2001	K2107130-014	01-08685	17.9	NR	2.0
NR = Not Reported		Average	14.8		

The water quality constituent concentrations used to simulate the Coeur d'Alene WWTP discharge in 2001 are shown in Figure 34, Figure 35, and Figure 36.

Note that Limno-Tech, Inc. (2001b) used the following discharge values based on September 1998 data: Temperature = 23.15^{o}C, SS=2.9 mg/l, LDOM=15.6 mg/l; RDOM=0 mg/l; Algae=0 mg/l; LPOM=0 mg/l; PO_4-P=0.52 mg/l; NH_4-N=3.86 mg/l; NO_3-N=15.9 mg/l; DO=3.67 mg/l; CBOD5=4.2 mg/l. It is unclear why Limno-Tech used LDOM and $CBOD_5$ since there is the possibility of counting O_2 demand more than once.

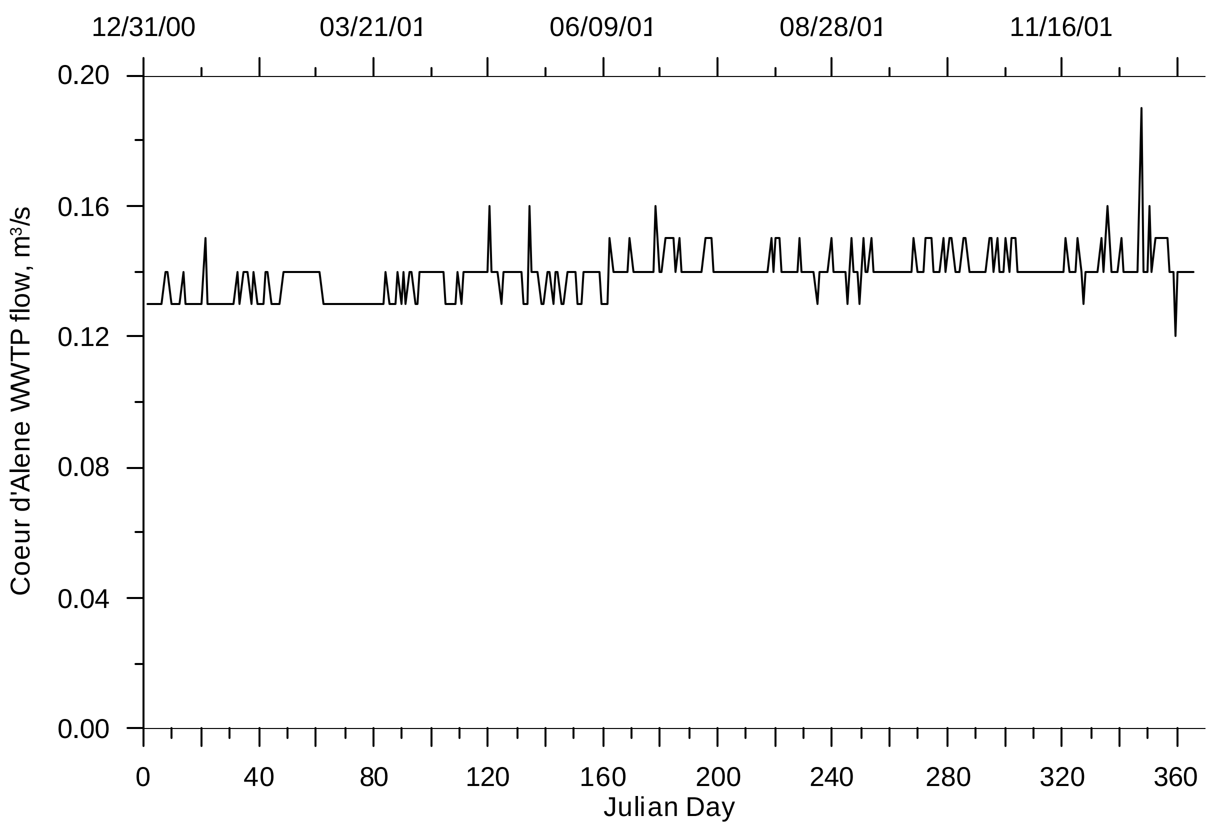


Figure 32: Coeur d'Alene WWTP flow rate, 2001.

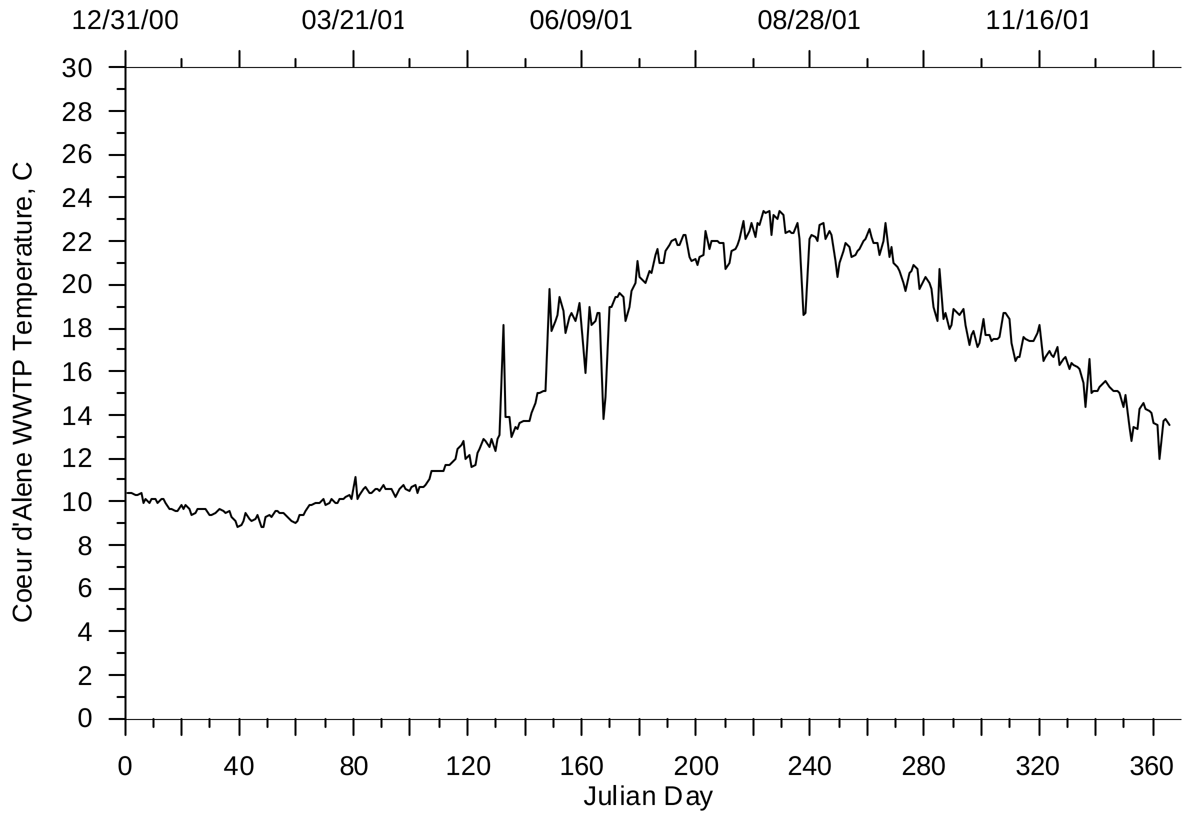


Figure 33: Coeur d'Alene WWTP temperatures, 2001.

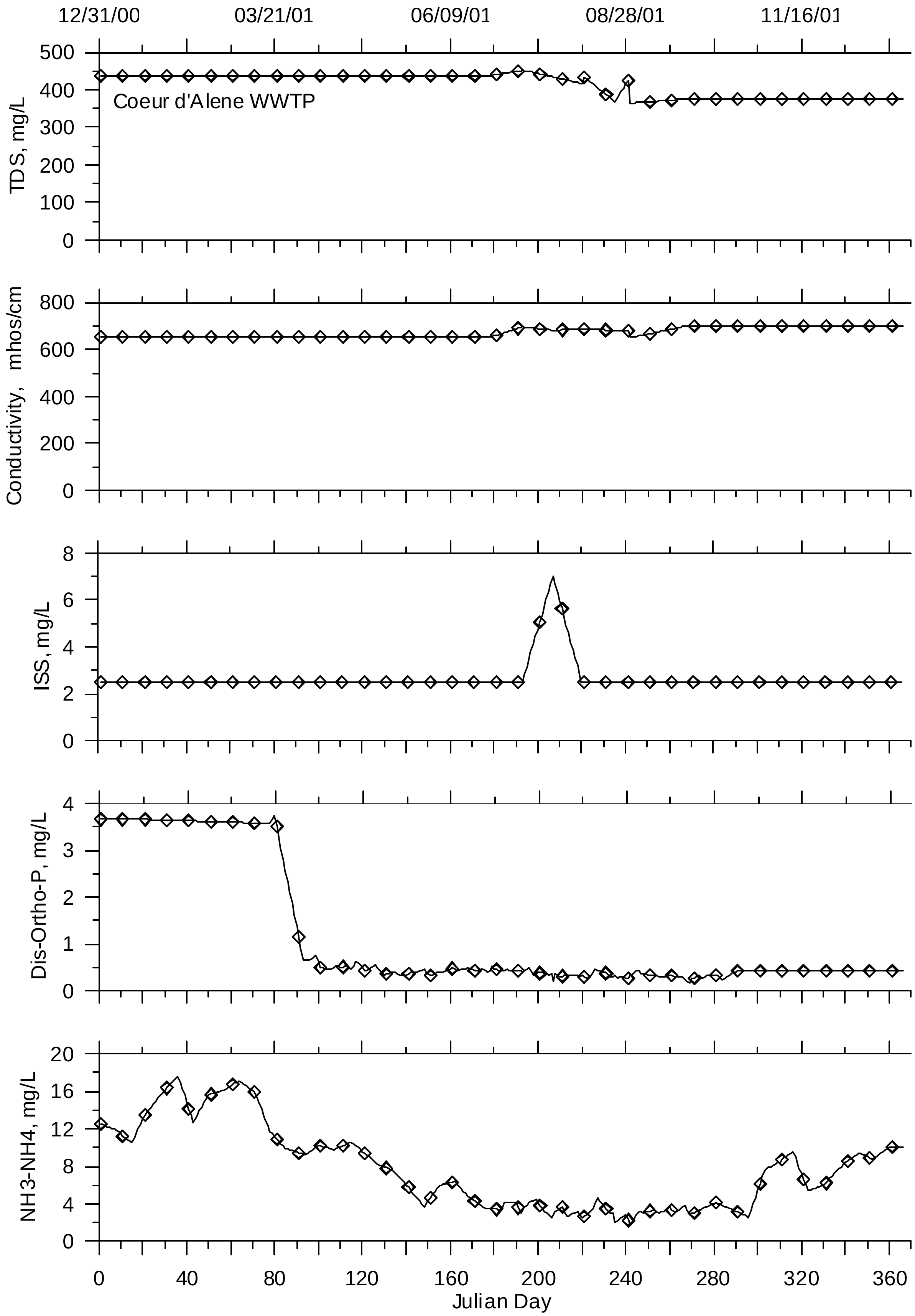


Figure 34: Coeur d'Alene WWTP discharge water quality conditions, 2001 (Part 1).

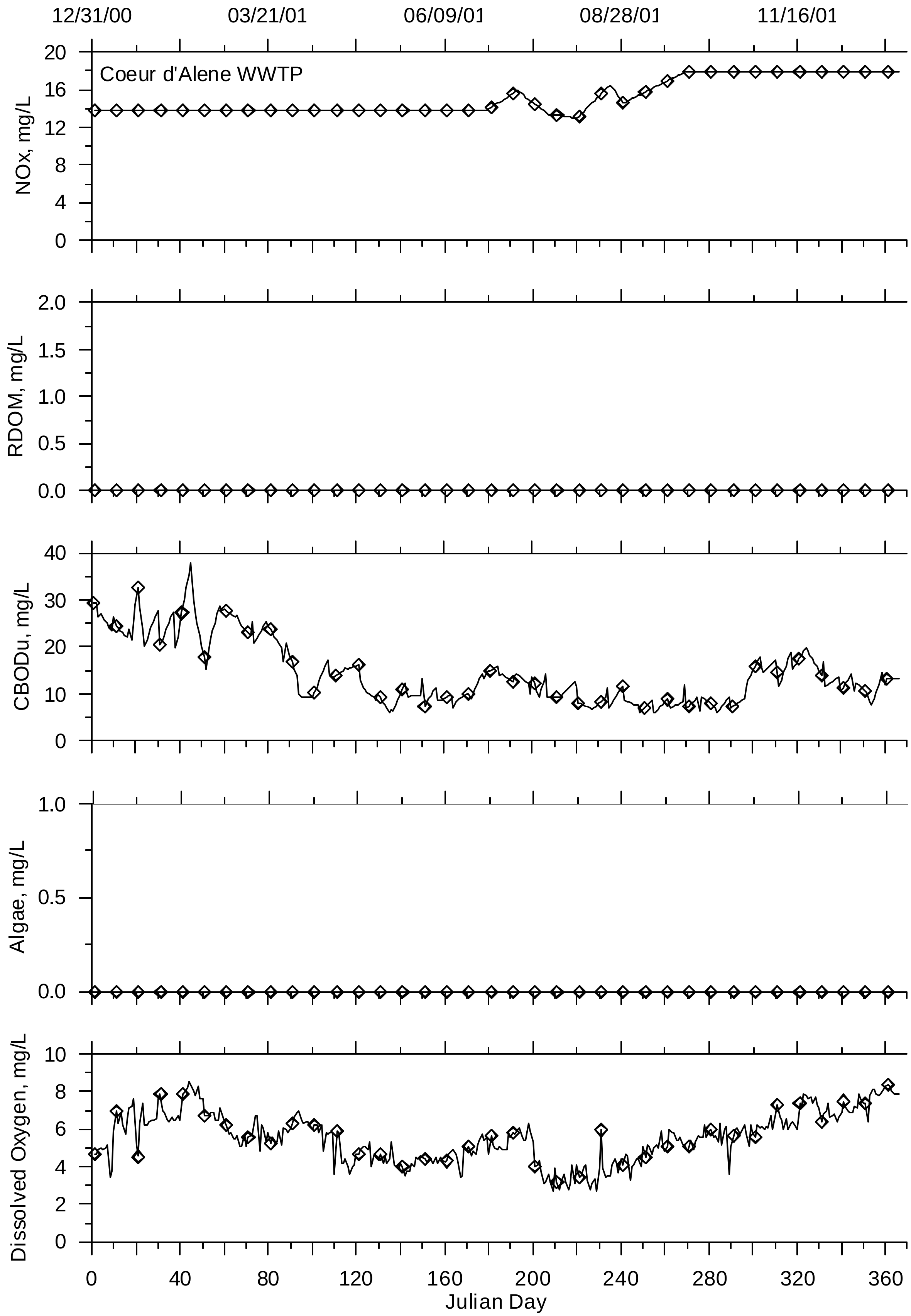


Figure 35: Coeur d'Alene WWTP discharge water quality conditions, 2001 (Part 2).

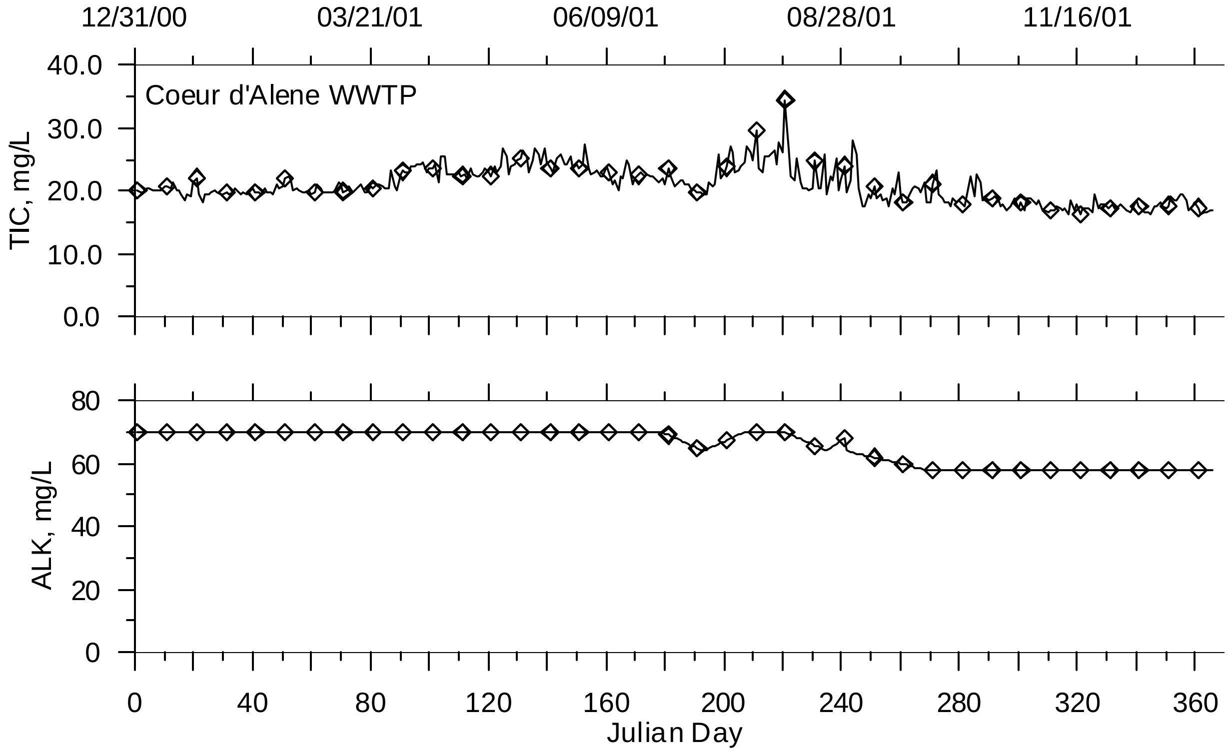


Figure 36: Coeur d'Alene WWTP discharge water quality conditions, 2001 (Part 3).

Year 2004

The City of Coeur d'Alene wastewater treatment plant daily discharge flow is shown in Figure 37. Figure 38 shows the discharge temperature for 2004 and shows a general seasonal warming trend into August and September with a sharp increase around April 30th to May 2nd.

The water quality constituent file for Coeur d'Alene WWTP was developed from pH, dissolved oxygen, CBODu, total phosphorus, ammonia nitrogen, chloride, conductivity, alkalinity, nitrite-nitrate nitrogen, soluble reactive phosphorus, total dissolved solids, and total non-volatile suspended solids data.

Water temperature, pH and alkalinity data were linearly interpolated to fill in data gaps and used to estimate inorganic carbon concentration by applying equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981).

Constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero.

Organic matter was simulated using a CBOD compartment. There were no $CBOD_u$ data collected in 2004 but in 2001 BOD_5 and $CBOD_u$ data were collected. The average decay coefficient from the 2001 data was 0.0792 day^{-1}. The BOD_5 data collected in 2004 were first interpolated to fill in data gaps and then used with the decay coefficient to calculate $CBOD_u$.

Because total phosphorus data were more frequent than soluble reactive phosphorus (SRP) data, for time periods when SRP data were sparse total phosphorus data were used to estimate SRP concentrations by assuming a ratio of 0.629 mg/l SRP per 1 mg/l Total Phosphorus from the 2001 data. This ratio was the average of coincidental SRP and total phosphorus Coeur d'Alene WWTP data.

Fecal coliform data did not exist and concentrations were set to zero. Tracer and algae concentrations were also set to zero.

There were no non-volatile suspended solids (NVSS) data collected in 2004. So a ratio was developed between NVSS and total suspended solids data (TSS) from 2001 data. The average ratio of NVSS to TSS (0.57) was then used to adjust the TSS data in 2004 to represent the inorganic suspended solids.

Dissolved oxygen, ammonia nitrogen, chloride, conductivity, and total dissolved solids concentrations were all determined using data and filling in data gaps by linear interpolation. There were no nitrite-nitrate nitrogen concentration data in 2004 so the average of the data from 2001 (14.8 mg/L) was used.

The water quality constituent concentrations used to simulate the Coeur d'Alene WWTP discharge are shown in Figure 39, Figure 40, and Figure 41.

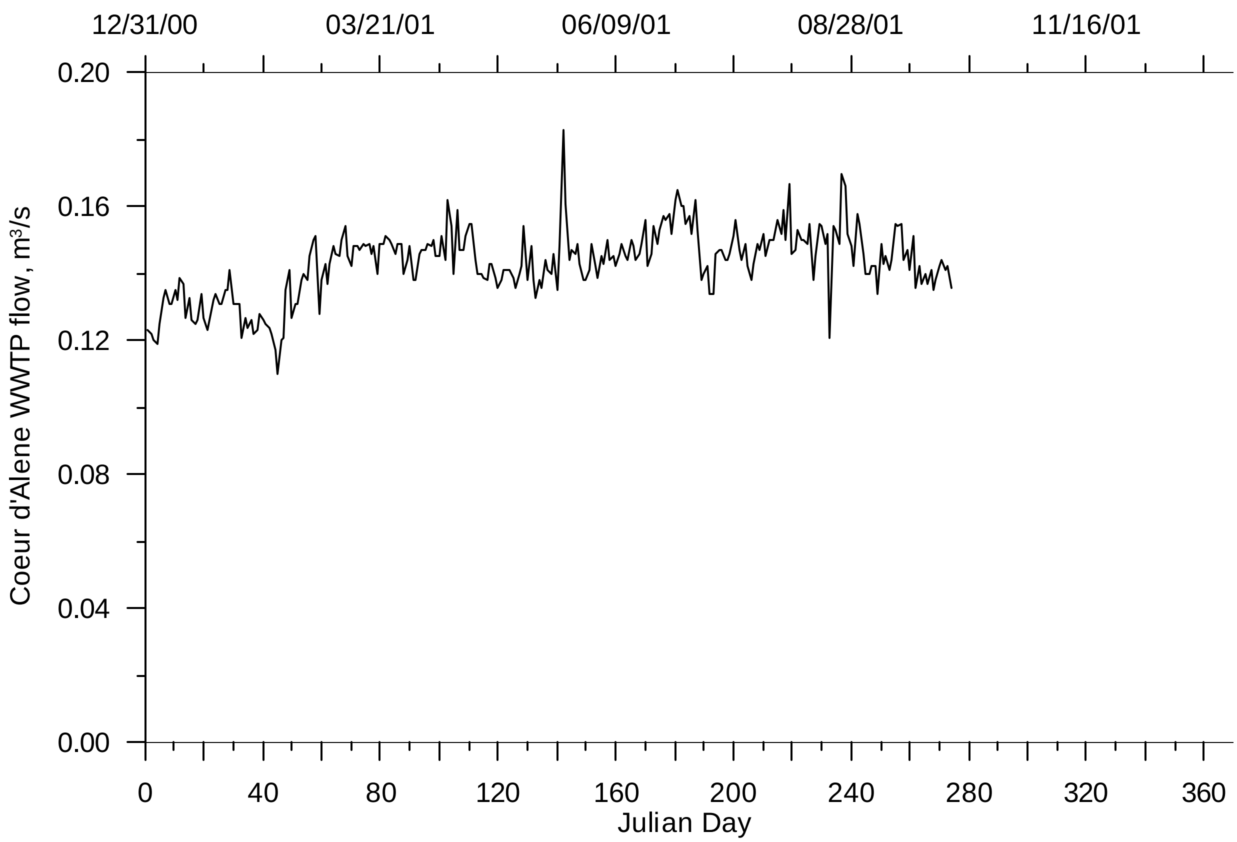


Figure 37: Coeur d'Alene WWTP flow rate, 2004.

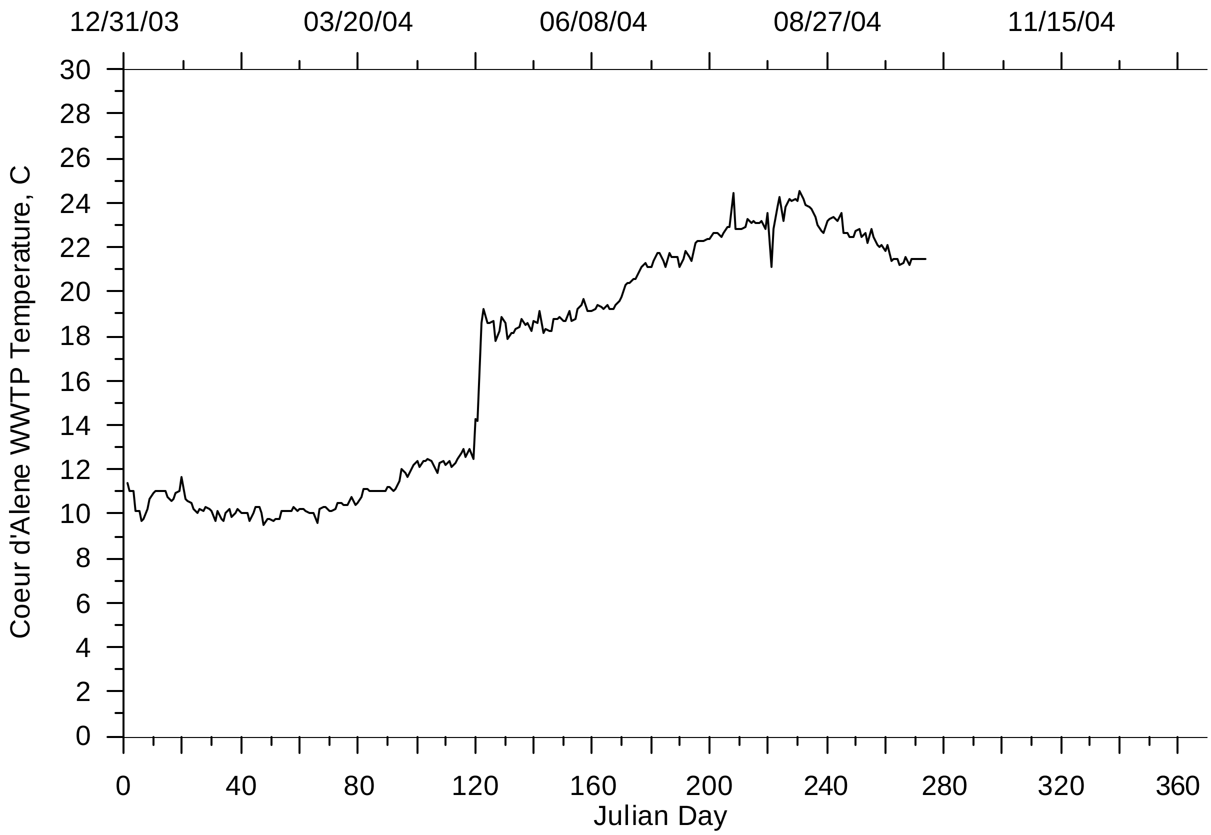


Figure 38: Coeur d'Alene WWTP temperatures, 2004.

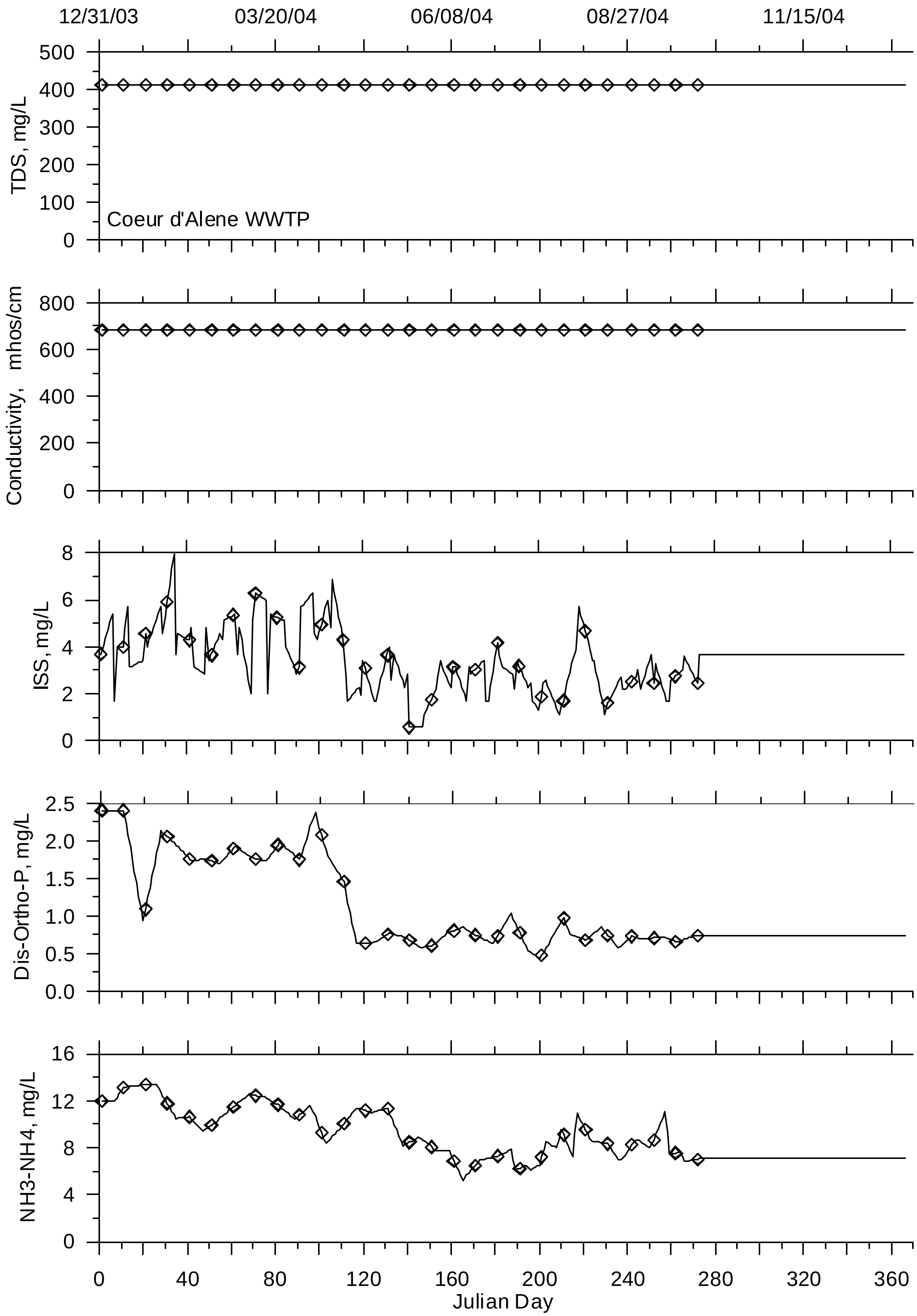


Figure 39: Coeur d'Alene WWTP discharge water quality conditions, 2004 (Part 1).

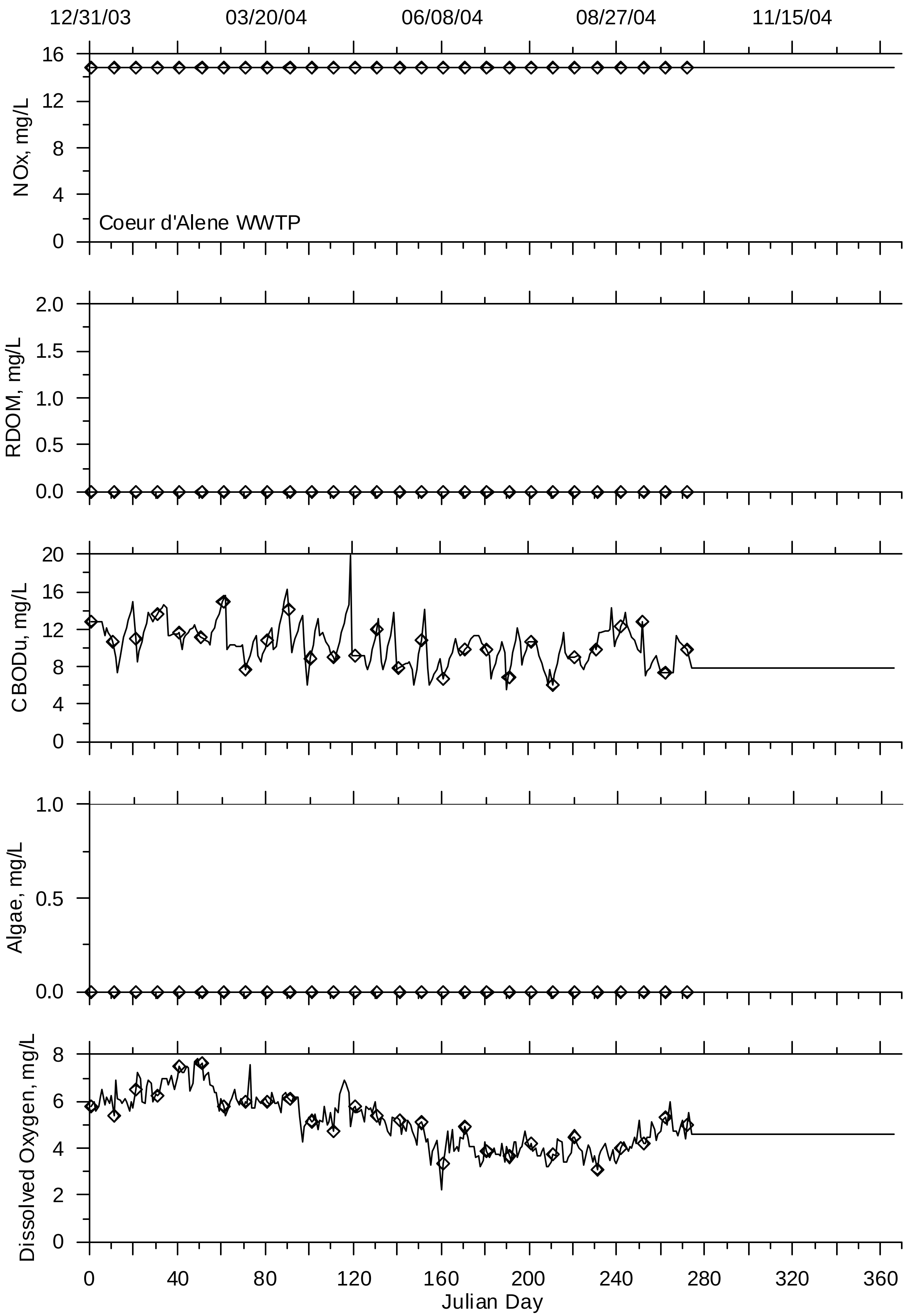


Figure 40: Coeur d'Alene WWTP discharge water quality conditions, 2004 (Part 2).

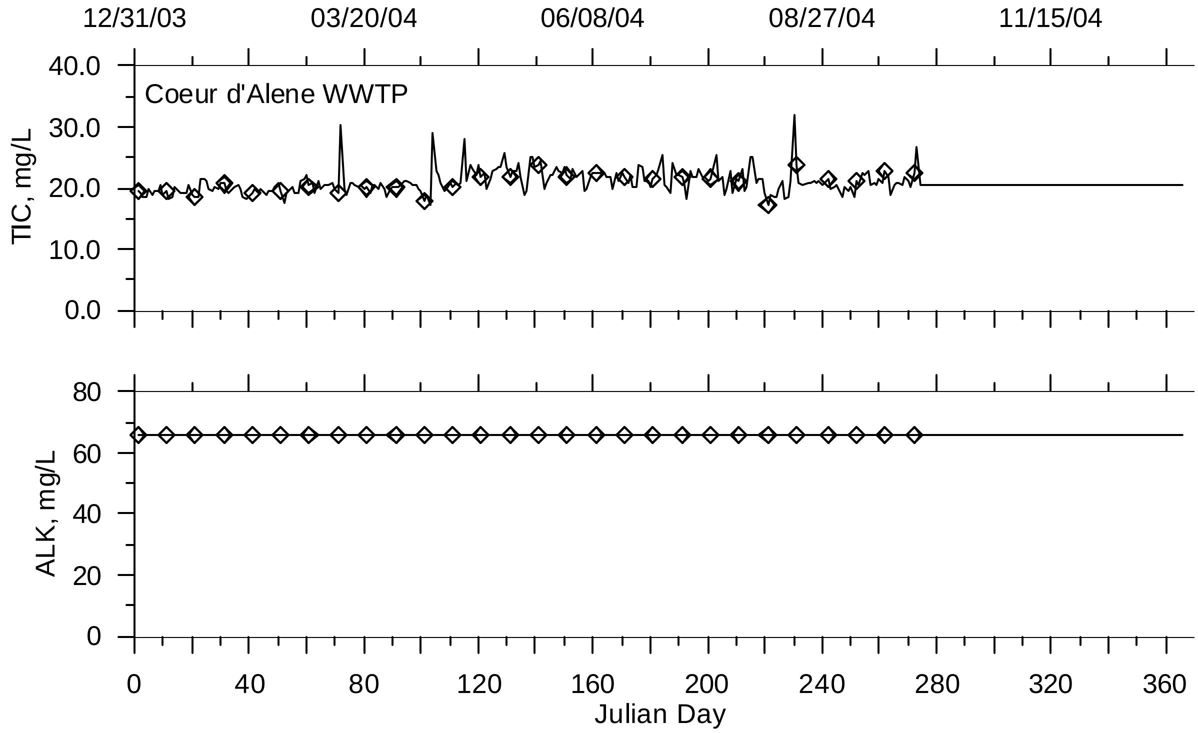


Figure 41: Coeur d'Alene WWTP discharge water quality conditions, 2004 (Part 3).

Hayden Area POTW

Year 2001

The Hayden Area Regional Sewer Board manages the effluent from the regional treatment plant, which discharges to the Spokane River. During the summer months the treatment plant does not discharge effluent to the Spokane River. The effluent is discharged to a lagoon and then land applied to crops. Figure 42 shows the Hayden discharge flow for 2001 (note the time periods when the effluent was not discharging to the Spokane River). Figure 43 shows the effluent temperature with a seasonal warming trend.

The Hayden Area POTW (Publicly Owned Treatment Works) point source water quality was characterized using conductivity, total dissolved solids, chloride, ammonia nitrogen, nitrite-nitrate nitrogen, soluble reactive phosphorus, alkalinity, BOD_5, pH, and non-volatile suspended solids data.

A separate CBOD compartment was used to simulate organic matter originating from the Hayden Area POTW. $CBOD_u$ concentrations were estimated from BOD_5 data using an average decay rate of 0.0838 day^{-1} based on subset of BOD_5 and $CBOD_u$ data where decay rates were calculated by the Washington Department of Ecology. Since organic matter was accounted for in the CBOD compartment, constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero.

Inorganic carbon concentrations were estimated from pH, alkalinity and temperature data using equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981). Algae and tracer concentrations were set to zero. Inorganic suspended solids concentrations were assumed to be equivalent to the non-volatile suspended solids data.

Ammonia nitrogen, chloride, coliform, conductivity, nitrite-nitrate nitrogen, soluble reactive phosphorus, and total dissolved solids concentrations were all determined using data and filling in data gaps by linear interpolation.

There were no dissolved oxygen data collected in 2001 to characterize the dissolved oxygen concentration of the discharge effluent. The dissolved oxygen concentration was assumed to be 4.7 mg/L. This concentration was based on an average of the City of Coeur d'Alene and Post Falls discharges in 2004 when there was more complete dissolved oxygen data. The assumption was considered reasonable for 2001 since the City of Coeur d'Alene treatment plant discharge dissolved oxygen concentration varied from 2.33 to 8.55 mg/L in 2001 and the City of Post Falls, ID had a dissolved oxygen concentration that varied from 0.91 to 7.18 mg/L in 2001.

The 2001 constituent concentrations for the Hayden Area POTW are plotted in Figure 44, Figure 45, and Figure 46.

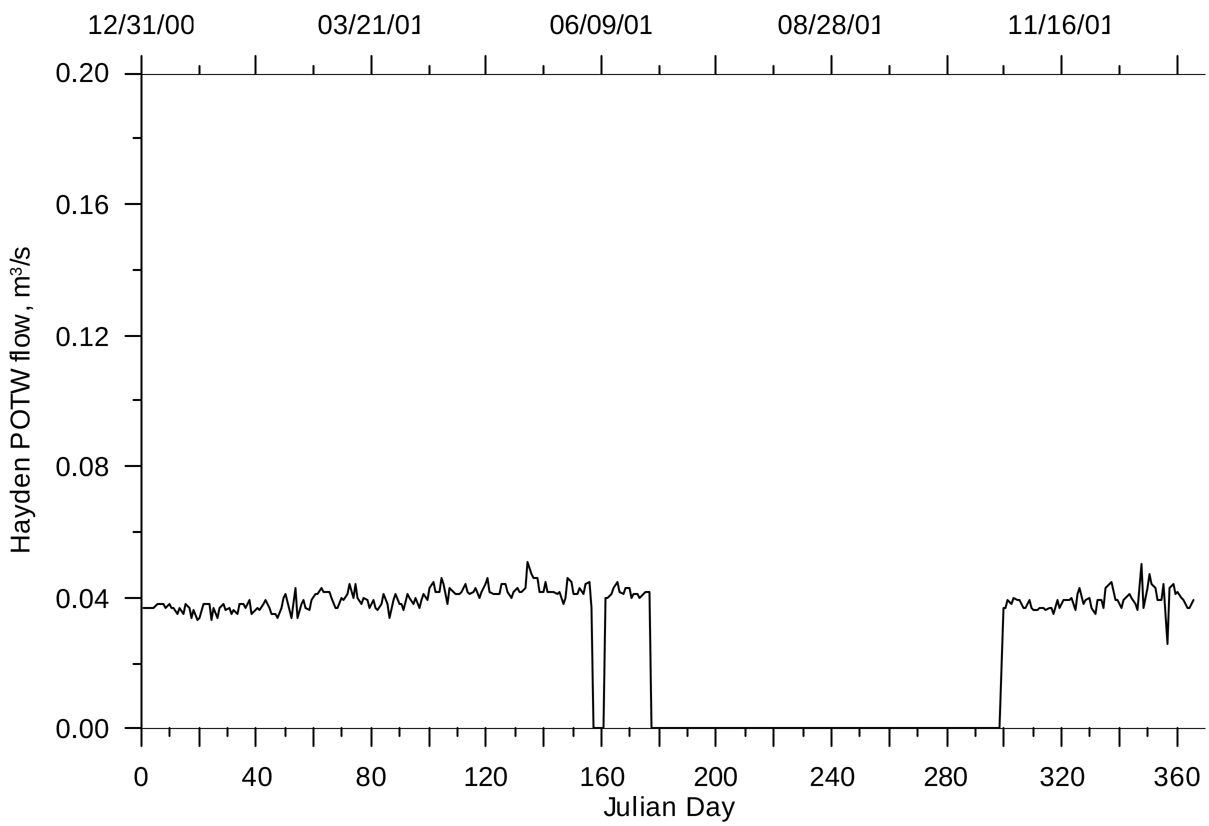


Figure 42: Hayden Area POTW flow rate, 2001.

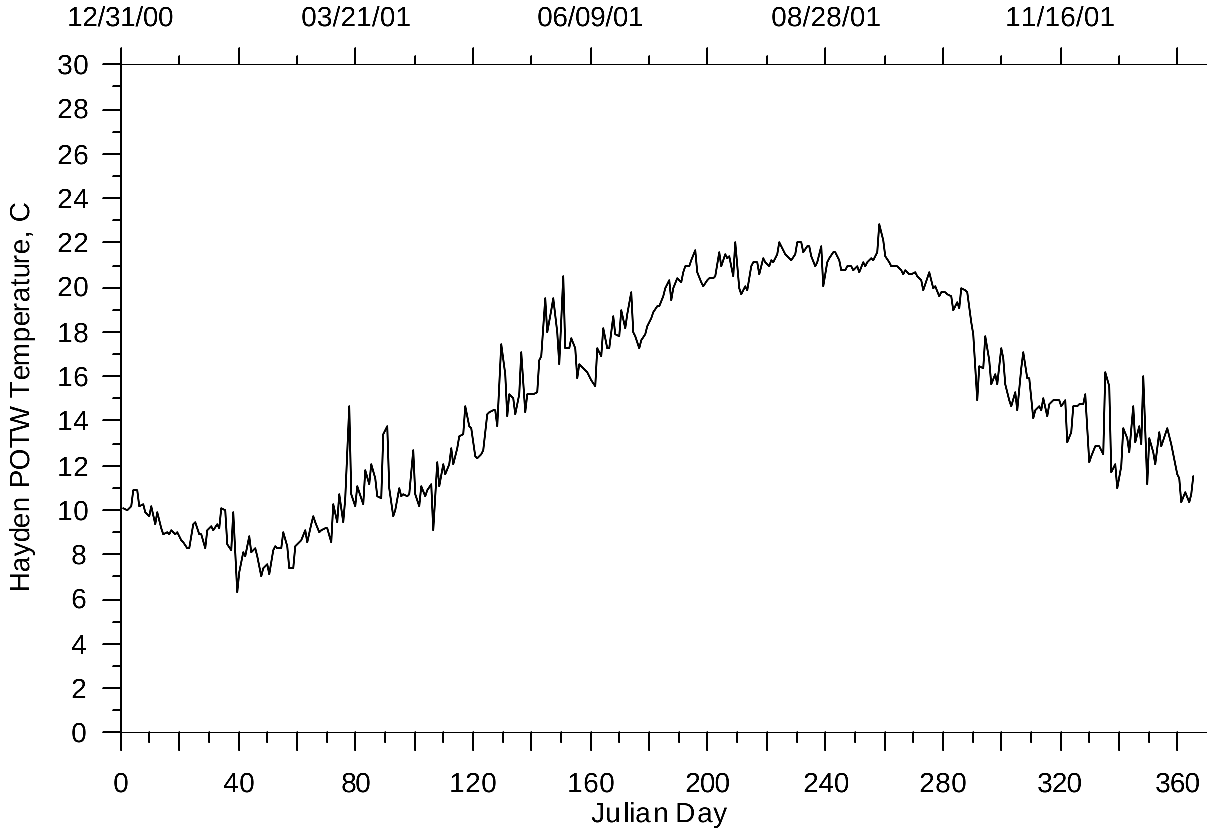


Figure 43: Hayden Area POTW temperature, 2001.

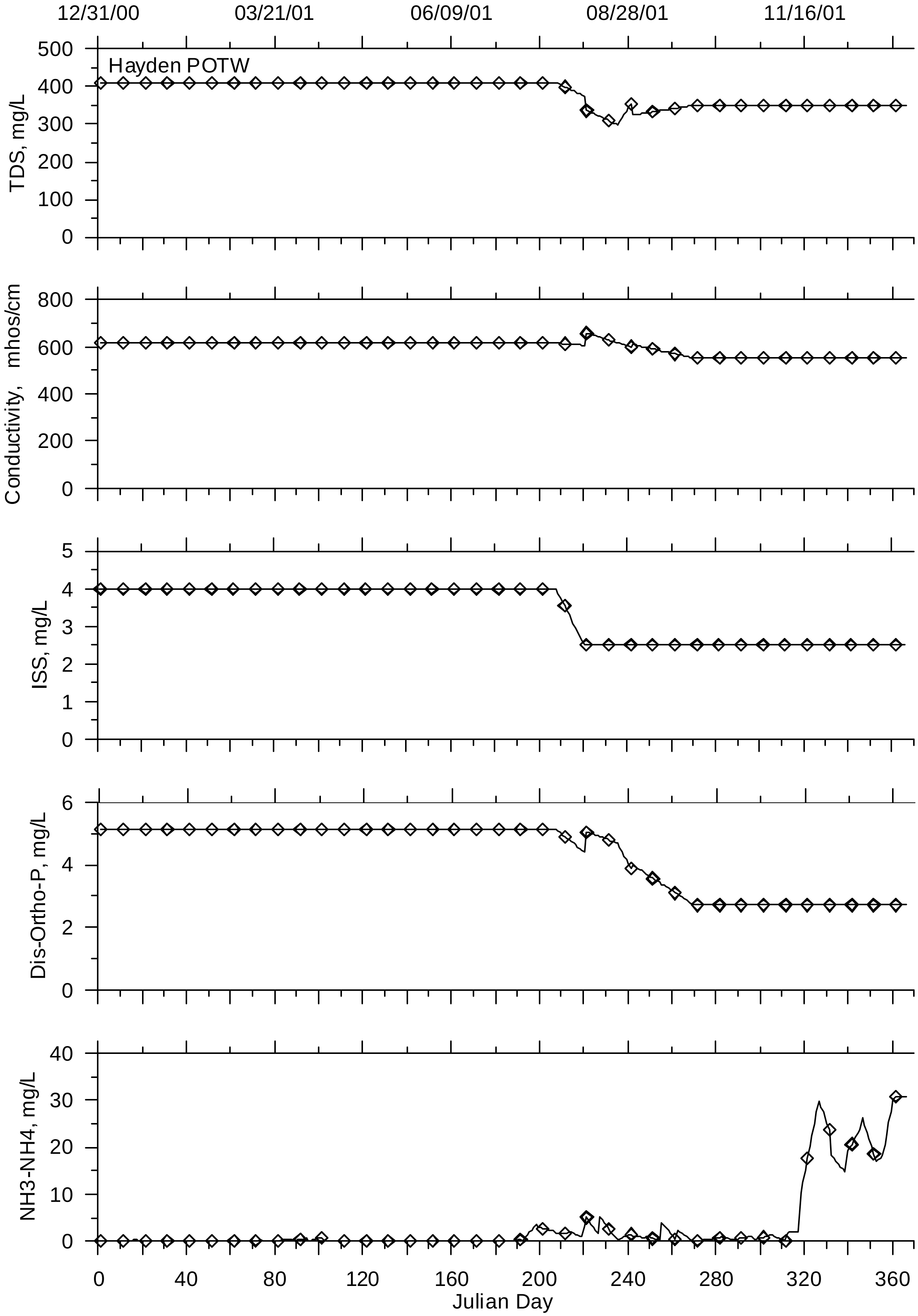


Figure 44: Hayden discharge water quality conditions, 2001 (Part 1).

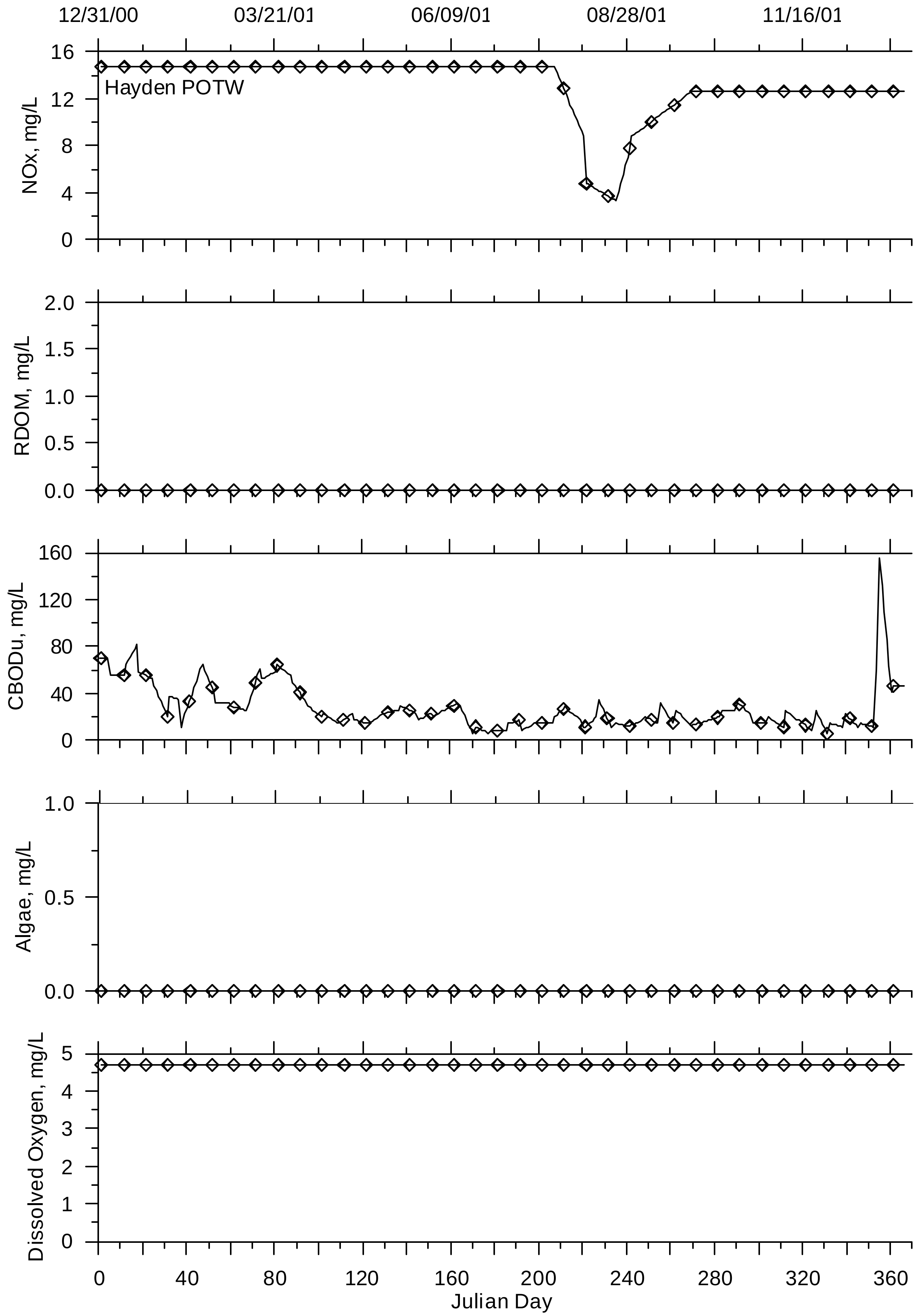


Figure 45: Hayden discharge water quality conditions, 2001 (Part 2).

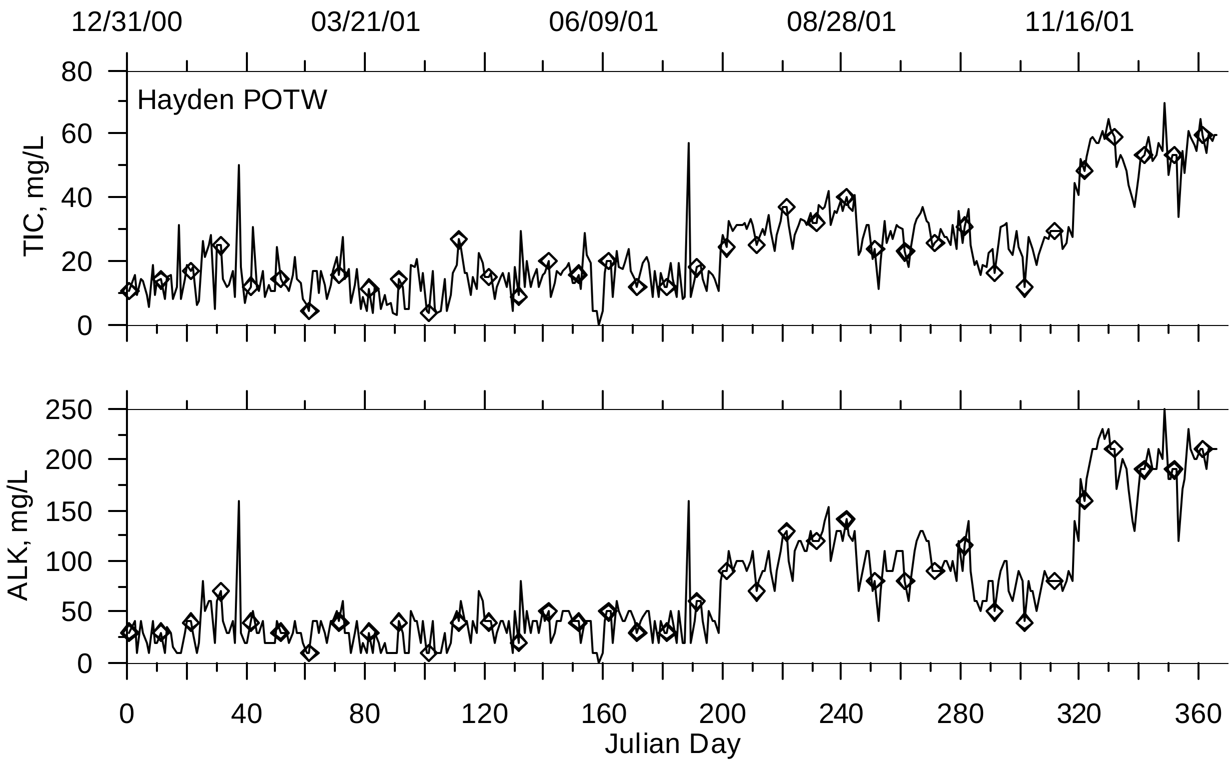


Figure 46: Hayden discharge water quality conditions, 2001 (Part 3).

Year 2004

The Hayden Area regional treatment plant does not discharge effluent to the Spokane River during the summer months. The effluent is discharged to a lagoon and then land applied to crops. Figure 47 shows the Hayden discharge flow for 2004. Figure 48 shows the effluent temperature (note that the data gap corresponds to the time period when there was no discharge to the Spokane River).

The Hayden Area POTW discharge water quality was characterized using temperature, chloride, ammonia nitrogen, fecal coliform, alkalinity, BOD_5, pH, and suspended solids data. There were no soluble reactive phosphorus, conductivity, nitrite-nitrate nitrogen, and total dissolved solids concentration data. The concentration for these constituents was set as a constant based on the annual average concentration of each in 2001.

There were no non-volatile suspended solids (NVSS) data collected in 2004. So a ratio was developed between NVSS and total suspended solids data (TSS) from 2001 data. The average ratio of NVSS to TSS (0.98) was then used to adjust the TSS data in 2004 to represent the inorganic suspended solids.

A separate CBOD compartment was used to simulate organic matter originating from the Hayden Area POTW. $CBOD_u$ concentrations were estimated from BOD_5 data using an average decay rate of 0.0838 day^{-1} based on subset of BOD_5 and $CBOD_u$ data where decay rates were calculated by the Washington Department of Ecology. Since organic matter was accounted for in the CBOD compartment, constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero.

Inorganic carbon concentrations were estimated from pH, alkalinity and temperature data using equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981). Algae and tracer concentrations were set to zero.

Ammonia nitrogen, chloride, and coliform concentrations were determined from data. Linear interpolation was used to fill data gaps.

There were no dissolved oxygen data collected in 2004 so the dissolved oxygen concentration was set to 4.7 mg/L. The concentration was based on an average of the City of Coeur d'Alene and Post Falls discharges in 2004 when there was more complete dissolved oxygen data.

The 2001 constituent concentrations for the Hayden Area POTW are plotted in Figure 49, Figure 50, and Figure 51.

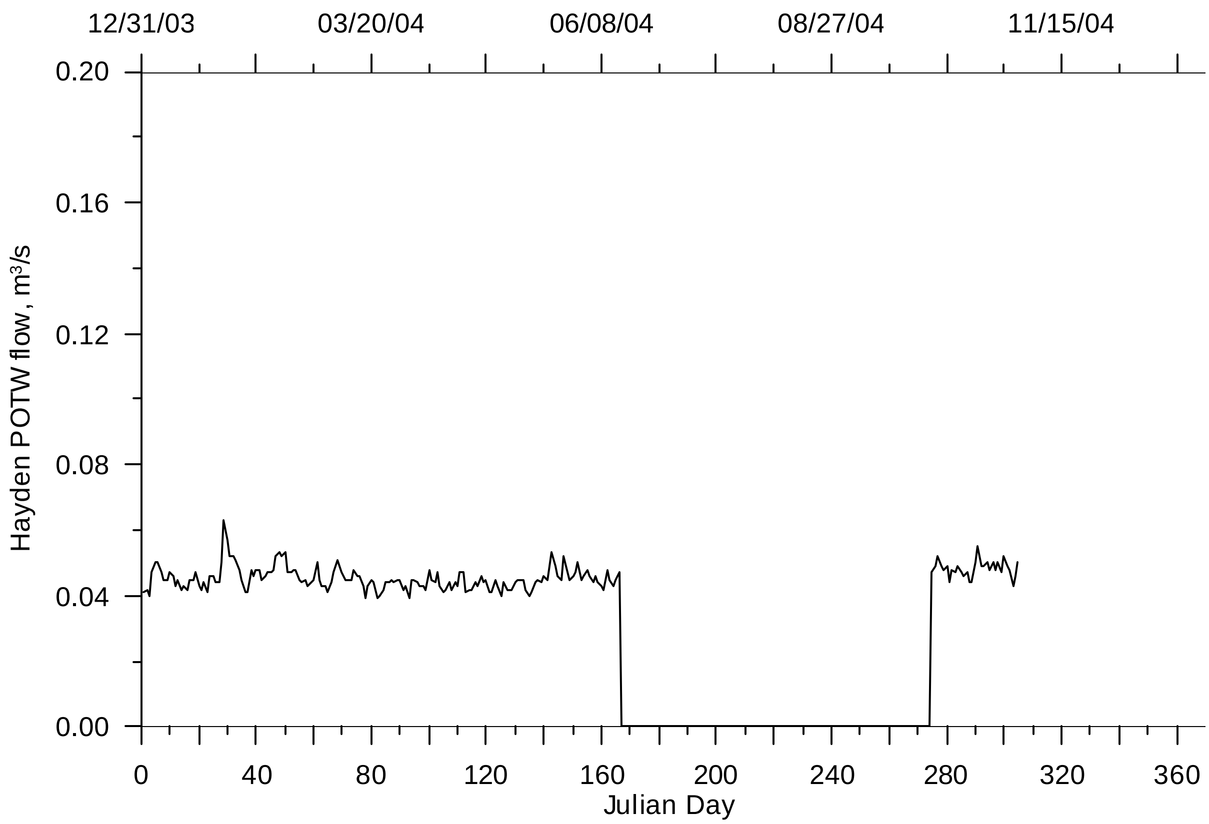


Figure 47: Hayden Area POTW flow rate, 2004.

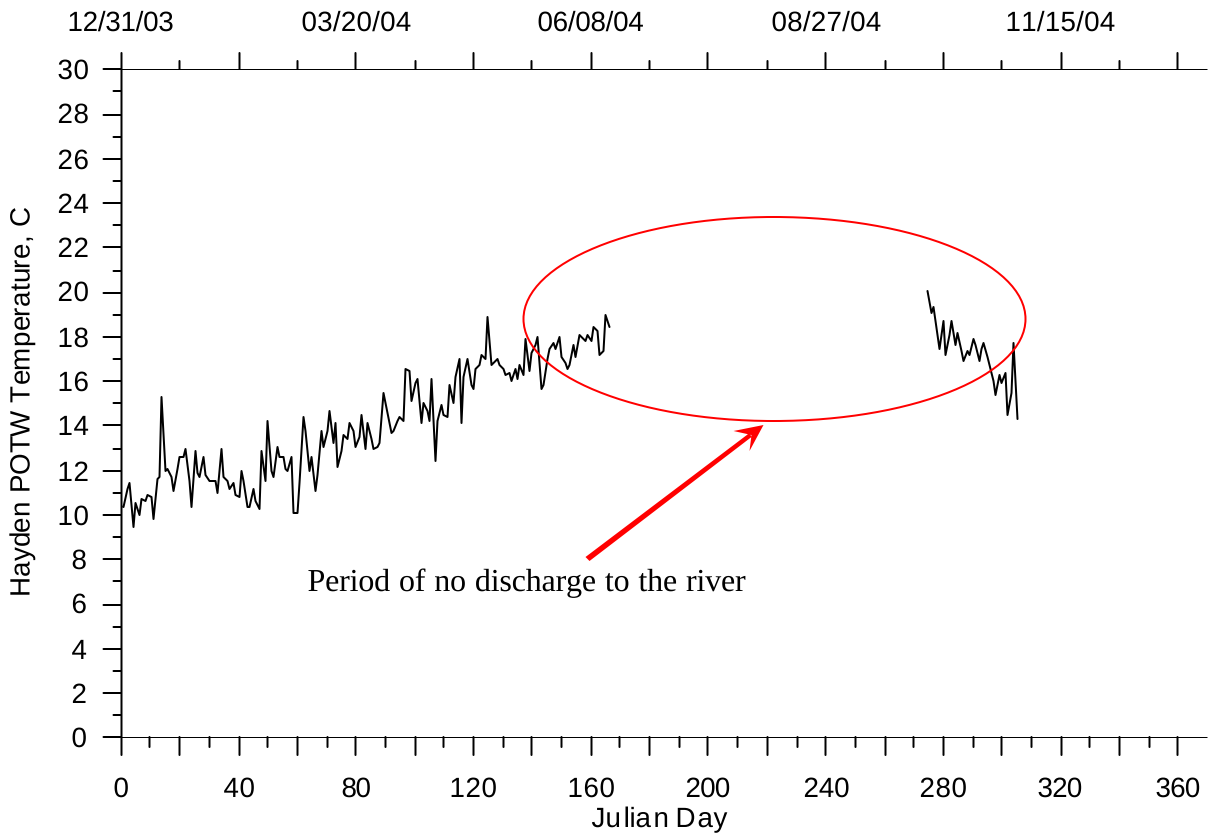


Figure 48: Hayden Area POTW temperature, 2004.

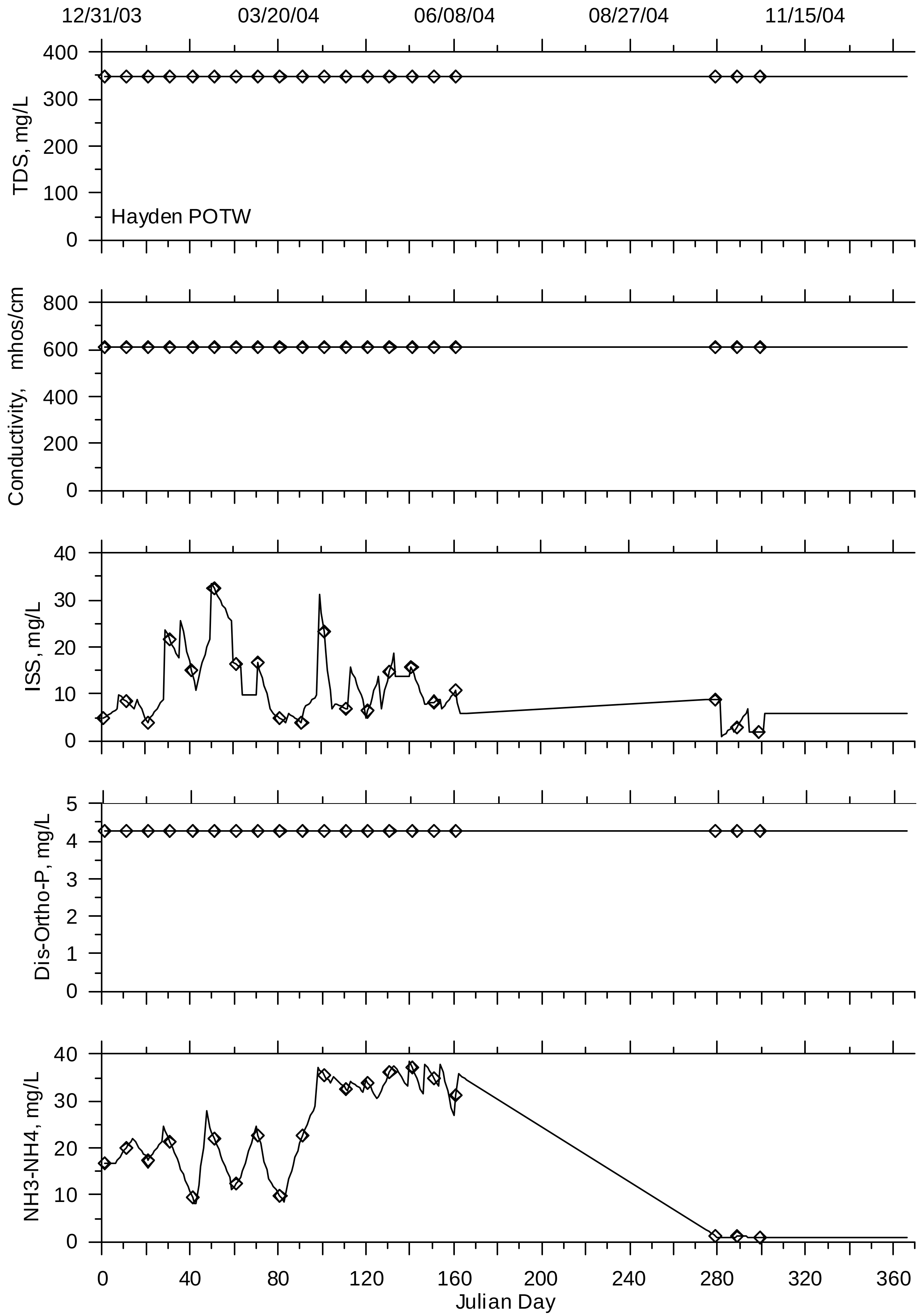


Figure 49: Hayden discharge water quality conditions, 2004 (Part 1).

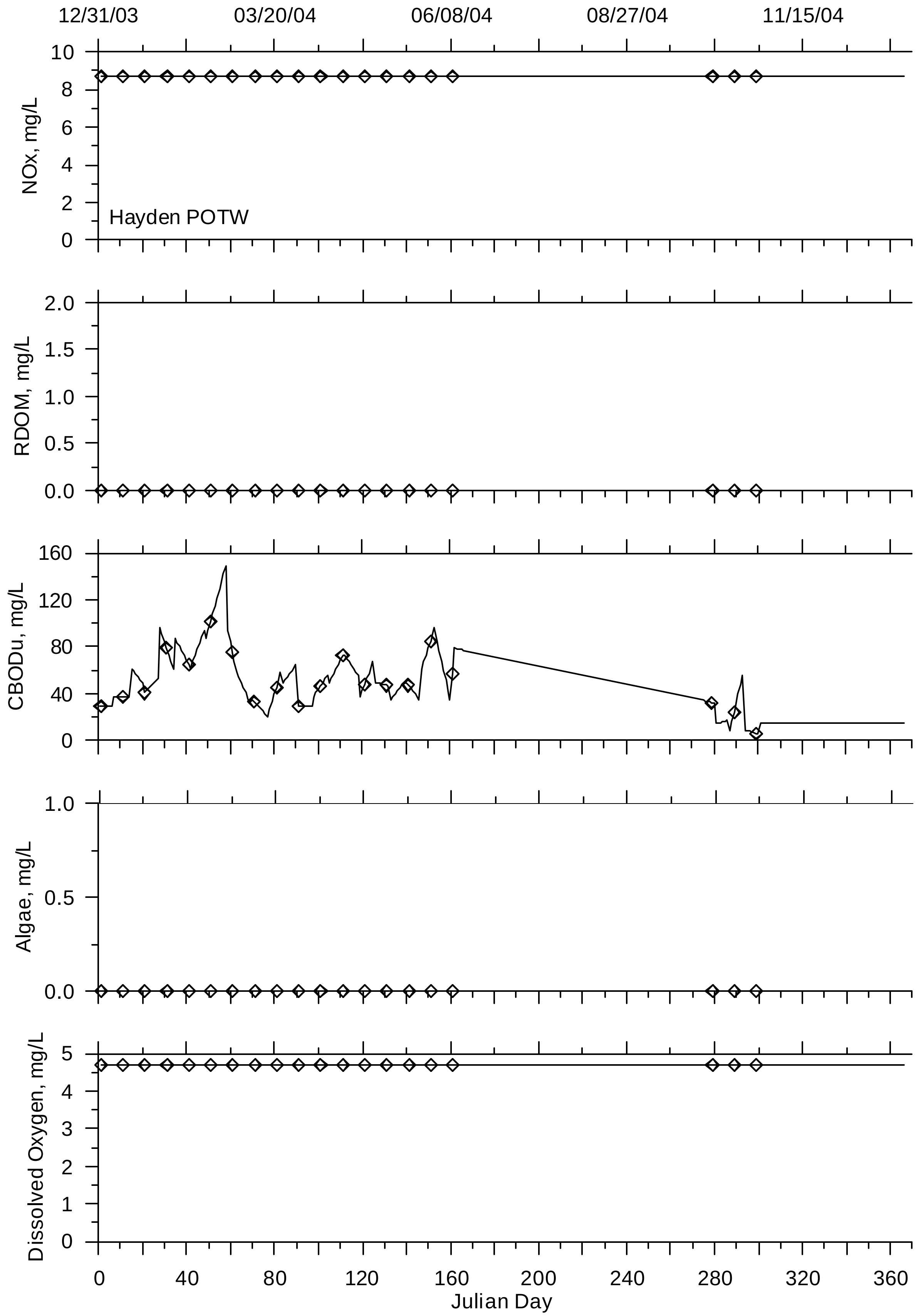


Figure 50: Hayden discharge water quality conditions, 2004 (Part 2).

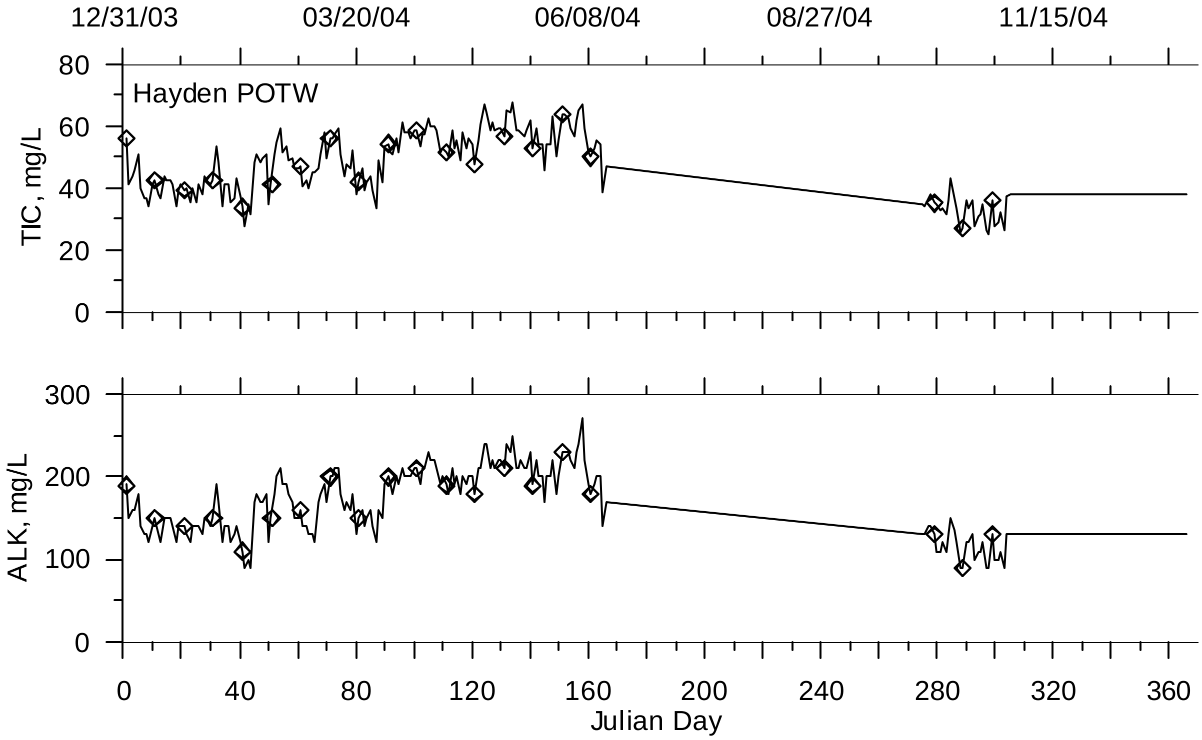


Figure 51: Hayden discharge water quality conditions, 2004 (Part 3).

Post Falls WWTP

Year 2001

The City of Post Falls wastewater treatment plant discharge flow for 2001 was shown in Figure 52. The flows were relatively low and consistent over the year. There was a data gap in the flow record for the month of November as shown in the figure by a straight horizontal line. This should not influence the modeling effort as the critical time period for the model simulation was from April to October 2001. Figure 53 shows the discharge temperature for 2001 and shows a general seasonal warming trend with a data gap in November.

The Post Falls WWTP water quality constituent file was developed from dissolved oxygen, BOD_5, alkalinity, total dissolved solids, pH, chloride, conductivity, nitrite-nitrate nitrogen, ammonia nitrogen, soluble reactive phosphorus, and total non-volatile suspended solids data.

Fecal Coliform data did not exist and concentrations were set to zero. Tracer and algae concentrations were also set to zero. Total dissolved solids, conductivity, chloride, inorganic (non-volatile) suspended solids, soluble reactive phosphorus, ammonia nitrogen, nitrite-nitrate nitrogen, dissolved oxygen, pH and alkalinity were all estimated using data and filling in data gaps by linear interpolation.

A separate CBOD compartment was used to simulate organic matter originating from the City of Post Falls WWTP. $CBOD_u$ concentrations were estimated from BOD_5 data using an average decay rate of 0.0660 day^{-1} based on subset of BOD_5 and $CBOD_u$ data where decay rates were calculated by the Washington Department of Ecology. Since organic matter was accounted for in the CBOD compartment, constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero.

Inorganic carbon concentrations were estimated from pH, alkalinity and temperature data using equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981).

The constituent concentrations of the Post Falls WWTP point source were shown in Figure 54, Figure 55, and Figure 56.

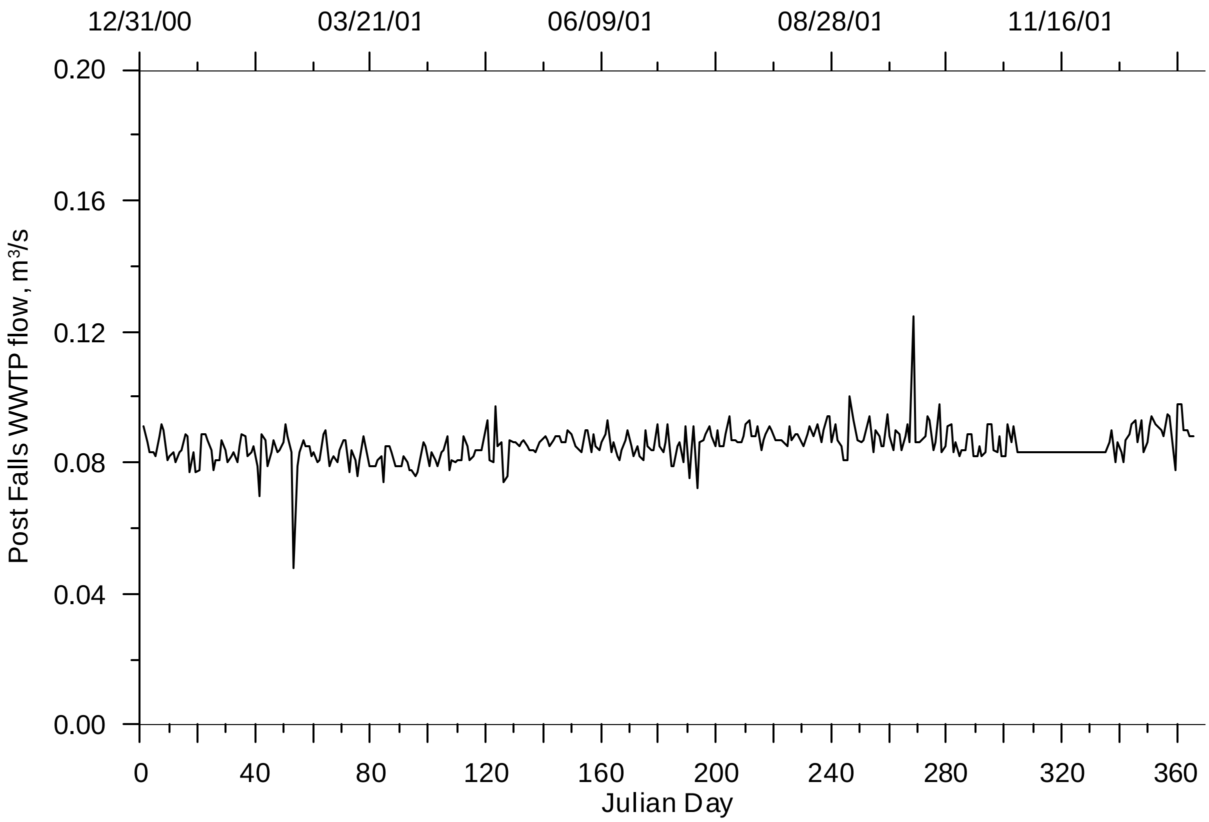


Figure 52: Post Falls WWTP flow rate, 2001.

