

Upper Spokane River Model: Model Calibration, 1991 and 2000



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Acknowledgements

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Introduction

The Upper Spokane River system under consideration is located in the Northeastern part of Washington State and runs from the Stateline with Idaho, River mile (RM) 96.0, downstream to Long Lake dam at RM 32.5. Figure 1 shows the river system and an outline the boundaries of the City of Spokane.

The Washington Department of Ecology is interested in a water quality model for the Upper Spokane River system for use in developing Total Maximum Daily Loads (TMDLs). The goals of this modeling effort are to:

- Gather data to construct a computer simulation model of the Spokane River system including Long Lake Reservoir and the pools behind Nine Mile dam, Upper Falls dam and Upriver dam.
- Ensure that the model accurately represents the system hydrodynamics and water quality (flow, temperature, dissolved oxygen and nutrient dynamics);

A hydrodynamic and water quality model, CE-QUAL-W2 Version 3.1 (Wells, 1997), is being applied to model the Spokane River system. CE-QUAL-W2 is a two dimensional (longitudinal-vertical), laterally averaged, hydrodynamic and water quality model that has been under development by the Corps of Engineers Waterways Experiments Station (Cole and Wells, 2000).

Prior reports prepared for this modeling study include:

- Annear *et al.* (2001) summarized background data for the modeling effort such as
 1. Inflows, temperatures, and water quality
 2. Meteorological conditions
 3. Bathymetry of the Spokane River and Long Lake and the model grid
 4. Reservoir operations and structure information

This report evaluates the model calibration and discusses issues relative to that calibration effort. The calibration effort focused on model predictions of hydrodynamics (flow and water level), temperature, and eutrophication model parameters (such as nutrients, algae, dissolved oxygen, organic matter, coliform). The model calibration periods were from February 1, 1991 to October 31, 1991 and from January 1, 2000 to October 31, 2000.

This information is divided into the following sections in this report:

- Hydrodynamic Calibration
- Temperature Calibration
- Water Quality Calibration
- Summary and Conclusions

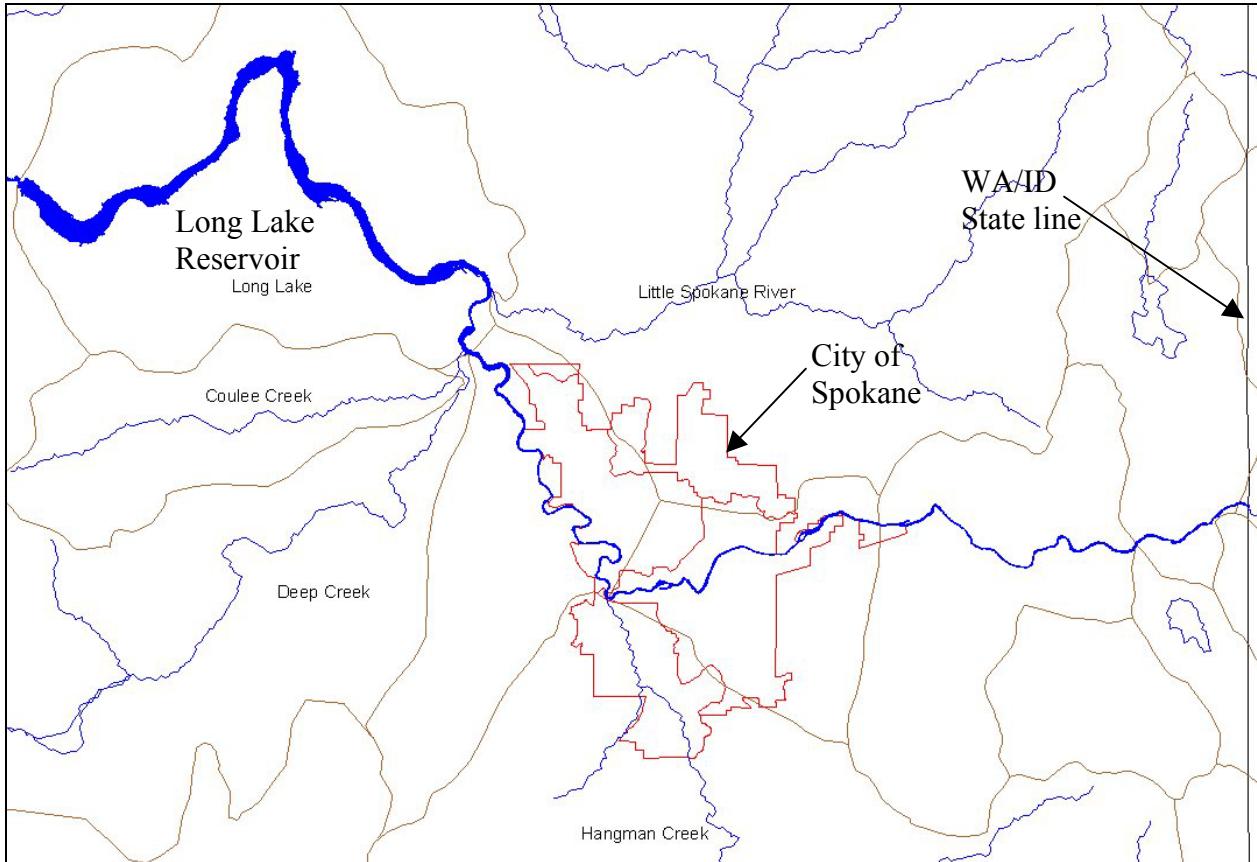


Figure 1. Model domain, WA-ID state line to Long Lake reservoir

Monitoring Sites

The monitoring sites utilized in the development and calibration of the Spokane River model consist of monitoring sites along the Spokane River and tributaries and point discharges to the river. Data consist of water level, flow, temperature, and water quality data.

There are several water level and flow gage stations along the Spokane River. Figure 2 shows a map of the model domain with several key water level and flow gage stations. Table 1 provides a list of the USGS gage stations.

Table 1. U.S. Geological Survey gage stations

Gage ID	Description	RM
USGS12419000	SPOKANE RIVER NR POST FALLS, ID	100.9
USGS12419500	Spokane R Above Liberty Br Nr Otis Orchard, Wash (Harvard Rd)	93.8
USGS12420500	SPOKANE RIVER AT GREENACRES, WA (Barker Rd)	90.3
USGS12422500	SPOKANE RIVER AT SPOKANE, WA	72.9
USGS12424000	HANGMAN CREEK AT SPOKANE, WA	72.3
USGS12431000	LITTLE SPOKANE RIVER AT DARTFORD, WA	56.9
USGS12433000	SPOKANE RIVER AT LONG LAKE, WA	32.1

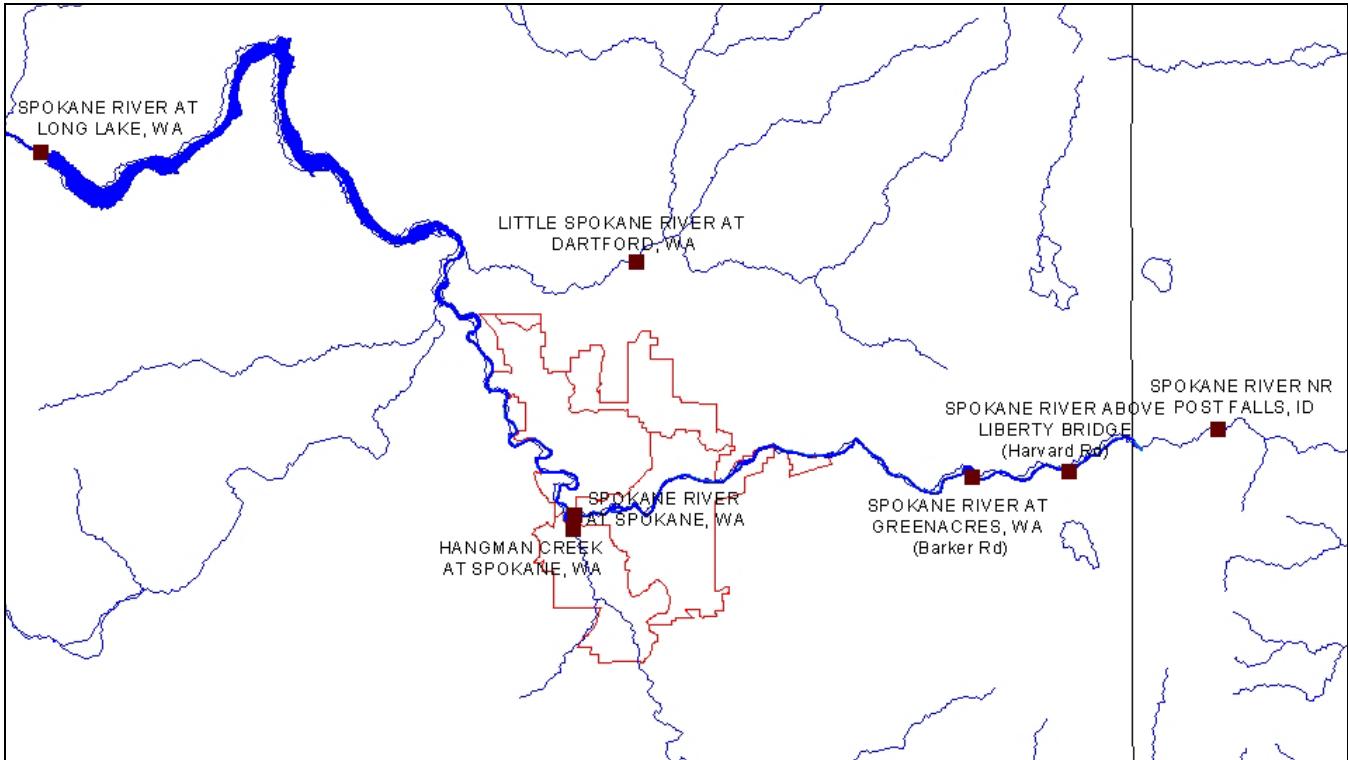


Figure 2. U.S. Geological Survey gage stations along the Spokane River

The Washington State Department of Ecology (DOE) provided the majority of the water quality data. Figure 3 shows a map of the upper Spokane region with all of the water quality monitoring sites identified. Figure 4 shows the water quality sites specifically in Long Lake. Monitoring sites in the Spokane River just above Nine Mile dam to the Upper Falls dam are shown in Figure 5. Spokane River monitoring sites just below and above the Upriver dam facilities are shown in Figure 6. Figure 7 shows the remaining monitoring sites above Upriver dam to the state line with Idaho. Table 2 lists all the water quality monitoring sites with their associated river mile. The data collected at these sites consisted of periodic grab samples, which were used to generate longitudinal profiles of the water quality parameters, and vertical profile data used for comparing vertical profiles in various parts of the river on the same day.

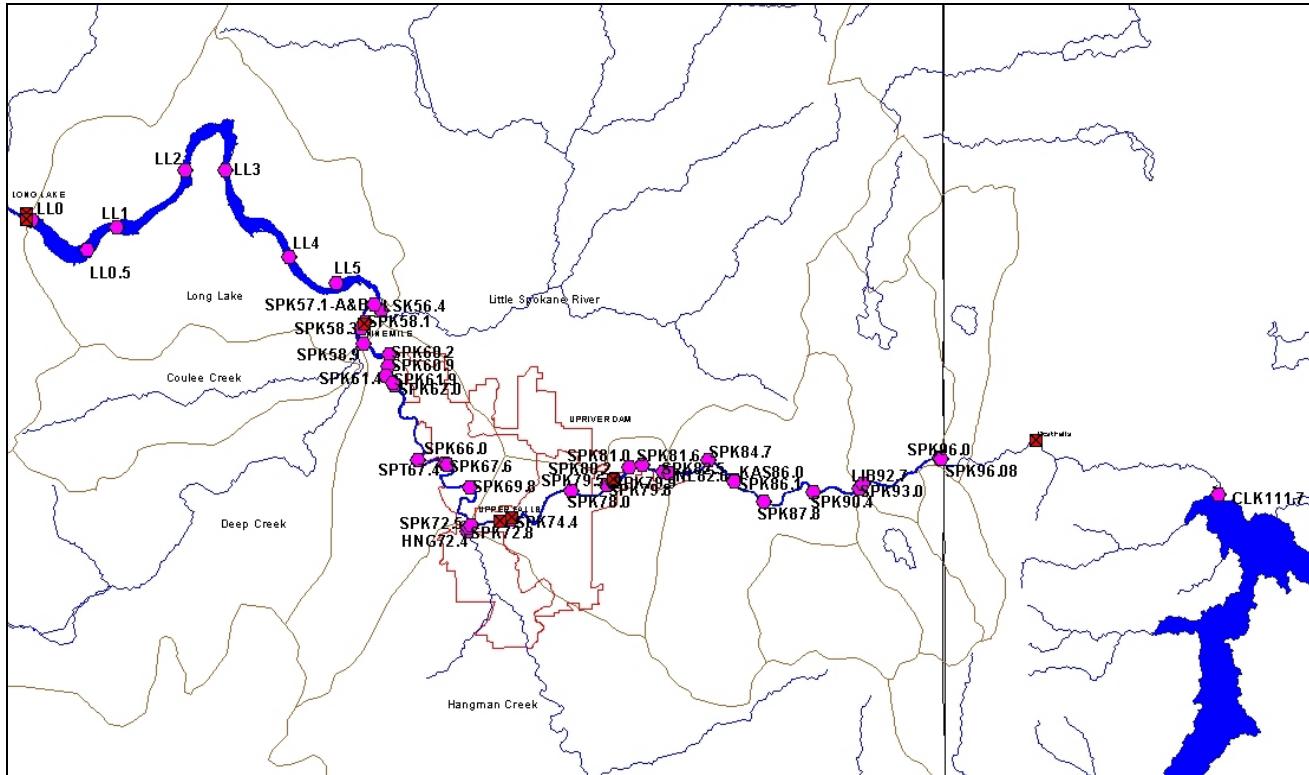


Figure 3. Water quality monitoring sites along the Spokane River and Long Lake reservoir

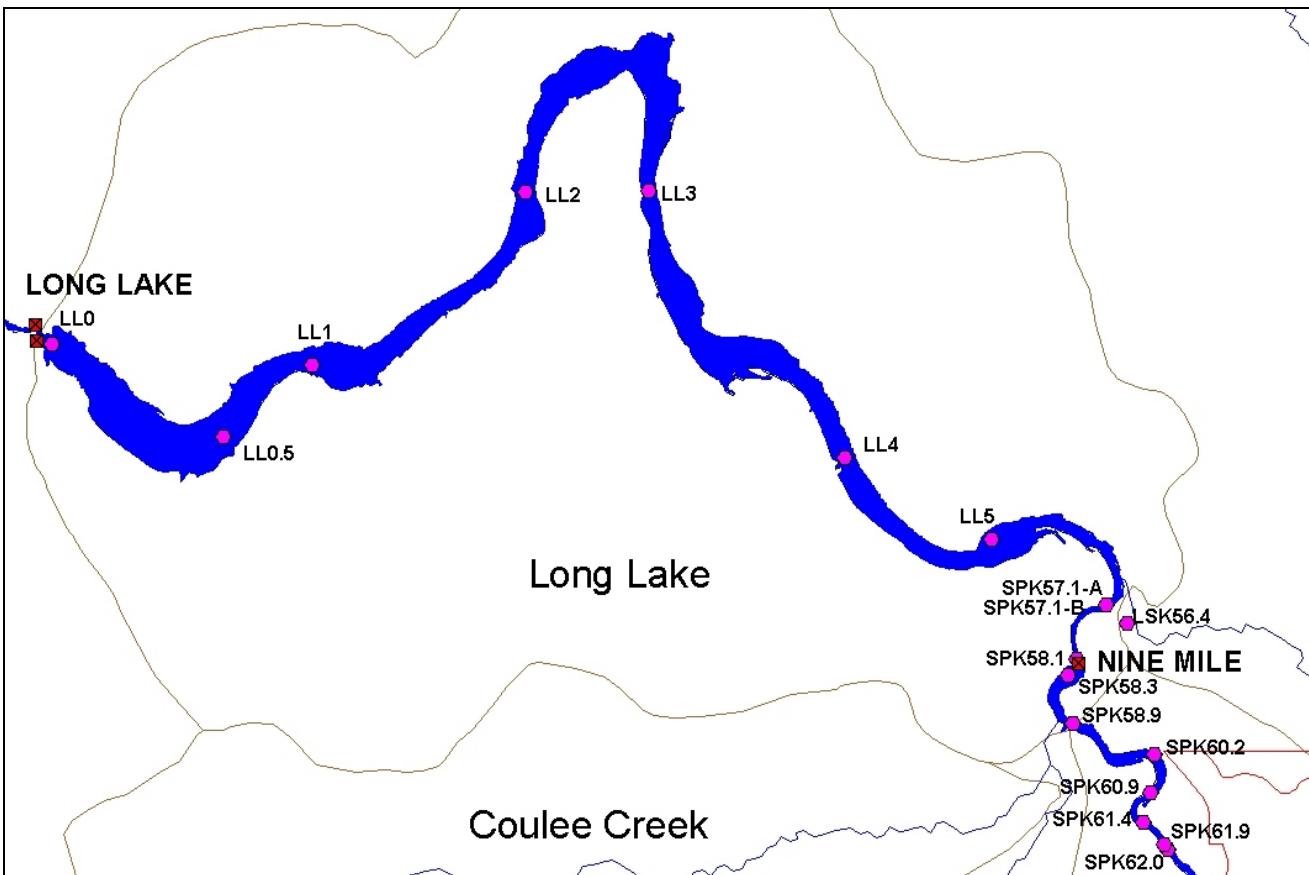


Figure 4. Water quality monitoring sites at Long Lake Reservoir

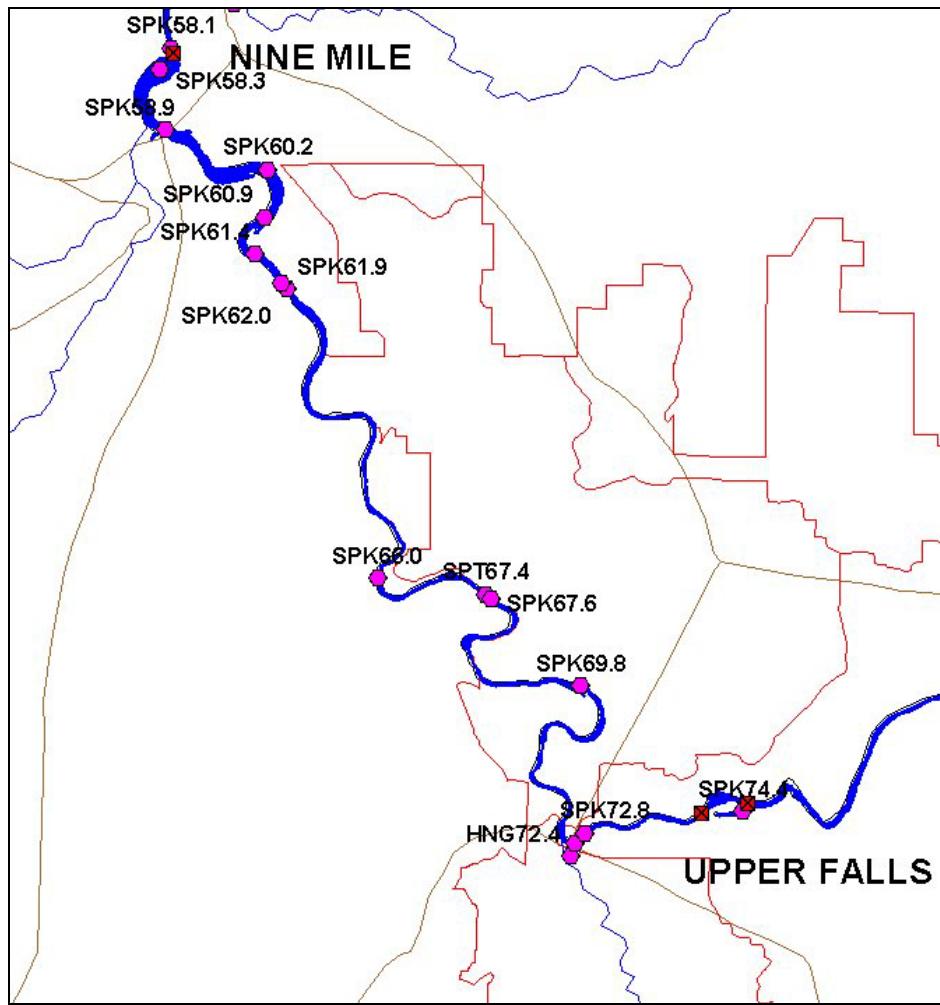


Figure 5. Water quality monitoring sites along Nine Mile Reservoir

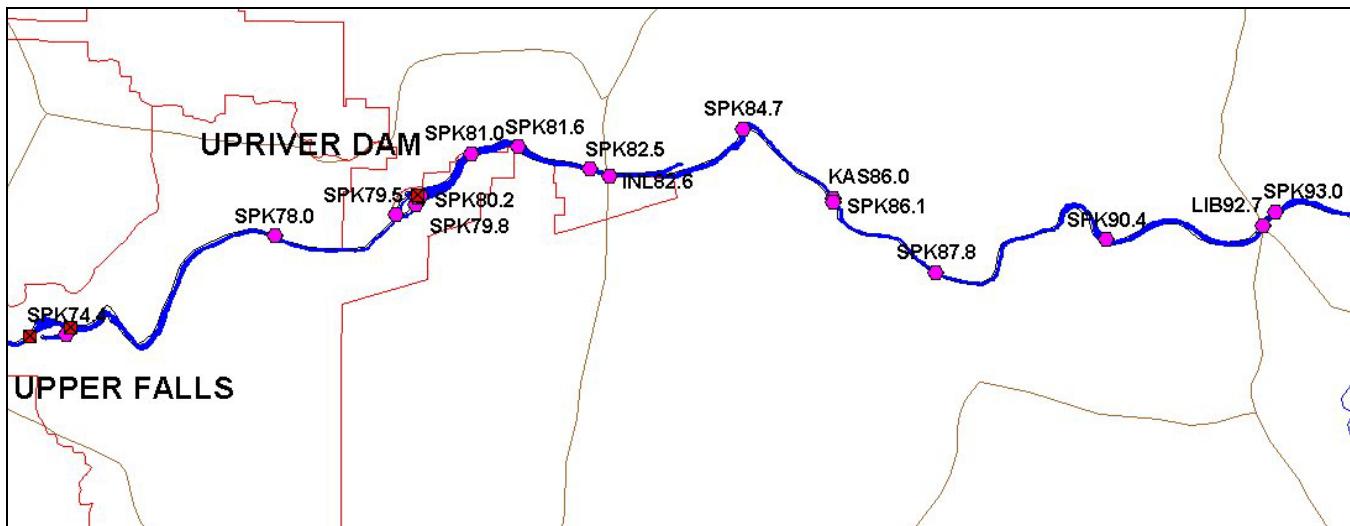


Figure 6. Water quality monitoring sites along the Spokane River near Upriver Dam

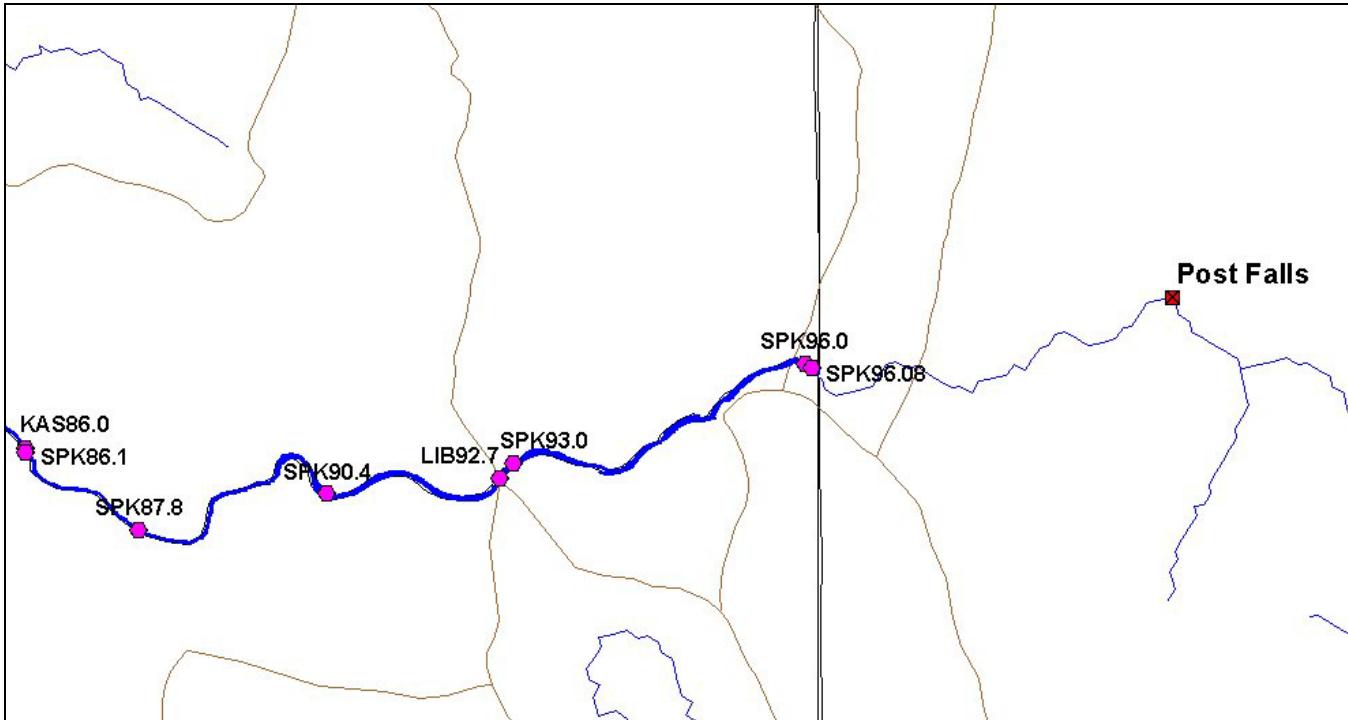


Figure 7. Water quality monitoring sites near the WA-ID state line

Table 2. Water Quality Monitoring sites

Site ID	Description	RM
LL0	Long Lake @ Station 0 (near dam)	32.66
LL0.5	Long Lake @ Station 0.5	35.90
LL1	Long Lake @ Station 1	37.62
LL2	Long Lake @ Station 2	42.06
LL3	Long Lake @ Station 3	46.42
LL4	Long Lake @ Station 4	51.47
LL5	Long Lake @ Station 5	54.20
LSK56.4	Little Spokane River @ Long Lake (near mouth): near HWY 291 Bridge.	56.40
SPK57.1-A	Spokane River @ Long Lake: a 1-mile below Nine Mile Dam.	57.10
SPK57.1-B	Spokane River @ Long Lake: a 1-mile below Nine Mile Dam.	57.10
SPK58.1	Just d/s of Nine Mile Dam at the road bridge	58.10
SPK58.3	Spokane River 0.2 mi above Nine mile Dam	58.30
SPK58.9	Spokane River 0.8 mi above Nine mile Dam	58.90
SPK60.2	Spokane River 2.1 mi above Nine mile Dam	60.20
SPK60.9	Spokane River 2.8 mi above Nine mile Dam	60.90
SPK61.4	Spokane River 3.3 mi above Nine mile Dam	61.40
SPK61.9	Spokane River 3.8 mi above Nine mile Dam	61.90
SPK62.0	Spokane R @ Seven Mile Br	62.00
SPK66.0	Spokane R @ Riverside State Park	66.00
SPT67.4	Spokane River WTP effluent discharge	67.40
SPK67.6	Spokane R Upstream Spokane WTP	67.60
SPK69.8	Spokane R near Fort Wright Bridge	69.80
HNG72.4	Hangman Creek at mouth, upstream with Confluence with Spokane River	72.40
SPK72.5	Spokane R Upstream of Hangman Cr.	72.50
SPK72.8	USGS gauging station, Spokane River at Spokane	72.80
SPK74.4	Spokane River @ Walkbridge behind Spokane Center	74.40
SPK78.0	Spokane R @ Green St. Bridge	78.00
SPK79.5	Downstream of Upriver Dam Powerhouse	79.50

There are four significant point sources along the Spokane River that were included in the modeling effort. The sites are listed in Table 3 along with their river mile location. Figure 8 shows the location of the four dischargers along the river. The data were obtained from the National Pollutant Discharge Elimination System (NPDES) through the WA Department of Ecology and additional data were obtained either directly from the dischargers or from WA Department of Ecology, which acquired the data from the dischargers. Each point source is characterized by flow, temperature, and additional water quality constituent concentrations.

Table 3. Point Source dischargers considered in the model

Discharger Description	RM	Model Segment
Liberty Lake WWTP	92.7	18
Kaiser Aluminum	86.0	43
Inland Empire Paper Co	82.6	56
Spokane River WWTP	67.4	115

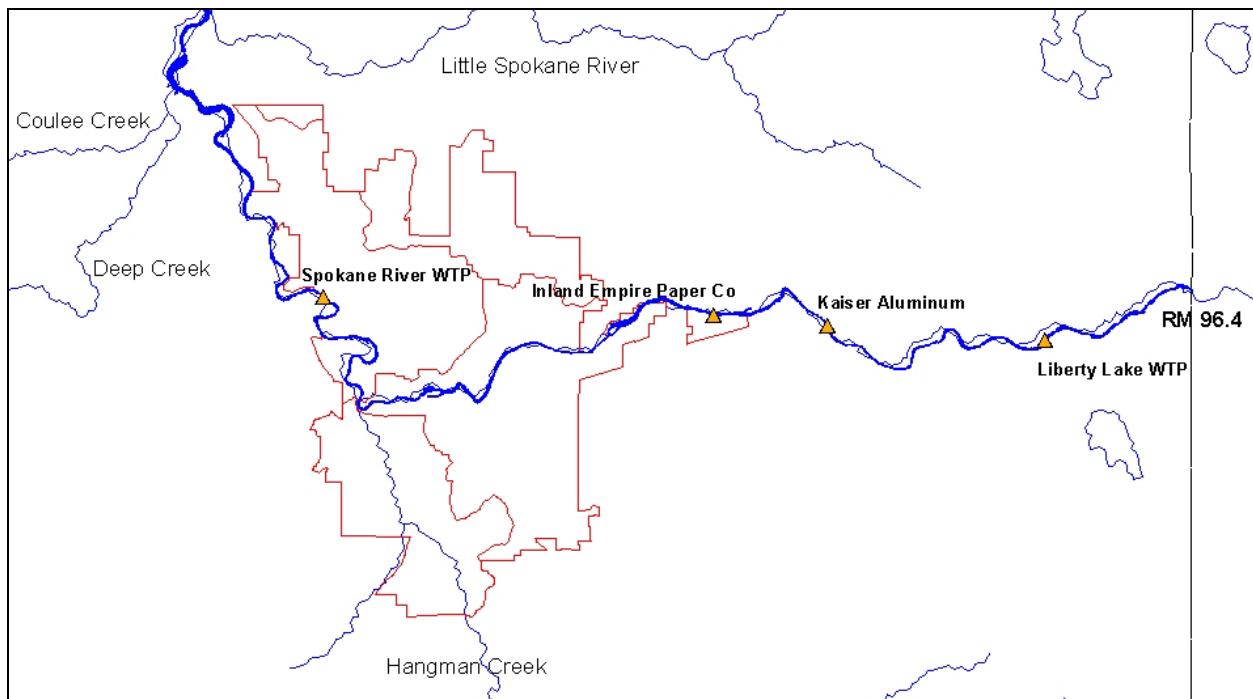


Figure 8. Point Discharges to the Spokane River

Hydrodynamic Calibration

Upriver Reservoir

The hydrodynamic calibration of the Upper Spokane River system was started at the furthest upstream location as the results of the water balance affect the water balance downstream. The Upriver reservoir is located at RM 80.2 and consists of a dam that operates as a “run-of-the-river” facility. Water level

data were compared with model results for both 1991 and 2000 as shown in Figure 9 and Figure 10, respectively. Table 4 shows water level statistics for 1991 and 2000.

Table 4. Water level error statistics for Upriver Reservoir, 1991 and 2000.

Year	n, # of data comparisons	Water level model -data error statistics	
		AME, m	RMS error, m
1991	271	0.151	0.180
2000	302	0.054	0.065

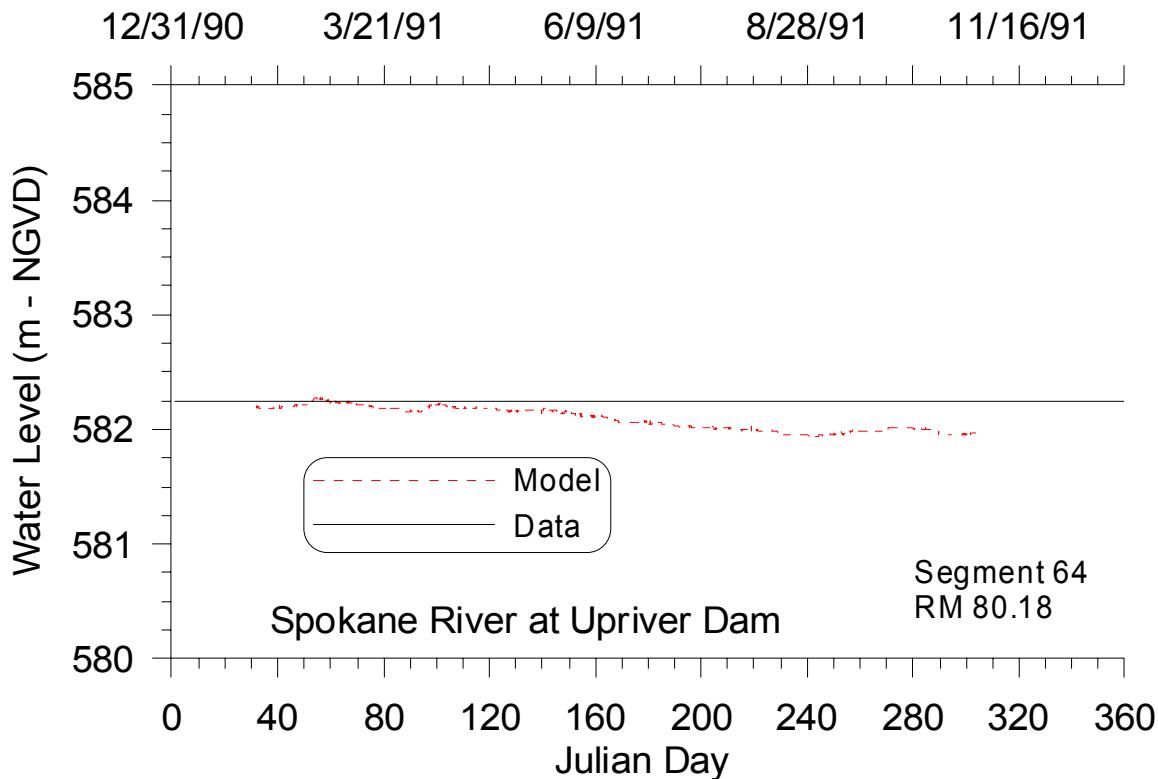


Figure 9. Water level prediction compared with 1991 data for the Spokane River at Upriver Dam.

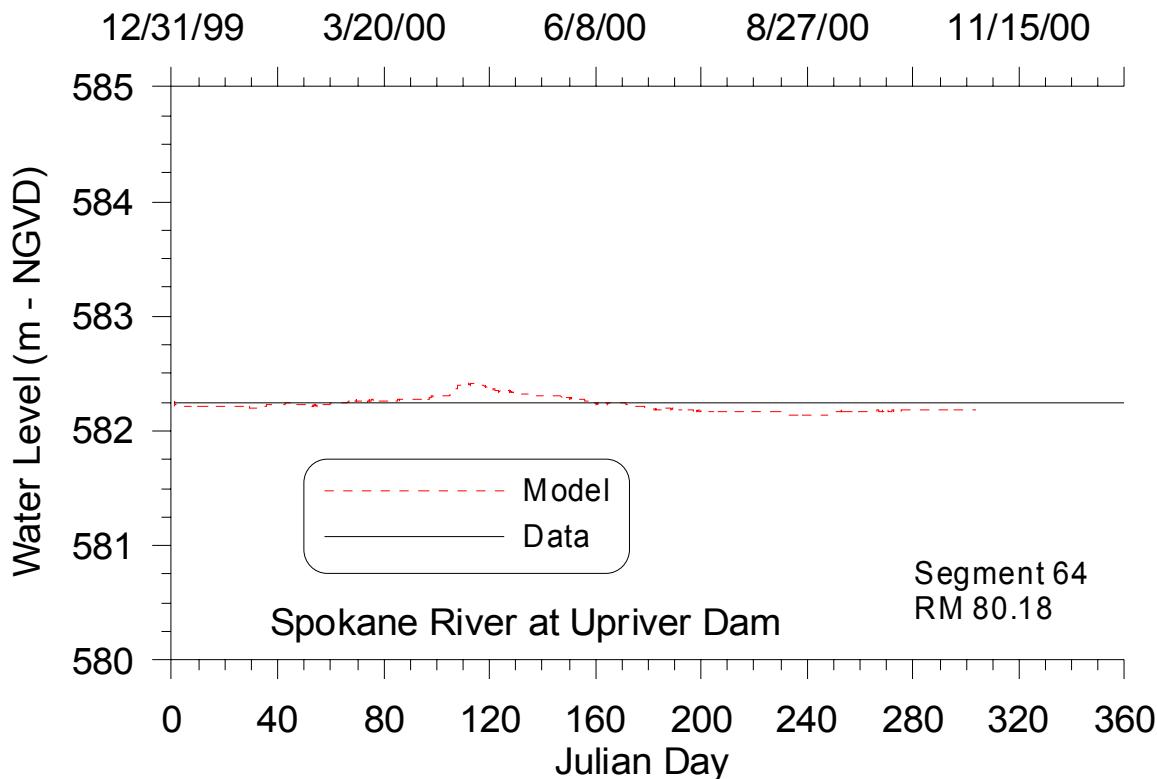


Figure 10. Water level prediction compared with 2000 data for the Spokane River at Upriver Dam.

Upper Falls Reservoir

The hydrodynamic calibration for the Upper Falls Reservoir was started after the Upriver Reservoir water balance was undertaken. The Upper Falls Reservoir Dam is located at RM 74.8 and is operated as a “run-of-the-river” facility. Water level data were compared with model results for both 1991 and 2000 as shown in Figure 11 and Figure 12 respectively. Table 5 shows water level statistics for 1991 and 2000.

Table 5. Water level error statistics for Upper Fall Reservoir, 1991 and 2000.

Year	N, # of data comparisons	Water level model –data error statistics	
		AME, m	RMS error, m
1991	271	0.055	0.065
2000	302	0.031	0.035

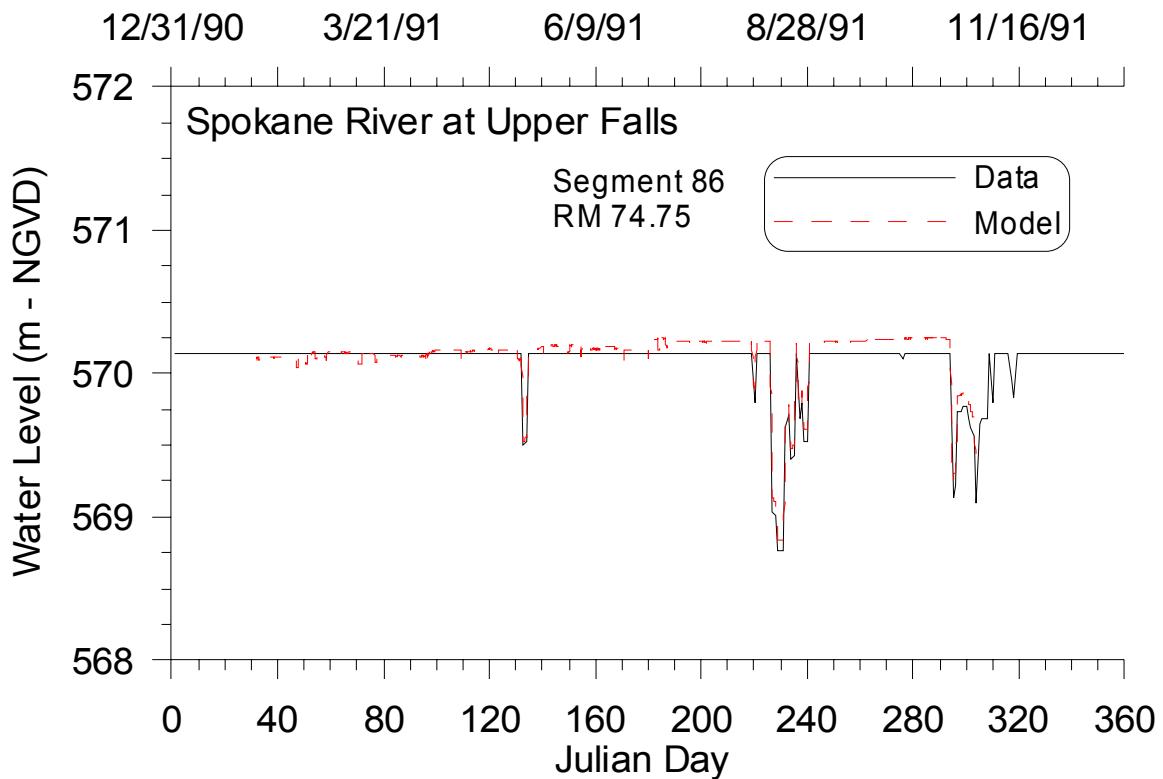


Figure 11. Water level prediction compared with 1991 data for the Spokane River at Upper Falls Dam.

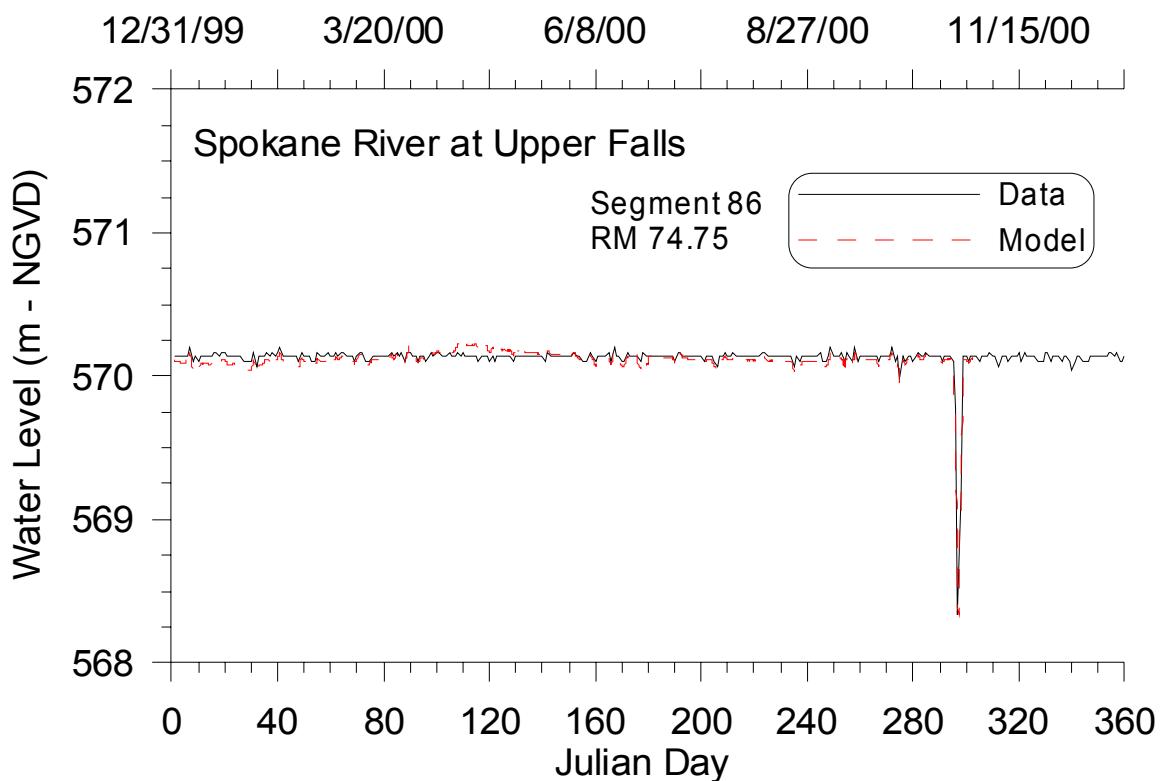


Figure 12. Water level prediction compared with 2000 data for the Spokane River at Upper Falls Dam.

Spokane River

The water level was only monitored at one site in 1991 and 3 sites in 2000 as shown in Table 6. Figure 13 shows the water level predictions and data for the Spokane River at Spokane for 1991. Figure 14, Figure 15, and Figure 16 compare year 2000 water level predictions and data for Harvard Rd, Barker Rd., and Spokane, respectively. Figure 17 shows the flow predictions and data for the Spokane River at Spokane for 1991. Flow predictions and data from 2000 were compared for the three sites in Figure 18, Figure 19, and Figure 20. Table 7 shows water level statistics for 1991 and 2000 for the three sites.

Table 6. Spokane River water level data sites

Site	River Mile	Segment	Water Level Data available
Spokane River at Spokane (USGS: 12422500)	72.9	97	1991, 2000
Spokane River at Harvard Rd (USGS: 12419500)	93.8	13	2000
Spokane River at Barker Rd (USGS: 12420500)	90.3	24	2000

Table 7. Water level error statistics for the Spokane River, 1991 and 2000.