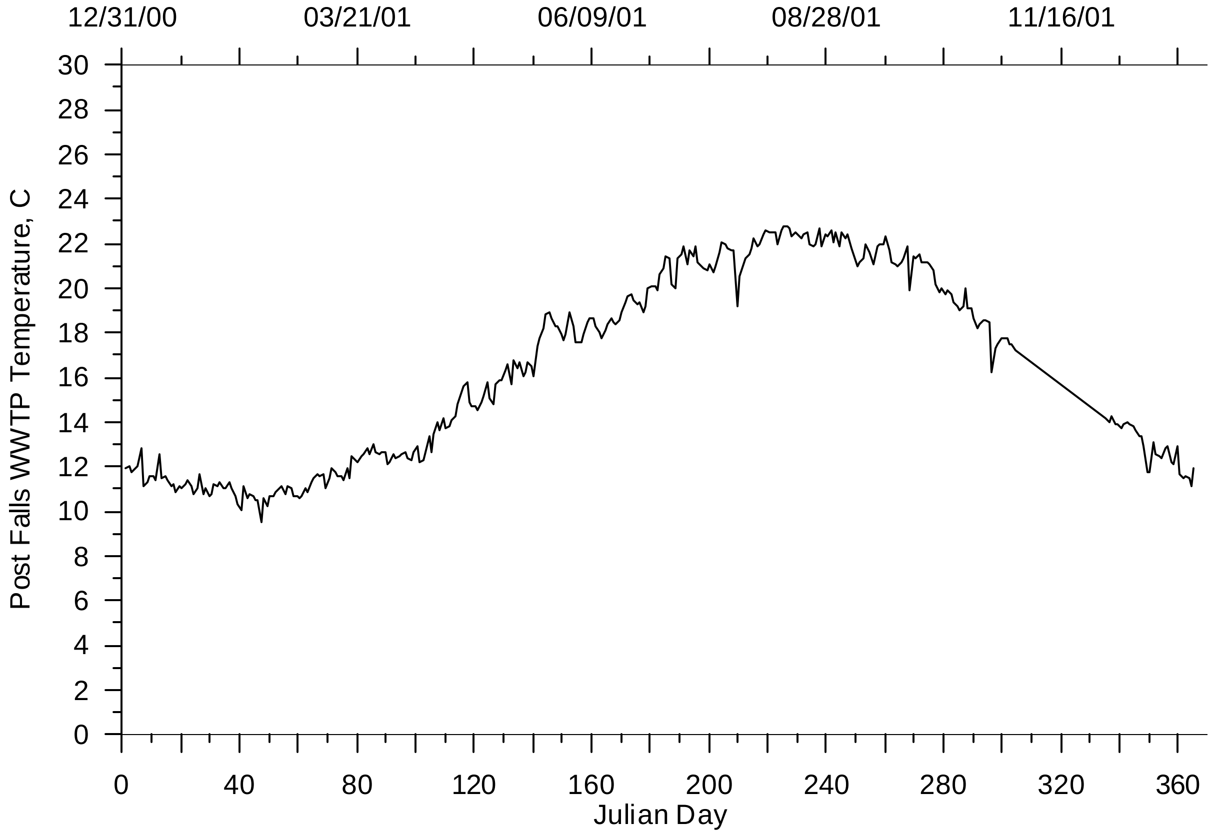


Figure 53: Post Falls WWTP temperatures, 2001.

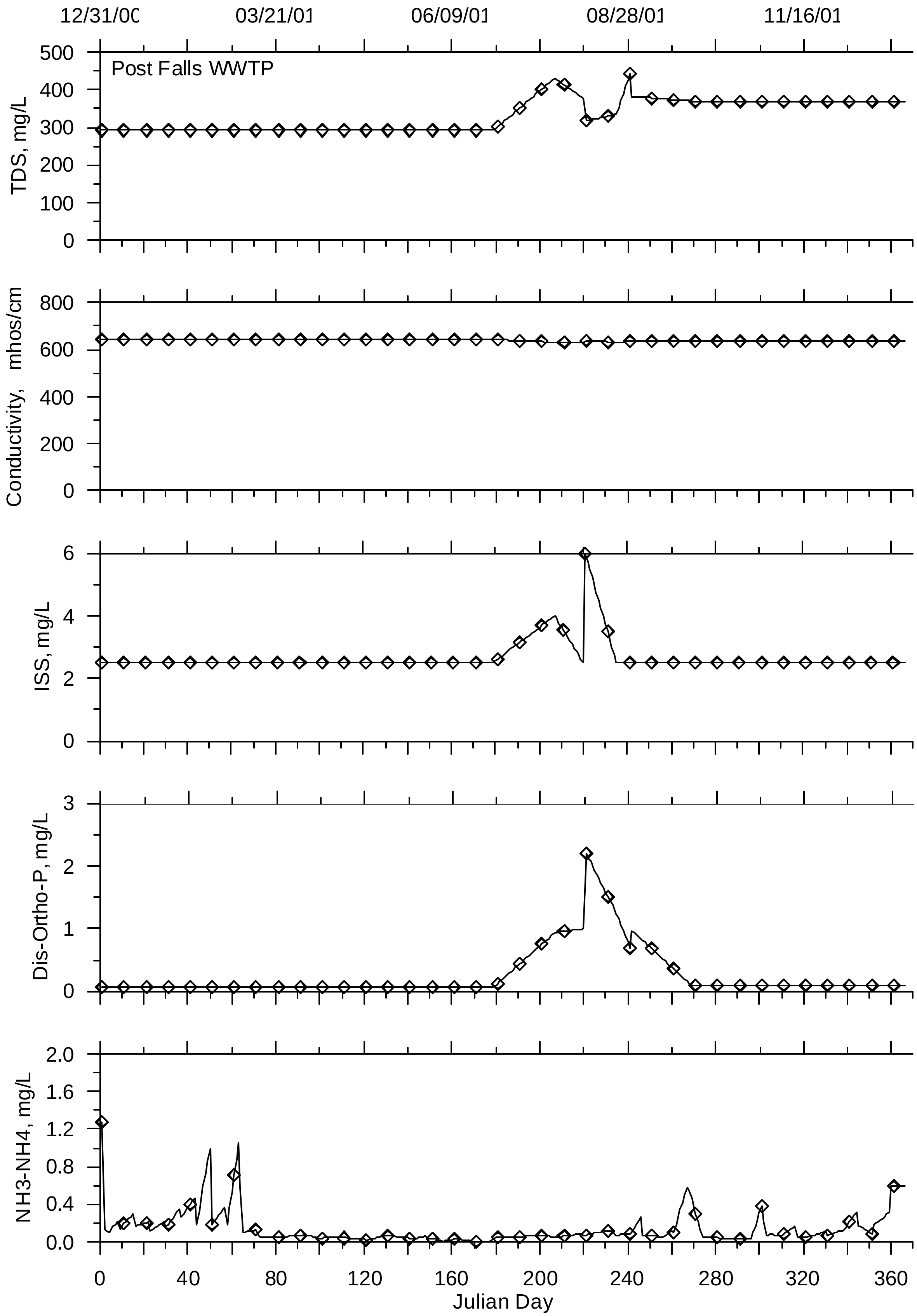


Figure 54: Post Falls discharge water quality conditions, 2001 (Part 1).

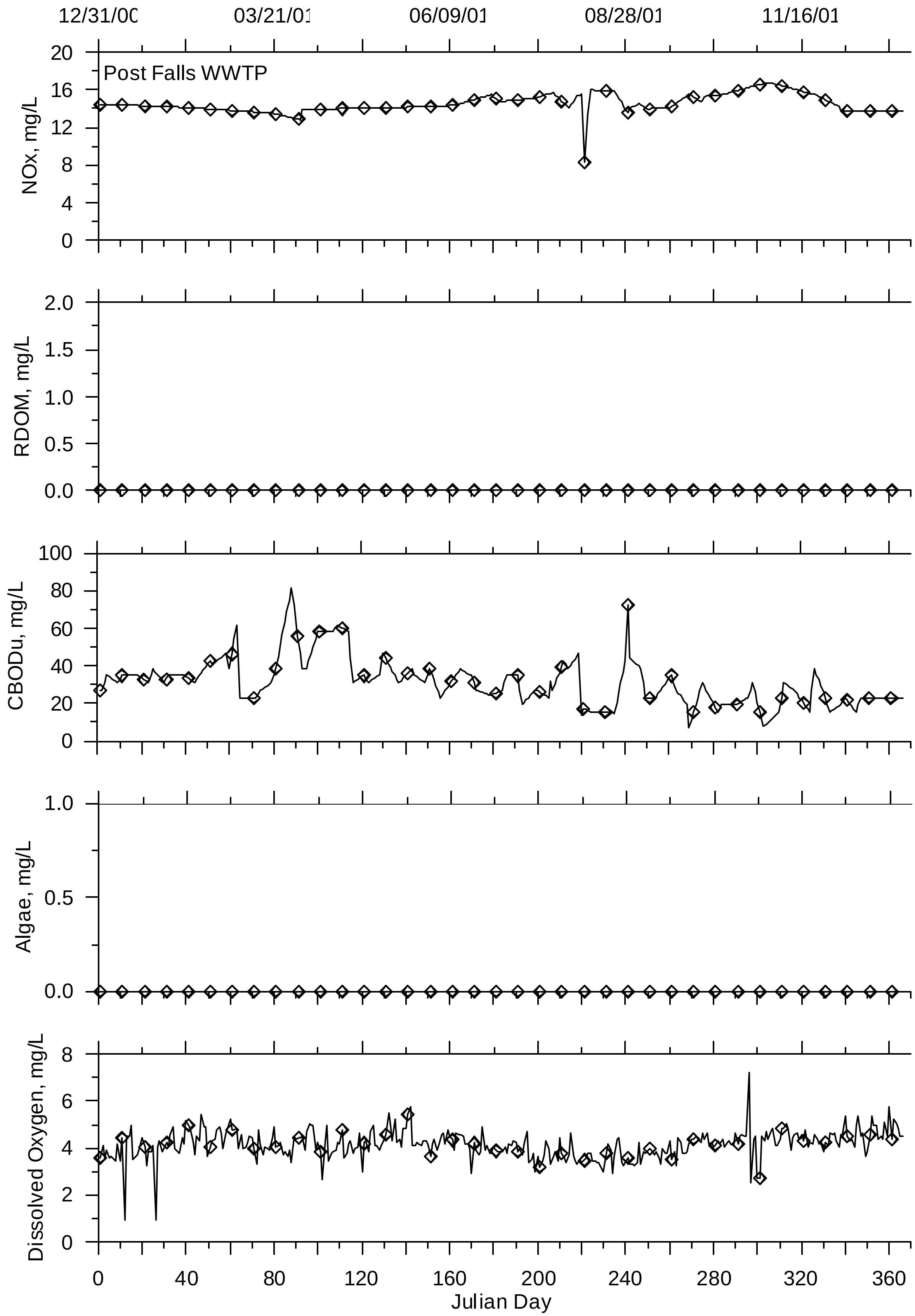


Figure 55: Post Falls discharge water quality conditions, 2001 (Part 2).

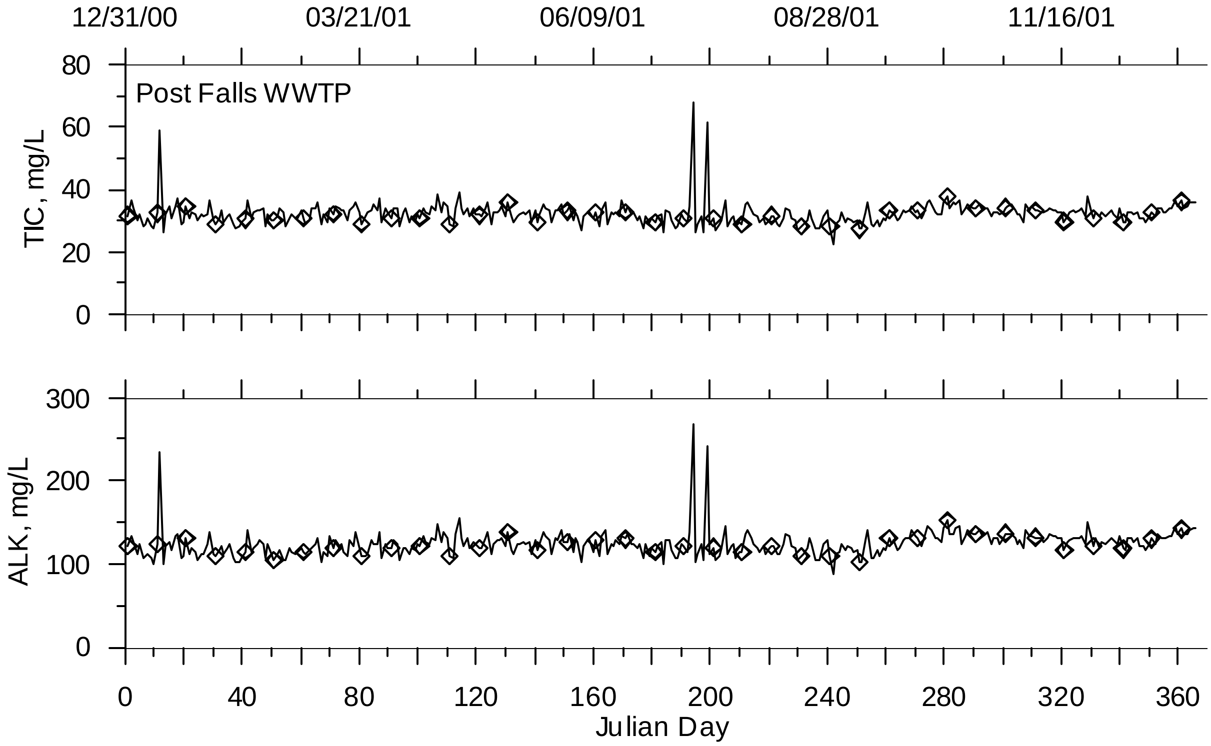


Figure 56: Post Falls discharge water quality conditions, 2001 (Part 3).

Year 2004

The City of Post Falls wastewater treatment plant discharge flow for 2004 was shown in Figure 57. The flows were relatively low and consistent over the year. Figure 58 shows the discharge temperature for 2004 and shows a general seasonal warming trend and cooling later in the year.

The Post Falls WWTP water quality constituent file was developed from dissolved oxygen, BOD_5, alkalinity, total dissolved solids, pH, chloride, fecal coliform, nitrite-nitrate nitrogen, ammonia nitrogen, total phosphorus, and total suspended solids data.

There were no total dissolved solids or conductivity data so the averages of the 2001 data for each were used as constant values for 2004. Tracer and algae concentrations were also set to zero. Chloride, total phosphorus, ammonia nitrogen, nitrite-nitrate nitrogen, dissolved oxygen, pH and alkalinity were all estimated using data and filling in data gaps by linear interpolation.

A separate CBOD compartment was used to simulate organic matter originating from the City of Post Falls WWTP. $CBOD_u$ concentrations were estimated from BOD_5 data using an average decay rate of 0.0660 day^{-1} based on subset of BOD_5 and $CBOD_u$ data where decay rates were calculated by the Washington Department of Ecology. Since organic matter was accounted for in the CBOD compartment, constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero.

There were no non-volatile suspended solids (NVSS) data collected in 2004. So a ratio was developed between NVSS and total suspended solids data (TSS) from 2001 data. The average ratio of NVSS to TSS (0.63) was then used to adjust the TSS data in 2004 to represent the inorganic suspended solids.

Since there were no soluble reactive phosphorus data in 2004 a ratio of soluble reactive phosphorus (SRP) to total phosphorus concentration was calculated from 2001 data. The average ratio of 0.6095 mg/l SRP per 1 mg/l Total Phosphorus was then used to adjust the total phosphorus data collected in 2004 to calculate the SRP for the model.

Inorganic carbon concentrations were estimated from pH, alkalinity and temperature data using equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981).

The constituent concentrations of the Post Falls WWTP point source are shown in Figure 59, Figure 60, and Figure 61

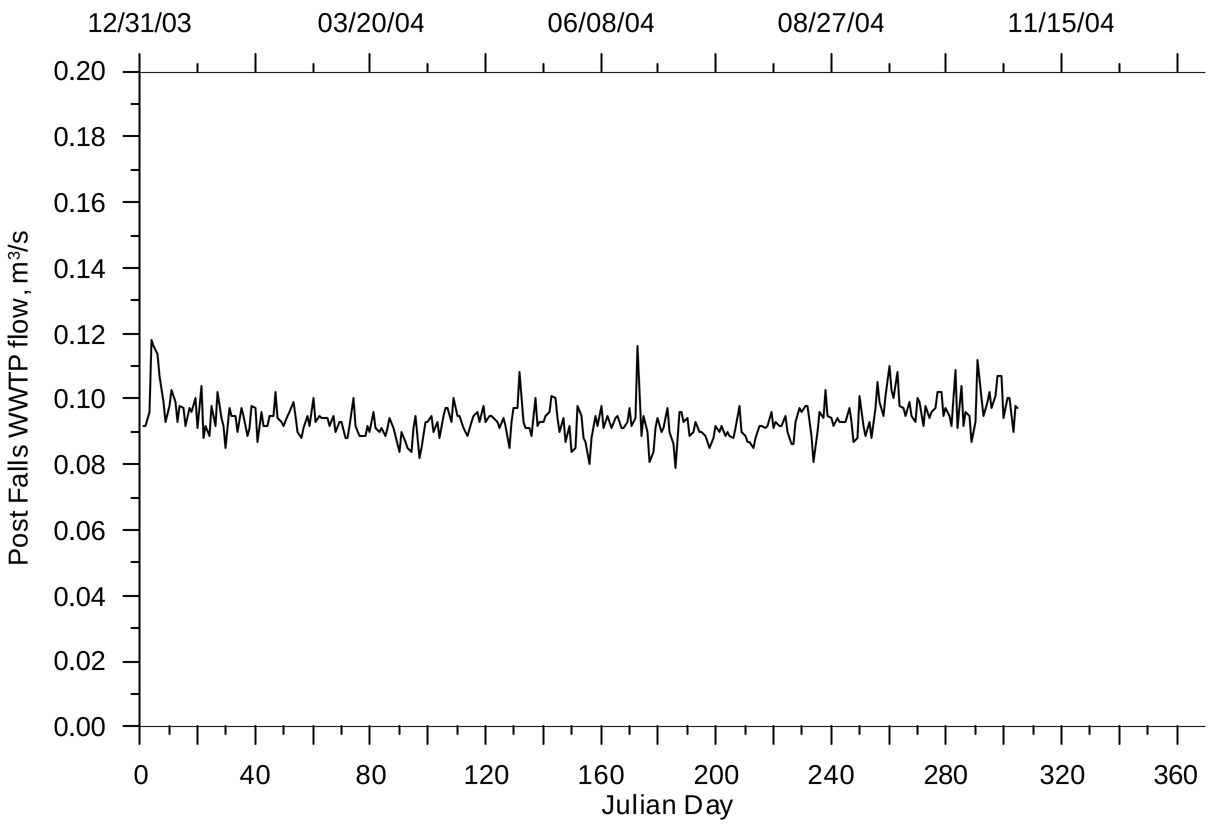


Figure 57: Post Falls WWTP flow rate, 2004.

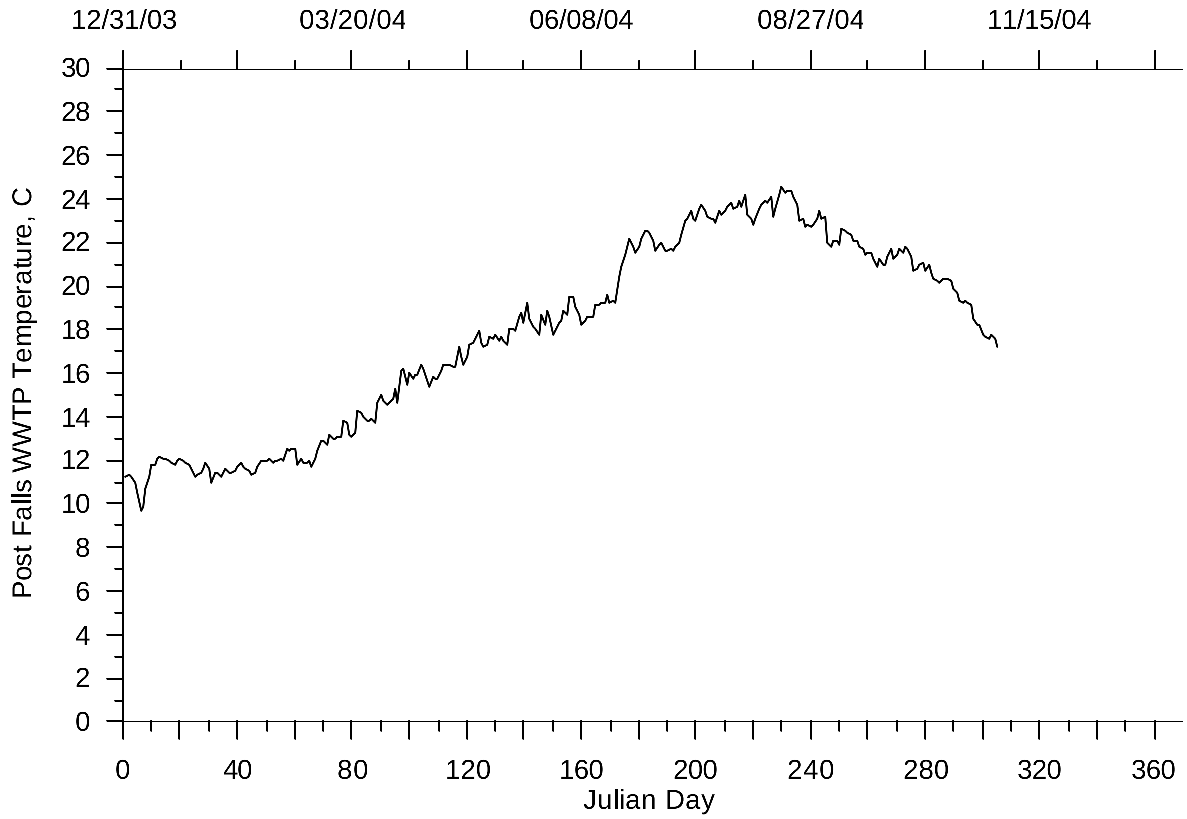


Figure 58: Post Falls WWTP temperatures, 2004.

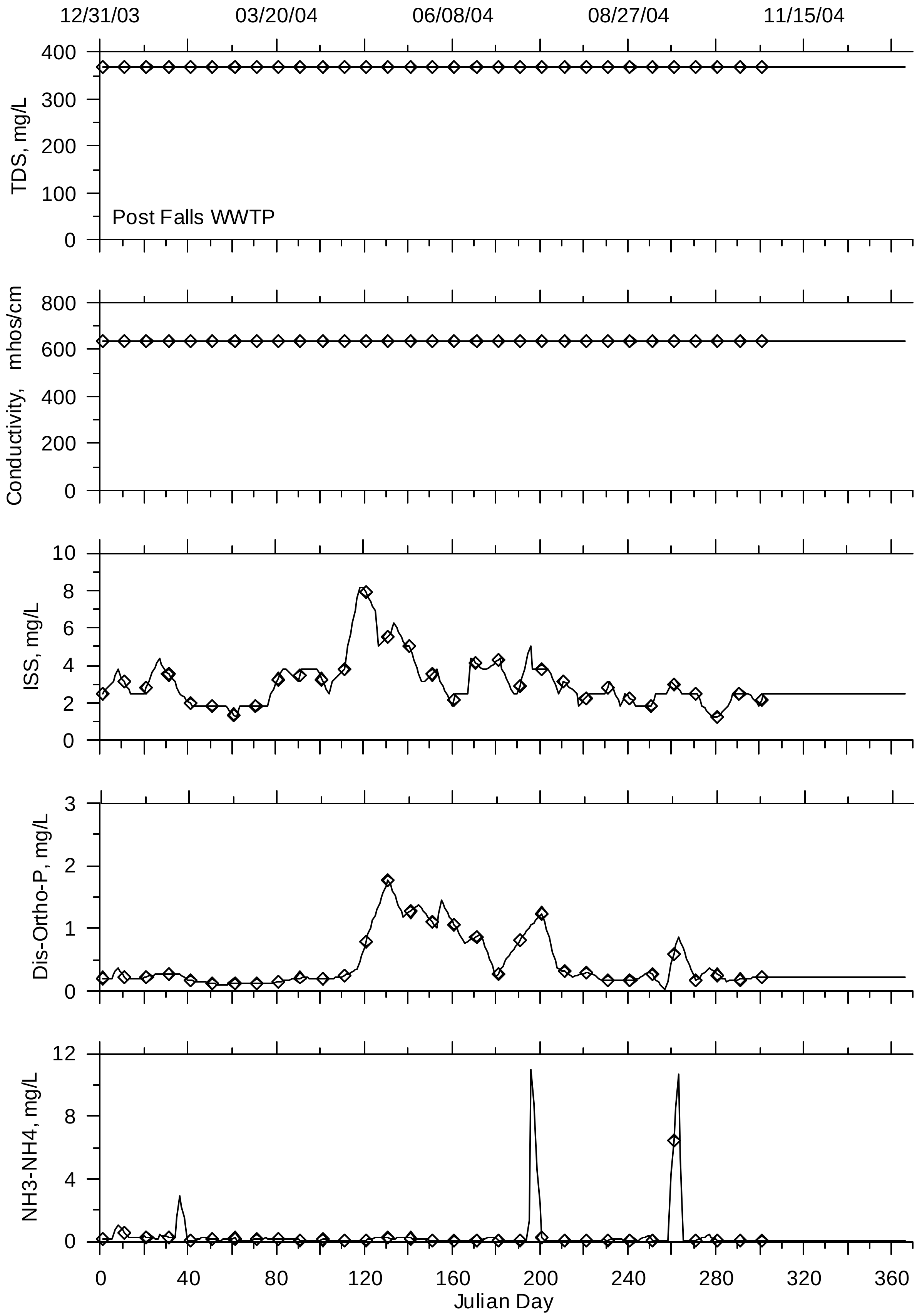


Figure 59: Post Falls discharge water quality conditions, 2004 (Part 1).

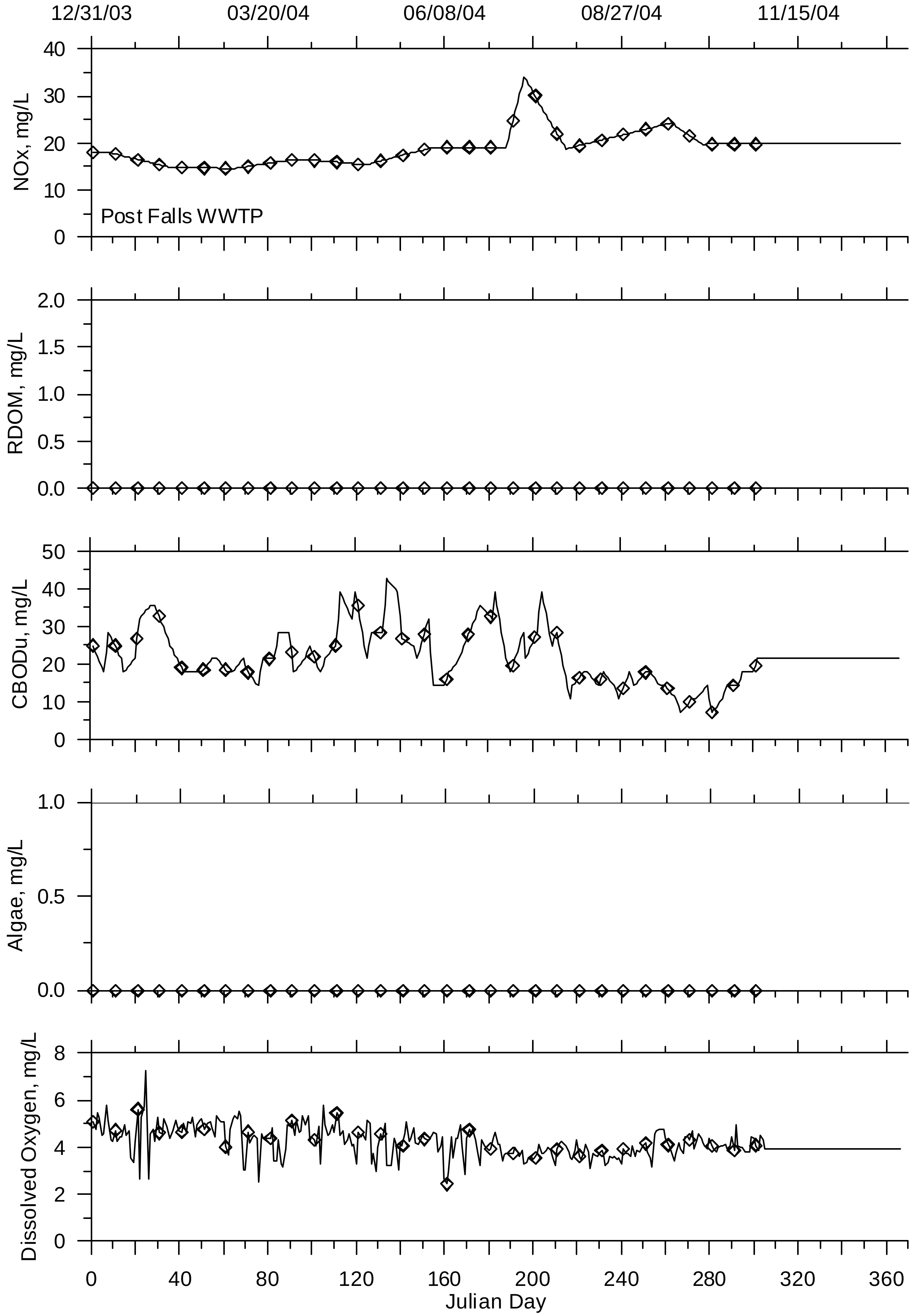


Figure 60: Post Falls discharge water quality conditions, 2004 (Part 2).

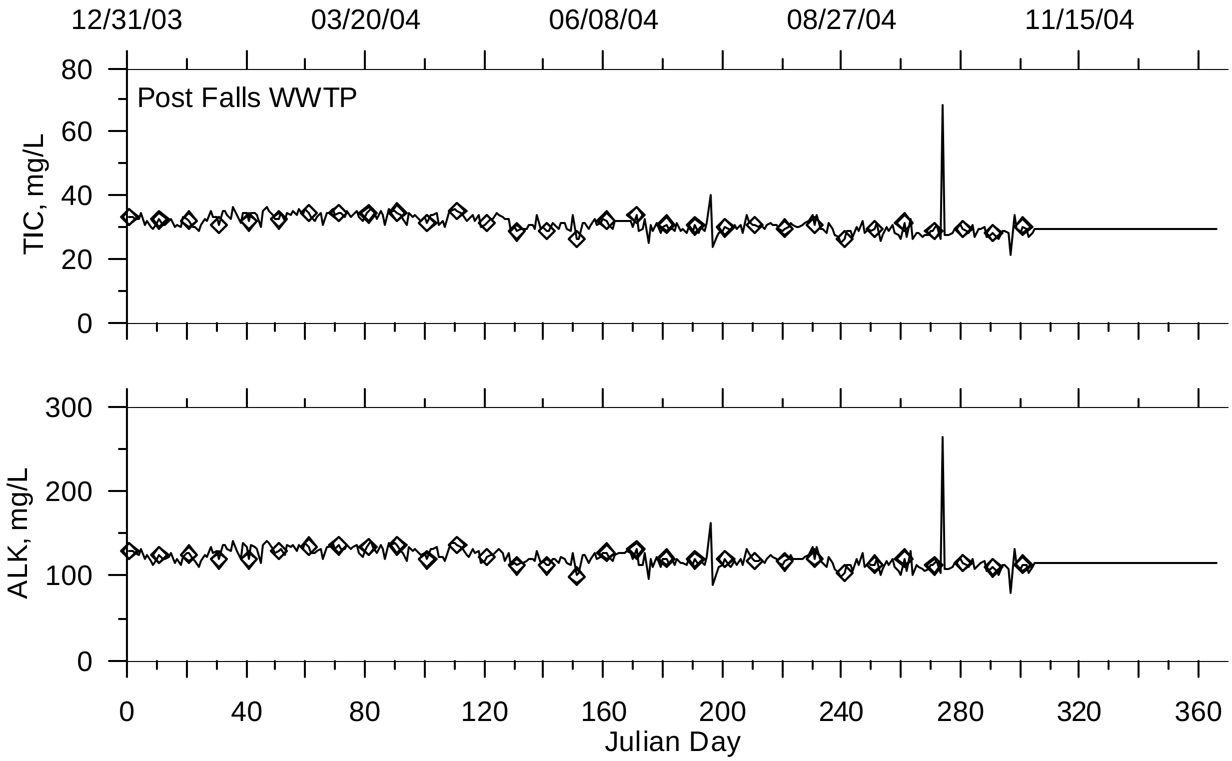


Figure 61: Post Falls discharge water quality conditions, 2004 (Part 3).

Post Falls Reservoir Operations

Year 2001

The Post Falls Dam consists of turbine and spillway discharges. The six turbines each had 4.57 m x 4.53 m (15 ft x 14.85 ft) gates located at a centerline elevation of 643.5 m NGVD. The active spillway on another part of the dam has a crest elevation of 645.27 m NGVD. Figure 62 shows the turbine and spillway flows in 2001. The plot shows a large spring freshet passing downstream and then reduced flows during the summer and early fall. Figure 63 shows the combined spillway and turbine flows in 2001 and the flow recorded at the USGS gage station (12419000) just downstream of the Post Falls Dam. The figure shows there were only minor differences between the dam operations flow records and the downstream gage station flow measurements. Therefore the USGS gage station flows were used in developing the upstream boundary condition and the flow downstream at Post Falls Dam.

Figure 64 shows the water surface elevation of Lake Coeur d'Alene during 2001 from the USGS gage station near the City of Coeur d'Alene (12415500). The plot shows the water level remained relatively constant over the summer and higher than during the fall through spring period.

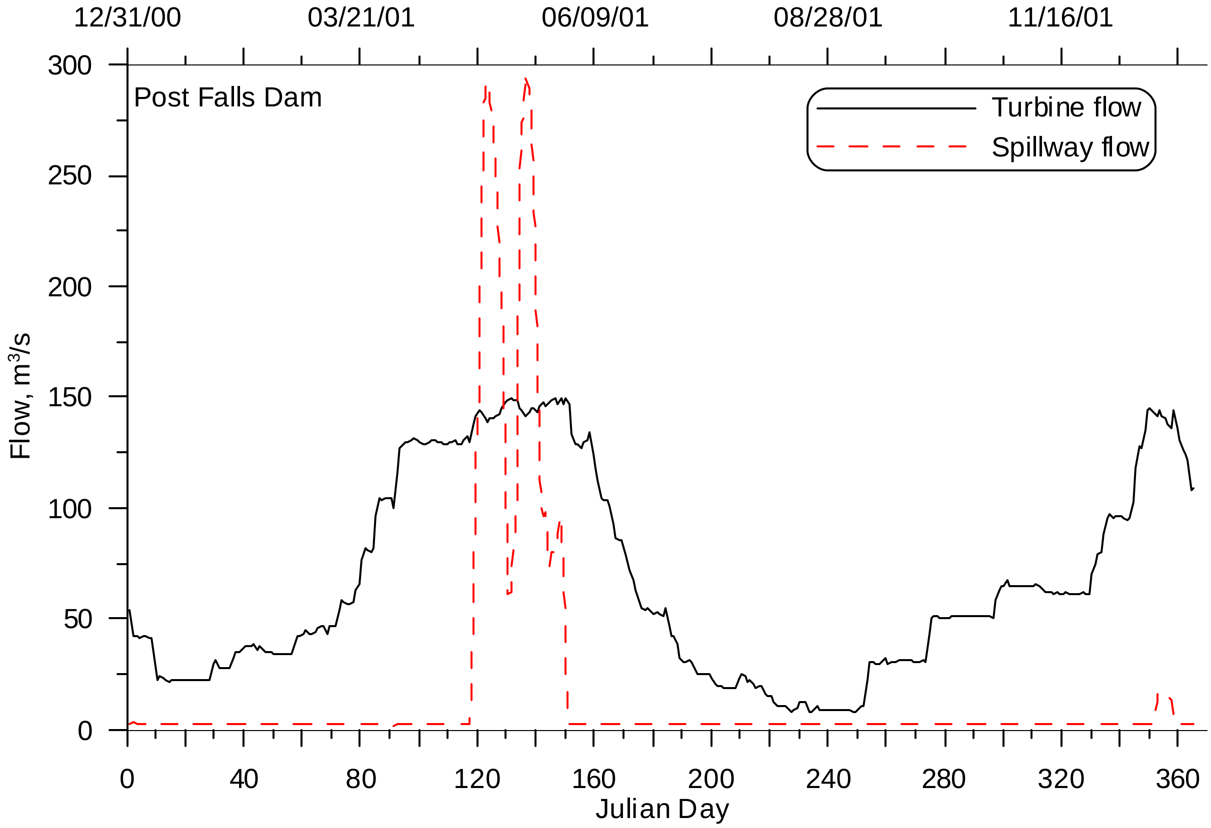


Figure 62: Post Falls Dam turbine and spillway flows, 2001.

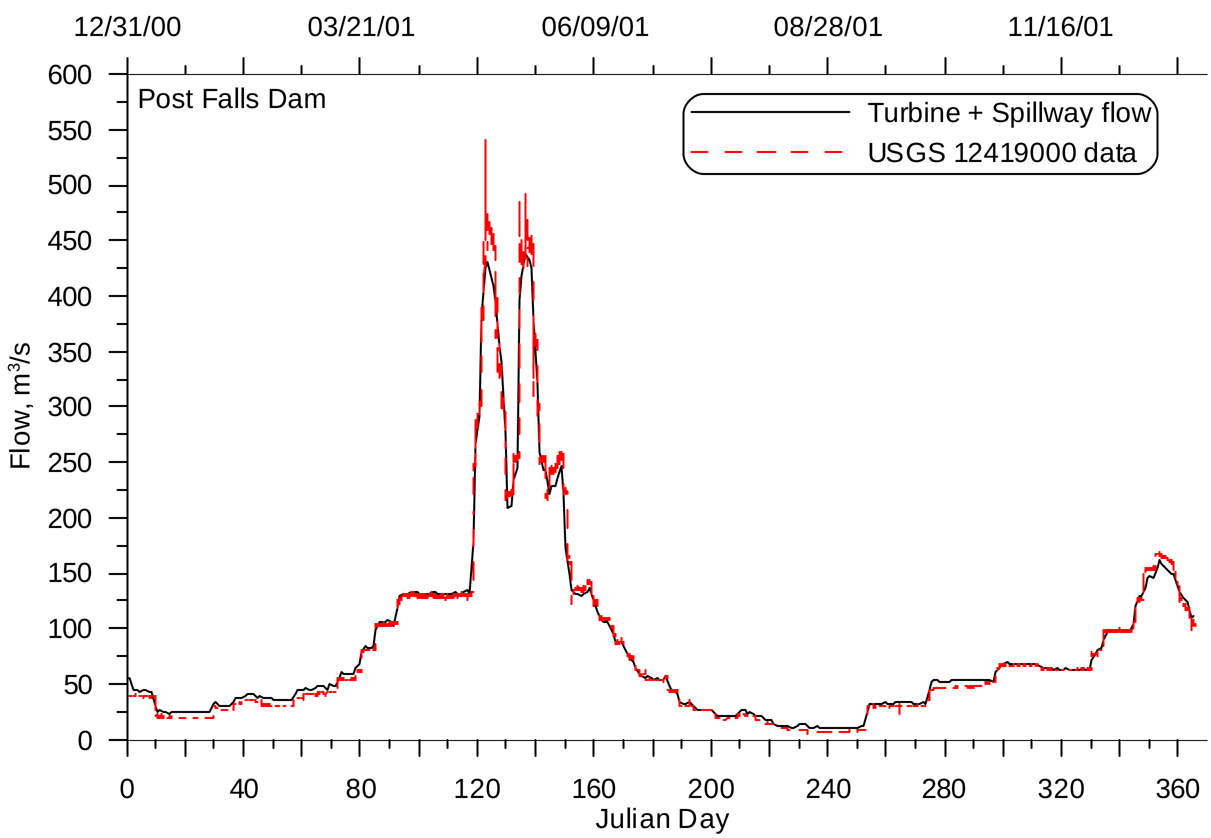


Figure 63: Post Falls Dam flows and downstream gage data, 2001.

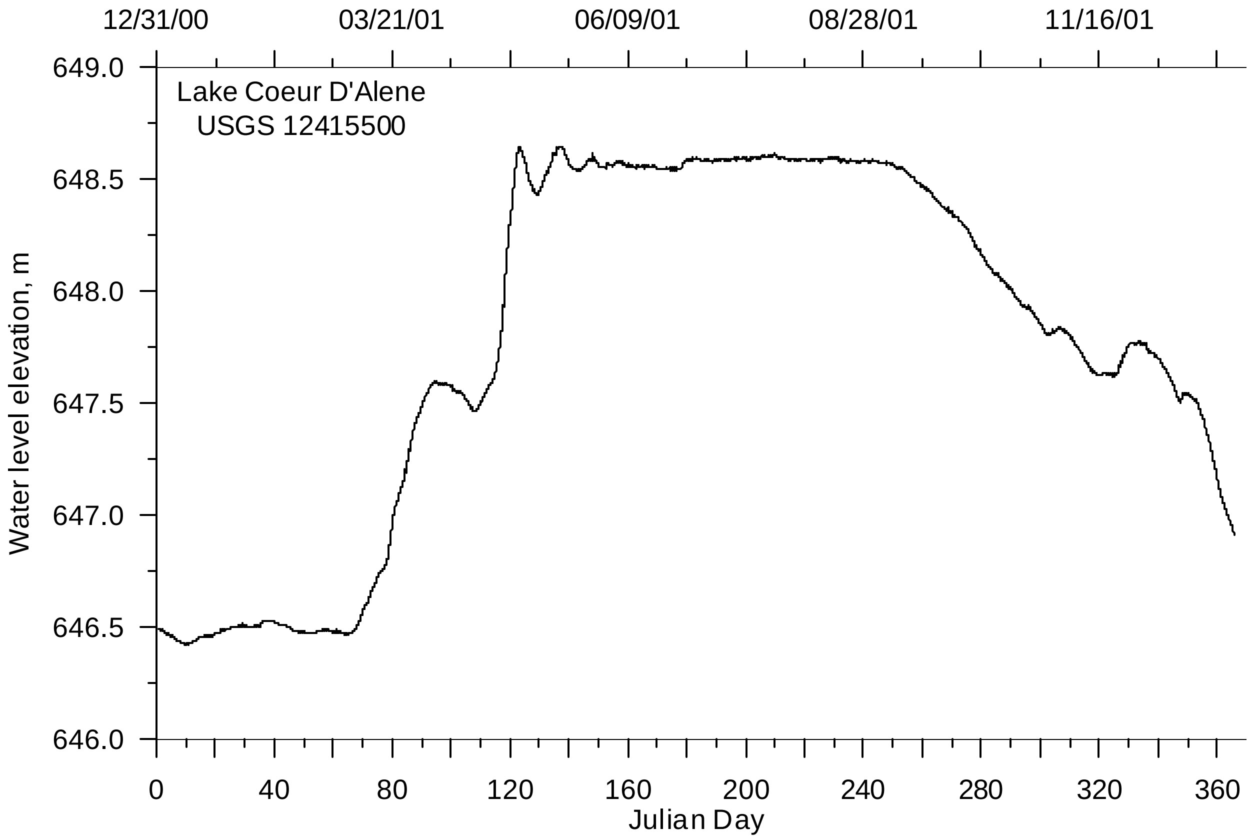


Figure 64: Coeur d'Alene Lake water surface elevations, 2001.

Year 2004

Figure 66 shows the turbine and spillway flows for 2004. The figure shows large spillway flows in the spring and late fall. Figure 66 shows the combined spillway and turbine flows in 2004 and the flow recorded at the USGS gage station (12419000) just downstream of the Post Falls Dam. The figure shows there are mostly minor differences between the dam operations flow records and the downstream gage station flow measurements. There were several periods in the spring when flow differences were larger and this may be due to inaccuracies turbine and spillway rating curves at higher flows. Similar to 2001, the USGS gage station flows were used in developing the upstream boundary condition and the flow downstream at Post Falls Dam.

Figure 67 shows the Lake Coeur d'Alene water surface elevation in 2004 from the USGS gage station near the City of Coeur d'Alene (12415500). The plot shows the water level remained relatively constant during the summer.

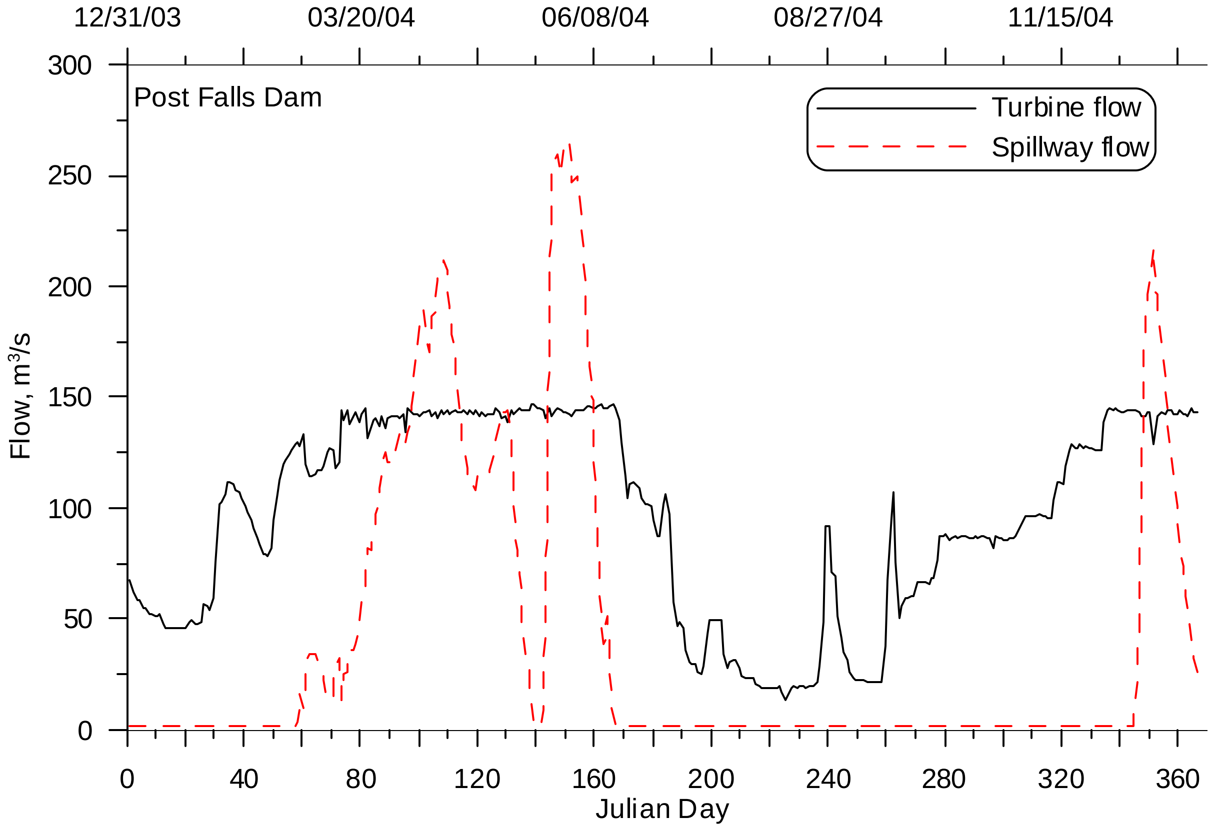


Figure 65: Post Falls Dam turbine and spillway flows, 2004.

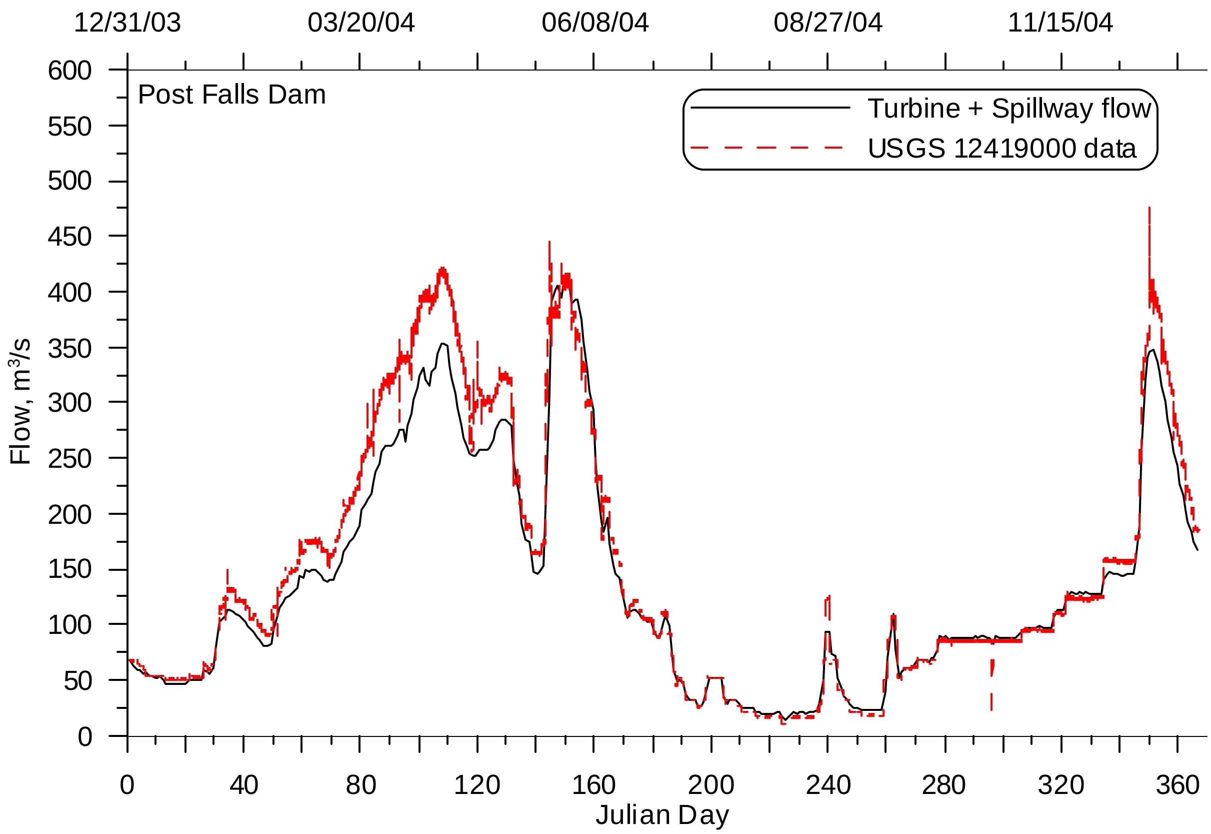


Figure 66: Post Falls Dam flows and downstream gage data, 2004.

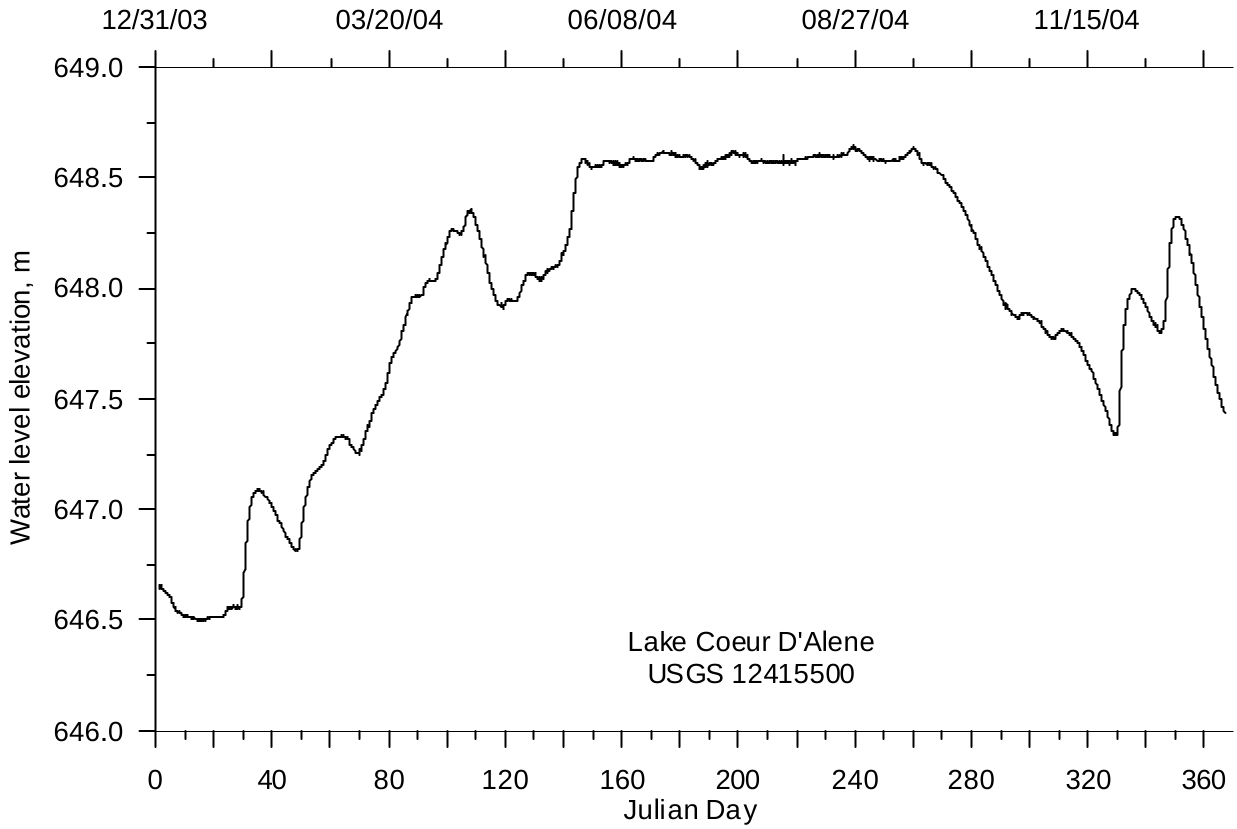


Figure 67: Coeur d'Alene Lake water surface elevations, 2004.

Groundwater

Year 2001

Figure 68 shows the distributed inflow between the U.S. Geological Survey (USGS) gage station (12419000) near Post Falls, ID (RM 101.5) and the ID-WA State Line in 2001. The change in flow occurring between Post Falls and the State Line was estimated by using flow data from a USGS gage station (12419500) at Harvard Road (RM 93.8) and near Post Falls, ID (12419000). Flow rates at Harvard Road were typically less than those at Post Falls gage due to losses to the aquifer. The difference in flow between Post Falls and Harvard Road gages was then used to estimate the flow at the state line, which is 4.7 miles downstream of Post Falls gage. The total distance between the Post Falls and Harvard Bridge gages is 7.7 miles, and the loss/gain to the aquifer occurring between Post Falls gage and the State Line was estimated by multiplying the difference in flow between Post Falls and Harvard Road gages by the fraction f of river miles between Post Falls gage and the State Line (f = 4.7 miles/7.7 miles). The gain/loss to the aquifer Q_{aquifer} (typically a loss) between Post Falls gage and the State Line was estimated from

$$Q_{\text{aquifer}} = \left(Q_{\text{Harvard}} - Q_{\text{PostFalls}}\right)\frac{4.7\text{ miles}}{7.7\text{ miles}}$$

This was the same method used to develop the upstream boundary condition for the Spokane River model for 1991, 2000 and 2001 (Annear et al, 2001; Slominski et al, 2002).

There were no losses to the aquifer for the model branch located between Lake Coeur d'Alene and Post Falls Dam (branch 1). Previous work (Limno-Tech, Inc., 2001b from Yearsley) used a constant outflow rate of –6.57 cms.

The river section between Post Falls Dam to the ID/WA State Line was a losing reach (predominantly outflow) in 2001, but temperature and water quality characteristics were developed for any possible inflow based on well data collected in the Sullivan Road area of the Upper Spokane River (Slominski et al., 2002). Figure 69 shows a time series plot of the groundwater temperature used for the distributed tributary. Figure 70, Figure 71, and Figure 72 show time series plots of the water quality characteristics used for the distributed tributary in the model.

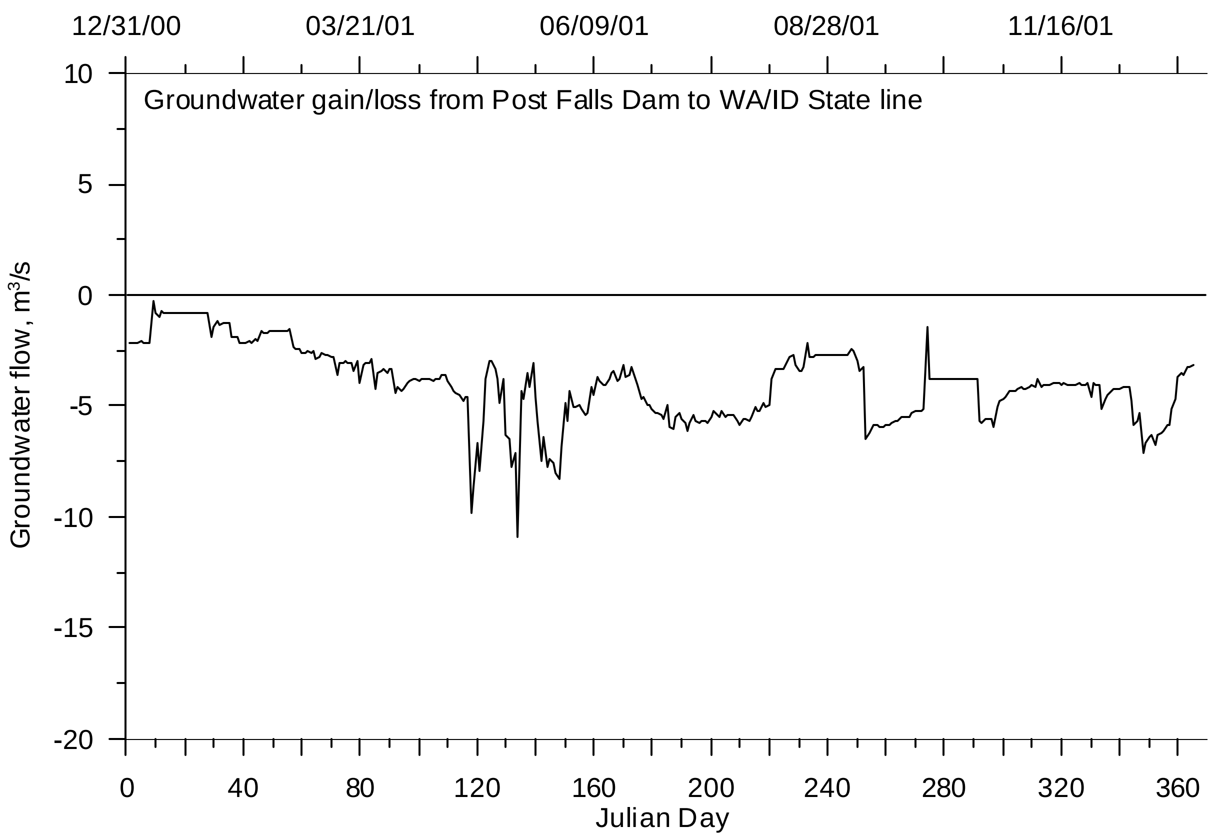


Figure 68: Spokane River distributed groundwater flow below Post Falls Dam, 2001.

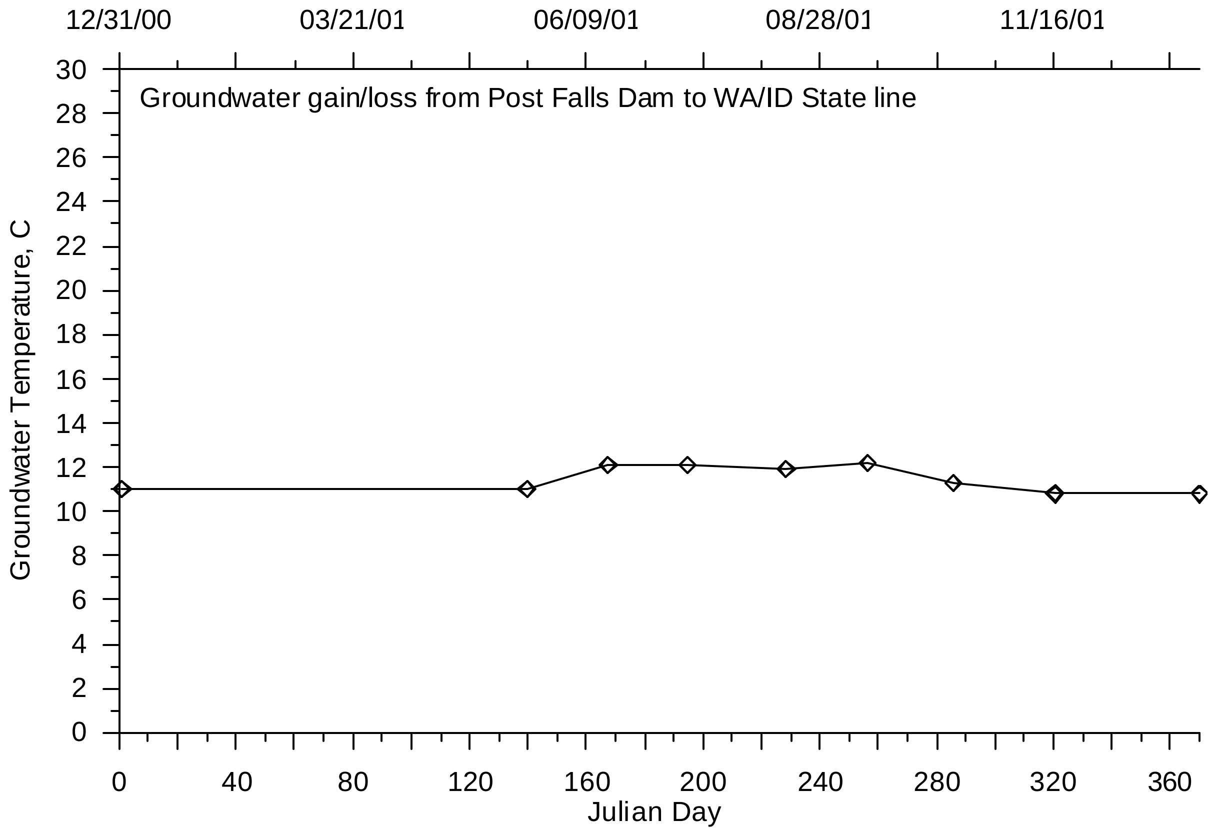


Figure 69: Spokane River distributed groundwater flow temperature below Post Falls Dam, 2001.

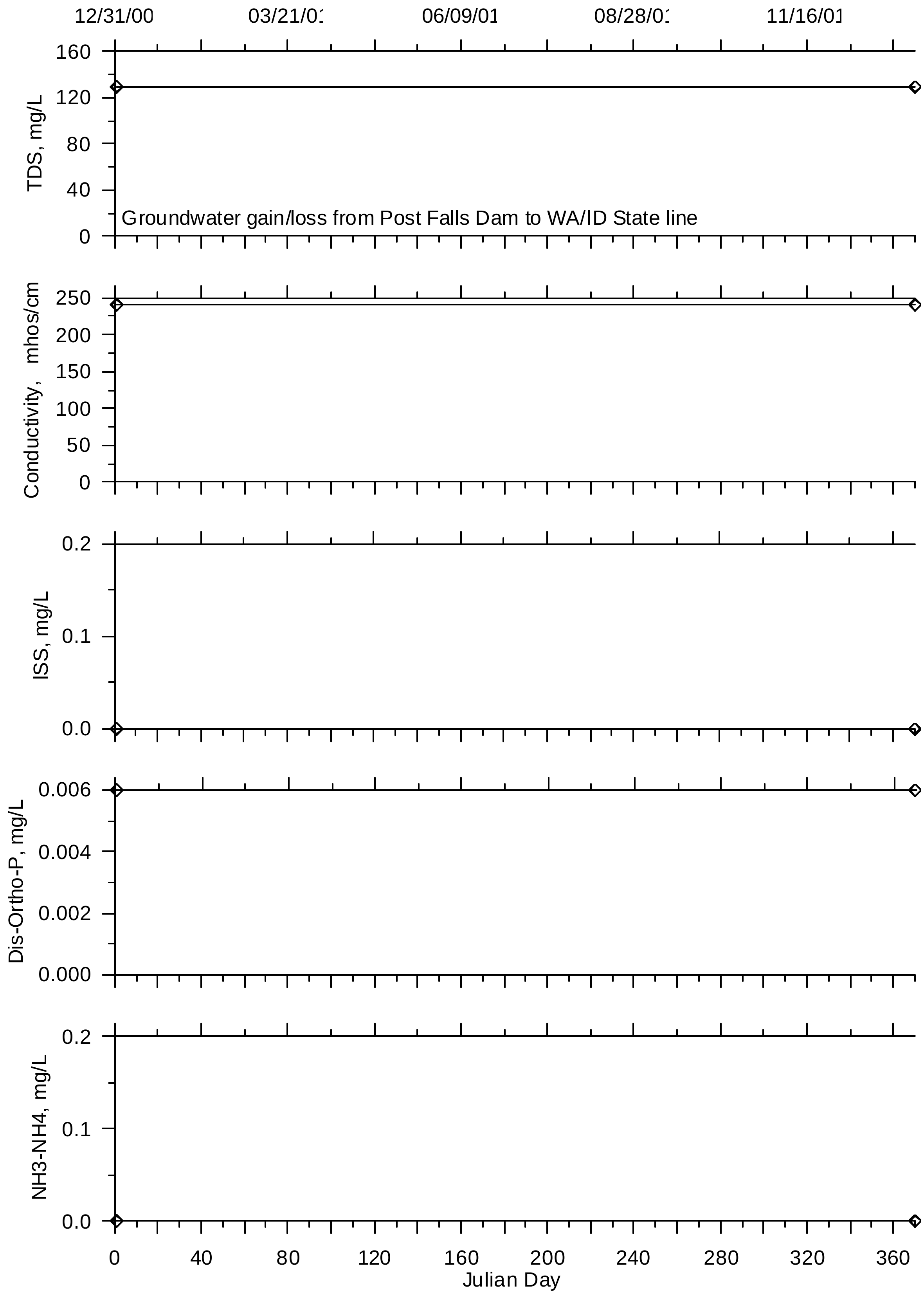


Figure 70: Spokane River distributed groundwater water quality conditions below Post Falls Dam, 2001 (Part 1).

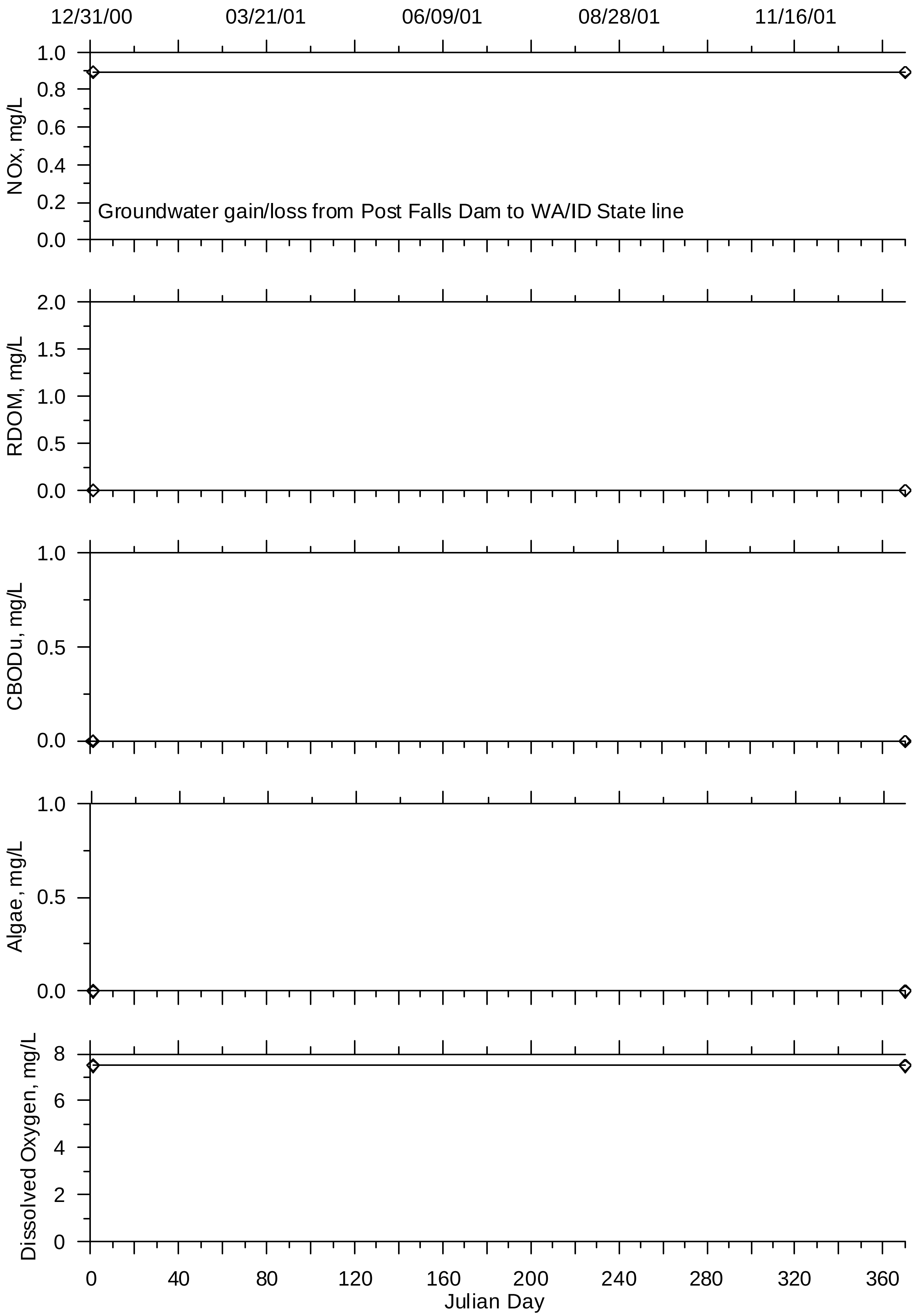


Figure 71: Spokane River distributed groundwater water quality conditions below Post Falls Dam, 2001 (Part 2).

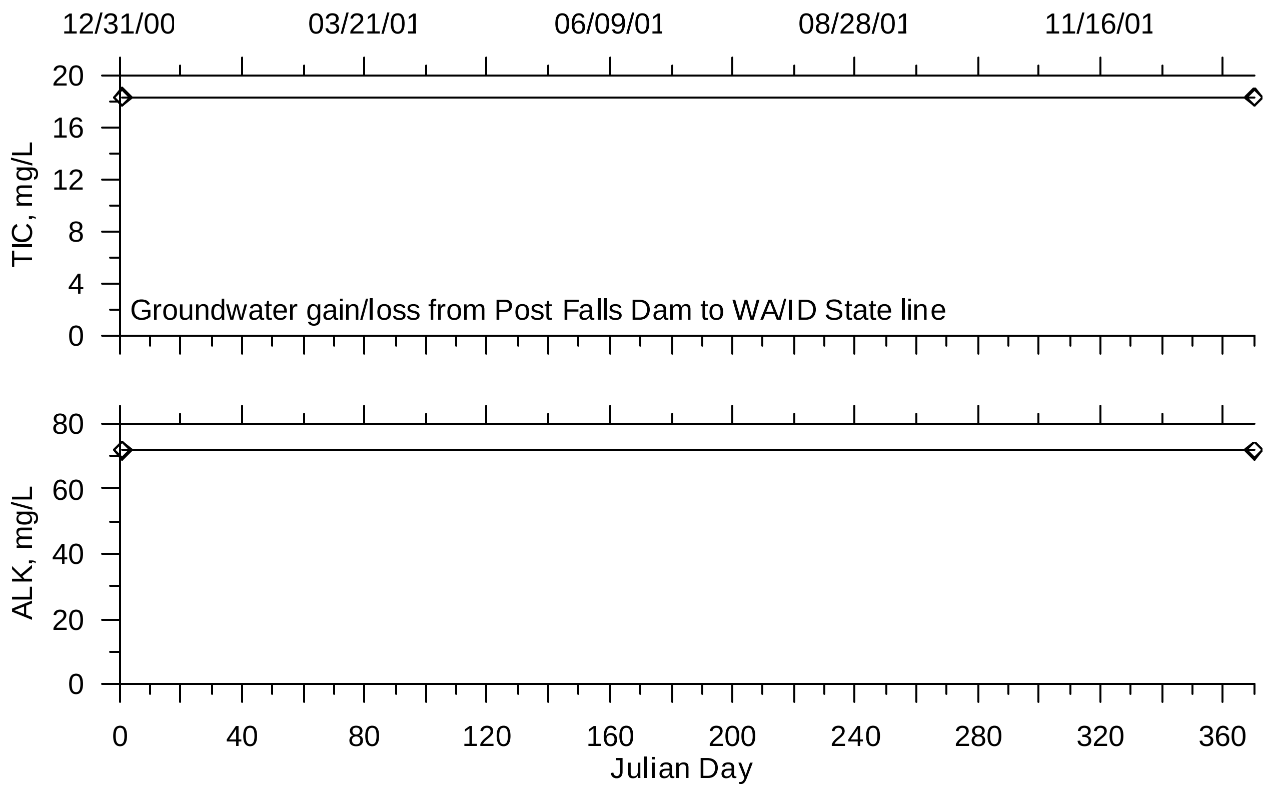


Figure 72: Spokane River distributed groundwater water quality conditions below Post Falls Dam, 2001 (Part 3).

Year 2004

The groundwater estimates for the Spokane River between the USGS gage near Post Falls, ID (12419000) and the ID/WA State Line in 2004 were calculated using the same method as for 2001. Figure 73 shows a time series plot of the daily average groundwater inflows and outflows. This figure shows there was primarily a groundwater loss in this section of the river with exception of two brief periods in late winter and early spring. Similar to the model developed in 2001, there were no losses to the aquifer for the model branch located between Lake Coeur d'Alene and Post Falls Dam (branch 1). Figure 74 shows a time series plot of the groundwater temperature used for the distributed tributary, which was held constant at 10^oC over the year based on data from 2001. The water quality characteristics used for the distributed tributary in the model in 2004 are the same as those used in the model for 2001.

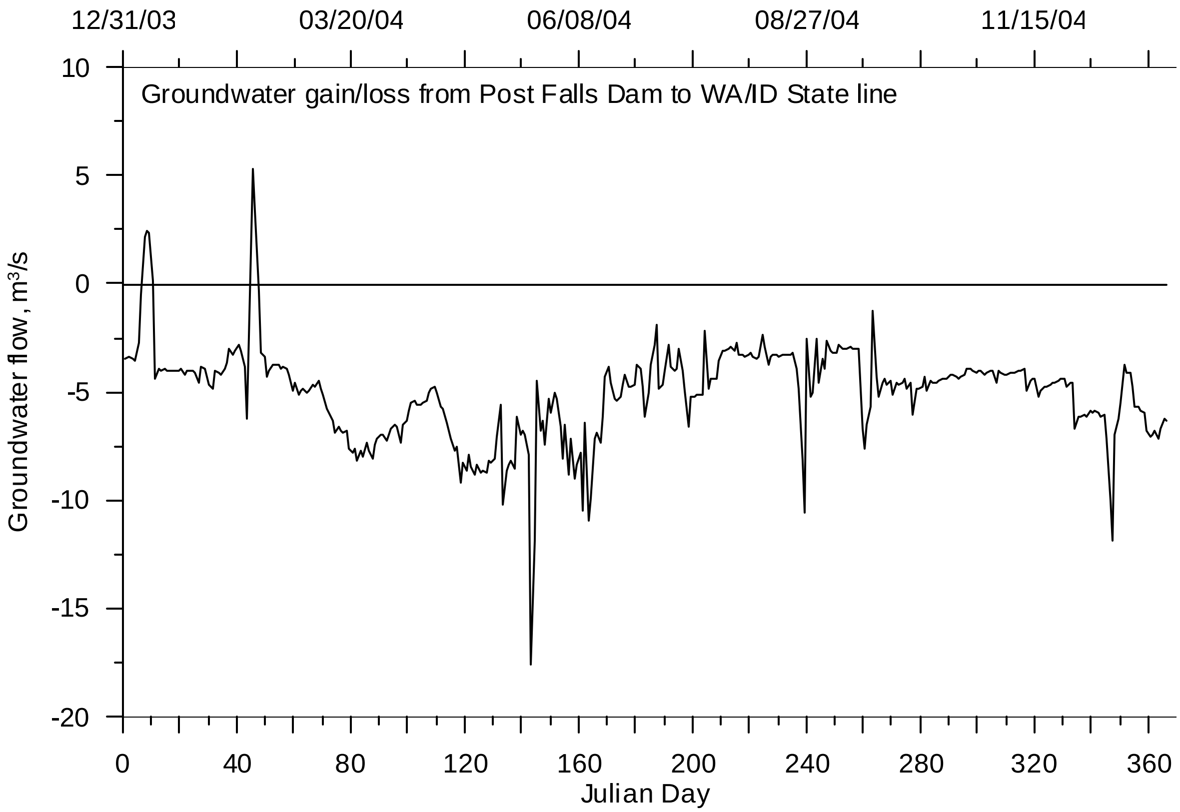


Figure 73: Spokane River distributed groundwater flow below Post Falls Dam, 2004.

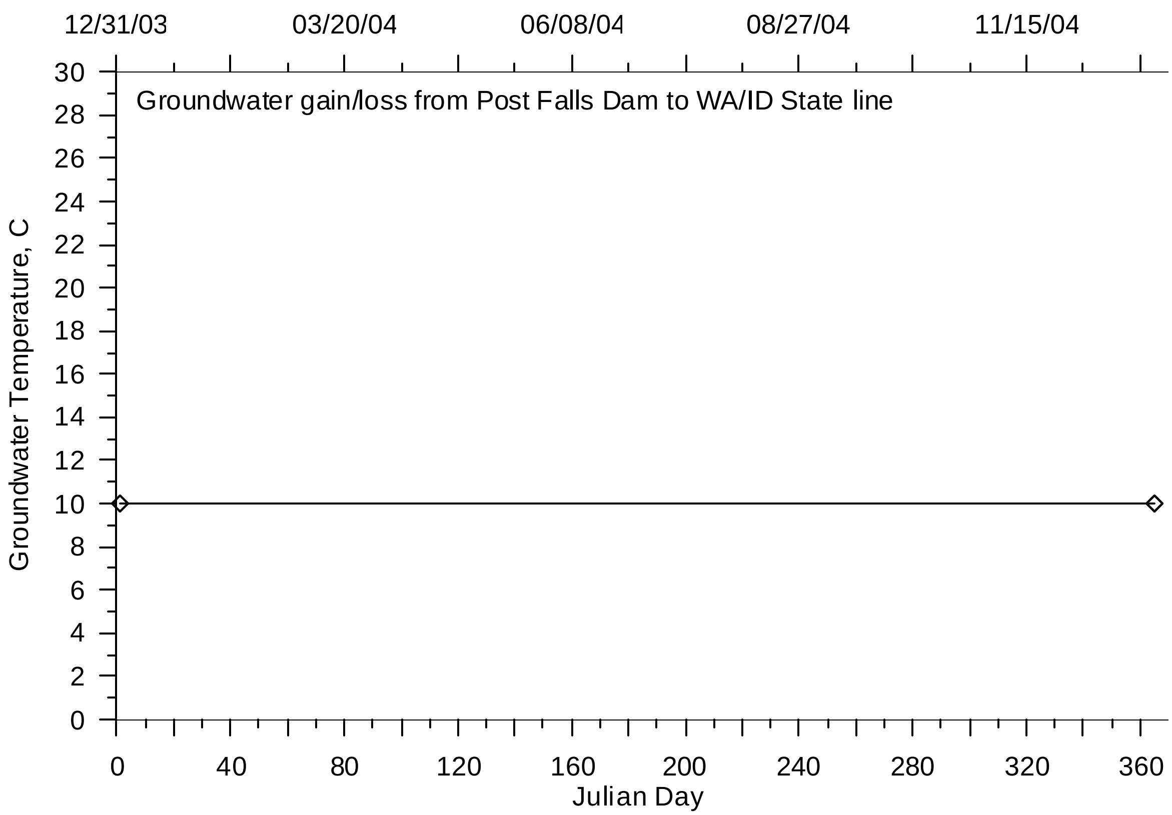


Figure 74: Spokane River distributed groundwater flow temperature below Post Falls Dam, 2004.

Meteorological Data

Meteorological data for the CE-QUAL-W2 model were taken from the Coeur d'Alene airport. Other sites were also available, such as the Spokane International Airport and the Spokane Felts Field (Figure 75). The model utilizes air and dew point temperature, wind speed and direction, and cloud cover or solar radiation. The airport sites did not have solar radiation data available. Solar radiation data from Odessa, WA were available.

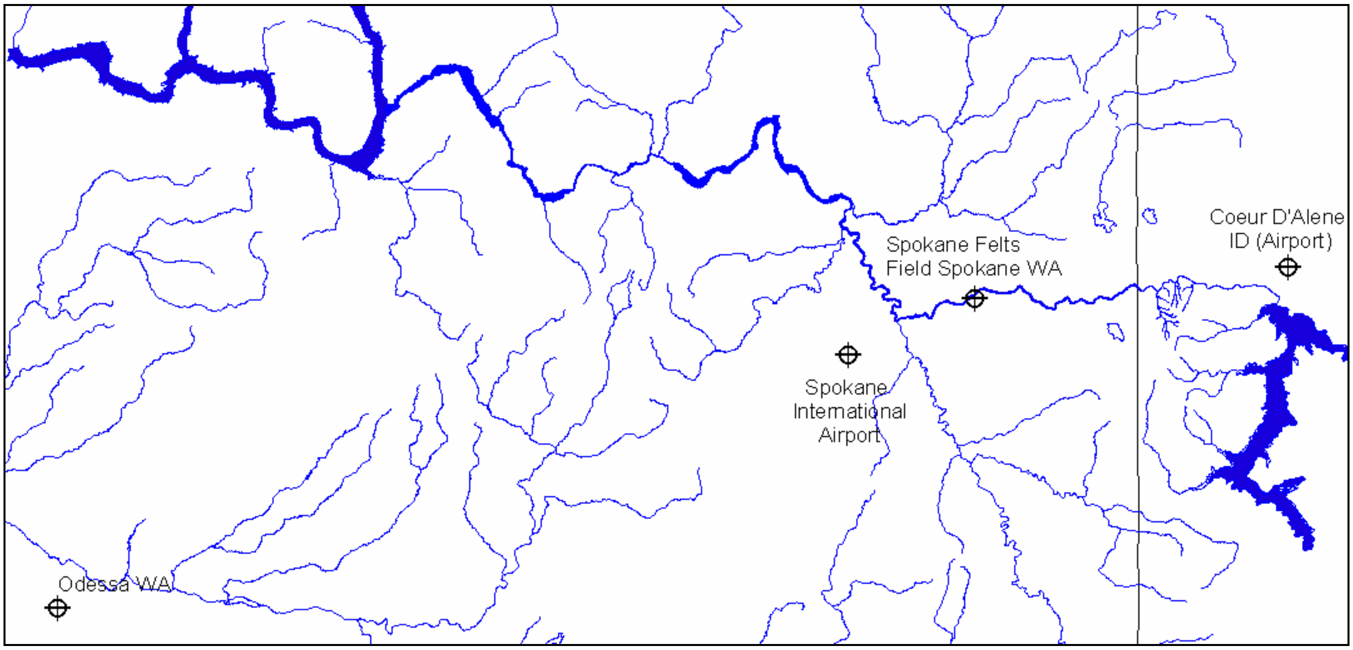


Figure 75: Meteorological stations near the Spokane River

Coeur d'Alene Airport

Year 2001

The meteorological station at the airport in the City of Coeur D'Alene, ID monitors air temperature, dew point temperature, wind speed and direction, cloud cover, visibility, and barometric pressure on an hourly basis.

The air temperature in 2001 had several data gaps, some only a few hours and others over a day in length. The short data gaps were filled using linear interpolation and the longer data gaps were filled using an air temperature correlation with the Spokane International Airport. Figure 76 shows an air temperature correlation between the two airports using hourly data from 2000 to 2005. The correlation equation was then used with the Spokane Airport air temperature data in 2001 to calculate air temperature at the Coeur d'Alene airport. Figure 77 shows the air temperature recorded at the airport. Data gaps that were filled in either by linear interpolation or the correlation with the Spokane airport are noted in the figure as red.

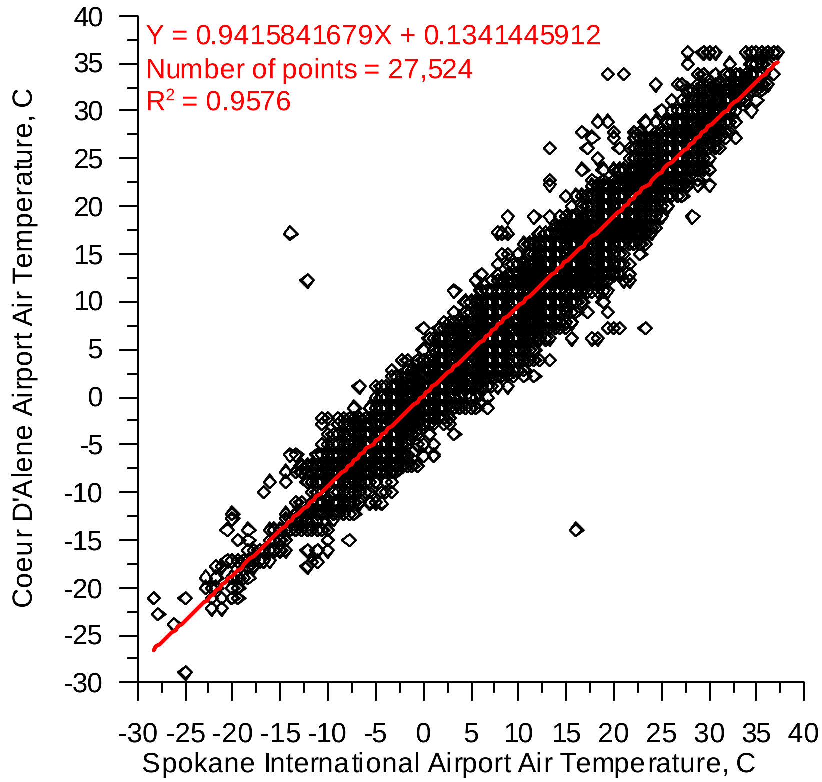


Figure 76: Air temperature correlation between Coeur d'Alene and Spokane airports

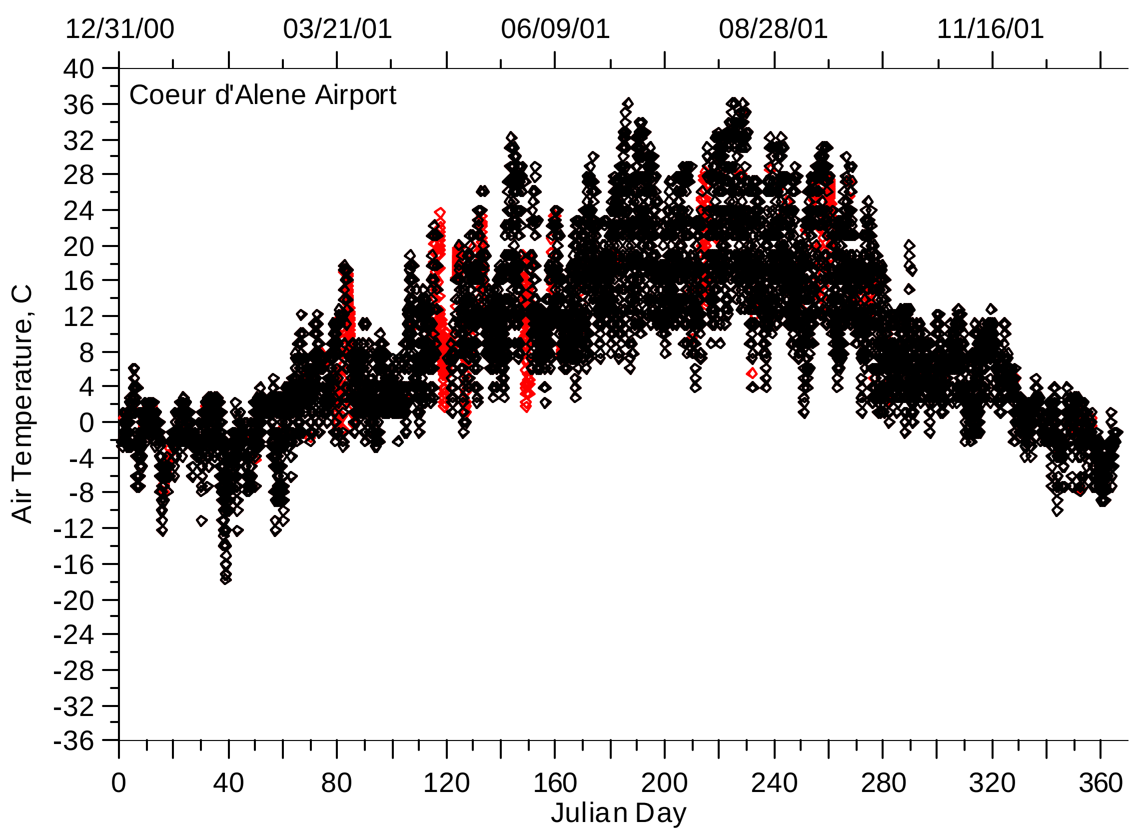


Figure 77: Air temperature at the Coeur d'Alene Airport, 2001. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

Similar to the air temperature the dew point temperature data in 2001 had data gaps which were small and several lasting longer than a day. The dew point temperature data were correlated to hourly data at the Spokane International Airport. Figure 78 shows the dew point temperature correlation between the two sites using data from 2000 to 2005 and provides the correlation equation. Brief data gaps in the Coeur d'Alene data were filled by linear interpolation and the larger gaps were filled using the correlation equation and the dew point temperature data from the Spokane airport. Figure 79 shows the dew point temperature in 2001 with muted diurnal fluctuations and a slight general increase into late summer. Data gaps which were filled in by interpolation or the correlation equation are noted in the figure in red.

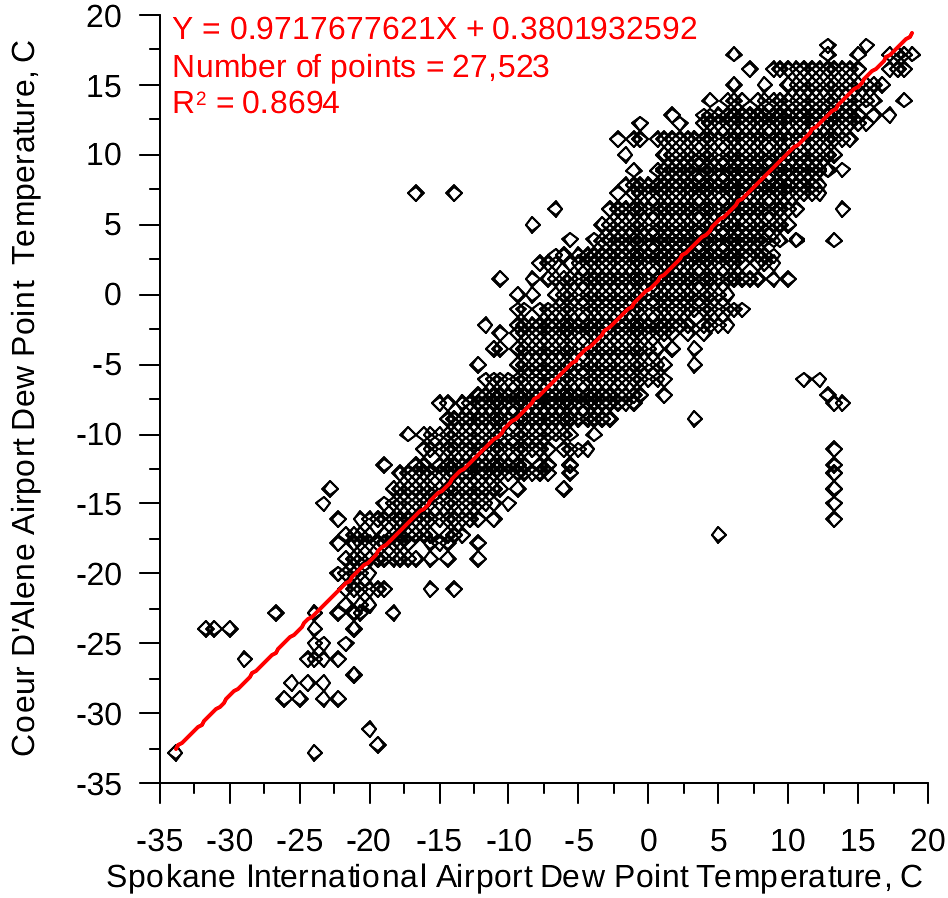


Figure 78: Dew point temperature correlation between Coeur d'Alene and Spokane airports

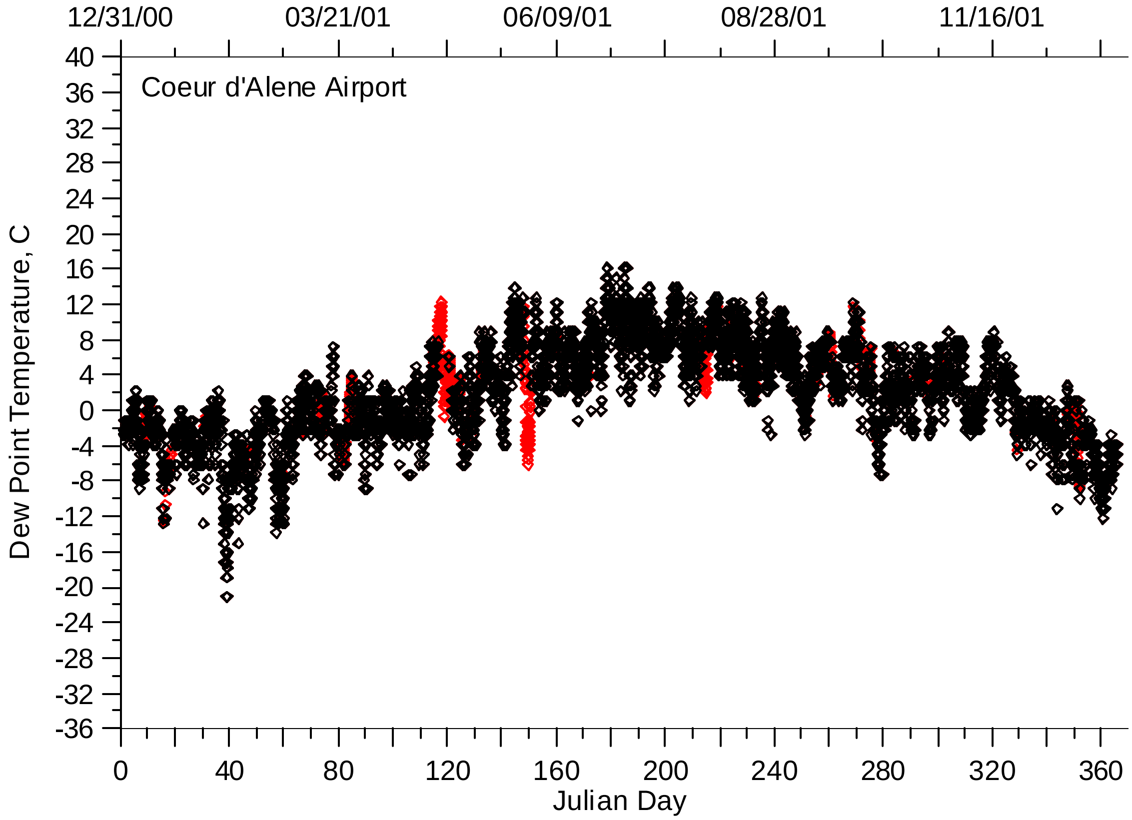


Figure 79: Dew point temperature at the Coeur d'Alene Airport, 2001. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

Both the wind speed and wind direction data contains data gaps which were either a few hours or more than one day in length. The shorter data gaps were filled by linear interpolation and the longer data gaps were filled by using wind speed data from the day(s) previous to the data gap. Data from the previous day was chosen to fill the longer data gaps since no reasonable correlation could be developed with the Spokane International Airport which had the most extensive data set. Figure 80 shows the wind speed data, which is highly variable and the figure shows the data gaps filled in with values noted in red. It should be noted that the measurement instrument was designed for high-speed wind measurements so any wind speed below approximately 1.5 m/s were set to zero.

Figure 81 plots the wind direction data in a rose diagram and indicates the predominant wind direction was from the north (0.0 to 5 degrees). This bias is mostly likely caused by the high-speed wind instrument measuring the wind direction at zero when the wind speed was measured below the threshold of 1.5 m/s. Ignoring this aspect of the rose diagram shows the predominant wind directions were from the Northeast and from the Southwest, which is similar to the wind directions measured at Spokane Felts Field airport and the International Airport.

Figure 82 shows the cloud cover data measured at the Coeur d'Alene airport. The cloud cover data recorded by the National Weather Service (NWS) were switched to a 1 to 8 scale after 1996. In order to compare data from years prior to 1996 and for use in the model, the cloud cover information for 2001 was converted to a scale of 0 to 10. Data gaps in the cloud cover data were filled by using linear interpolation which resulted in cloud cover values between the standard data collection values.

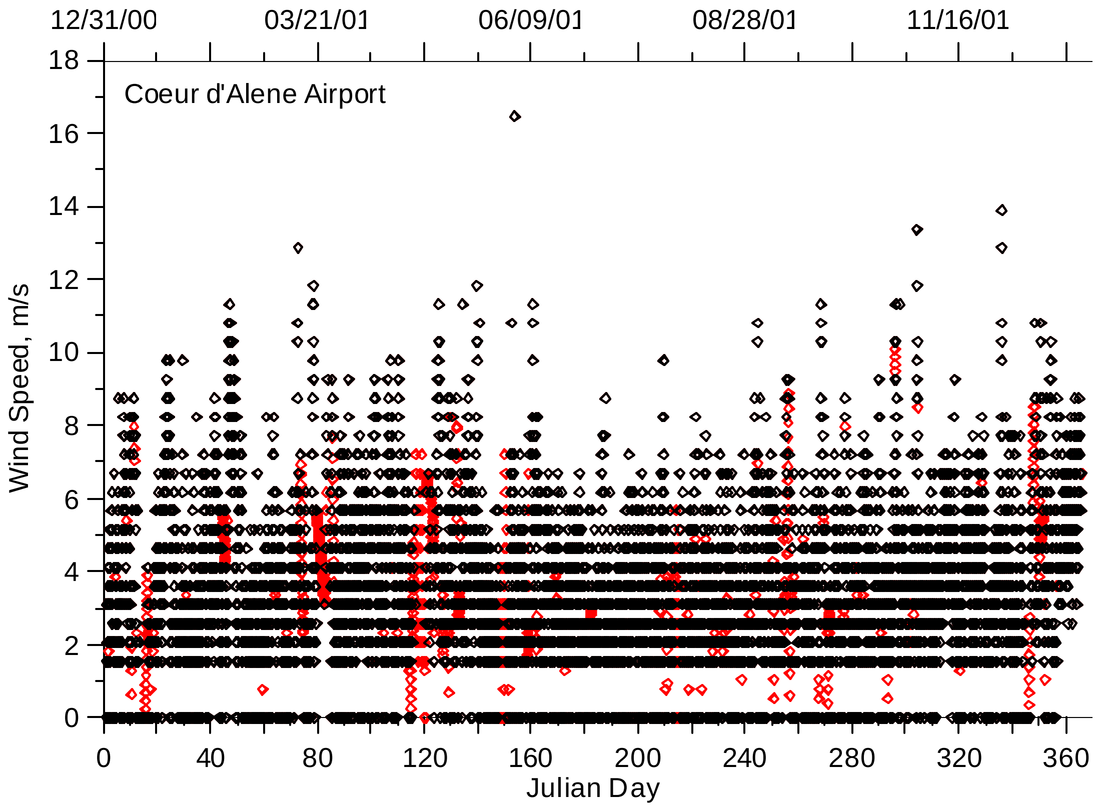


Figure 80: Wind speed at the Coeur d'Alene Airport, 2001. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

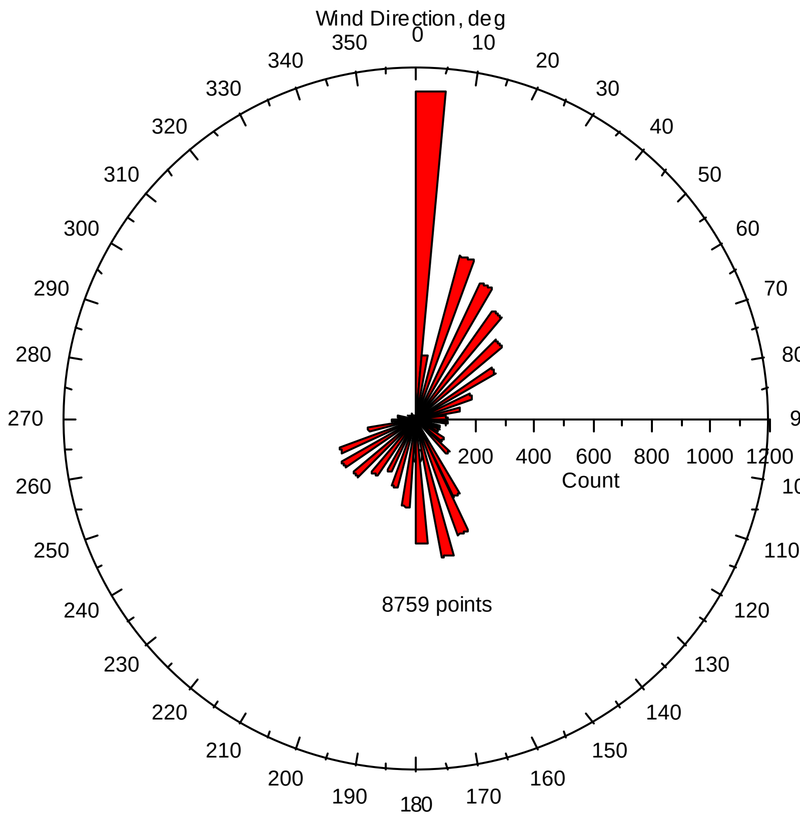


Figure 81: Wind direction, degrees from North, at the Coeur d'Alene Airport, 2001.

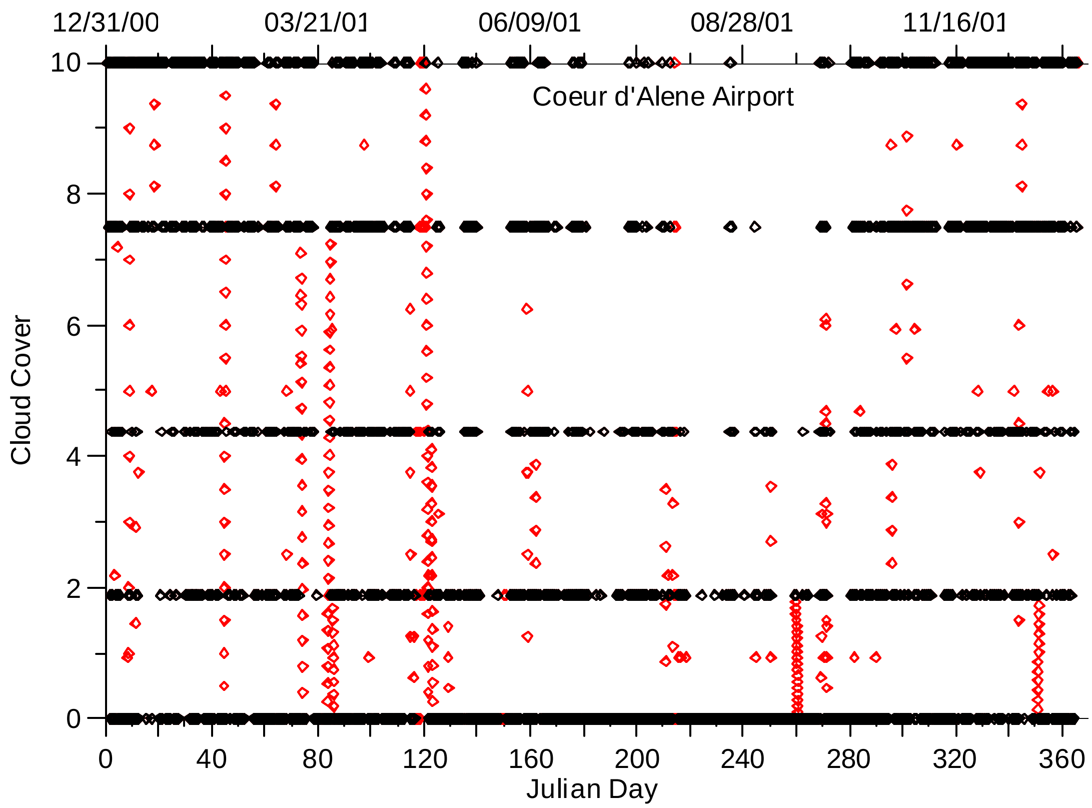


Figure 82: Cloud Cover, x10, at the Coeur d'Alene Airport, 2001. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

Year 2004

For the 2004 model development the meteorological station at the airport in the City of Coeur D'Alene was used again.

The air temperature data in 2004 had several gaps, which were filled by linear interpolation for short time periods and by the air temperature correlation equation presented in Figure 76 for longer time periods. Figure 83 shows a time series plot of the air temperature at the airport in 2004. Information used to fill in the data gaps was shown in red. The same procedure was used for the dew point temperature data in 2004. Small data gaps were filled by linear interpolation and larger data gaps were filled using the dew point temperature data from the Spokane International airport and the correlation equation presented in Figure 78. Figure 84 shows a time series of the dew point temperature in 2004.

The wind speed and direction data in 2004 also contained data gaps. The same procedures used to fill the data gaps in 2001 were used with the 2004 data. Figure 85 shows the wind speed data, which is highly, and indicates where the data gaps were filled with points in red. It should be noted that the measurement instrument was designed for high-speed wind measurements so any wind speed below approximately 1.5 m/s were set to zero.

Figure 86 plots the wind direction data in a rose diagram and indicates the predominant wind direction was from the north (0.0 to 5 degrees). This bias, also in the 2001 data, is mostly likely because the high-speed wind instrument measures the wind direction at zero when the wind speed is measured below the threshold of 1.5 m/s. Ignoring this aspect of the rose diagram shows the predominant wind directions are the same as in 2001 with winds from the Northeast and the Southwest.

Figure 87 shows the cloud cover data measured at the Coeur d'Alene airport in 2004. Similar to the data in 2001 the data gaps were filled by using linear interpolation which resulted in cloud cover values between the standard data collection values.

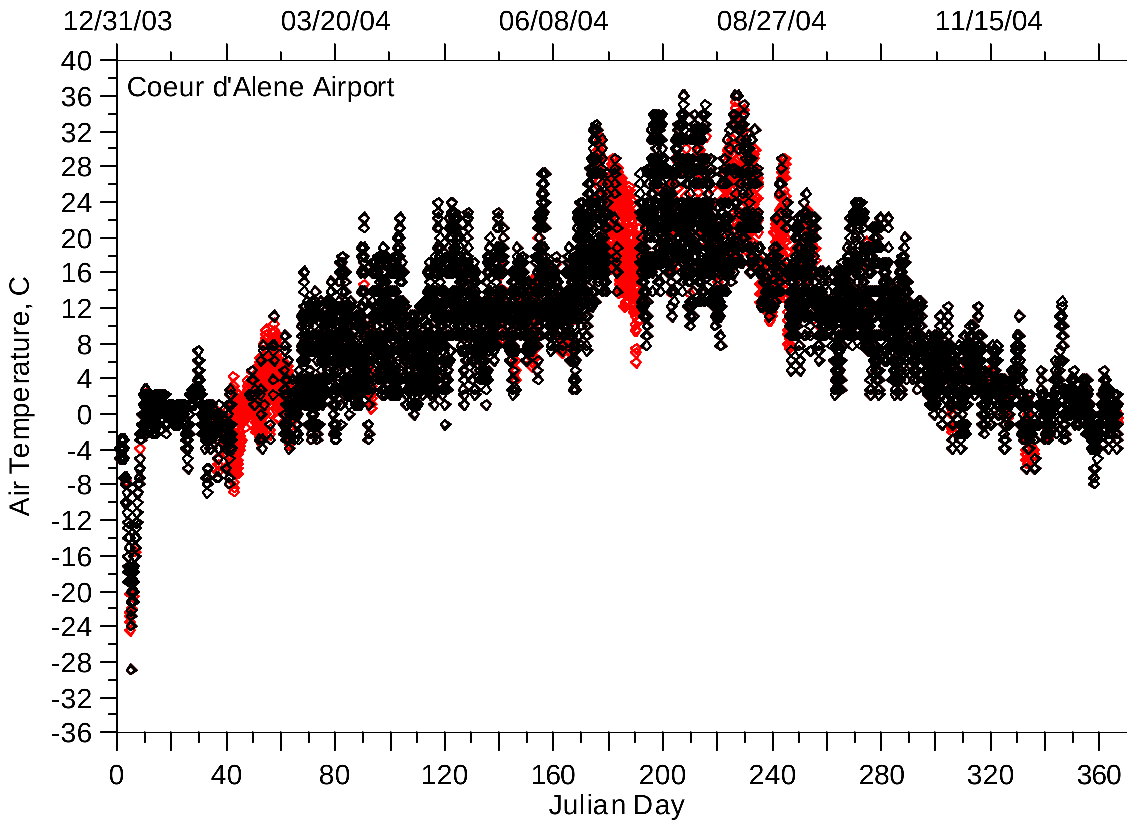


Figure 83: Air temperature at the Coeur d'Alene Airport, 2004. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

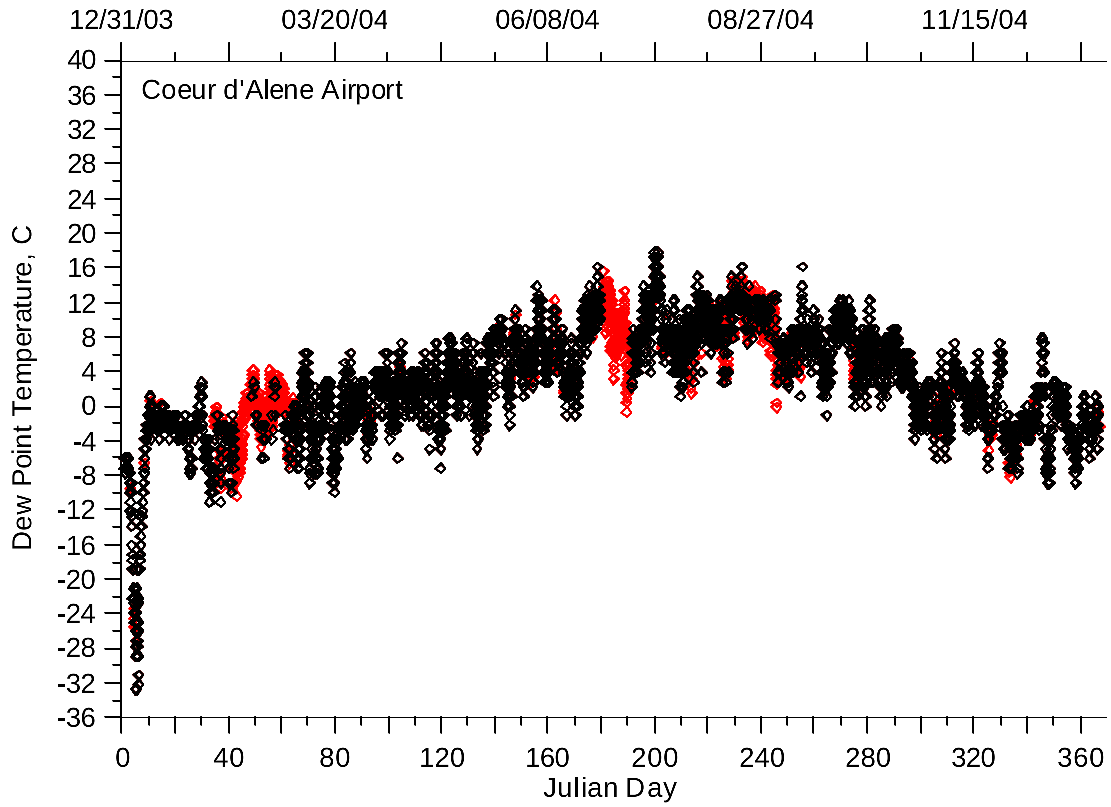


Figure 84: Dew point temperature at the Coeur d'Alene Airport, 2004. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

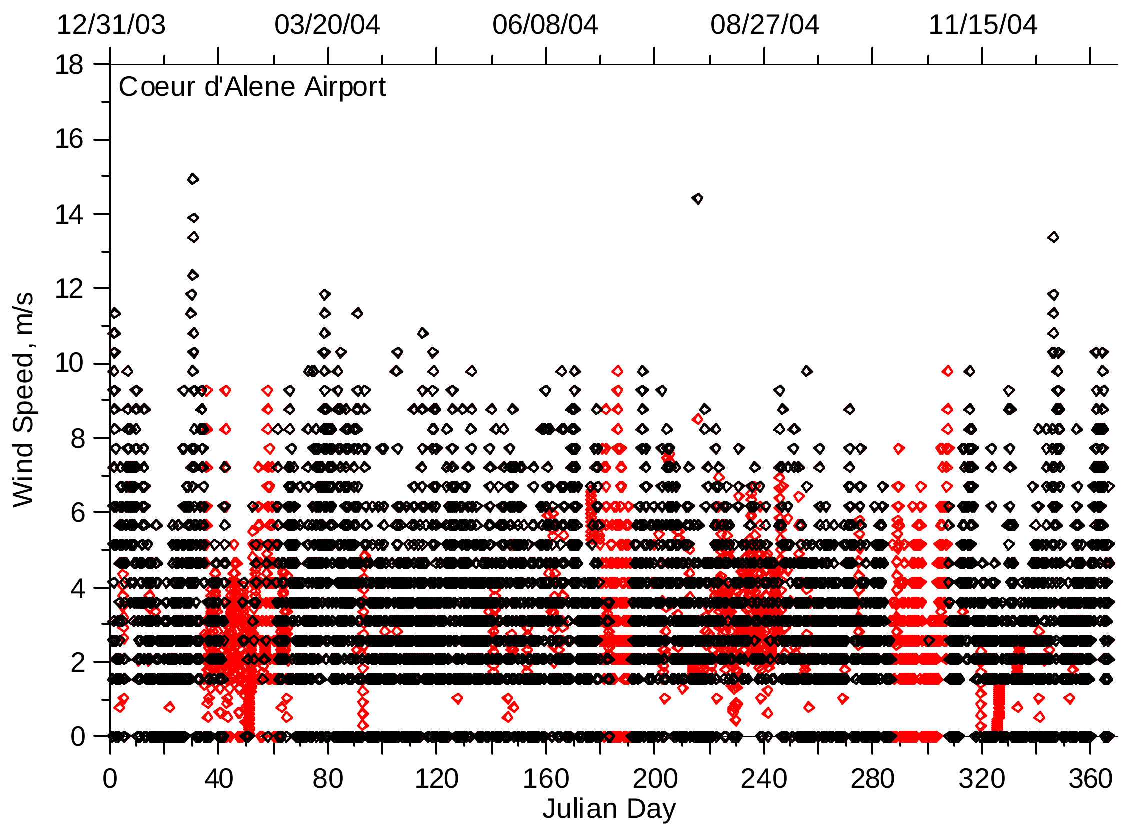


Figure 85: Wind speed at the Coeur d'Alene Airport, 2004. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

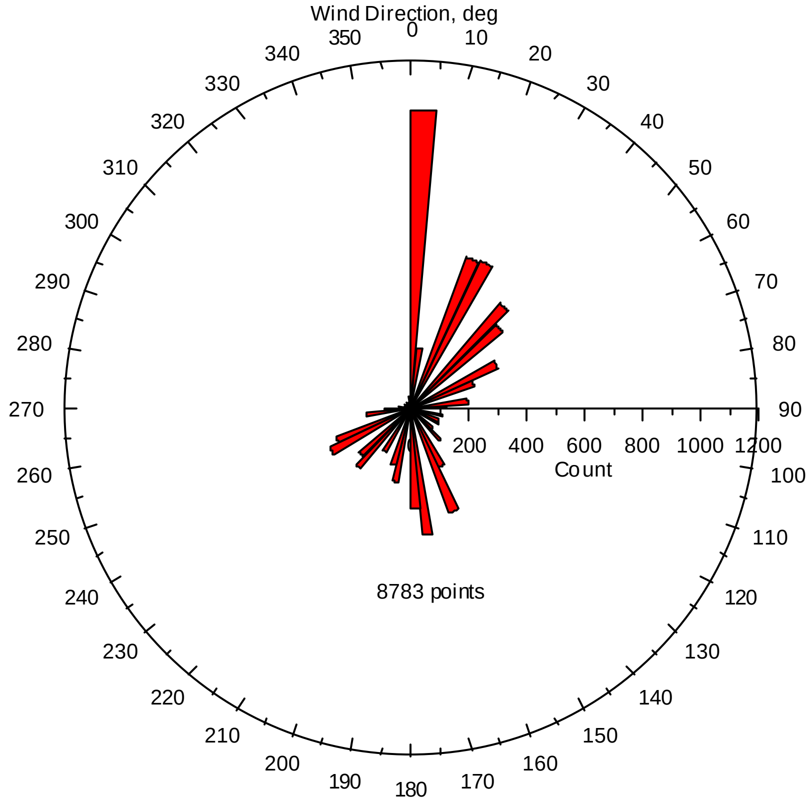


Figure 86: Wind direction, degrees from North, at the Coeur d'Alene Airport, 2004.

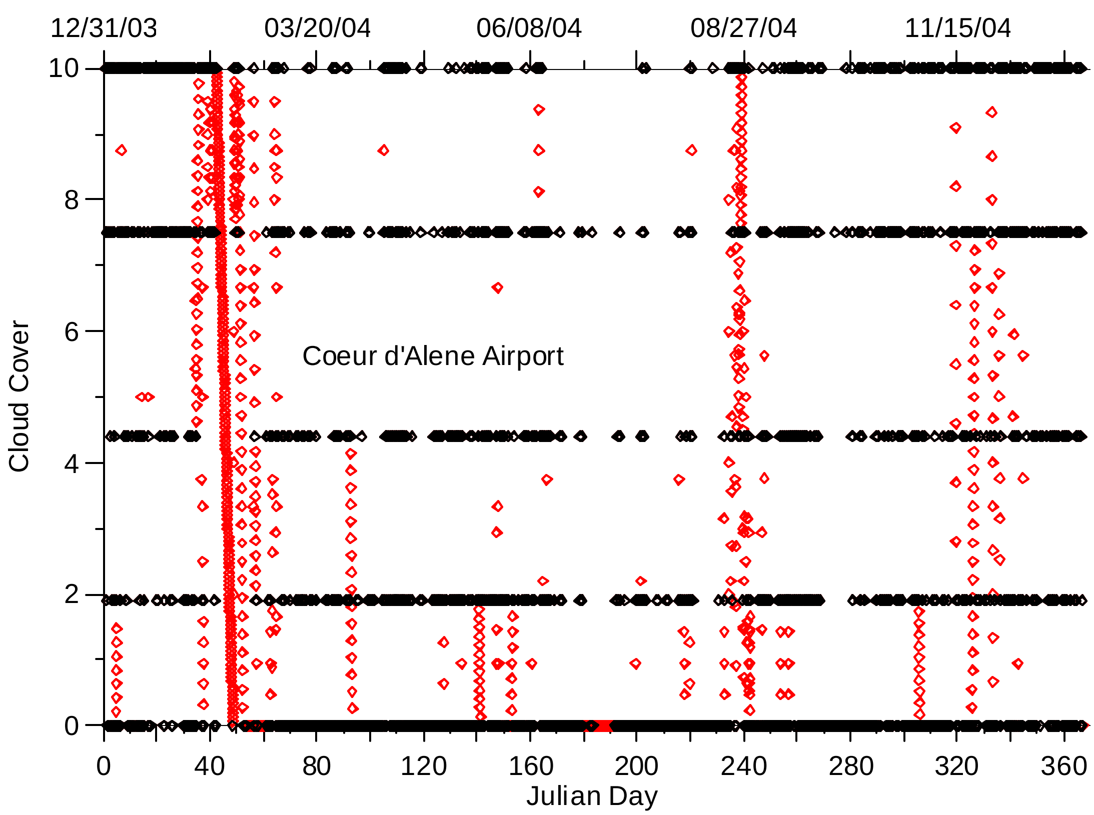


Figure 87: Cloud Cover, x10, at the Coeur d'Alene Airport, 2004. Data gaps which were filled in by interpolation or the correlation equation were shown in red.

Odessa, WA

The meteorological site in Odessa, WA (see Figure 75) collected solar radiation data. Although this site was 94 miles from the river section in Idaho the solar data provided a record of solar radiation in the area. The solar radiation data collected at Odessa in 2001 is shown in Figure 88. The solar radiation data collected in 2004 at Odessa is shown in Figure 89. The solar data in 2004 shows several small data gaps which were filled by linear interpolation or by using data from the previous day for longer gaps in the data.

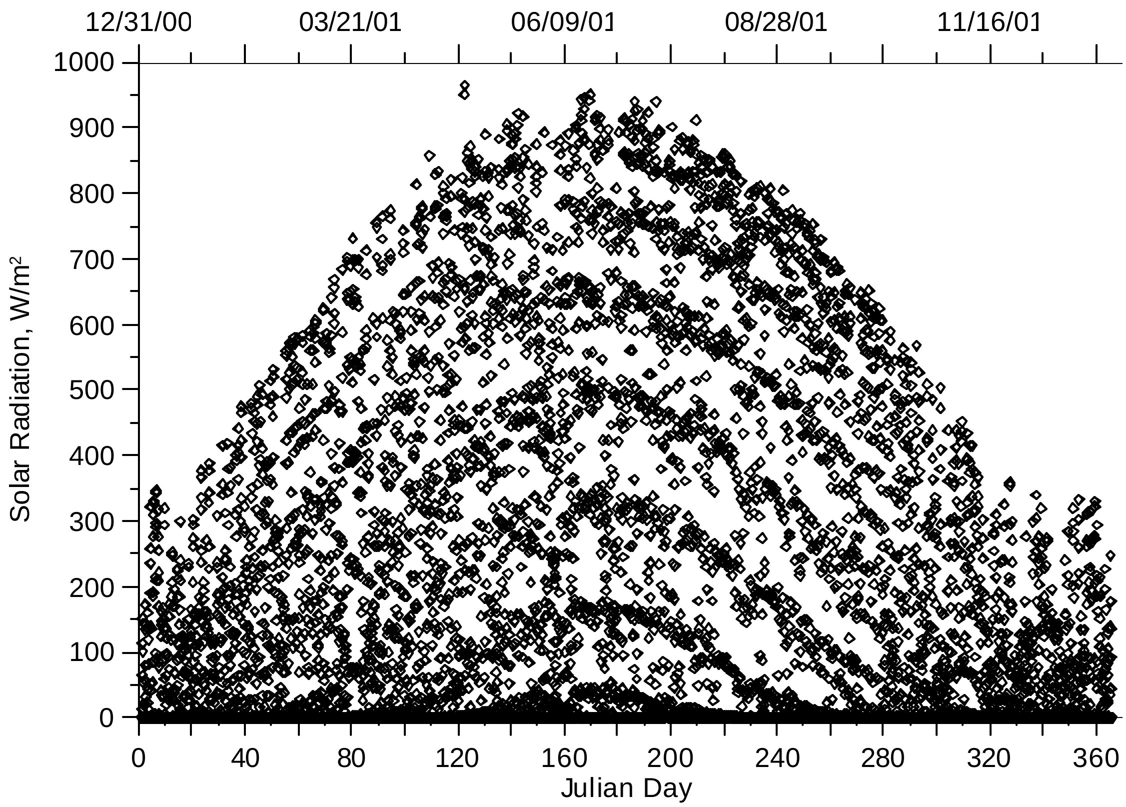


Figure 88: Solar radiation at Odessa, WA, 2001.

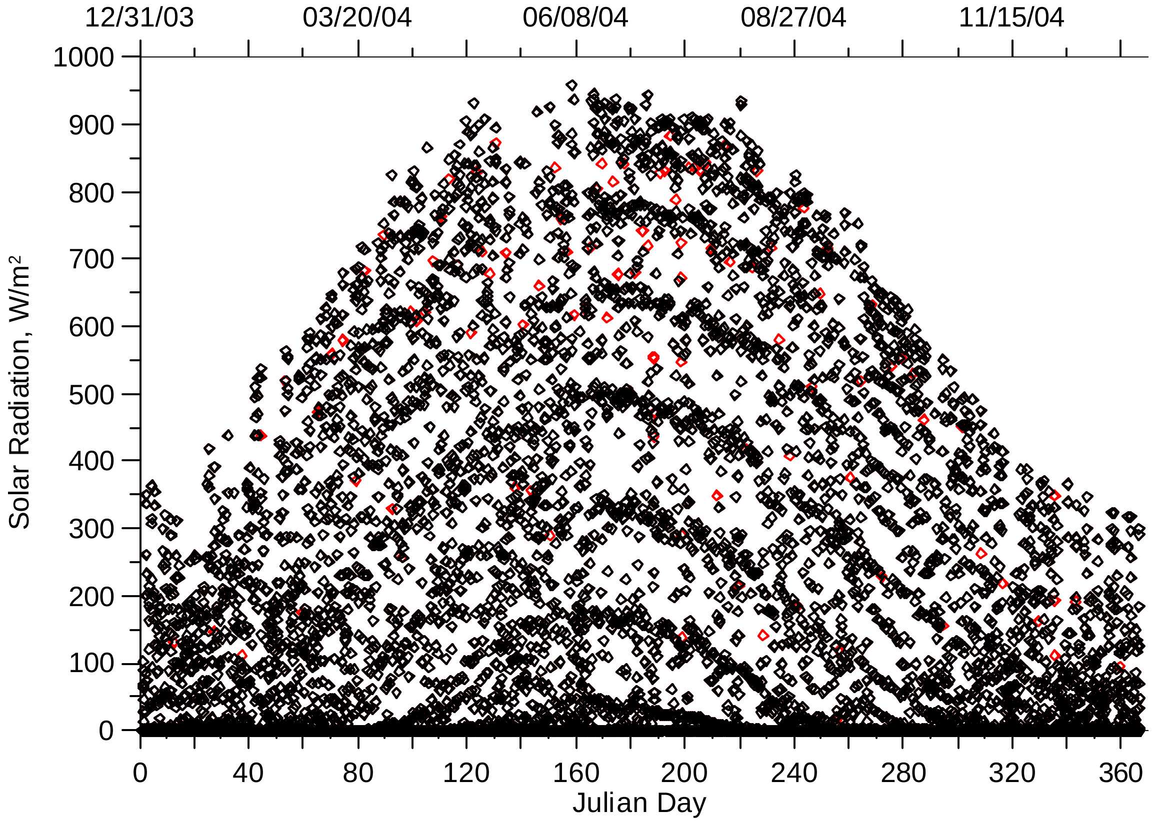


Figure 89: Solar radiation at Odessa, WA, 2004.

Topographic Shade Data

Topographic shade data were developed for the Spokane River between Post Falls Dam and the WA/ID State Line. The GIS database for the Spokane River included the topography around the Spokane River model area and the model segment center point coordinates were determined in the grid development.

The first step in the analysis was determining how far away from the river the topography would be analyzed. Using a shaded relief of the topography in GIS the distance away from the river to analyze was approximately 800 m.

The next step was to calculate the end points of 18 arrays surrounding each model segment (every 20 degrees). The topography data were then used to create a grid data set in SURFER, a contour plotting program. The array endpoints were then used to "slice" the grid in SURFER to create a series of points, with associated elevations, for each of the 18 arrays around each model segment. Figure 90 shows a plot of the arrays for model segments 30 and 62. The elevation points along each array were used to calculate the highest slope between each point and the model segment center point. The arc tangent of the highest slope was then calculated for each array. The inclination angles for each array with then put in a shade input file for the CE-QUAL-W2 model. The shade file did not include vegetative shade.

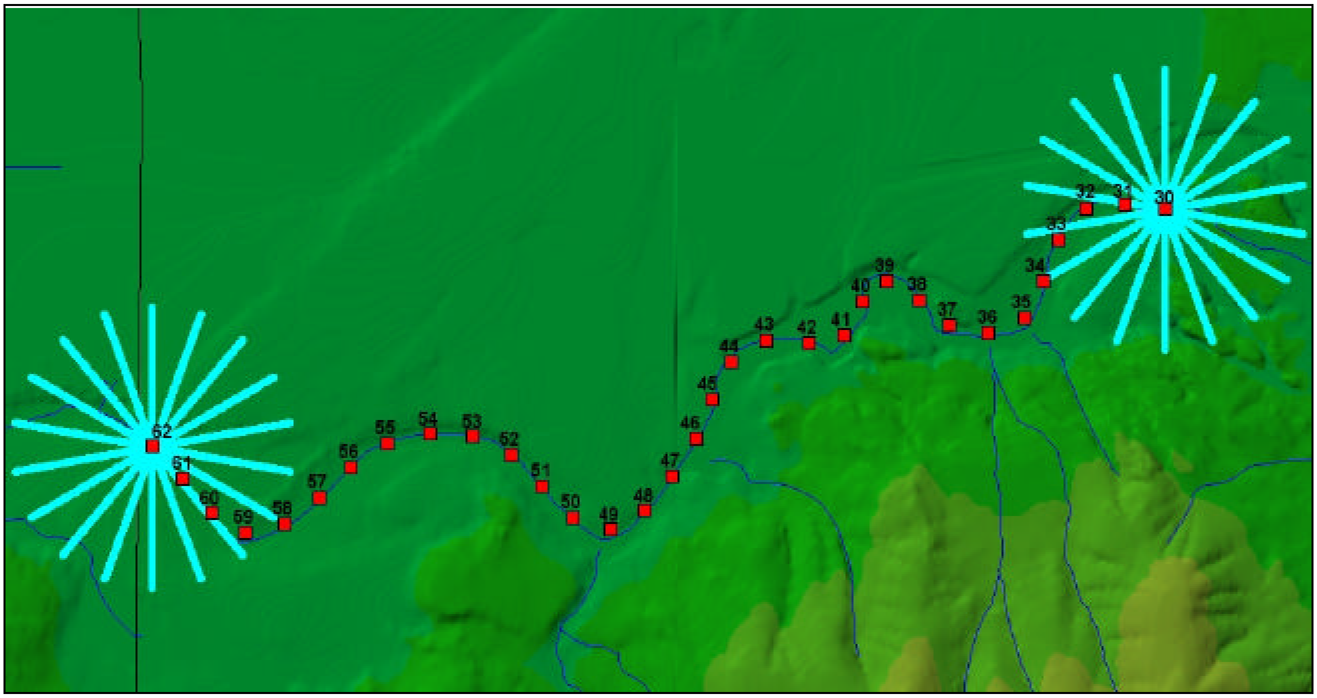


Figure 90: Inclination angle arrays for model segments 30 and 62

Periphyton Data

Year 2001

A periphyton algorithm was developed for the CE-QUAL-W2 model to evaluate their contribution to nutrient and dissolved oxygen dynamics in the Spokane River. Samples were collected at 8 sites on the Spokane River in WA as listed in Table 12 in August and September 2001. Table 13 and Table 14 show the mean biomass and chlorophyll data from August 2001 for each site based on several samples collected. Table 15 and Table 16 show the mean biomass and chlorophyll data from September 2001 for each site based on several samples collected. Table 17 and Table 18 show the mean biomass and chlorophyll data for each site based on new growth over 28 days from incubated substrates at each site. Table 13 and Table 15 show that the periphyton samples were highly variable depending on depth and location.

Table 12: Periphyton Data Sites

Site Code	Description	River Mile
SL	Stateline Bridge	96.0
BSB	Barker Road Bridge	90.4
TI	Trent Road Bridge	85.3
BGS	Green St. Bridge	78.0
CPS	Clark Pump Station	72.7
ASP	Above Spokane WWTP	67.6
BGC	Below Gun Club	64.6
BNM	Below Nine Mile Dam	58.1

Table 13: August 2001 Site Mean Biomass from Natural Substrates					
RM	Depth (m)	ODW (g/m2)	AFODW (g/m2)	Autotrophic Index (Mono Chl a)	Autotrophic Index (Tri Chl a)
96.0	1.17	120.24	8.49	244.51	222.74
90.4	1.47	13.15	3.33	358.46	334.78
85.3	1.21	20.75	4.93	418.41	386.32
78.0	0.69	129.19	22.95	283.53	259.21
72.7	0.71	24.37	8.86	215.76	202.55
67.6	0.93	41.94	9.33	276.97	263.53
64.6	0.65	39.43	15.42	196.19	190.08
58.1	0.79	279.24	11.63	162.86	153.99

Table 14: August 2001 Site Mean Chlorophyll from Natural Substrates									
RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	24.2	140	1.1	0.0	36.6	4.3	40.4	3.1	1.6
90.4	22.5	175	1.3	0.0	10.8	0.8	11.6	1.3	0.3
85.3	12.5	280	1.2	0.1	14.4	0.8	15.4	0.9	1.0
78.0	14.3	271	0.7	0.4	26.8	2.3	28.9	4.5	1.4
72.7	15.7	270	0.7	0.3	44.0	3.0	47.0	5.2	4.9
67.6	15.2	210	0.9	0.4	43.4	2.0	45.9	4.7	1.8
64.6	16.0	329	0.6	0.3	77.9	-0.1	80.6	1.6	4.9
58.1	18.1	326	0.8	0.0	80.0	4.8	85.7	2.1	5.5

Table 15: September 2001 Sites Mean Biomass from Natural Substrates					
RM	Depth (m)	ODW (g/m2)	AFODW (g/m2)	Autotrophic Index (Mono Chl a)	Autotrophic Index (Tri Chl a)
96.0	1.39	172.10	9.46	236.79	211.01
90.4	1.78	21.61	5.08	413.41	382.36
85.3	0.97	36.75	5.01	436.66	404.29
78.0	0.78	67.81	8.59	312.56	288.26
72.7	0.62	75.91	8.15	347.10	303.12
67.6	0.79	26.88	8.80	320.92	292.22
64.6	0.72	47.65	19.89	192.81	185.45
58.1	0.68	557.08	12.21	306.63	278.79

Table 16: September 2001 Site Mean Chlorophyll from Natural Substrates									
RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	20.5	135	1.5	0.0	44.2	7.4	50.0	5.4	1.9
90.4	17.5	90	1.8	0.0	11.6	1.0	12.6	1.7	0.6
85.3	10.7	240	1.0	0.1	12.6	1.2	13.6	1.8	0.6
78.0	11.5	230	0.8	0.5	30.3	2.3	32.4	5.3	1.0
72.7	13.4	250	0.6	0.2	27.9	5.4	32.0	3.7	2.0
67.6	14.0	220	0.8	0.3	29.4	2.9	32.0	3.0	1.8
64.6	13.9	240	0.7	0.1	103.3	1.7	107.7	6.4	4.4
58.1	15.1	268	0.7	0.1	43.9	3.3	47.3	3.1	2.6

Table 17: September 2001 Sites Mean Biomass, New Growth Over 28 days on Incubated Substrates					
RM	Depth (m)	ODW (g/m2)	AFODW (g/m2)	Autotrophic Index (Mono Chl a)	Autotrophic Index (Tri Chl a)
96.0	1.39	96.87	15.42	176.35	153.27
90.4	1.65	21.18	2.96	362.73	284.44
85.3	0.97	34.29	4.60	327.87	301.46
78.0	0.77	40.79	9.08	276.48	256.77
72.7	0.62	19.94	5.86	291.91	266.61
67.6	0.79	22.90	5.05	351.24	308.10
64.6	0.71	29.81	10.43	180.35	172.28
58.1	0.61	68.20	7.31	200.76	185.50

Table 18: September 2001 Site Mean Chlorophyll, New Growth Over 28 days on Incubated Substrates									
RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	20.5	135	1.5	0.0	90.2	18.1	103.5	13.9	4.0
90.4	17.5	90	1.6	0.0	9.0	2.1	10.5	2.1	0.0
85.3	10.7	240	1.0	0.1	14.9	1.6	16.3	2.5	0.7
78.0	11.5	230	0.8	0.6	34.9	2.4	37.2	5.8	1.7
72.7	13.4	250	0.6	0.2	20.9	2.2	22.9	1.2	1.5
67.6	14.0	220	0.8	0.3	16.4	1.1	17.5	1.1	1.6
64.6	13.9	240	0.7	0.1	67.2	0.5	69.9	1.6	4.1
58.1	15.1	268	0.6	0.1	43.4	3.5	46.9	3.1	3.2

The CE-QUAL-W2 model computes the organic matter of the active periphyton, which corresponds to the ODW (oven dry weight) of the active periphyton. The field data though includes any bacterial mass associated with this periphyton, which is shown in the autotrophic index. As a result, the W2 model would have a bias to being less than the field data for ODW since W2 is only modeling the active periphyton.

The autotrophic index is determined by dividing the ash-free dry weight by the average chlorophyll a. This is basically a carbon to chlorophyll a ratio. For phytoplankton, this ranges from 13-34 (Chapra, 1997), but according to the periphyton data, the autotrophic index is about an order of magnitude higher with an average index in August, 2001 of 270 and an average index in September, 2001 of 271. The higher autotrophic index would indicate there is more than just periphyton biomass in the grab samples. One would therefore expect that the CE-QUAL-W2 model would substantially predict less biomass than the ODW values shown above.

Although the periphyton ODW data is highly variable spatially, it was compared to model results for completeness and to indicate where future field monitoring might be focused if there is a need to better characterize periphyton densities in the river. Additionally, periphyton influences the water quality dynamics in the model and was an important state variable in the model.

Calibration

Data available for calibration included flow, temperature, dissolved oxygen, pH, conductivity, soluble reactive phosphorus, ammonia nitrogen, nitrite-nitrate nitrogen, chlorophyll a, $CBOD_u$, total organic carbon and dissolved organic carbon data. Dissolved oxygen, temperature, pH and conductivity continuous data from a 13-day period in August were also available. The system model was calibrated for 2001 and 2004. The model kinetic coefficients used in the 2001 uncalibrated model (Wells et al., 2003) and the calibrated model were shown in Table 19.

Table 19: W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*	Initial Calibration Values	Final Calibration Values
Hydrodynamics and Longitudinal Transport					
AX	Longitudinal eddy viscosity (for momentum dispersion)	m^2/sec	1	1	1
DX	Longitudinal eddy diffusivity (for dispersion of heat and constituents)	m^2/sec	1	1	1
Temperature					
CBHE	Coefficient of bottom heat exchange	Wm^2/sec	0.30	0.30	0.30
TSED	Sediment (ground) temperature	^oC	12.8	11.5	11.5 and 12.0
WSC	Wind sheltering coefficient		0.85	0.2-1.4	0.8 to 1.0
BETA	Fraction of incident solar radiation absorbed at the water surface		0.45	0.45	0.45
Water Quality					

Table 19: W2 Model Water Quality Parameters					
Variable	**Description**	**Units**	**Typical values***	**Initial Calibration Values**	**Final Calibration Values**
EXH20	Extinction for water	/m	0.25	0.25	0.25
EXSS	Extinction due to inorganic suspended solids	$m^3/m/g$	0.01	0.01	0.01
EXOM	Extinction due to organic suspended solids	$m^3/m/g$	0.17	0.1	0.1
EXA	Extinction due to organic algal type 1	$m^3/m/g$	0.1	0.1	0.1
SSS	Suspended solids settling rate	m/day	2	1.5	1.0
AG1	Algal growth rate for algal type 1	/day	1.1	1.5	1.6
AM1	Algal mortality rate for algal type 1	/day	0.01	0.1	0.1
AE1	Algal excretion rate for algal type 1	/day	0.01	0.04	0.04
AR1	Algal dark respiration rate for algal type 1	/day	0.02	0.04	0.04
AS1	Algal settling rate for algal type 1	/day	0.14	0.2	0.2
ASAT1	Saturation intensity at maximum photosynthetic rate for algal type 1	W/m^2	150	40	40
APOM1	Fraction of algal biomass lost by mortality to detritus for algal type 1		0.8	0.8	0.8
AT11	Lower temperature for algal growth for algal type 1	^oC	10	8	8
AT21	Lower temperature for maximum algal growth for algal type 1	^oC	30	10	10
AT31	Upper temperature for maximum algal growth for algal type 1	^oC	35	20	20
AT41	Upper temperature for algal growth for algal type 1	^oC	40	30	30
AK11	Fraction of algal growth rate at ALGT1 for algal type 1		0.1	0.1	0.1
AK21	Fraction of maximum algal growth rate at ALGT2 for algal type 1		0.99	0.99	0.99
AK31	Fraction of maximum algal growth rate at ALGT3 for algal type 1		0.99	0.99	0.99
AK41	Fraction of algal growth rate at ALGT4 for algal type 1		0.1	0.1	0.1
ALGP-A1	Stoichiometric equivalent between organic matter and phosphorus for algal type 1		0.011	0.005	0.005
ALGN-A1	Stoichiometric equivalent between organic matter and nitrogen for algal type 1		0.08	0.08	0.08
ALGC-A1	Stoichiometric equivalent between organic matter and carbon for algal		0.45	0.45	0.45

Table 19: W2 Model Water Quality Parameters					
Variable	**Description**	**Units**	**Typical values***	**Initial Calibration Values**	**Final Calibration Values**
	type 1				
EG1	Periphyton growth rate for Periphyton type 1	/day	1.1	1.5	1.2
EM1	Periphyton mortality rate for Periphyton type 1	/day	0.01	0.1	0.1
EE1	Periphyton excretion rate for Periphyton type 1	/day	0.01	0.04	0.04
ER1	Periphyton dark respiration rate for Periphyton type 1	/day	0.02	0.04	0.15
EB1	Periphyton burial rate for Periphyton type 1	/day	0.001	0.001	0.001
ESAT1	Saturation intensity at maximum photosynthetic rate for Periphyton type 1	W/m^2	150	150	150
EPOM1	Fraction of Periphyton biomass lost by mortality to detritus for Periphyton type 1		0.8	0.8	0.8
ET11	Lower temperature for Periphyton growth for Periphyton type 1	^oC	10	1	1
ET21	Lower temperature for maximum Periphyton growth for Periphyton type 1	^oC	30	3	3
ET31	Upper temperature for maximum Periphyton growth for Periphyton type 1	^oC	35	20	20
ET41	Upper temperature for Periphyton growth for Periphyton type 1	^oC	40	30	30
EK11	Fraction of Periphyton growth rate at ALGT1 for Periphyton type 1		0.1	0.1	0.3
EK21	Fraction of maximum Periphyton growth rate at ALGT2 for Periphyton type 1		0.99	0.99	0.99
EK31	Fraction of maximum Periphyton growth rate at ALGT3 for Periphyton type 1		0.99	0.99	0.99
EK41	Fraction of Periphyton growth rate at ALGT4 for Periphyton type 1		0.1	0.1	0.1
EP-E1	Stoichiometric equivalent between organic matter and phosphorus for Periphyton type 1		0.011	0.005	0.004
EN-E1	Stoichiometric equivalent between organic matter and nitrogen for Periphyton type 1		0.08	0.08	0.06

Table 19: W2 Model Water Quality Parameters					
Variable	Description	Units	Typical values*	Initial Calibration Values	Final Calibration Values
EC-E1	Stoichiometric equivalent between organic matter and carbon for Periphyton type 1		0.45	0.45	0.45
LDOMDK	Labile DOM decay rate	/day	0.12	0.08	0.08
LRDDK	Labile to refractory decay rate	/day	0.001	0.001	0.001
RDOMDK	Maximum refractory decay rate	/day	0.001	0.001	0.0013
LPOMDK	Labile Detritus decay rate	/day	0.06	0.08	0.08
POMS	Detritus settling rate	m/day	0.35	0.1	0.4
RPOMDK	Refractory Detritus decay rate	/day		0.001	0.001
OMT1	Lower temperature for organic matter decay	^{o}C	4	4	4
OMT2	Lower temperature for maximum organic matter decay	^{o}C	20	30	30
OMK1	Fraction of organic matter decay rate at OMT1		0.1	0.1	0.1
OMK2	Fraction of organic matter decay rate at OMT2		0.99	0.99	0.99
SDK	Sediment decay rate	/day	0.06	0.1	0.1
PARTP	Phosphorous partitioning coefficient for suspended solids		1.2	0	0
AHSP	Algal half-saturation constant for phosphorous	g/m	0.009	0.003	0.003
NH4DK	Ammonia decay rate (nitrification rate)	/day	0.12	0.4	0.4
AHSN	Algal half-saturation constant for ammonia	g/m^3	0.014	0.014	0.014
NH4T1	Lower temperature for ammonia decay	^{o}C	5	5	5
NH4T2	Lower temperature for maximum ammonia decay	^{o}C	20	25	25
NH4K1	Fraction of nitrification rate at NH4T1		0.1	0.1	0.1
NH4K2	Fraction of nitrification rate at NH4T2		0.99	0.99	0.99
NO3DK	Nitrate decay rate (denitrification rate)	/day	0.102	0.05	0.05
NO3T1	Lower temperature for nitrate decay	^{o}C	5	5	5
NO3T2	Lower temperature for maximum	^{o}C	20	25	25

Table 19: W2 Model Water Quality Parameters					
Variable	**Description**	**Units**	**Typical values***	**Initial Calibration Values**	**Final Calibration Values**
	nitrate decay				
NO3K1	Fraction of denitrification rate at NO3T1		0.1	0.1	0.1
NO3K2	Fraction of denitrification rate at NO3T2		0.99	0.99	0.99
O2NH4	Oxygen stoichiometric equivalent for ammonia decay		4.57	4.57	4.57
O2OM	Oxygen stoichiometric equivalent for organic matter decay		1.4	1.4	1.4
O2AR	Oxygen stoichiometric equivalent for dark respiration		1.4	1.1	1.1
O2AG	Oxygen stoichiometric equivalent for algal growth		1.4	1.4	1.4
ORGP	Stoichiometric equivalent between organic matter and phosphorus		0.011	0.005	0.001
ORGN	Stoichiometric equivalent between organic matter and nitrogen		0.08	0.08	0.01
ORGC	Stoichiometric equivalent between organic matter and carbon		0.45	0.45	0.6
O2LIM	Dissolved oxygen concentration at which anaerobic processes begin	g/m^3	0.05	0.1	0.1
CO2R	Sediment carbon dioxide release rate, fraction of sediment oxygen demand		1.25**	0.10	1.25
SOD	Zero-order sediment oxygen demand for each segment	$gO_2\ m^{-2}\ day^{-1}$	0.1 - 1.0	0.10	0.50
* Cole and Wells (2000), **Corrected value, see discussion below					

The carbon dioxide release rate from the sediments as a fraction of the zero-order sediment oxygen demand listed in Cole and Wells (2000) as 0.10 as a typical value was not correct. The next User Manual will update this value to 1.25. Carbon dioxide release rates as high as 1.4 have been used in earlier modeling studies. If one considers the CO_2 release as a fraction of O_2 uptake from

$$C_6H_{12}O_6 + 6O_2 \leftrightarrow 6CO_2 + 6H_2O$$

the stoichiometric ratio of O_2 to CO_2 is 32 gO_2/44 gCO_2 or 0.8 gO_2/gCO_2 which results in a CO2REL of 1/0.8 or 1.25.

Model calibration data (hydrodynamic, temperature and water quality) in 2001 and 2004 were compiled from WA Department of Ecology, ID Department of Environmental Quality and the U.S. Geological Survey. Figure 91 shows the location of monitoring sites in 2001 and 2004. Table 20 lists the hydrodynamic monitoring sites for 2001 and 2004 and Table 21 list the temperature and water quality monitoring sites for both years.

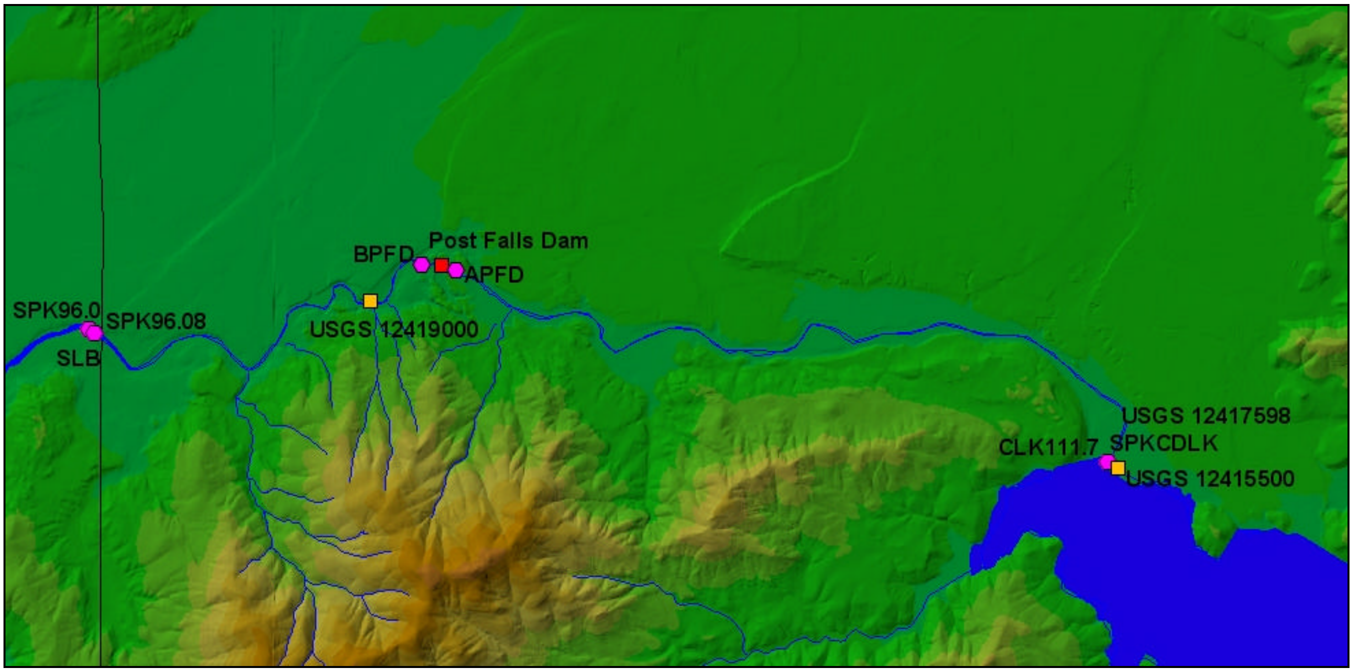


Figure 91: Hydrodynamic, temperature and water quality monitoring sites for calibration, 2001 and 2004.

Table 20: Flow and water level elevation calibration sites, 2001 and 2004.

Site	Description	RM	Data	Model Segment	Years
USGS 12415500	Coeur D'Alene Lake at Coeur D'Alene ID	111.05	WL	2	2001 & 2004
USGS 12419000	Spokane River near Post Falls, ID	100.52	Q and WL	36	2001 & 2004
SPK96.0	Grab samples	96.00	Q	62	2001
Stateline	flow estimate based on groundwater gain and loss and USGS at Post Falls	96.00	Q	62	2001 & 2004

Table 21: Temperature and water quality calibration sites, 2001 and 2004.

Site	Description	RM	Data	Model Segment	Years
CLK111.7	Lake Coeur d'Alene outlet	111.05	WQ	2	2001
USGS 12417598	Spokane River at Lake Outlet at Coeur D'Alene ID	111.05	Temp & WQ	2	2004
SPKCDLK	Spokane River at Lake Coeur d'Alene Outlet, IDEQ	111.05	WQ	2	2004
APFD	Above Post Falls Dam, IDEQ	101.30	WQ	27	2004
USGS 12419000	Post Falls Gage Station	100.52	Temp	36	2001
BPFD	Below Post Falls Dam, IDEQ	101.14	WQ	30	2004
SPK96.08	Spokane River near the Stateline	96.10	Temp & WQ	62	2001

Site	Description	RM	Data	Model Segment	Years
SLB95.8	Stateline Bridge, IDEQ	96.00	WQ	62	2004
SPK96.0	Spokane River at the Stateline Bridge, 400 ft upstream of Stateline Bridge.	96.00	Temp & WQ	62	2001 & 2004

Hydrodynamics

Year 2001

Model water surface elevation predictions were compared with water surface elevation data at model segment 2, the outlet to Lake Coeur d'Alene (USGS: 12415500), as shown in Figure 92. The outflow from the Post Falls Dam was compared to the USGS gage station near Post Falls, ID (12419000) 0.8 mi downstream of the dam in Figure 93. Model predictions of flow and water surface elevation were compared to data the USGS gage station in Figure 94 and Figure 95, respectively.

Model flow predictions were compared with flow estimates based on flow data from Post Falls and Harvard Bridge in Figure 96. These flow estimates were made by considering the decrease in flow occurring between Post Falls and Harvard Bridge and the distance between Post Falls and the State Line relative to the distance between Post Falls and Harvard Bridge (see "groundwater" section).

Overall model flow predictions were fairly close to data throughout the system. Water surface elevations predicted at the USGS gage showed some disagreement with data but were within the vertical grid resolution of the model (1 m).

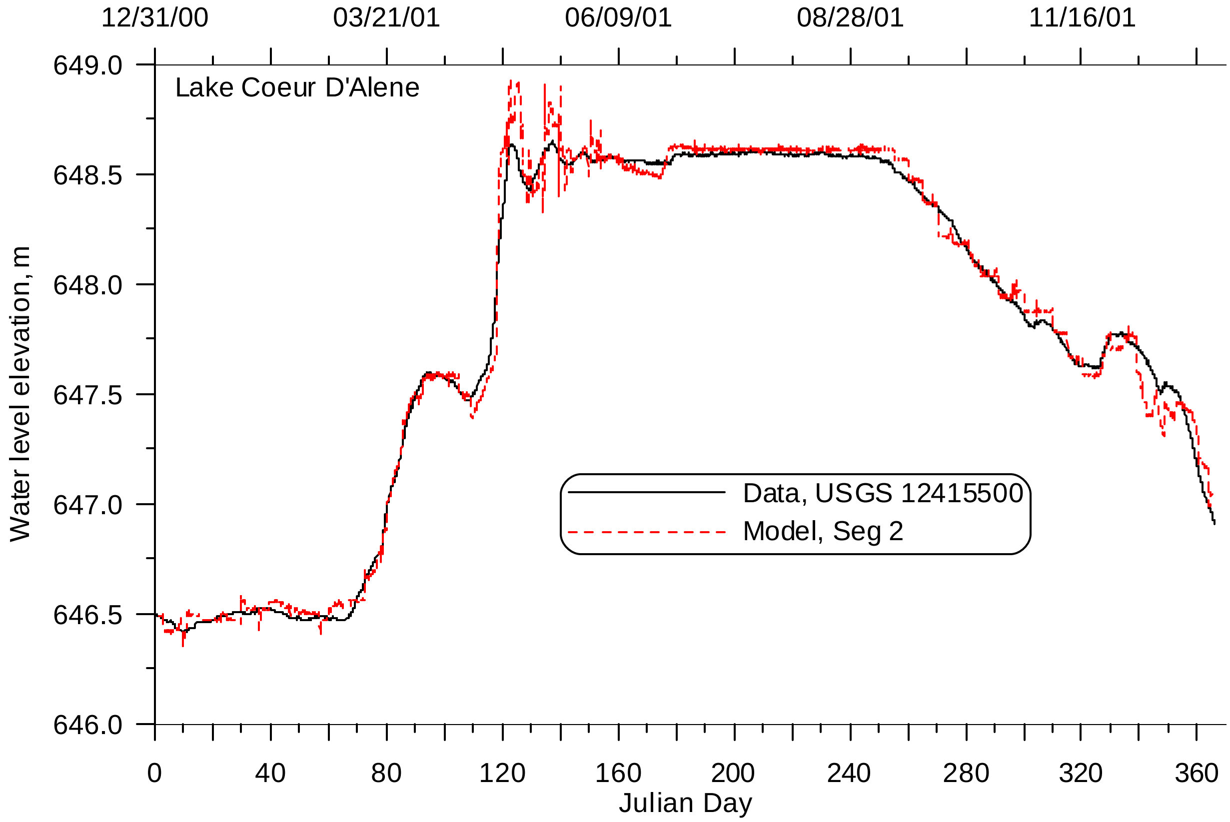


Figure 92: Model-data water level elevation comparison for Lake Coeur d'Alene, 2001.