Year:	1991			2000		
	Location	N, # of data comparisons	AME, m	RMS, m	N, # of data comparisons	AME, m
Segment 13, RM 93.8	NA	NA	NA	14519	0.304	0.414
Segment 24, RM 90.3	NA	NA	NA	13791	0.101	0.114
Segment 97, RM 72.9	26101	0.113	0.132	3268	0.098	0.112

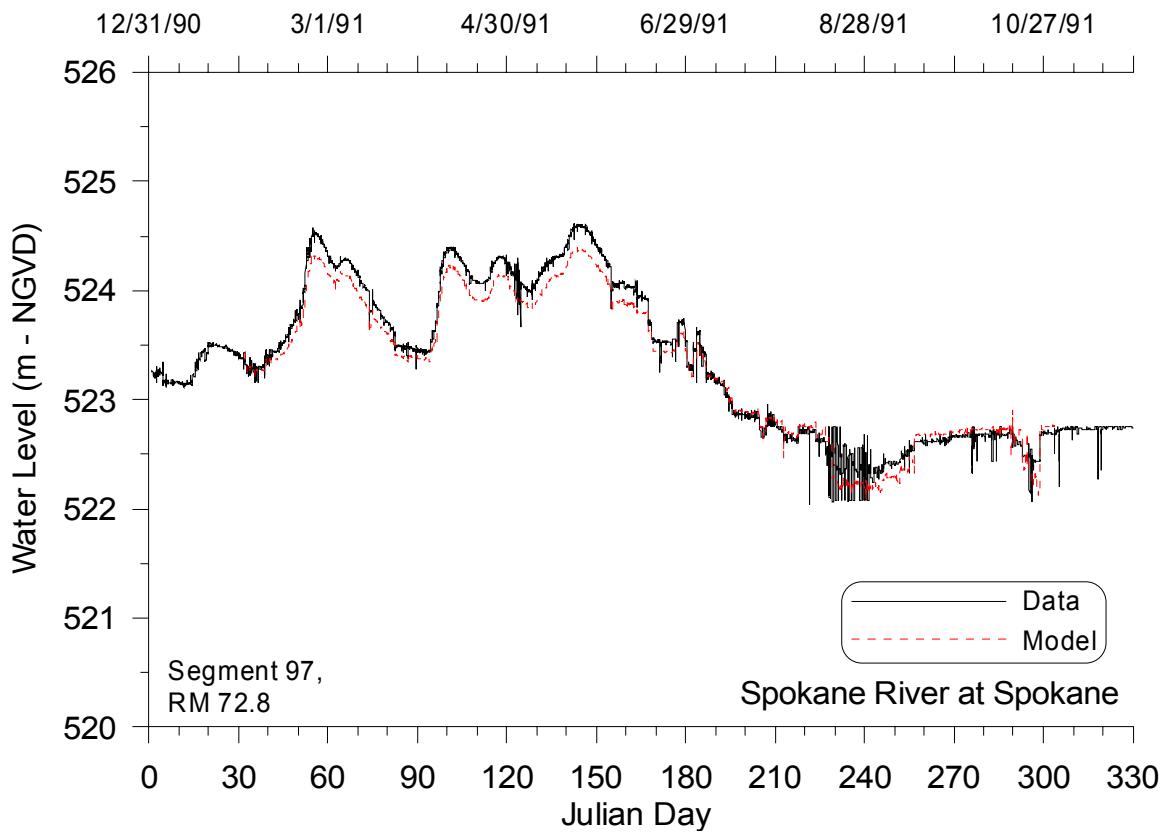


Figure 13. Water level prediction compared with 1991 data for the Spokane River at Spokane.

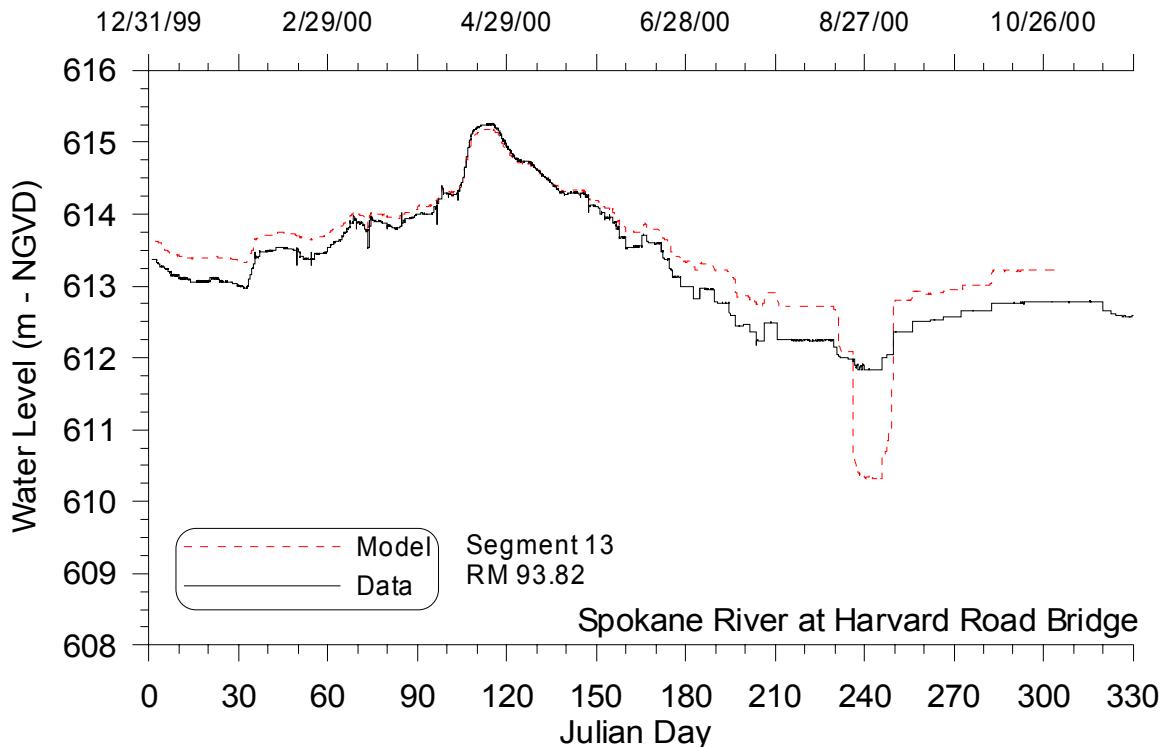


Figure 14. Water level prediction compared with 2000 data for the Spokane River at Harvard Road Bridge.

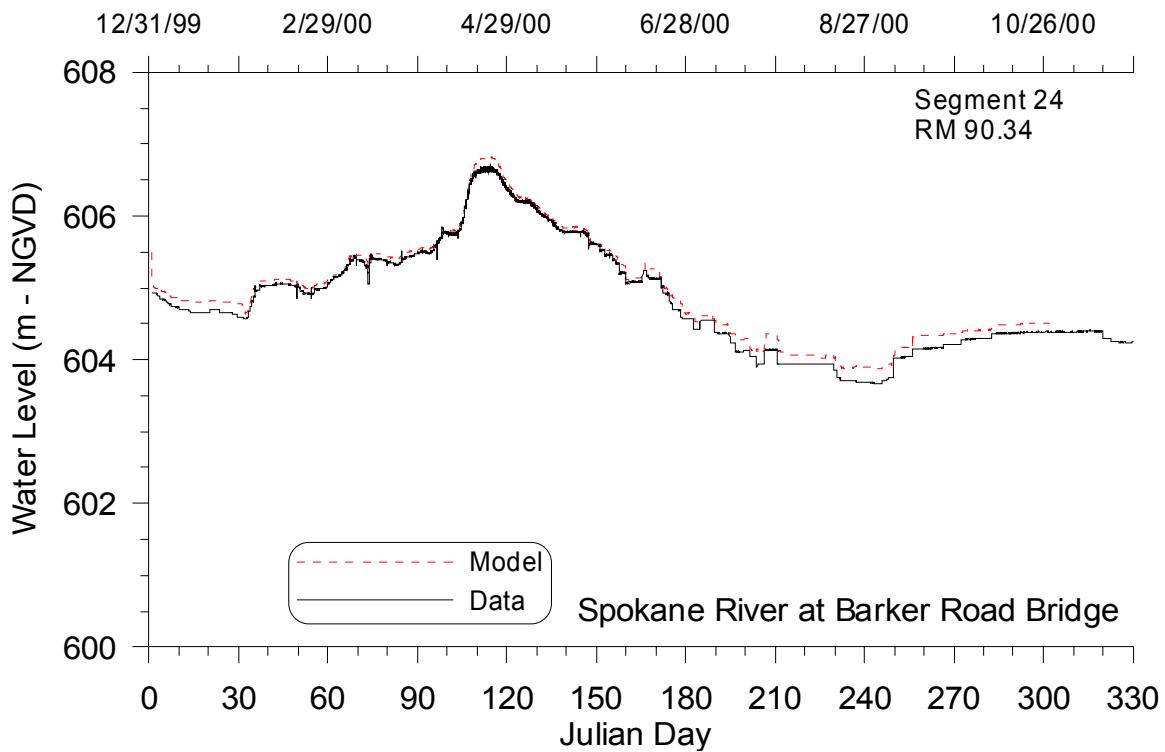


Figure 15. Water level prediction compared with 2000 data for the Spokane River at Barker Road Bridge.

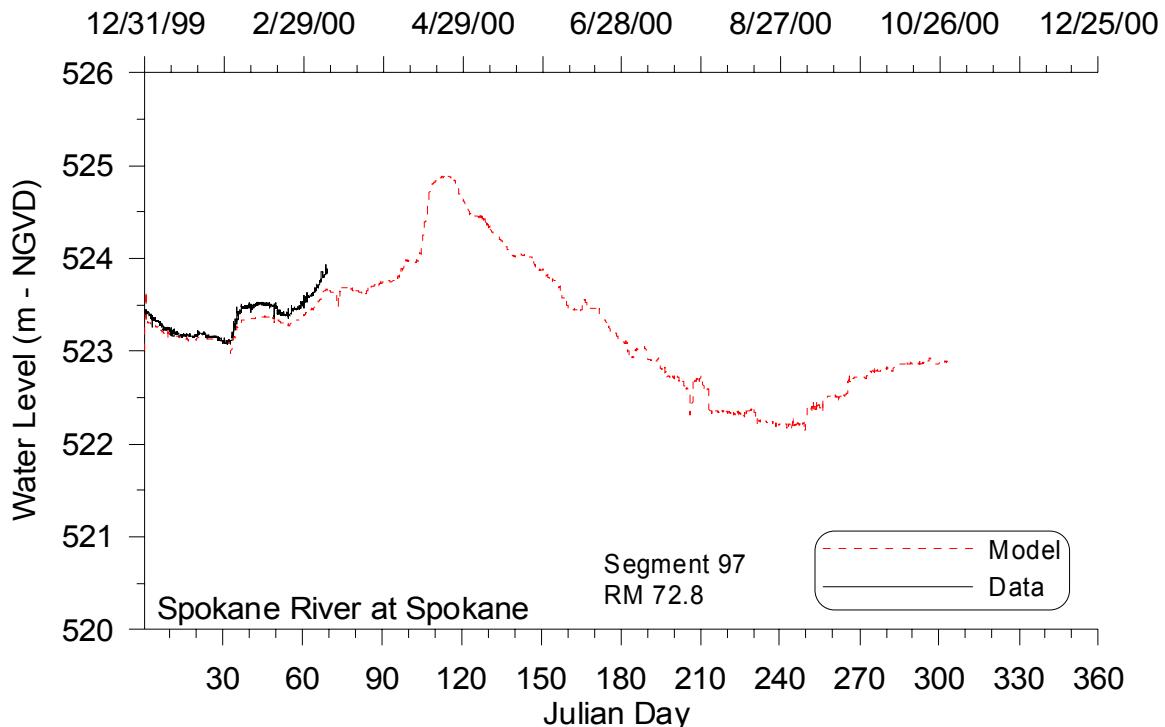


Figure 16. Water level prediction compared with 2000 data for the Spokane River at Spokane.

Table 8. Flow error statistics for the Spokane River, 1991 and 2000

Year:	1991			2000		
Location	N, # of data	AME,	RMS,	N, # of data	AME,	RMS,

	comparisons	m^3/s	m^3/s	comparisons	m^3/s	m^3/s
Segment 13, RM 93.8	NA	NA	NA	14519	1.89	3.83
Segment 24, RM 90.3	NA	NA	NA	13791	2.22	4.26
Segment 97, RM 72.9	26101	5.34	8.58	25385	4.23	5.91

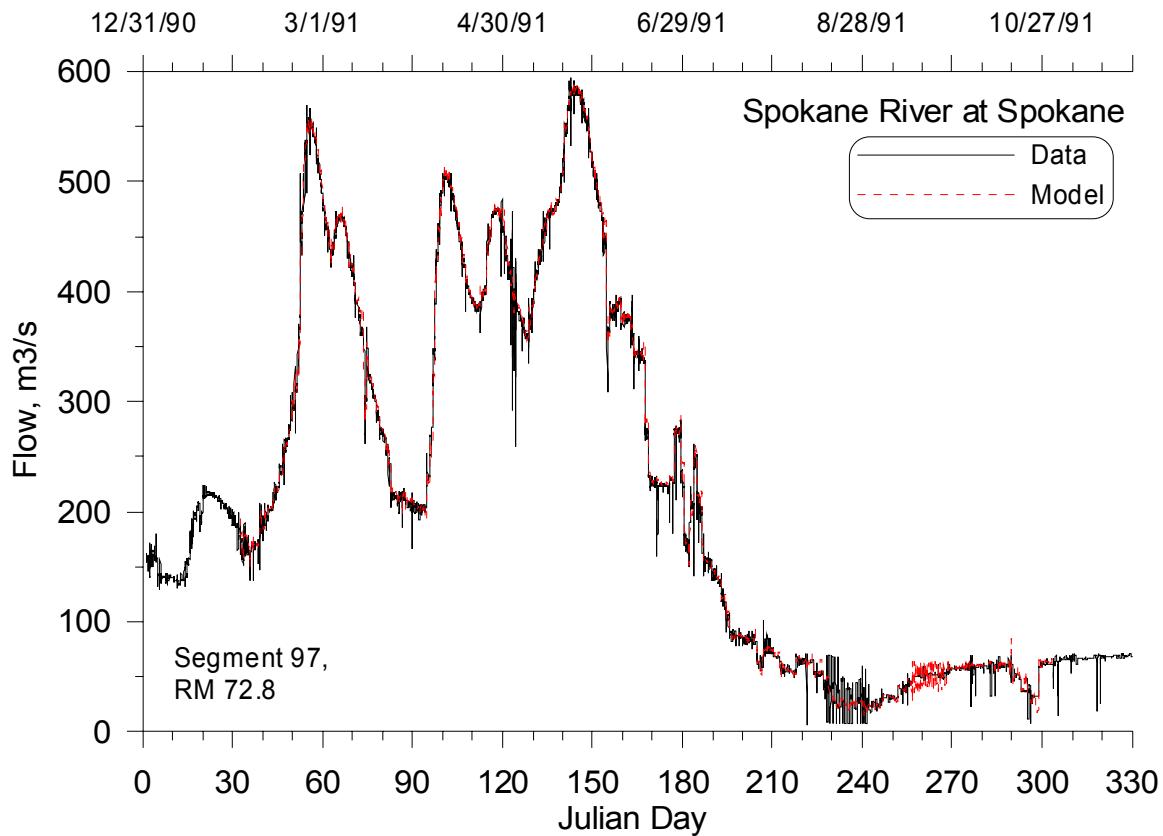


Figure 17. Flow prediction compared with 1991 data for the Spokane River at Spokane.

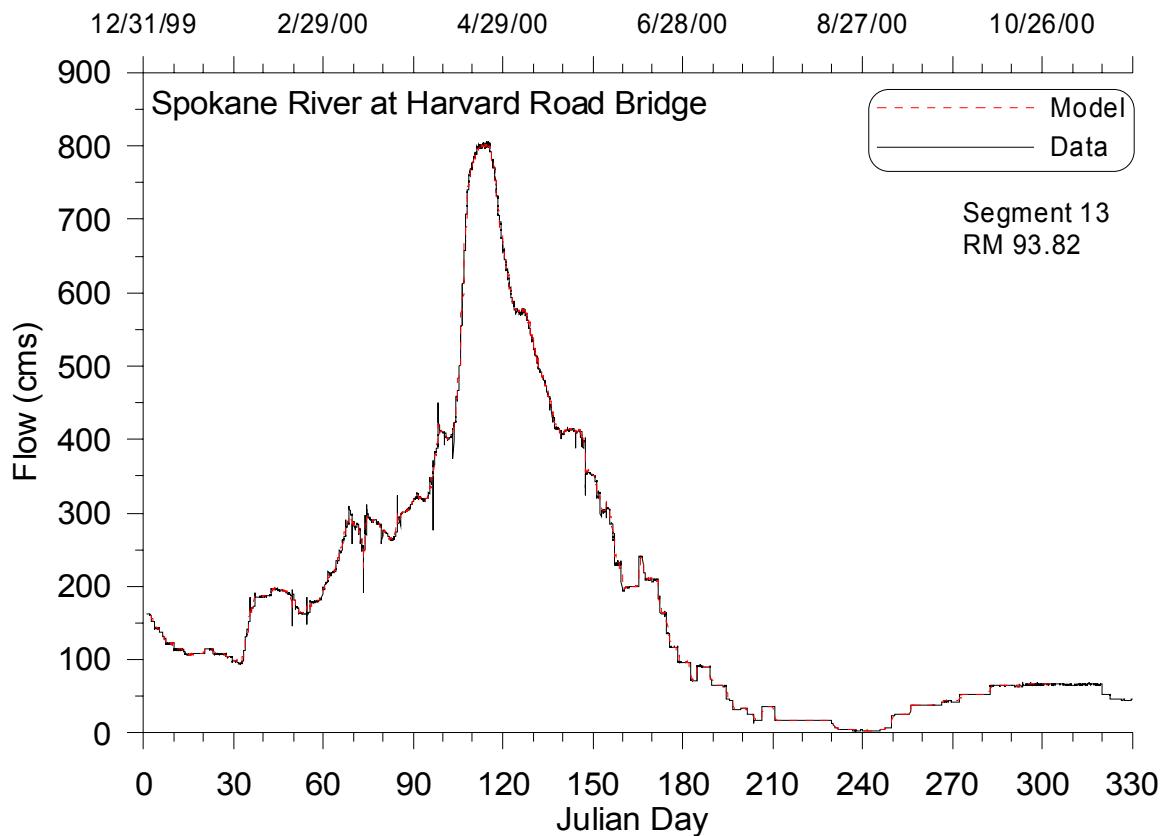


Figure 18. Flow prediction compared with 2000 data for the Spokane River at Harvard Road Bridge.

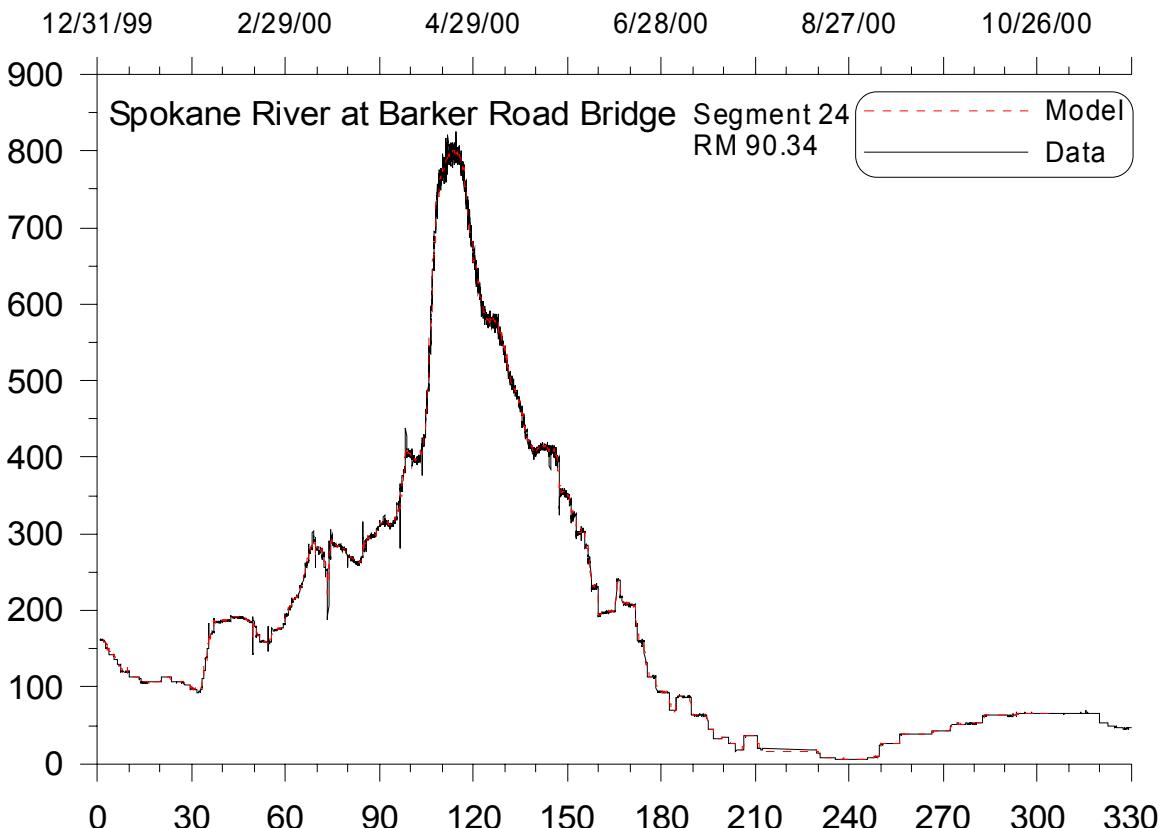


Figure 19. Flow prediction compared with 2000 data for the Spokane River at Barker Road Bridge.

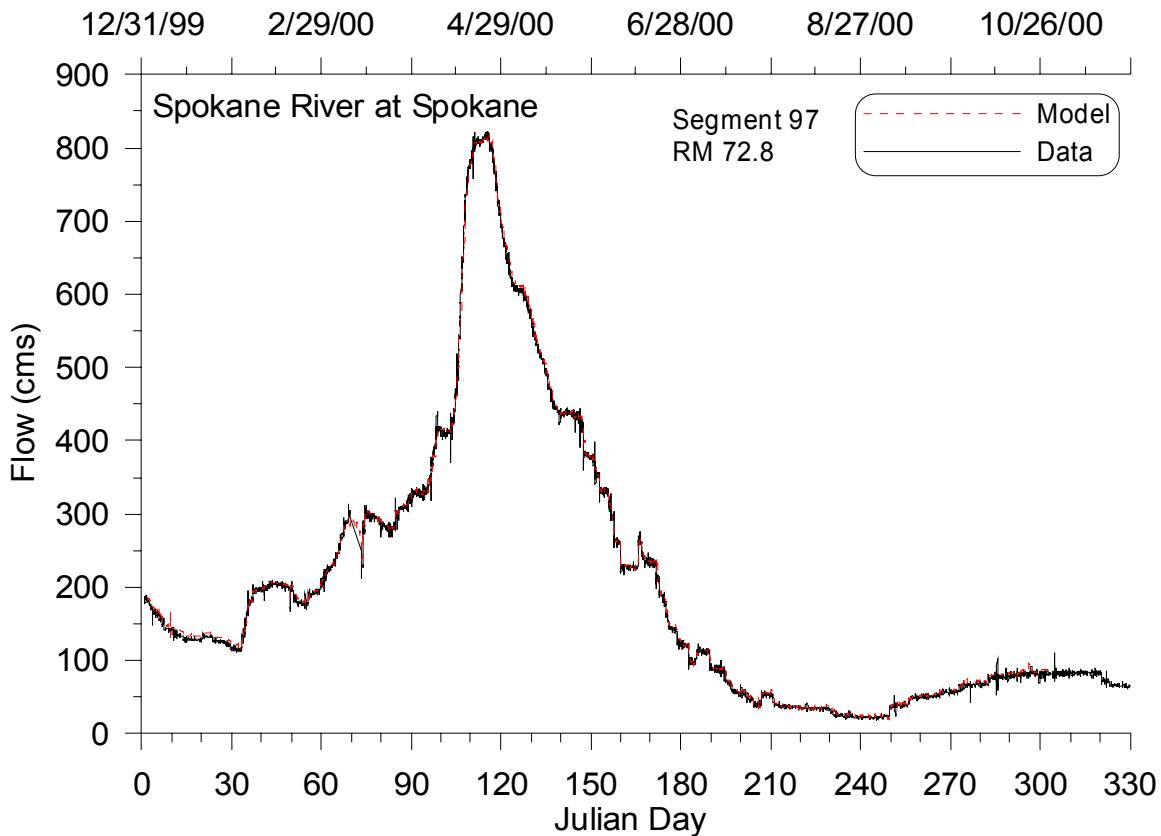


Figure 20. Flow prediction compared with 2000 data for the Spokane River at Spokane.

Nine Mile Reservoir

Nine Mile Reservoir Dam is located at RM 57.8 and the pool extends upstream for approximately 4 miles. The dam and reservoir are operated as a “run-of-the-river” facility. Figure 21 compares the water level data and model results for 1991. Figure 22 compares water level data and model results for 2000. Table 9 shows water level statistics for Nine Mile Reservoir in 1991 and 2000.

Table 9. Water level error statistics for Nine Mile Reservoir, 1991 and 2000.

Year	N, # of data comparisons	Water level model –data error statistics	
		AME, m	RMS error, m
1991	271	0.036	0.043
2000	302	0.058	0.073

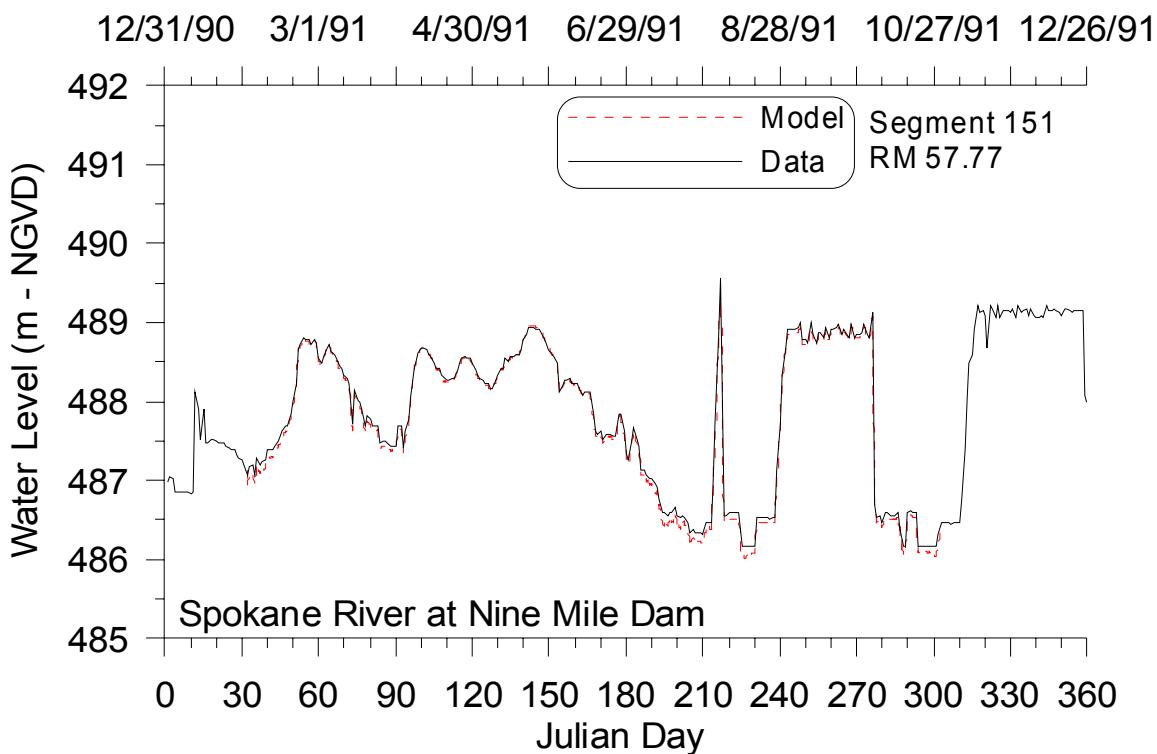


Figure 21. Water level prediction compared with 1991 data for the Spokane River at Nine Mile Dam.

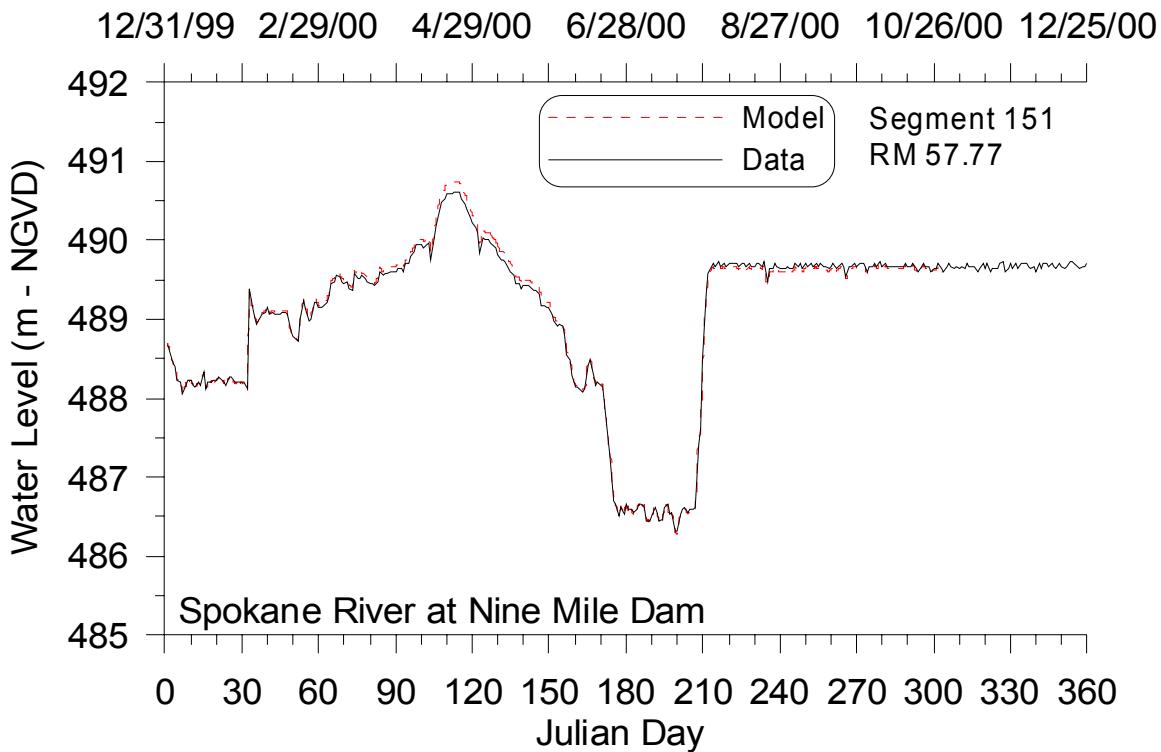


Figure 22. Water level prediction compared with 2000 data for the Spokane River at Nine Mile Dam.

Long Lake

Long Lake Dam is located at RM 32.5 and the lake backs up to one mile below Nine Mile Dam at RM 57.8. The lake is operated to store as much water as possible for irrigation with water passing downstream predominantly through turbines. Figure 23 compares the water level data and model results for 1991. Figure 24 compares water level data and model results for 2000. Table 10 shows water level statistics for Nine Mile Reservoir in 1991 and 2000.

Table 10. Water level error statistics for Long Lake, 1991 and 2000.

Year	N, # of data comparisons	Water level model -data error statistics	
		AME, m	RMS error, m
1991	271	0.033	0.040
2000	302	0.038	0.045

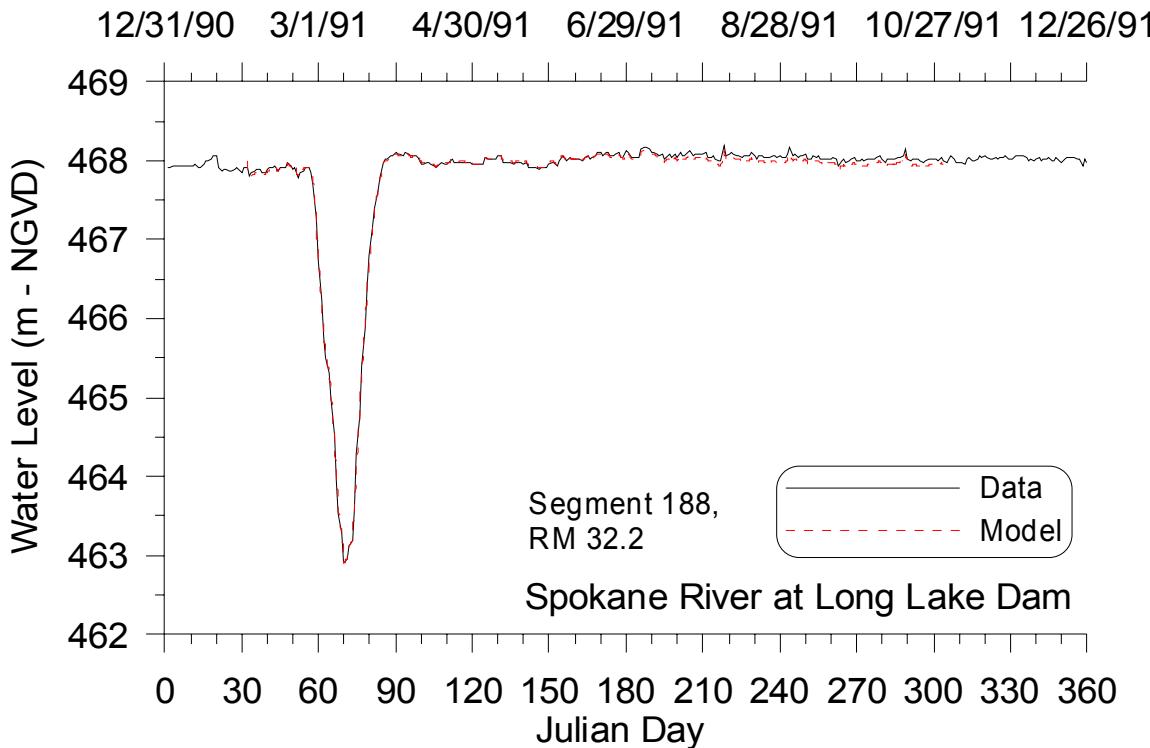


Figure 23. Water level prediction compared with 1991 data for the Spokane River at Long Lake Dam.

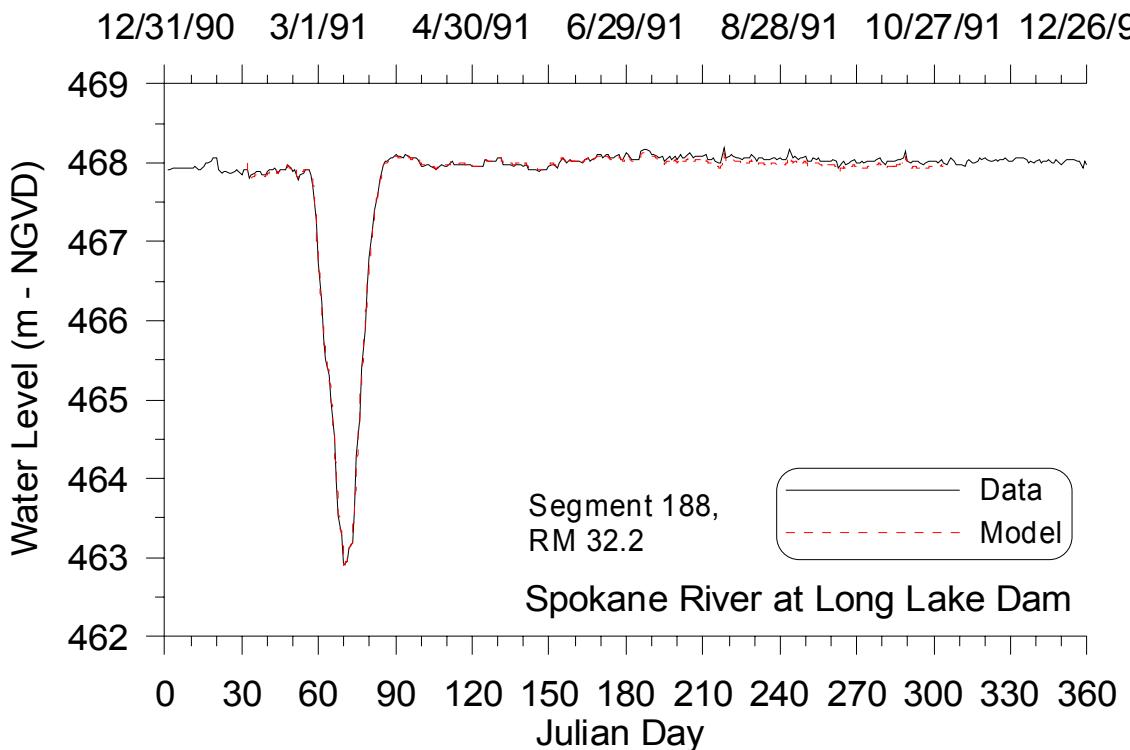


Figure 24. Water level prediction compared with 2000 data for the Spokane River at Long Lake Dam.

Temperature Calibration

Parameters affecting temperature calibration included wind sheltering coefficients, groundwater inflow temperature, and the accurate representation of reservoir outflows. Temperature predictions in Long Lake and Nine Mile Reservoir were particularly sensitive to the wind-sheltering coefficient. In these reservoirs, wind sheltering was increased during the summer in order to simulate the reservoir's vertical temperature profile. The wind-sheltering coefficient was reduced from 0.85 to 0.2 after Julian Day 180. For other sections of the river, wind-sheltering coefficients between 0.5 and 1.40 were applied for the entire year. Groundwater temperatures were estimated from well data. This was further discussed in the data report.

Year 1991

Vertical Profiles

During 1991 temperature profiles were only collected in Long Lake Reservoir. Model output profiles from each sampling site were compared with 12 data profiles. Table 11 lists the sites in Long Lake where temperature profiles were collected. Figure 25 through Figure 29 show temperature profiles from 1991 in the lake from Station 4 (RM 51.5) downstream to Station 0 (RM 32.7). Table 12 shows overall error statistics for all sites. The AME and RMS error for the vertical profiles were less than 0.8°C for all sampling sites.

Table 11. Long Lake temperature profiles sites for 1991

Site ID	Description	Segment Number	River Mile
LL0	Long Lake @ Station 0 (near dam)	187	32.66

Site ID	Description	Segment Number	River Mile
LL1	Long Lake @ Station 1	180	37.62
LL2	Long Lake @ Station 2	174	42.06
LL3	Long Lake @ Station 3	168	46.42
LL4	Long Lake @ Station 4	161	51.47

Table 12. Temperature profile error statistics, 1991

Site	N, # of data profile comparisons	Temperature model -data error statistics	
		AME, °C	RMS error, °C
LL0	12	0.67	0.75
LL1	12	0.58	0.67
LL2	12	0.48	0.56
LL3	12	0.52	0.56
LL4	12	0.71	0.78

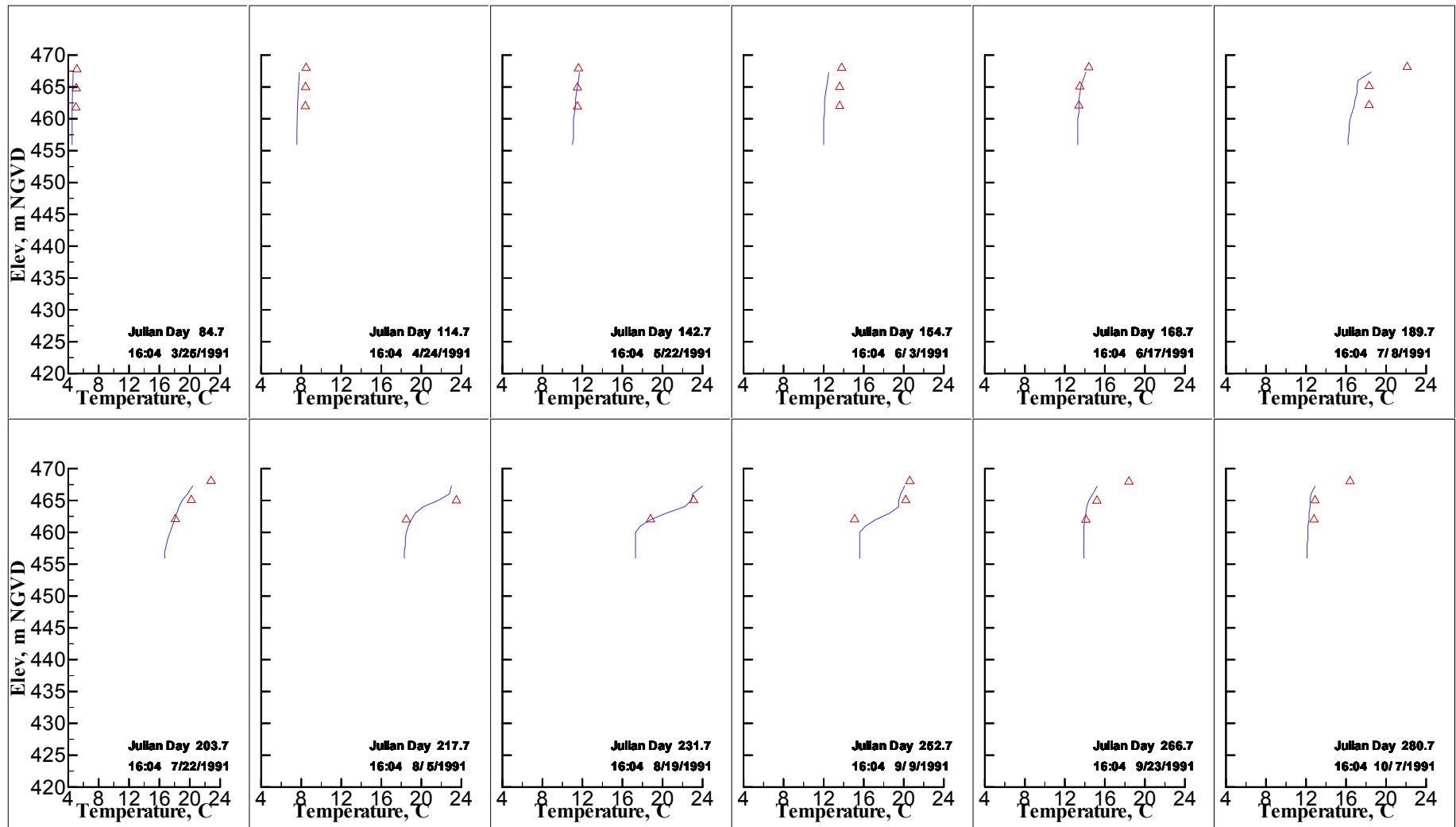


Figure 25. Comparison of model predicted vertical temperature profiles and 1991 data for Long Lake at Station 4 (Segment 161).

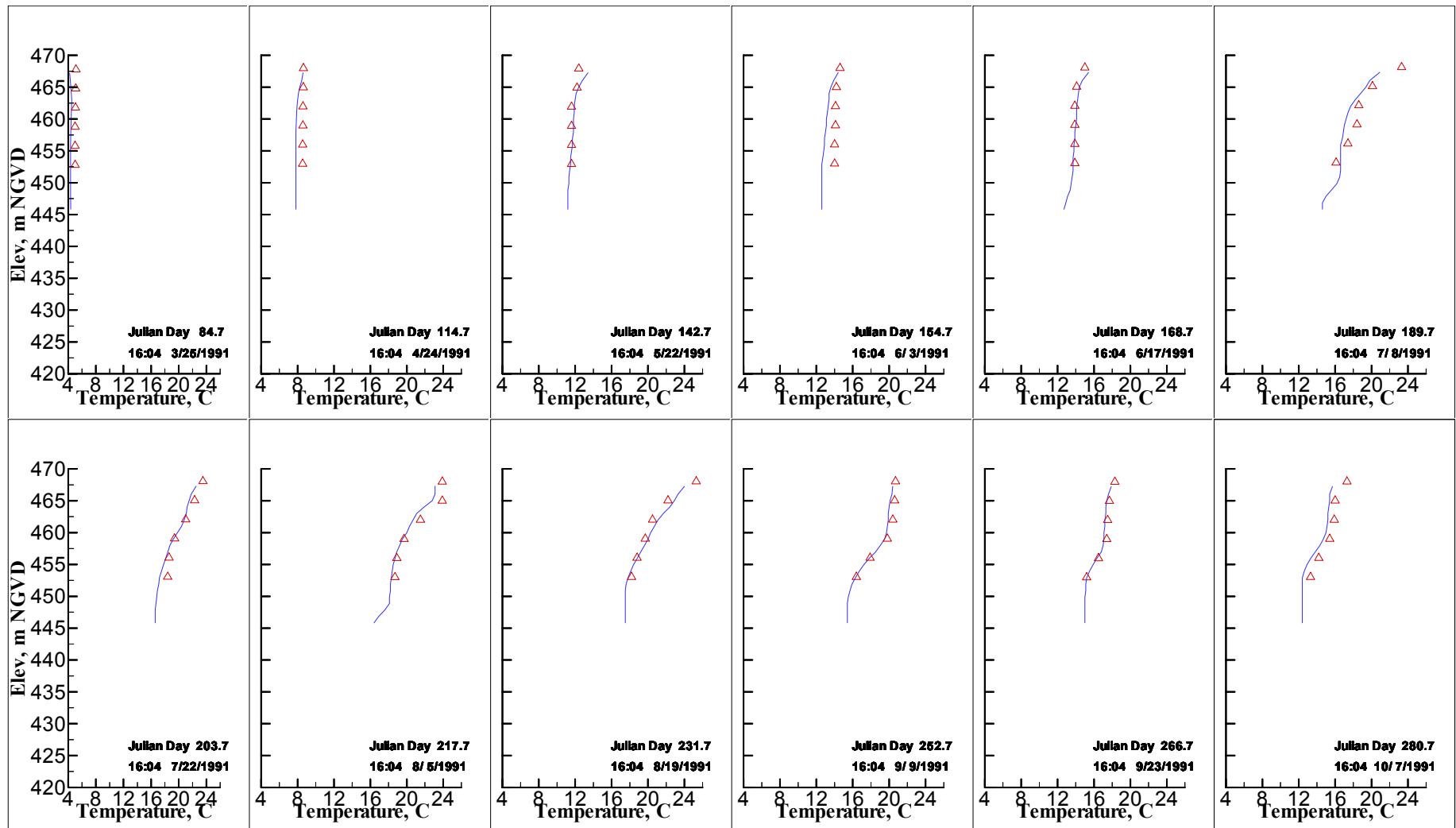


Figure 26. Comparison of model predicted vertical temperature profiles and 1991 data for Long Lake at Station 3 (Segment 168).