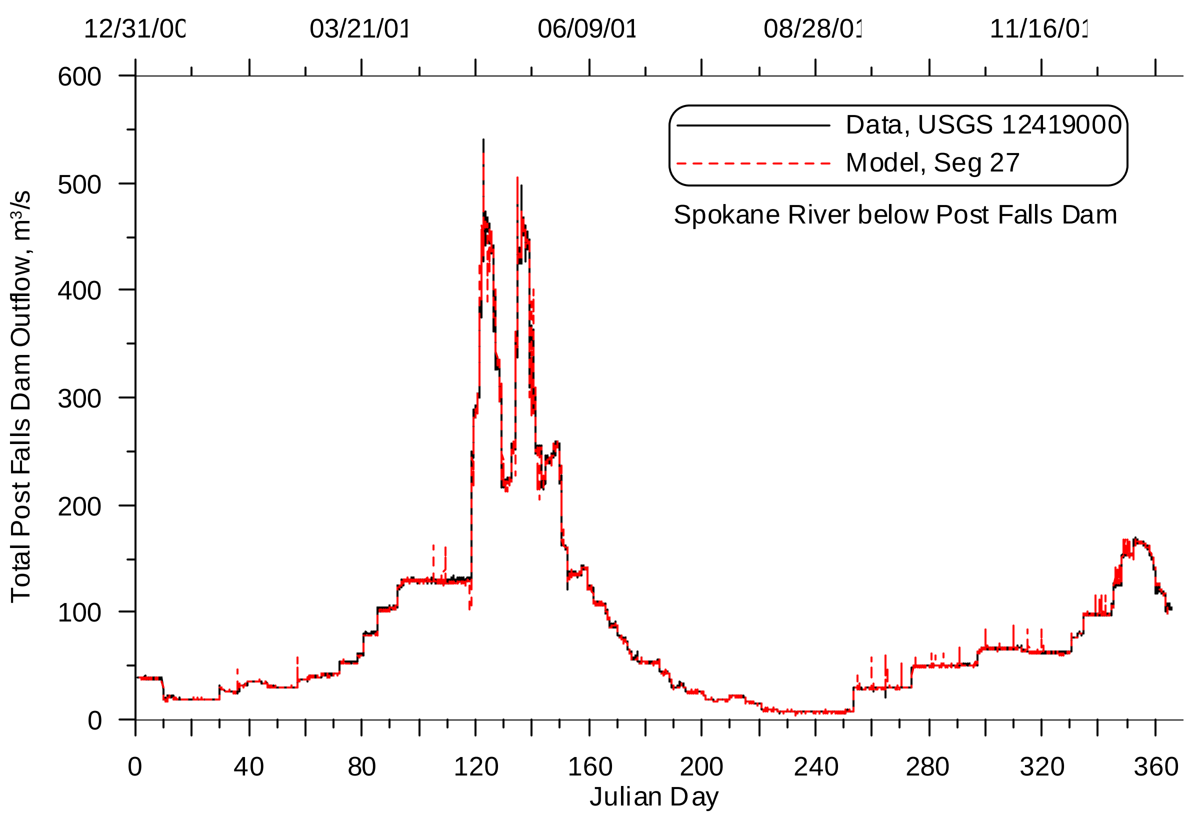


Figure 93: Model-data flow comparison downstream of Post Falls Dam, 2001. (USGS gage station is 0.8 mi downstream)

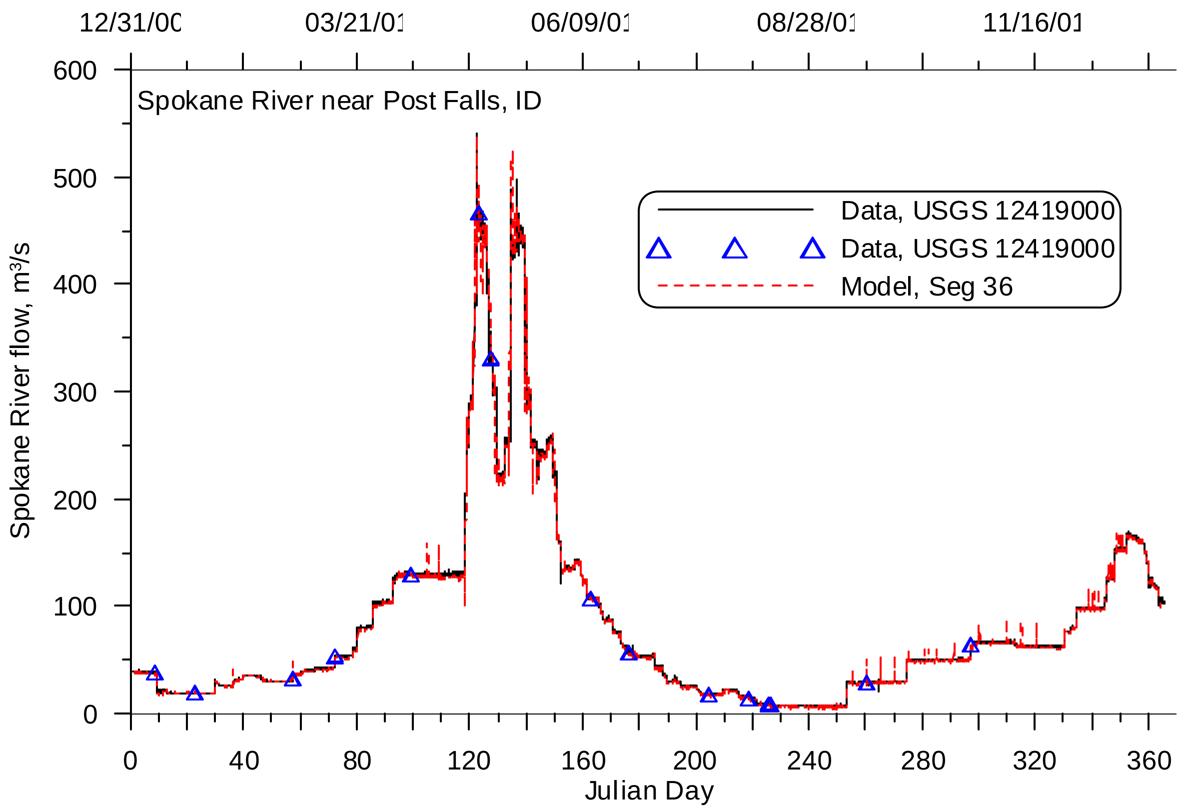


Figure 94: Model-data flow comparison at USGS gage station near Post Falls, ID, 2001.

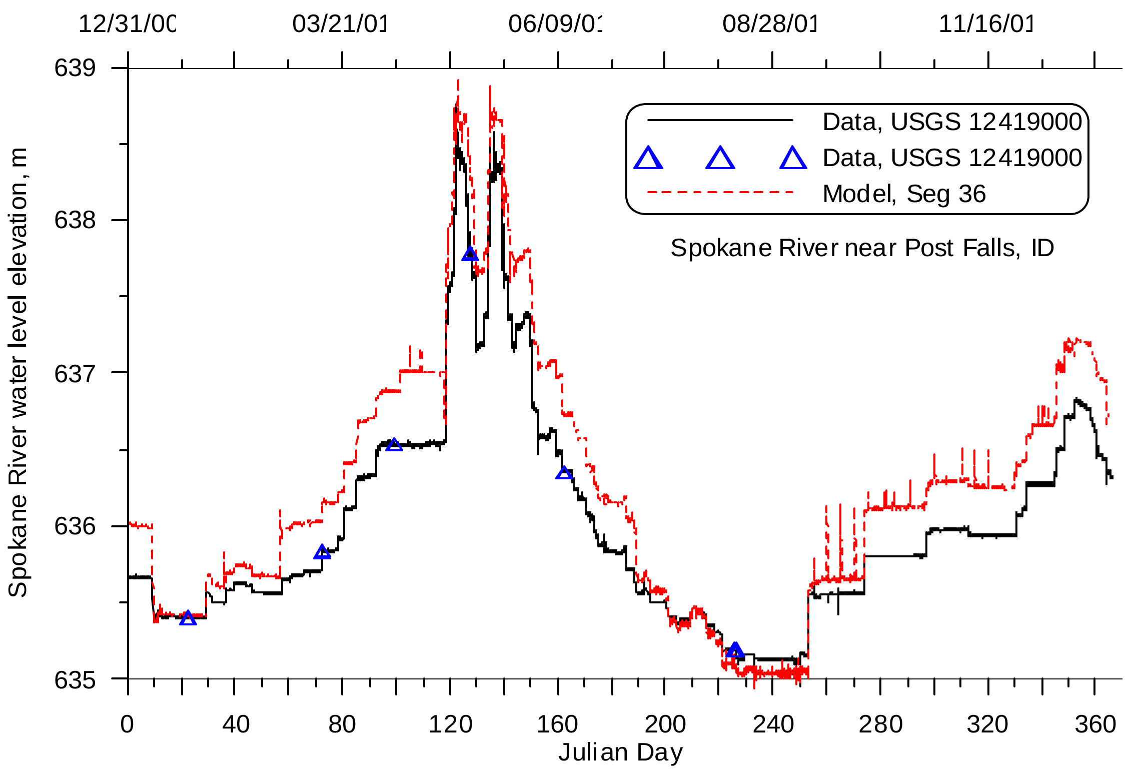


Figure 95: Model-data water level elevation comparison at USGS gage station near Post Falls, ID, 2001.

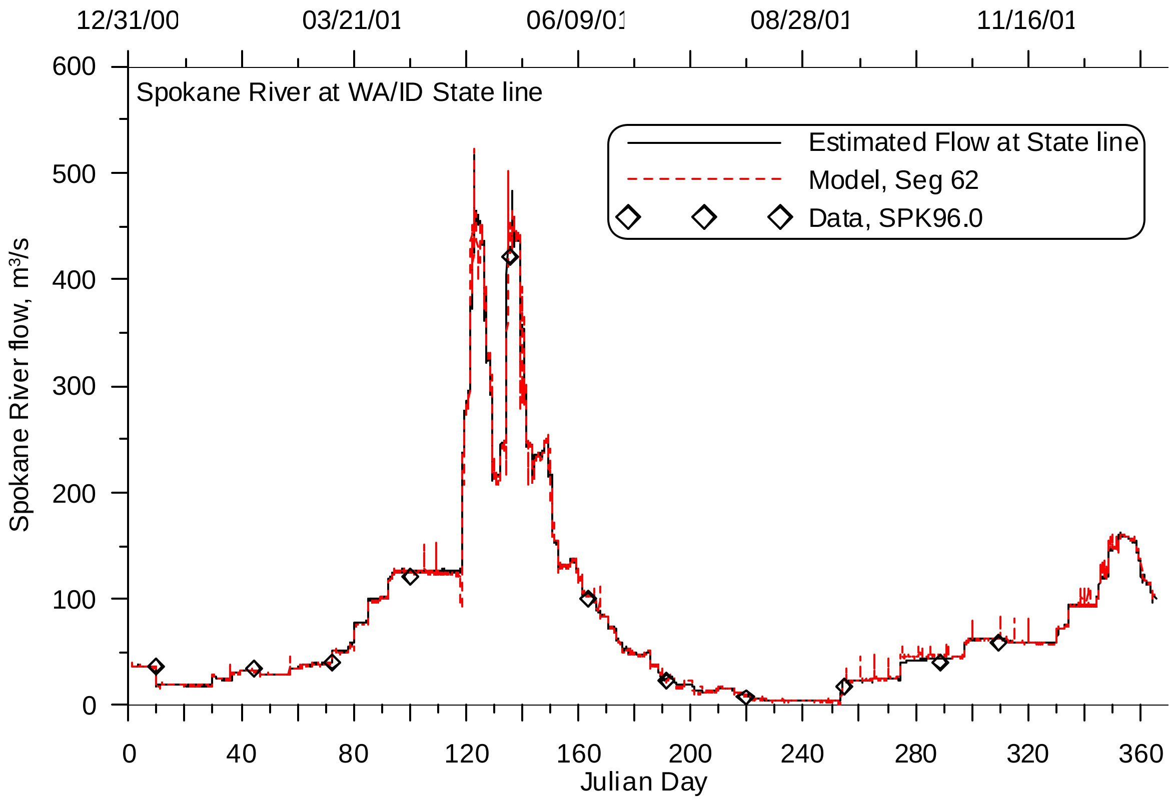


Figure 96: Model-data flow comparison at the State Line with flowestimates and grab sample data, 2001. The flow estimates were based on flow rate data collected at Post Falls and Harvard Bridge.

Year 2004

Model water surface elevation predictions were compared with water surface elevation data at Model segment 2, the outlet to Lake Coeur d'Alene (USGS: 12415500), as shown in Figure 97, for January to September, 2004. The outflow from the Post Falls Dam was compared to the USGS gage station near Post Falls, ID (12419000) 0.8 mi downstream of the dam in Figure 98. Model predictions of flow and water surface elevation were compared to data at the USGS gage station in Figure 99 and Figure 100, respectively.

Model flow predictions were compared with flow estimates at the WA/ID State Line based on flow data from Post Falls and Harvard Bridge in Figure 101. These flow estimates were made by considering the decrease in flow occurring between Post Falls and Harvard Bridge and the distance between Post Falls and the State Line relative to the distance between Post Falls and Harvard Bridge (see "groundwater" section).

Overall model flow predictions were fairly close to data throughout the system. Water surface elevations predicted at the USGS gage showed some disagreement with data but were within the vertical grid resolution of the model (1 m) and within the error reporting for the elevation benchmark for the this site.

Systematic error of water level below Post-Falls Dam could be corrected by higher quality bathymetric data in this reach.

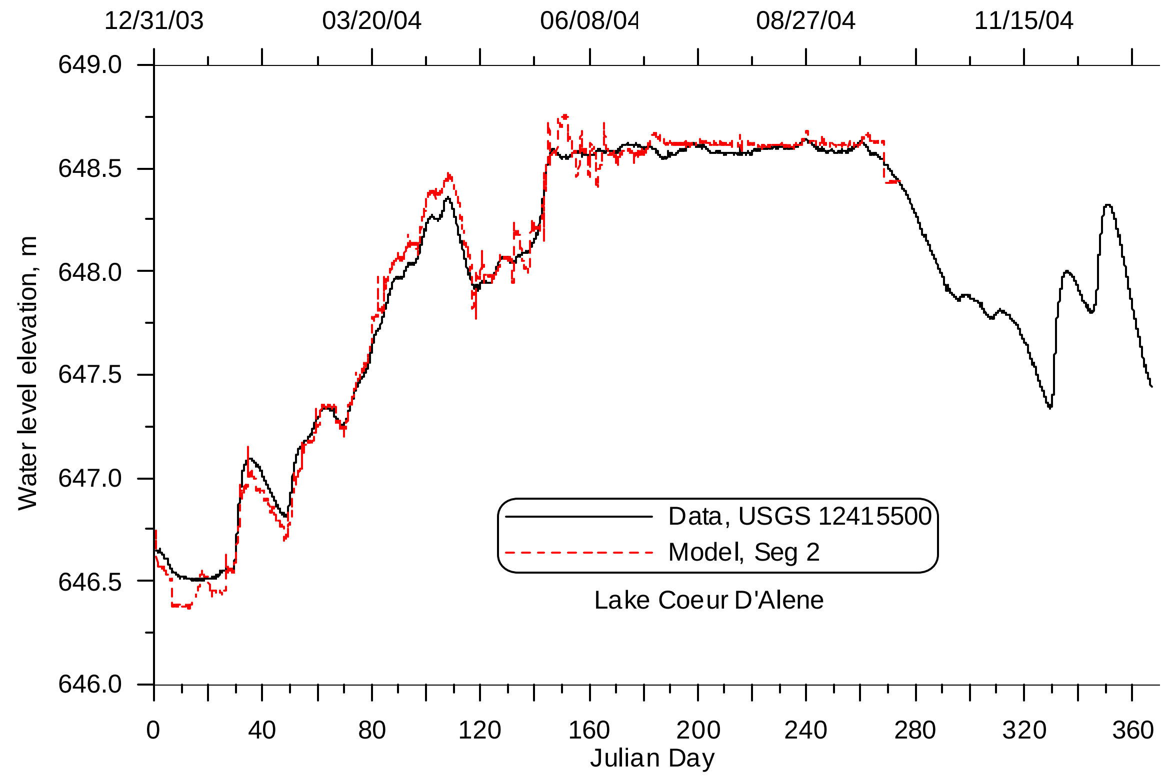


Figure 97: Model-data water level elevation comparison for Lake Coeur d'Alene, 2004.

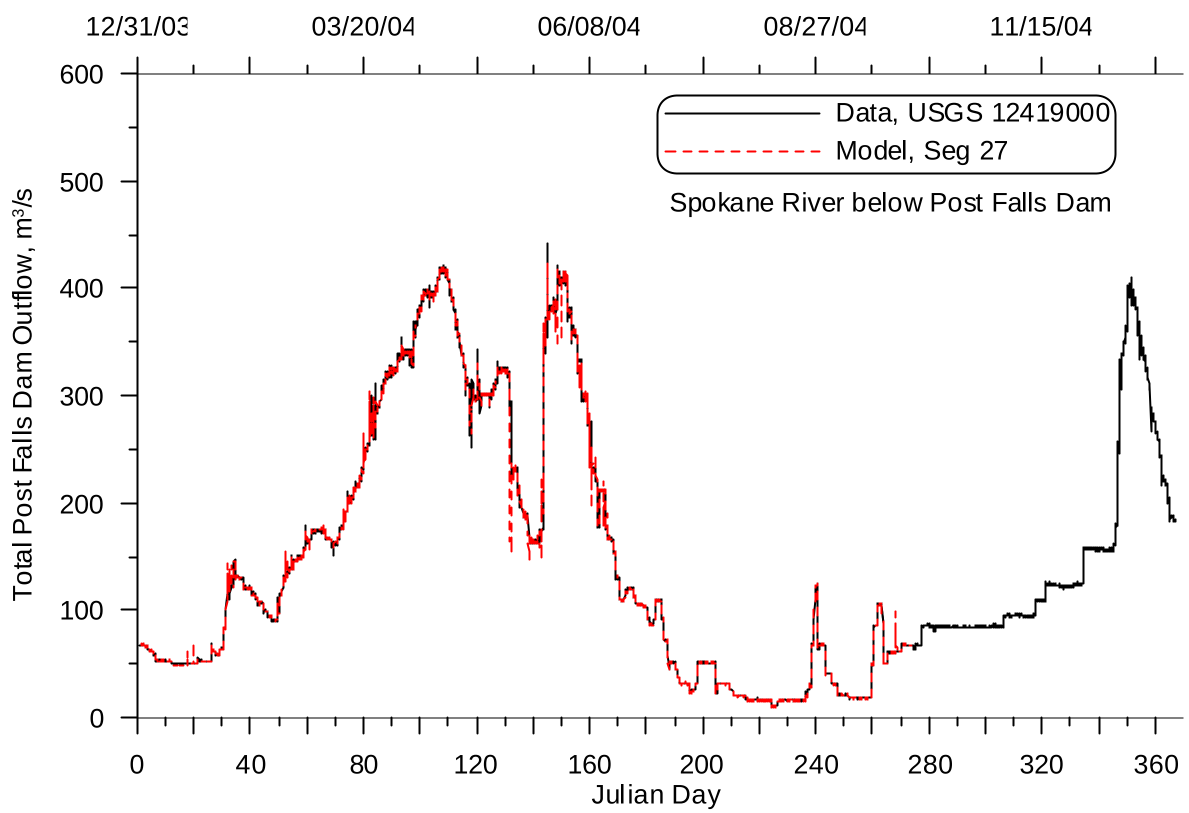


Figure 98: Model-data flow comparison downstream of Post Falls Dam, 2004. (USGS gage station is 0.8 mi downstream)

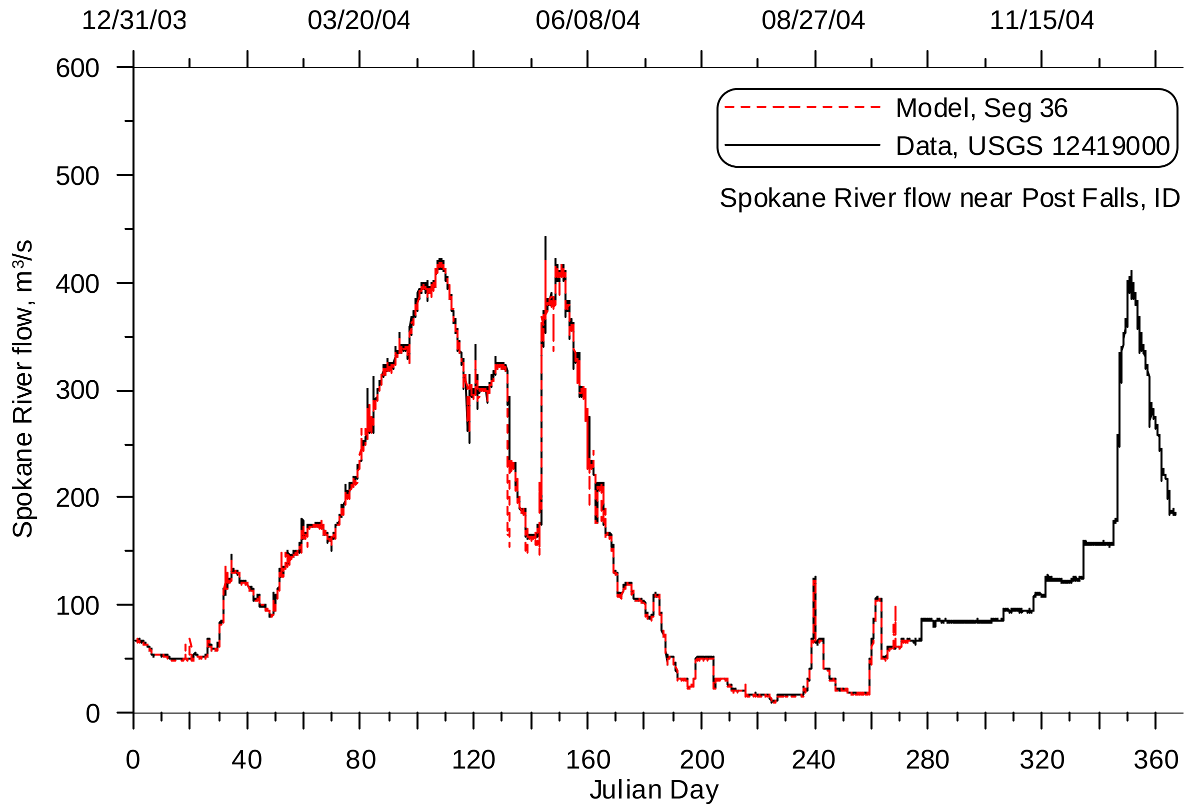


Figure 99: Model-data flow comparison at USGS gage station near Post Falls, ID, 2004.

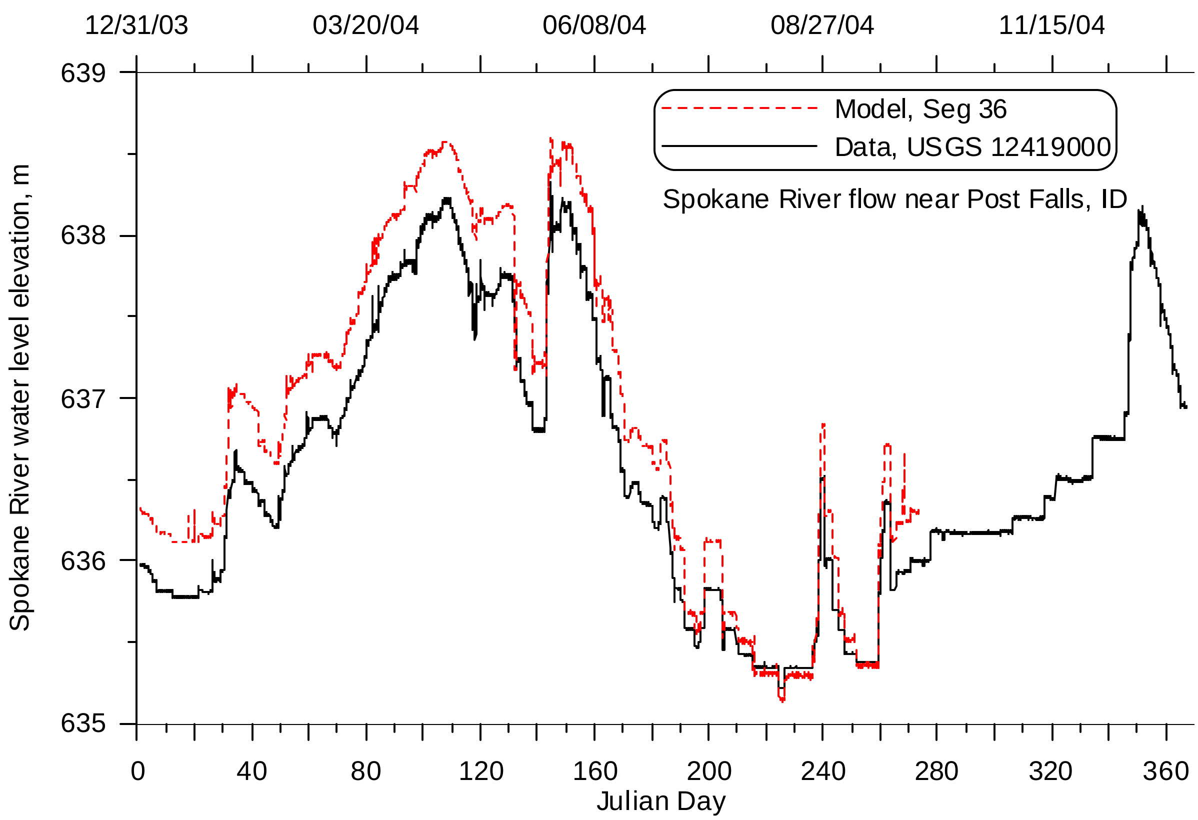


Figure 100: Model-data water level elevation comparison at USGS gage station near Post Falls, ID, 2004.

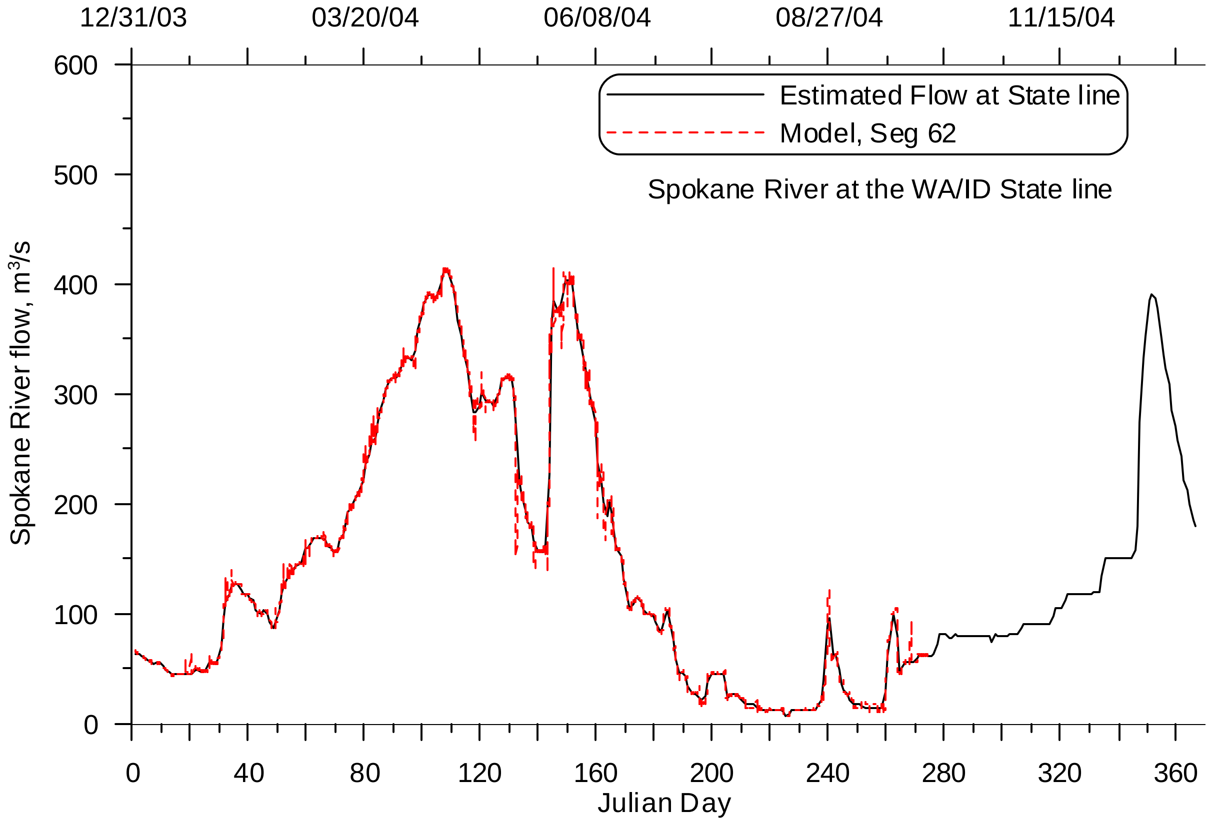


Figure 101: Model-data flow comparison at the State Line with flow estimates and grab sample data, 2004. The flow estimates were based on flow rate data collected at Post Falls and Harvard Bridge.

Wetted-Width Survey

Wetted-channel widths from the model were compared to channel width data from digital ortho-rectified quadrangle photographs of the river channel and survey data provided by Ken Merrill (WA Dept. of Ecology. There were two digital ortho-rectified quadrangle photographs taken of the river in 1992 and 1998 which were used to make measurements of the wetted width of the channel every 100 ft along the river. Figure 102 shows the measurement points along the river compared to the model grid segment center points. The daily average flow from the USGS gage station near Post Falls, ID (12419000) for the two days when the photos were taken were used to run the model for two weeks under constant flow. The wetted-widths of the channel from the model were then compared with data for the specific flows and model segments. Table 22 list the daily average flows run through the model and listed the corresponding model segments for comparison with data.

A wetted-width channel survey was conducted by Ken Merrill of WA Department of Ecology on June 15, 2005. The survey points are shown in Figure 103 along with the corresponding model segments. Table 22 lists the daily average flow used in the model. Figure 104 shows a comparison between wetted-width channel data and model output for all model runs (various flows) and survey data. The figure shows there is good model-data agreement for the various flows run through the model. The large channel width estimates between river mile 98.5 and 99.0 are biased since islands shown in the digital ortho-rectified photographs were not subtracted from the width estimates.

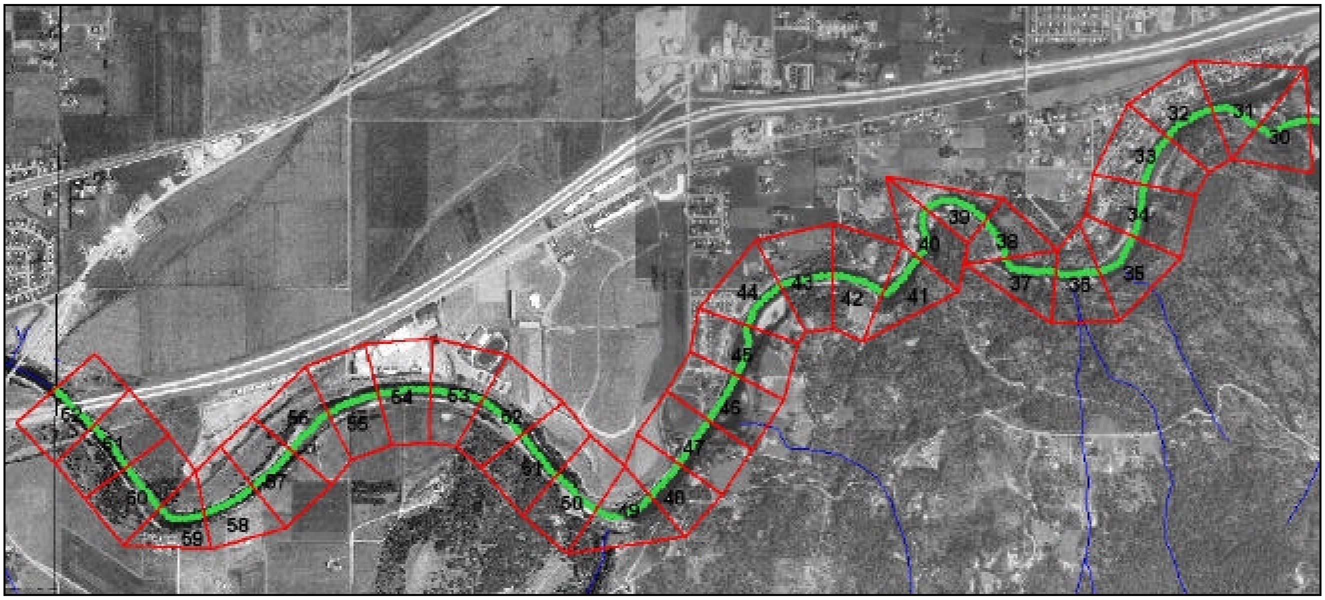


Figure 102: Wetted-width channel measurements, taken from digital ortho-rectified quadrangle maps and model segment center points (squares)

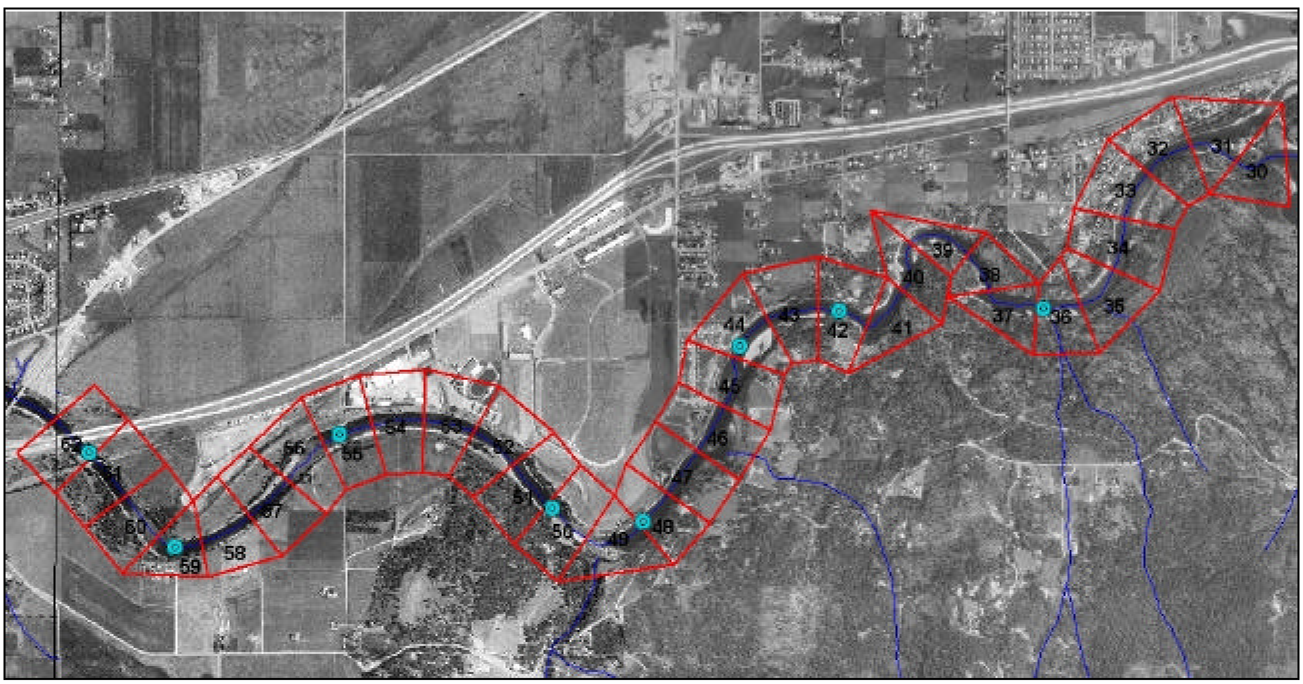


Figure 103: 2005 wetted-width channel survey locations and model grid center points (squares)

Table 22: Wetted-width channel survey data and measurement data from digital ortho-photos

Digital Ortho-Quad Photo	Date	Flow, cfs	Flow, m3/s	Model Segments
Liberty Lake	05/22/1992	4,470	126.6	47 to 62
Post Falls	06/09/1998	5,370	152.1	30 to 46
NA (Ecology Survey)	06/15/2005	2,500	70.8	36 to 62

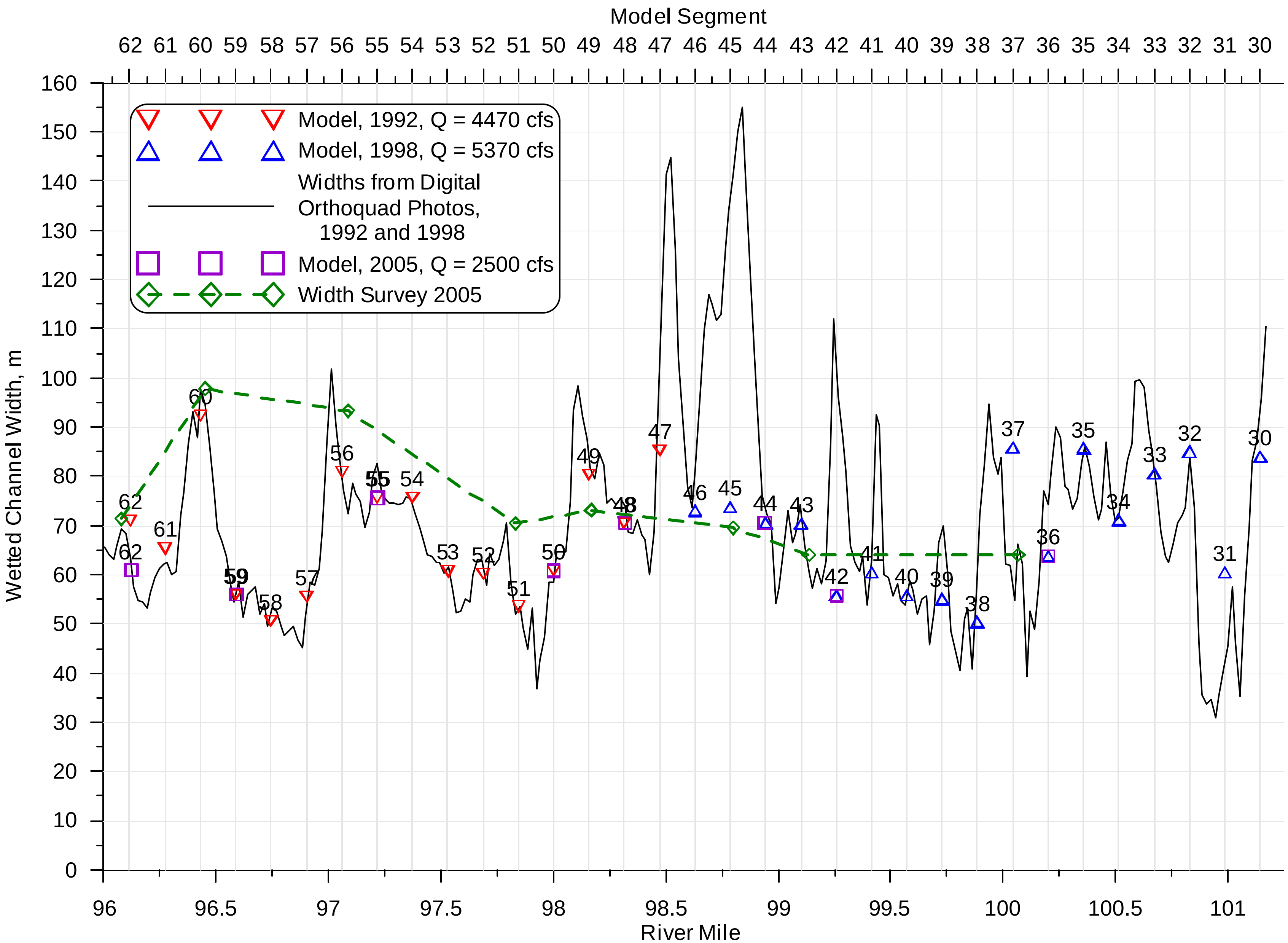


Figure 104: Model-data wetted channel width comparison on the Spokane River between Post Falls Dam and the WA/ID State line.

Water Temperature

Year 2001

Model water temperature predictions were compared to data collected at the USGS gage station near Post Falls, ID (12419000) as shown in Figure 105. The figure shows the model does well predicting the season variations and some weather patterns. Diurnal variations are similar but during some time periods the model is a little too cold. This is systematic error based on the temperature boundary condition at the lake.

Model temperature predictions were compared with data collected at the State Line in 2001 in Figure 106. Data consisted of periodic grab samples and two sets of continuous temperature data. Figure 107 shows a time series plot comparing the model predictions with data over the time window of continuous temperature data. Both figures indicate the model does well predicating river temperatures at the State Line.

The model used theoretical solar radiation and cloud cover data. Solar data from Odessa, WA was tested in the model but there was less model-data agreement so it was not used.

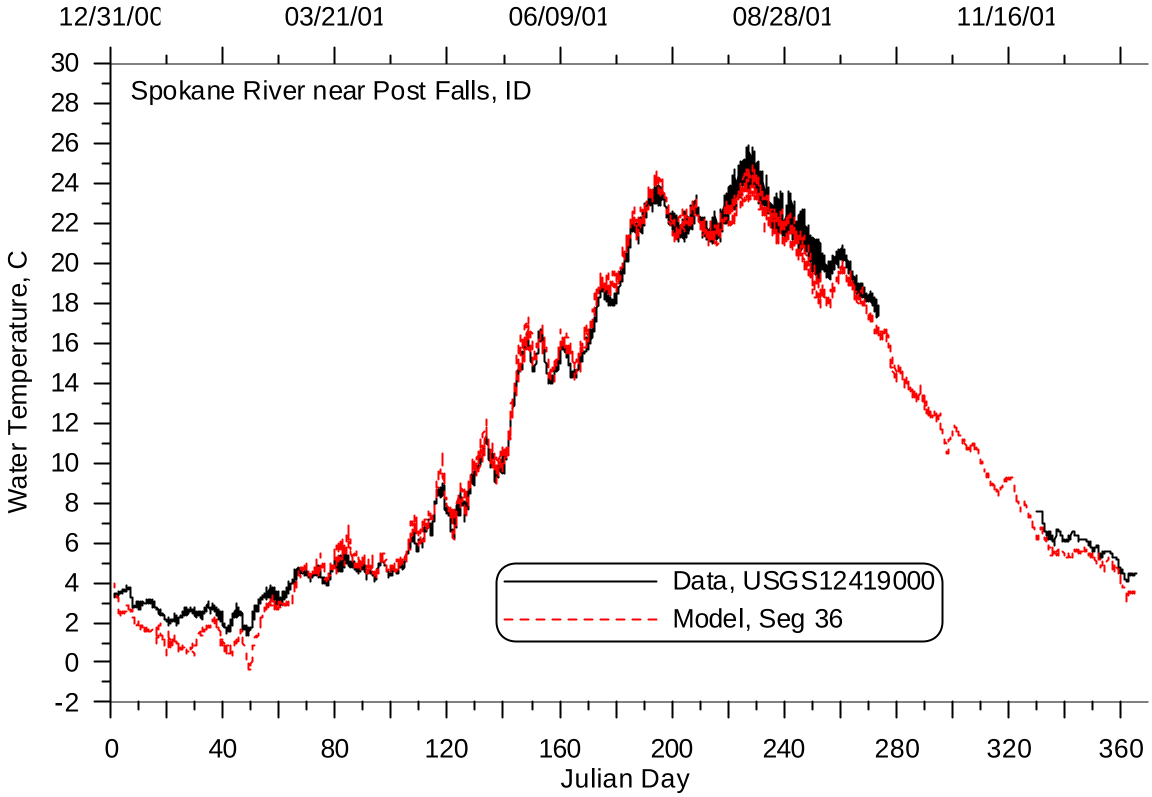


Figure 105: Model-data water temperature comparison at USGS gage station near Post Falls, ID, 2001.

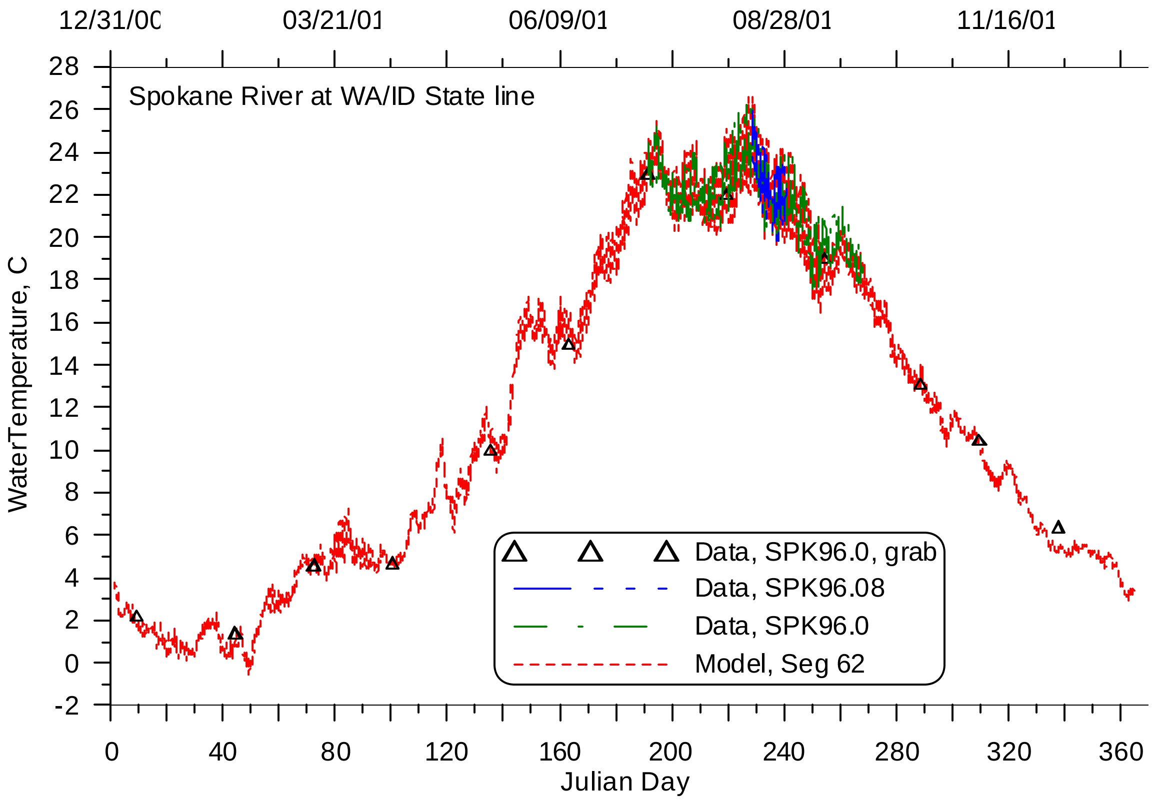


Figure 106: Model-data water temperature comparison at State Line, 2001.

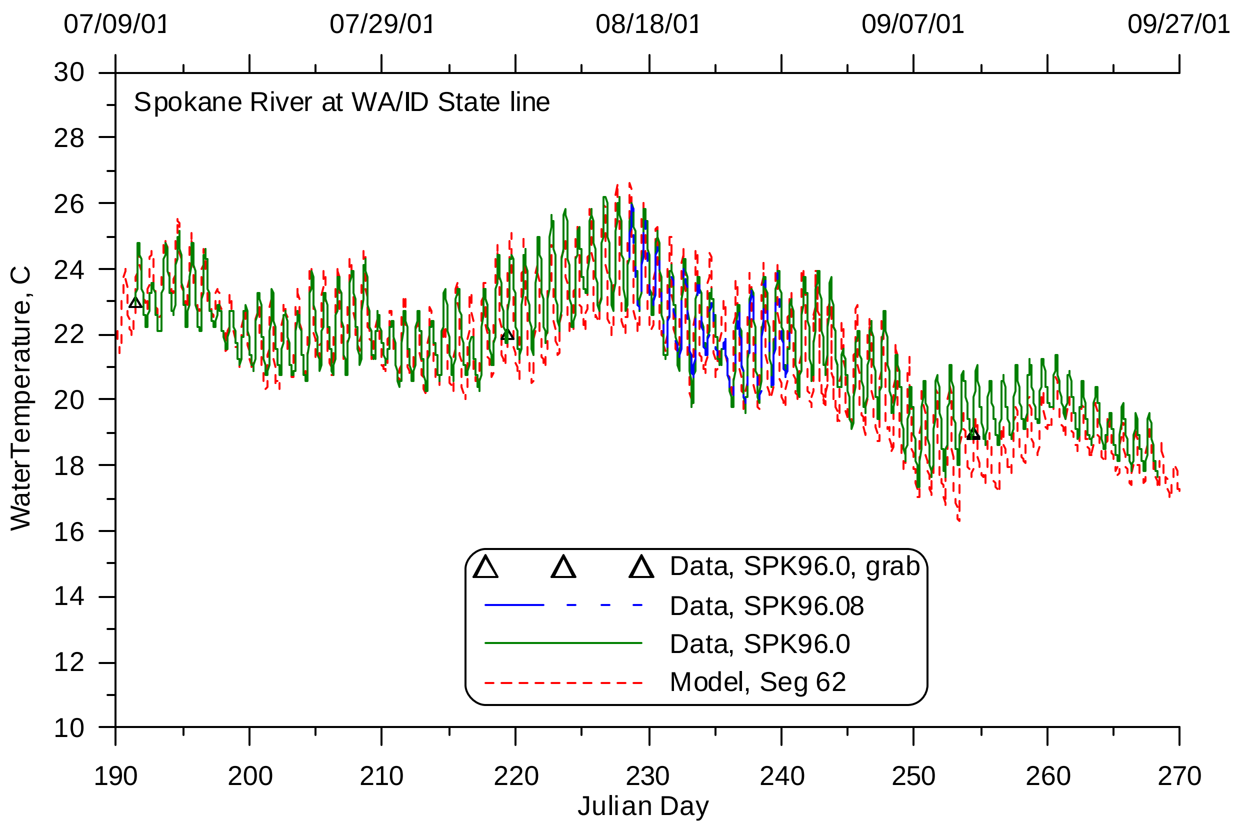


Figure 107: Model-data water temperature comparison at State line from July 9th to September 27th, 2001.

Year 2004

In 2004, water temperature data were collected with discrete grab samples at specific depths and during short period using Hydrolab instrument. Figure 108 shows model model-data water temperature comparison at the outlet of Lake Coeur d'Alene, which is basically the model boundary condition. Figure 109 shows a model-data temperature comparison above Post Falls Dam and Figure 110 shows a comparison between the model and data below Post Falls Dam. Figure 111 shows a comparison of model temperature predictions with data at the WA/ID State Line. The figures all show there is good model-data agreement at each of the sites.

The model used theoretical solar radiation and cloud cover data. Solar data from Odessa, WA was tested in the model but there was less model-data agreement so it was not used.

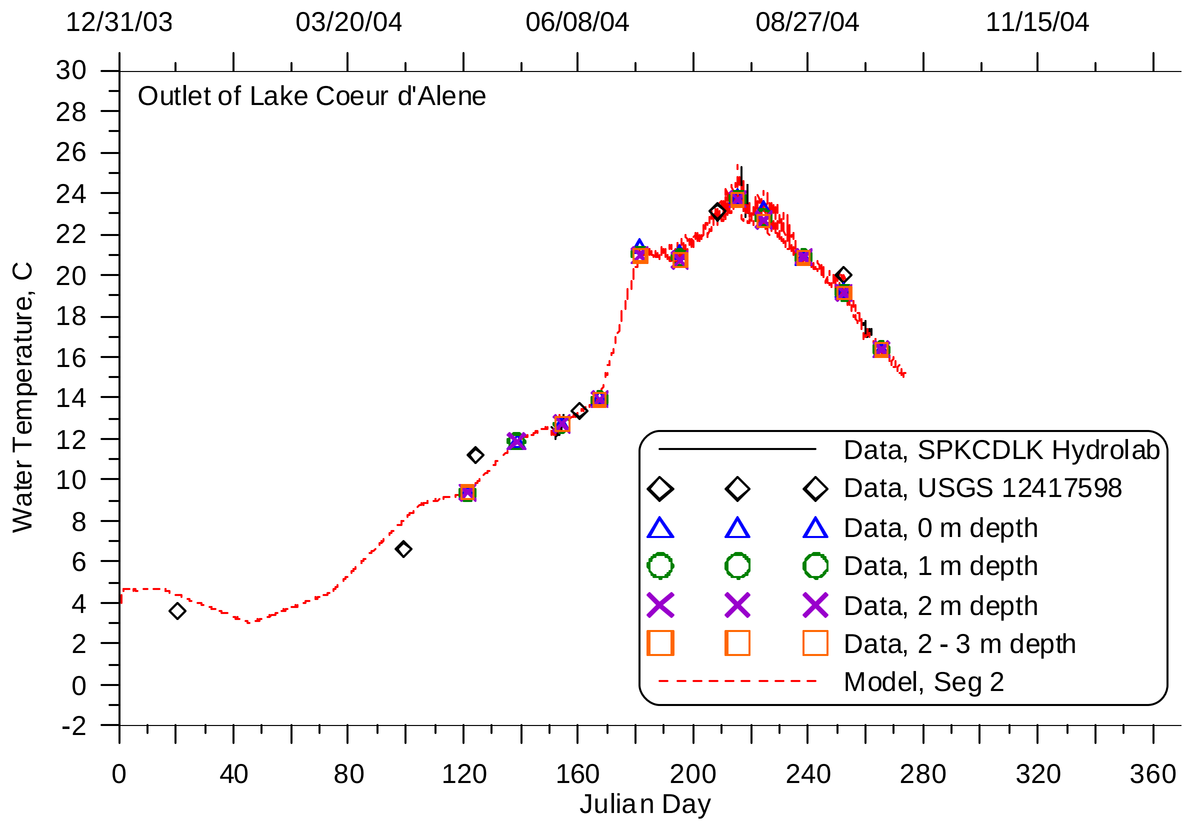


Figure 108: Model-data water temperature comparison at outlet to Lake Coeur d'Alene, 2004.

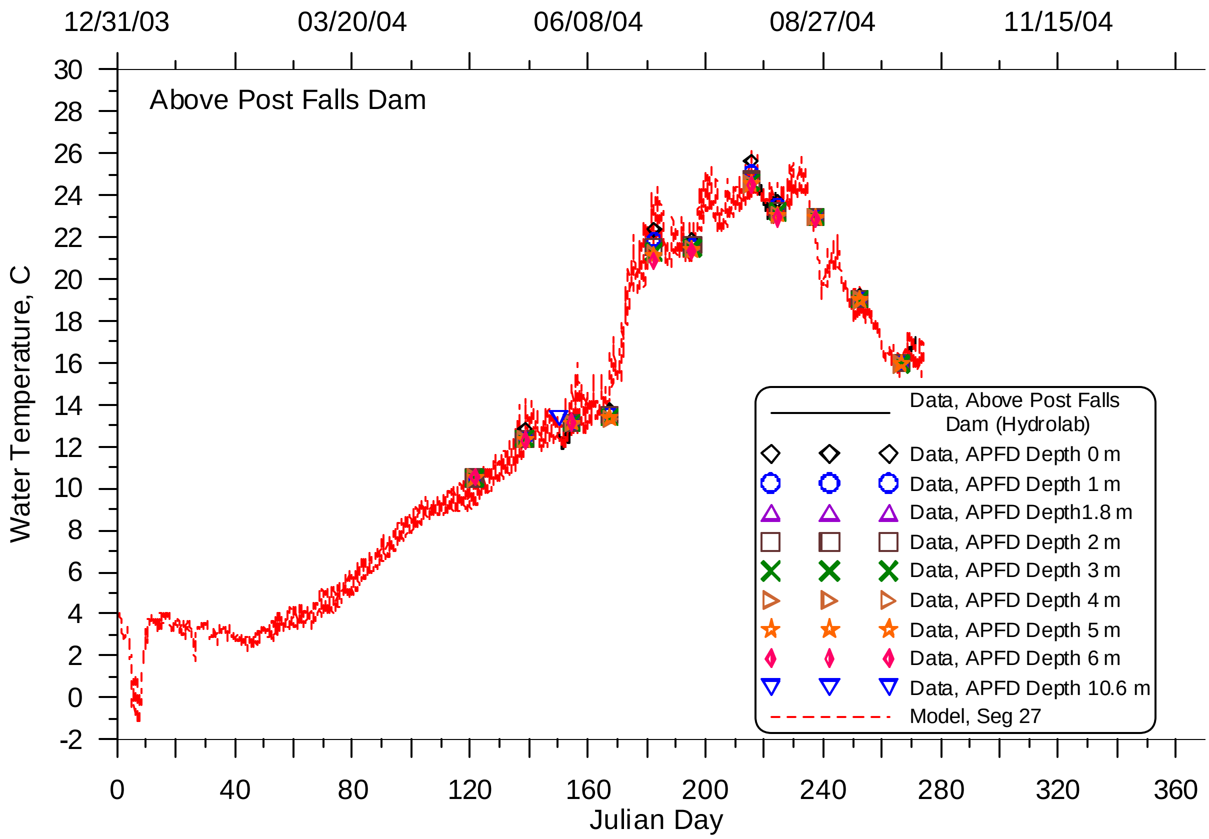


Figure 109: Model-data water temperature comparison upstream of Post Falls Dam, 2004.

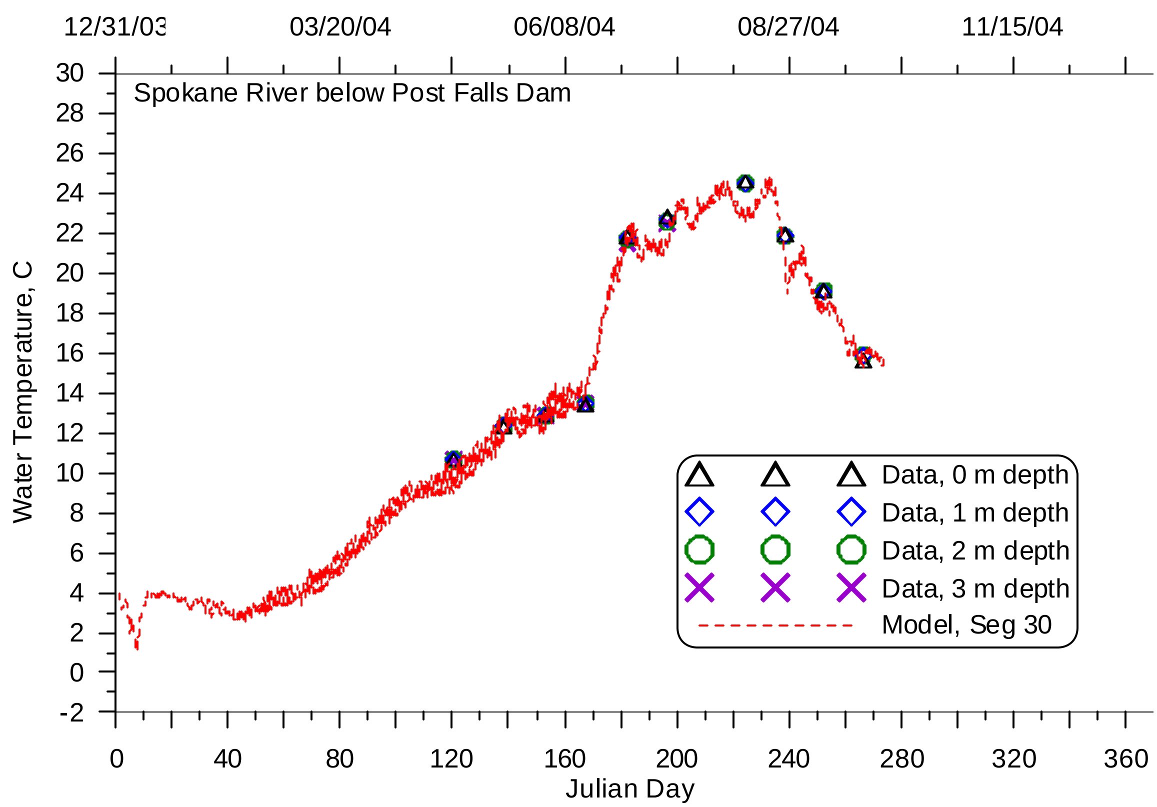


Figure 110: Model-data water temperature comparison below Post Falls Dam, 2004.

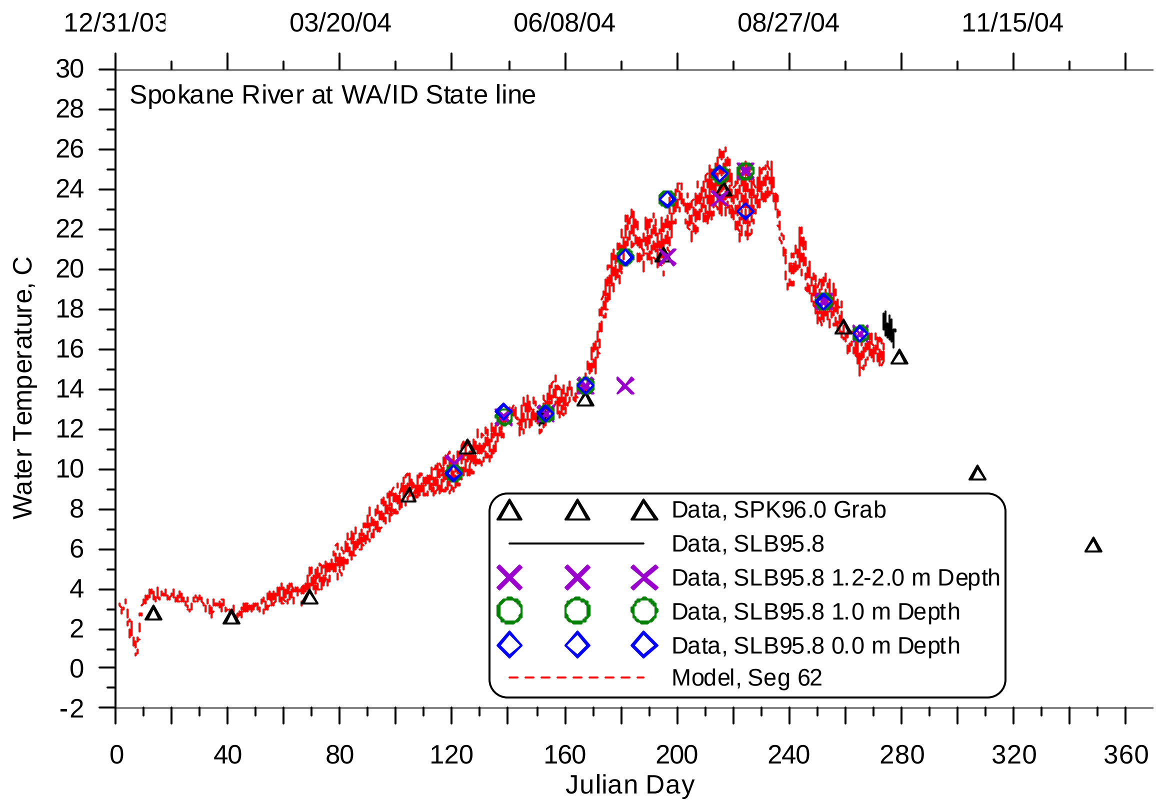


Figure 111: Model-data water temperature comparison at State line, 2004.

Water Quality

Year 2001

The model-data comparisons for 2001 include both the latest model calibration results (red dotted line) and the uncalibrated model results from the initial model run from Wells et al. (2003) (blue dash-dot line).

Conductivity

Figure 112, Figure 113, and Figure 114 show comparisons between model predicted conductivity and data at the outlet to Lake Coeur d'Alene (model upstream boundary), the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. Conductivity was modeled as a conservative constituent and provided a way to confirm the accuracy of the water balance.

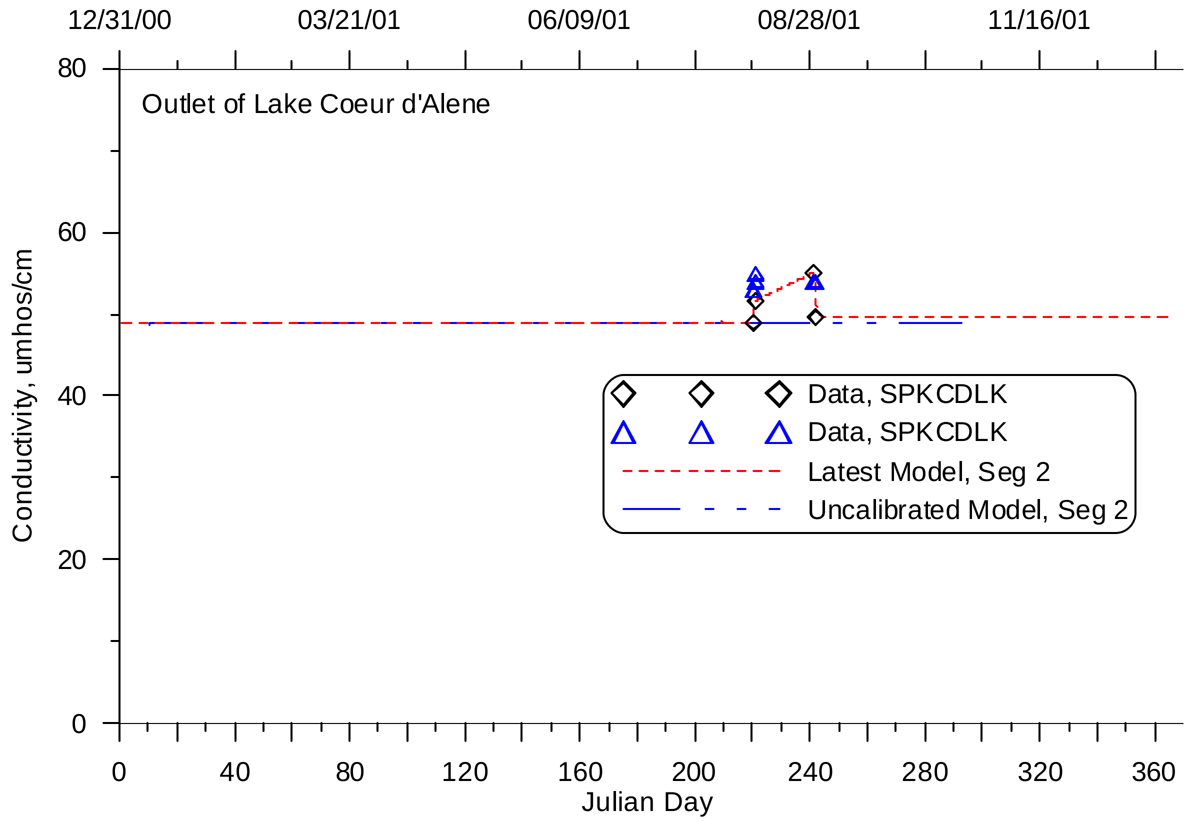


Figure 112: Model-data conductivity comparison, at Lake Coeur d'Alene outlet, 2001.

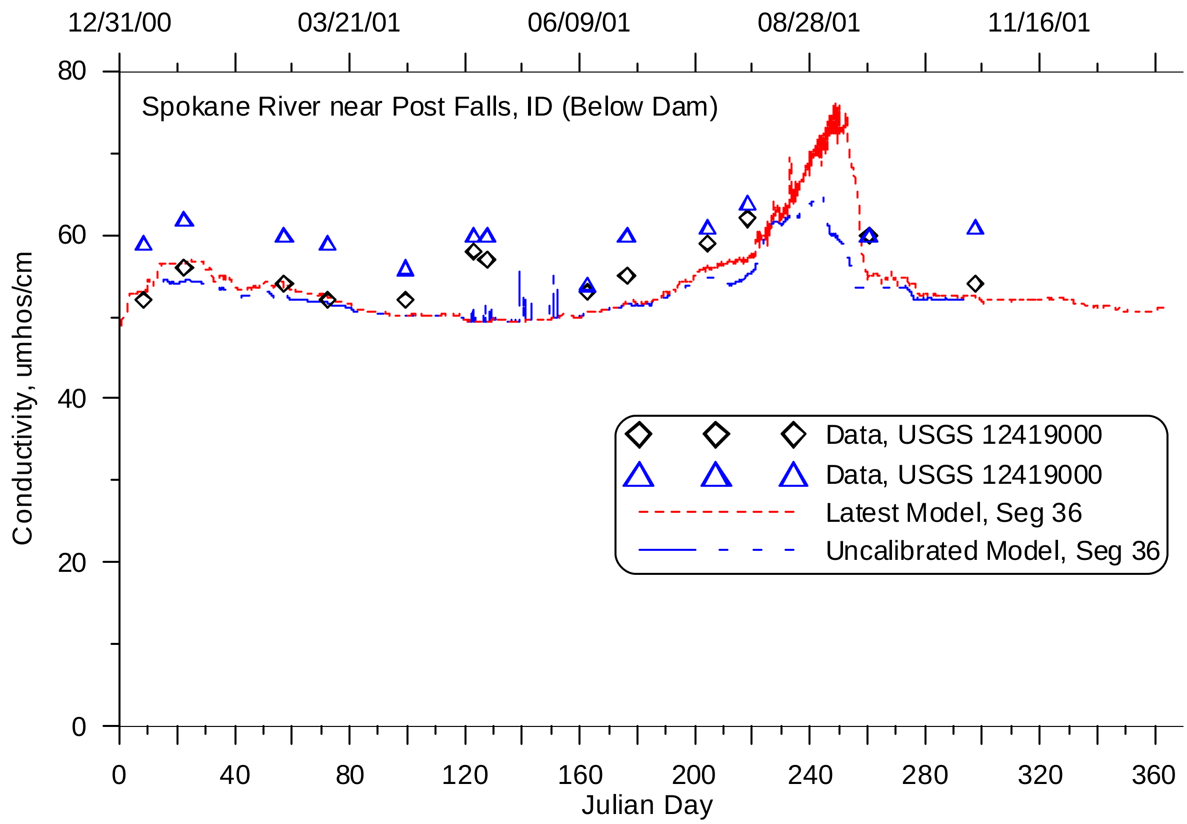


Figure 113: Model-data conductivity comparison, 0.8 mi downstream of Post Falls Dam, 2001.

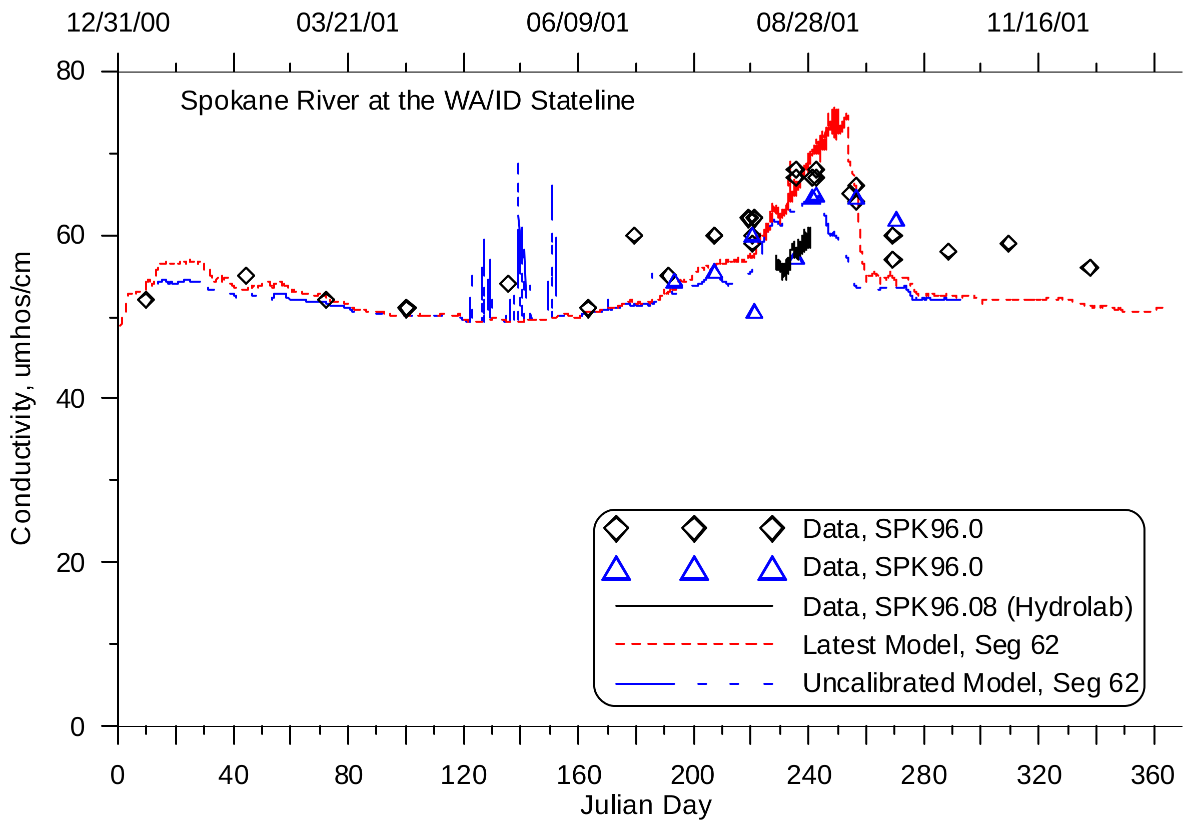


Figure 114: Model-data conductivity comparison, at the WA/ID State Line, 2001.

Soluble Reactive Phosphorus

Figure 115, Figure 116, and Figure 117 show comparisons between model predicted soluble reactive phosphorus concentration and data at the outlet to Lake Coeur d'Alene, the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. The figures show the model predictions match the data well. Diurnal fluctuations in the phosphorus concentrations were due to uptake and release by periphyton.

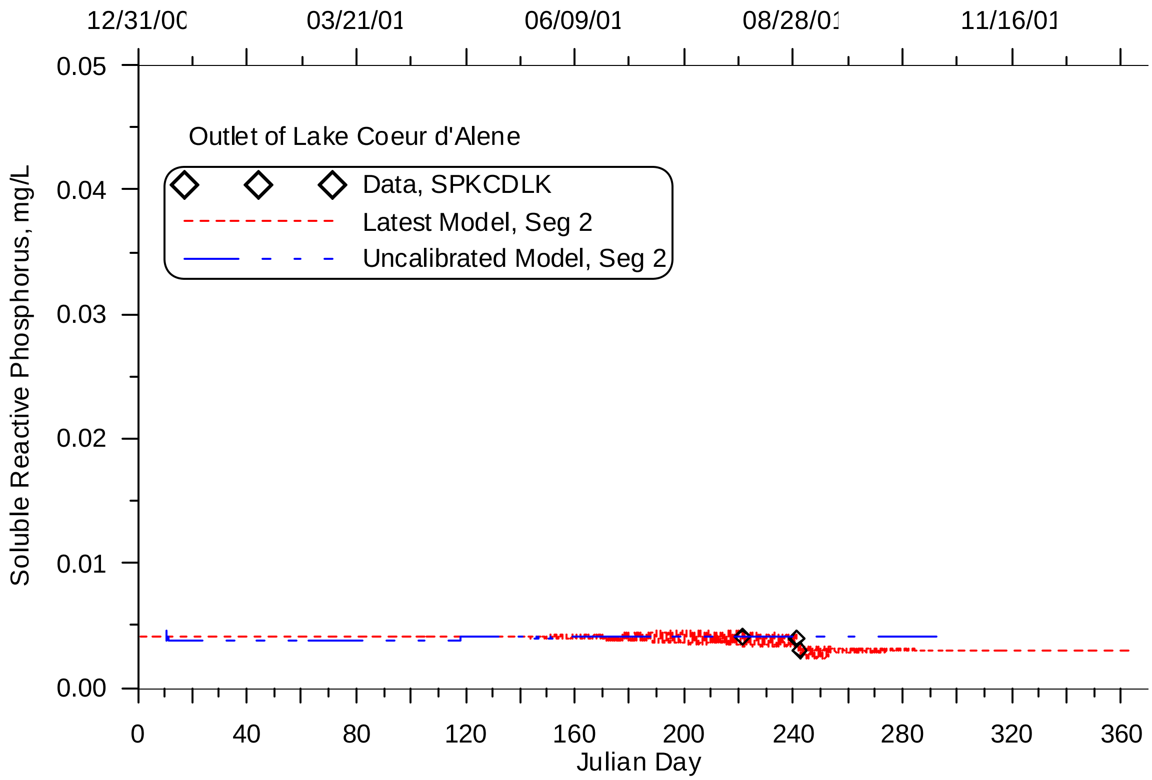


Figure 115: Model-data soluble reactive phosphorus comparison, at Lake Coeur d'Alene outlet, 2001.

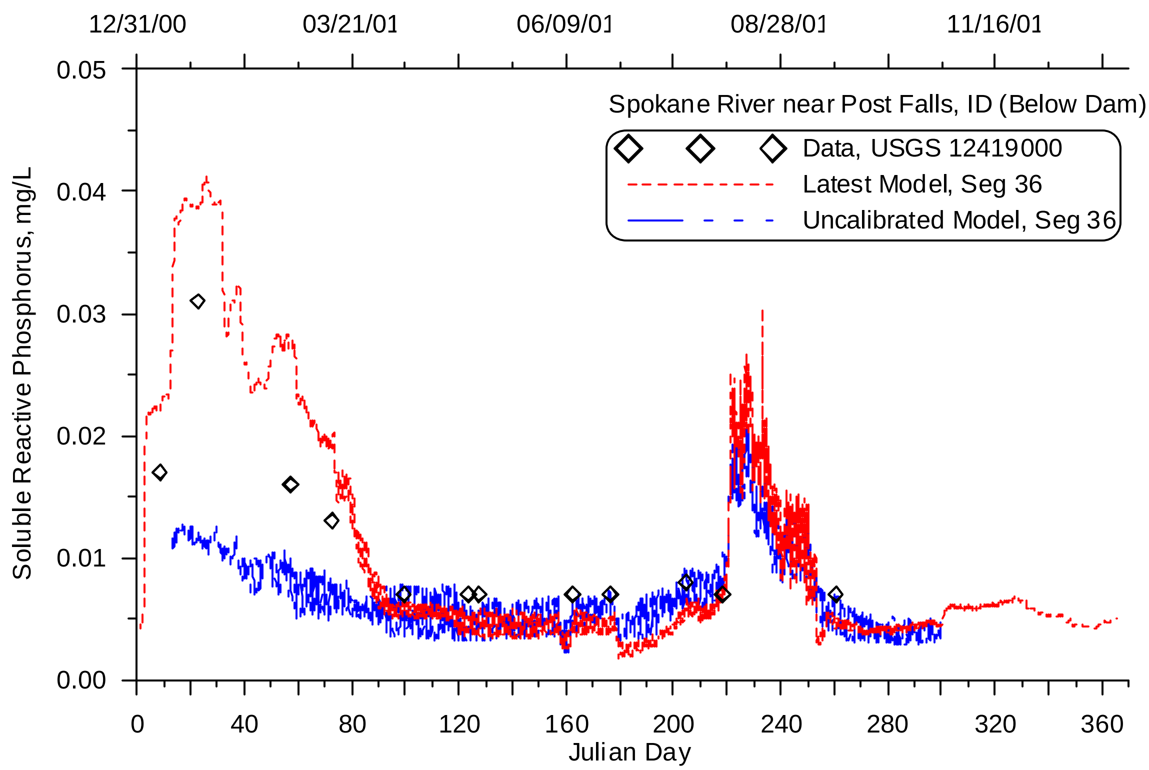


Figure 116: Model-data soluble reactive phosphorus comparison, 0.8 mi downstream of Post Falls Dam, 2001.

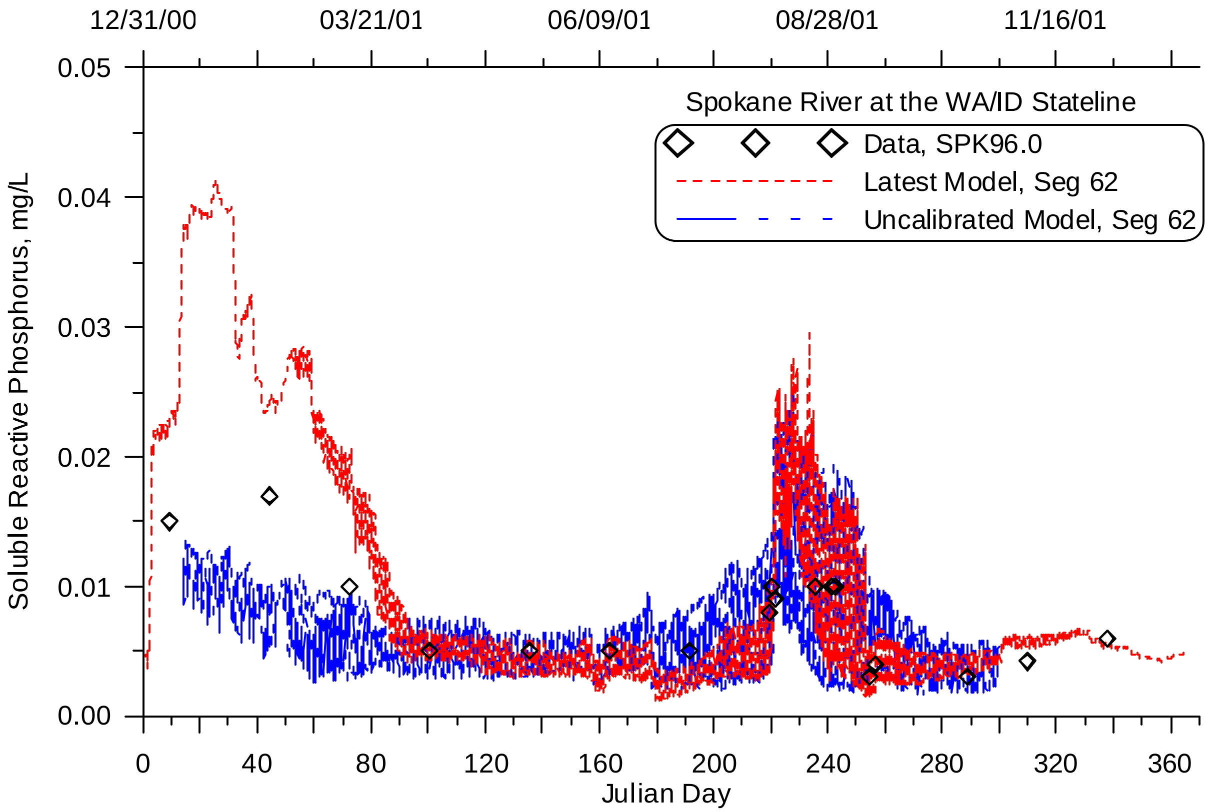


Figure 117: Model-data soluble reactive phosphorus comparison, at the WA/ID State Line, 2001.

Total Phosphorus

Figure 118, Figure 119, and Figure 120show comparisons between model predicted total phosphorus concentration and data at the outlet to Lake Coeur d'Alene (upstream boundary condition), the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. The uncalibrated model results show total phosphorus concentrations higher throughout the system than the latest model results. Diurnal fluctuations in the phosphorus concentrations were due to uptake and release by periphyton.

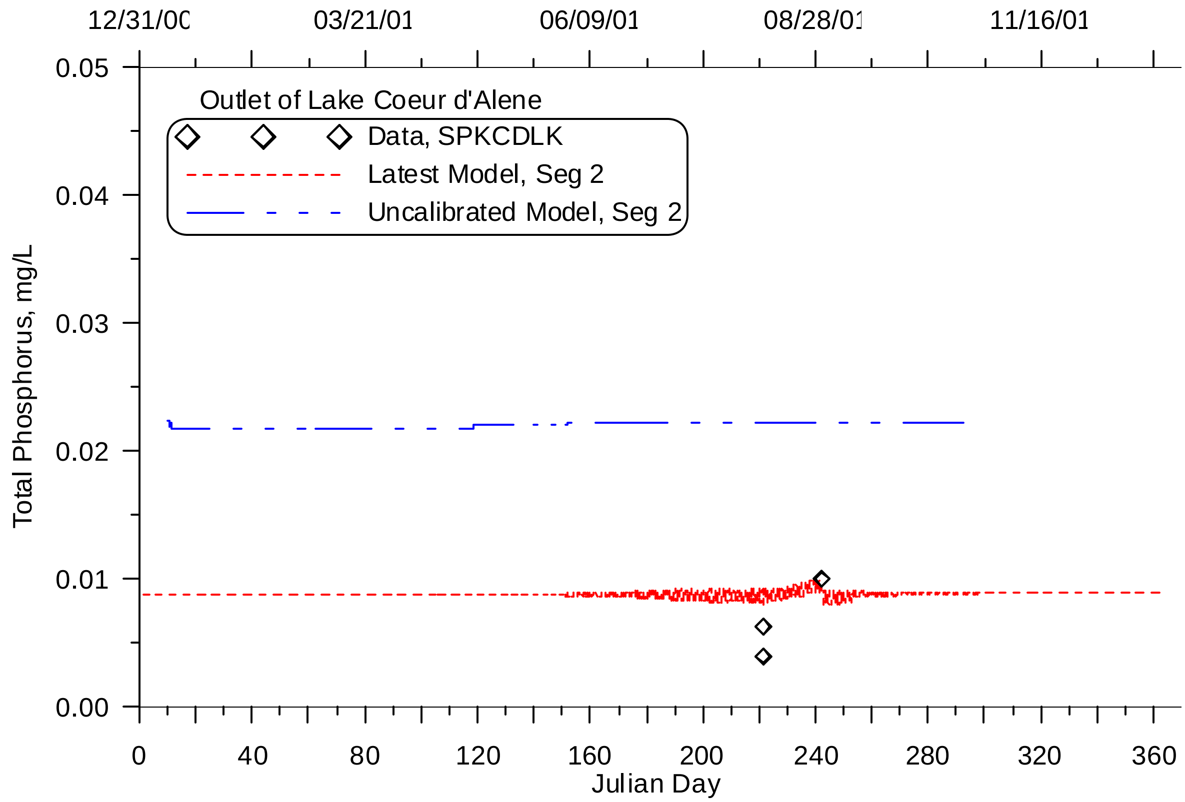


Figure 118: Model-data total phosphorus comparison, at the Lake Coeur d'Alene outlet, 2001.

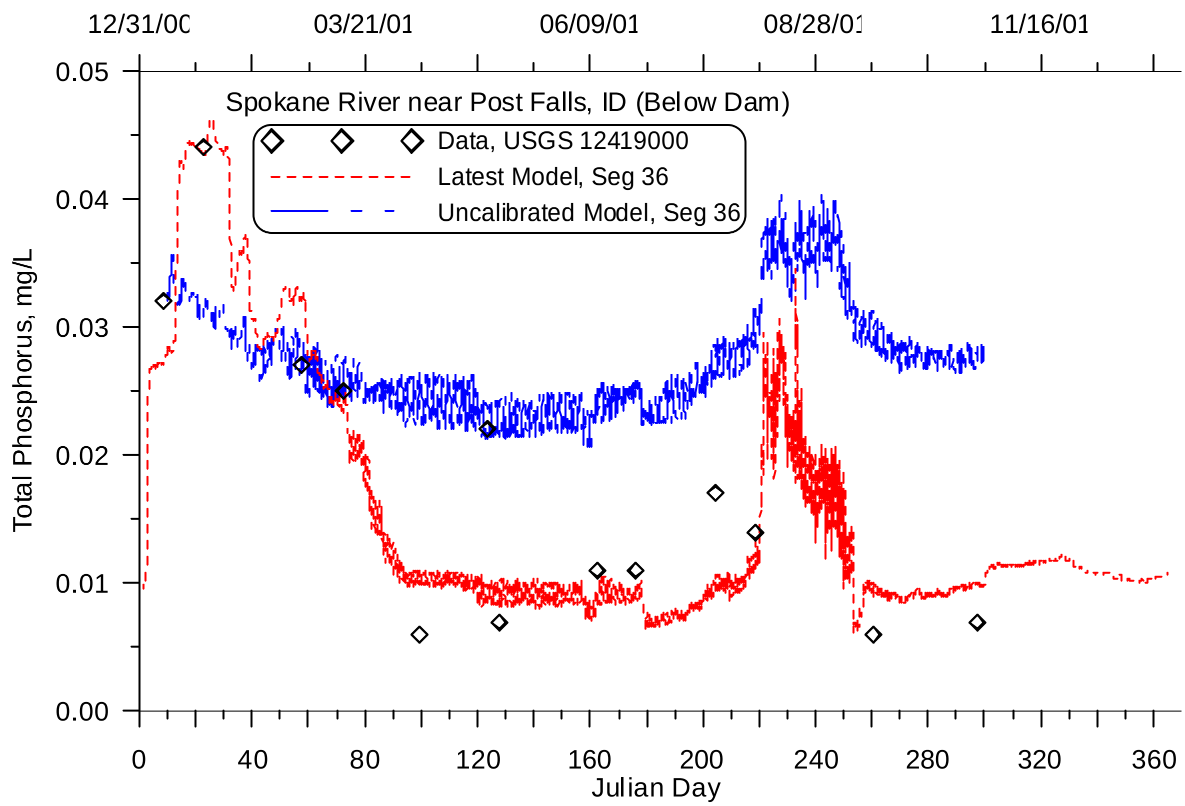


Figure 119: Model-data total phosphorus comparison, 0.8 mi downstream of Post Falls Dam, 2001.

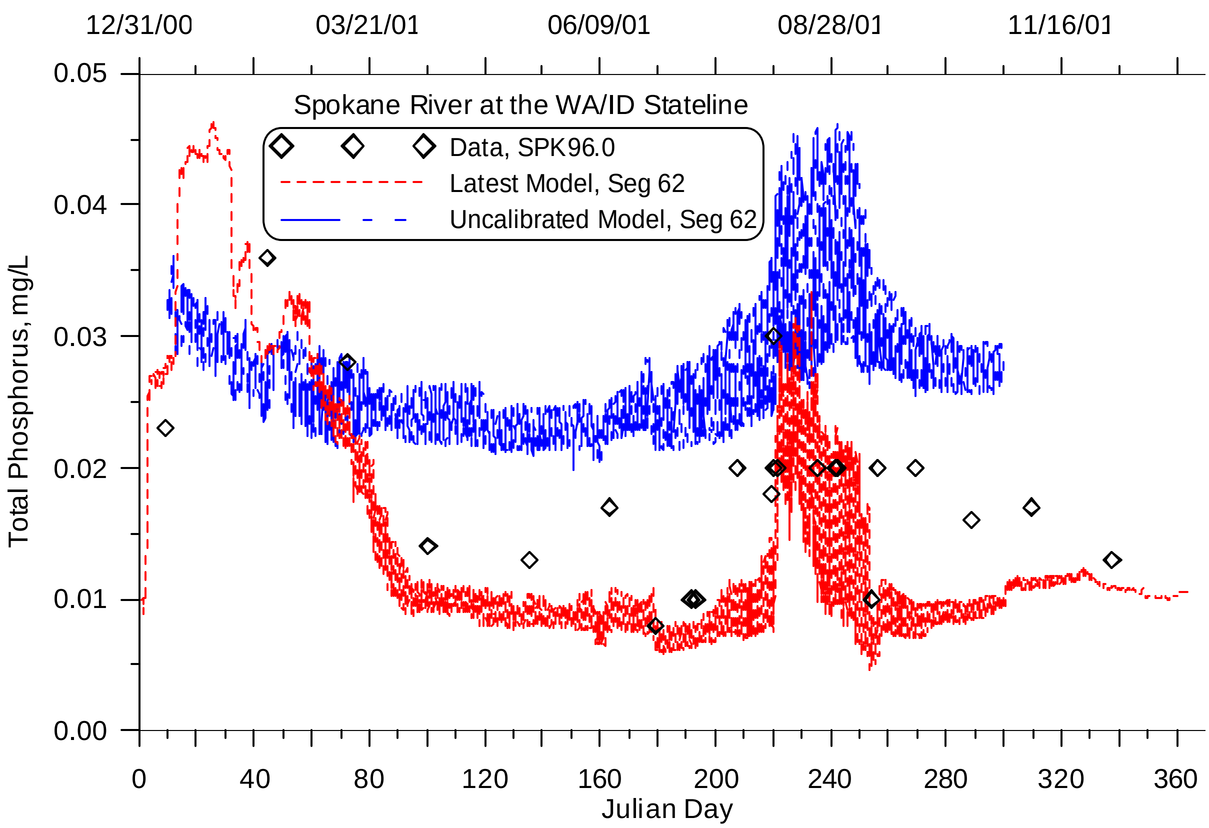


Figure 120: Model-data total phosphorus comparison, at the WA/ID State Line, 2001.

Nitrate-Nitrite

Figure 121, Figure 122, and Figure 123 show comparisons between model predicted nitrate-nitrite nitrogen concentration and data at the outlet to Lake Coeur d'Alene (upstream boundary condition), the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. Figure 121 shows the initial concentration at the upstream boundary condition which had limited data. Figure 122 shows there is good model-data agreement just below the Post Falls Dam in the river. Figure 123 shows there is also relatively good model-data agreement at the State Line with slightly less agreement later in the year due to periphyton uptake. Diurnal fluctuations in the nitrate-nitrite nitrogen concentrations were due to uptake and release by periphyton.

Figure 124 shows the model sensitivity at the WA/ID State Line to changes in the upstream boundary nitrate-nitrite concentration. The calibrated model is shown as the blue dot-dash line where the upstream boundary concentration for nitrate-nitrite was based on the two data points in 2001 (0.01 mg/L). The figure also shows several different lines representing different upstream boundary conditions based on data sets in 2001 and 2004.

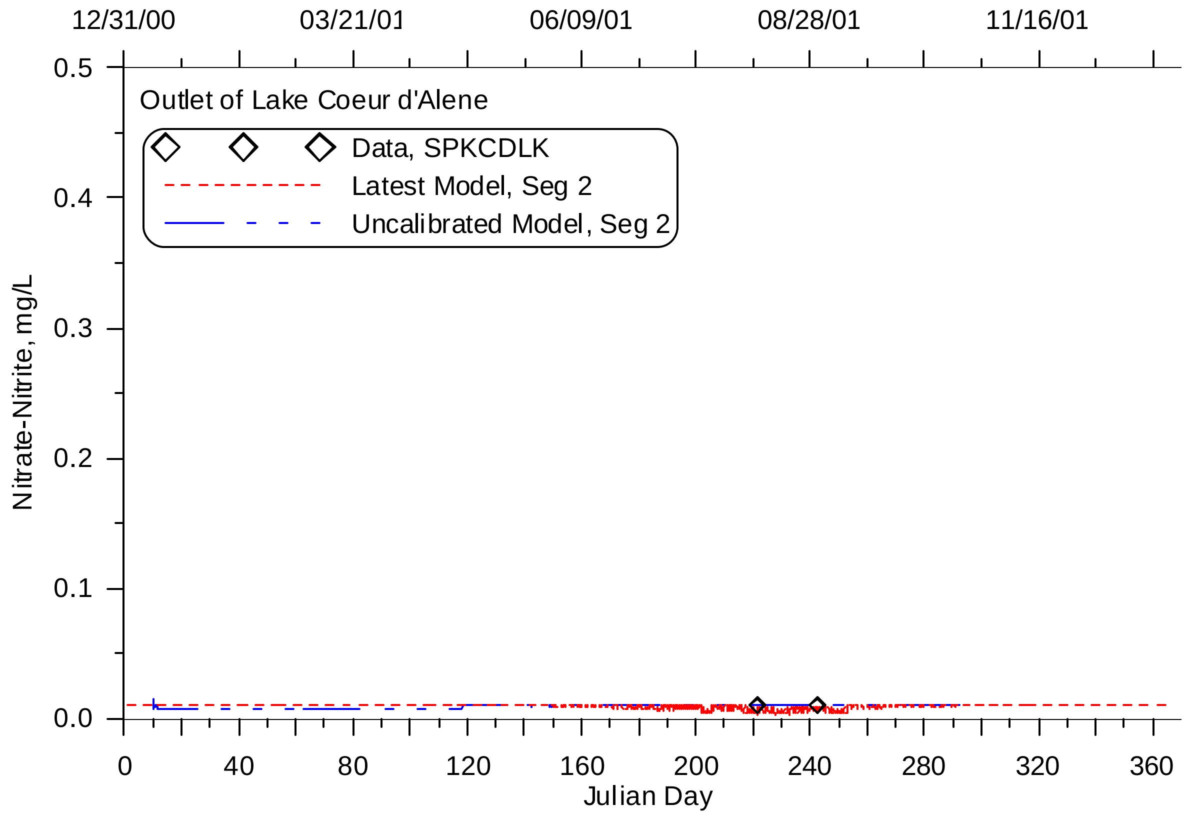


Figure 121: Model-data nitrate-nitrite comparison, at the Lake Coeur d'Alene outlet, 2001.

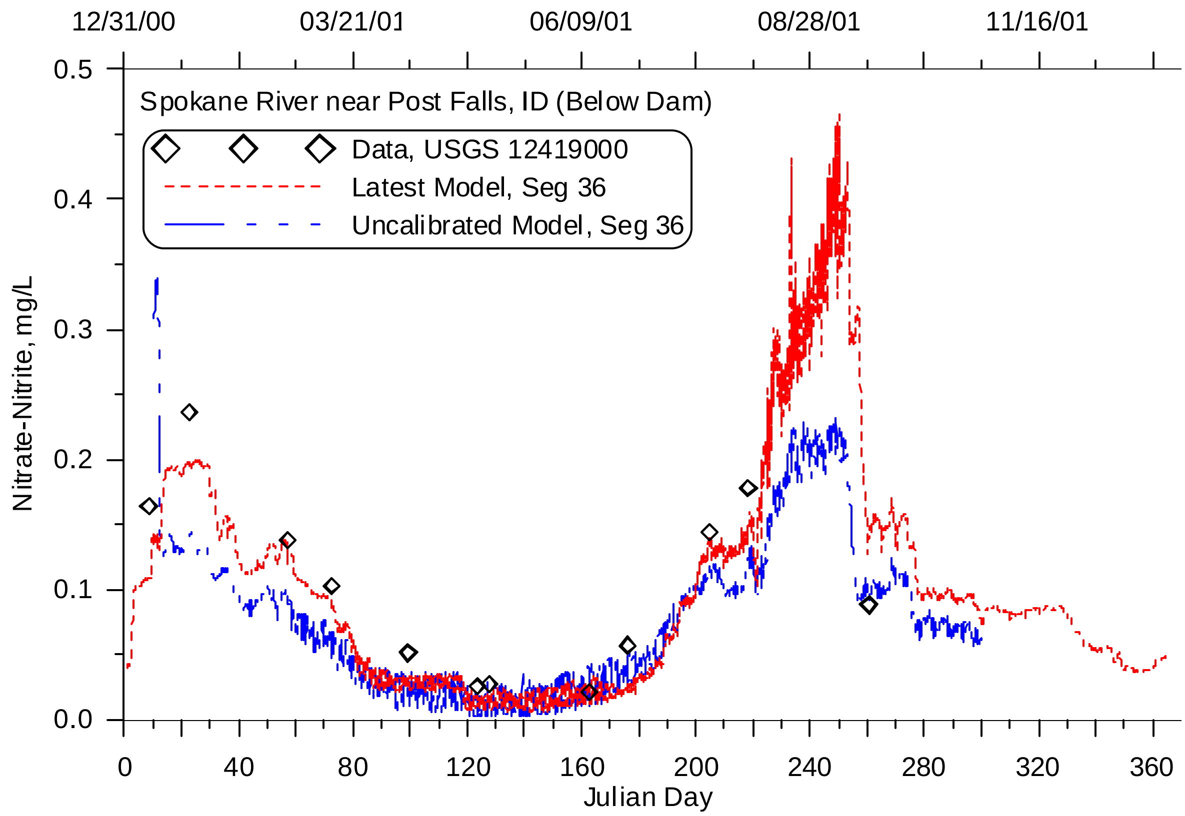


Figure 122: Model-data nitrate-nitrite comparison, 0.8 mi downstream of Post Falls Dam, 2001.

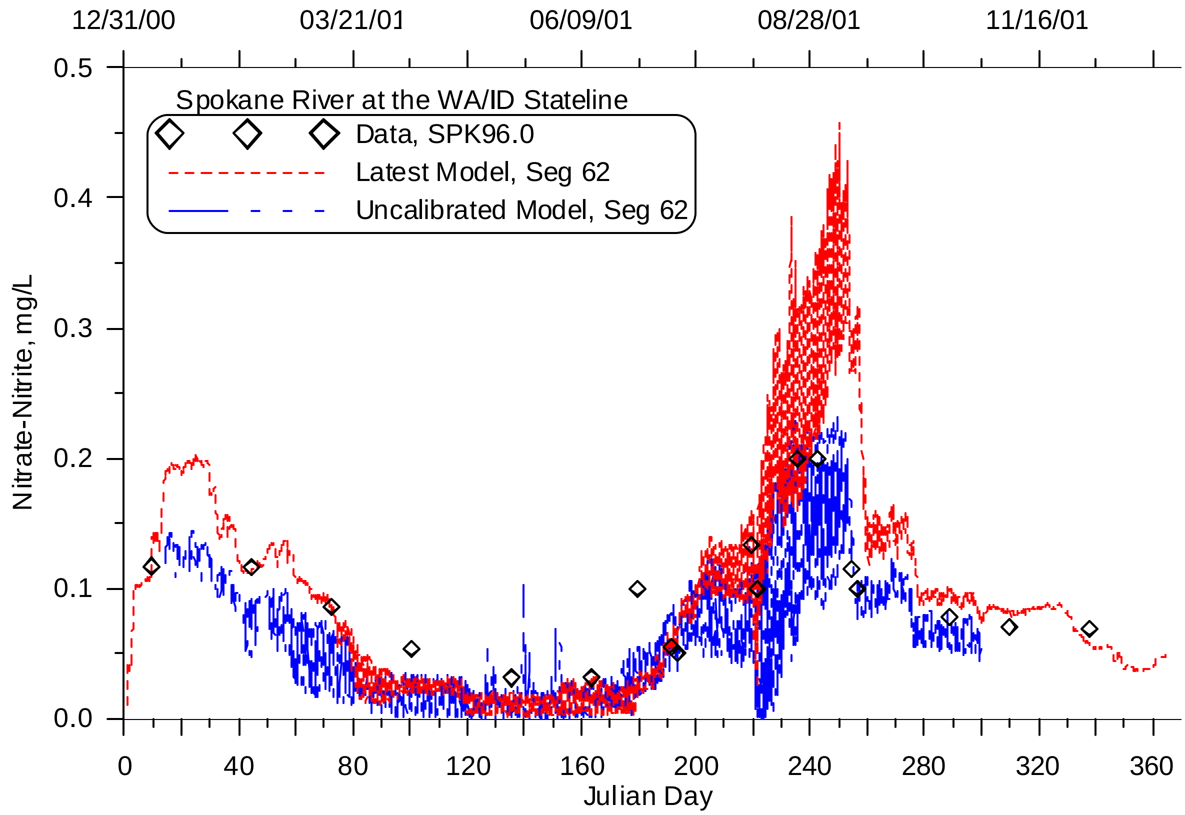


Figure 123: Model-data nitrate-nitrite comparison, at the WA/ID State Line, 2001.

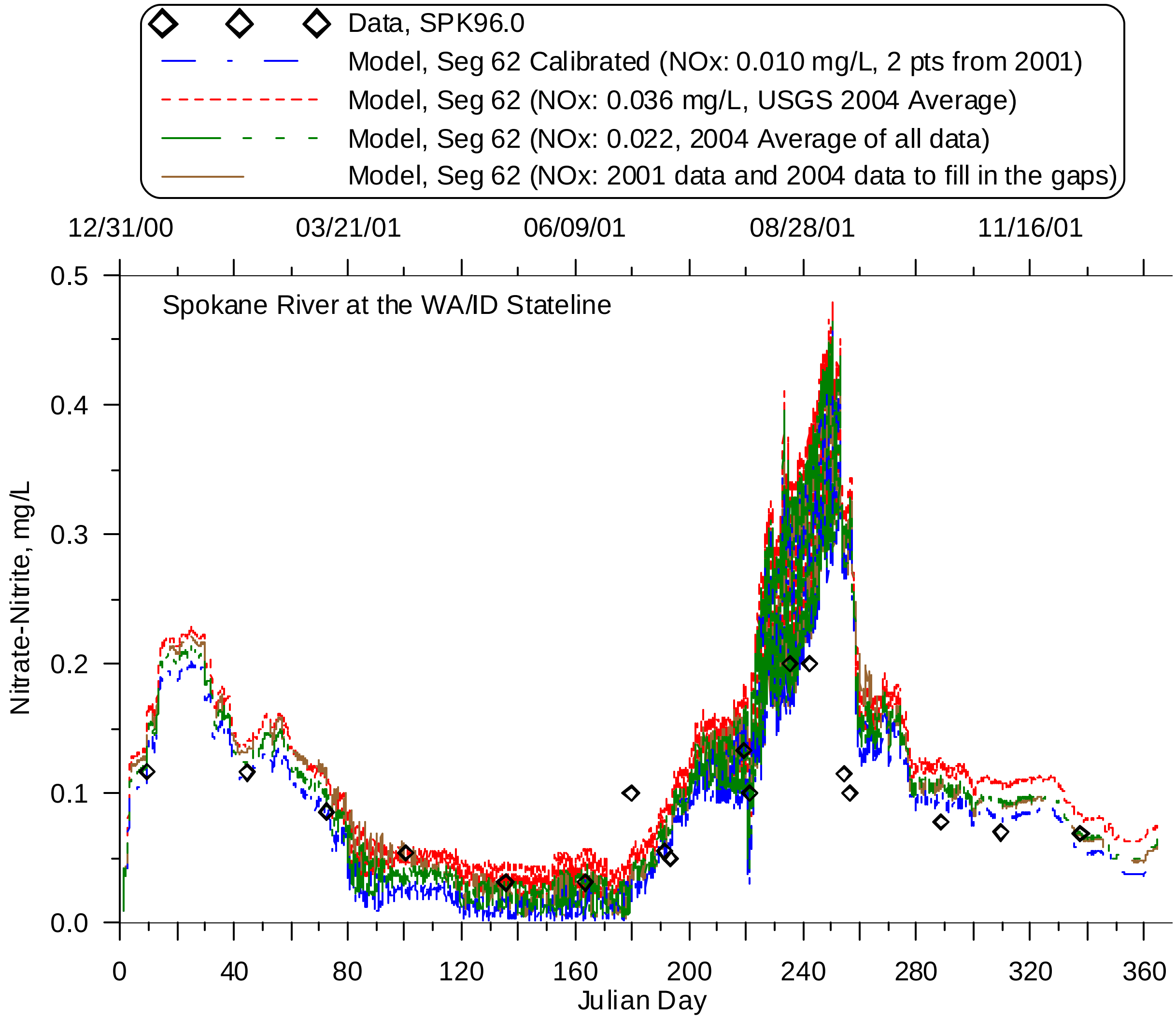


Figure 124: Model sensitivity to nitrate-nitrite concentration at the WA/ID State Line, 2001, based on different upstream boundary conditions

Ammonia

Figure 125, Figure 126, and Figure 127 show comparisons between model predicted ammonia nitrogen concentration and data at the outlet to Lake Coeur d'Alene (upstream boundary condition), the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. The figures show there were very low ammonia concentrations in the river and the model predicted these low-levels.

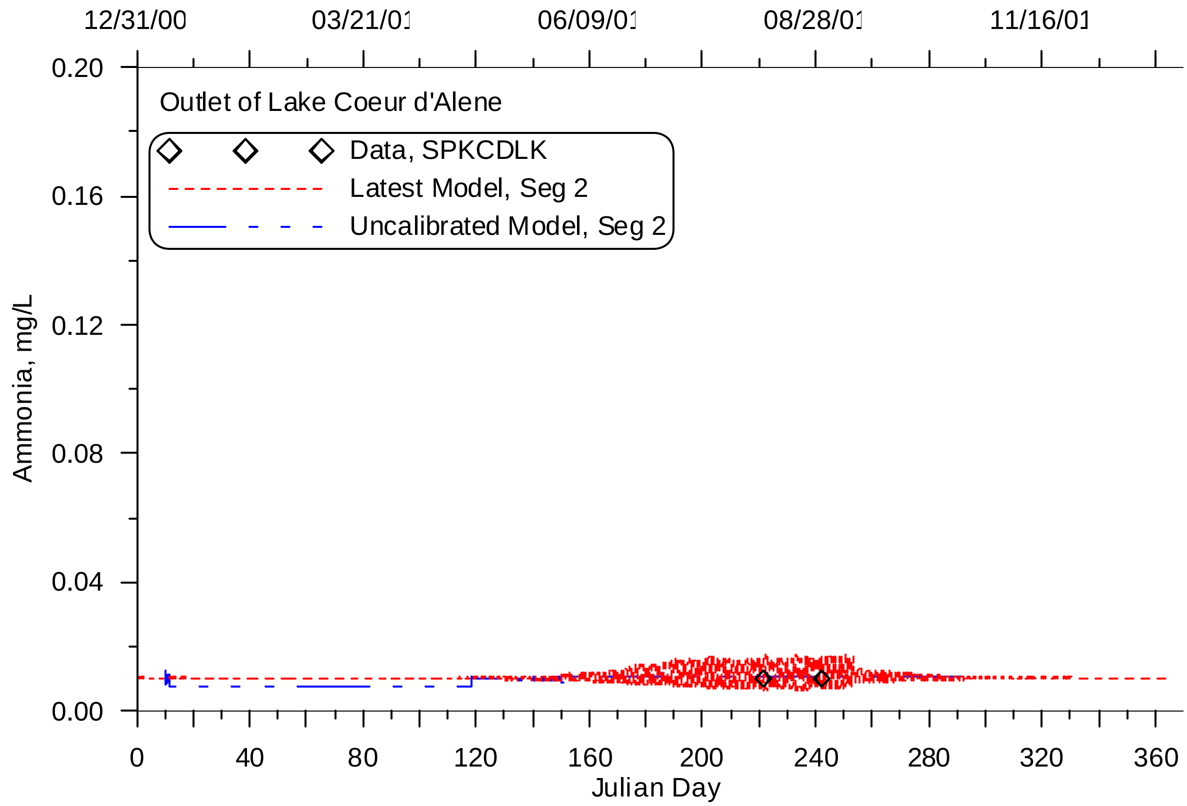


Figure 125: Model-data ammonia comparison, at the Lake Coeur d'Alene outlet, 2001.

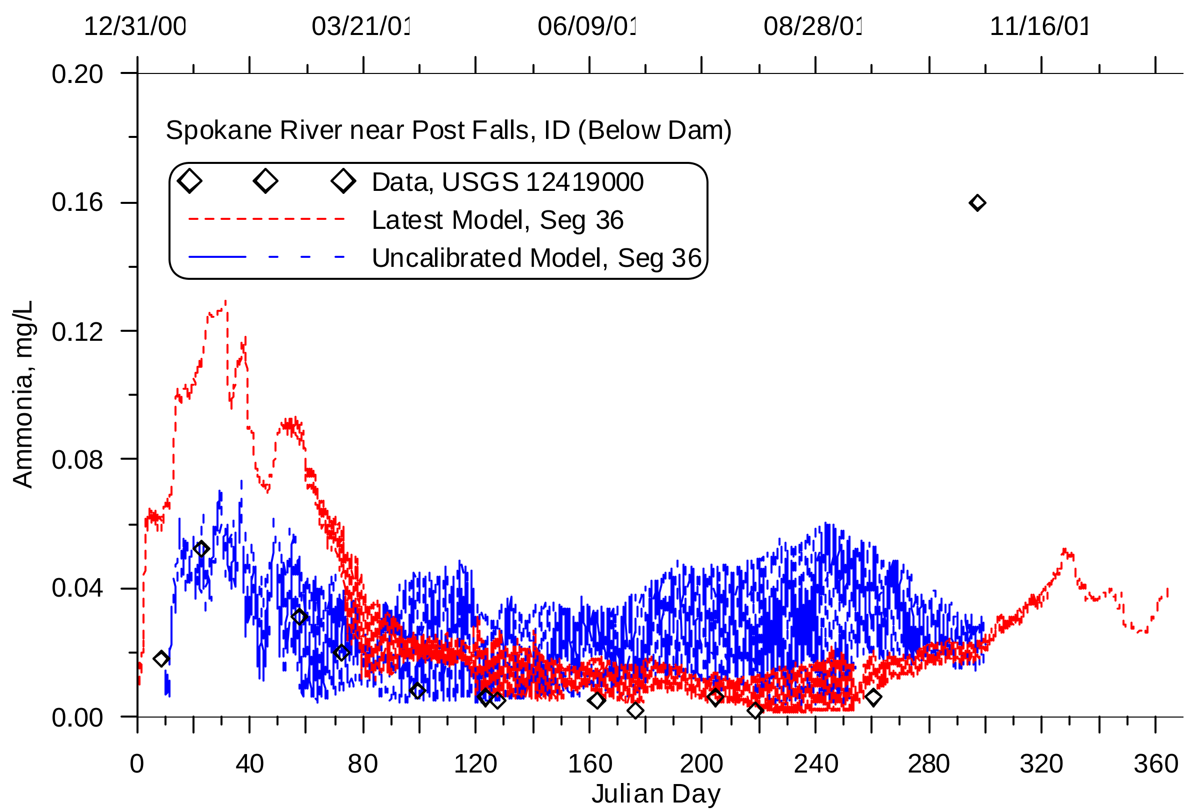


Figure 126: Model-data ammonia comparison, 0.8 mi downstream of Post Falls Dam, 2001.

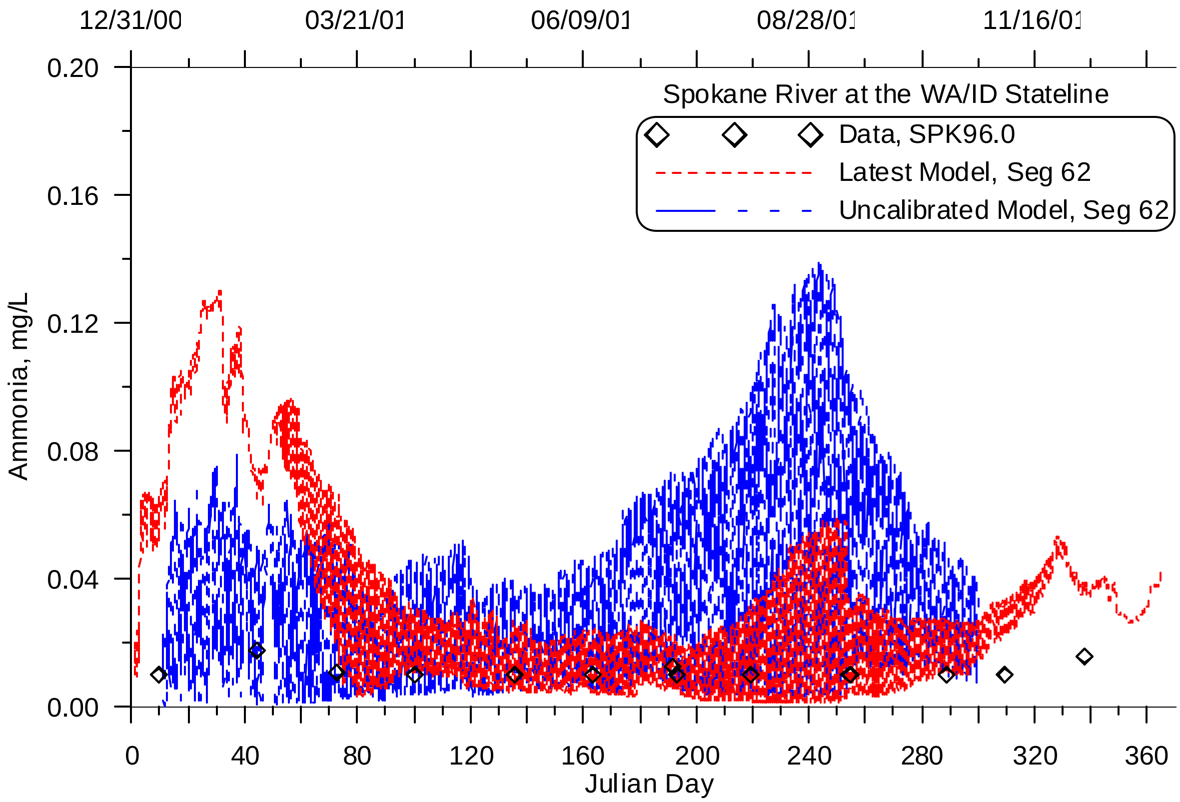


Figure 127: Model-data ammonia comparison, at the WA/ID State Line, 2001.

Total Kjeldahl Nitrogen

Figure 128 and Figure 129 show comparisons between model predicted total Kjeldahl nitrogen concentration and data at the outlet to Lake Coeur d'Alene (upstream boundary condition) and the WA/ID State Line, respectively. Diurnal fluctuations in the total Kjeldahl nitrogen concentrations were due to uptake and release by periphyton

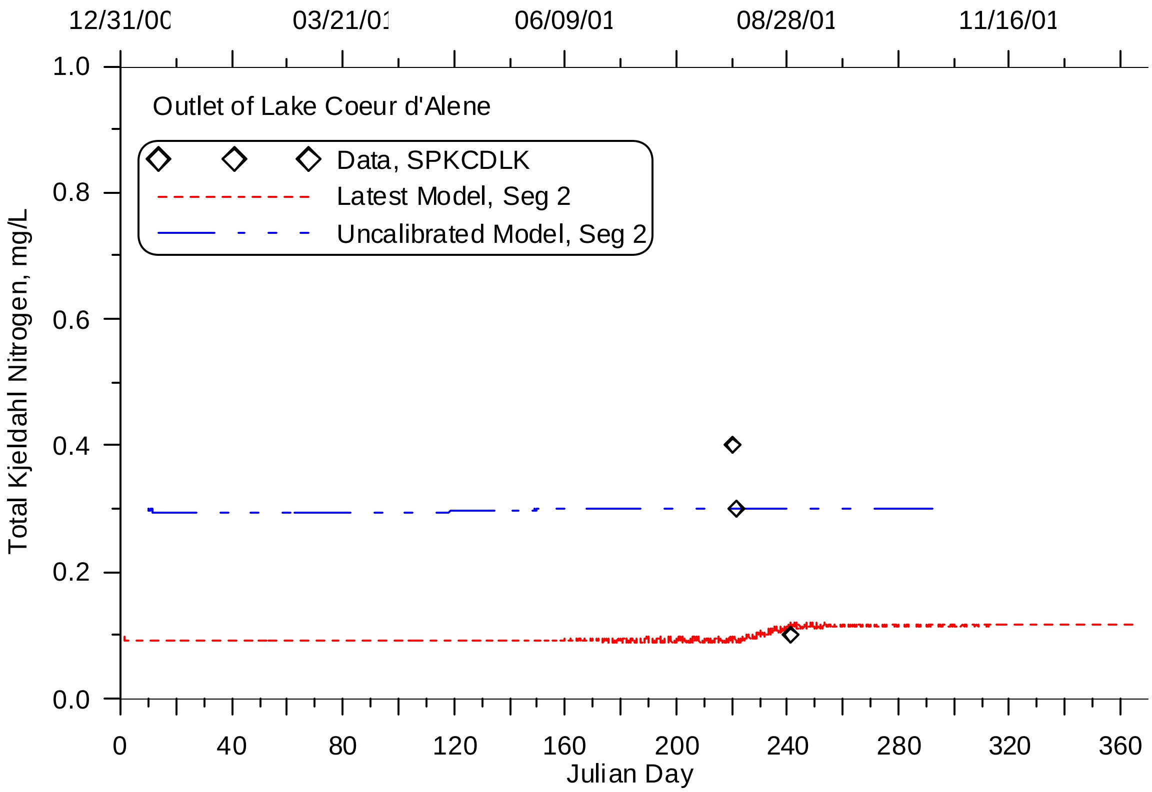


Figure 128: Model-data total kjeldahl nitrogen comparison, at the Lake Coeur d'Alene outlet, 2001.

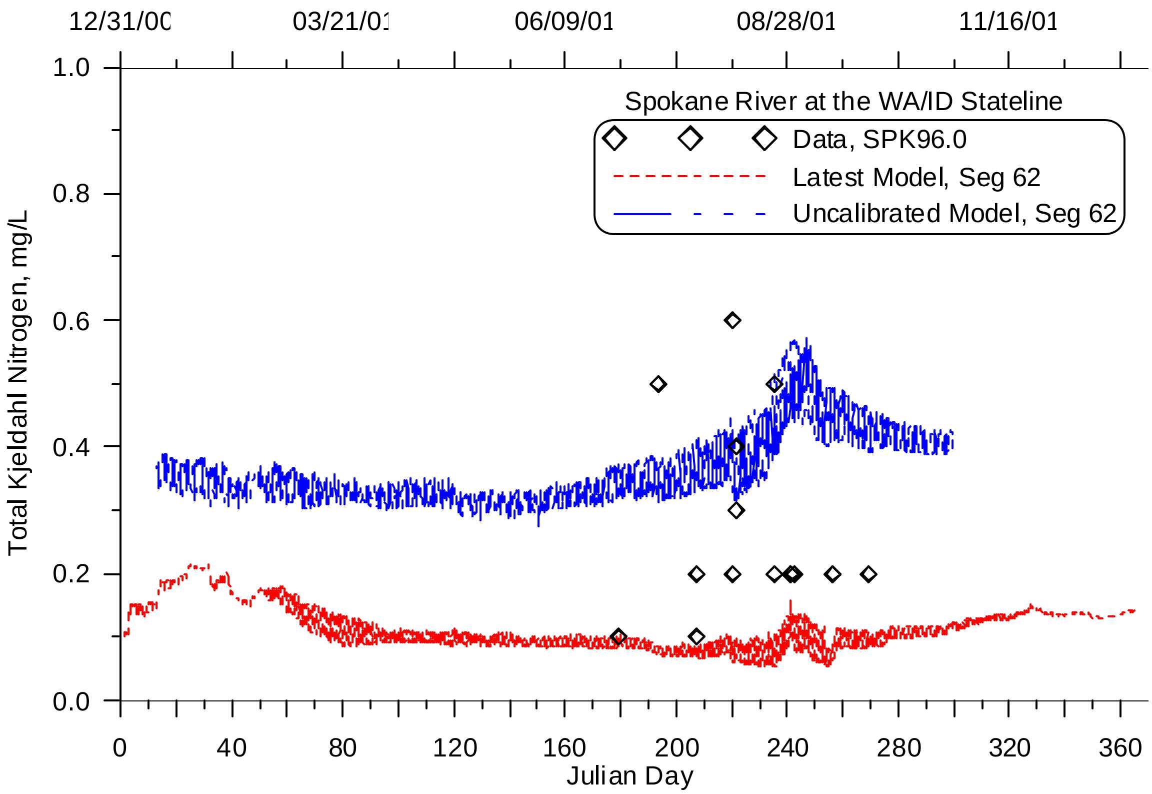


Figure 129: Model-data total kjeldahl nitrogen comparison, at the WA/ID State Line, 2001.

Total Persulfate Nitrogen

Figure 130 and Figure 131 show comparisons between model predicted total persulfate nitrogen concentration and data at the outlet to Lake Coeur d'Alene (upstream boundary condition) and the WA/ID State Line, respectively. Figure 130 shows the concentration at the upstream boundary condition was slightly higher than the data. The increased concentration was due to introducing 1.0 mg/L of refractory dissolved organic matter that also has a nutrient fraction. Diurnal fluctuations in the total persulfate nitrogen concentrations were due to uptake and release by periphyton.

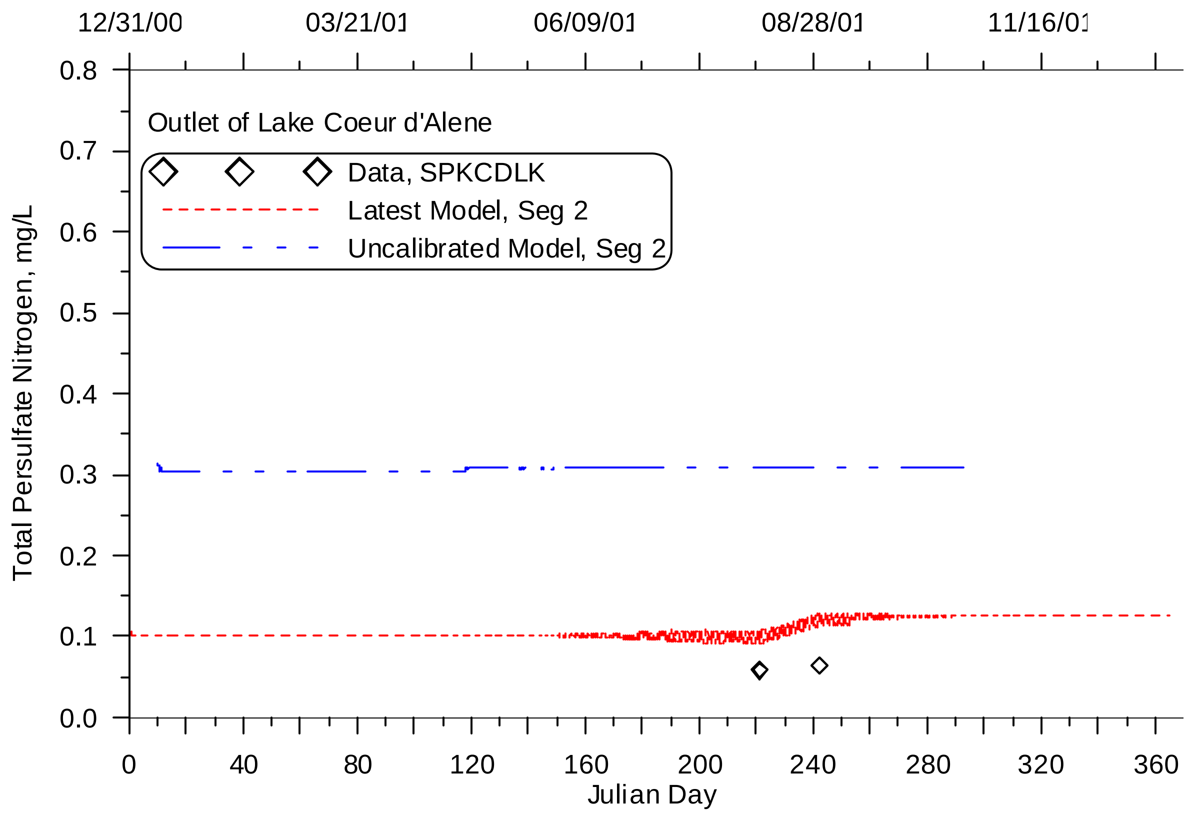


Figure 130: Model-data total persulfate nitrogen comparison, at the Lake Coeur d'Alene outlet, 2001.

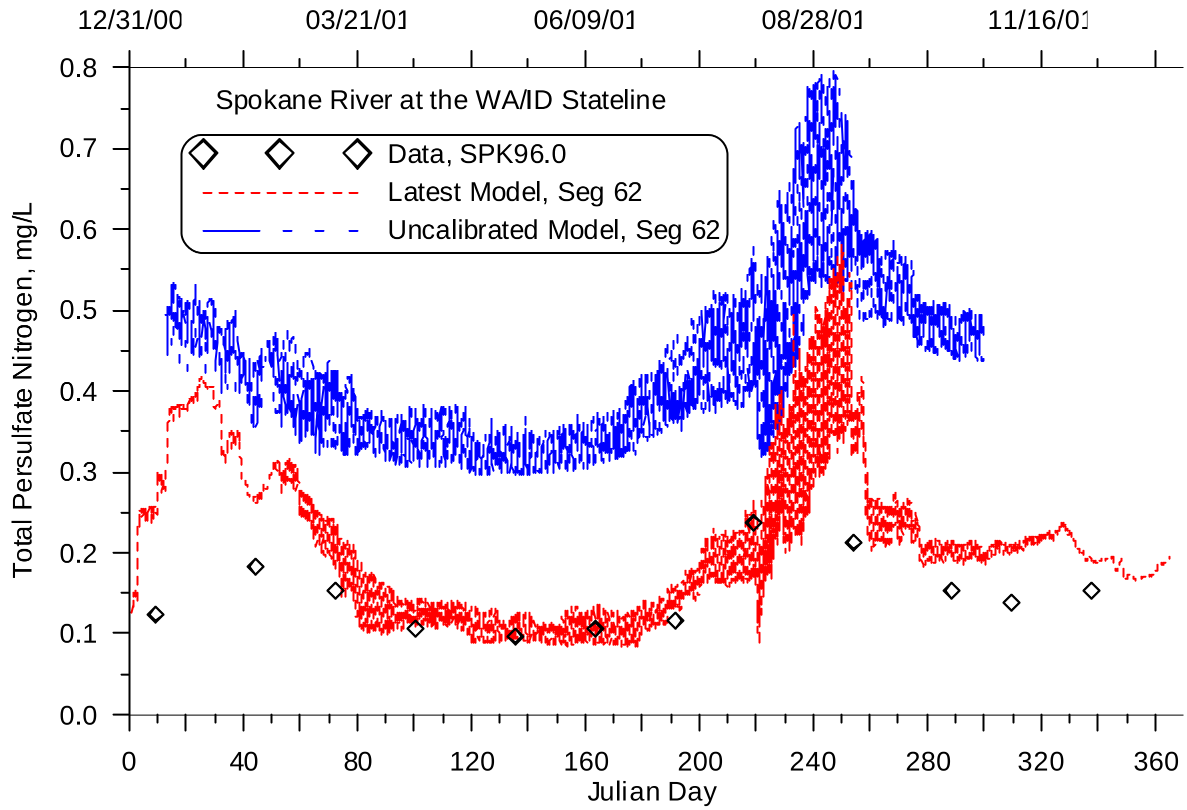


Figure 131: Model-data total persulfate nitrogen comparison, at the WA/ID State Line, 2001.

pH

Figure 132, Figure 133, and Figure 134 show comparisons between model predicted pH and data at the outlet to Lake Coeur d'Alene, the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. Figure 132 shows the inflow pH at the upstream boundary condition, which was more variable than the few data points plotted. The pH upstream boundary condition was developed using historical data and discussed above. Figure 133 and Figure 134 show good model-data agreement downstream in the river with increased diurnal fluctuations due to growth and respiration of periphyton, which shows up in both the data and model predictions.

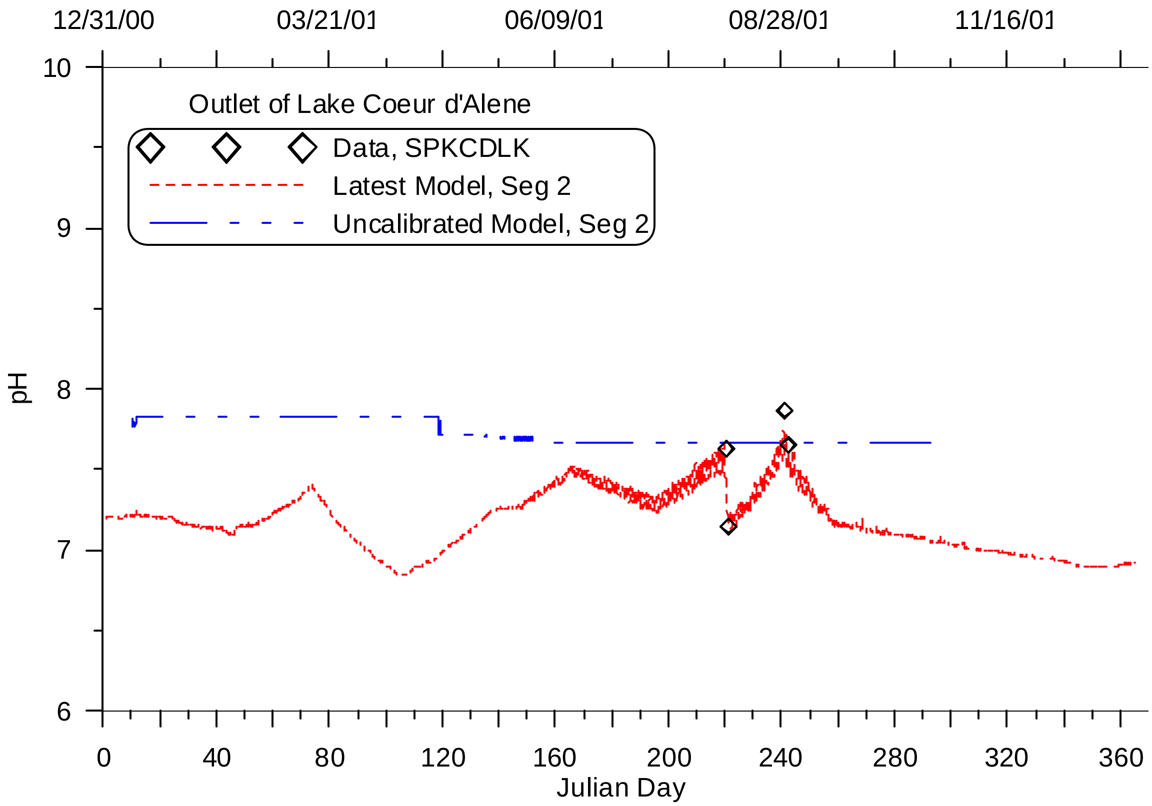


Figure 132: Model-data pH comparison, at the Lake Coeur d'Alene outlet, 2001.

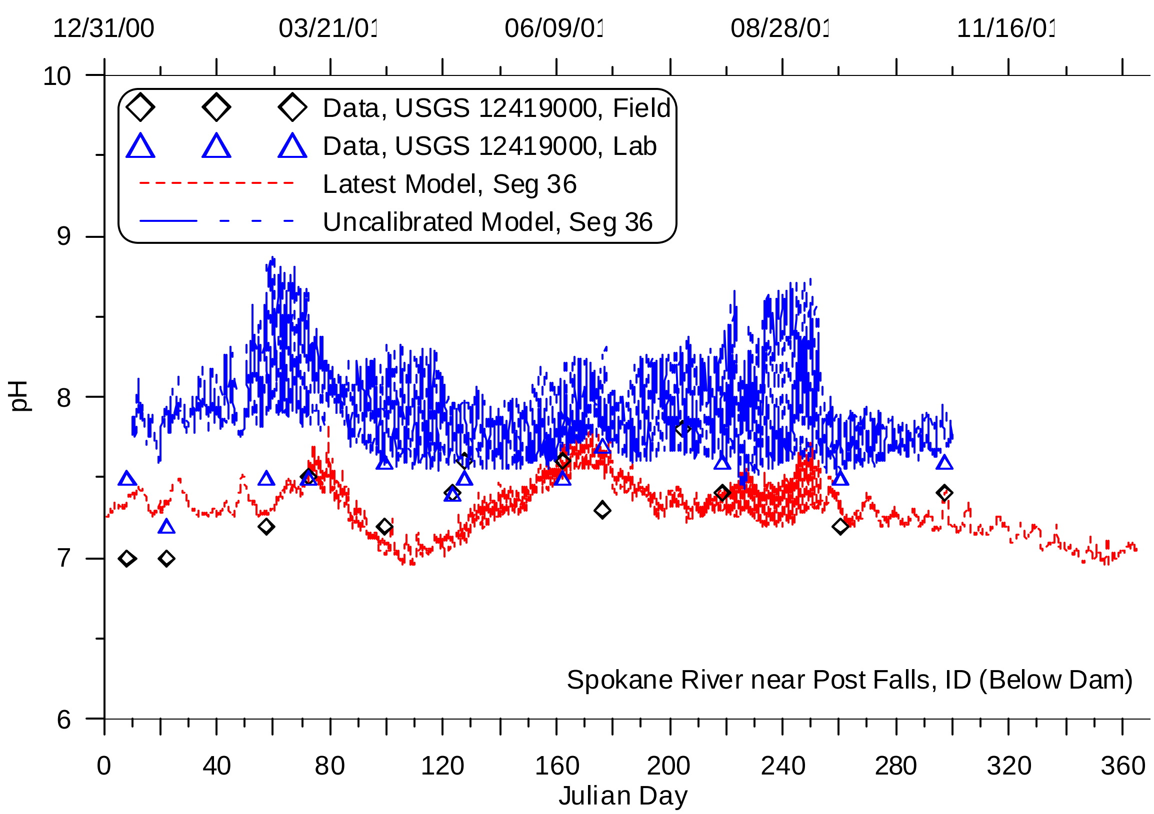


Figure 133: Model-data pH comparison, 0.8 mi downstream of Post Falls Dam, 2001.

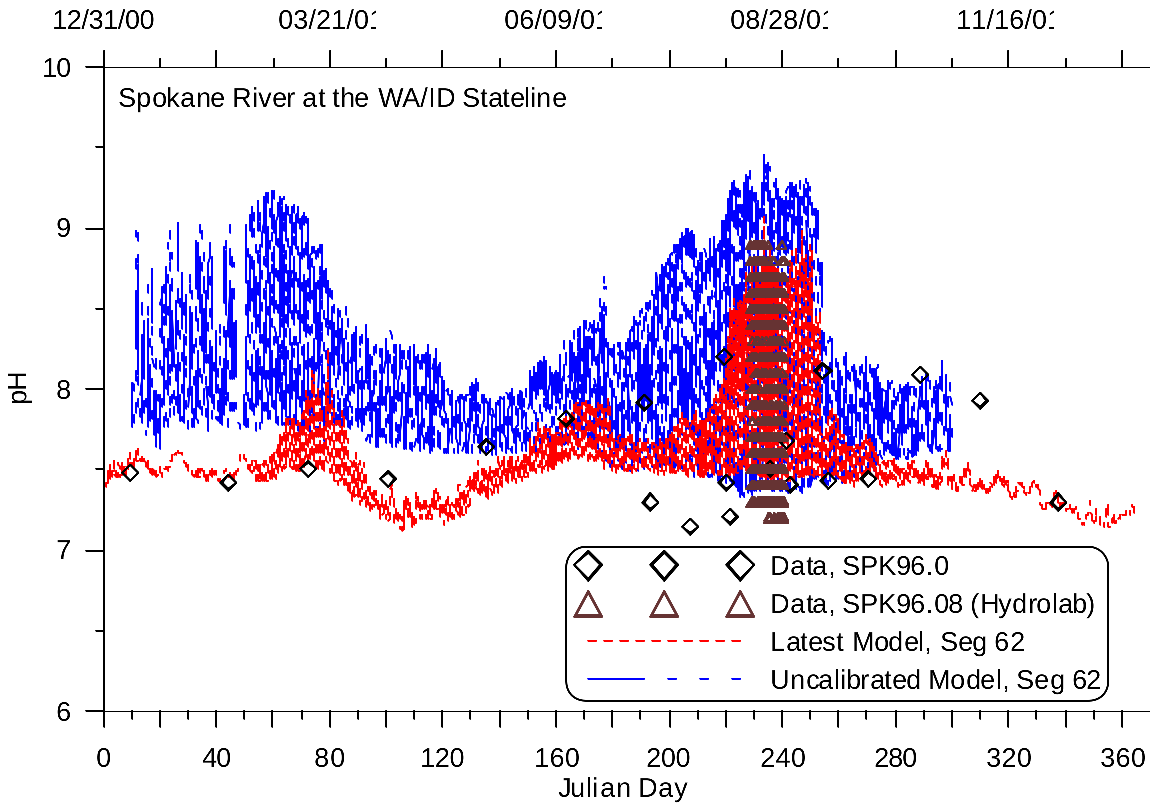


Figure 134: Model-data pH comparison, at the WA/ID State Line, 2001.

Dissolved Oxygen

Figure 135, Figure 136, and Figure 137 show comparisons between model predicted dissolved oxygen concentrations and data at the outlet to Lake Coeur d'Alene (upstream boundary condition), the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. Figure 135 shows the inflow dissolved oxygen concentration at the upstream boundary condition, which was based on the dissolved oxygen saturation and historical data. Diurnal fluctuations in the dissolved oxygen concentrations were due to growth and respiration of periphyton.

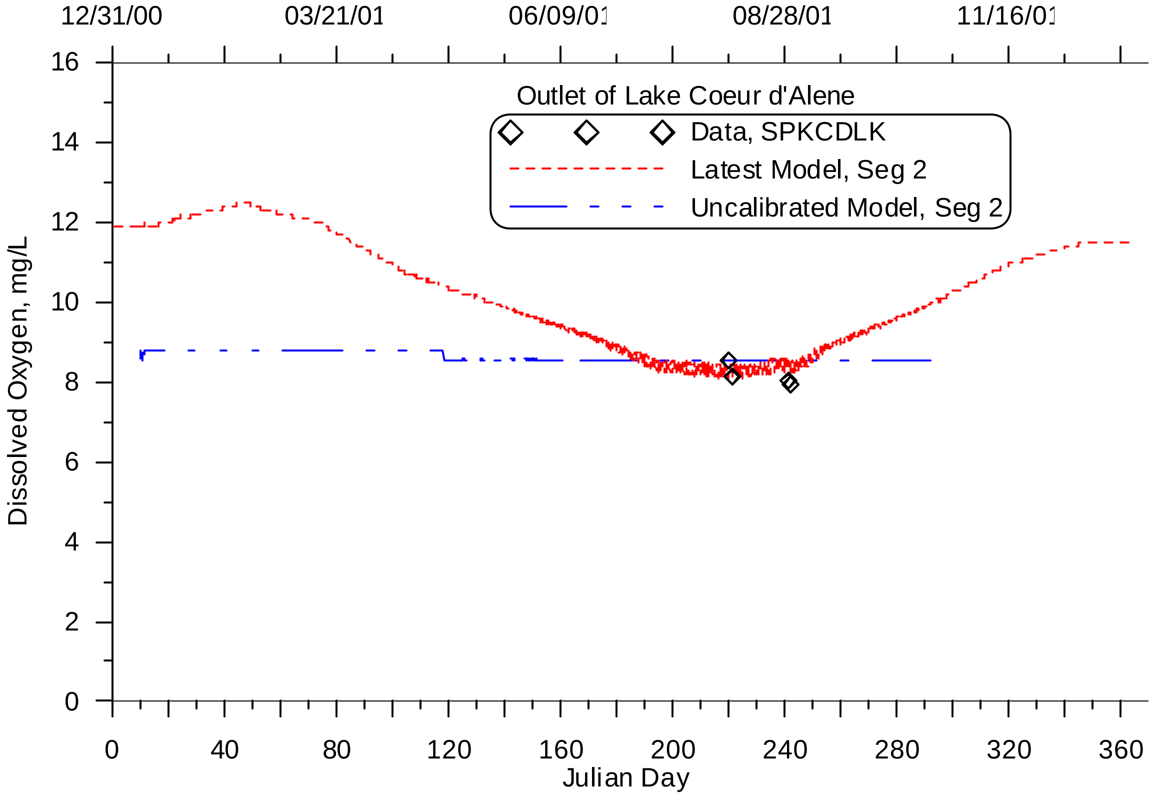


Figure 135: Model-data dissolved oxygen comparison, at the Lake Coeur d'Alene outlet, 2001.

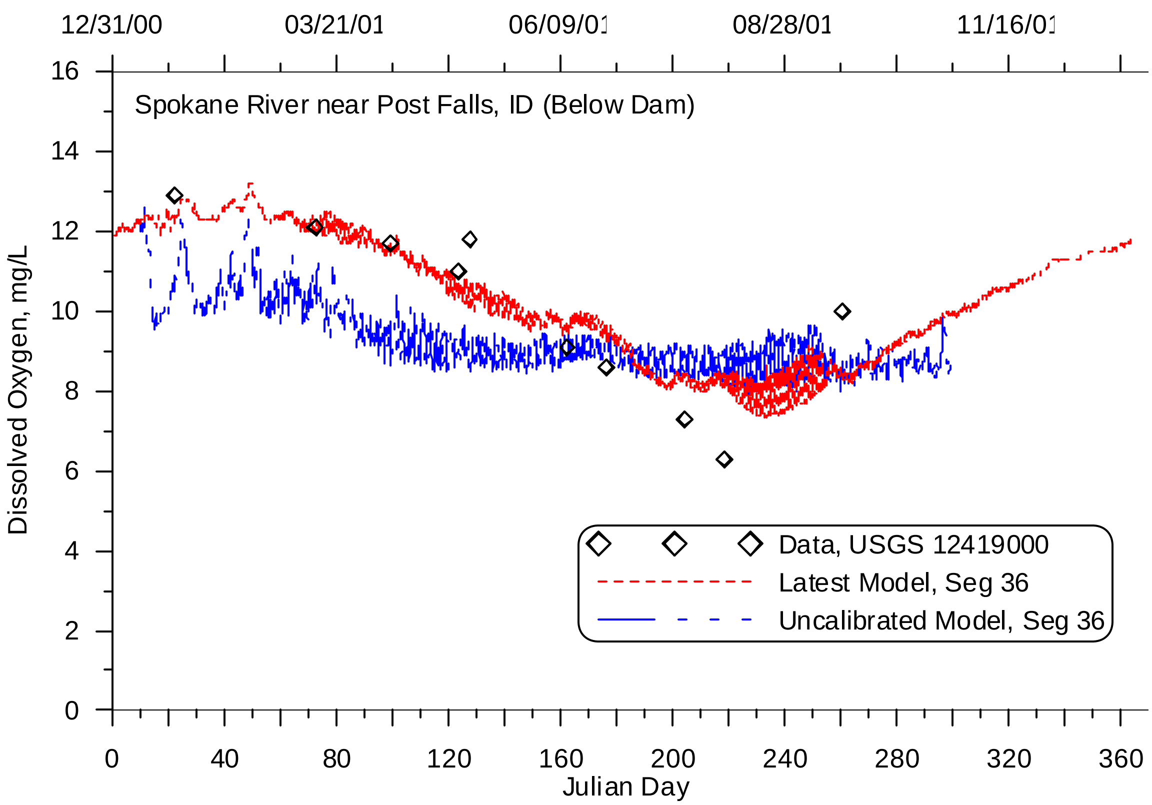


Figure 136: Model-data dissolved oxygen comparison, 0.8 mi downstream of Post Falls Dam, 2001.

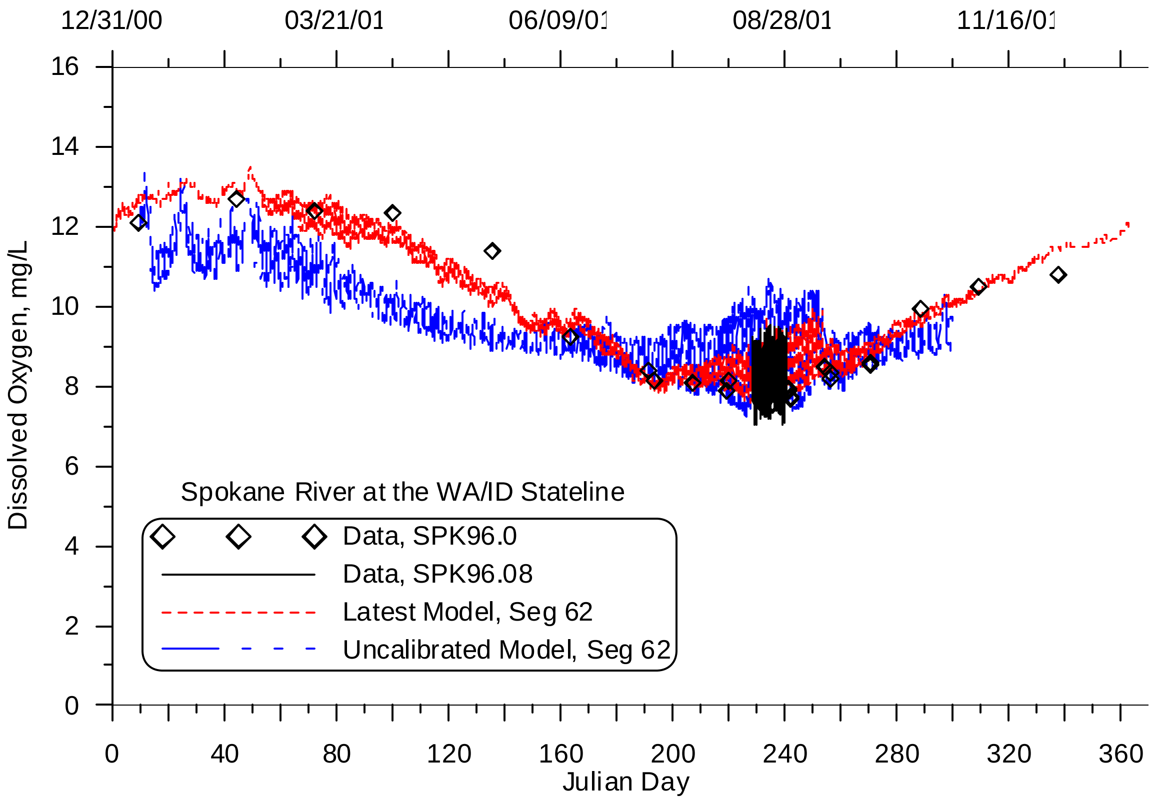


Figure 137: Model-data dissolved oxygen comparison, at the WA/ID State Line, 2001.

Periphyton

Figure 138 shows comparisons between model predicted periphyton biomass concentration and data at the WA/ID State Line. The data in the figure represents the average biomass from several samples collected at different depths on each of two days. The figure indicates the model predicted biomass may be under predicting compared to the data as expected. The periphyton biomass concentration data varied between 13 and 280 g/m^2 in August and between 20 and 557 g/m^2 in September. The model output presents the average (active) periphyton biomass concentration across the model segment. Discrepancies in model predictions of periphyton and field data are discussed in the Section on 'Periphyton Data'.

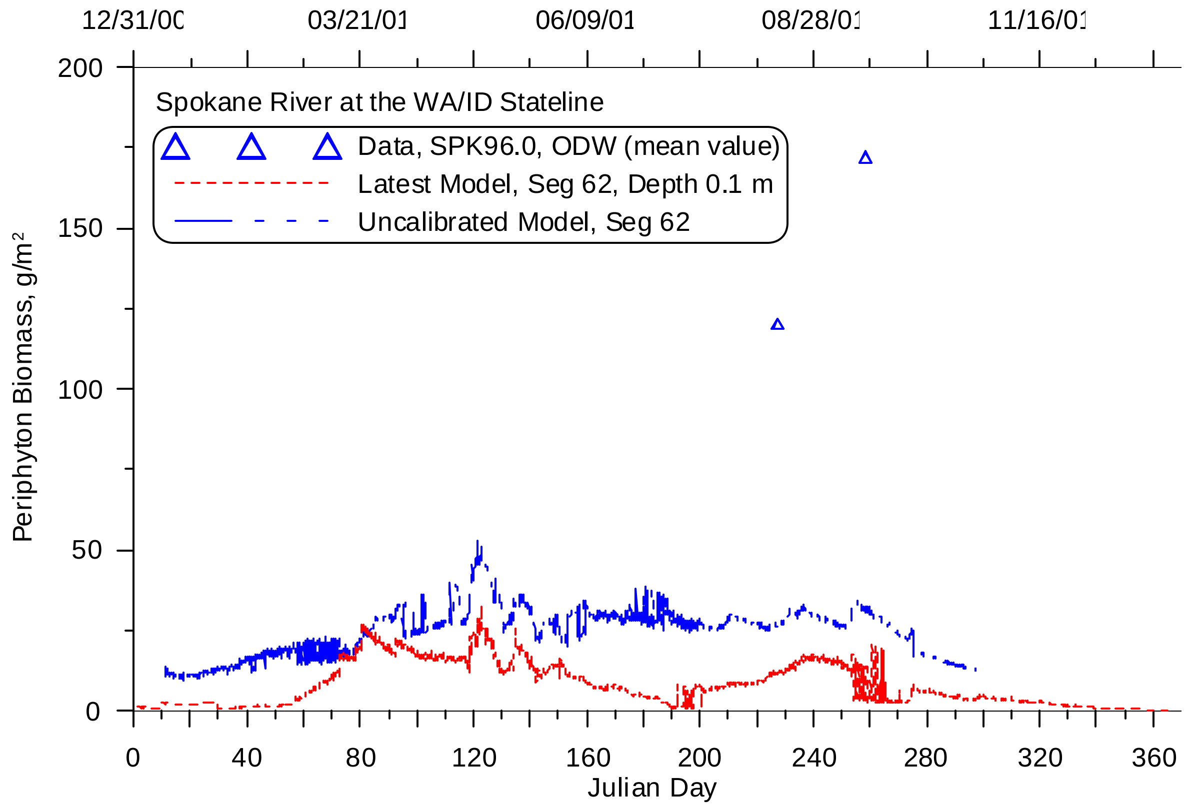


Figure 138: Model-data periphyton biomass comparison, at the WA/ID State Line, 2001.

Chlorophyll a

Figure 139 and Figure 140 show comparisons between model predicted chlorophyll a concentrations and data at the outlet to Lake Coeur d'Alene and the WA/ID State Line, respectively. The two figures show there is good model-data agreement and overall chlorophyll a concentration are low. CE-QUAL-W2 models algae using dry weight concentration. Model predicted concentrations were converted to chlorophyll a by assuming a ratio of 130 mg/l algae to 1 µg/l chlorophyll a.

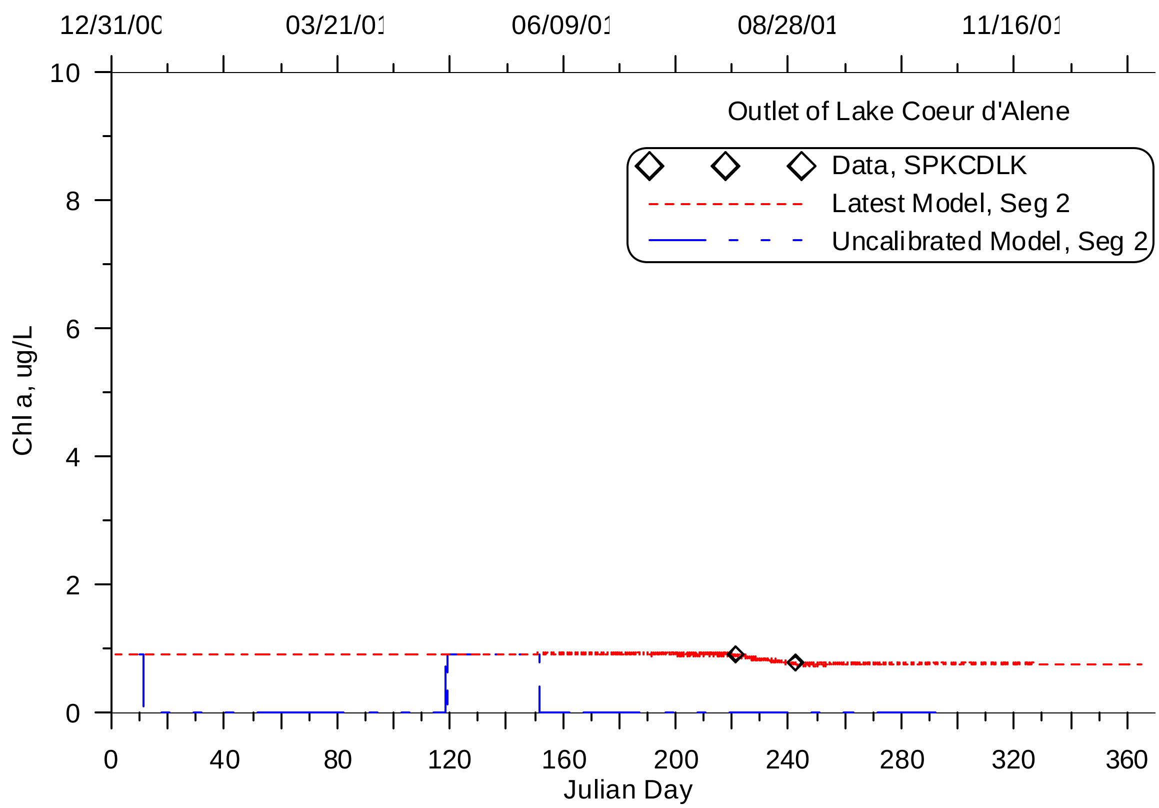


Figure 139: Model-data chlorophyll a comparison, at the Lake Coeur d'Alene outlet, 2001.

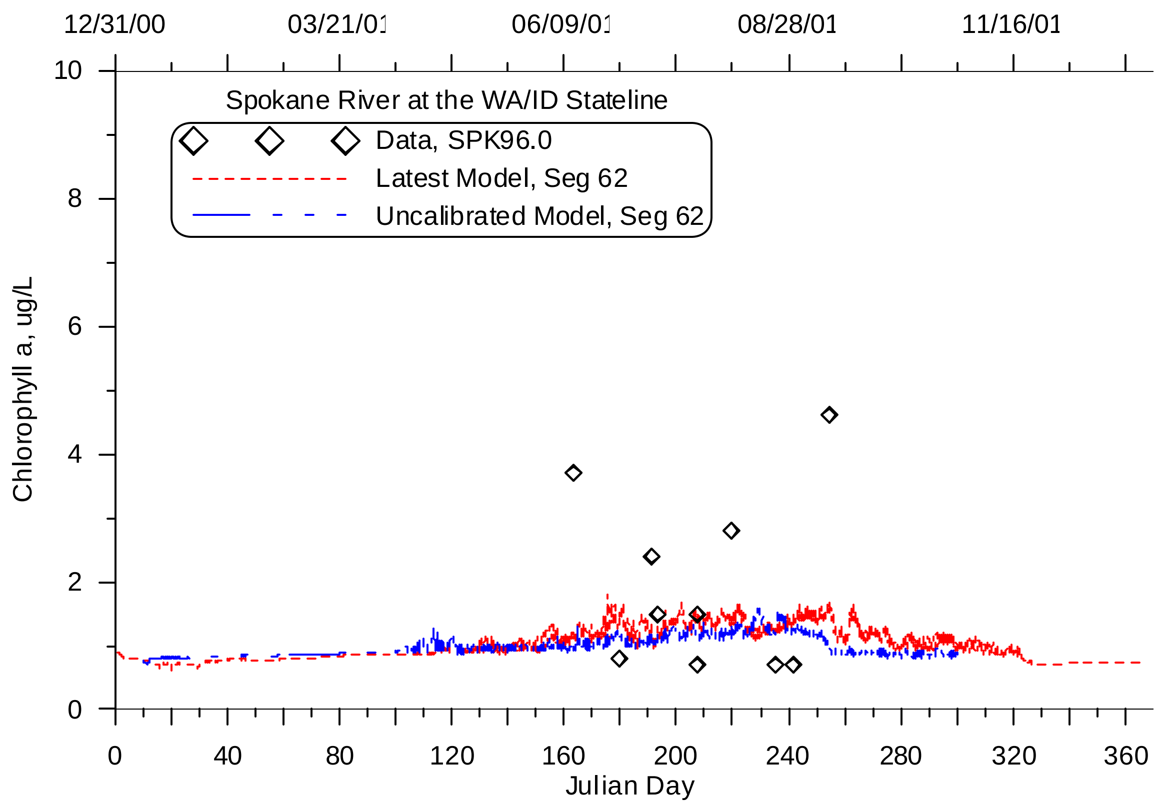


Figure 140: Model-data chlorophyll a comparison, at the WA/ID State Line, 2001.

Carbonaceous Biochemical Oxygen Demand

Figure 141 and Figure 142 show comparisons between model predicted ultimate carbonaceous biochemical oxygen demand ($CBOD_u$) concentrations and data at the outlet to Lake Coeur d'Alene and the WA/ID State Line, respectively.

Figure 141 shows the inflow carbonaceous biochemical oxygen demand concentrations at the upstream boundary condition, which were slightly higher than data. The difference between the model and data can be accounted for by two issues: the model predicted $CBOD_u$ assumes all organic matter has been decayed to completion whereas the data reflects the time limits over which the test was conducted, and the model also includes in the $CBOD_u$ calculation the decay of the refractory dissolved organic matter which was added to the model (1.0 mg/L). The total $CBOD_u$ represents the sum of all $CBOD_u$ compartments simulated in the model. Figure 142 shows reasonable model-data agreement at the WA/ID State Line.