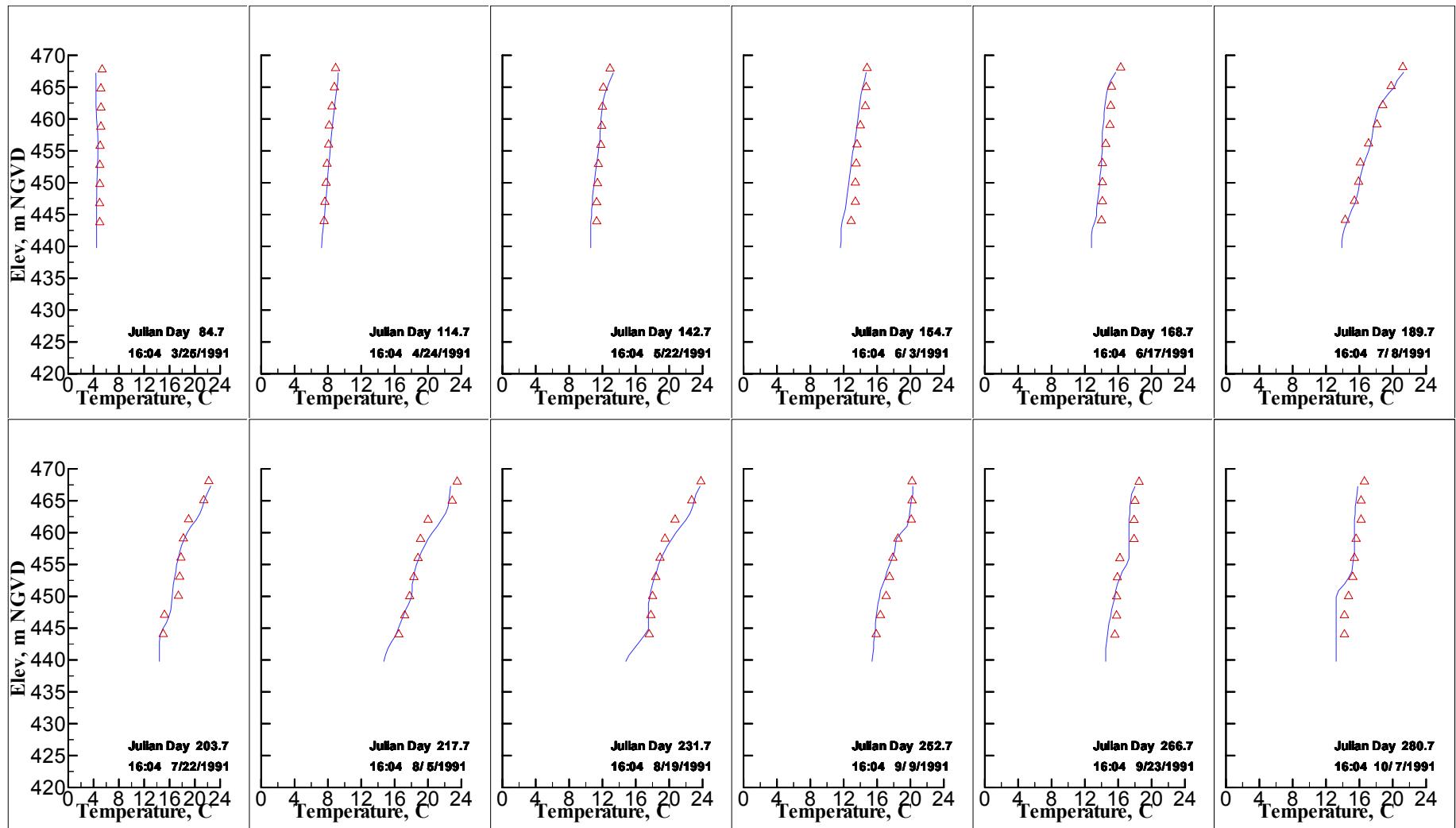


Figure 27. Comparison of model predicted vertical temperature profiles and 1991 data for Long Lake at Station 2 (Segment 174).

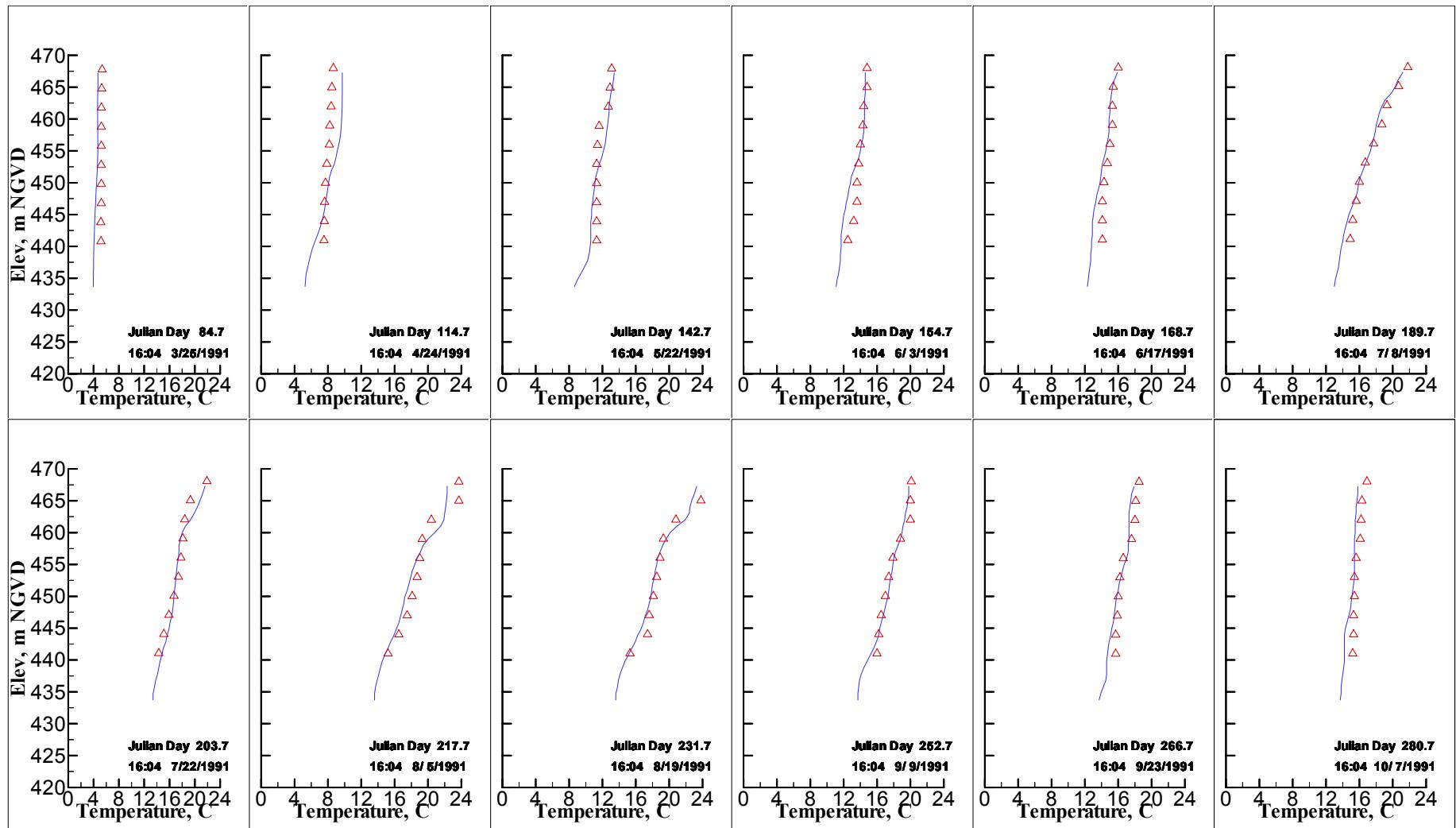


Figure 28. Comparison of model predicted vertical temperature profiles and 1991 data for Long Lake at Station 1 (Segment 180).

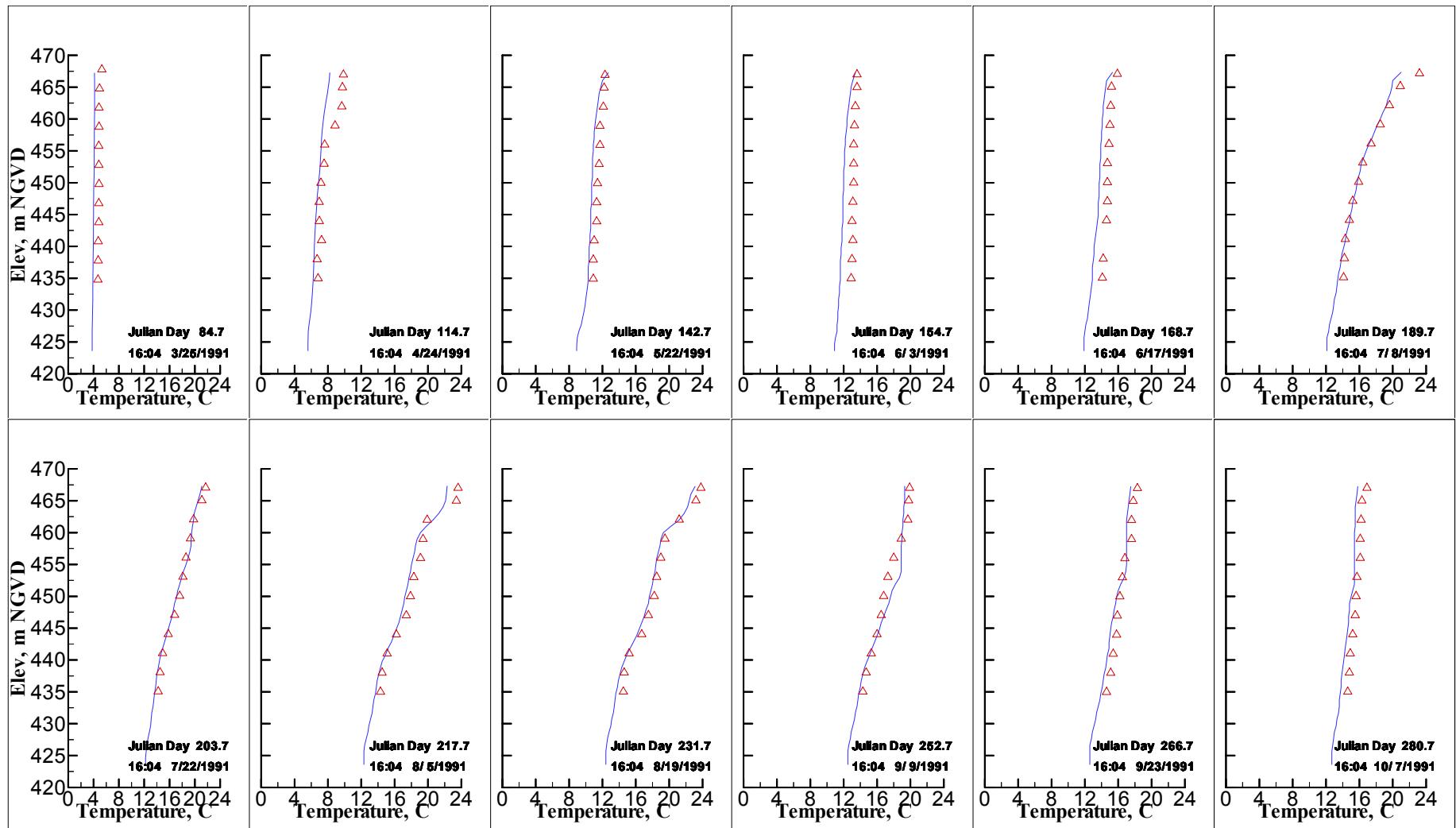


Figure 29. Comparison of model predicted vertical temperature profiles and 1991 data for Long Lake at Station 0 (Segment 187).

Time Series

Time series temperature data were collected at several locations along the Spokane River during 1991. Table 13 shows a list of sites where temperature time series data were collected. Figure 30 compares time series temperature model results with data for sites in the segment range 2 through 119 (RM 96 to 66). Figure 31 shows time series comparisons for sites in the segment range 135 to 154 (RM 62 to 58.1). No time series data were collected in Long Lake in 1991. Soltero et al., 1992, collected data in Long Lake several times during 1991, but the data represented a composite sample from the euphotic zone at each site. The model results represent temperatures at the surface layer. Table 14 shows time series temperature error statistics for all data sites in 1991.

Table 13. Temperature time series sites, 1991

Site ID	Description	Segment Number	River Mile
SPK58.1	Bridge below Nine Mile Dam	154	58.1
SPK62.0	Spokane R @ Seven Mile Br	135	62.0
SPK66.0	Spokane R @ Riverside State Park	119	66.0
SPK69.8	Spokane R near Fort Wright Bridge	106	69.8
SPK72.8	USGS gauging station, Spokane River at Spokane	97	72.8
SPK96.0	Spokane R @ Stateline Bridge	2	96.0

Table 14. Temperature time series error statistics, 1991

Site	n, # of data comparisons	Temperature model –data error statistics	
		AME, °C	RMS error, °C
SPK72.8	17	1.05	1.23
SPK69.8	17	0.86	1.07
SPK66.0	13	0.50	0.57
SPK62.0	17	1.03	1.18
SPK58.1	17	1.39	1.55

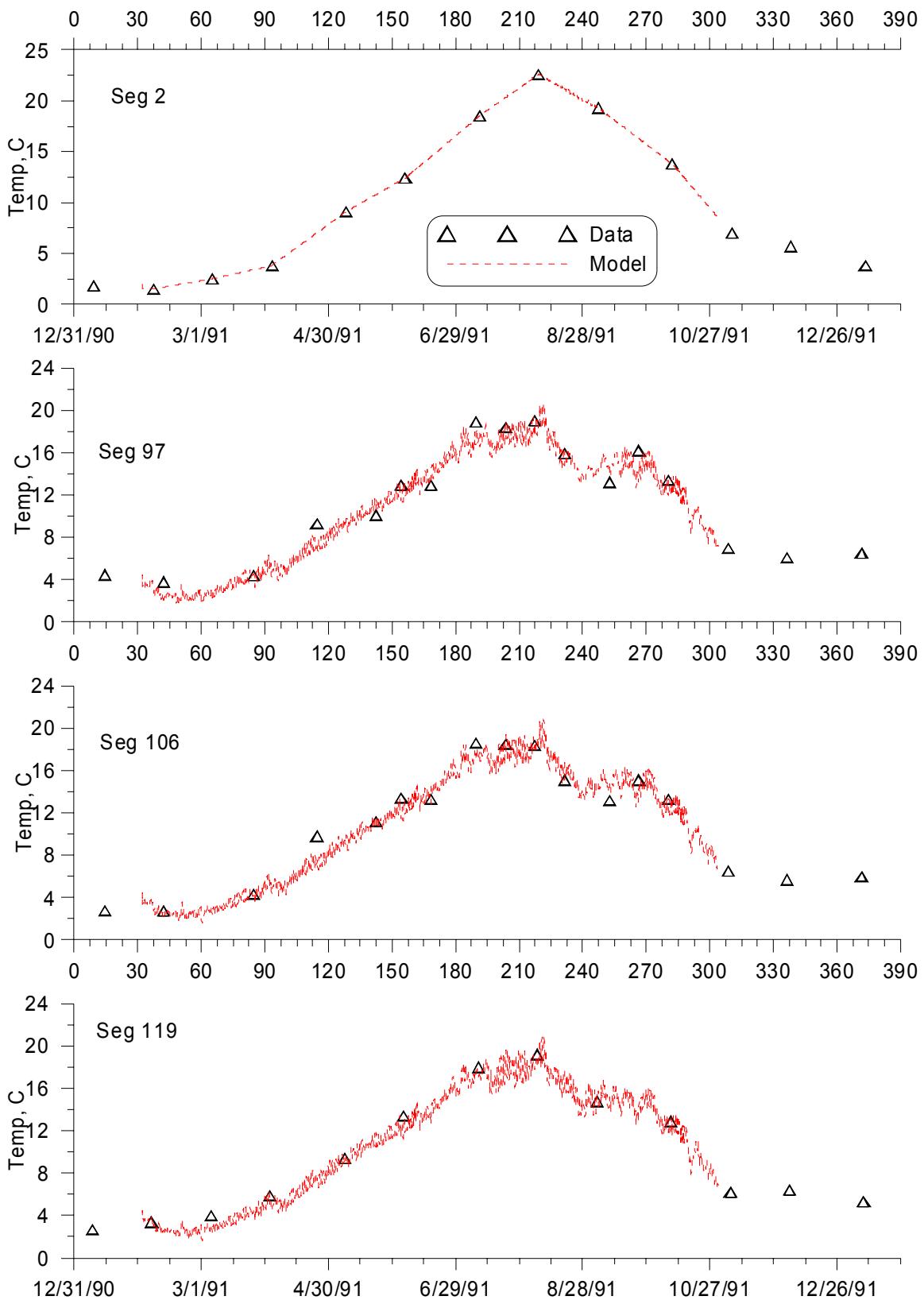


Figure 30. Comparison of model temperature predictions and data for the Spokane River at Stateline Bridge (segment 2), Spokane River at Spokane (segment 97), Spokane River near Fort Wright Bridge (segment 106), and the Spokane River at Riverside State Park (segment 119).

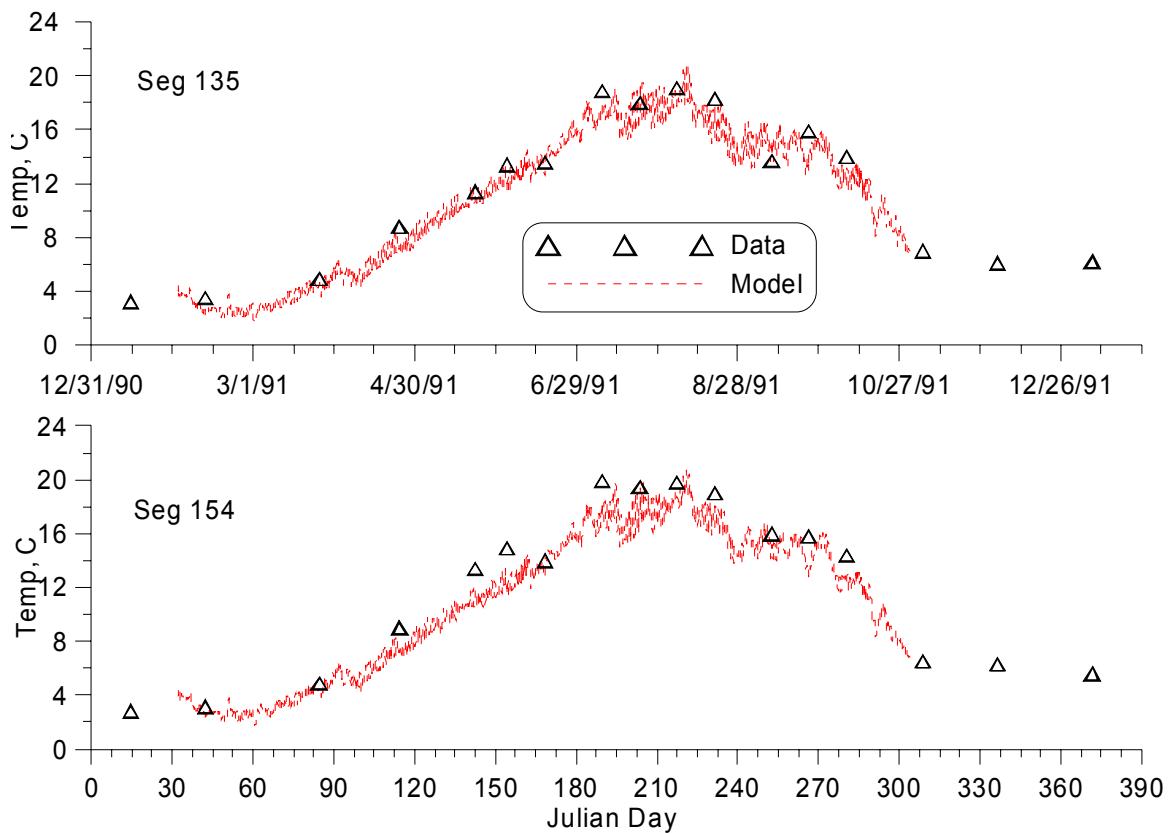


Figure 31. Comparison of model temperature predictions and data for the Spokane River 3.8 miles above Nine Mile Dam (segment 135) and the Spokane River at bridge below Nine Mile Dam (segment 154).

Year 2000

Vertical Profiles

In 2000 not as many vertical profiles were collected at sites within Long Lake but additional sites were added in Nine Mile Reservoir and Upriver Reservoir. Table 15 lists the sites where temperature vertical profiles were collected. Figure 36 through Figure 41 show temperature profile comparisons for Nine Mile Reservoir and Figure 42 through Figure 48 show temperature profile comparisons for Long Lake Reservoir. Table 16 shows temperature error statistics for the vertical profiles compared in 2000.

Table 15. Temperature profile sites, 2000.

Site ID	Description	Segment Number	River Mile
LL0	Long Lake @ Station 0 (near dam)	187	32.7
LL0.5	Long Lake @ Station 0.5	183	35.9
LL1	Long Lake @ Station 1	180	37.6
LL2	Long Lake @ Station 2	174	42.1
LL3	Long Lake @ Station 3	168	46.4
LL4	Long Lake @ Station 4	161	51.5
LL5	Long Lake @ Station 5	157	54.2
SPK58.3	Spokane River above Nine mile Dam: 0.2 miles upstream of dam	150	58.3
SPK58.9	Spokane River above Nine mile Dam: 0.8 miles upstream of dam	147	58.9
SPK60.2	Spokane River above Nine mile Dam: 2.1 miles upstream of dam	143	60.2

SPK60.9	Spokane River above Nine mile Dam: 2.8 miles upstream of dam	141	60.9
SPK61.4	Spokane River above Nine mile Dam: 3.3 miles upstream of dam	139	61.4
SPK61.9	Spokane River above Nine mile Dam: 3.8 miles upstream of dam	135	61.9
SPK80.2	Spokane River above Upriver Dam: 0.4 miles upstream of dam	64	80.2
SPK81.0	Spokane River above Upriver Dam: 1.2 miles upstream of dam	62	81.0
SPK81.6	Spokane River above Upriver Dam: 1.8 miles upstream of dam	60	81.6
SPK82.5	Spokane River above Upriver Dam: 2.7 miles upstream of dam	57	82.5

Table 16. Temperature profile error statistics, 2000

Site	n, # of data profile comparisons	Temperature model –data error statistics	
		AME, °C	RMS error, °C
LL0	3	0.79	1.16
LL0.5	1	1.17	1.79
LL1	7	0.86	1.07
LL2	3	0.55	0.71
LL3	7	0.86	0.93
LL4	3	0.68	0.98
LL5	3	0.82	0.91
SPK58.3	1	0.54	0.54
SPK58.9	1	0.84	0.85
SPK60.2	2	0.40	0.41
SPK60.9	2	0.63	0.63
SPK61.4	2	0.86	0.86
SPK61.9	1	1.20	1.20
SPK80.2	2	2.67	2.70
SPK81.0	2	2.14	2.16
SPK81.6	2	2.03	2.06
SPK82.5	1	3.49	3.51

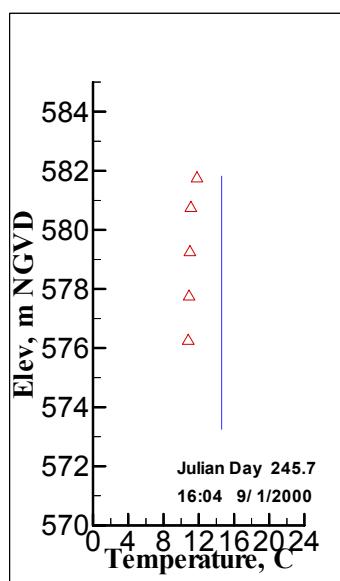


Figure 32. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 2.7 miles upstream of Upriver Dam (Segment 57).

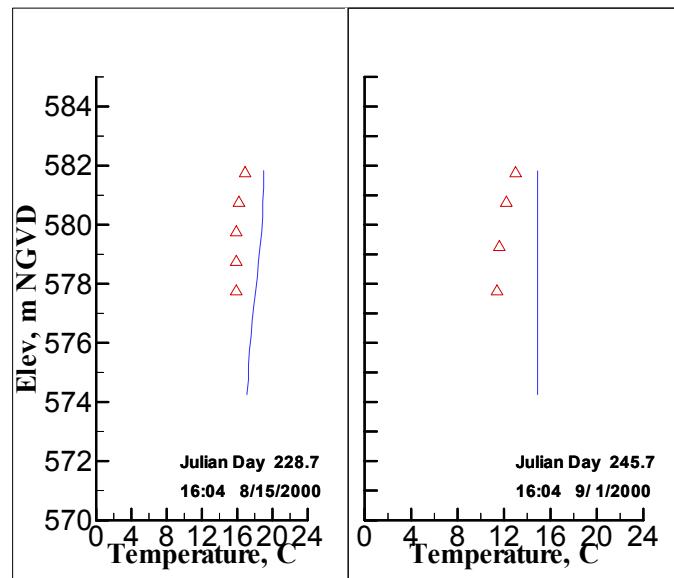


Figure 33. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 1.8 miles upstream of Upriver Dam (Segment 60).

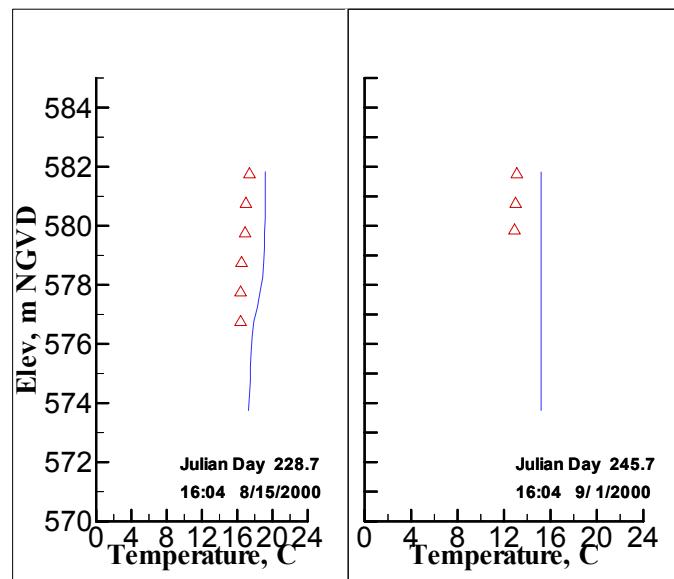


Figure 34. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 1.2 miles upstream of Upriver Dam (Segment 62).

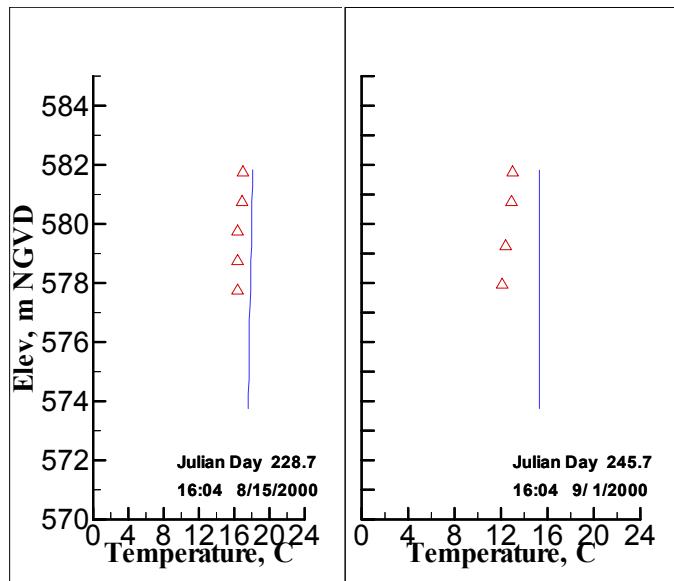


Figure 35. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 0.4 miles upstream of Upriver Dam (Segment 64).

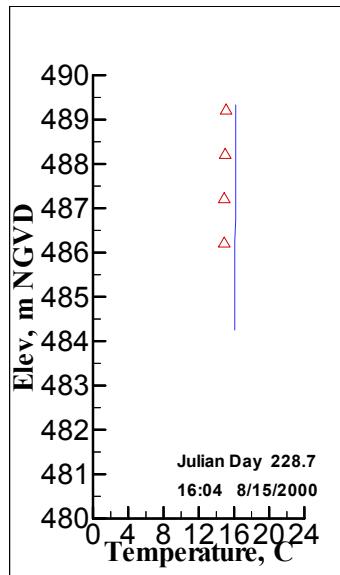


Figure 36. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 3.8 miles upstream of Nine Mile Dam (Segment 135).

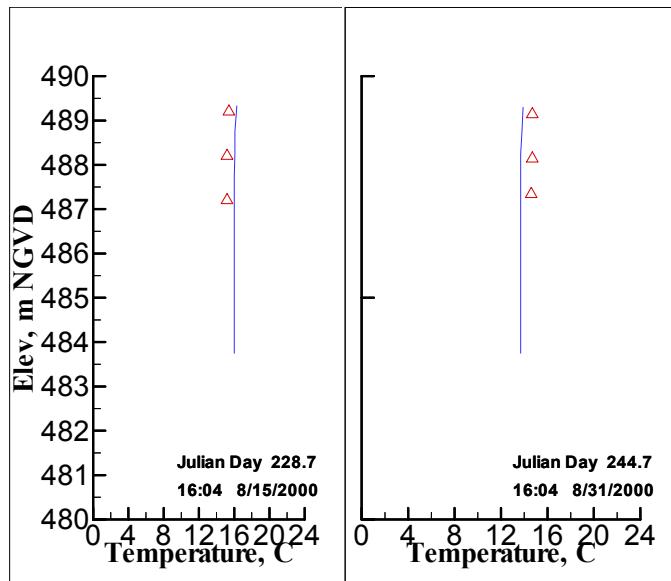


Figure 37. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 3.3 miles upstream of Nine Mile Dam (Segment 139).

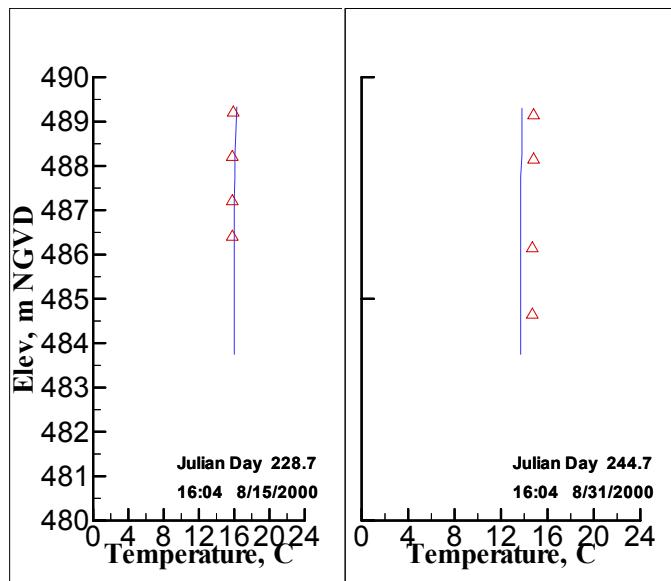


Figure 38. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 2.8 miles upstream of Nine Mile Dam (Segment 141).

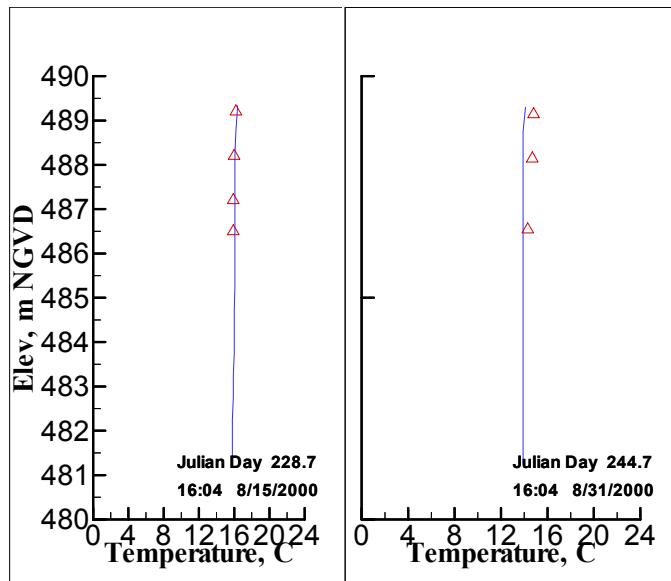


Figure 39. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 2.1 miles upstream of Nine Mile Dam (Segment 143).

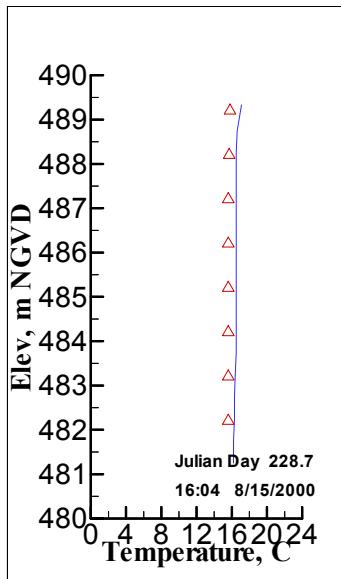


Figure 40. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 0.8 miles upstream of Nine Mile Dam (Segment 147).

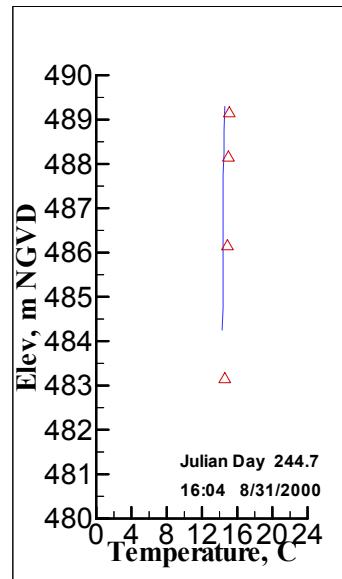


Figure 41. Comparison of model predicted vertical temperature profiles and 2000 data for the Spokane River 0.2 miles upstream of Nine Mile Dam (Segment 150).

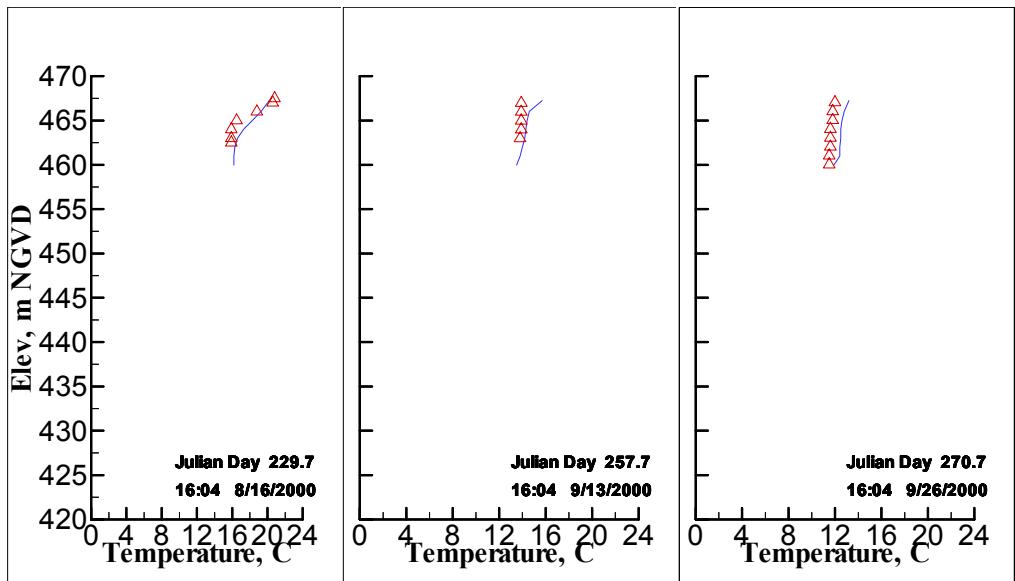


Figure 42. Comparison of model predicted vertical temperature profiles and 2000 data for Long Lake at Station 5 (Segment 157).

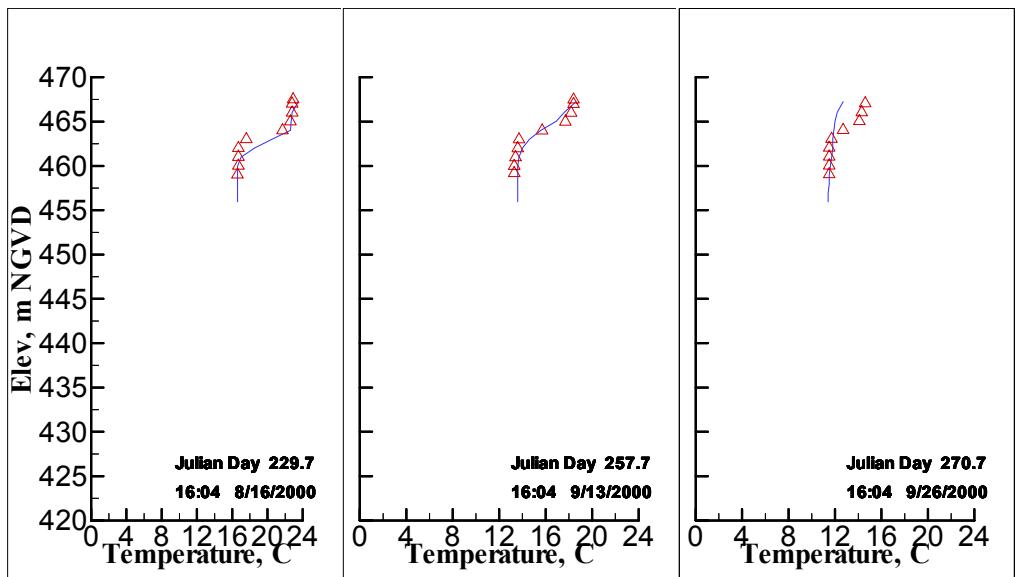


Figure 43. Comparison of model predicted vertical temperature profiles and 2000 data for Long Lake at Station 4 (Segment 161).

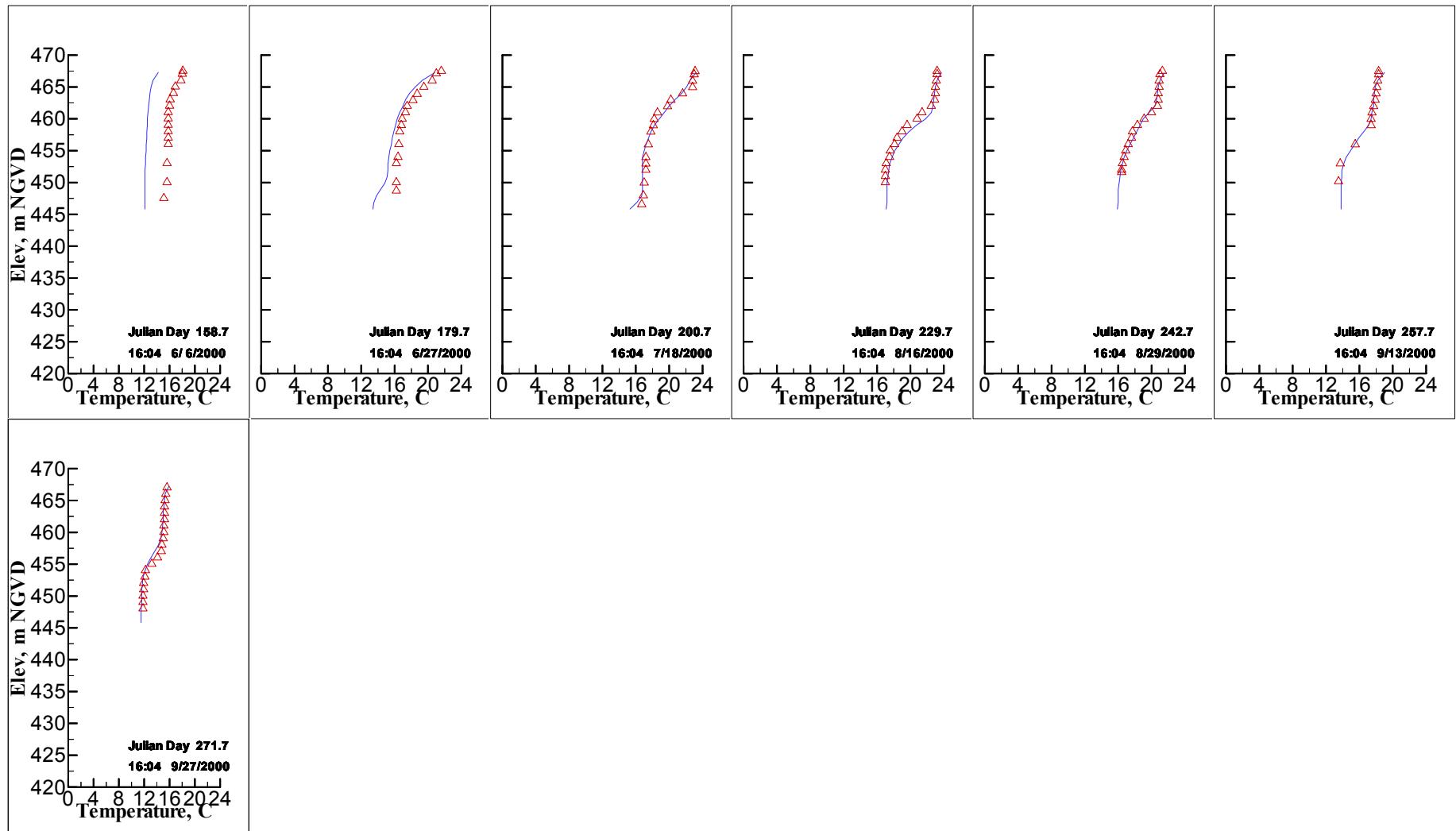


Figure 44. Comparison of model predicted vertical temperature profiles and 2000 data for Long Lake at Station 3 (Segment 168).

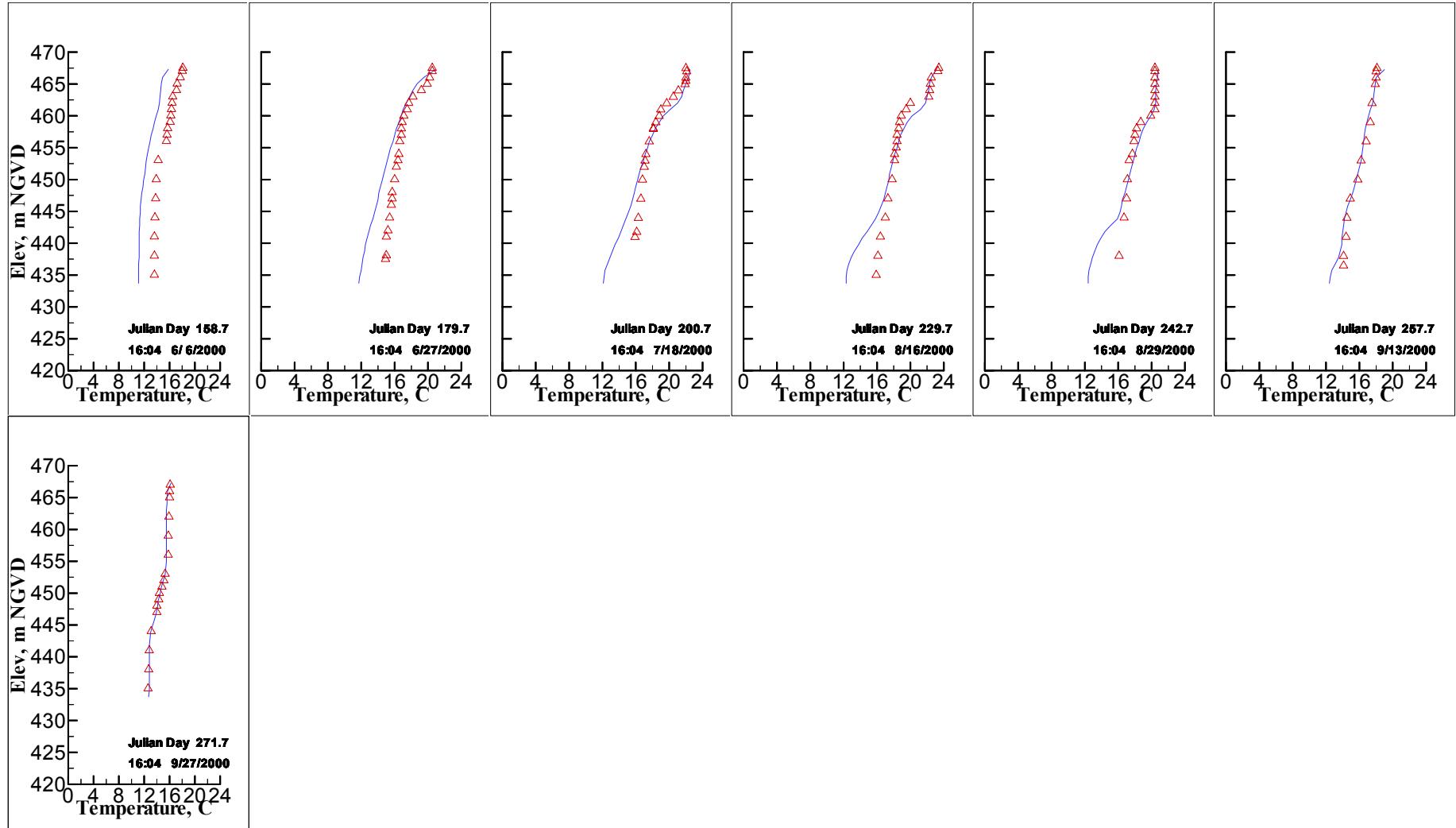


Figure 45. Comparison of model predicted vertical temperature profile and 2000 data for Long Lake at Station 1 (Segment 180).

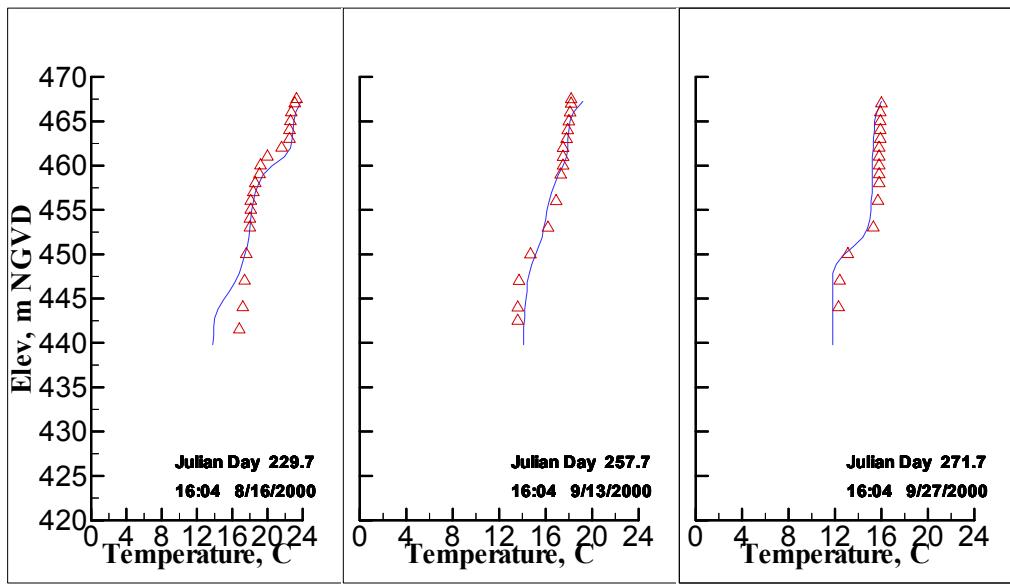


Figure 46. Comparison of model predicted vertical temperature profiles and 2000 data for Long Lake at Station 2 (Segment 174).