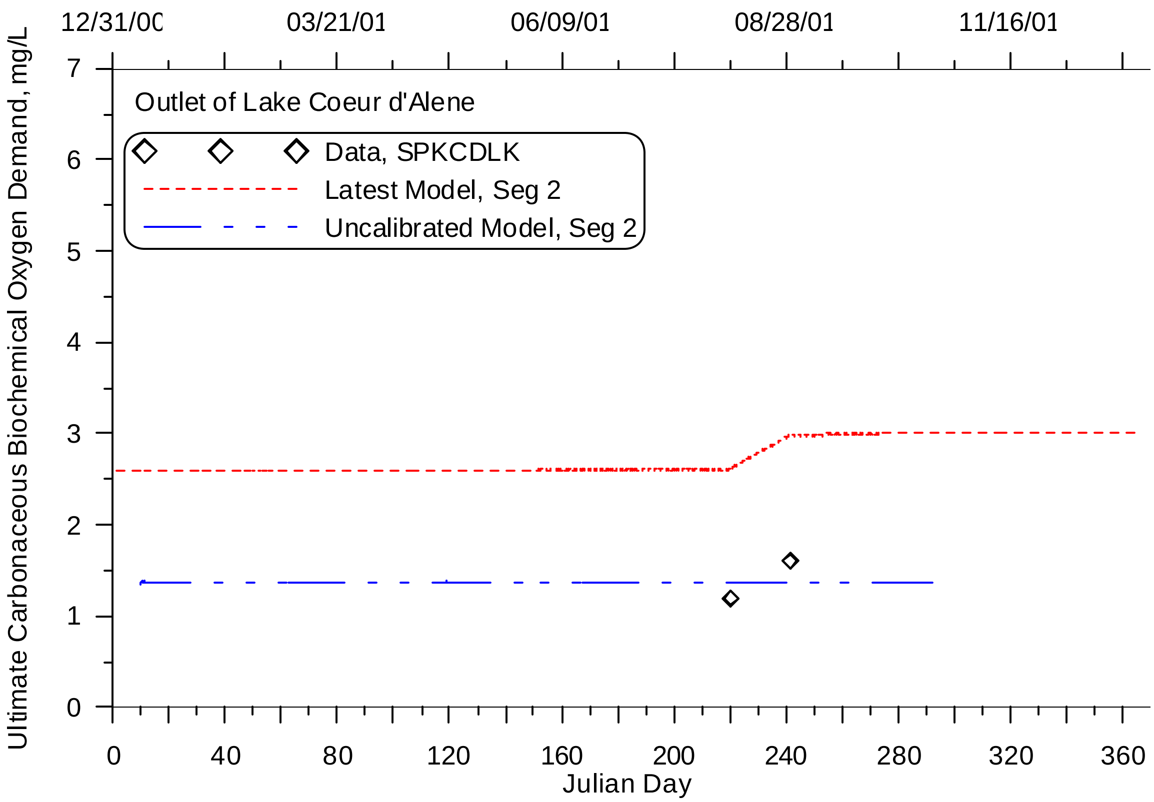


Figure 141: Model-data carbonaceous biochemical oxygen demand comparison, at the Lake Coeur d'Alene outlet, 2001.

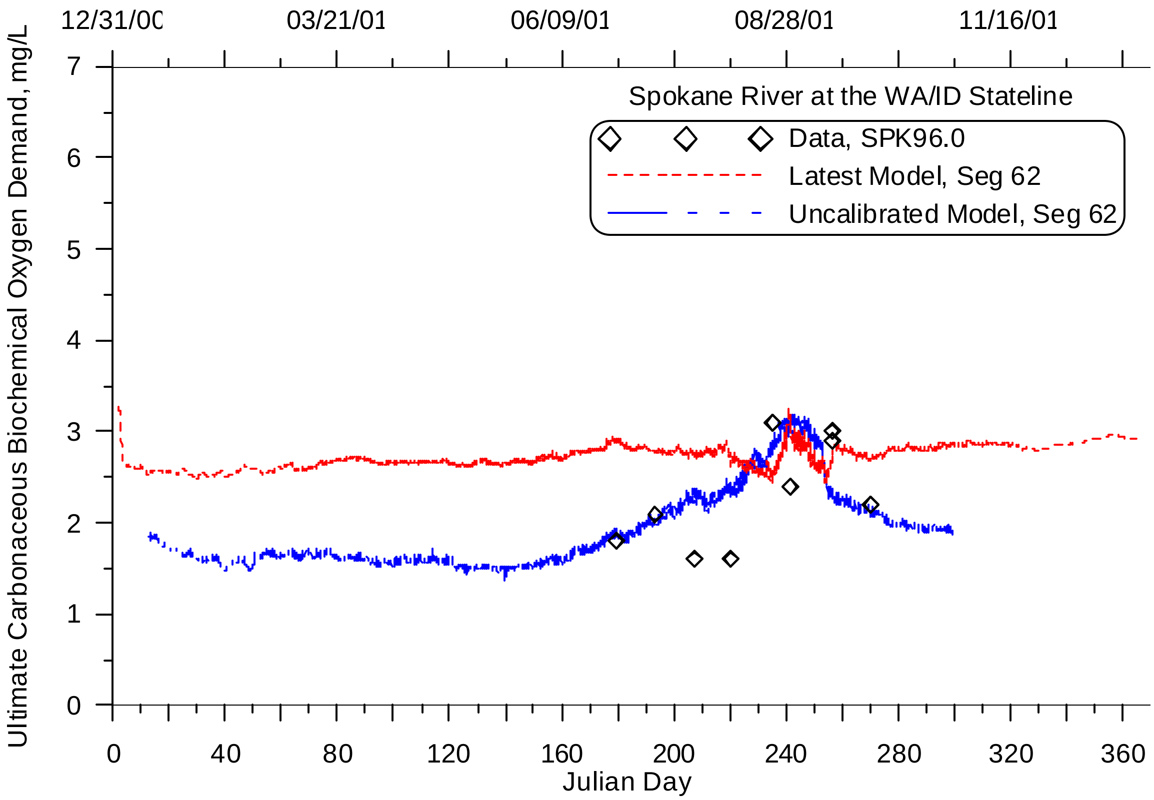


Figure 142: Model-data carbonaceous biochemical oxygen demand comparison, at the WA/ID State Line, 2001.

Dissolved Organic Carbon

Figure 143 and Figure 144 show comparisons between model predicted dissolved organic carbon (DOC) concentrations and data at the outlet to Lake Coeur d'Alene and the WA/ID State Line, respectively. The two figures show there is relatively good model-data agreement with the model slightly under-predicting the DOC concentration at the upstream boundary condition.

Improvements to the DOC and TOC concentration results were attained through adding a refractory dissolved organic matter (RDOM) compartment of 1.0 mg/L, constant over the simulation. There was a lack of data at the upstream boundary condition to characterize the DOC and TOC concentrations and the addition of the RDOM compartment influences the TOC and DOC concentrations downstream. Future field should focus on improving the data set at the upstream boundary condition location.

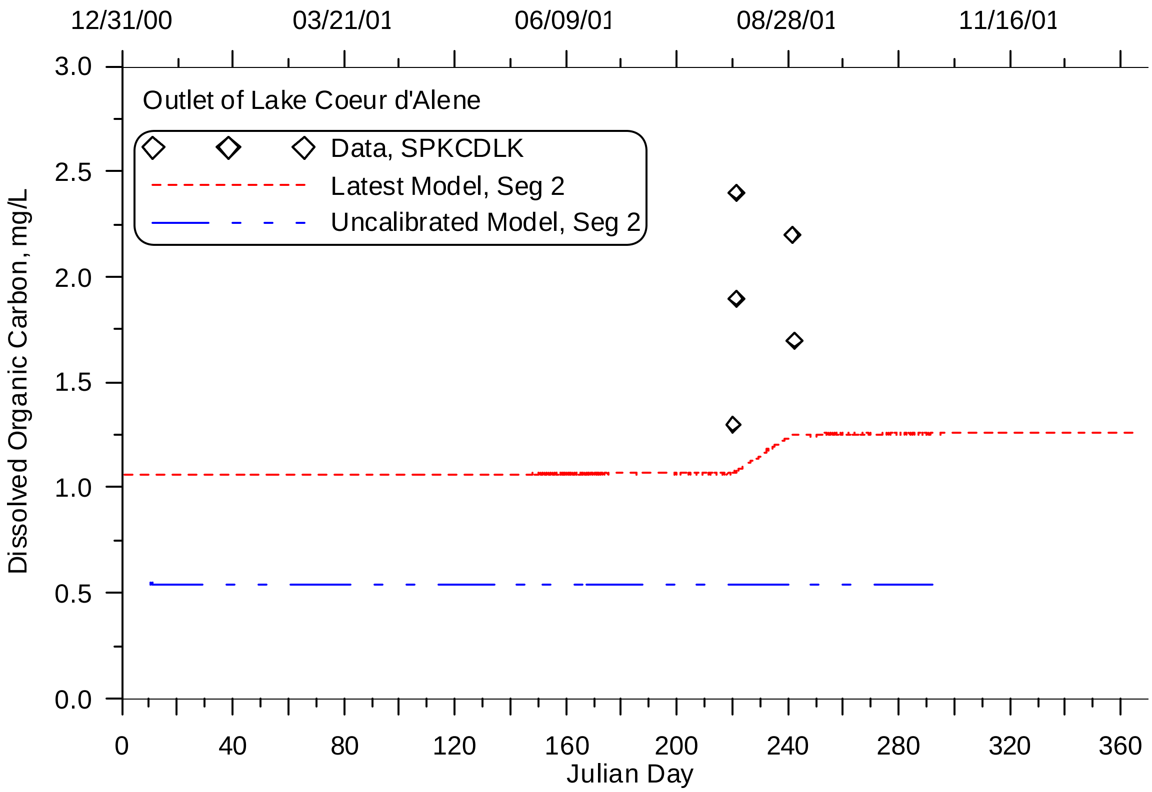


Figure 143: Model-data dissolved organic carbon comparison, at the Lake Coeur d'Alene outlet, 2001.

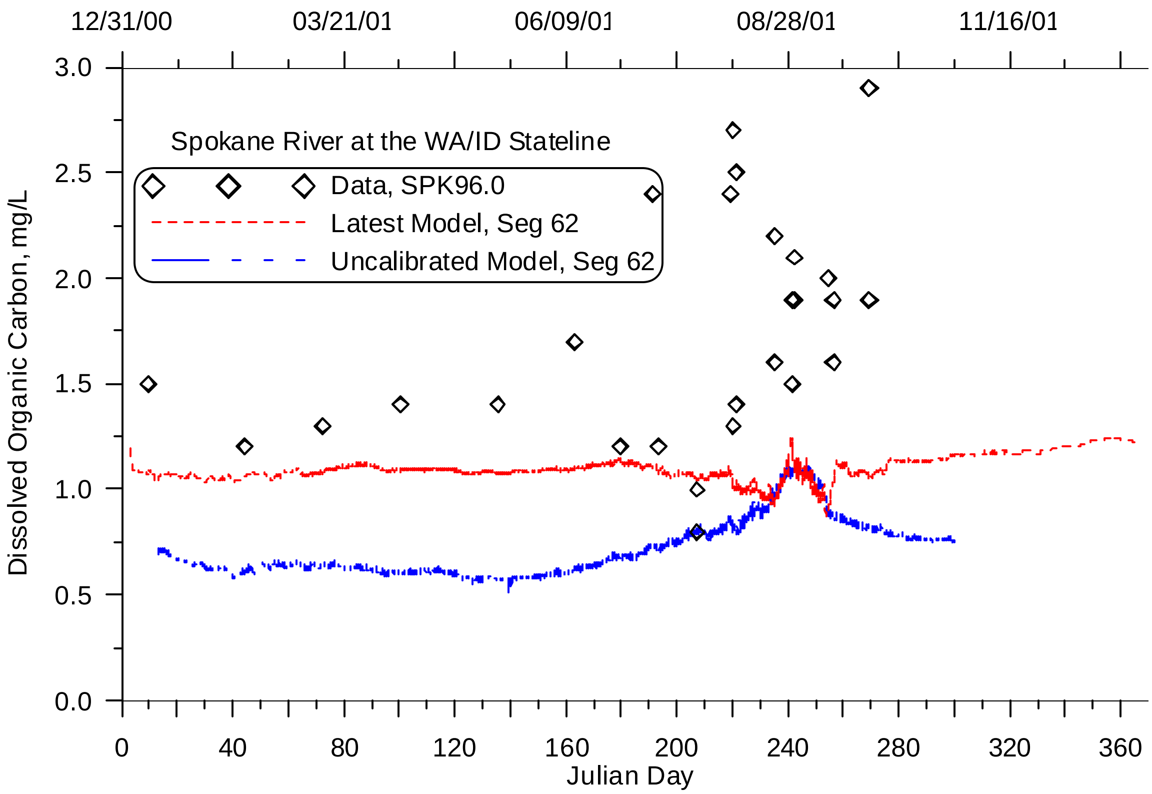


Figure 144: Model-data dissolved organic carbon comparison, at the WA/ID State Line, 2001.

Total Organic Carbon

Figure 145 and Figure 146 show comparisons between model predicted total organic carbon (TOC) concentrations and data at the outlet to Lake Coeur d'Alene and the WA/ID State Line, respectively. The two figures show there is good model-data agreement at both sites.

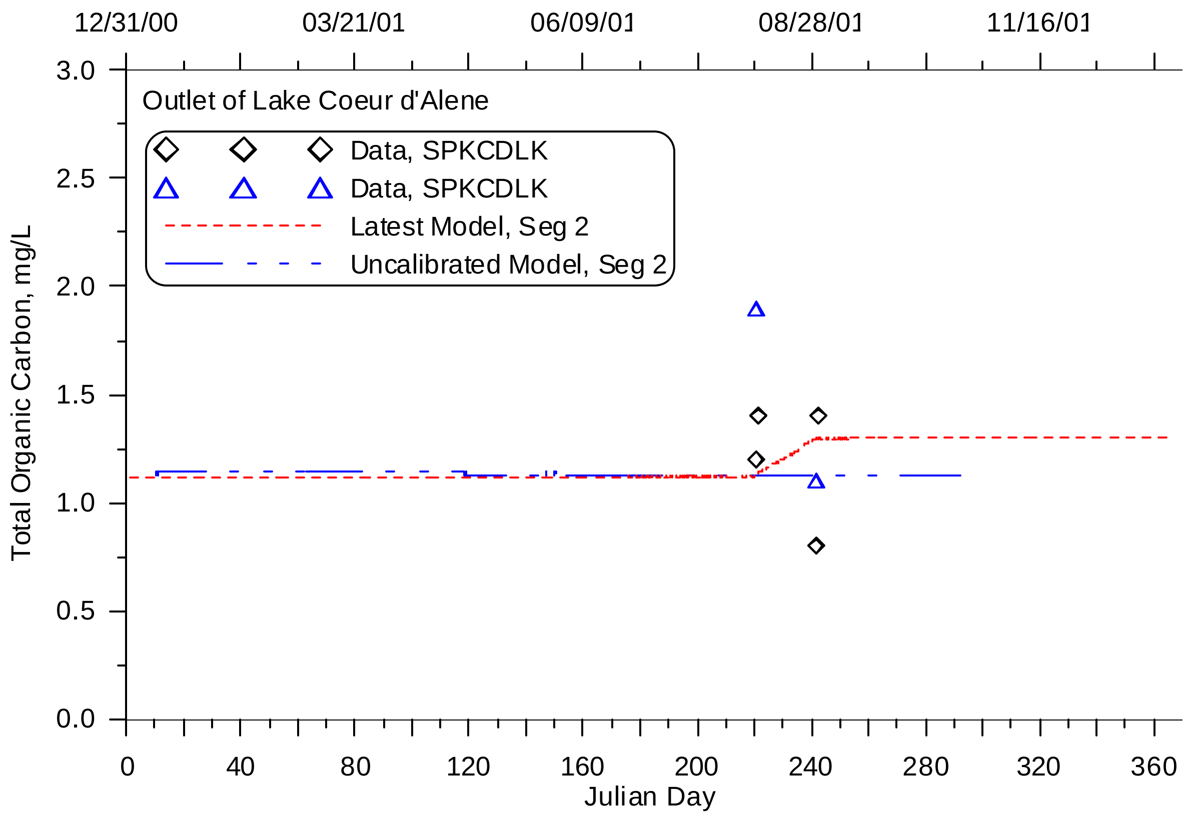


Figure 145: Model-data total organic carbon comparison, at the Lake Coeur d'Alene outlet, 2001.

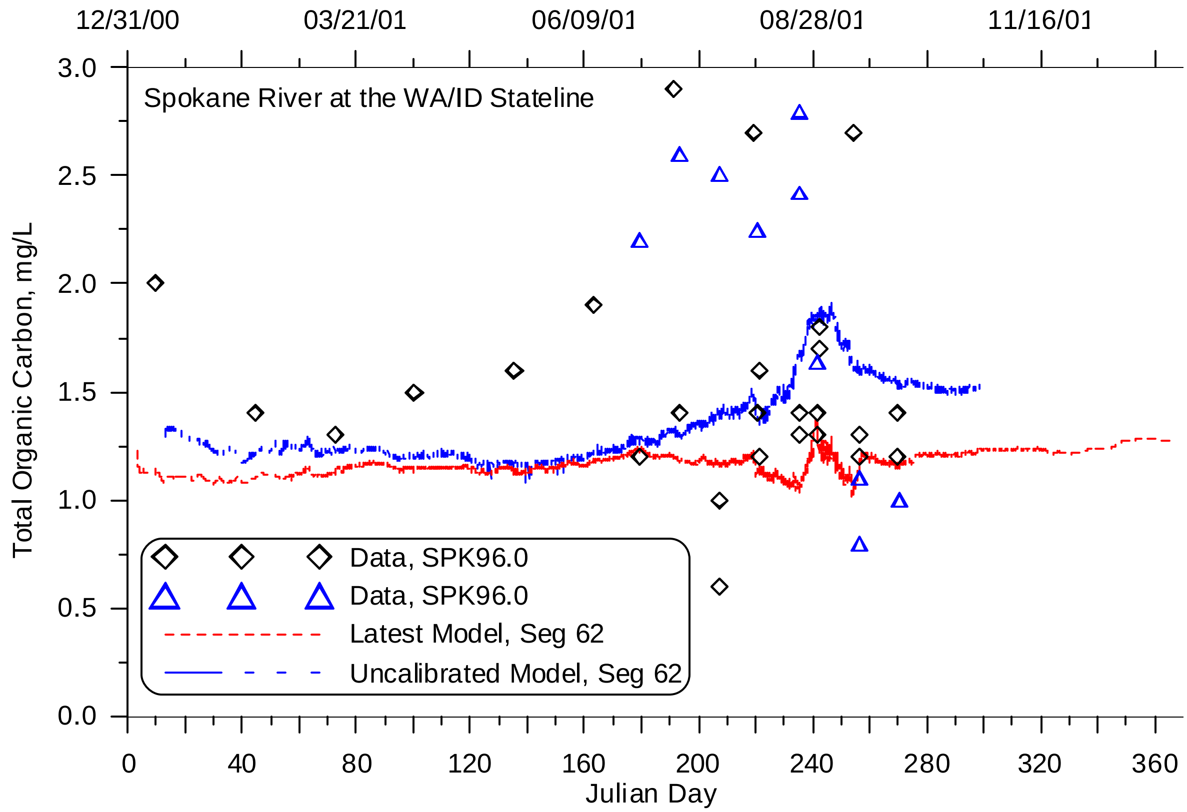


Figure 146: Model-data total organic carbon comparison, at the WA/ID State Line, 2001.

Total Dissolved Solids

Figure 147 and Figure 148 show comparisons between model predicted total dissolved solids concentration and data at the outlet to Lake Coeur d'Alene and the WA/ID State Line, respectively. Total dissolved solids were modeled as a conservative constituent.

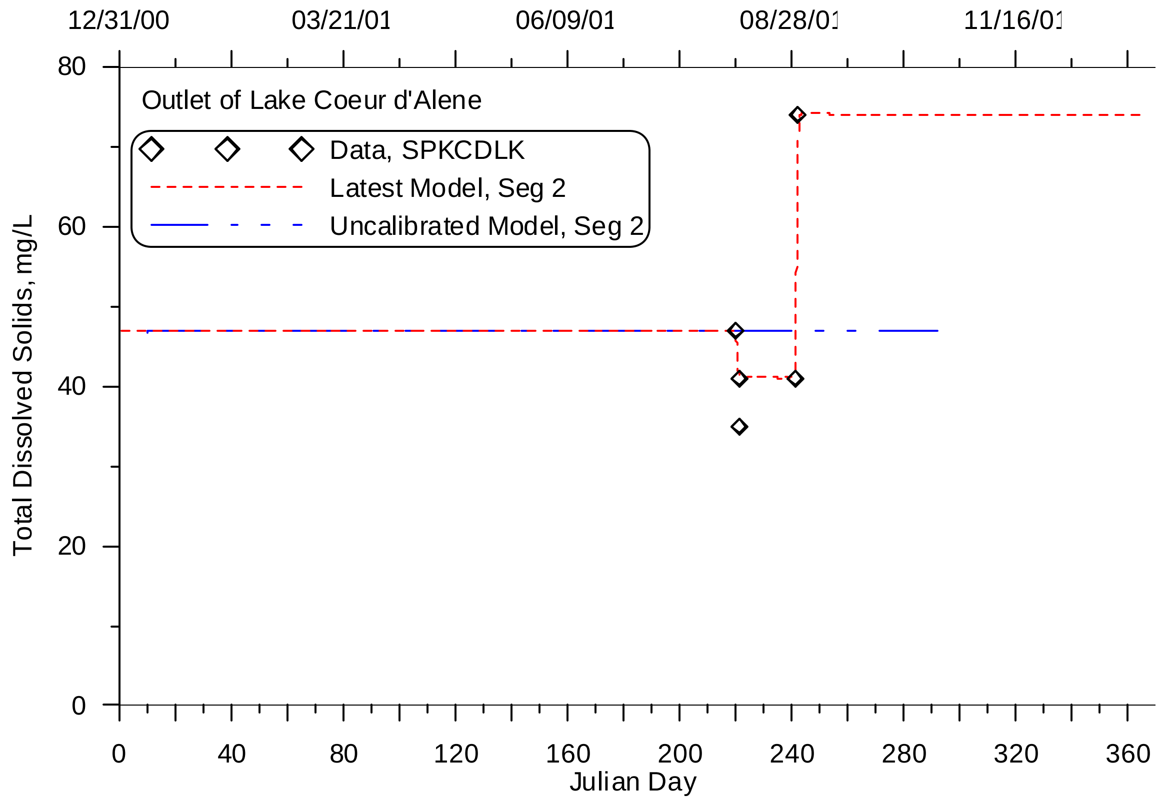


Figure 147: Model-data total dissolved solids comparison, at the Lake Coeur d'Alene outlet, 2001.

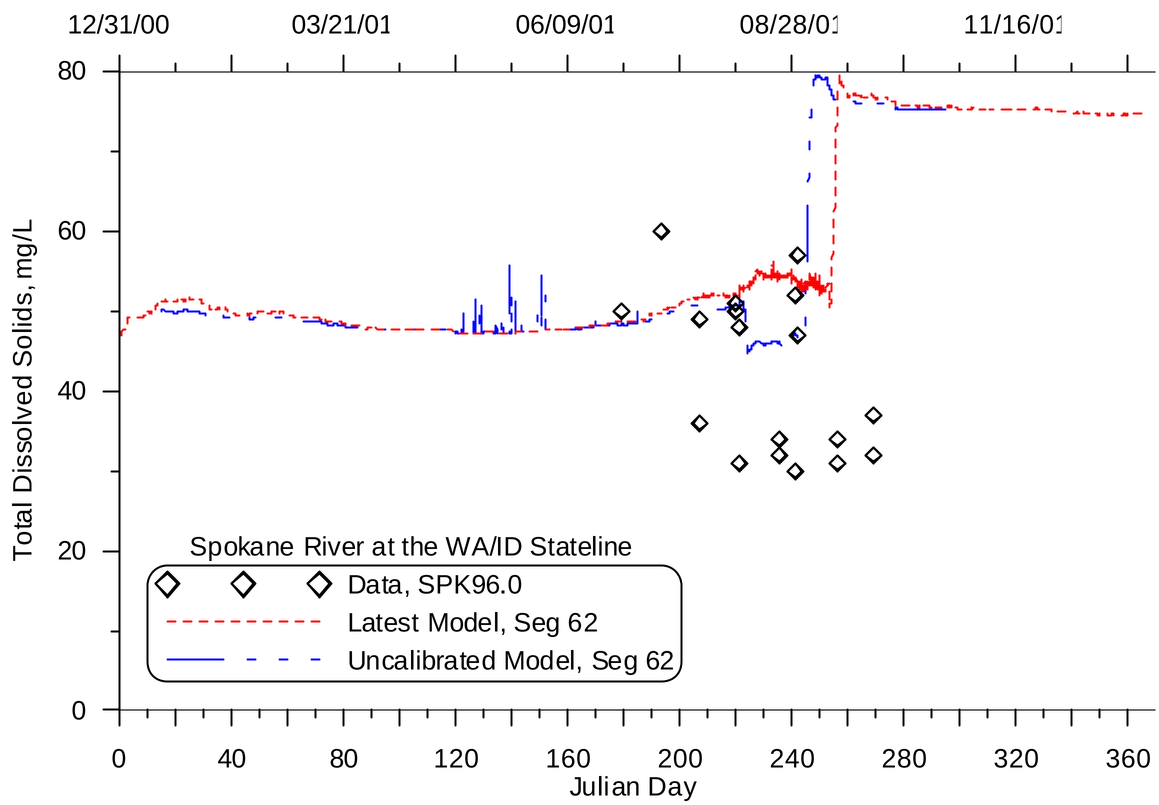


Figure 148: Model-data total dissolved solids comparison, at the WA/ID State Line, 2001.

Alkalinity

Figure 149, Figure 150, and Figure 151 show comparisons between model predicted alkalinity concentration and data at the outlet to Lake Coeur d'Alene, the USGS gage station near Post Falls, ID and the WA/ID State Line, respectively. The figures show there is good model-data agreement and that the concentration is dependent on the upstream boundary condition.

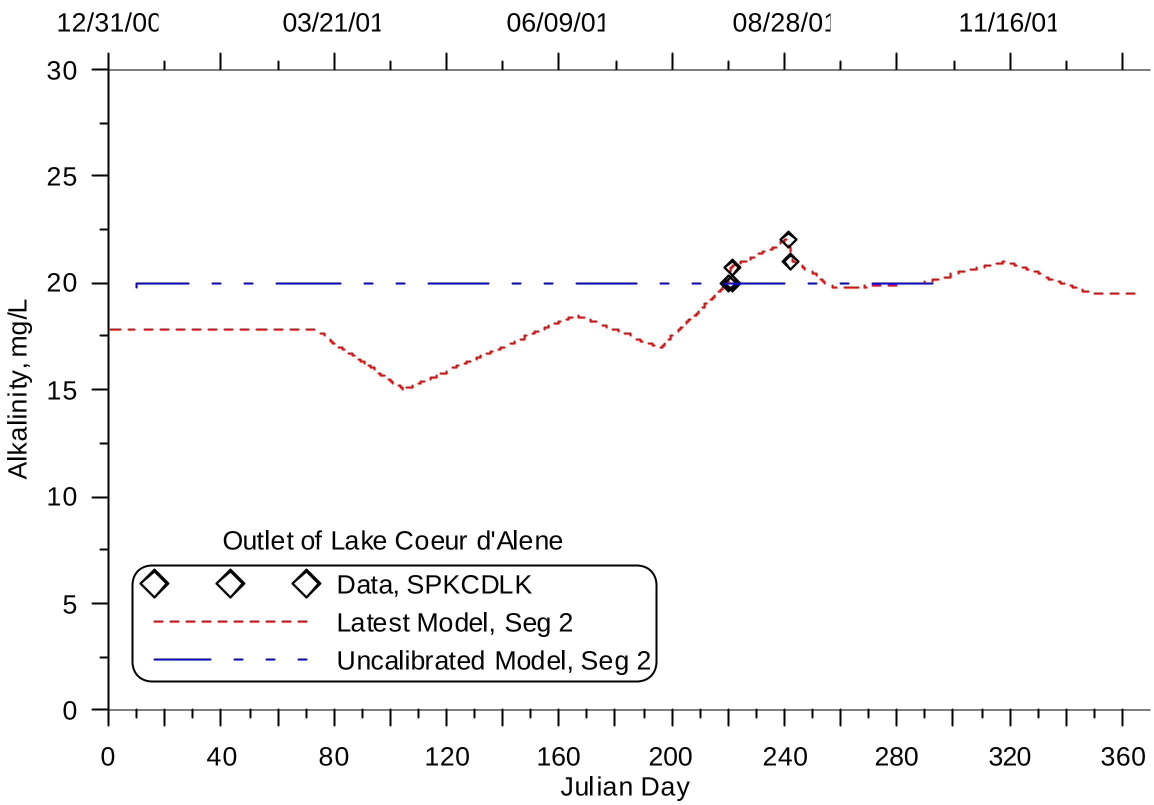


Figure 149: Model-data alkalinity comparison, at the Lake Coeur d'Alene outlet, 2001.

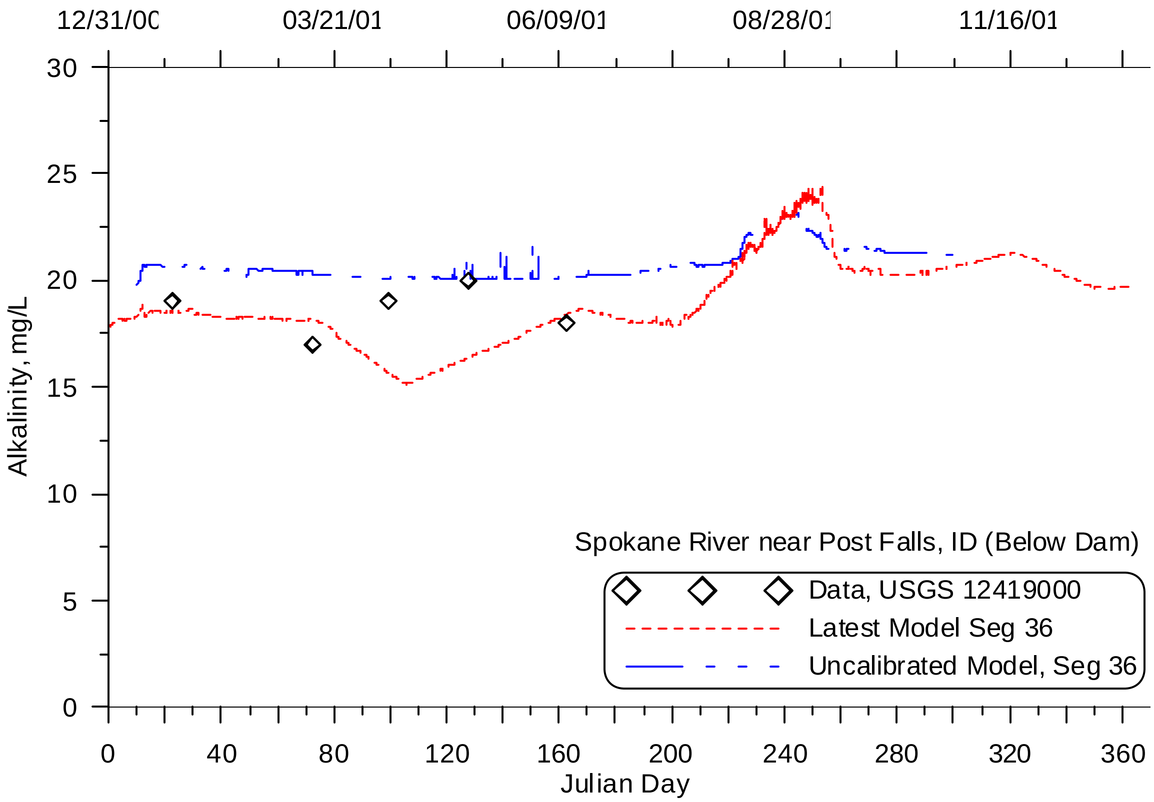


Figure 150: Model-data alkalinity comparison, 0.8 mi downstream of Post Falls Dam, 2001.

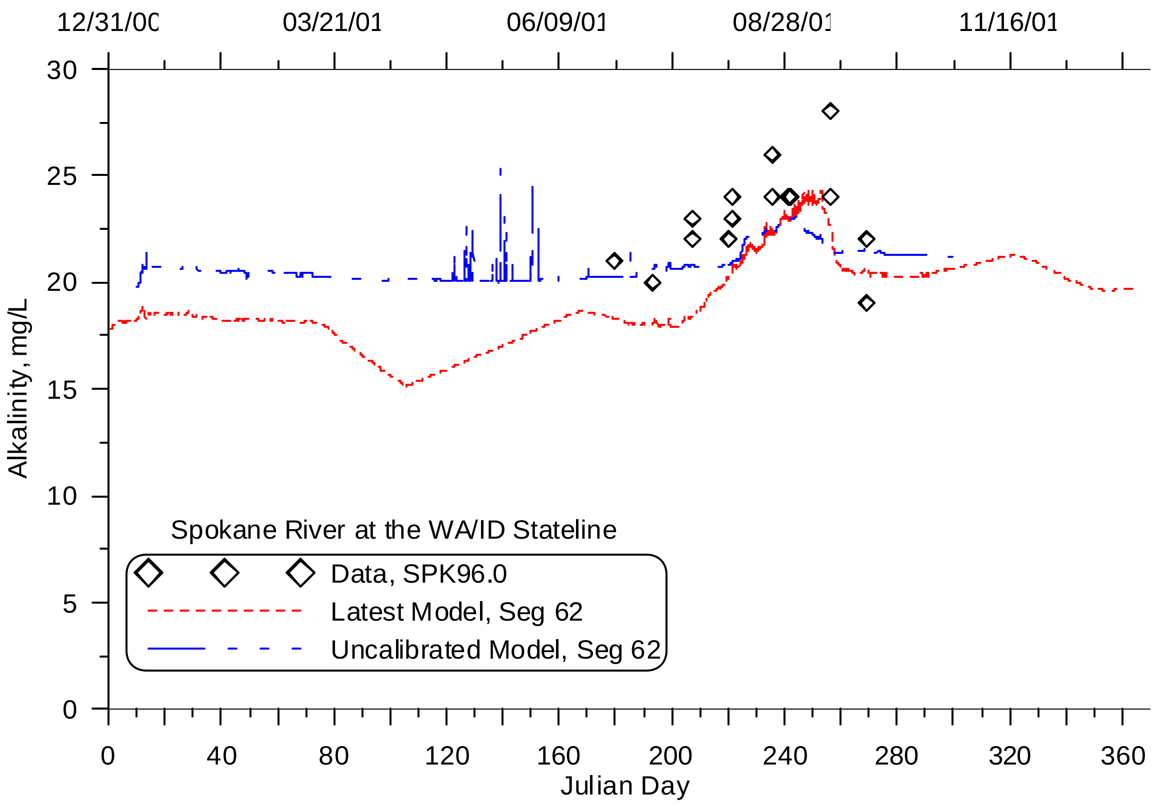


Figure 151: Model-data alkalinity comparison, at the WA/ID State Line, 2001.

Year 2004

Conductivity

Figure 152, Figure 153, Figure 154, and Figure 155 show comparisons between model predicted conductivity and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively. Conductivity was modeled as a conservative constituent. The figures show the model does well simulating conductivity at each location, confirming the accuracy of the water balance.

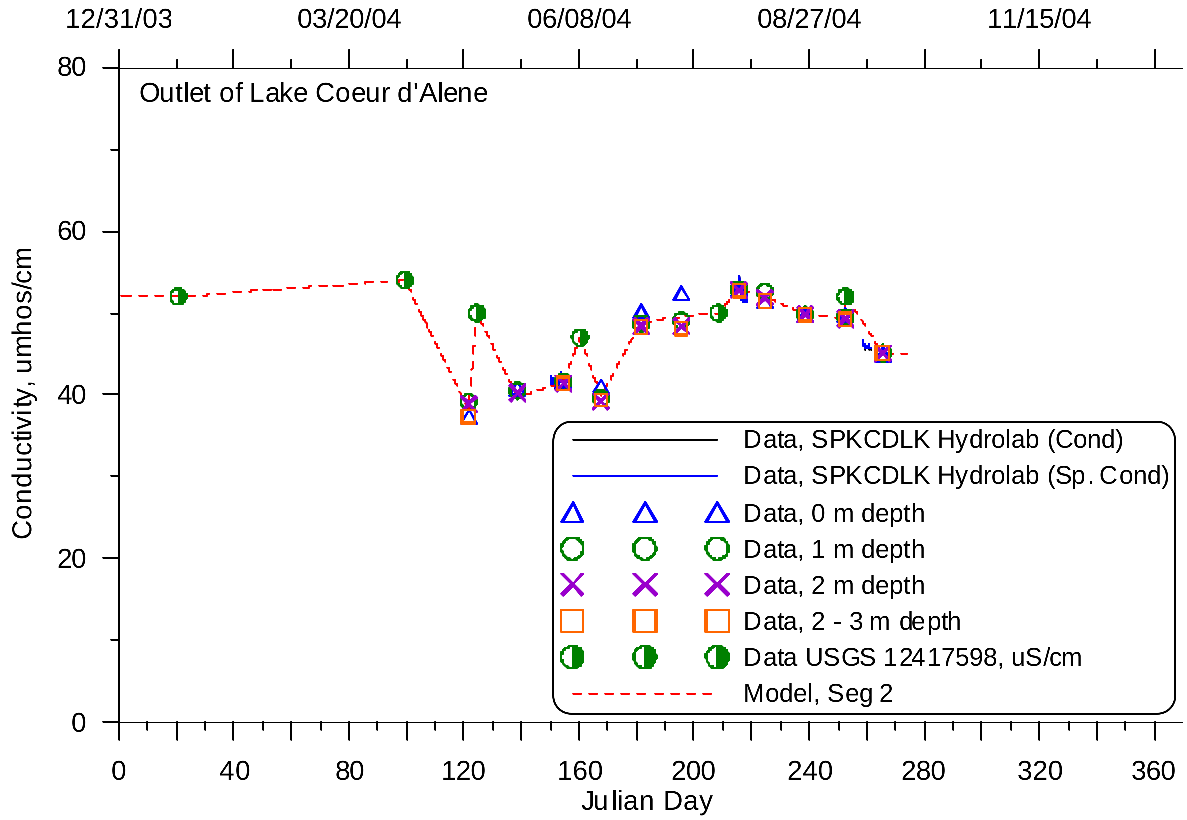


Figure 152: Model-data conductivity comparison, at the Lake Coeur d'Alene outlet, 2004.

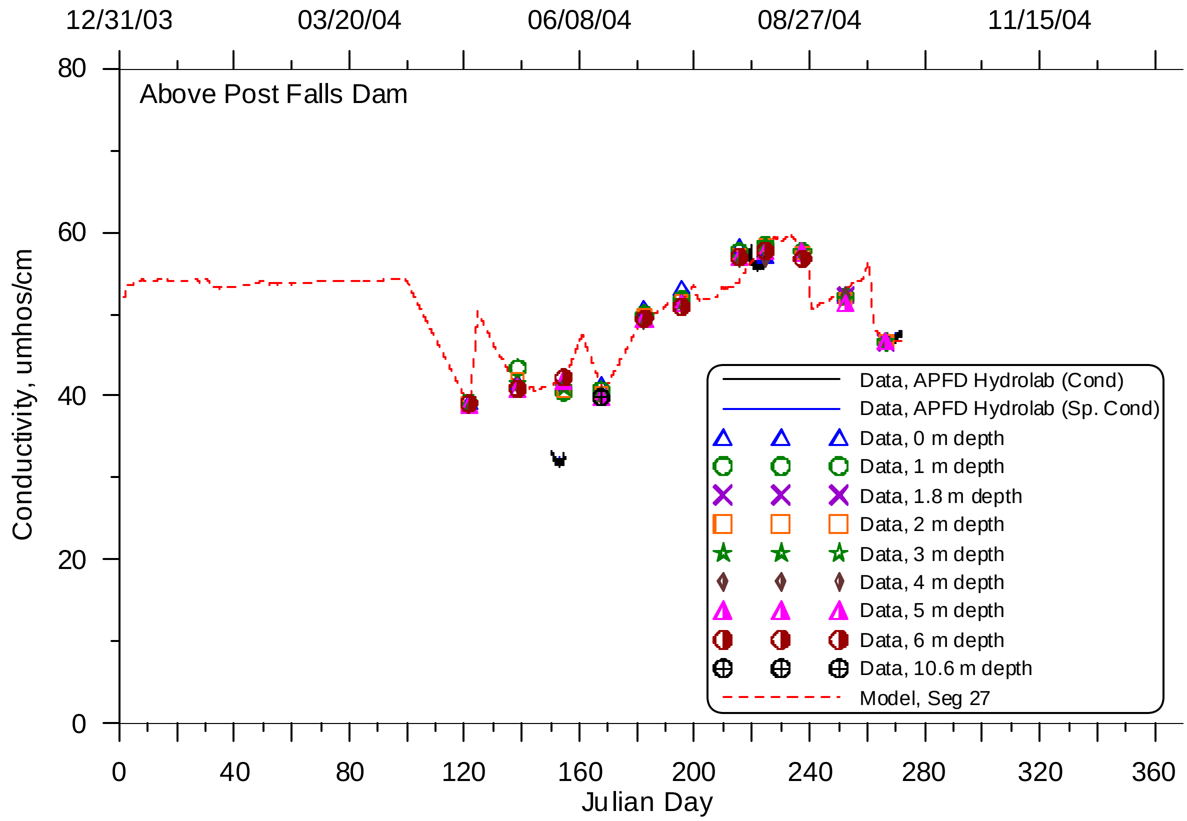


Figure 153: Model-data conductivity comparison, above Post Falls Dam, 2004.

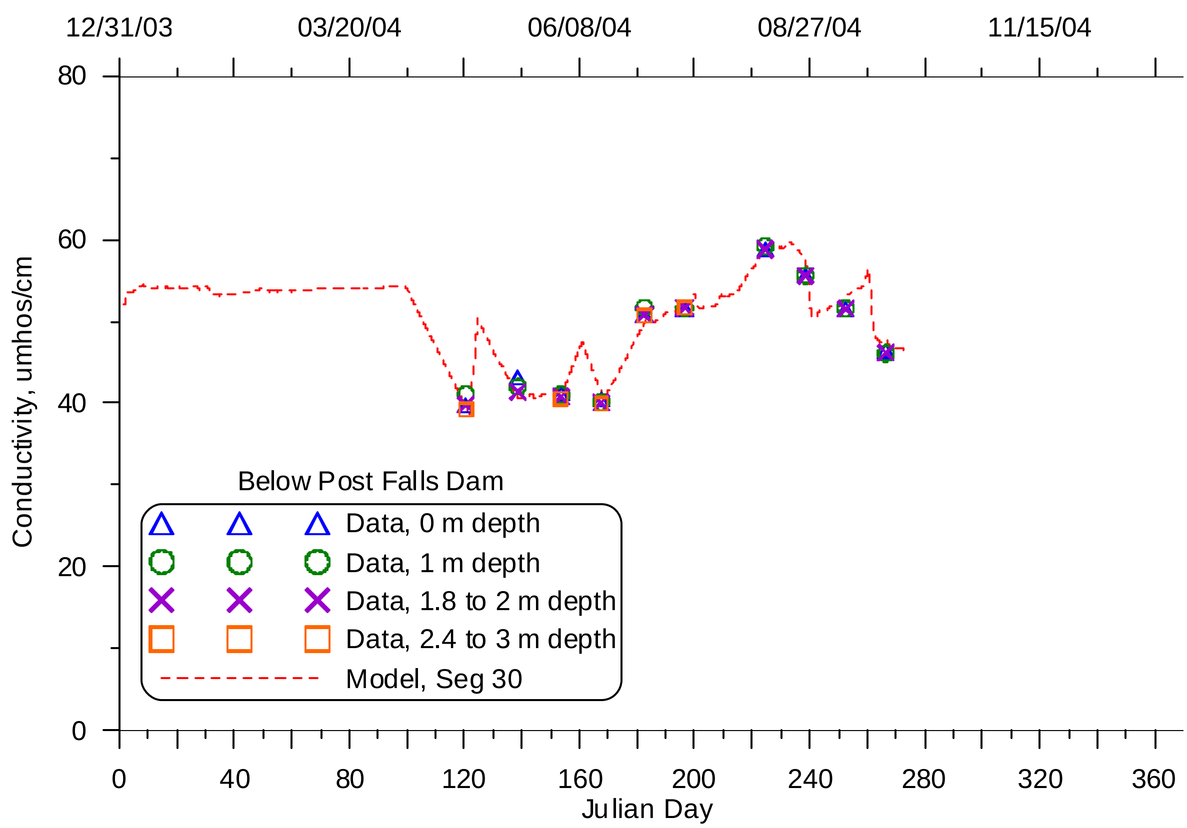


Figure 154: Model-data conductivity comparison, below Post Falls Dam, 2004.

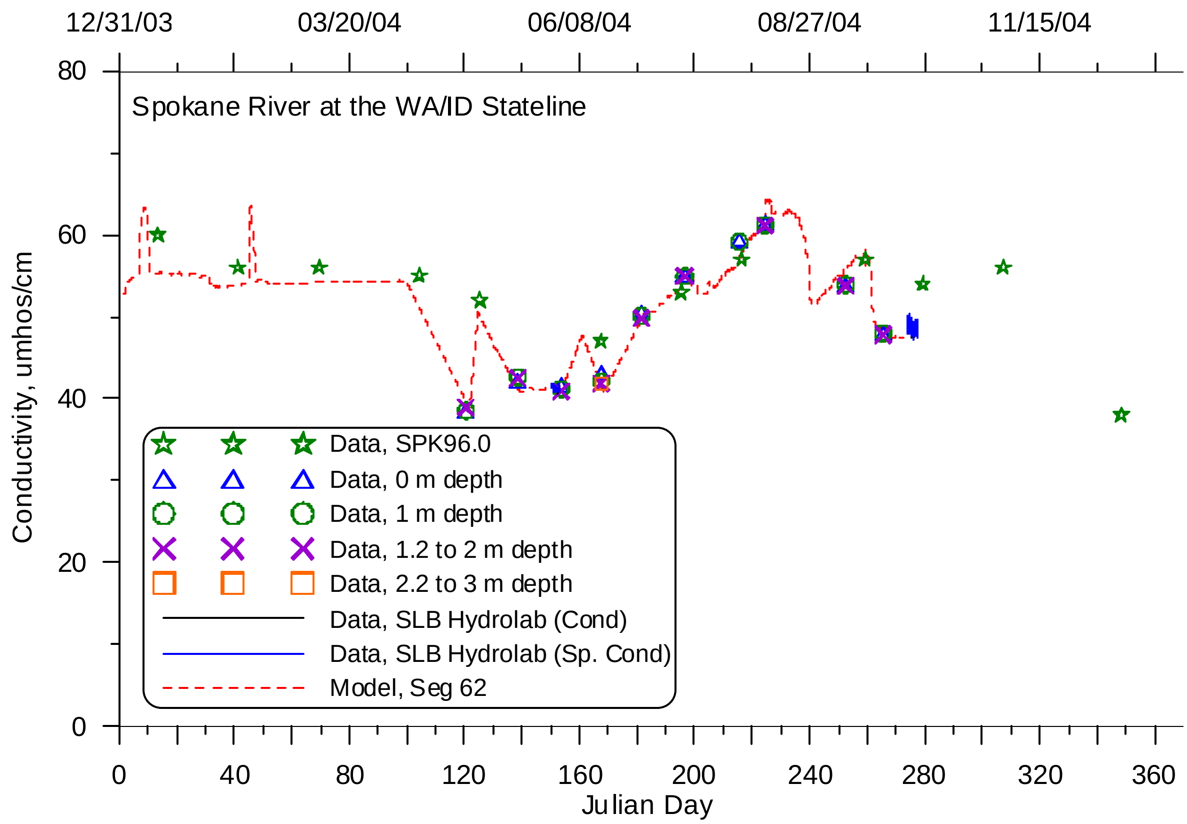


Figure 155: Model-data conductivity comparison, at the WA/ID State Line, 2004.

Soluble Reactive Phosphorus

Figure 156, Figure 157, Figure 158, and Figure 159 show comparisons between model predicted soluble reactive phosphorus concentration and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively. The figures show the model prediction match well with the data at each of the sites. Diurnal fluctuations in the phosphorus concentrations were due to uptake and release by periphyton.

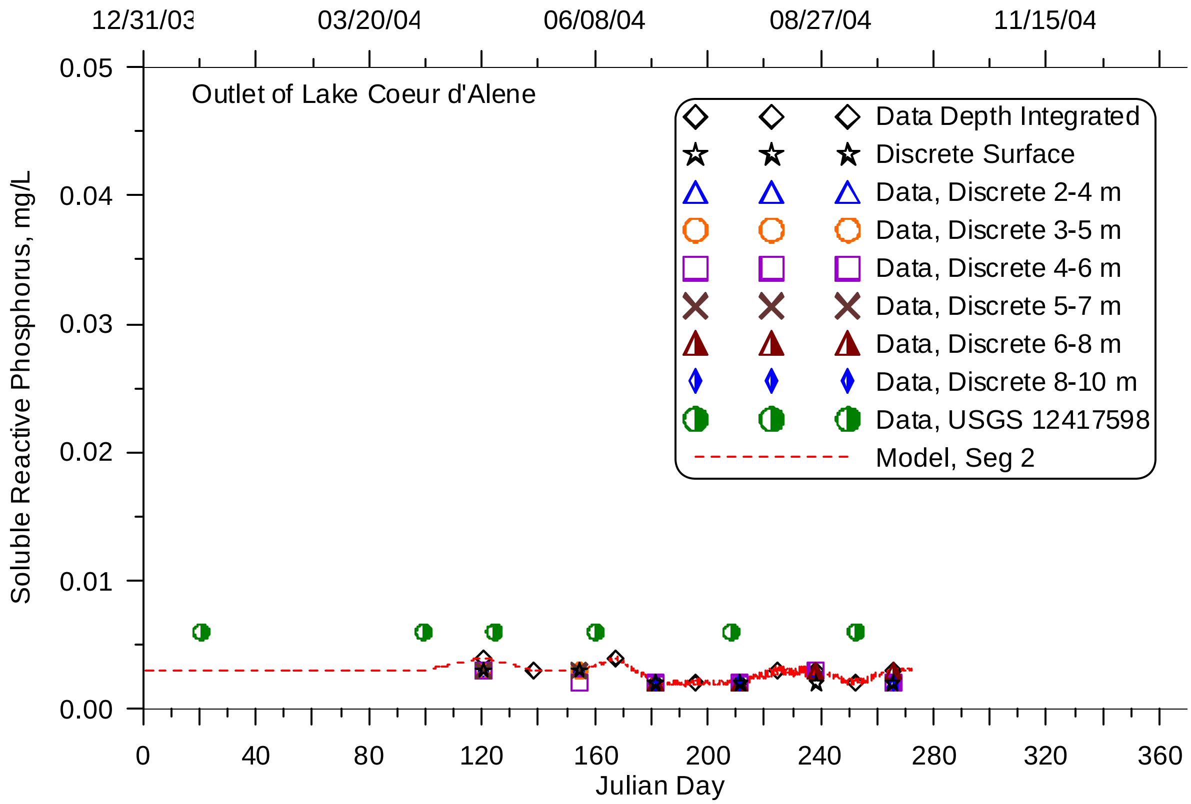


Figure 156: Model-data soluble reactive phosphorus comparison, at the Lake Coeur d'Alene outlet, 2004.

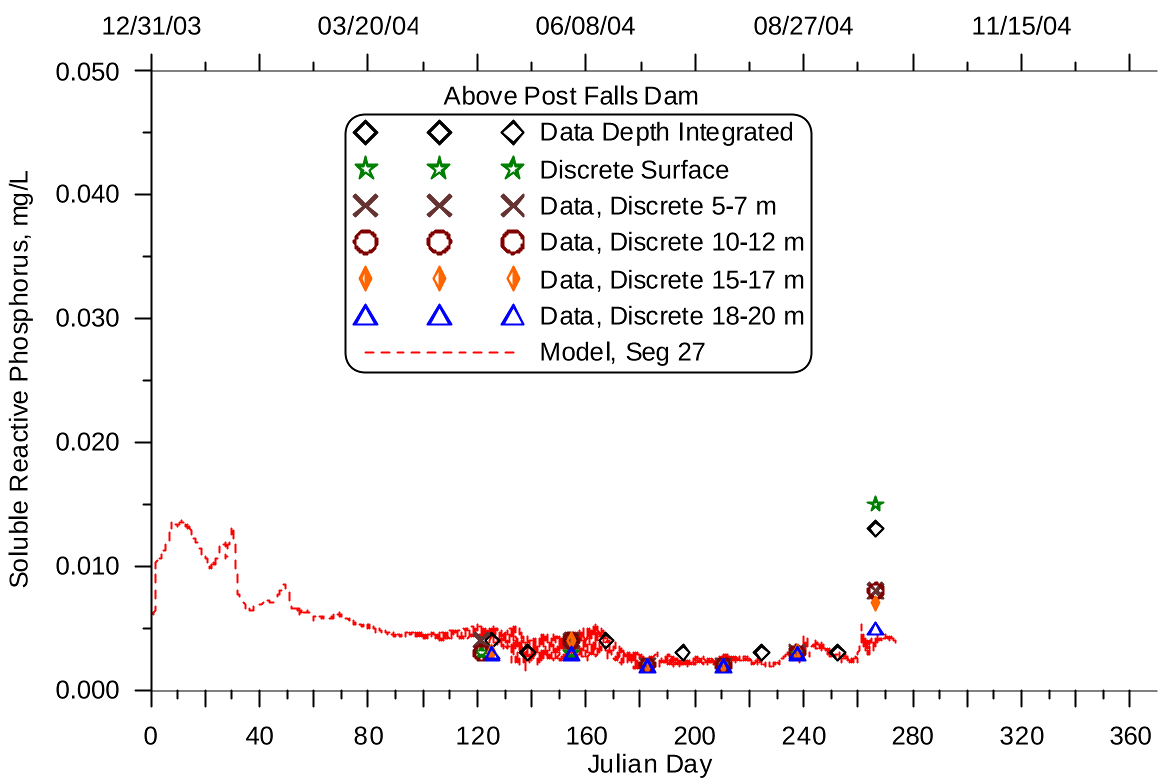


Figure 157: Model-data soluble reactive phosphorus comparison, above Post Falls Dam, 2004.

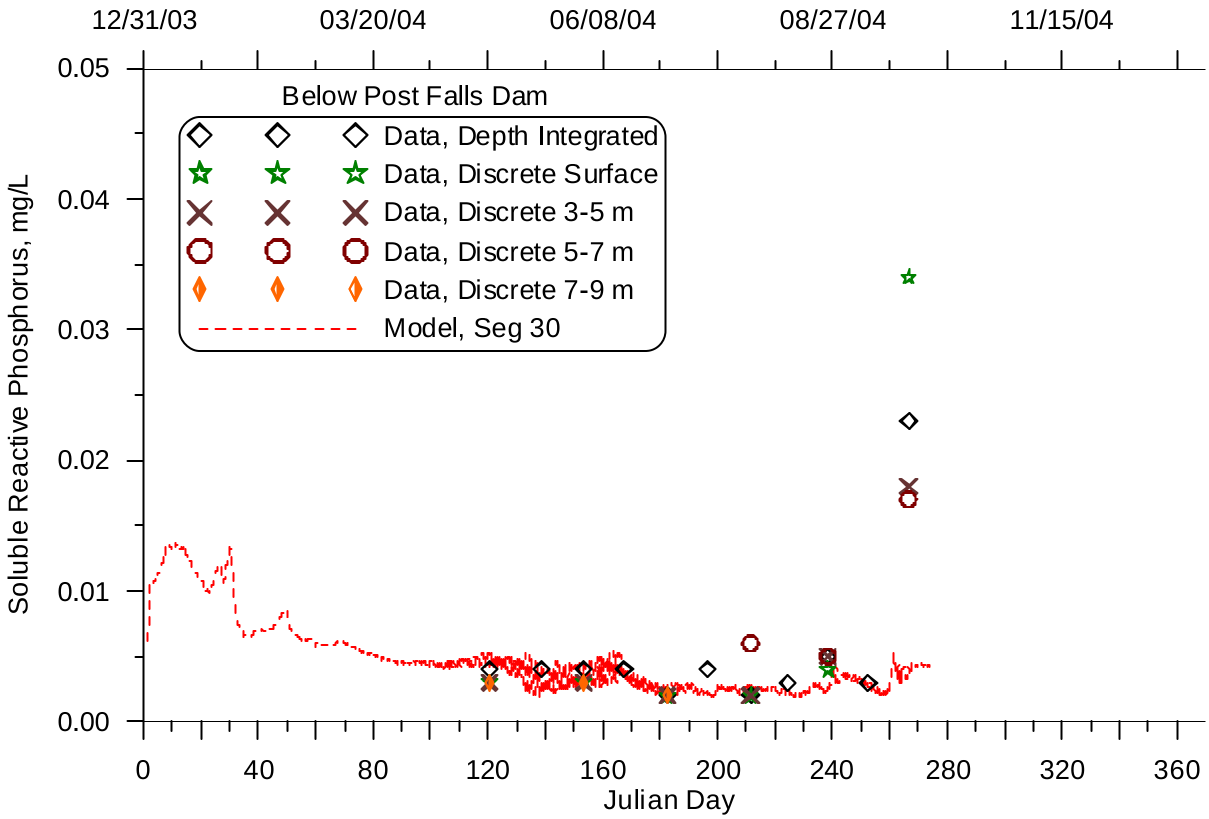


Figure 158: Model-data soluble reactive phosphorus comparison, below Post Falls Dam, 2004.

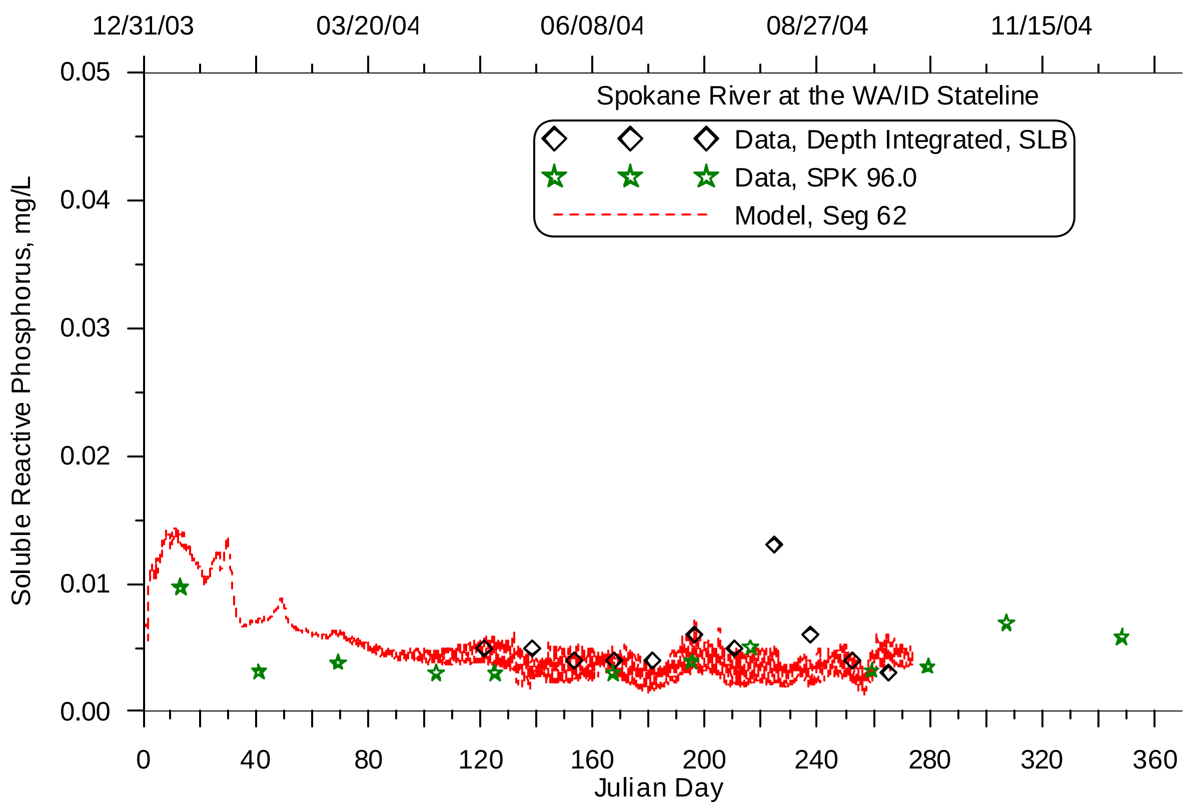


Figure 159: Model-data soluble reactive phosphorus comparison, at the WA/ID State Line, 2004.

Total Phosphorus

Figure 160, Figure 161, Figure 162, and Figure 163 show comparisons between model predicted total phosphorus concentration and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively. The figures show the model prediction match well with the data at each of the sites. The diurnal fluctuations in the total phosphorus concentrations were due to uptake and release by periphyton.

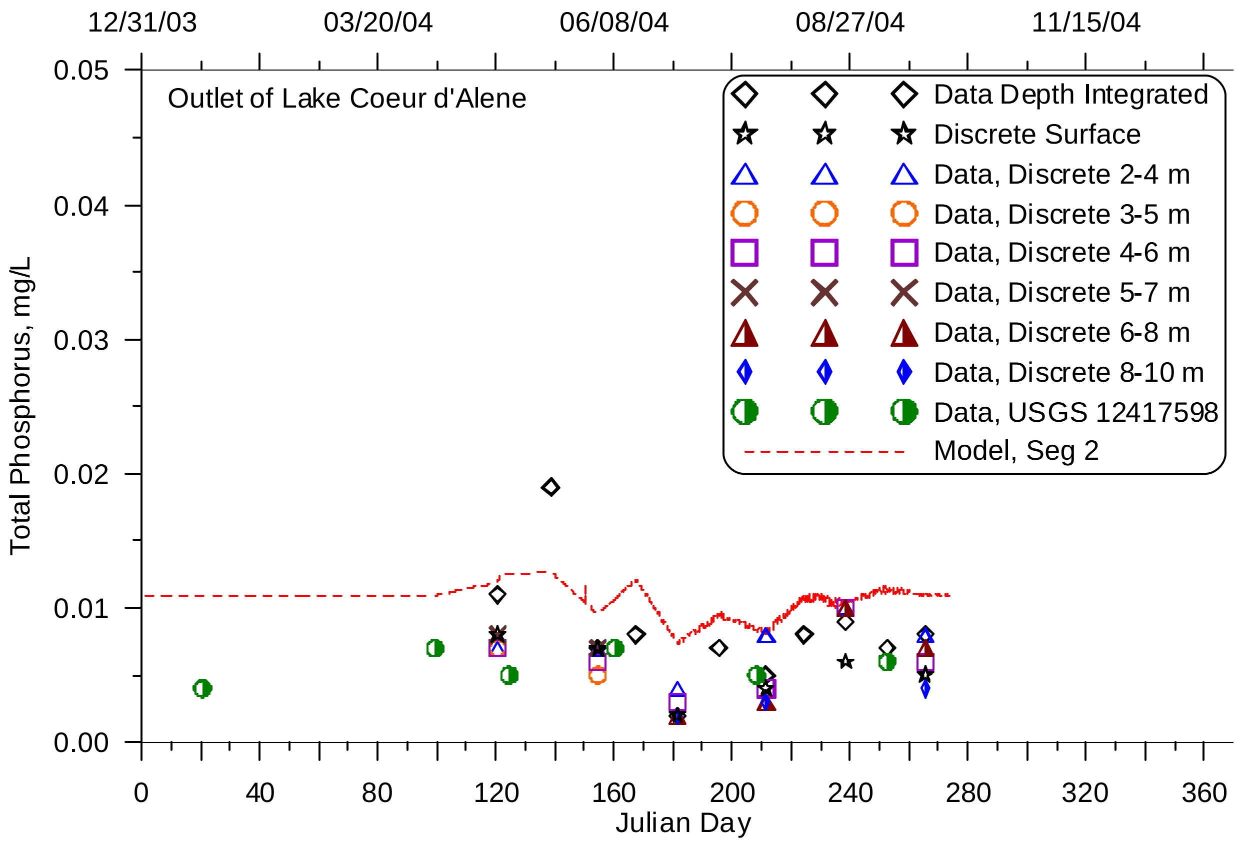


Figure 160: Model-data total phosphorus comparison, at the Lake Coeur d'Alene outlet, 2004.

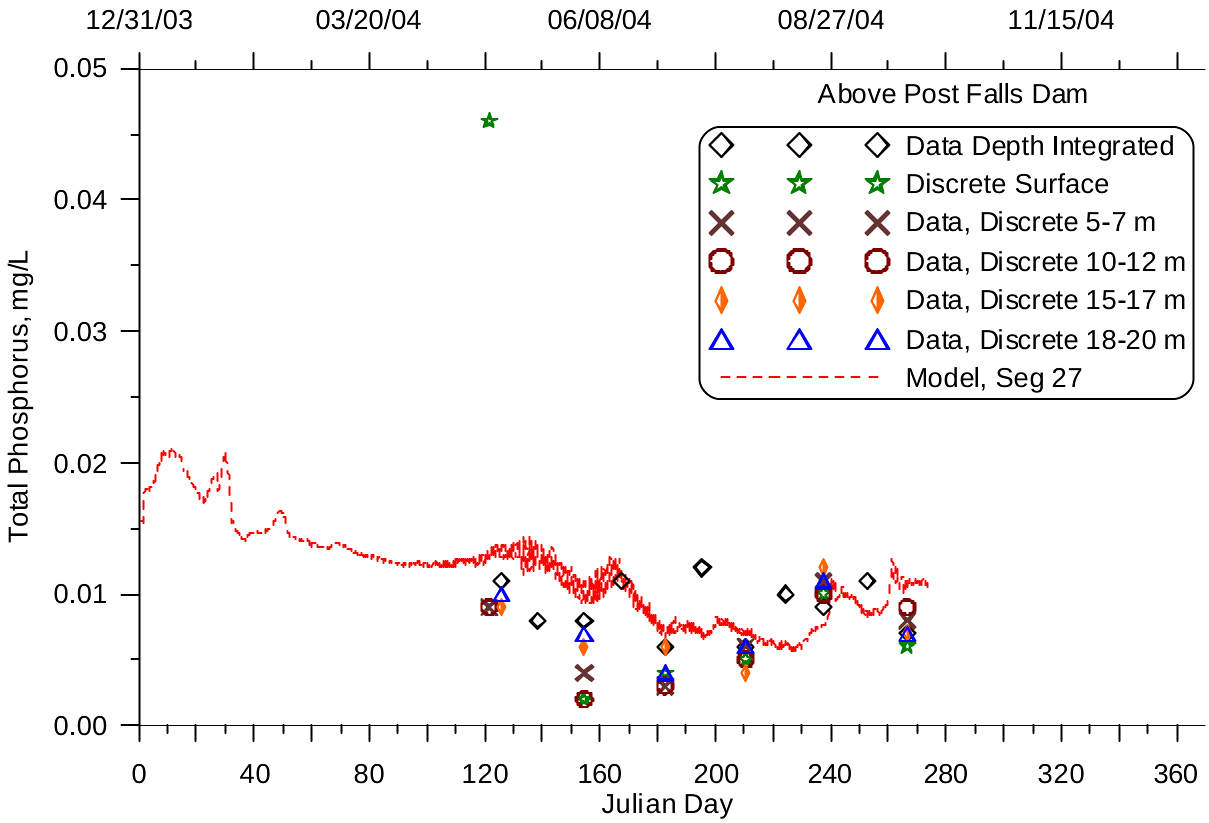


Figure 161: Model-data total phosphorus comparison, above Post Falls Dam, 2004.

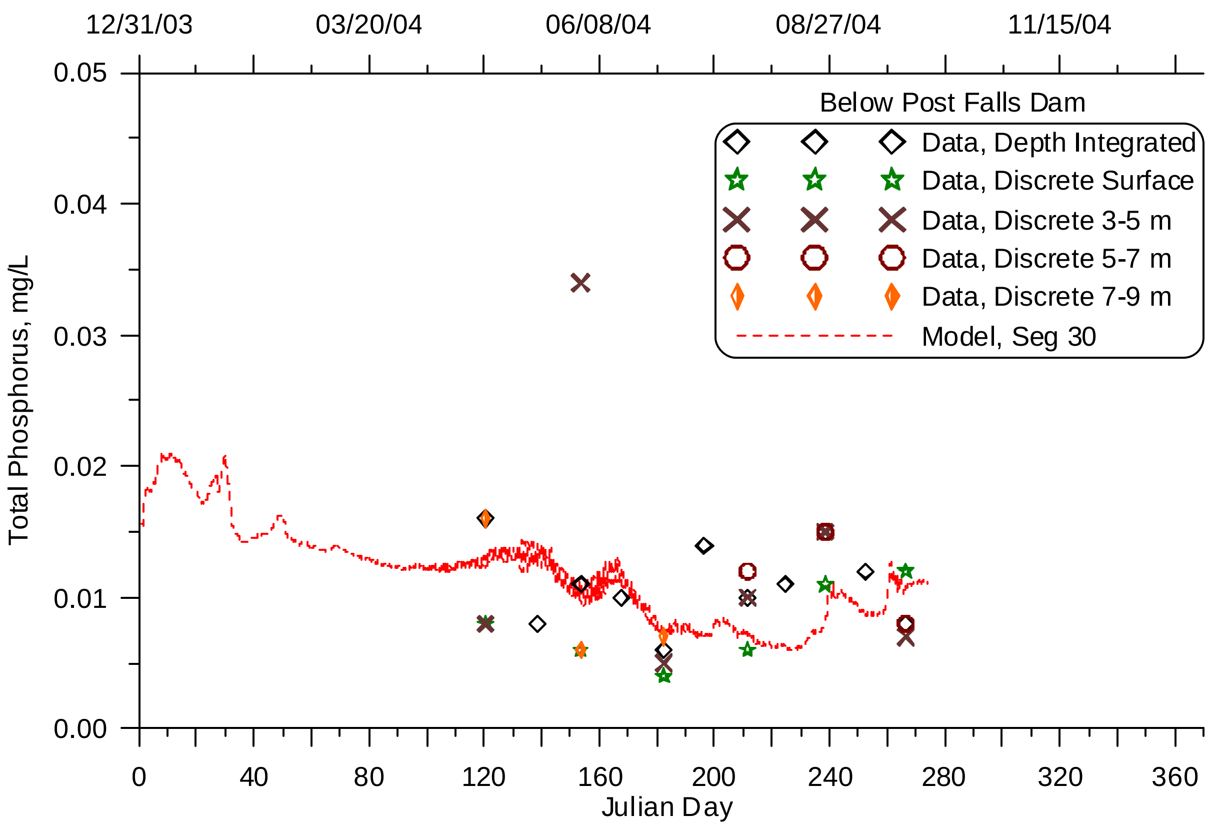


Figure 162: Model-data total phosphorus comparison, below Post Falls Dam, 2004.

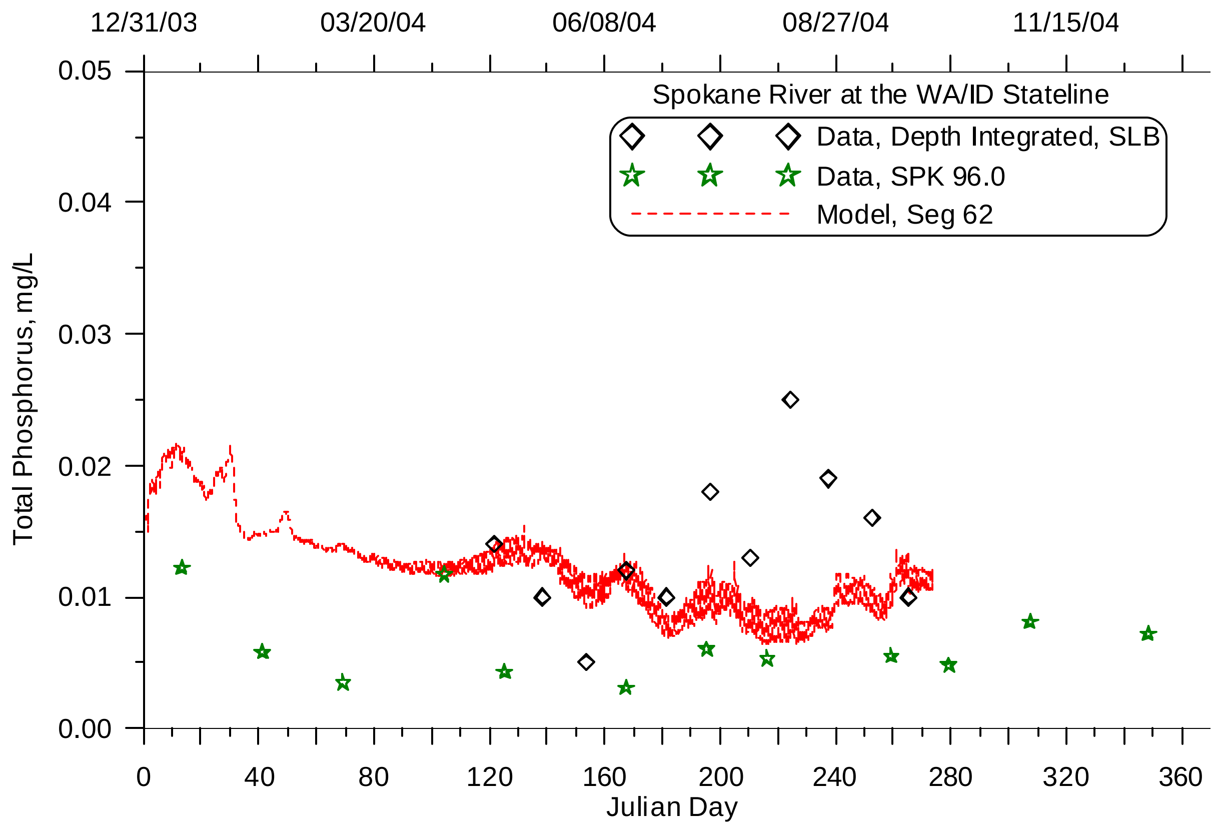


Figure 163: Model-data total phosphorus comparison, at the WA/ID State Line, 2004.

Nitrate-Nitrite

Figure 164, Figure 165, Figure 166, and Figure 167 show comparisons between model predicted nitrate-nitrite nitrogen concentration and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively. The figures show the model predictions match well with the data at each of the sites. The figures also indicate there is not much difference between the discrete water quality samples taken at different depths. The diurnal fluctuations in the nitrate-nitrite nitrogen concentrations were due to uptake and release by periphyton.

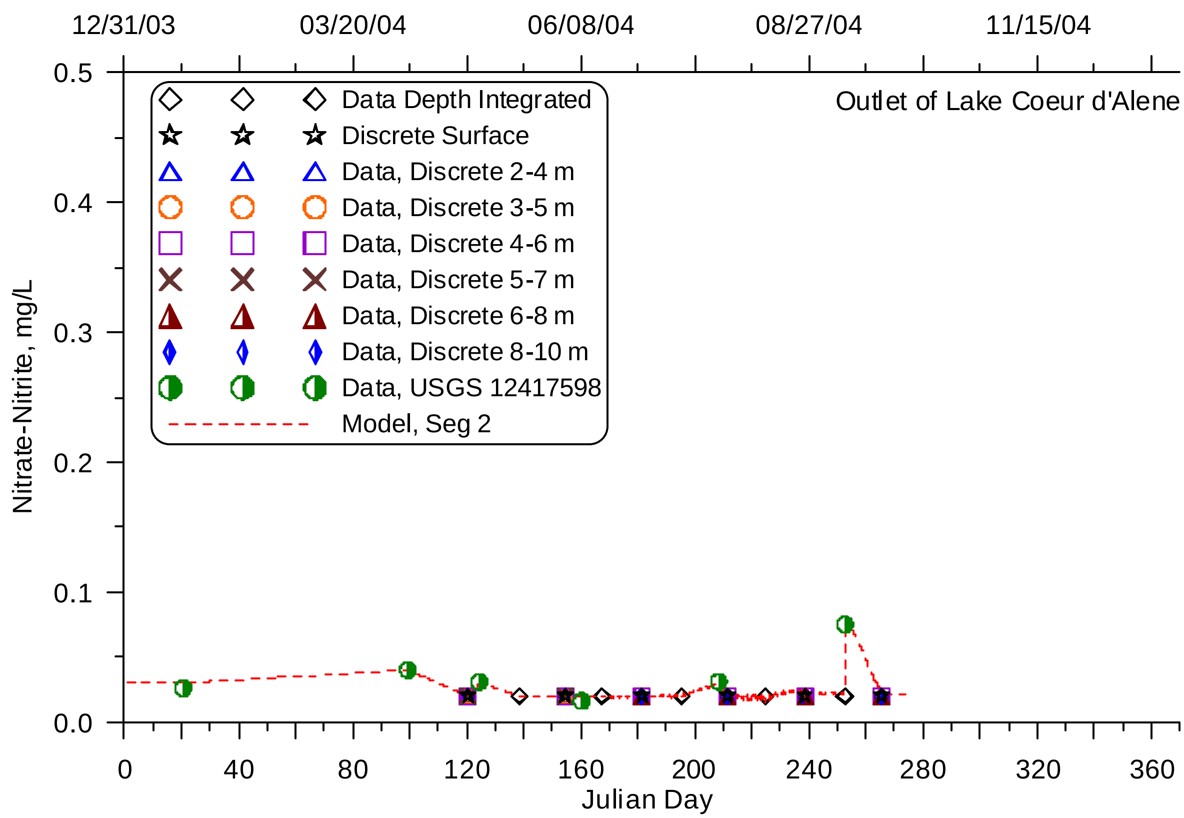


Figure 164: Model-data nitrate-nitrite comparison, at the Lake Coeur d'Alene outlet, 2004.

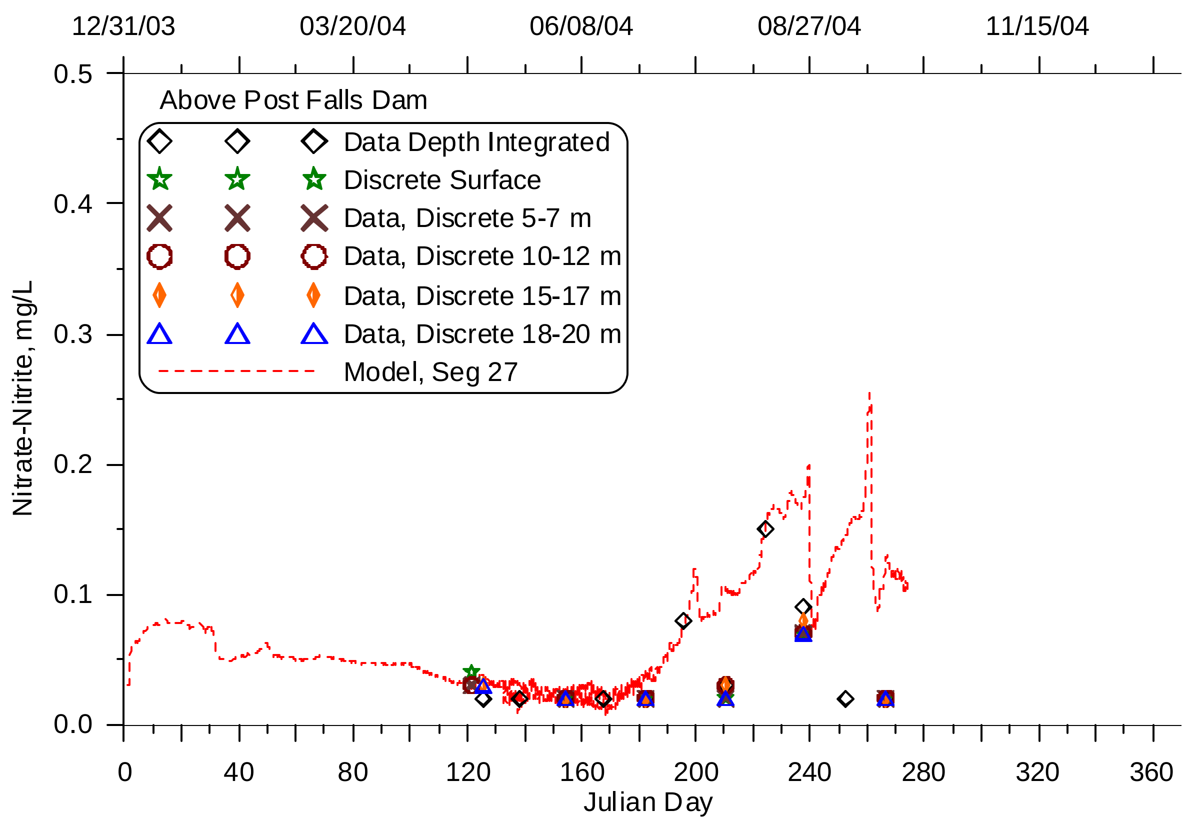


Figure 165: Model-data nitrate-nitrite comparison, above Post Falls Dam, 2004.