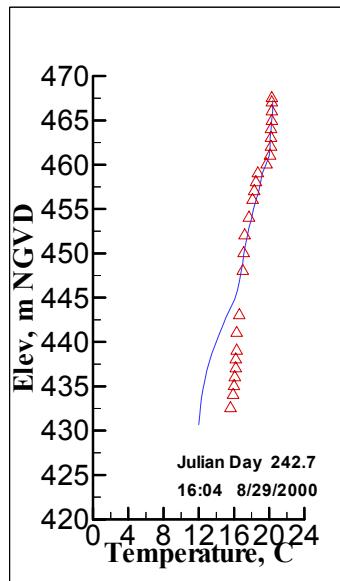


Figure 47. Comparison of model predicted vertical temperature profile and 2000 data for Long Lake at Station 0.5 (Segment 183).

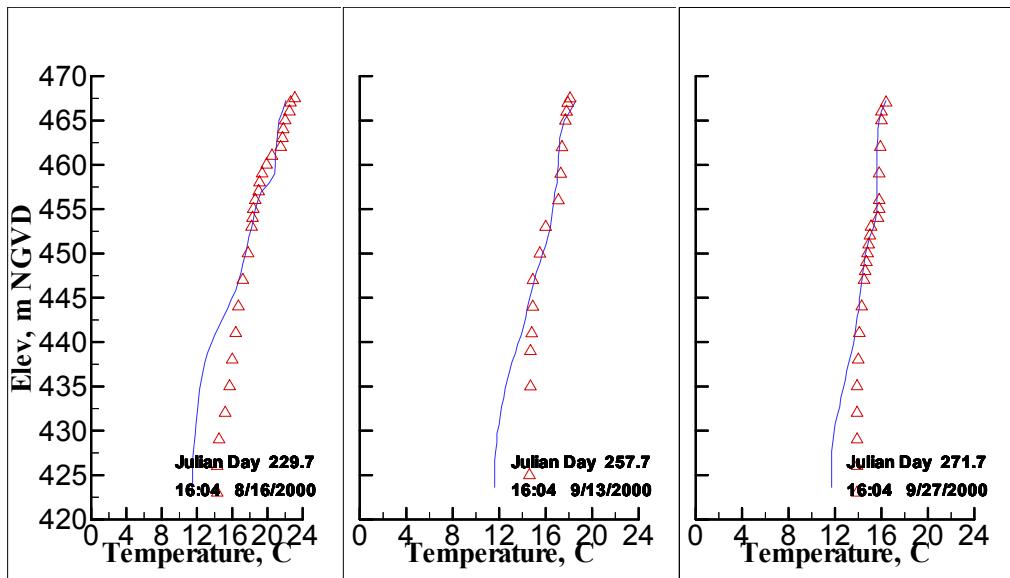


Figure 48. Comparison of model predicted vertical temperature profile and 2000 data for Long Lake at Station 0 (Segment 187).

Time Series

During 2000 time series temperature data were collected at several locations along the Spokane River. Critical to predicting temperatures in the river were correct simulation of aquifer exchanges. The methodology used to predict aquifer exchanges were discussed in the data report. Groundwater temperatures used in the model were based upon well data. The Table 17 shows a list of sites where temperature time series data were collected. Figure 49 compares time series temperature model results with data for sites in the segment range 2 through 36 (RM 96 to 87.8). Figure 50 shows time series comparisons for sites in the segment range 48 to 73 (RM 84.7 to 78). Figure 51 shows time series comparisons for sites in the segment range 89 to 114 (RM 74.4 to 67.6). Figure 52 shows time series comparisons for sites in the segment range 119 to 150 (RM 66 to 58.3). Figure 53 shows time series comparisons for sites in the segment range 154 and 155 (RM 58.1 to 57.1). Table 18 shows time series temperature error statistics for all data sites in 2000.

Table 17. Temperature time series sites, 2000

Site ID	Description	Segment Number	River Mile
SPK57.1-A	Spokane River @ Long Lake: a 1 mile downstream of Nine Mile Dam.	155	57.1
SPK58.1	Just d/s of Nine Mile Dam at the Charles road bridge	154	58.1
SPK58.3	Spokane River above Ninemile Dam: about 0.2 miles upstream of Nine Mile Dam.	150	58.3
SPK60.9	Spokane River above Ninemile Dam: about 2.8 miles upstream of Nine Mile Dam.	141	60.9
SPK62.0	Spokane R @ Seven Mile Br	135	62.0
SPK66.0	Spokane R @ Riverside State Park	119	66.0
SPK67.6	Spokane R Upstream Spokane WTP	114	67.6
SPK69.8	Spokane R near Fort Wright Bridge	106	69.8
SPK72.8	USGS gauging station, Spokane River at Spokane	97	72.8
SPK74.4	Spokane River @ Walkbridge behind Spokane Center	89	74.4

Site ID	Description	Segment Number	River Mile
SPK78.0	Spokane R @ Green St. Bridge	73	78.0
SPK79.8	Spokane R Upstream Upriver Dam Powerhouse	67	79.8
SPK79.9	Spokane River above Upriver Dam: about 0.1 miles upstream of Upriver Dam Powerhouse.	64	79.9
SPK84.7	Spokane R Foot Bridge @ Plante Ferry Park	48	84.7
SPK87.8	Spokane R @ Sullivan Rd. Bridge	36	87.8
SPK90.4	Spokane R @ Barker Rd. Bridge	24	90.4
SPK93.0	Spokane R @ Harvard Rd. Bridge	17	93.0
SPK96.0	Spokane R @ Stateline Bridge	2	96.0

Table 18. Temperature time series error statistics, 2000

Site	n, # of data comparisons	Temperature model –data error statistics	
		AME, °C	RMS error, °C
SPK57.1-A	1968	0.76	1.07
SPK58.1	13	0.98	1.35
SPK58.3	784	0.59	0.71
SPK60.9	626	0.56	0.70
SPK62.0	8	0.28	0.35
SPK66.0	12	1.09	1.84
SPK67.6	8	0.61	0.79
SPK69.8	8	0.70	0.87
SPK72.8	8	0.61	0.71
SPK74.4	8	0.64	0.74
SPK78.0	8	0.75	0.93
SPK79.8	8	0.59	0.76
SPK79.9	773	2.54	2.63
SPK84.7	8	0.79	0.93
SPK87.8	8	0.58	0.69
SPK90.4	9	0.74	0.89
SPK93.0	9	0.52	0.60

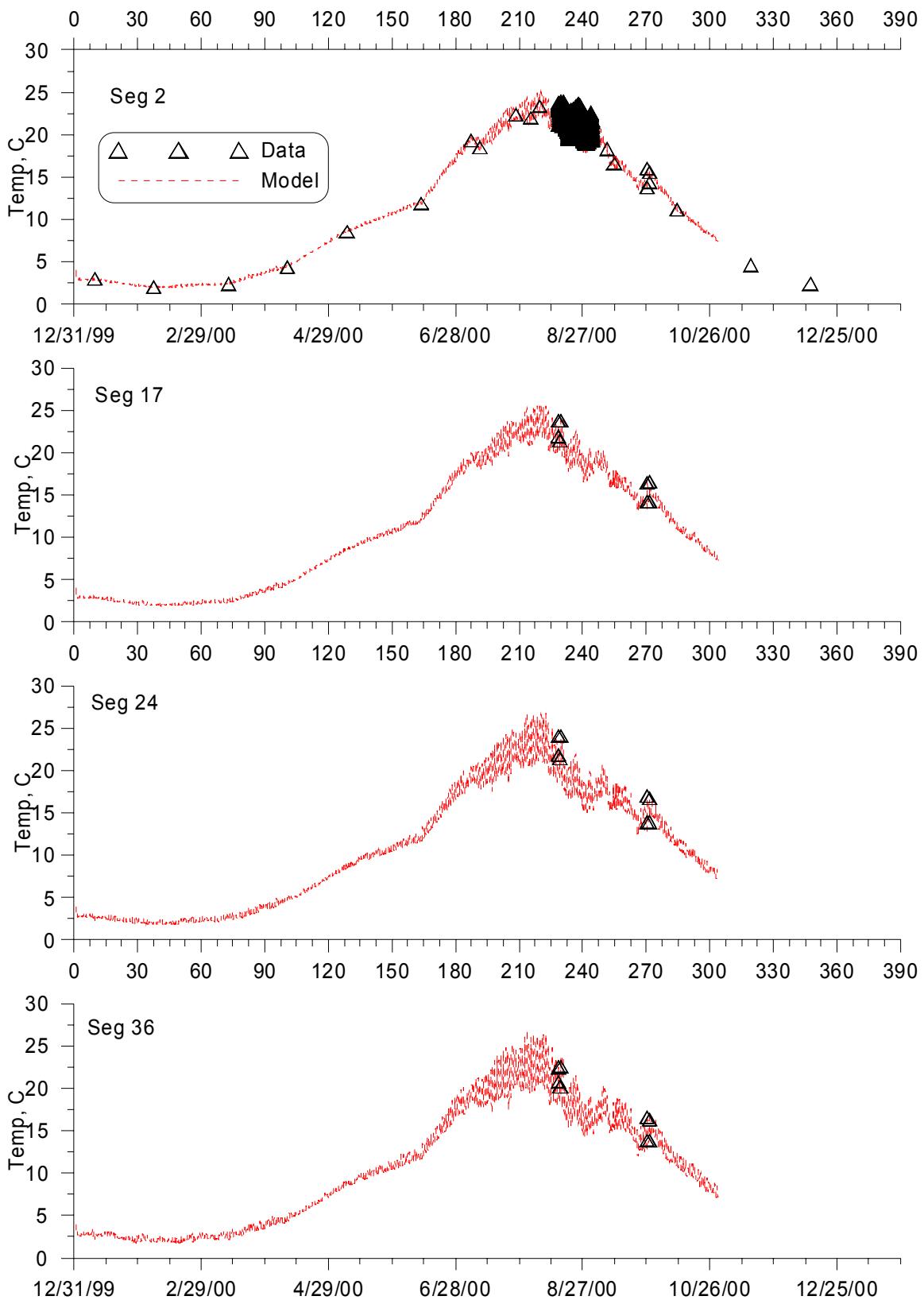


Figure 49. Comparison of model temperature predictions and data for the Spokane River at Stateline Bridge (segment 2), Spokane River at Harvard Road Bridge (segment 17), Spokane River at Barker Road Bridge (segment 24), and the Spokane River at Sullivan Road Bridge (segment 36).

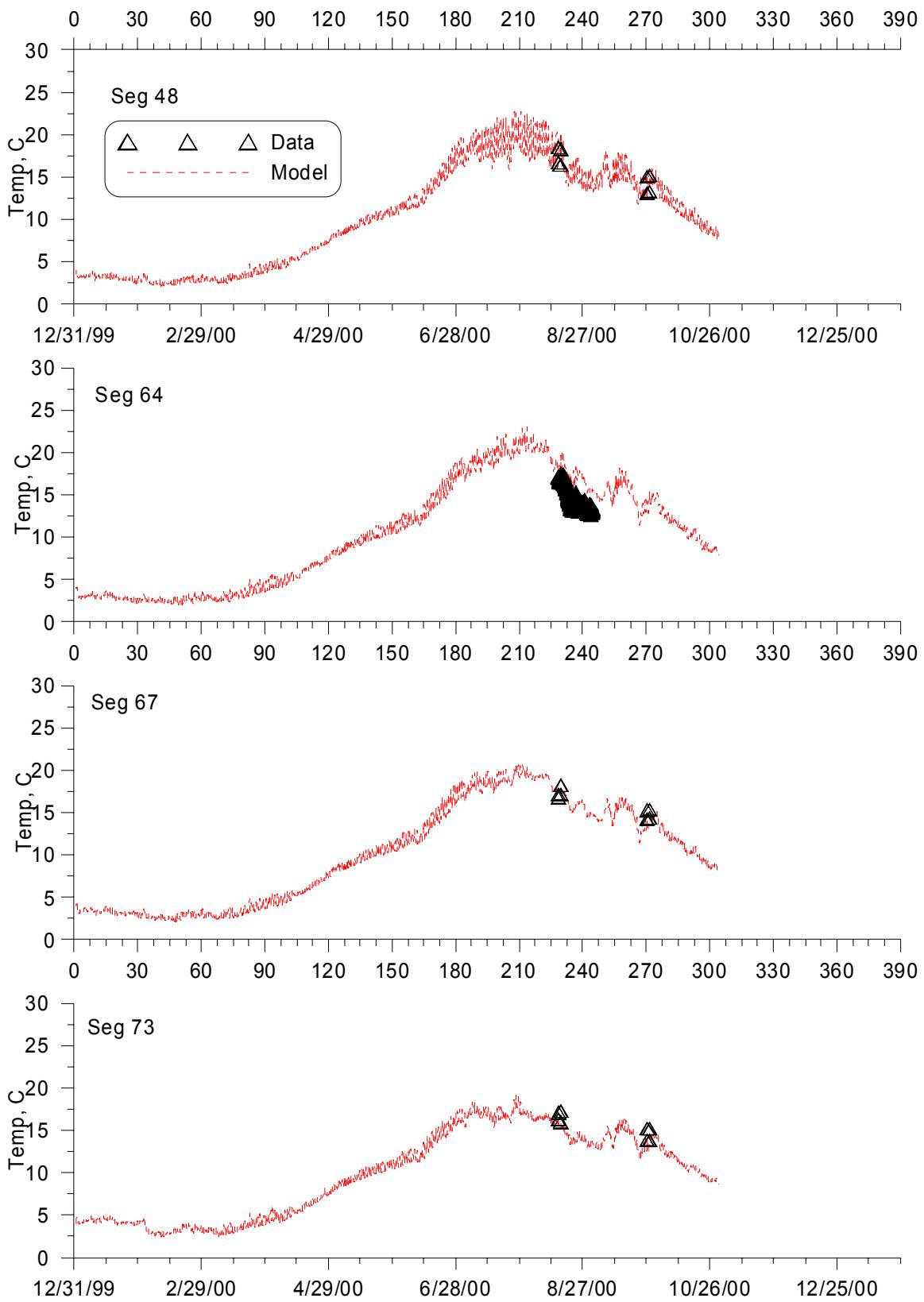


Figure 50. Comparison of model temperature predictions and data for the Spokane River Foot Bridge at Plante Ferry Park (segment 48), Spokane River above Upriver Dam (segment 64), Spokane River Upstream of Upriver Power House (segment 67), and the Spokane River at Green Street Bridge (Segment 73).

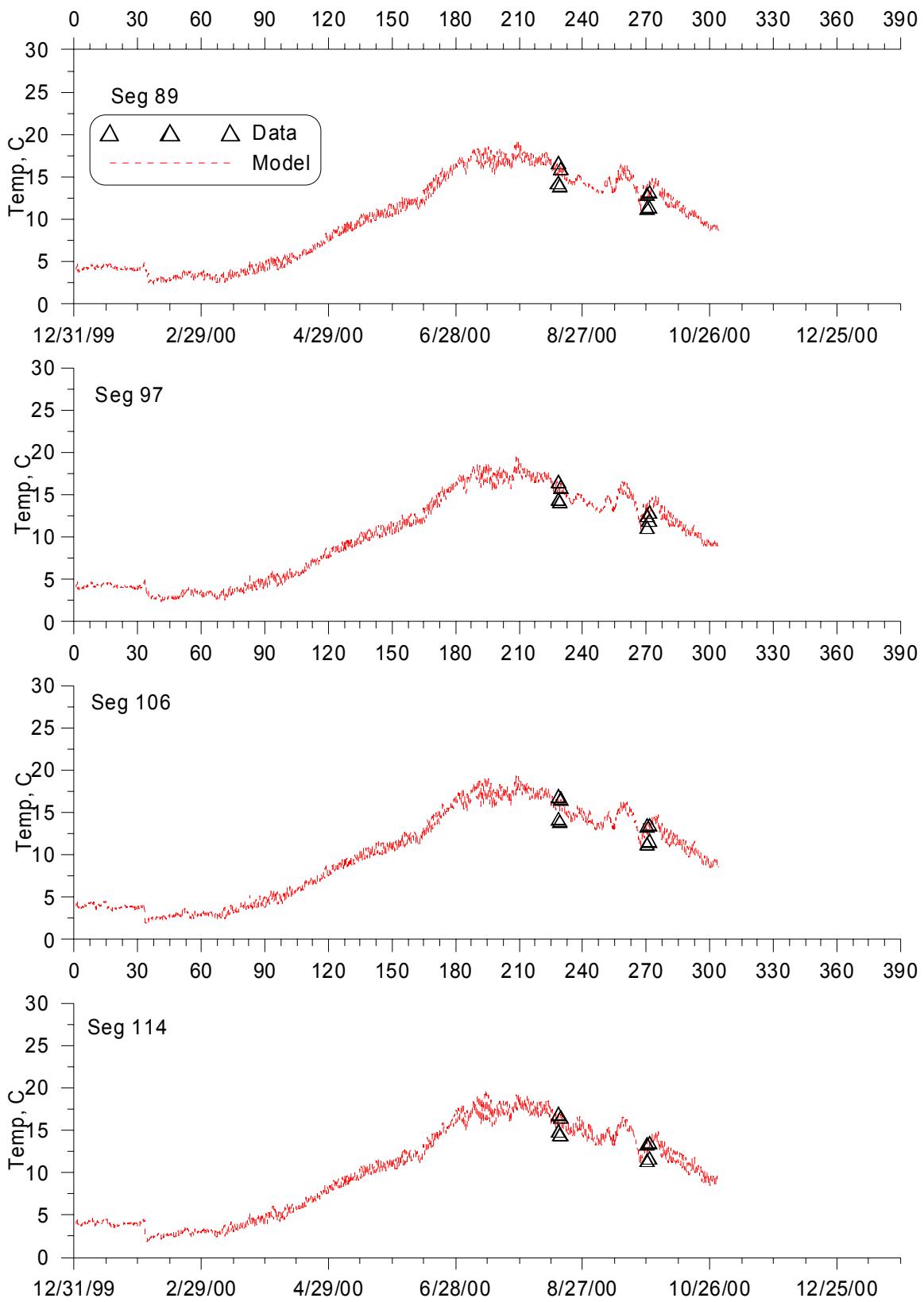


Figure 51. Comparison of model temperature predictions and data for the Spokane River behind Spokane Center (segment 89), Spokane River at Spokane (segment 97), Spokane River near Fort Wright Bridge (segment 106), and the Spokane River upstream of Spokane Wastewater Treatment Plant (segment 114).

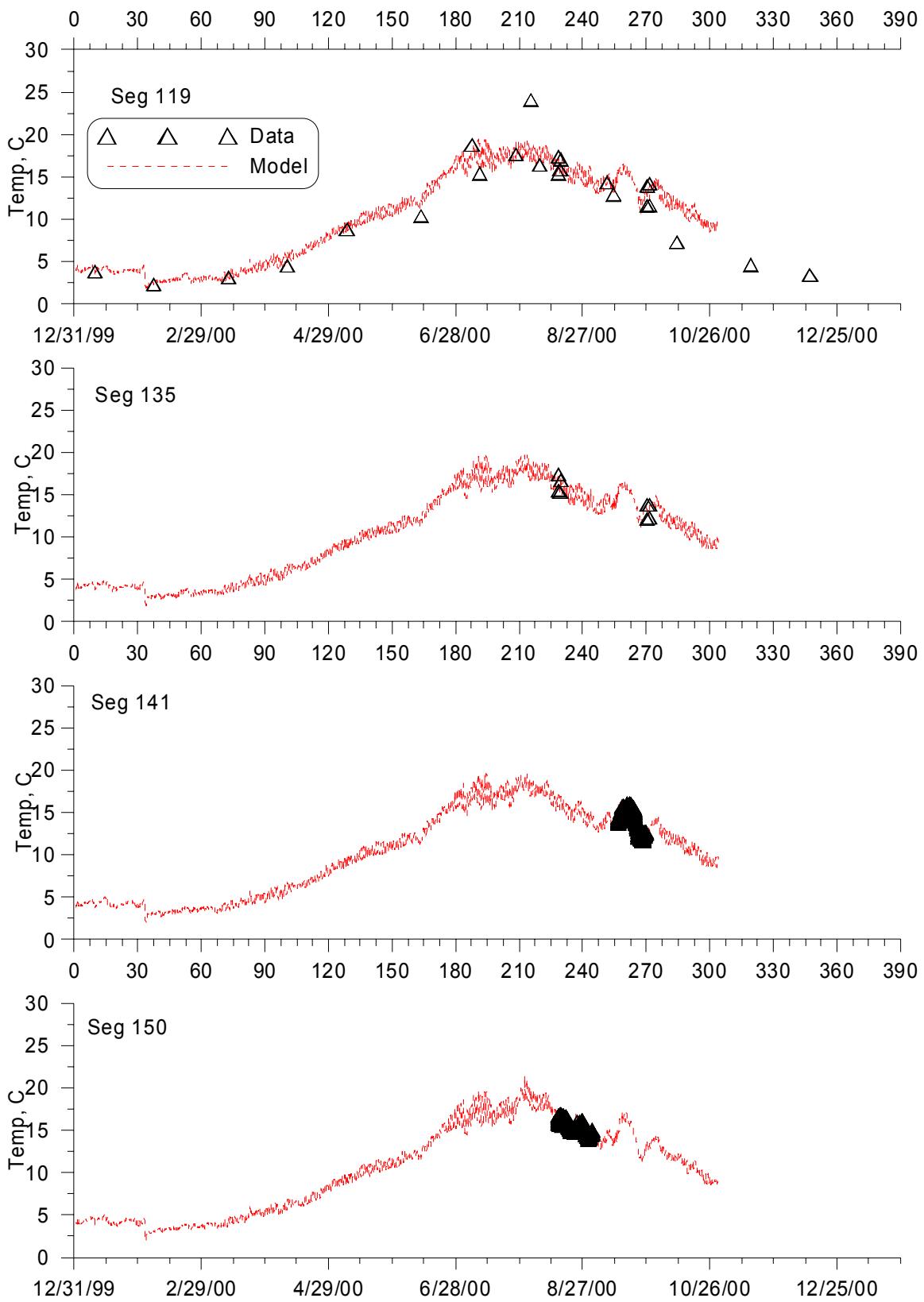


Figure 52. Comparison of model temperature predictions and data for the Spokane River at Riverside State Park (segment 119), Spokane River at Seven Mile Bridge (segment 135), Spokane River 2.8 miles upstream of Nine Mile Dam (segment 141), and the Spokane River 0.2 miles upstream of Nine Mile Dam (segment 150).