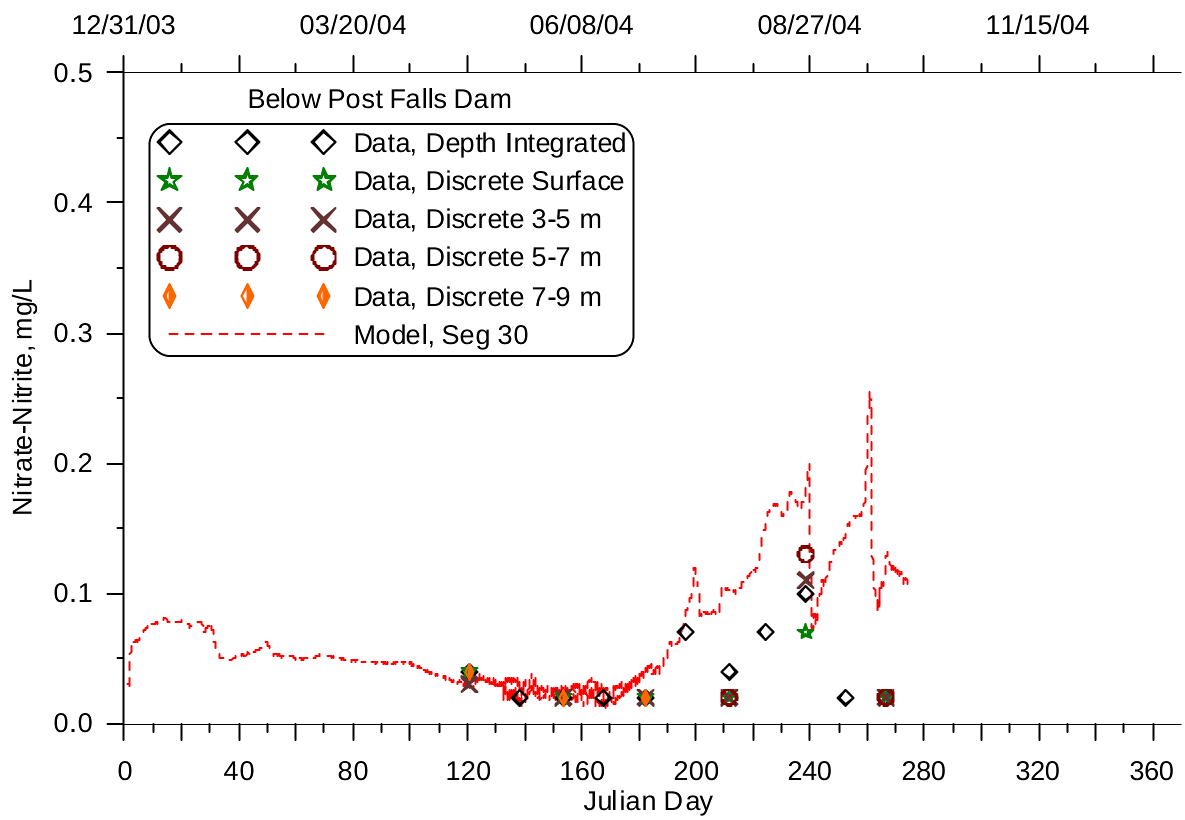


Figure 166: Model-data nitrate-nitrite comparison, below Post Falls Dam, 2004.

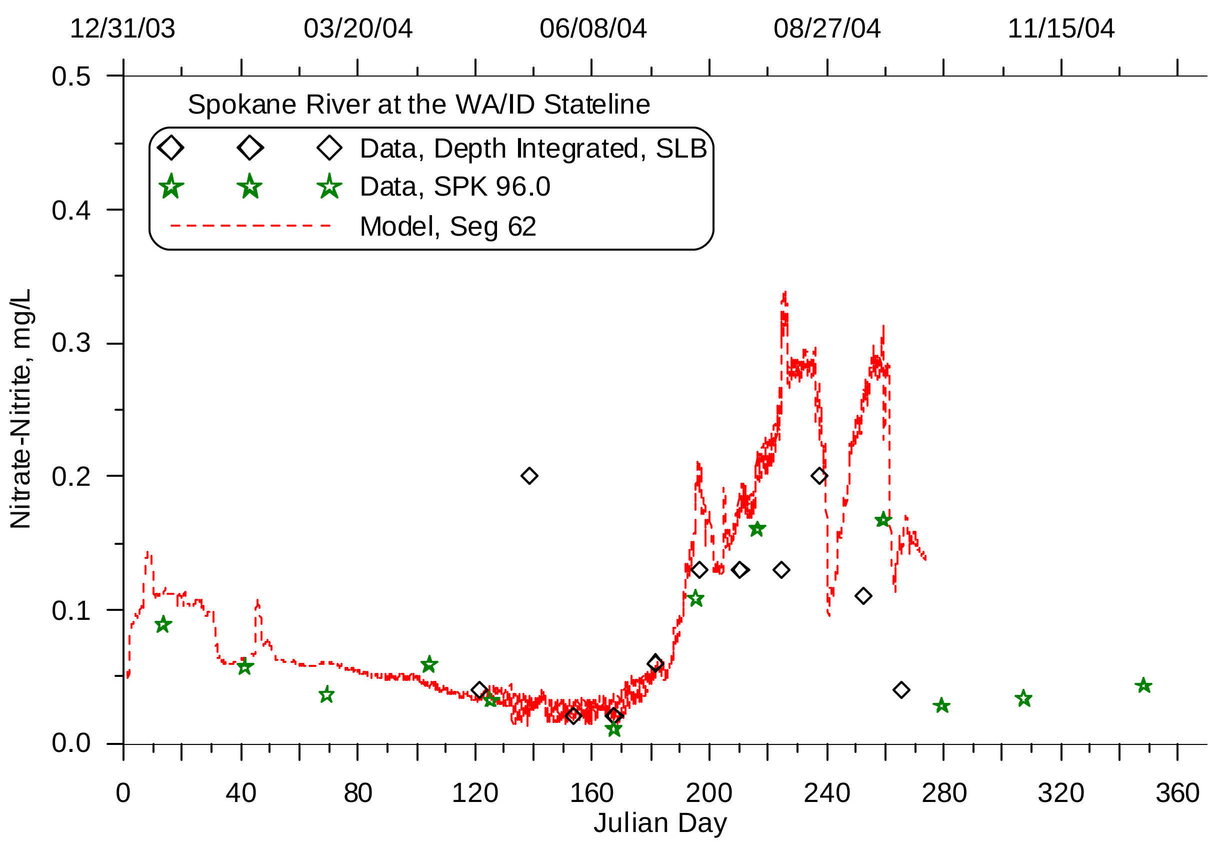


Figure 167: Model-data nitrate-nitrite comparison, at the WA/ID State Line, 2004.

Ammonia

Figure 168 and Figure 169 show comparisons between model predicted ammonia nitrogen concentration and data at the outlet to Lake Coeur d'Alene and the WA/ID State Line, respectively. The figures show the model predictions match well with the data at each of the sites. The diurnal fluctuations in the ammonia nitrogen concentrations were due to uptake and release by periphyton.

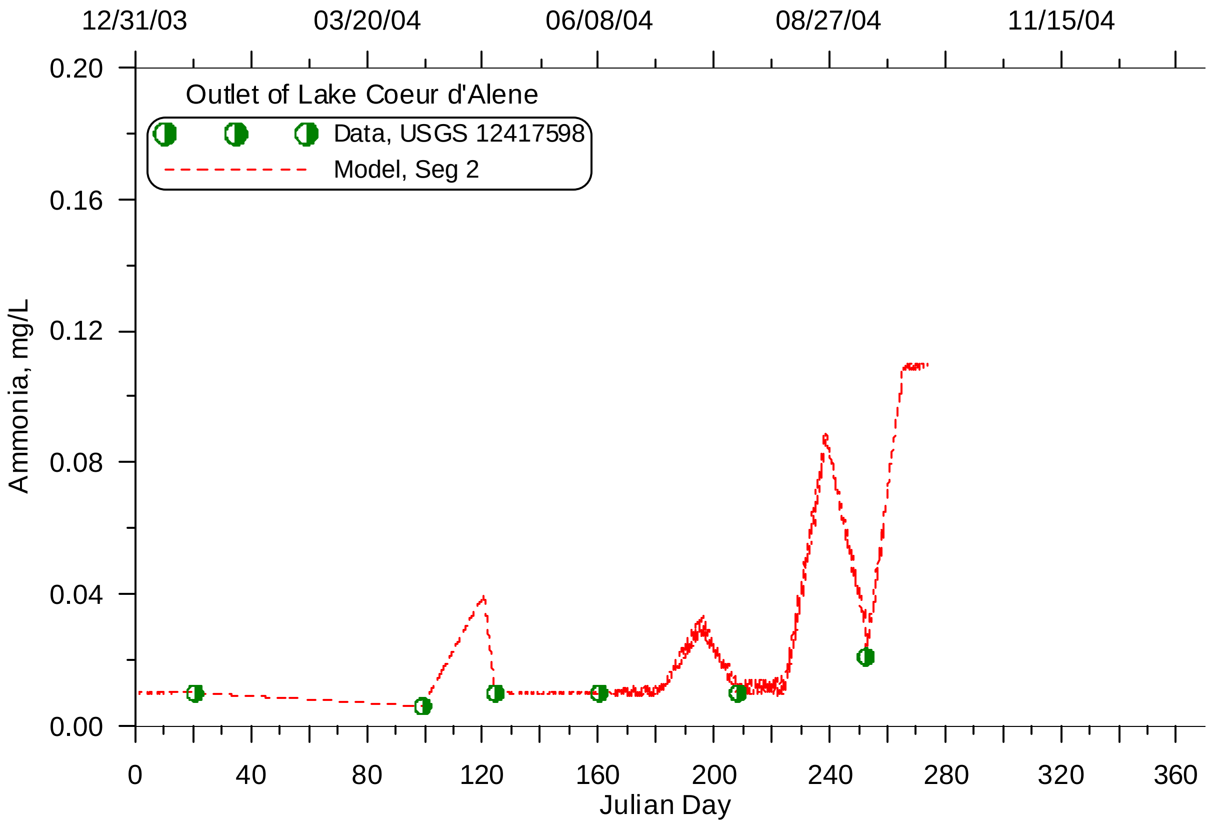


Figure 168: Model-data ammonia comparison, at the Lake Coeur d'Alene outlet, 2004.

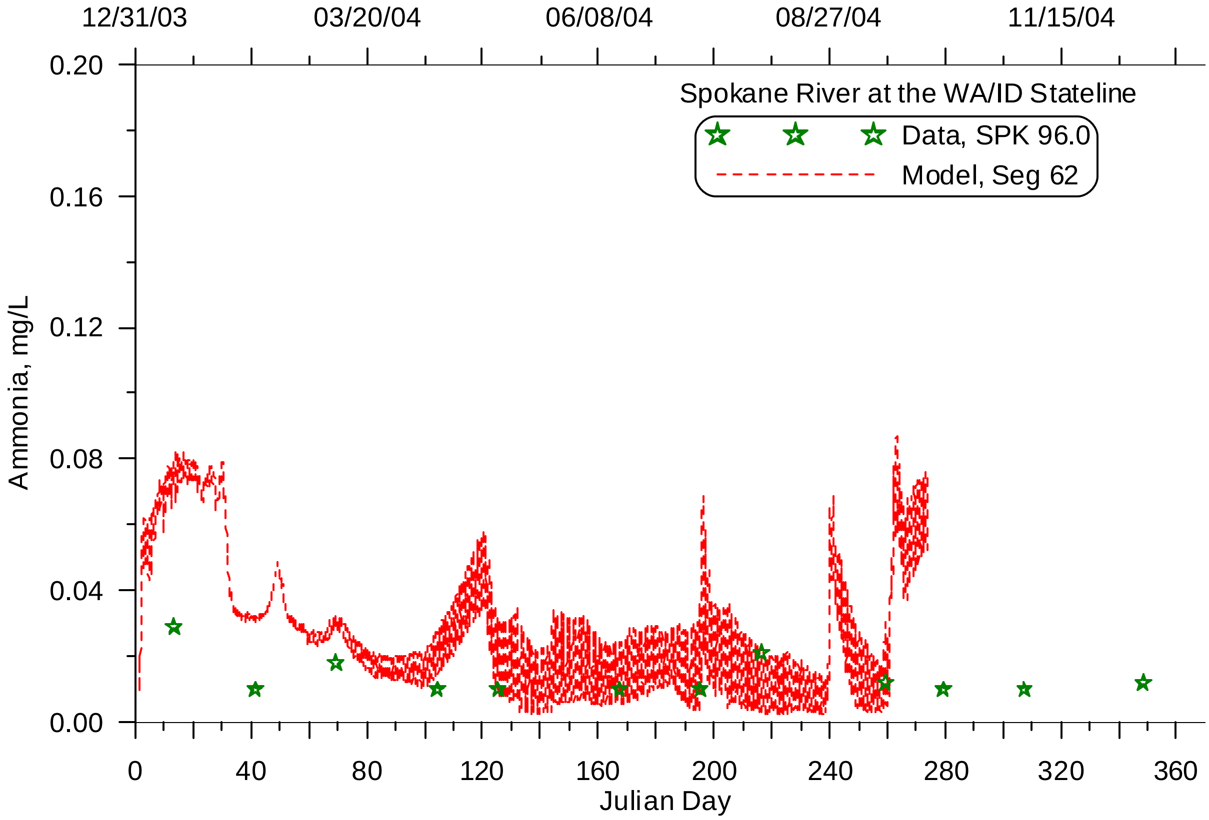


Figure 169: Model-data ammonia comparison, at the WA/ID State Line, 2004.

Total Persulfate Nitrogen

Figure 170, Figure 171, Figure 172, Figure 173 show comparisons between model predicted total persulfate nitrogen concentration and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively. Figure 170 shows the concentration at the upstream boundary condition was slightly higher than the data. The increased concentration was due to introducing 0.5 mg/L of refractory dissolved organic matter that also has a nutrient fraction. The figures for the three sites downstream all show there is good model-data agreement at each site. The diurnal fluctuations in the total persulfate nitrogen concentrations were due to uptake and release by periphyton.

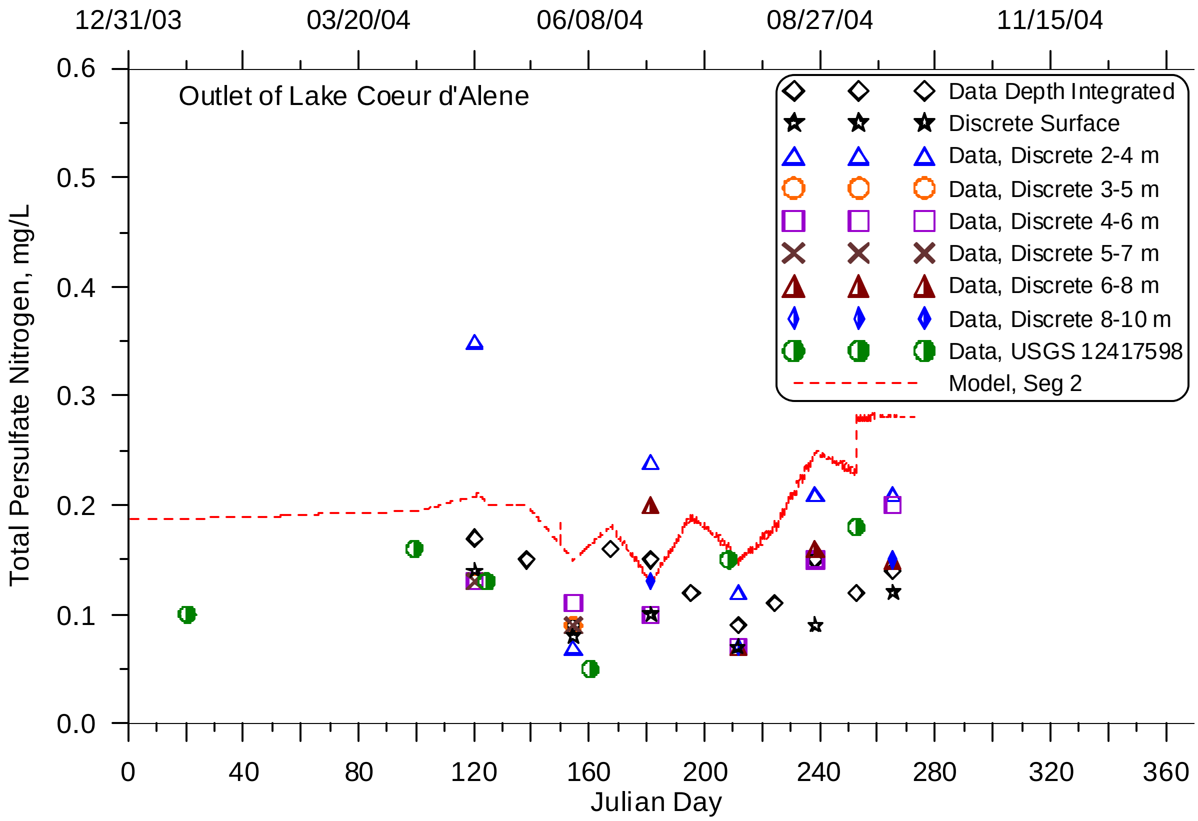


Figure 170: Model-data total persulfate nitrogen comparison, at the Lake Coeur d'Alene outlet, 2004.

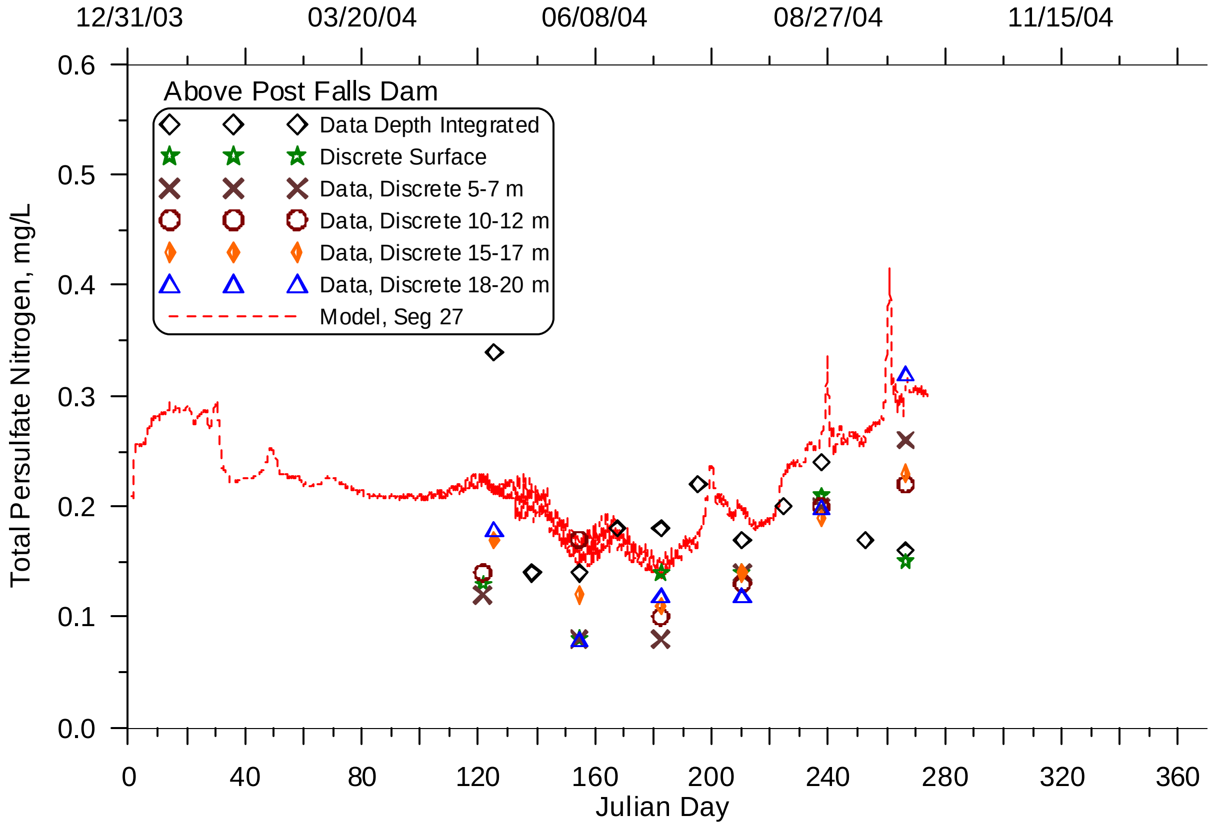


Figure 171: Model-data total persulfate nitrogen comparison, above Post Falls Dam, 2004.

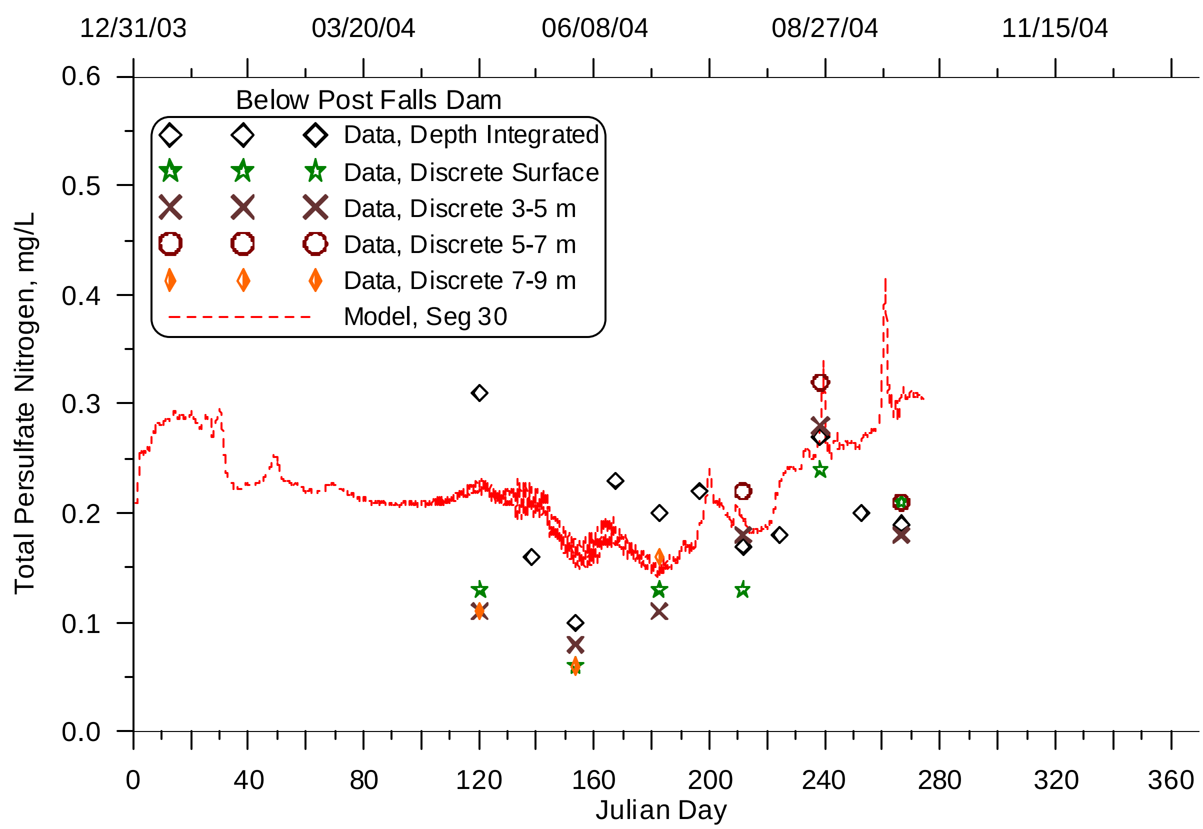


Figure 172: Model-data total persulfate nitrogen comparison, below Post Falls Dam, 2004.

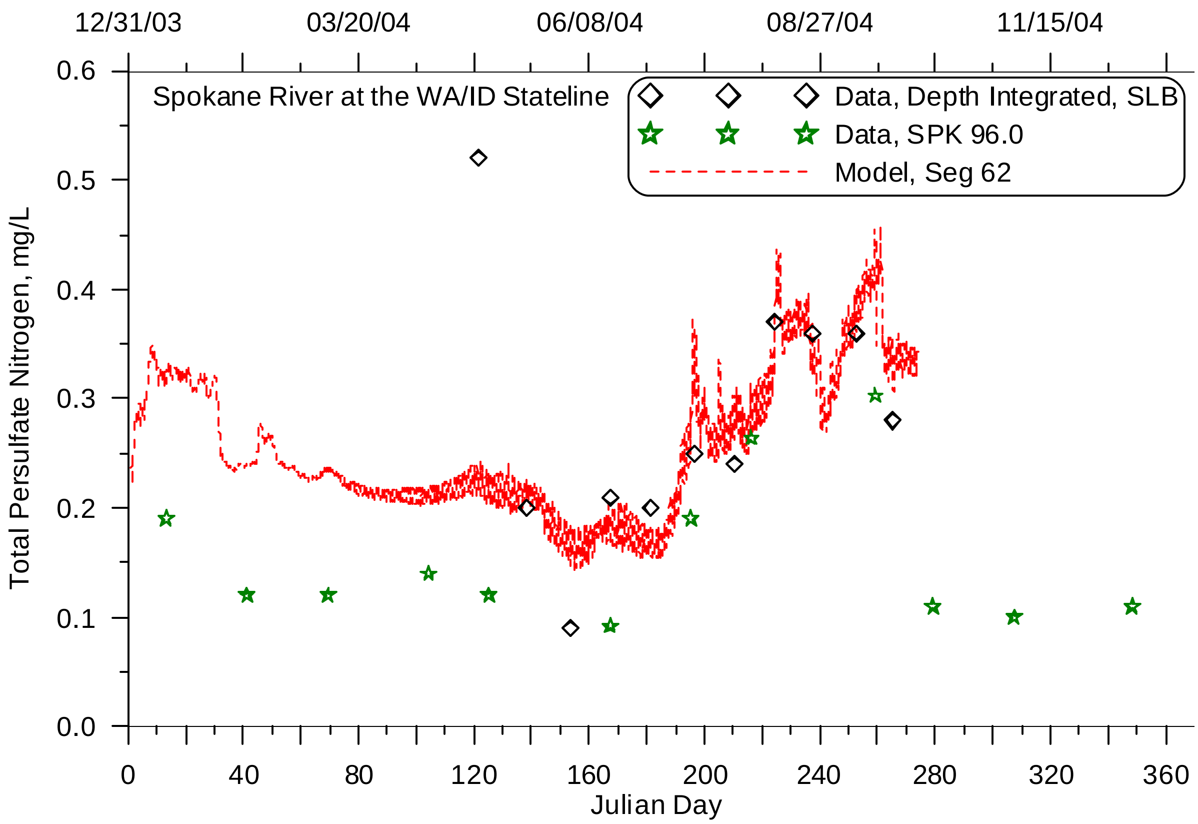


Figure 173: Model-data total persulfate nitrogen comparison, at the WA/ID State Line, 2004.

pH

Figure 174, Figure 175, Figure 176, and Figure 177 show comparisons between model predicted pH and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively. Figure 174 shows the inflow pH at the upstream boundary condition, which is less variable than the data.

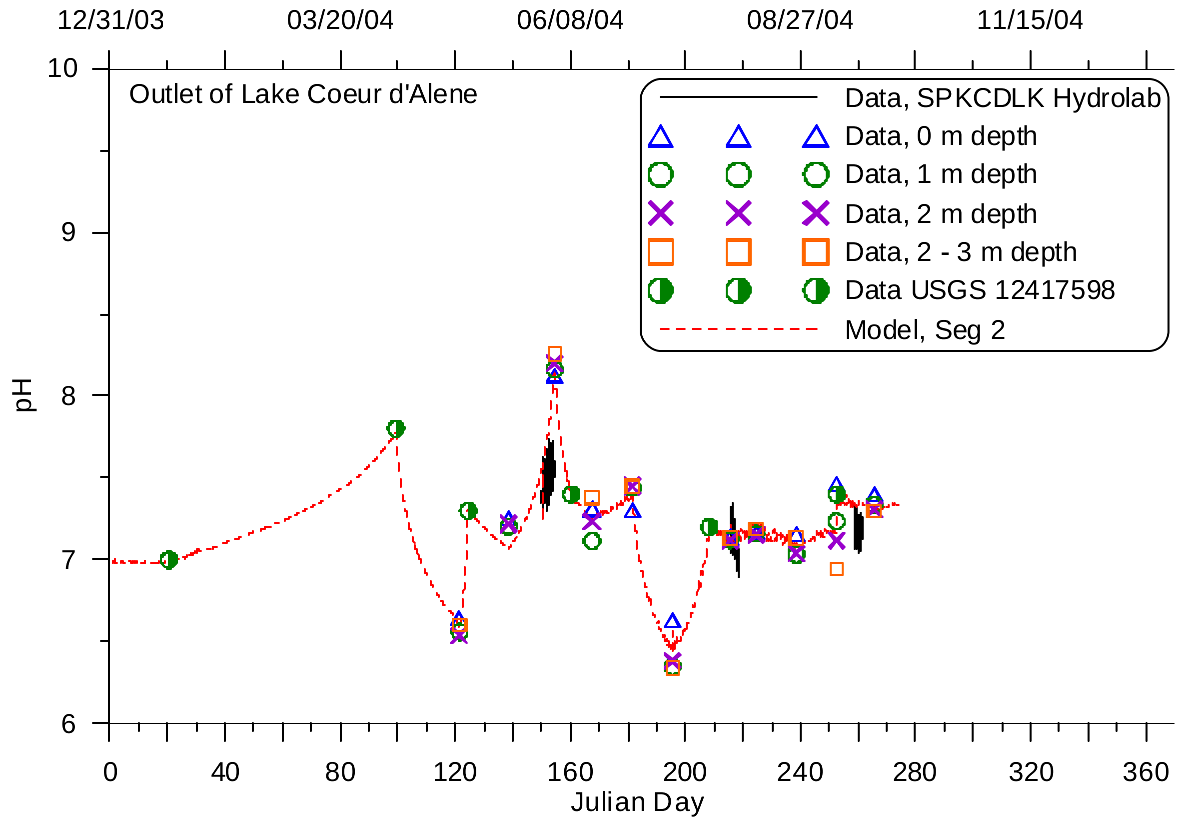


Figure 174: Model-data pH comparison, at the Lake Coeur d'Alene outlet, 2004.

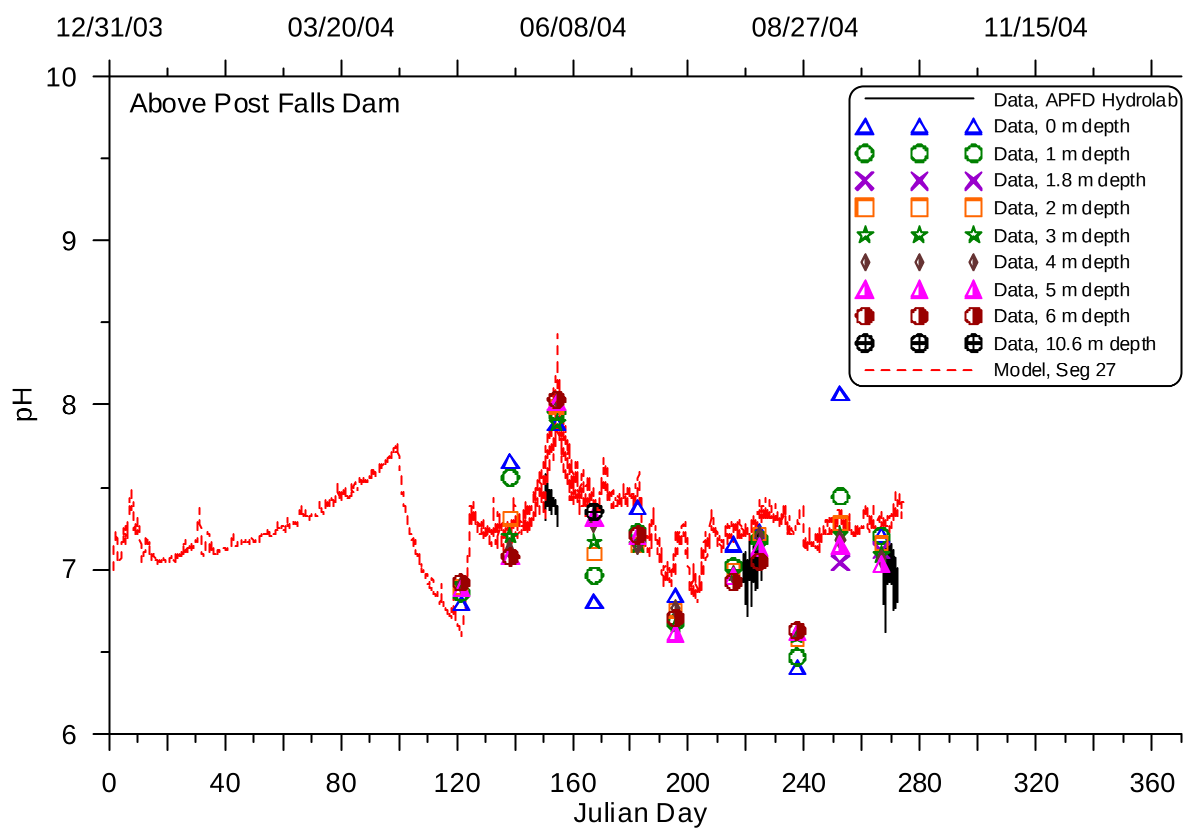


Figure 175: Model-data pH comparison, above Post Falls Dam, 2004.

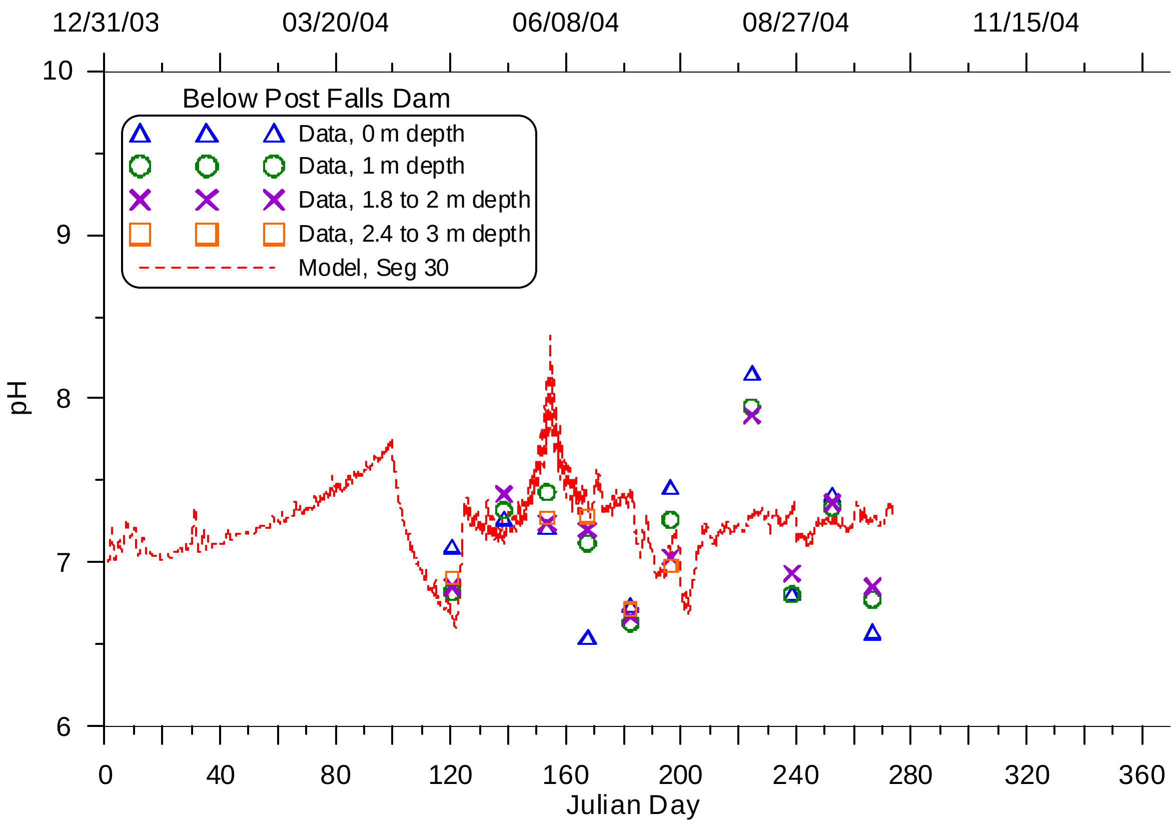


Figure 176: Model-data pH comparison, below Post Falls Dam, 2004.

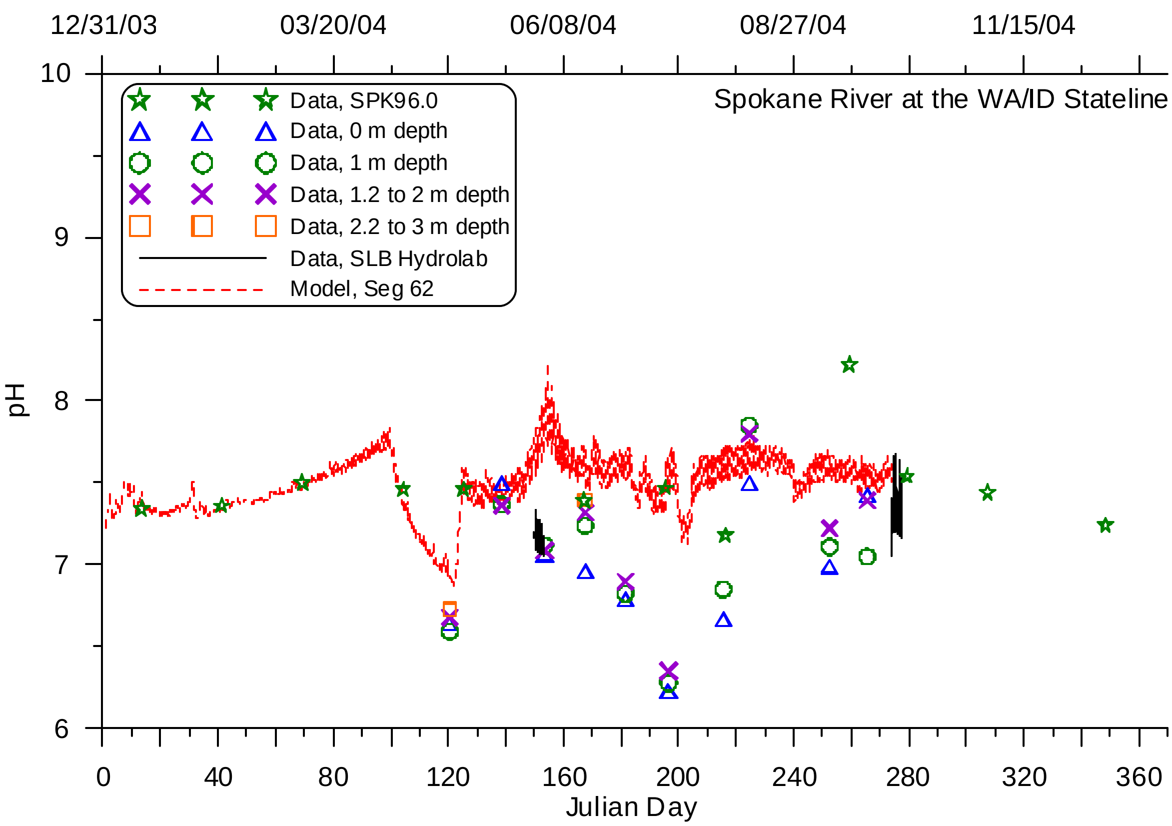


Figure 177: Model-data pH comparison, at the WA/ID State line, 2004.

Dissolved Oxygen

Figure 178, Figure 179, Figure 180, and Figure 181 show comparisons between model predicted dissolved oxygen concentrations and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively. The upstream boundary condition for temperature was based on using the dissolved oxygen saturation concentration, estimated from data. Figure 178 shows the dissolved oxygen concentration at upstream boundary condition compared to the data.

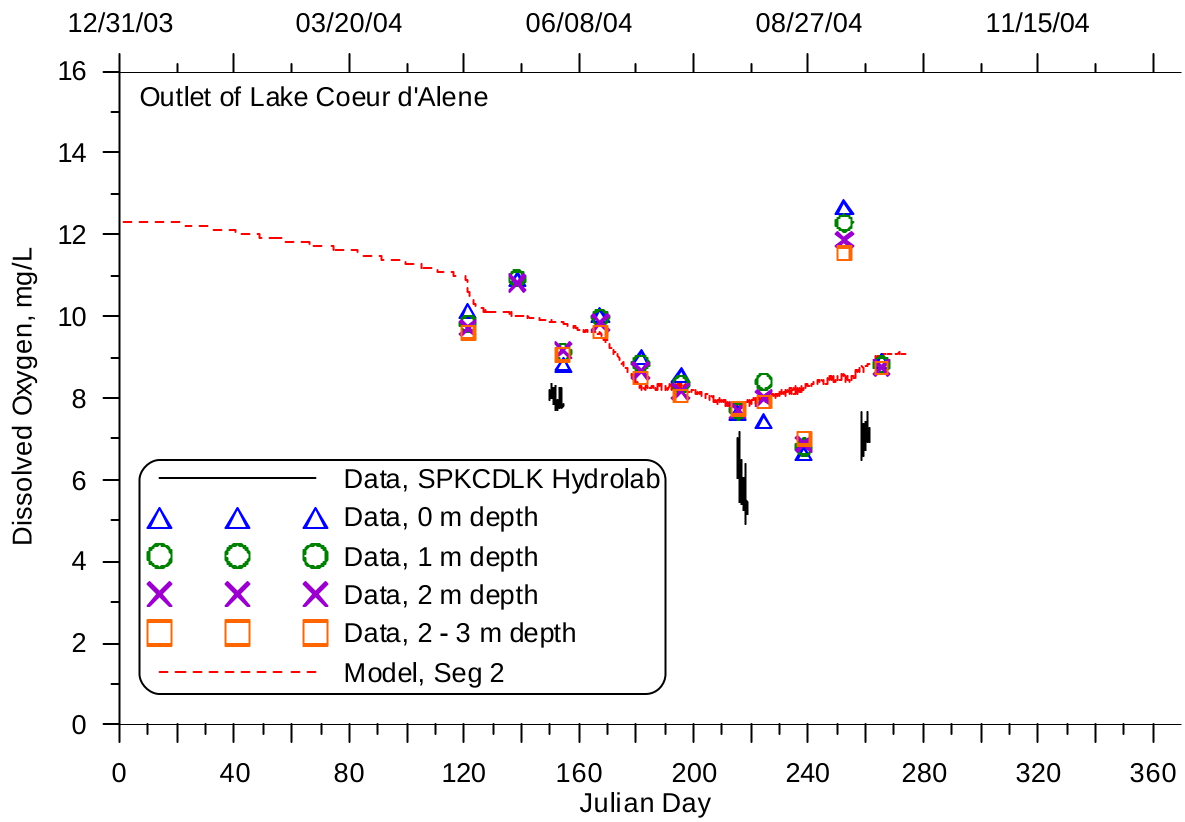


Figure 178: Model-data dissolved oxygen comparison, at the Lake Coeur d'Alene outlet, 2004.

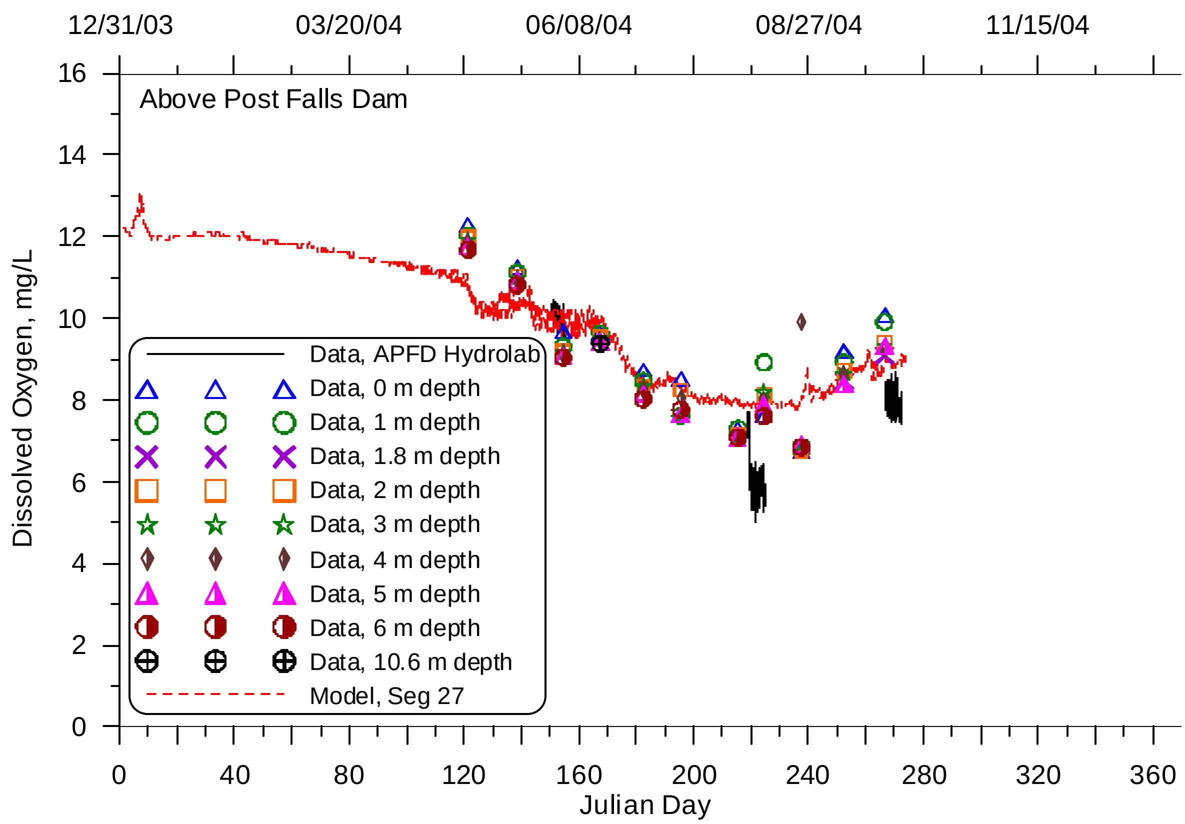


Figure 179: Model-data dissolved oxygen comparison, above Post Falls Dam, 2004.

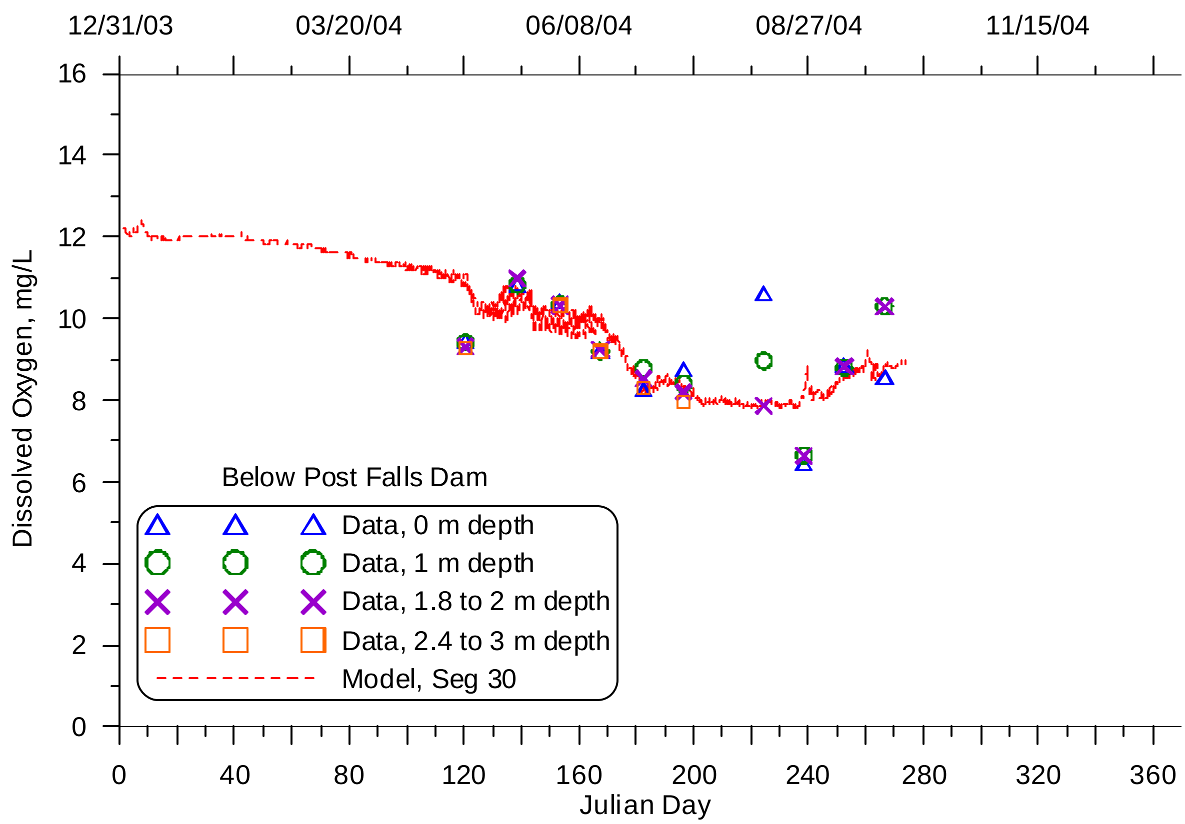


Figure 180: Model-data dissolved oxygen comparison, below Post Falls Dam, 2004.

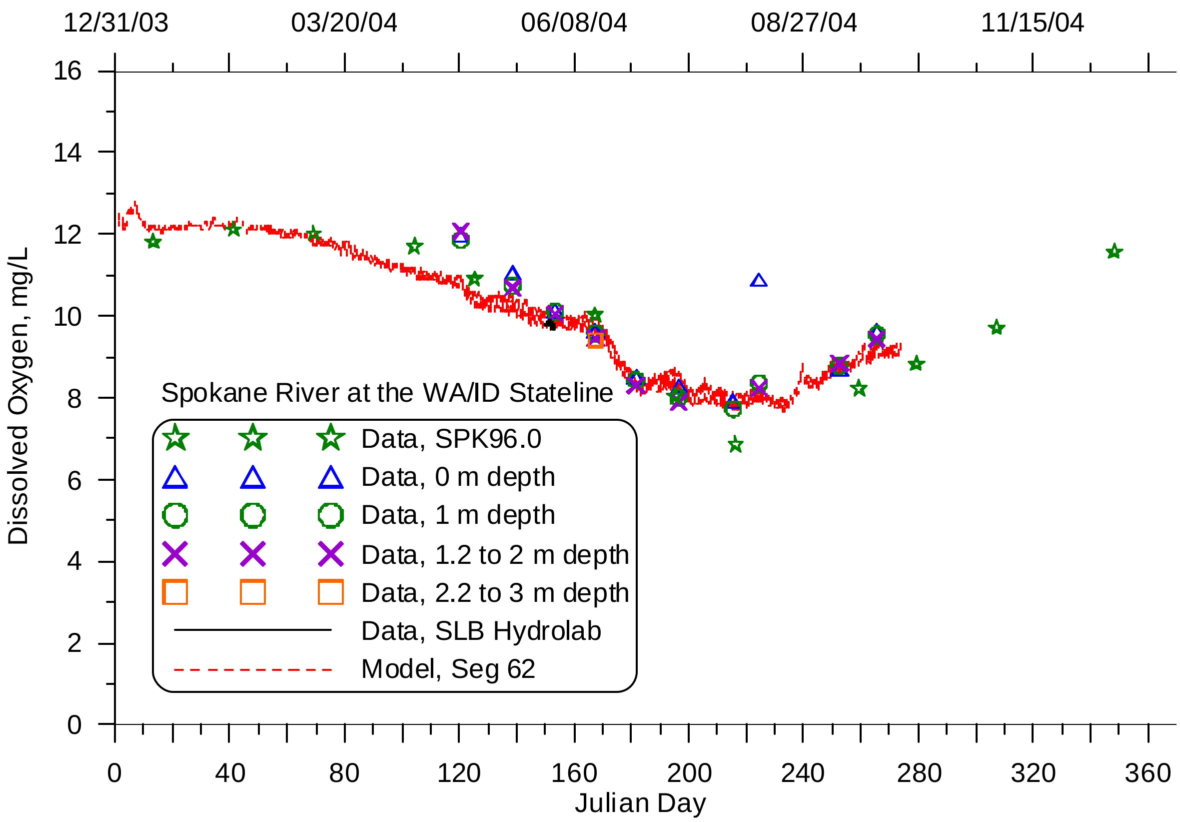


Figure 181: Model-data dissolved oxygen comparison, at the WA/ID State Line, 2004.

Periphyton

Figure 182 shows comparisons between model predicted periphyton biomass concentration and data at the WA/ID State Line in 2004. The data in the figure represents the average biomass from several samples collected at different depths on one day in August and one in September in ***2001***. In 2004 river flows were higher than in 2001 so there may have been less periphyton biomass due to higher stream velocities and larger depths of water (and hence less solar radiation available). The model output presents the average periphyton biomass concentration across the model segment with the highest density of 20 g/m^2.

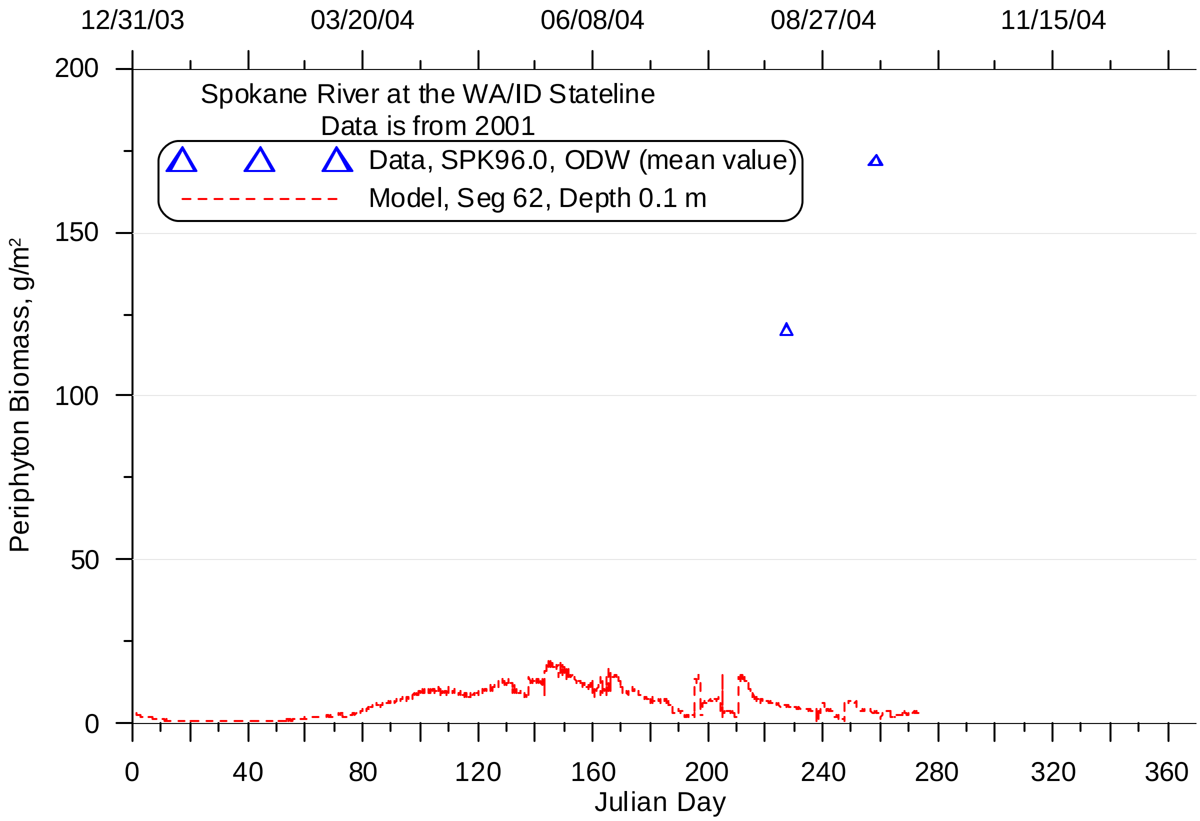


Figure 182: Model-data periphyton biomass comparison, at the WA/ID State Line, 2004 (Data is from 2001).

Chlorophyll a

Figure 183, Figure 184, Figure 185, and Figure 186 show comparisons between model predicted chlorophyll a concentrations and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively.

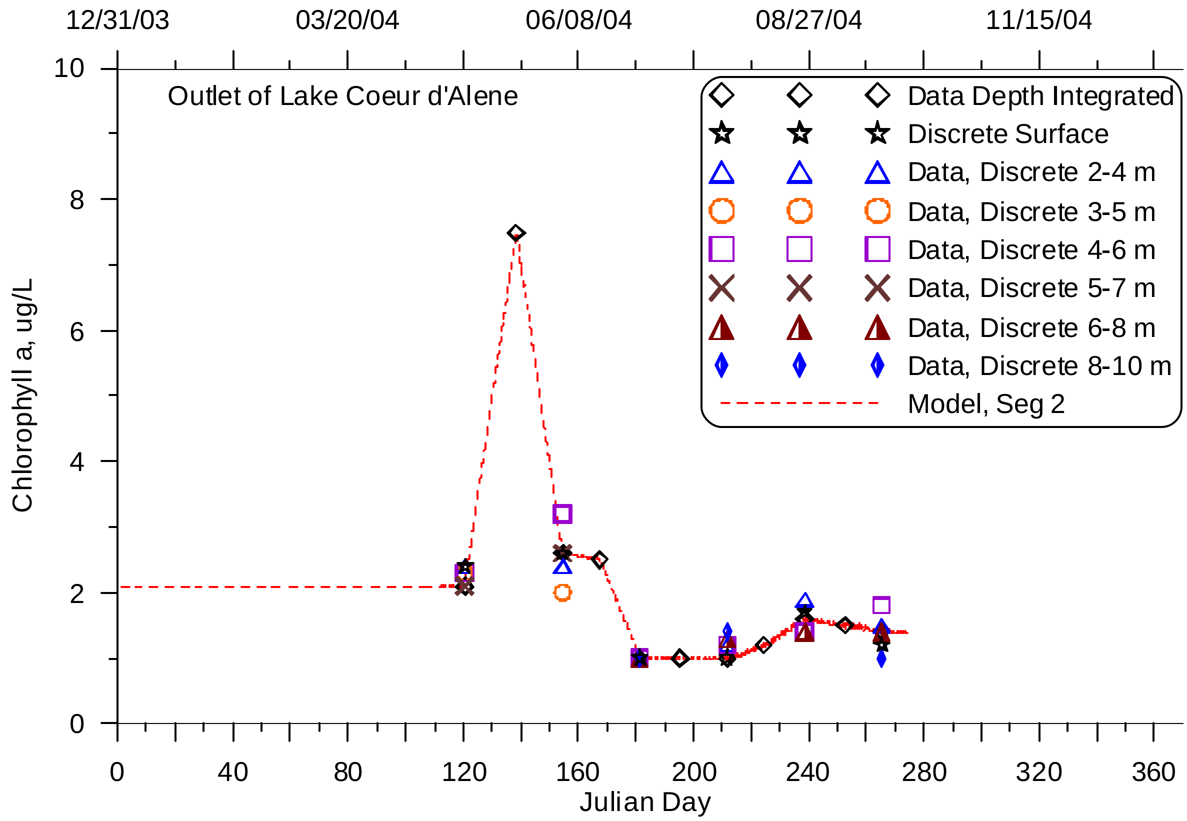


Figure 183: Model-data chlorophyll a comparison, at the Lake Coeur d'Alene outlet, 2004.

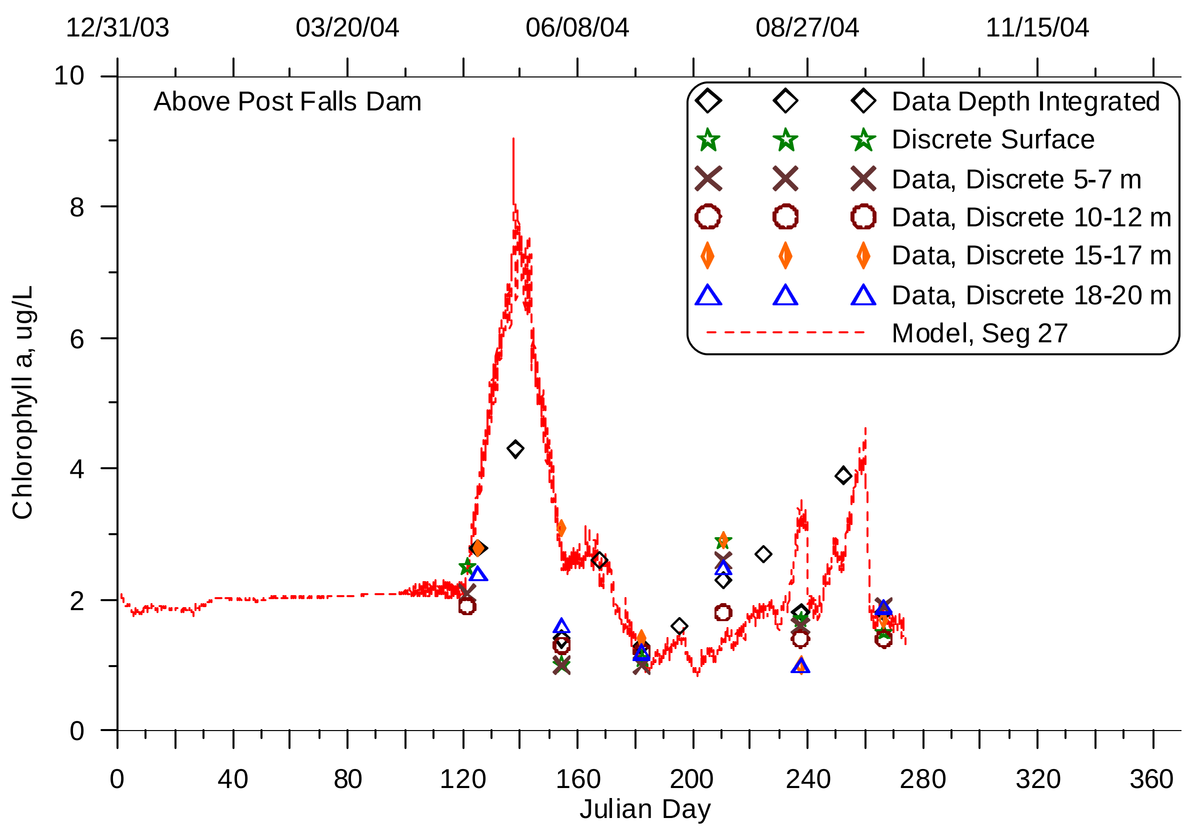


Figure 184: Model-data chlorophyll a comparison, above Post Falls Dam, 2004.

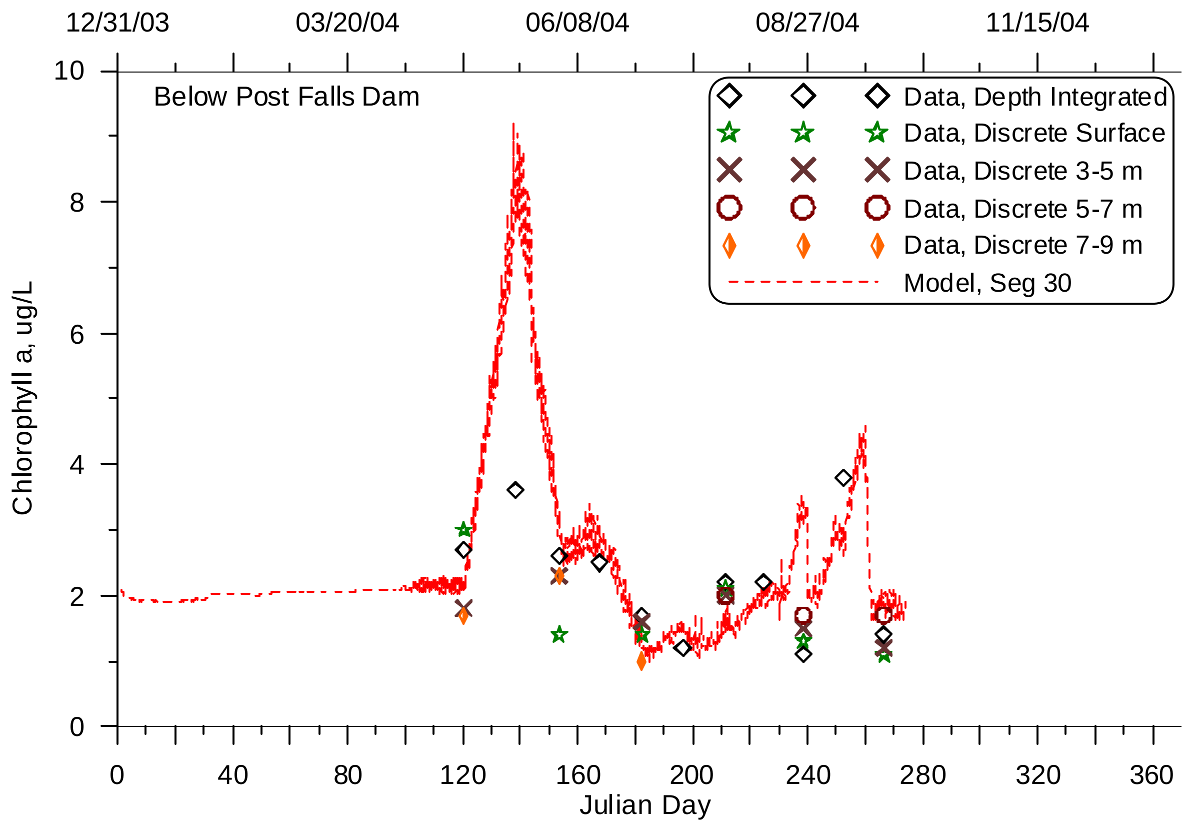


Figure 185: Model-data chlorophyll a comparison, below Post Falls Dam, 2004.

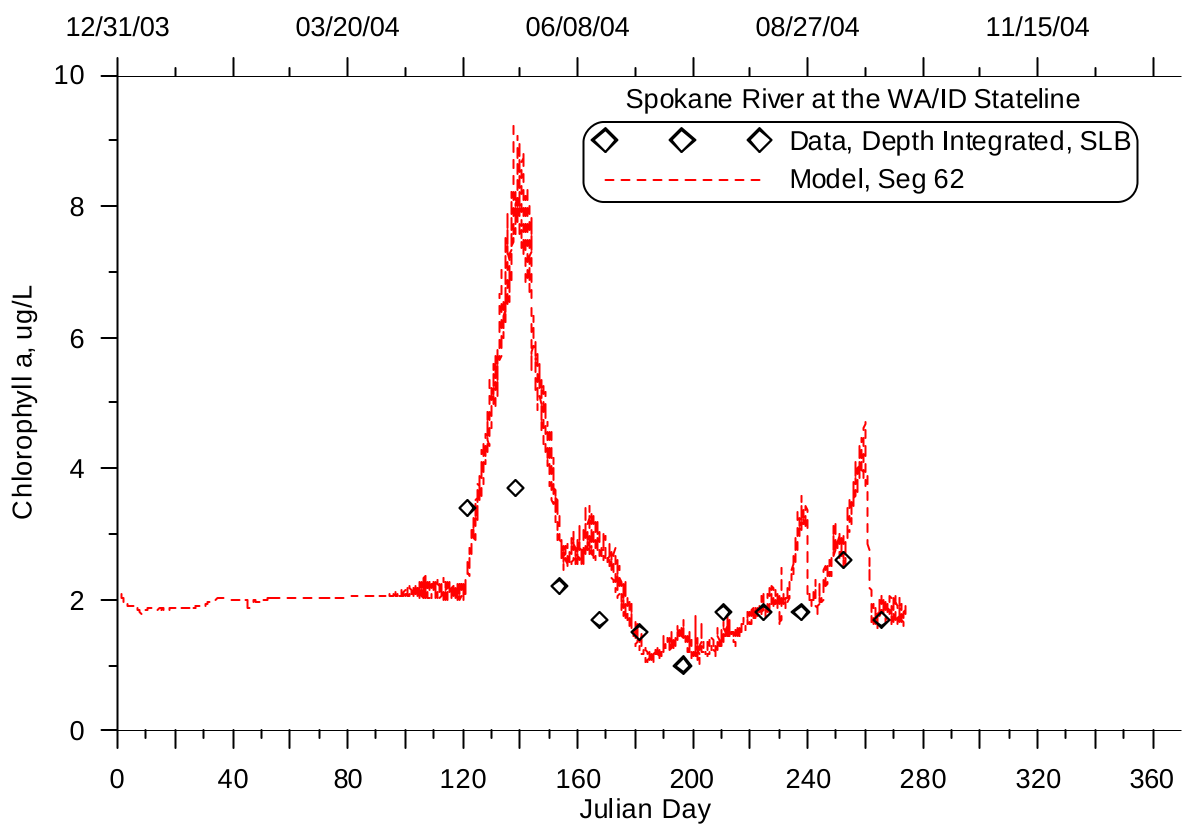


Figure 186: Model-data chlorophyll a comparison, at the WA/ID State Line, 2004.

Carbonaceous Biochemical Oxygen Demand

Figure 187, Figure 188, Figure 189, and Figure 190 show comparisons between model predicted ultimate carbonaceous biochemical oxygen demand ($CBOD_u$) concentrations and data at the outlet to Lake Coeur d'Alene, upstream and downstream of Post Falls Dam, and the WA/ID State Line, respectively.

Figure 187 shows the inflow carbonaceous biochemical oxygen demand concentrations at the upstream boundary condition, which were slightly higher than data. The difference between the model and data can be accounted for by two issues: the model predicted $CBOD_u$ assumes all organic matter has been decayed to completion whereas the data reflects the time limits over which the test was conducted, and the model also includes in the $CBOD_u$ calculation the decay of the refractory dissolved organic matter which was added to the model (0.5 mg/L). The model-data comparisons downstream show there is relatively good agreement.

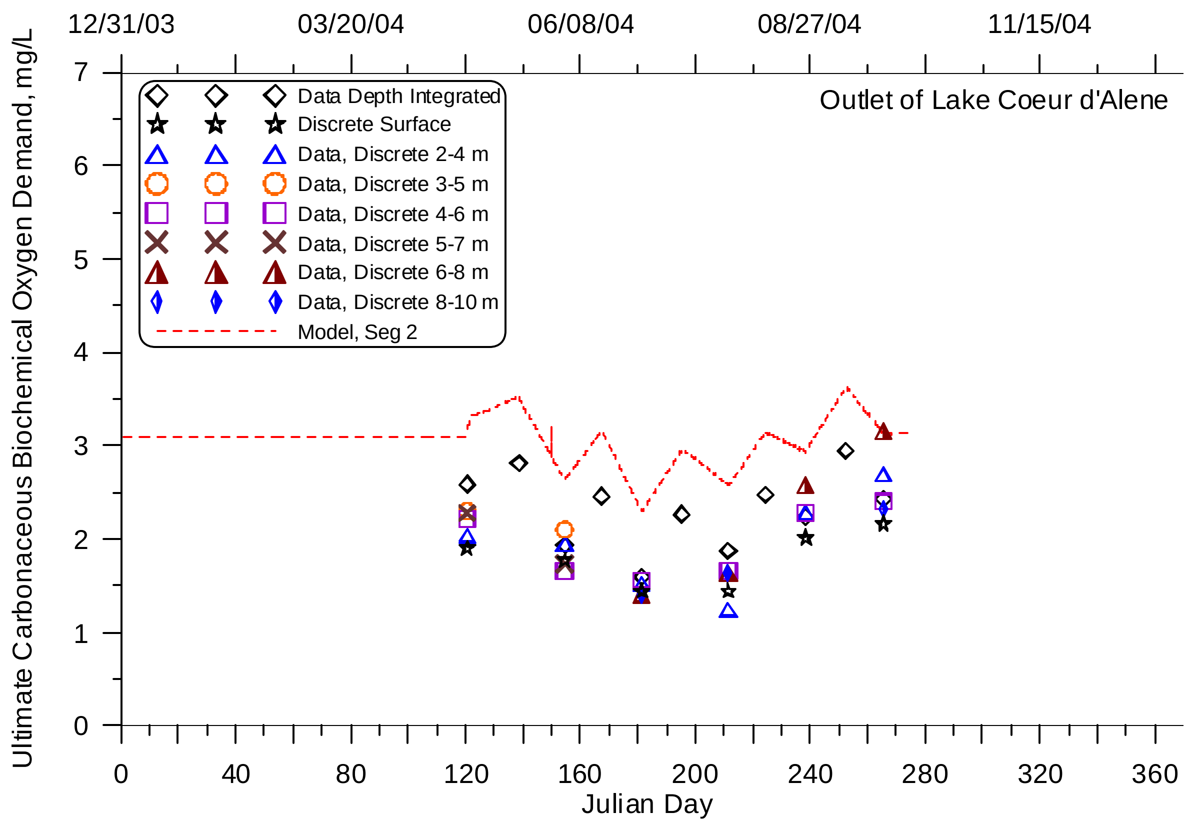


Figure 187: Model-data carbonaceous biochemical oxygen demand comparison, at the Lake Coeur d'Alene outlet, 2004.

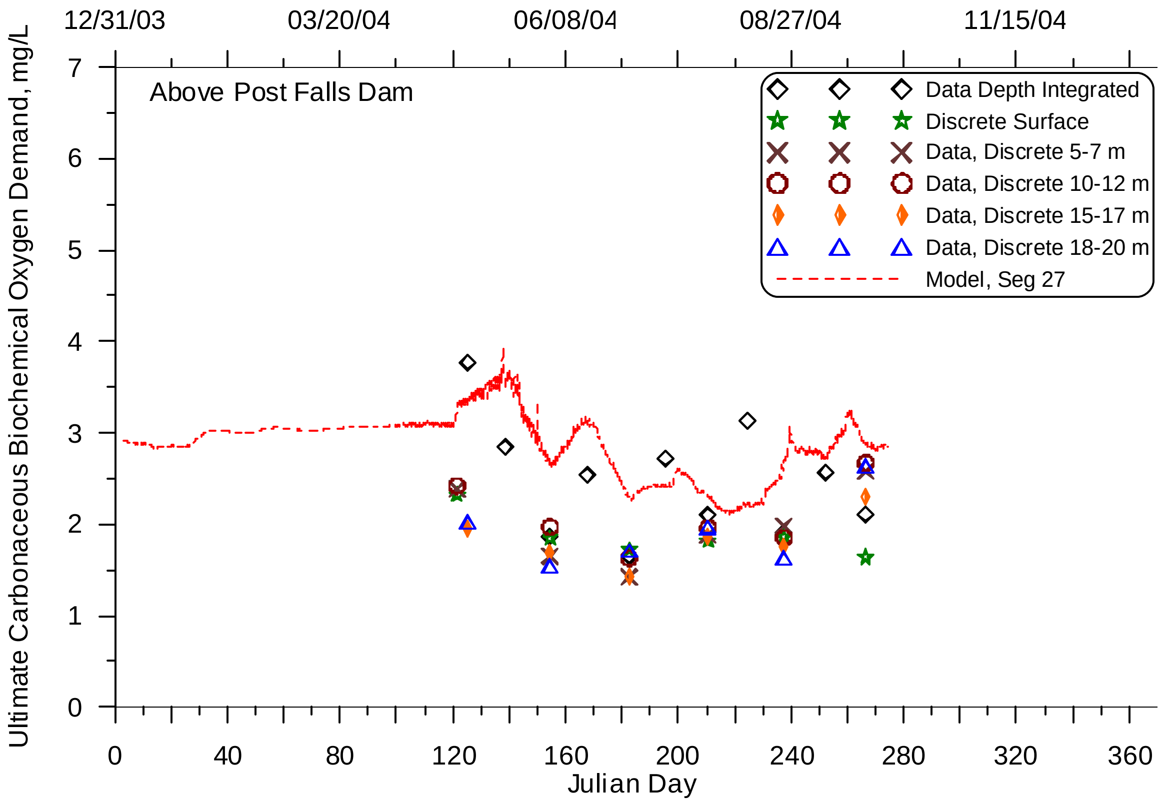


Figure 188: Model-data carbonaceous biochemical oxygen demand comparison, above Post Falls Dam, 2004.

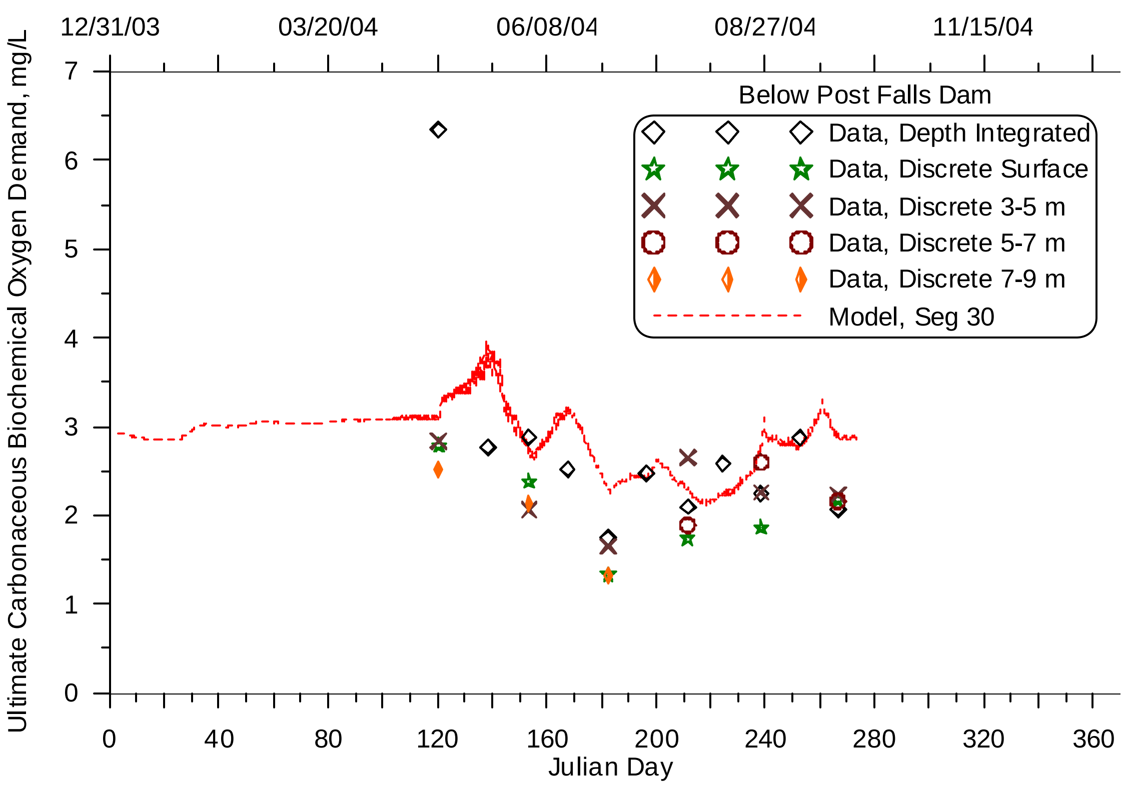


Figure 189: Model-data carbonaceous biochemical oxygen demand comparison, below Post Falls Dam, 2004.

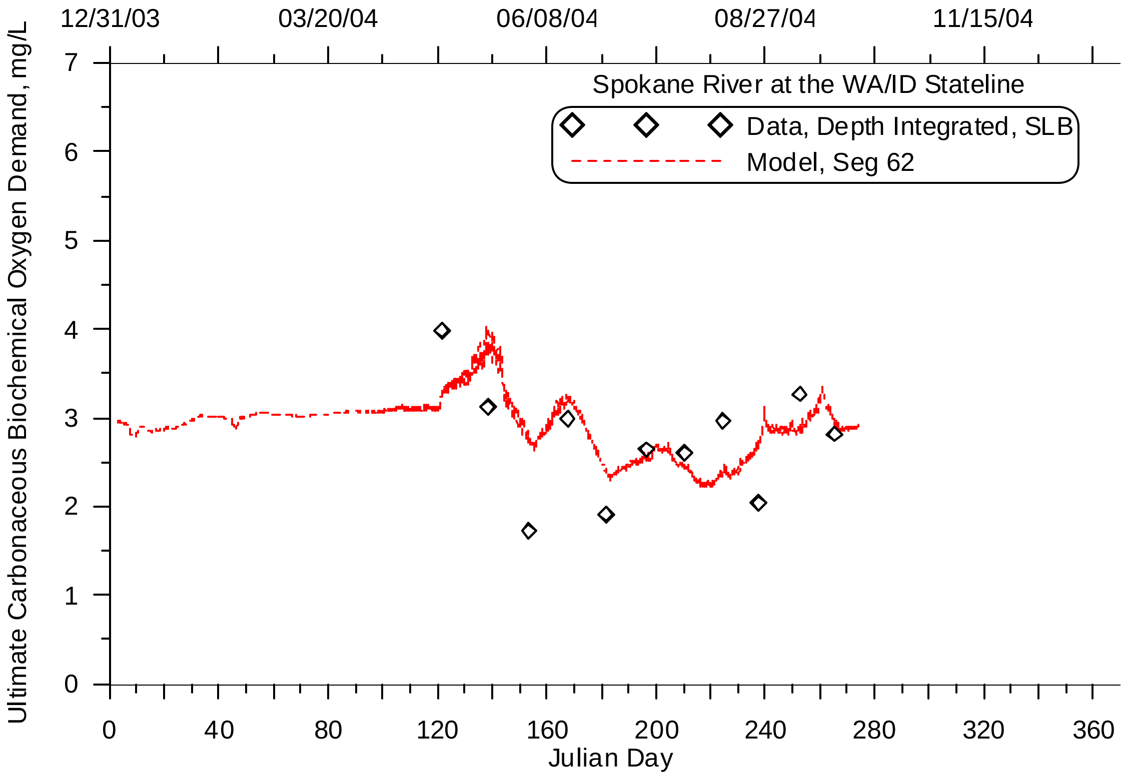


Figure 190: Model-data carbonaceous biochemical oxygen demand comparison, at the WA/ID State Line, 2004.

Total Suspended Solids

Figure 191 and Figure 192 show comparisons between model predicted total suspended solids concentration and data at the outlet to Lake Coeur d'Alene and the WA/ID State Line, respectively. Total suspended solids were modeled as a conservative constituent and are dependent on the upstream boundary condition. The figures show the model does reasonably well with less agreement at the downstream end of the model. This may be due to a lack of data at the upstream boundary condition.

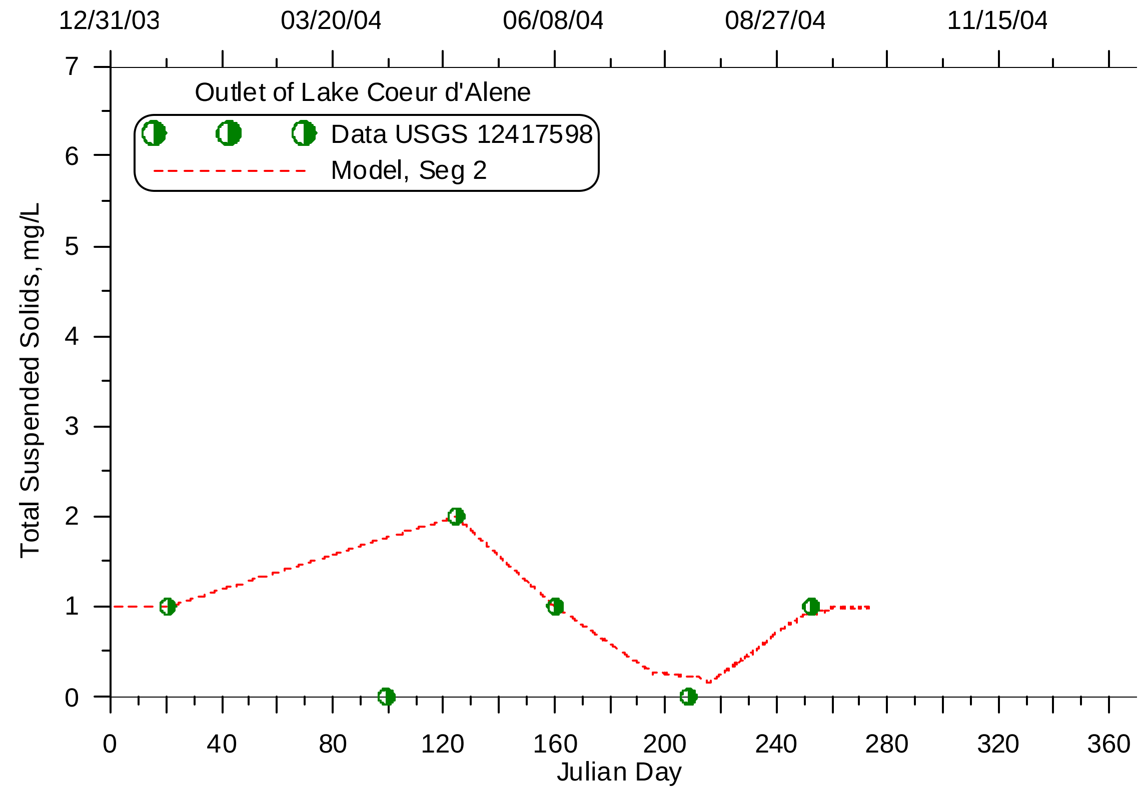


Figure 191: Model-data total suspended solids comparison, at the Lake Coeur d'Alene outlet, 2004.

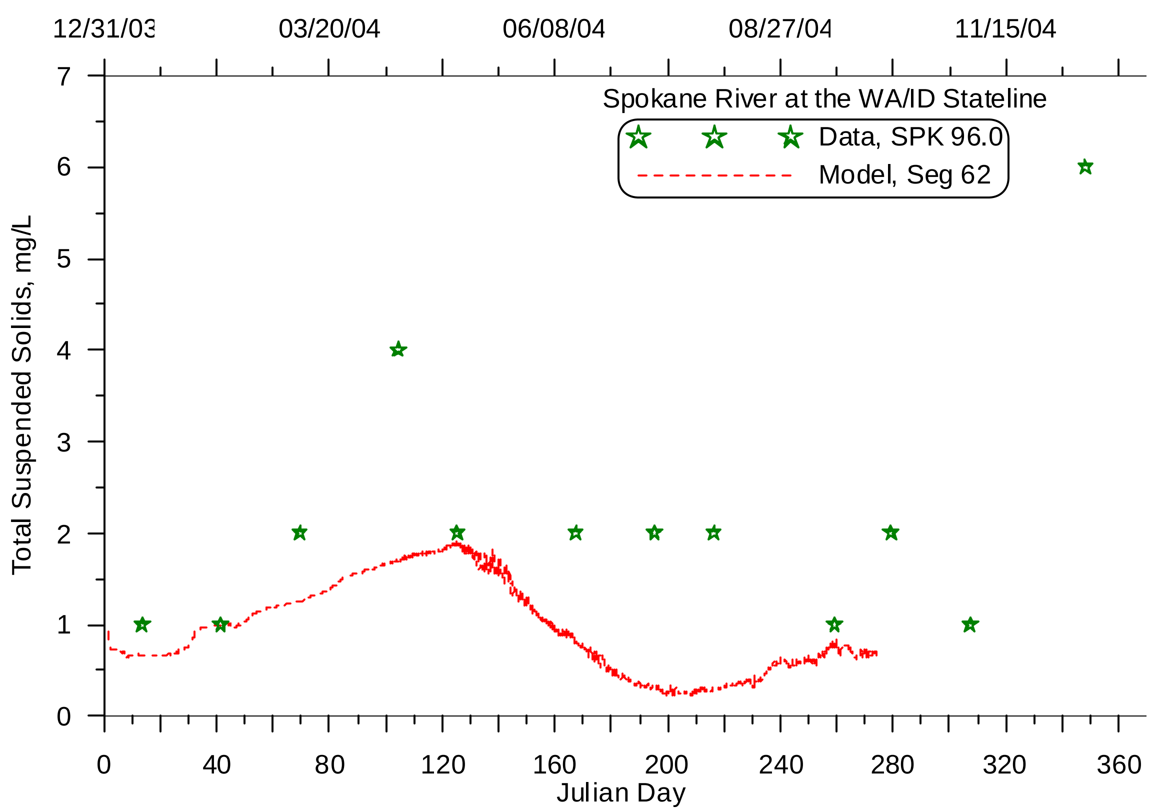


Figure 192: Model-data total suspended solids comparison, at the WA/ID State Line, 2004.

Travel Time

The 2001 and 2004 models of the Spokane River in Idaho were run with the model calculating the depth averaged velocity at each model segment. Figure 193 shows a time series plot of the depth averaged horizontal velocity in 2001 at model segments 26 and 27, which are just upstream of the Post Falls Dam. Differences in velocity are related to differences in cross-sectional area. Figure 194 shows a time series plot of the depth averaged horizontal velocity in 2001 at model segments 61 and 62 at the WA/ID State Line. Again the differences in velocity between the two model segments are due differences in cross-sections.

Figure 195 shows a time series plot of the depth averaged horizontal velocity in 2004 at model segments 26 and 27, above the Post Falls Dam. Figure 196 shows a time series plot of the depth averaged horizontal velocity in 2004 at model segments 61 and 62 at the WA/ID State Line.

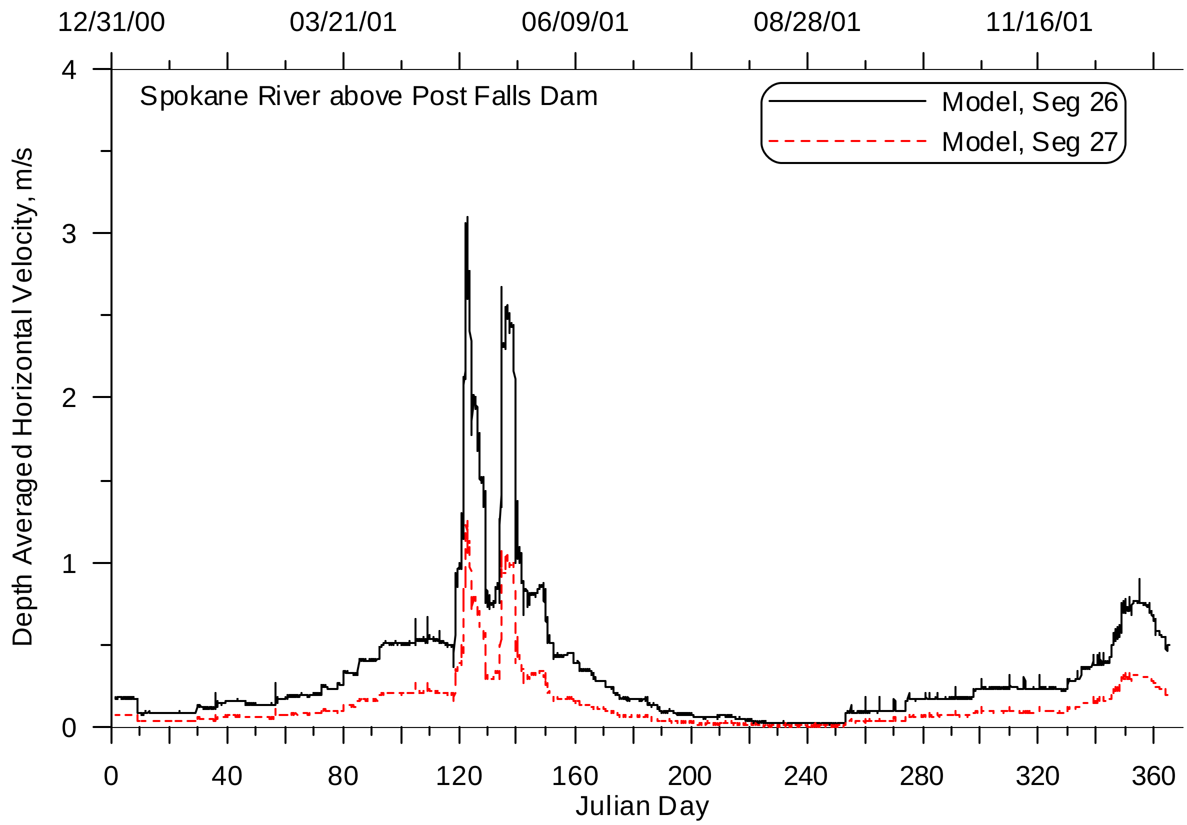


Figure 193: Depth averaged velocity above the Post Falls Dam, 2001.

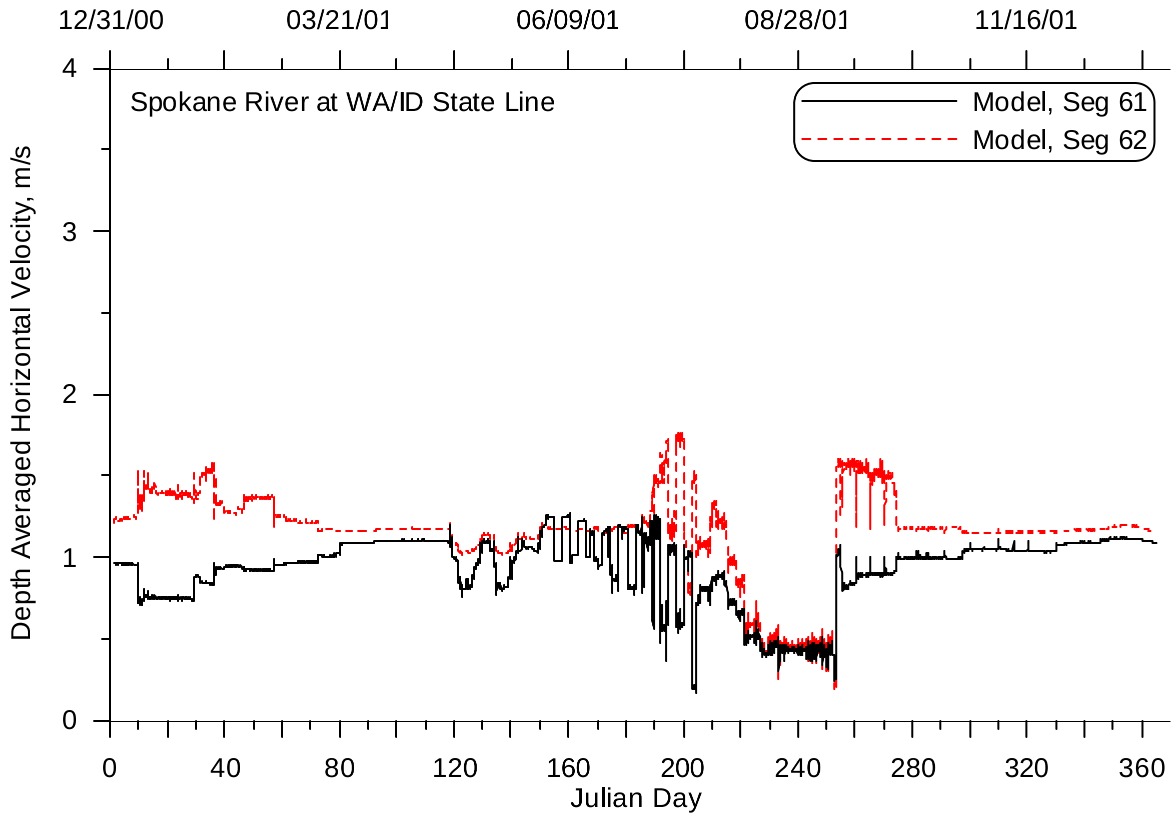


Figure 194: Depth averaged velocity at the WA/ID State Line, 2001.

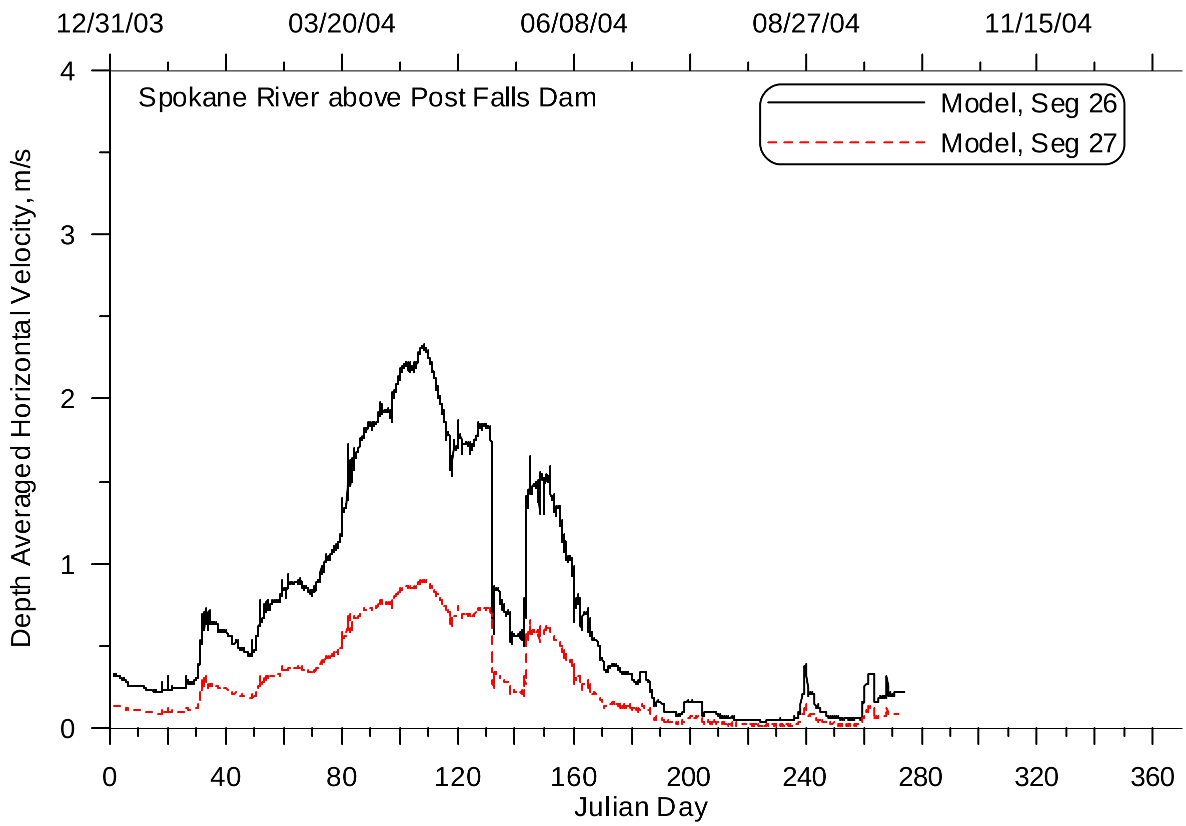


Figure 195: Depth averaged velocity above the Post Falls Dam, 2004.

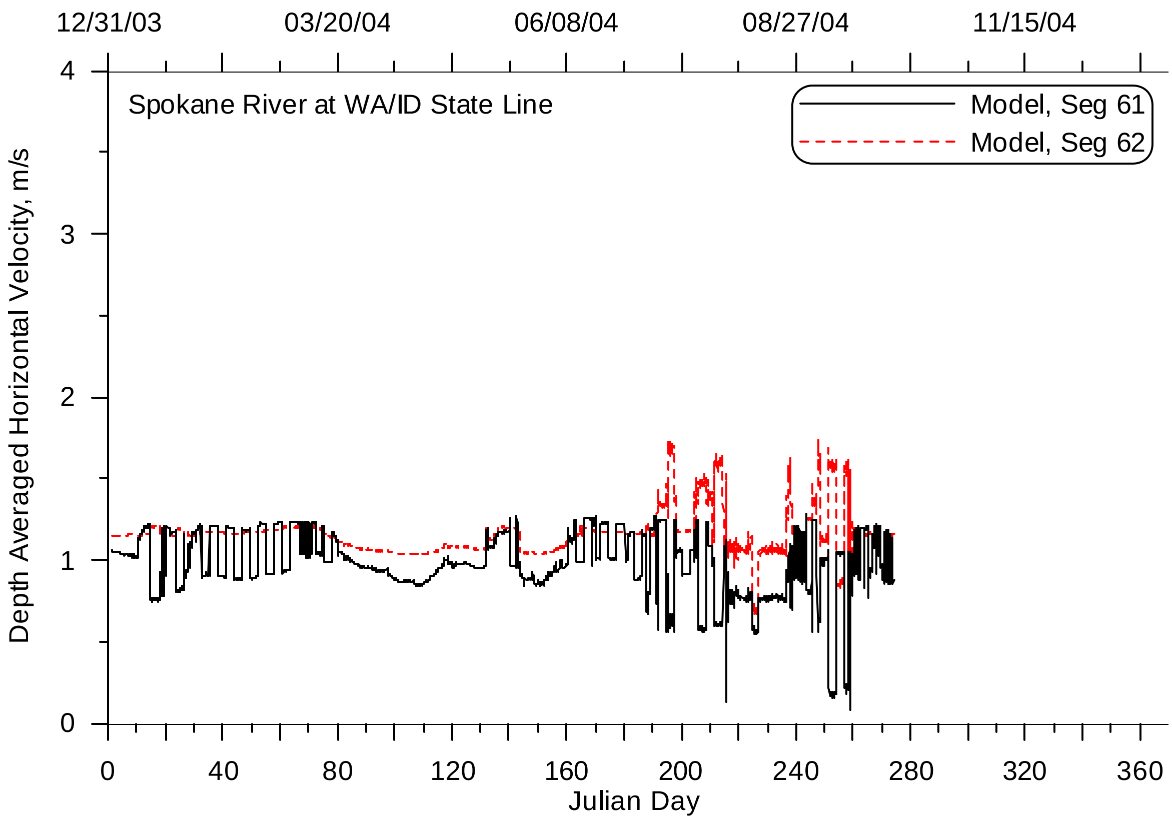


Figure 196: Depth averaged velocity at the WA/ID State Line, 2004.

The depth averaged horizontal velocities at each model segment were averaged across the model simulation and across the river reaches above and below the Post Falls Dams. The averaged horizontal velocities for each reach were then used to calculate the travel time in each reach in 2001 and 2004. Table 23 shows the average velocities and travel times for the Spokane River above Post Falls Dam and the Spokane River below Post Falls Dam. The table shows the river below had a travel time of 2 to 2.5 hours and the river/lake section above Post Falls Dam had a travel time of 18 to 32.5 hours.

Table 23: Average velocities and travel times in 2001 and 2004

		2001	2001	2004	2004
Reach	Distance, km	Average Velocity, m/s	Travel Time, hrs	Average Velocity, m/s	Travel Time, hrs
Above Post Falls Dam	16.74	0.14	32.51	0.26	17.95
Spokane River below Post Falls Dam	8.34	1.00	2.32	1.09	2.13

Nutrient Loading

The total phosphorus loading during the model simulation period and the summer (May 1st to September 30th) were calculated for both simulation years. As noted in the model Skalan Creek had flows set to zero since there were no flow data for the creek and the creek's contribution to the model was expected to small. As a result of zero flow, there was no nutrient loading for the creek.

The total phosphorus loading was calculated by adding up the soluble reactive phosphorus, the fraction of phosphorus in algae, and the fraction of phosphorus in the CBOD compartment over time for the model simulation period or the summer for each model inflow.

The total nitrogen loading was calculated by adding up the ammonia, nitrite-nitrate, the fraction of nitrogen in algae, and the fraction of nitrogen in the CBOD compartment over time for the model simulation period or the summer for each model inflow.

Model Simulation Periods, 2001 and 2004

The total phosphorus and total nitrogen loadings were calculated over the model simulation periods in 2001 (January 1st to December 31st) and 2004 (January 1st to September 30th). Table 24 shows the total phosphorus and nitrogen loading for the upstream boundary condition and the tributary inflows from the dischargers.

Figure 197 and Figure 198 show pie diagrams of the fraction of total phosphorus and total nitrogen loading to the Spokane River for each inflow source in 2001, respectively. Figure 199 and Figure 200 show pie diagrams of the fraction of total phosphorus and total nitrogen loading to the Spokane River for each inflow source in 2004, respectively. The figure indicates the largest source of nitrogen and phosphorus loading to the Spokane River in ID is from Lake Coeur d'Alene, due to the large flows to the Spokane River.

Table 24: Total phosphorus and total nitrogen loading, 2001 and 2004.

Source	January 1st – December 31st, 2001		January 1 – September 30th, 2004	
	P load, kg	N load, kg	P load, kg	N load, kg
Upstream Boundary, Lake Coeur d'Alene	19,884	320,328	36,454	662,898
City of Coeur d'Alene WWTP	5,172	105,252	4,045	84,614
Hayden POTW	3,765	17,325	2,950	24,609
Post Falls WWTP	1,105	45,564	1,307	46,091
Skalan Creek	0	0	0	0

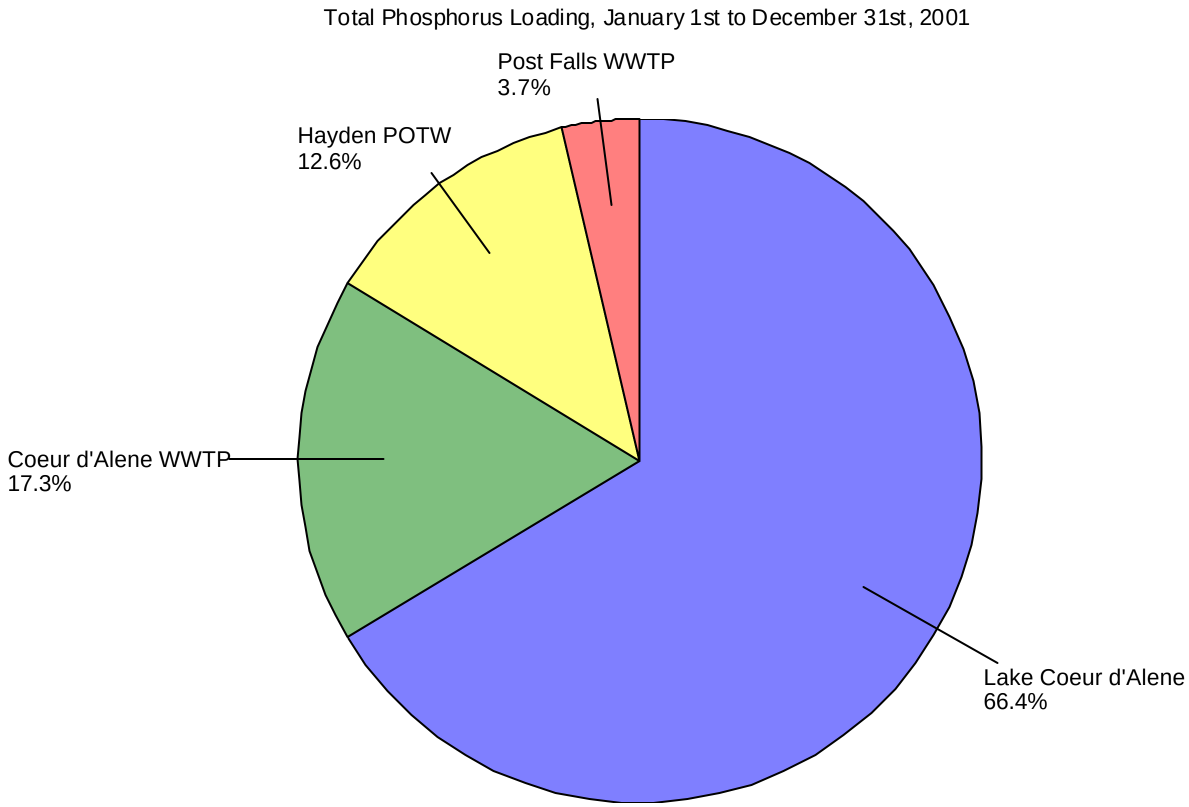


Figure 197: Total phosphorus loading, model simulation year 2001.

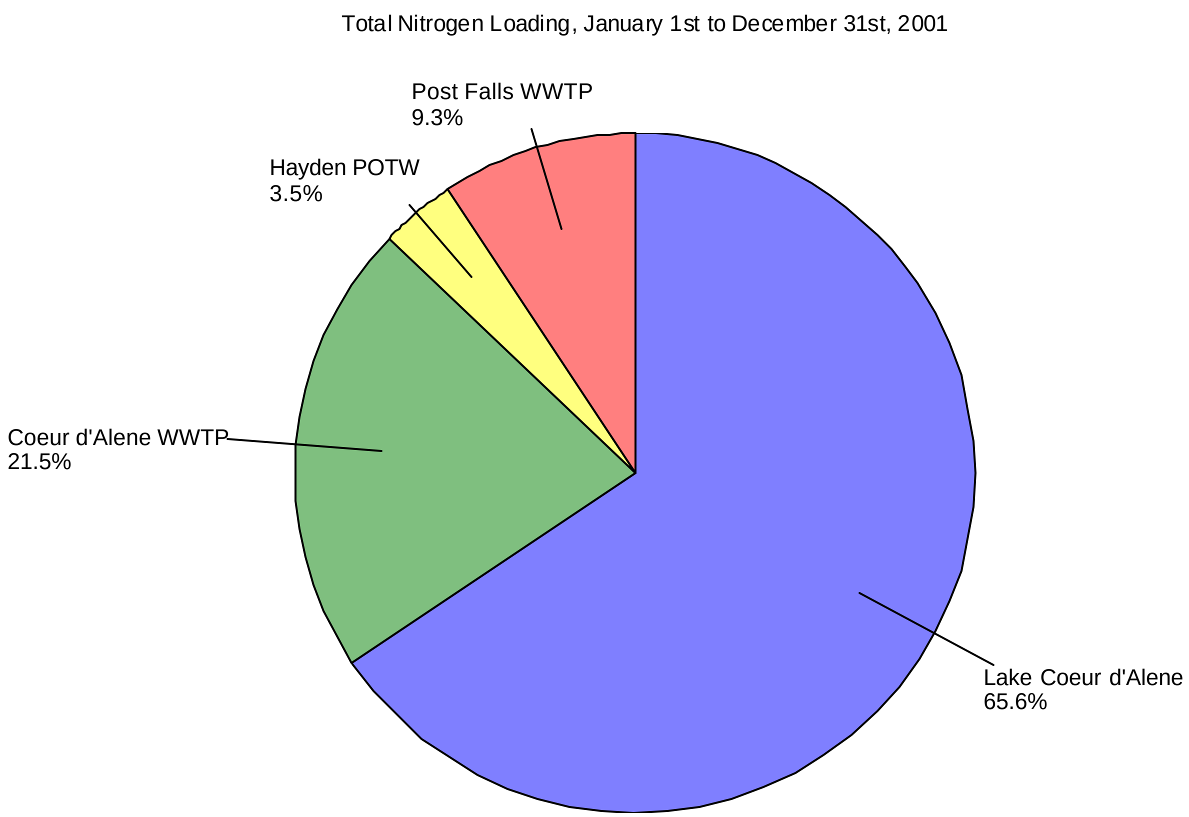


Figure 198: Total nitrogen loading, model simulation year 2001.

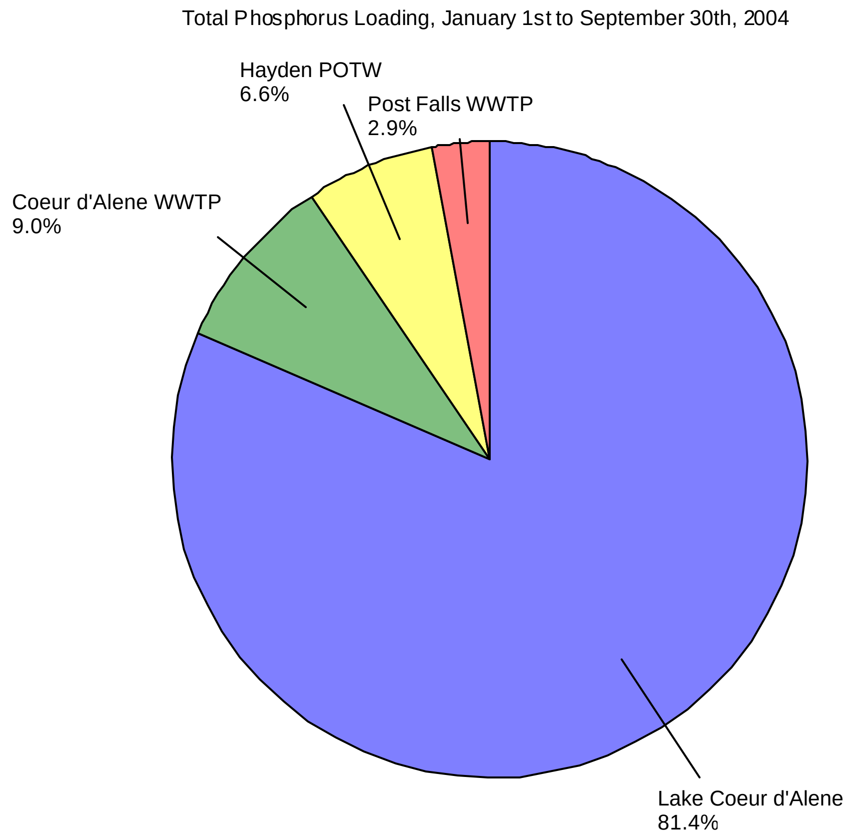


Figure 199: Total phosphorus loading, model simulation year 2004.

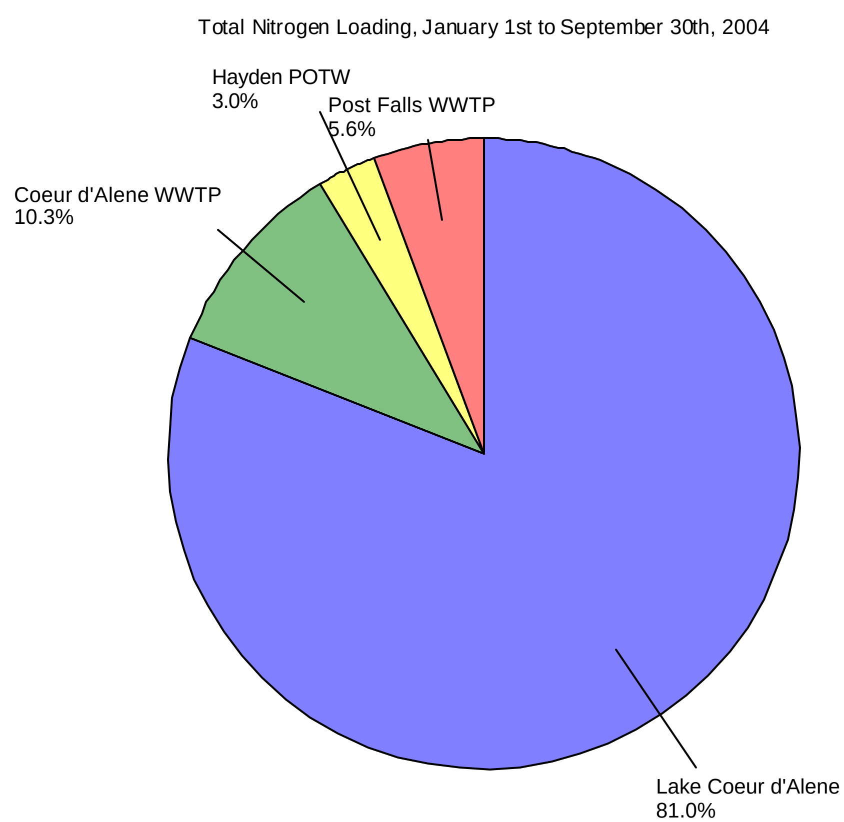


Figure 200: Total nitrogen loading, model simulation year 2004.

Summers, 2001 and 2004

The total phosphorus and total nitrogen loadings were calculated over the summer (May 1st to September 30th) in 2001 and 2004. Table 25 shows the total phosphorus and nitrogen loading for the upstream boundary condition and the tributary inflows from the dischargers.

Figure 201 and Figure 202 show pie diagrams of the fraction of total phosphorus and total nitrogen loading to the Spokane River for each inflow source in 2001, respectively. Figure 203 and Figure 204 show pie diagrams of the fraction of total phosphorus and total nitrogen loading to the Spokane River for each inflow source in 2004, respectively. The figures indicate the largest source of nitrogen and phosphorus loading to the Spokane River in ID during the low flow period of the summer is from Lake Coeur d'Alene.

Table 25: Total Phosphorus and Total Nitrogen loading from May 1st to September 30th, 2001 and 2004.

Source	January 1st – September 30th, 2001		January 1st – September 30th, 2004	
	P load, kg	N load, kg	P load, kg	N load, kg
Upstream Boundary, Lake Coeur d'Alene	9,691	149,740	16,088	288,356
City of Coeur d'Alene WWTP	763	36,674	1,440	45,904
Hayden POTW	994	3,139	806	8,419
Post Falls WWTP	750	19,461	991	28,621
Skalan Creek	0	0	0	0

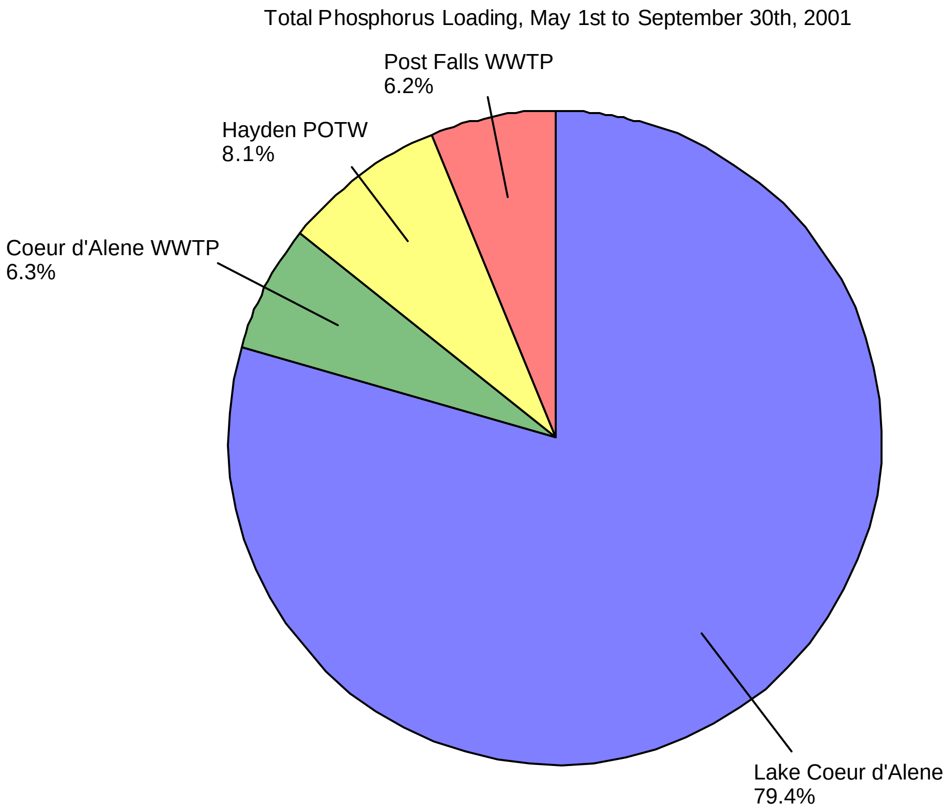


Figure 201: Total phosphorus loading, May 1st to September 30th, 2001.

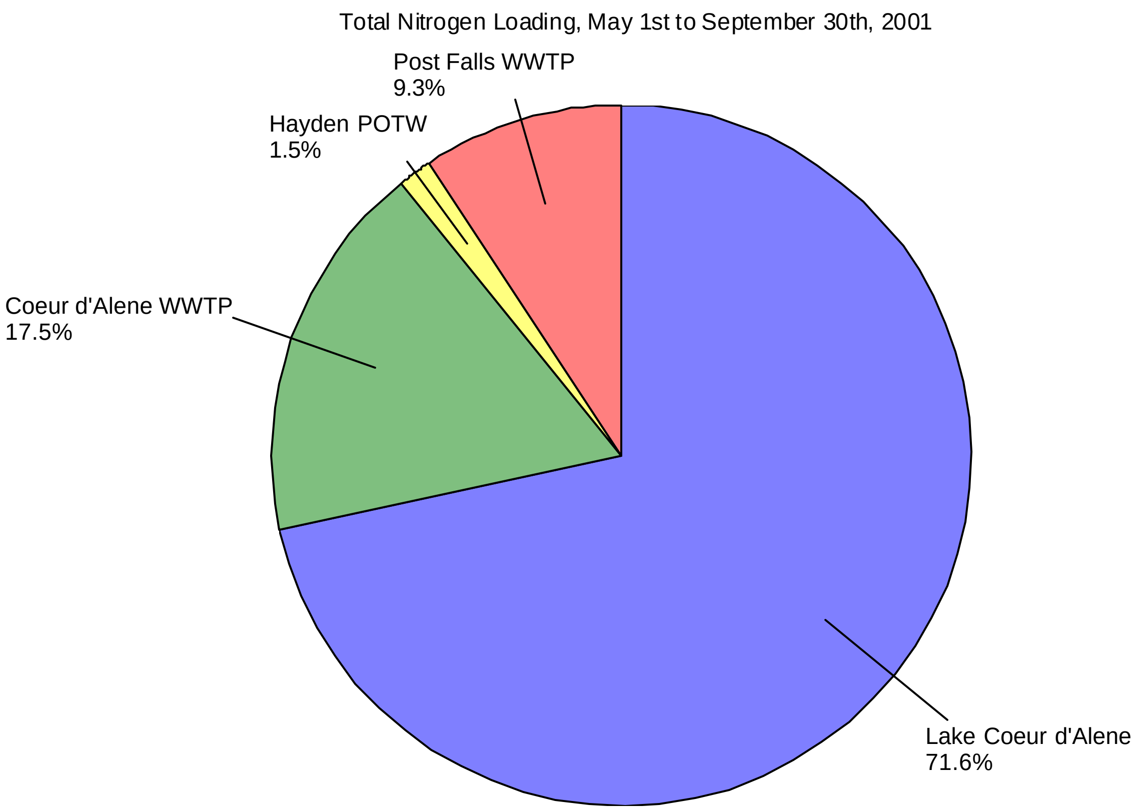


Figure 202: Total nitrogen loading, May 1st to September 30th, 2001.

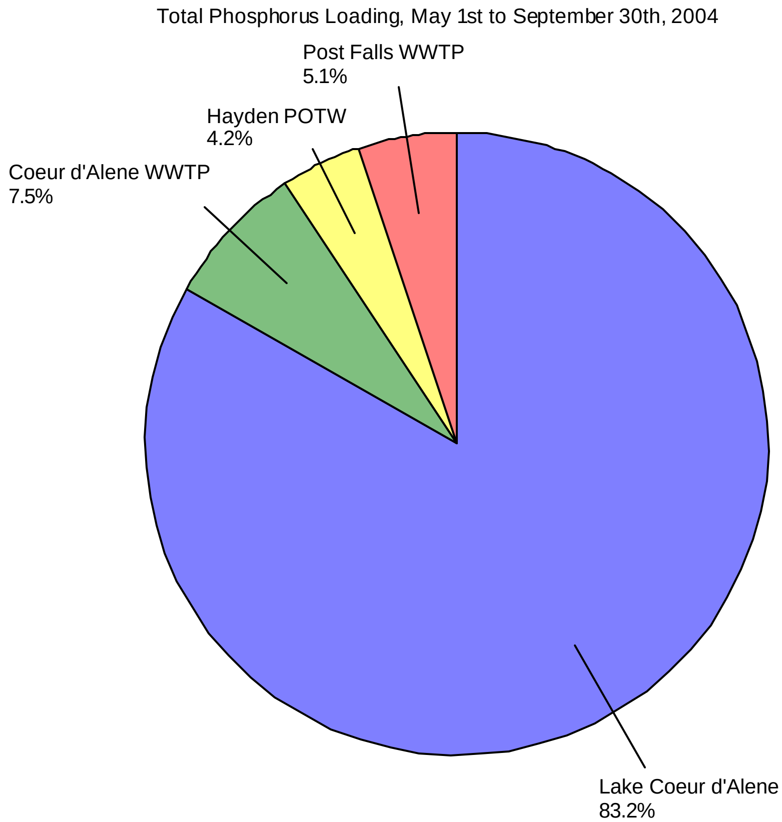


Figure 203: Total phosphorus loading, May 1st to September 30th, 2004.

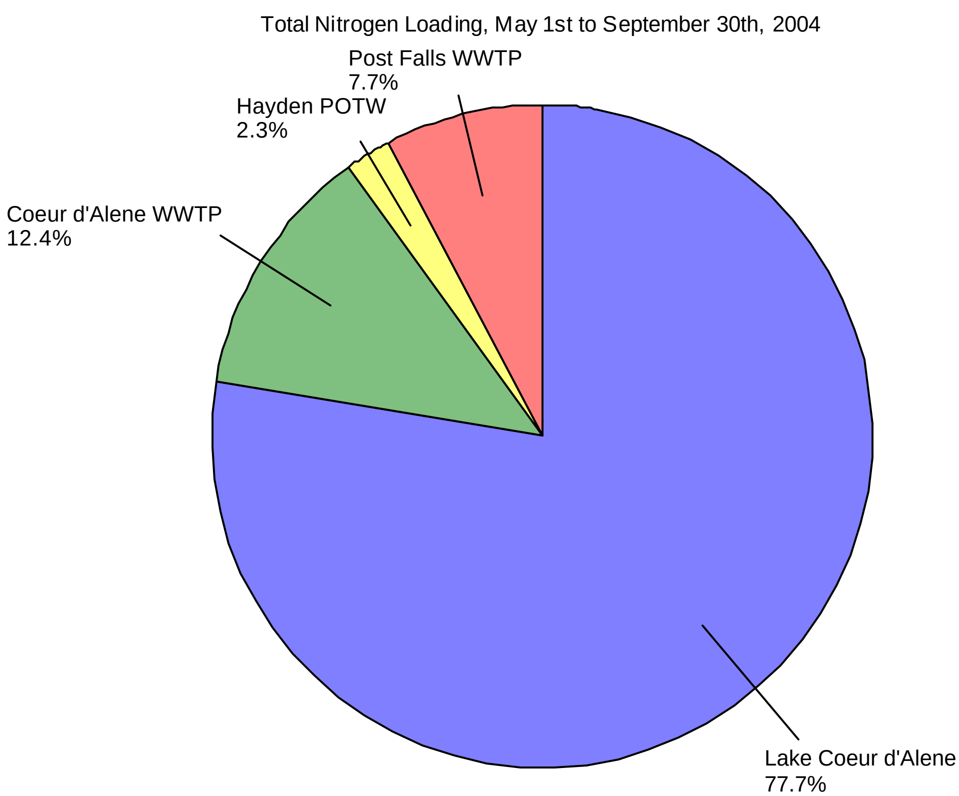


Figure 204: Total nitrogen loading, May 1st to September 30th, 2004.

Monthly Loading, 2001 and 2004

The total phosphorus and total nitrogen loadings were calculated monthly for 2001 and 2004. The fraction of total phosphorus and total nitrogen attributed to the upstream boundary condition and the dischargers along the Spokane River were calculated were then calculated.

Figure 205 and Figure 206 show time series plots of the monthly total phosphorus and total nitrogen mass loading fractions for 2001. The figures show that in January and February of 2001 the highest total phosphorus and total nitrogen loading was from the City of Coeur d'Alene WWTP. In addition, during the month of August when river flows are lowest the City of Post Falls WWTP has the highest total phosphorus and the second highest total nitrogen loading to the river. In August, 2001 the City of Coeur d'Alene has the highest total nitrogen loading compared to the other dischargers and the upstream boundary condition.

Figure 207 and Figure 208 show time series plots of the monthly total phosphorus and total nitrogen mass loading fractions for 2004. Both figures show that from January through September the largest loading of total phosphorus and total nitrogen to the river was the upstream boundary condition in 2004.

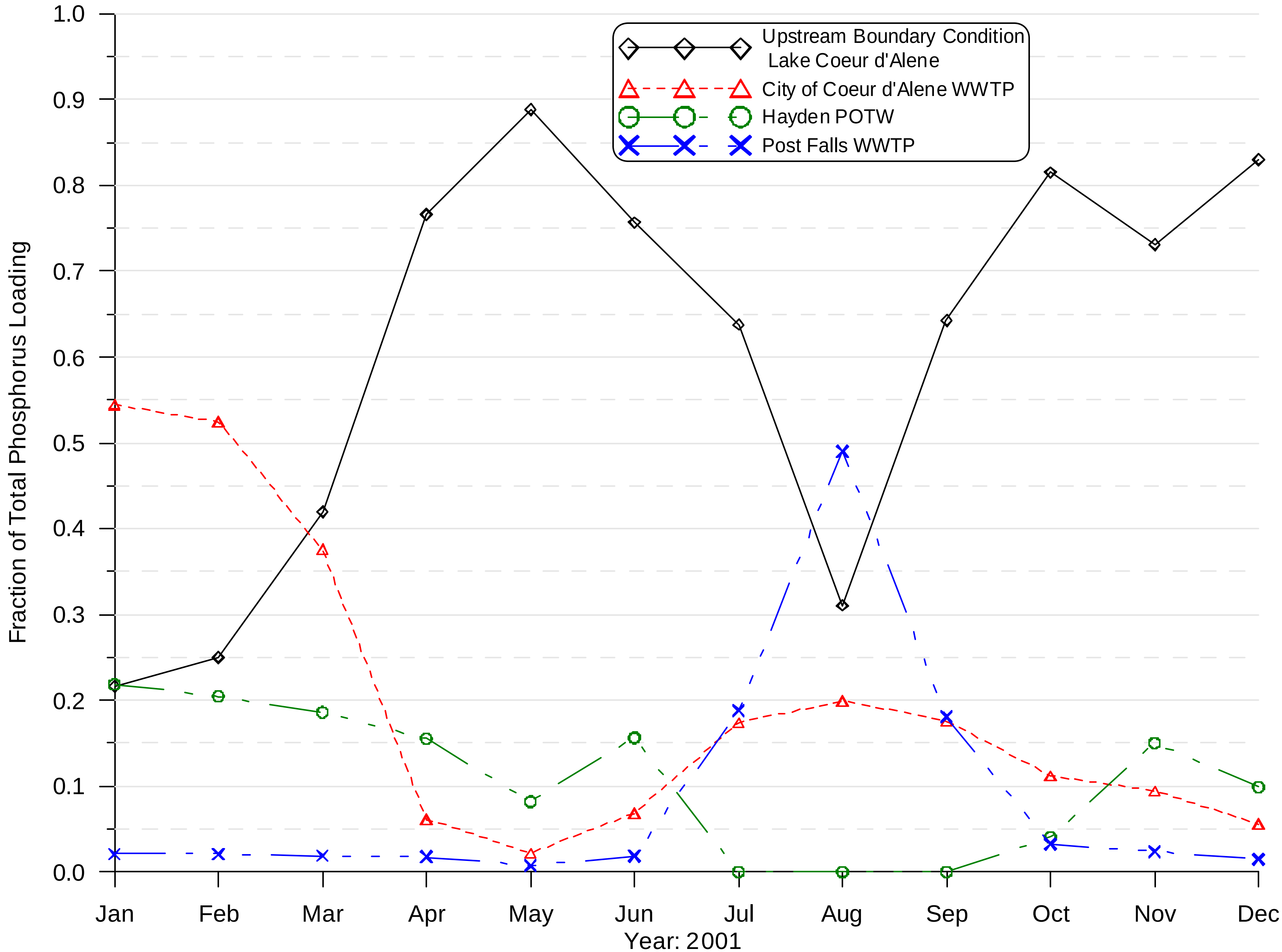


Figure 205: Monthly fractions of total phosphorus loading for boundary conditions, 2001.

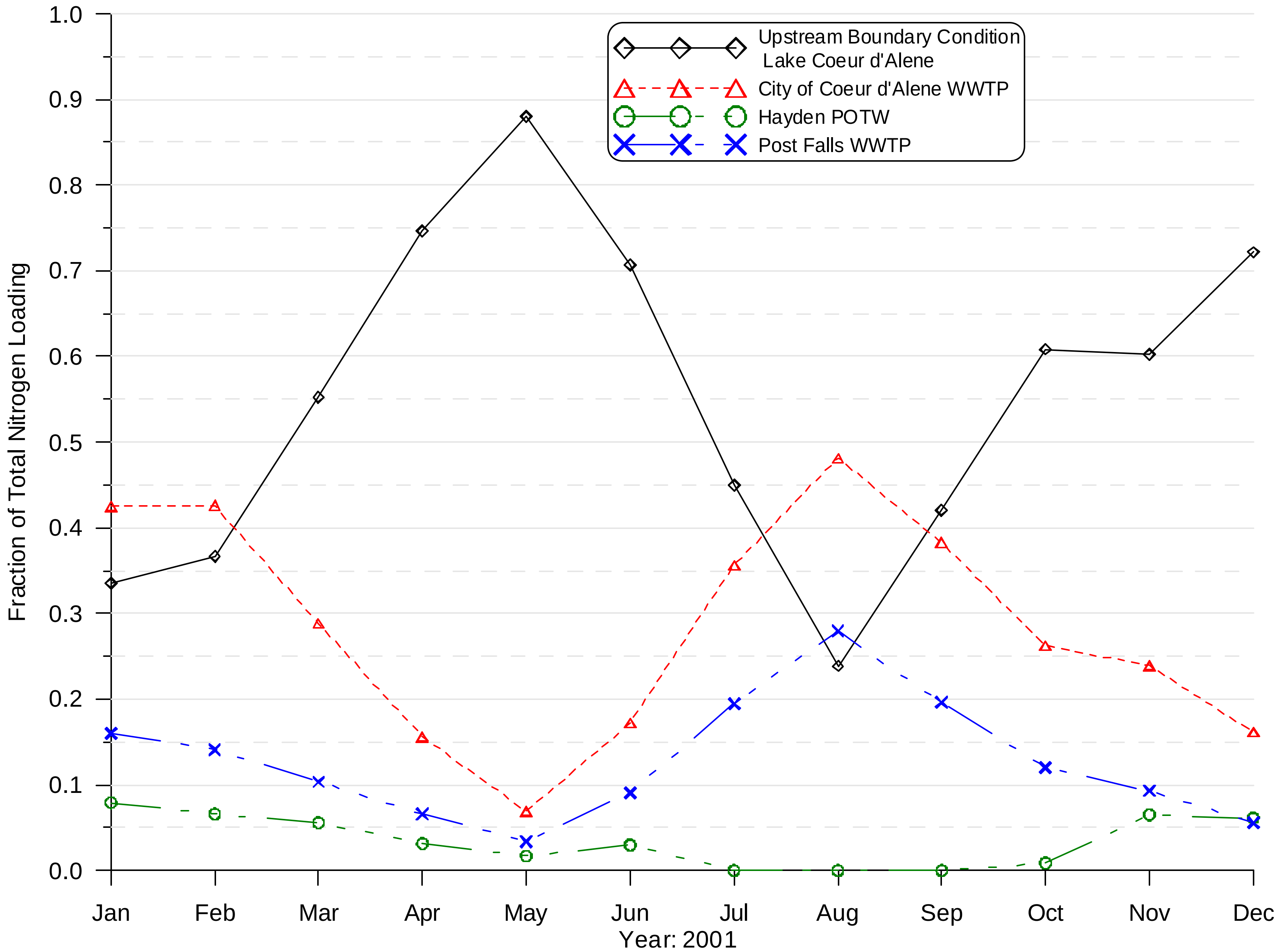


Figure 206: Monthly fractions of total nitrogen loading for boundary conditions, 2001.

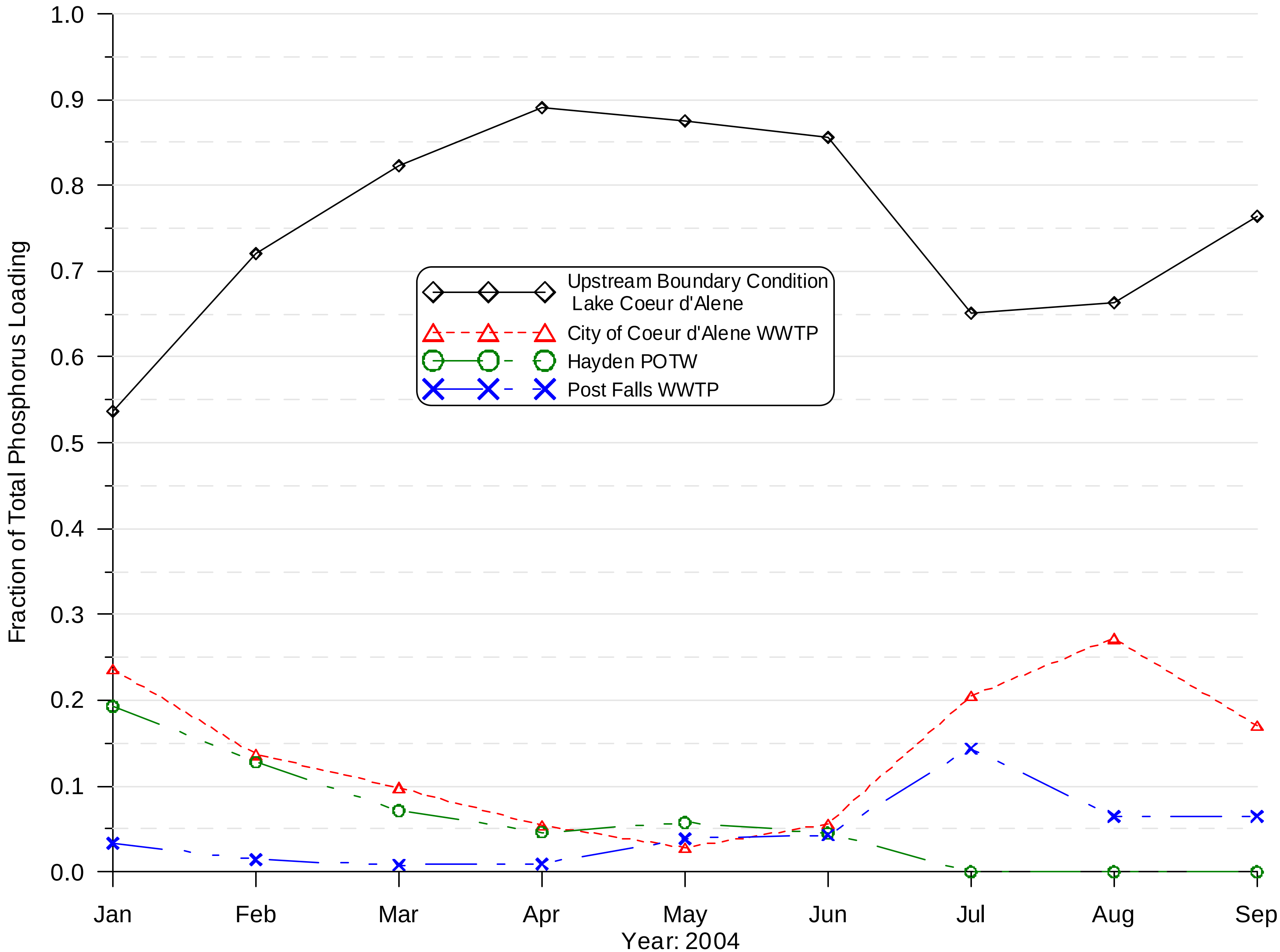


Figure 207: Monthly fractions of total phosphorus loading for boundary conditions, 2004.

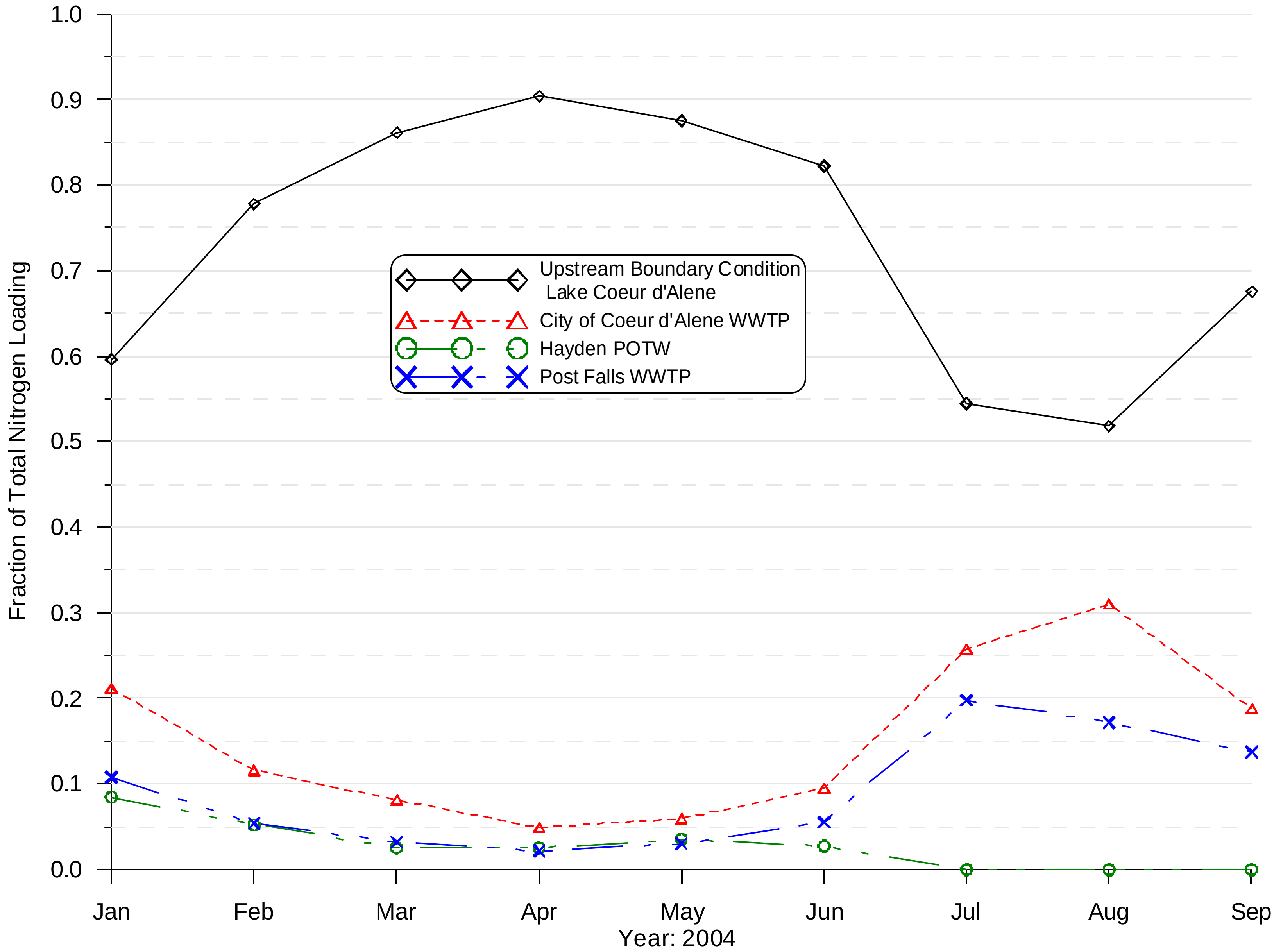


Figure 208: Monthly fractions of total nitrogen loading for boundary conditions, 2004.

Calibration Discussion

In order to improve the model foundation, the bathymetry of the Spokane River above and below Post Falls Dam should be updated by fieldwork. Below the Post Falls Dam, only 2 cross-sections have been taken over about a 6-mile stretch. More frequent cross-sections, 2-4 per mile would be necessary to accurately model this stretch of the river. Above Post-Falls Dam, the most recent bathymetry was done in 1991 with only 5 cross-sections over almost a 10-mile stretch of river. A complete 3-D mapping of the River above Post Falls Dam needs to be made using GIS or other format to catalog the updated bathymetry information.

By far, the upstream water quality concentrations were most important for achieving reasonable model-data agreement at the ID-WA state line. Efforts to improve that boundary condition, especially continuous temperature and dissolved oxygen and pH would be especially valuable in predicting the proper response in the river.

Ideally, the Spokane River model should have included Coeur d'Alene (CDA) lake model (Golder, 2004). This was not possible for 2004 since the CDA model was not calibrated to 2004. This would have allowed the model to supply the boundary conditions for the entire period of record.

Temperature predictions might be improved by replacing the 2001 temperature data from the USGS gage station near Post Falls, ID at the upstream boundary with continuous data collected near the City of Coeur d'Alene. Beyond a few data points in August, there were no temperature data at the upstream boundary. The model's temperature sensitivity to wind sheltering could also be tested. The evaporation formulation could be examined as well to help further calibrate temperatures. More continuous temperature data downstream of Post Falls Dam will allow a better understanding of diurnal fluctuations and how temperature was influenced by Post Falls Dam operations. The topographic shade model input was found to have little influence on the temperature results in the river.

Parameters that were important in the model calibration included dissolved oxygen reaeration equations, periphyton growth rates, periphyton half saturation parameters for phosphorus and nitrogen, ammonia nitrogen preference equation for periphyton, and the stoichiometry of the periphyton.

The reaeration formulation used for the Spokane River above Post Falls Dam was a lake formulation from Cole and Buchak (1995) where K_a is the reaeration rate, day^{-1}:

$$K_a = \frac{K_L}{H} = \frac{0.5 + 0.05W^2}{H}$$

where K_L is the reaeration velocity in m/day, H is the depth in m, and W is the wind speed at 10 m height, m/s. The Spokane River below Post Falls Dam used a river reaeration formulation for pool and riffle stream from Melching and Flores (1999) where K_a is the reaeration rate, day^{-1}:

$$K_a = 517(US)^{0.524} Q^{-0.242} \text{ for Q} < 0.556 \text{ m}^3\text{/s, and}$$
$$K_a = 596(US)^{0.528} Q^{-0.136} \text{ for Q} > 0.556 \text{ m}^3\text{/s}$$

where U is the velocity, m/s; S is the slope, m/m; and Q is the flow, m^3/s.

One factor having a significant influence on pH calibration was the sediment carbon dioxide release rate, which is based on the fraction of sediment oxygen demand (CO2R). Figure 209 shows the pH model predictions at the WA/ID State Line for two different sediment carbon dioxide release rates with no other changes to the model kinetic coefficients or model input files. The figure indicates that by increasing the carbon dioxide release rate, the overall pH is reduced during the summer and the diurnal swings are reduced slightly as well. This could be important in accounting for the secondary bacterial activity associated with periphyton.

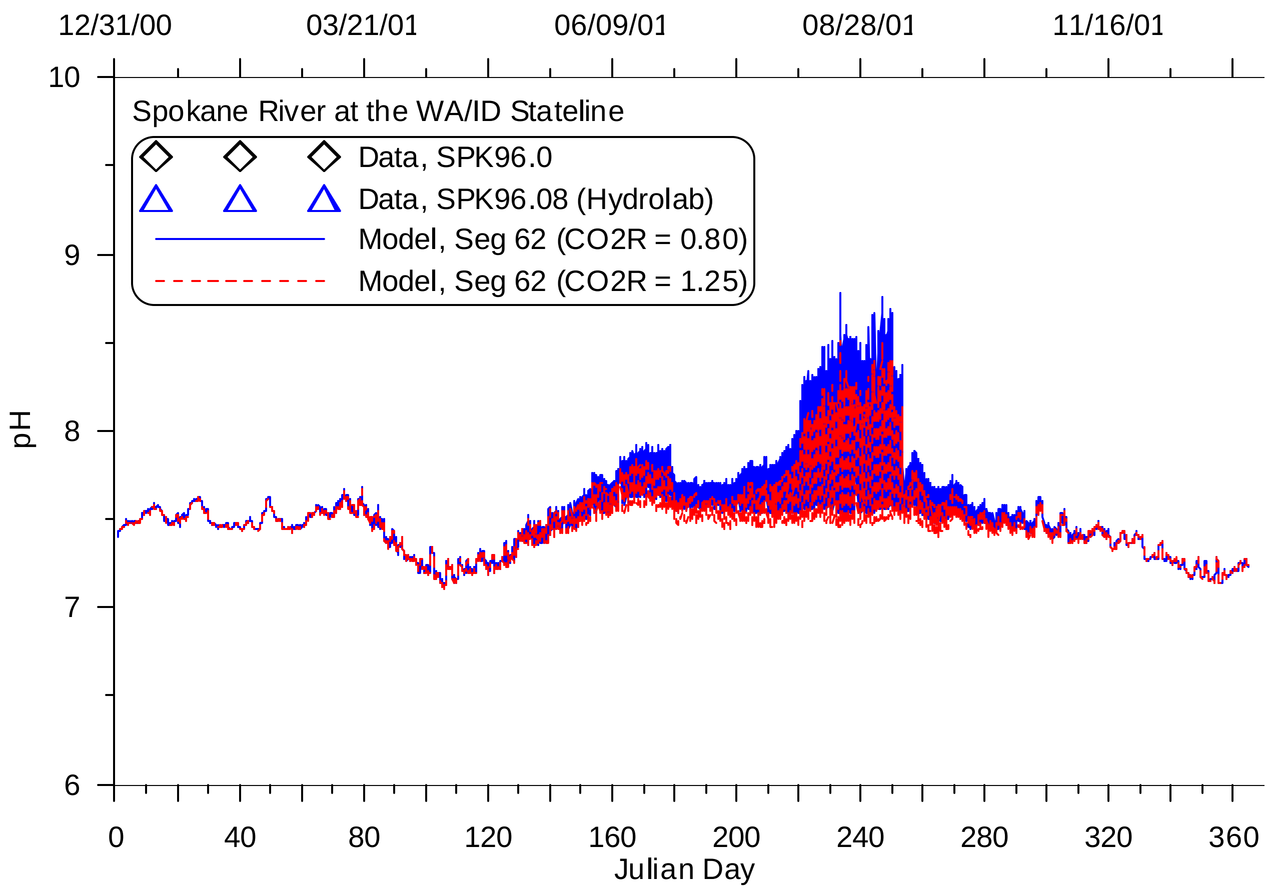


Figure 209: Model comparisons showing the impact of pH to adjustments in the sediment carbon dioxide release rate as a fraction of sediment oxygen demand

Summary

This report summarizes the model development and calibration for a water quality model of the Spokane River from the outlet of Lake Coeur d'Alene to the Washington-Idaho State Line for 2001 and 2004. The model uses the U. S. Army Corps of Engineers CEQUALW2 Version 3.1 river-reservoir-estuary code. Since the CE-QUAL-W2 model allows the user to separate the river basin into separate branches (collections of model longitudinal segments or computational cells) and water bodies (collections of branches with similar kinetic coefficients, turbulence closure, and meteorological forcing) the W2 model was composed of both riverine and reservoir sections, such as

- The Spokane River
- Post Falls Dam pool to Lake Coeur d'Alene outlet

The system model required that boundary conditions and the topography of river and reservoir sections be determined. Data in support of this modeling effort were shown in this report. This includes data such as:

- Dynamic inflow/discharge rates
- Dynamic inflow/discharge temperatures
- Dynamic inflow/discharge water quality constituents
- Dynamic meteorological data (air temperature, dew point temperature, wind speed, wind direction and cloud cover or short wave solar radiation)
- Model bathymetry

The meteorological data used in the model were developed from the meteorological data from the Coeur d'Alene Airport.

The water quality model of the Spokane River from Lake Coeur d'Alene to the Idaho-Washington was calibrated for 2001 and 2004. Parameters simulated include flow, water level, temperature, dissolved oxygen, phytoplankton, periphyton, pH, soluble reactive phosphorus, ammonia nitrogen, nitrite-nitrate nitrogen and carbonaceous BOD ultimate. Discharges located along this river section have been modeled using individual CBOD compartments and decay rates.

Calibration can be improved with better water quality data to characterize the upstream boundary conditions and the conditions of the dischargers along the river. Efforts should be made to collect more comprehensive water quality data for the dischargers and the upstream boundary condition and bathymetric data below Post Falls Dam. In addition, the Coeur d'Alene Lake model should be added to the Spokane River model.

Table 26 lists a summary of the model-data error statistics for hydrodynamic, temperature and water quality characteristics at the WA/ID State line for 2001 and 2004. Appendix B provides a list of the equations used to calculate mean error, absolute mean error and root mean square error.

Table 26: Summary of model-data error statistics at the WA/ID State Line, 2001 and 2004

	2001				2004			
	Number of Comparisons	Mean Error	Absolute ME	RMS Error	Number of Comparisons	Mean Error	Absolute ME	RMS Error
Flow, cms	34943	-78.03	78.03	117.66	272	-146.80	146.80	191.71
Temperature, C	3704	-0.41	0.79	0.98	369	-0.19	0.40	0.60
pH	607	0.01	0.50	0.64	369	0.55	0.56	0.58
Conductivity, umhos/cm	615	7.37	7.60	7.79	369	0.19	0.69	0.96
DO, mg/L	611	0.17	0.61	0.74	342	0.18	0.22	0.30
NH3, mg/L	13	0.012	0.016	0.025	20	-0.048	0.065	0.127
TKN, mg/L	16	-0.198	0.198	0.249				
TPN, mg/L	12	0.041	0.051	0.065	20	0.033	0.080	0.103
Nox, mg/L	21	0.015	0.047	0.074	20	0.032	0.051	0.073
SRP, mg/L	23	-0.001	0.003	0.004	20	0.000	0.002	0.003
TP, mg/L	30	-0.008	0.008	0.009	20	0.001	0.006	0.008
CBODU, mg/L	11	0.376	0.656	0.723	11	0.096	0.463	0.547
TDS, mg/L	18	15.27	16.97	22.98				
TSS mg/L		-2.127	2.127	3.299	9	-0.94	0.94	1.22
DOC, mg/L	27	-0.67	0.70	0.86				
TOC mg/L	27	-0.39	0.45	0.65				
ALK mg/L	18	-2.14	2.31	2.65				
Chl a ug/L	10	-0.62	1.12	1.46	11	0.57	0.87	1.37

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Appendix A – Location of Model Segments according to River Mile

Table 27 below gives x, y coordinates, segment orientation, and River Miles of each model segment in the CE-QUAL-W2 model of the Spokane River in the State of Idaho.

Table 27: Segment numbers and RM for W2 model.

X, m	Y, m	Segment Orientation, RADIANS	Segment Orientation, Deg	Seg #	RM	RM start	111.5			
				63						
497018.4	5282402	2.36	135.4	62	96.12	End BR 2 Washington-Idaho border				
497189.1	5282217	2.43	139.4	61	96.27					
497349.4	5282022	2.47	141.7	60	96.43					
497542.1	5281911	1.67	95.7	59	96.59					
497765.4	5281962	1.05	60.3	58	96.74					
497966.1	5282110	0.82	46.8	57	96.90					
498145.7	5282286	0.78	44.5	56	97.06					
498351.8	5282419	1.22	69.7	55	97.22					
498595.3	5282473	1.49	85.1	54	97.37					
498844.1	5282459	1.76	101.1	53	97.53					
499062.1	5282353	2.29	131	52	97.69					
499238.6	5282174	2.44	139.6	51	97.84					
499415.9	5281997	2.28	130.5	50	98.00					
499626.1	5281929	1.45	83.3	49	98.16	Skalan Creek				
499824.8	5282036	0.73	41.7	48	98.32					
499980.0	5282235	0.6	34.3	47	98.47					
500117.3	5282447	0.55	31.5	46	98.63					
500209.9	5282673	0.22	12.6	45	98.79					
500315.3	5282886	0.7	39.9	44	98.94					
500517.1	5283005	1.37	78.4	43	99.10					
500758.1	5282991	1.9	108.6	42	99.26					
500962.6	5283033	0.82	46.7	41	99.41					
501070.7	5283229	0.18	10.5	40	99.57					
501206.0	5283342	1.6	91.6	39	99.73					
501391.9	5283238	2.52	144.3	38	99.89					
501563.7	5283094	1.98	113.5	37	100.04					
501788.4	5283049	1.58	90.7	36	100.20					
501994.6	5283135	0.75	43.1	35	100.36					
502101.7	5283345	0.21	11.9	34	100.51					
502185.4	5283578	0.48	27.6	33	100.67					
502347.3	5283756	1	57.3	32	100.83	Post Falls WWTP				
502564.5	5283781	1.93	110.5	31	100.99		DLX=	253	m	
502795.1	5283755	1.43	82.1	30	101.14	Start BR2 Spokane River				

				29						
		2.09		28		Post Falls Dam				
		2.09		27	101.30					
		2.09		26	101.70					
		2.36		25	102.10					
		2.36		24	102.50					
		1.4		23	102.90					
		2.36		22	103.30					
		2.36		21	103.70					
		0.79		20	104.10					
		1.05		19	104.50					
		2.36		18	104.90					
		1.83		17	105.30					
		1.48		16	105.70					
		0.79		15	106.10					
		2.36		14	106.50					
		1.48		13	106.90					
		1.05		12	107.30					
		0.79		11	107.70					
		1.83		10	108.10					
		1.66		9	108.50	Hayden Lake POTW				
		1.83		8	108.90					
		2.09		7	109.30					
		2.09		6	109.70					
		2.09		5	110.10					
		2.36		4	110.50	Coeur d'Alene WWTP				
		3.49		3	110.90		DLX=	644	m	
		3.67		2	111.30	BR 1 Lake Coeur d'Alene-Spokane River				
		3.67		1						

Appendix B - Statistics Calculations

Model-data error statistics were computed using the following formulas for the mean, absolute mean, and root mean square error:

$$Mean\_Error(ME) = \frac{\sum_{1}^{n}(\text{model} - \text{data})}{n} \qquad \textbf{(1)}$$

$$Absolute\_Mean\_Error(AME) = \frac{\sum_{1}^{n} abs(\text{model} - \text{data})}{n} \qquad \textbf{(2)}$$

$$Root\_Mean\_Square\_Error(RMS) = \sqrt{\frac{\sum_{1}^{n}(\text{model} - \text{data})^2}{n}} \qquad \textbf{(3)}$$

where n is the number of observations, model is the model predicted state variable and data is the field data variable.