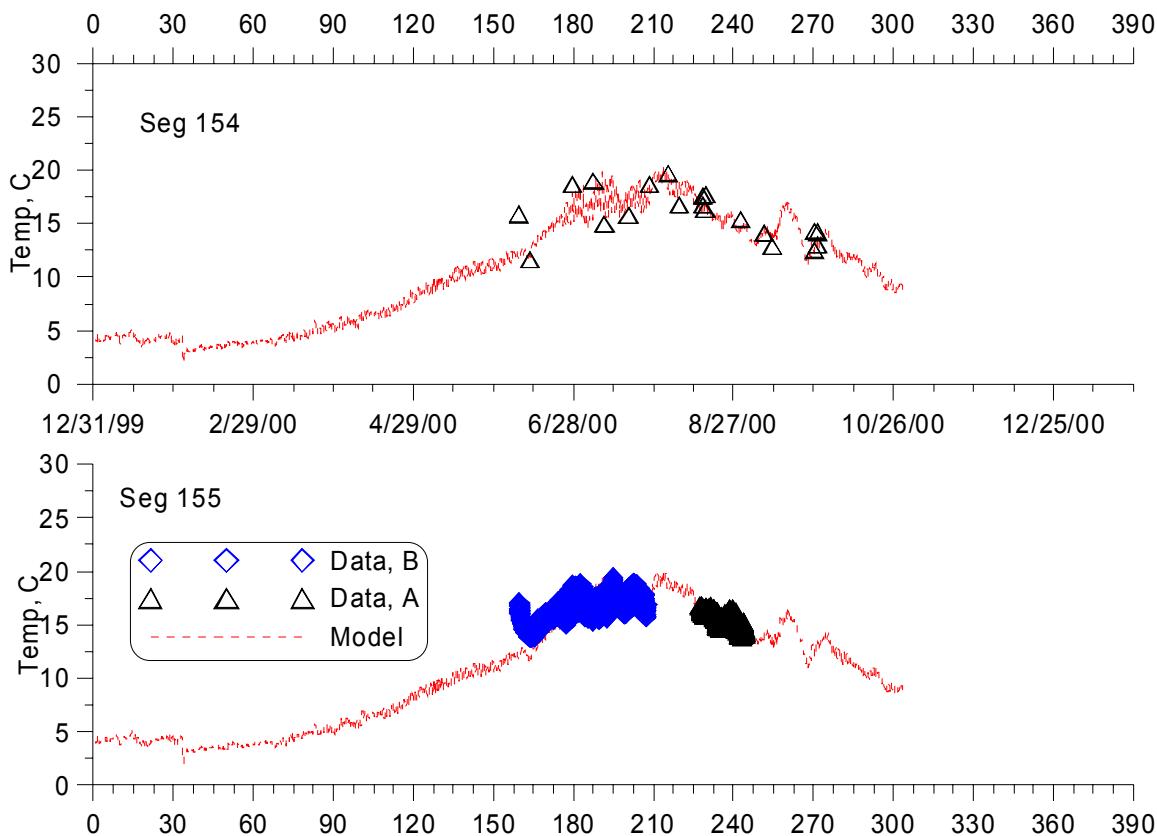


Figure 53. Comparison of model temperature predictions and data for the Spokane River downstream of Nine Mile Dam at the road bridge (segment 154) and Spokane River 1 mile downstream of Nine Mile Dam (segment 155). Blue data points are from station 57.1-B and black data points are from station 57.1-A, which were different instruments at the same location.

Water Quality

The general approach toward water quality calibration was to keep coefficient values close to commonly accepted literature values. With a few exceptions, the same model coefficients were used for 1991 and 2000. If during the process of calibration a particular combination of coefficient values did not produce good results, values would then be changed back to their default values, and a new avenue would be investigated.

Vertical profile and time series water quality data were collected at several sites throughout the Upper Spokane basin. Some sites have limited time periods or number of constituents monitored. Table 19 shows a general list of the sites with columns indicating which sites have vertical profiles and time series comparisons. Water quality model parameters used during the calibration are shown in Table 20.

Table 19. Water quality sites monitored in 1991 and 2000

Site ID	Description	Seg.	RM	1991 Vert. profile	1991 Time Series	2000 Vert. profile	2000 Time Series
LL0	Long Lake @ Station 0 (near dam)	187	32.7	YES	YES	YES	
LL0.5	Long Lake @ Station 0.5	183	35.9			YES	
LL1	Long Lake @ Station 1	180	37.6	YES	YES	YES	

Table 19. Water quality sites monitored in 1991 and 2000

Site ID	Description	Seg.	RM	1991 Vert. profile	1991 Time Series	2000 Vert. profile	2000 Time Series
LL2	Long Lake @ Station 2	174	42.1	YES	YES	YES	
LL3	Long Lake @ Station 3	168	46.4	YES	YES	YES	
LL4	Long Lake @ Station 4	161	51.5	YES	YES	YES	
LL5	Long Lake @ Station 5	157	54.2			YES	
SPK57.1-A	Spokane River @ Long Lake: a 1 mile downstream of Nine Mile Dam.	155	57.1				YES
SPK57.1-B	Spokane River @ Long Lake: a 1 mile downstream of Nine Mile Dam.	155	57.1				YES
SPK58.1	Just d/s of Nine Mile Dam at the road bridge	154	58.1		YES		YES
SPK58.3	Spokane River above Nine mile Dam: about 0.2 miles upstream of dam	150	58.3			YES	YES
SPK58.9	Spokane River above Nine mile Dam: about 0.8 miles upstream of dam	147	58.9			YES	
SPK60.2	Spokane River above Nine mile Dam: about 2.1 miles upstream of dam	143	60.2			YES	
SPK60.9	Spokane River above Nine mile Dam: about 2.8 miles upstream of dam	141	60.9			YES	YES
SPK61.4	Spokane River above Nine mile Dam: about 3.3 miles upstream of dam	139	61.4			YES	
SPK61.9	Spokane River above Nine mile Dam: about 3.8 miles upstream of dam	135	61.9			YES	
SPK62.0	Spokane R @ Seven Mile Br	135	62.0		YES		YES
SPK66.0	Spokane R @ Riverside State Park	119	66.0		YES		YES
SPK67.6	Spokane R Upstream Spokane WTP	114	67.6				YES
SPK69.8	Spokane R near Fort Wright Bridge	106	69.8		YES		YES
SPK72.5	Spokane R Upstream of Hangman Cr.	97	72.5				YES
SPK72.8	USGS gauging station, Spokane River at Spokane	97	72.8		YES		
SPK74.4	Spokane River @ Walkbridge behind Spokane Center	89	74.4				YES
SPK78.0	Spokane R @ Green St. Bridge	73	78.0				YES
SPK79.8	Spokane R Upstream Upriver Dam Powerhouse	67	79.8				YES
SPK79.9	Spokane River above Upriver Dam: about 0.1 miles upstream of dam	64	79.9				YES
SPK80.2	Spokane River above Upriver Dam: about 0.4 miles upstream of dam	64	80.2			YES	
SPK81.0	Spokane River above Upriver Dam: about 1.2 miles upstream of dam	62	81.0			YES	
SPK81.6	Spokane River above Upriver Dam: about 1.8 miles upstream of dam	60	81.6			YES	
SPK82.5	Spokane River above Upriver Dam: about 2.7 miles upstream of dam	57	82.5			YES	
SPK84.7	Spokane R Foot Bridge @ Plante Ferry Park	48	84.7				YES
SPK87.8	Spokane R @ Sullivan Rd. Bridge	36	87.8				YES

Table 19. Water quality sites monitored in 1991 and 2000

Site ID	Description	Seg.	RM	1991 Vert. profile	1991 Time Series	2000 Vert. profile	2000 Time Series
SPK90.4	Spokane R @ Barker Rd. Bridge	24	90.4				YES
SPK93.0	Spokane R @ Harvard Rd. Bridge	17	93.0				YES
SPK96.0	Spokane R @ Stateline Bridge	2	96.0		YES		YES

Table 20. W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*		Calibration Values
Hydrodynamics and Longitudinal Transport					
AX	Longitudinal eddy viscosity (for momentum dispersion)	m ² /sec	1		1
DX	Longitudinal eddy diffusivity (for dispersion of heat and constituents)	m ² /sec	1		1
Temperature					
CBHE	Coefficient of bottom heat exchange	Wm ² /sec	7.0 x 10 ⁻⁸	7.0 x 10 ⁻⁸	
TSED	Sediment (ground) temperature	°C	12.8	11.5	
WSC	Wind sheltering coefficient		0.85	0.2-1.4	
BETA	Fraction of incident solar radiation absorbed at the water surface		0.45	0.45	
Water Quality					
EXH20	Extinction for water	/m	0.25	0.25	
EXSS	Extinction due to inorganic suspended solids	m ³ /m/g	0.01	0.01	
EXOM	Extinction due to organic suspended solids	m ³ /m/g	0.17	0.10	
EXA	Extinction due to organic algal type 1	m ³ /m/g	0.10	0.10	
SSS	Suspended solids settling rate	m/day	2	1.5	
AG1	Algal growth rate for algal type 1	/day	1.1	1.5	
AM1	Algal mortality rate for algal type 1	/day	0.01	0.1	
AE1	Algal excretion rate for algal type 1	/day	0.01	0.04	
AR1	Algal dark respiration rate for algal type 1	/day	0.02	0.04	
AS1	Algal settling rate for algal type 1	/day	0.14	0.2	
ASAT1	Saturation intensity at maximum photosynthetic rate for algal type 1	W/m ²	150	40	
APOM1	Fraction of algal biomass lost by mortality to detritus for algal type 1		0.8	0.8	
AT11	Lower temperature for algal growth for algal type 1	°C	10	8	
AT21	Lower temperature for maximum algal growth for algal type 1	°C	30	10	
AT31	Upper temperature for maximum algal growth for algal type 1	°C	35	20	
AT41	Upper temperature for algal growth for algal type 1	°C	40	30	
AK11	Fraction of algal growth rate at ALGT1 for algal type 1		0.1	0.1	
AK21	Fraction of maximum algal growth rate at ALGT2 for algal type 1		0.99	0.99	

Table 20. W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*	Calibration Values
AK31	Fraction of maximum algal growth rate at ALGT3 for algal type 1		0.99	0.99
AK41	Fraction of algal growth rate at ALGT4 for algal type 1		0.1	0.1
ALGP-A1	Stoichiometric equivalent between organic matter and phosphorus for algal type 1		0.011	0.005
ALGN-A1	Stoichiometric equivalent between organic matter and nitrogen for algal type 1		0.08	0.08
ALGC-A1	Stoichiometric equivalent between organic matter and carbon for algal type 1		0.45	0.45
EG1	Periphyton growth rate for Periphyton type 1	/day	1.1	1.5
EM1	Periphyton mortality rate for Periphyton type 1	/day	0.01	0.10
EE1	Periphyton excretion rate for Periphyton type 1	/day	0.01	0.04
ER1	Periphyton dark respiration rate for Periphyton type 1	/day	0.02	0.04
EB1	Periphyton burial rate for Periphyton type 1	/day	0.001	0.001
ESAT1	Saturation intensity at maximum photosynthetic rate for Periphyton type 1	W/m ²	150	150
EPOM1	Fraction of Periphyton biomass lost by mortality to detritus for Periphyton type 1		0.8	0.8
ET11	Lower temperature for Periphyton growth for Periphyton type 1	°C	10	1
ET21	Lower temperature for maximum Periphyton growth for Periphyton type 1	°C	30	3
ET31	Upper temperature for maximum Periphyton growth for Periphyton type 1	°C	35	20
ET41	Upper temperature for Periphyton growth for Periphyton type 1	°C	40	30
EK11	Fraction of Periphyton growth rate at ALGT1 for Periphyton type 1		0.1	0.1
EK21	Fraction of maximum Periphyton growth rate at ALGT2 for Periphyton type 1		0.99	0.99
EK31	Fraction of maximum Periphyton growth rate at ALGT3 for Periphyton type 1		0.99	0.99
EK41	Fraction of Periphyton growth rate at ALGT4 for Periphyton type 1		0.1	0.1
EP-E1	Stoichiometric equivalent between organic matter and phosphorus for Periphyton type 1		0.011	0.005
EN-E1	Stoichiometric equivalent between organic matter and nitrogen for Periphyton type 1		0.08	0.08
EC-E1	Stoichiometric equivalent between organic matter and carbon for Periphyton type 1		0.45	0.45
LDOMDK	Labile DOM decay rate	/day	0.12	0.08
LRDDK	Labile to refractory decay rate	/day	0.001	0.001
RDOMDK	Maximum refractory decay rate	/day	0.001	0.001
LPOMDK	Labile Detritus decay rate	/day	0.06	0.08
POMS	Detritus settling rate	m/day	0.35	0.1
RPOMDK	Refractory Detritus decay rate	/day		0.001

Table 20. W2 Model Water Quality Parameters				
Variable	Description	Units	Typical values*	Calibration Values
OMT1	Lower temperature for organic matter decay	°C	4	4
OMT2	Lower temperature for maximum organic matter decay	°C	20	30
OMK1	Fraction of organic matter decay rate at OMT1		0.1	0.1
OMK2	Fraction of organic matter decay rate at OMT2		0.99	0.99
SDK	Sediment decay rate	/day	0.06	0.1
PARTP	Phosphorous partitioning coefficient for suspended solids		1.2	0
AHSP	Algal half-saturation constant for phosphorous	g/m	0.009	0.003
NH4DK	Ammonia decay rate (nitrification rate)	/day	0.12	0.40
AHSN	Algal half-saturation constant for ammonia	g/m ³	0.014	0.014
NH4T1	Lower temperature for ammonia decay	°C	5	5
NH4T2	Lower temperature for maximum ammonia decay	°C	20	25
NH4K1	Fraction of nitrification rate at NH4T1		0.1	0.1
NH4K2	Fraction of nitrification rate at NH4T2		0.99	0.99
NO3DK	Nitrate decay rate (denitrification rate)	/day	0.102	0.05
NO3T1	Lower temperature for nitrate decay	°C	5	5
NO3T2	Lower temperature for maximum nitrate decay	°C	20	25
NO3K1	Fraction of denitrification rate at NO3T1		0.1	0.1
NO3K2	Fraction of denitrification rate at NO3T2		0.99	0.99
O2NH4	Oxygen stoichiometric equivalent for ammonia decay		4.57	4.57
O2OM	Oxygen stoichiometric equivalent for organic matter decay		1.4	1.4
O2AR	Oxygen stoichiometric equivalent for dark respiration		1.4	1.1
O2AG	Oxygen stoichiometric equivalent for algal growth		1.4	1.4
BIOP	Stoichiometric equivalent between organic matter and phosphorus		0.011	0.005
BION	Stoichiometric equivalent between organic matter and nitrogen		0.08	0.08
BIOC	Stoichiometric equivalent between organic matter and carbon		0.45	0.45
O2LIM	Dissolved oxygen concentration at which anaerobic processes begin	g/m ³	0.05	0.1

* Cole and Wells (2000)

Conductivity

Conductivity was modeled as a conservative constituent and provided a check for the model's overall water balance. The groundwater conductivity was generally higher than the conductivity of water at the state line upstream boundary. Vertical profiles of conductivity in Long Lake were also used to

determine if the zone of interflow, which was caused by cool Spokane River inflows, was being simulated.

Year 1991

Conductivity profiles were collected in Long Lake in 1991 for 12 different days. No profiles were collected upstream of Long Lake in 1991. Figure 54 to Figure 58 show conductivity profile data and model results for five locations in Long Lake from RM 32.7 to 54.5. An interflow zone of high conductivity in Long Lake, created by upstream inflows, was shown as an increase in conductivity occurring at mid-depth in the reservoir (Figure 54). The model generally does well reproducing this “bulge” in conductivity concentrations. Figure 59 shows conductivity time series data compared with model results for RM 66. Figure 60 shows conductivity time series data compared with model results for RM 58.1. Table 21 shows AME and RMS error statistics for the conductivity vertical profiles and Table 22 includes error statistics for the time series comparisons.

Table 21. Conductivity profile error statistics, 1991

Site	n, # of data profile comparisons	Conductivity model –data error statistics	
		AME, mhos/cm	RMS error, mhos/cm
LL0	12	13.38	14.92
LL1	12	13.96	15.75
LL2	12	15.04	16.51
LL3	12	14.65	16.20
LL4	12	13.04	14.32

Table 22. Conductivity time series error statistics, 1991

Site	n, # of data comparisons	Conductivity model –data error statistics	
		AME, mhos/cm	RMS error, mhos/cm
SPK66.0	13	15.20	21.81
SPK58.1	21	11.66	16.24

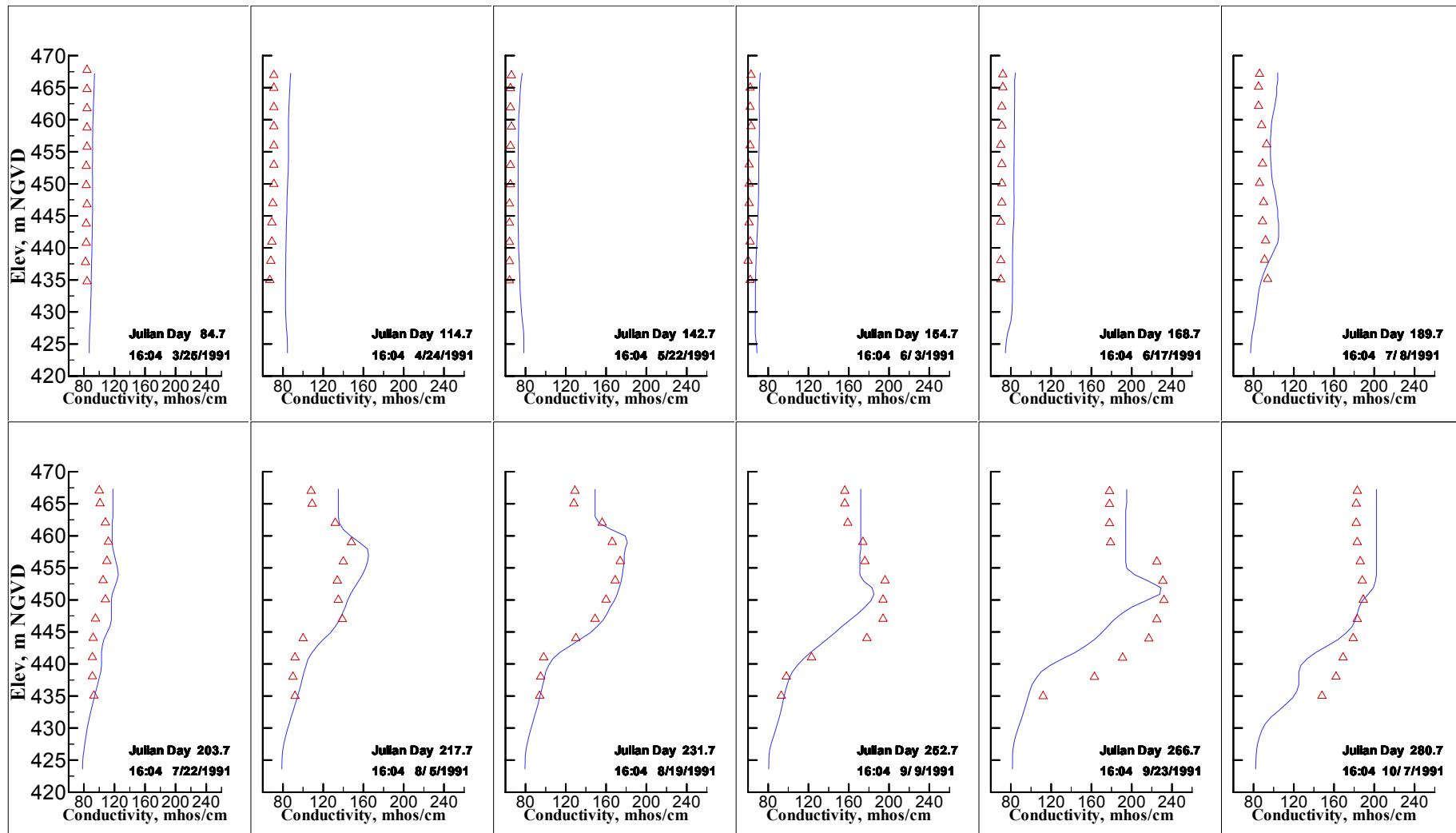


Figure 54. Comparison of model predicted vertical conductivity profiles and 1991 data for Long Lake at Station 0 (Segment 187).

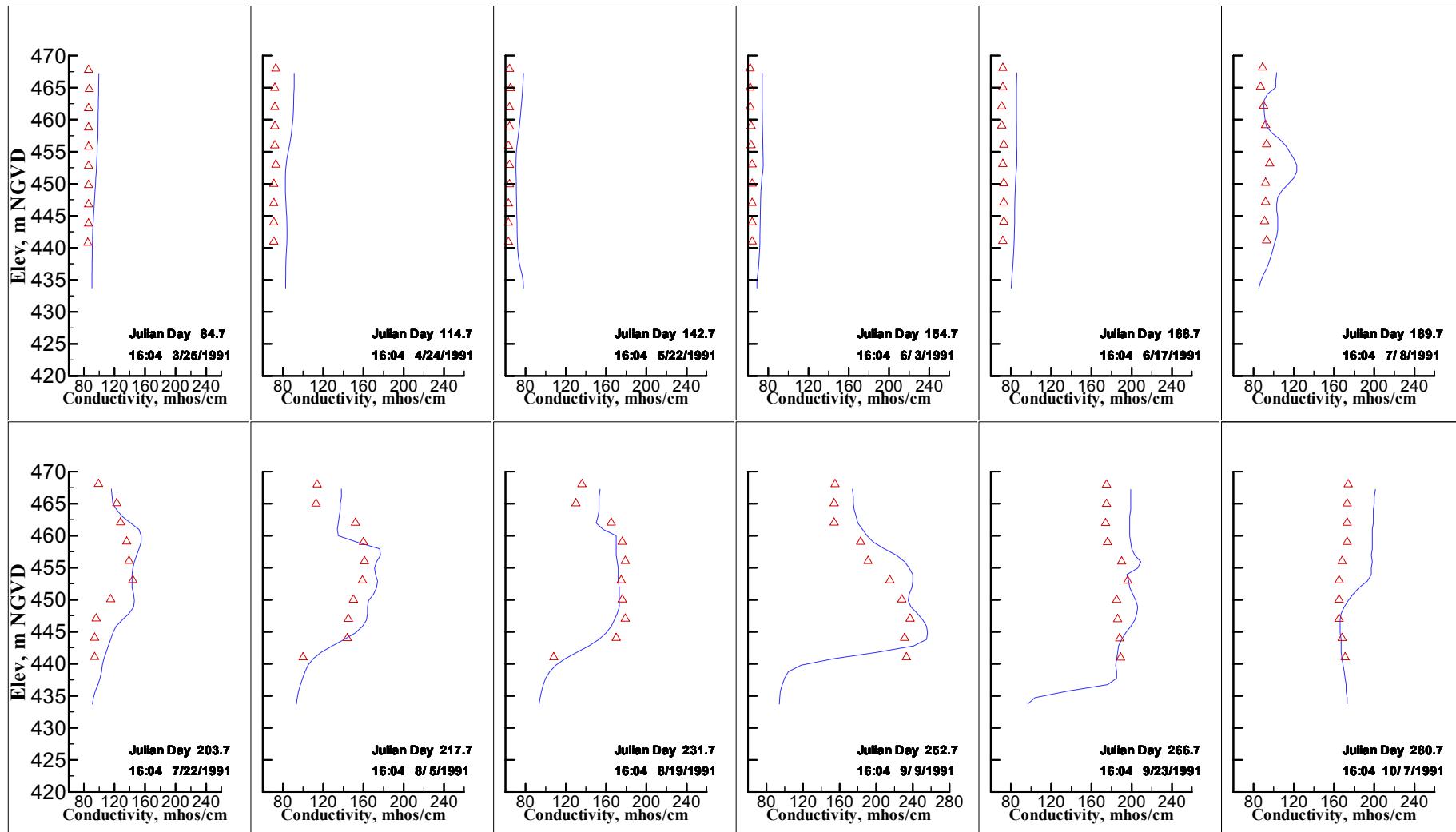


Figure 55. Comparison of model predicted vertical conductivity profiles and 1991 data for Long Lake at Station 1 (Segment 180).

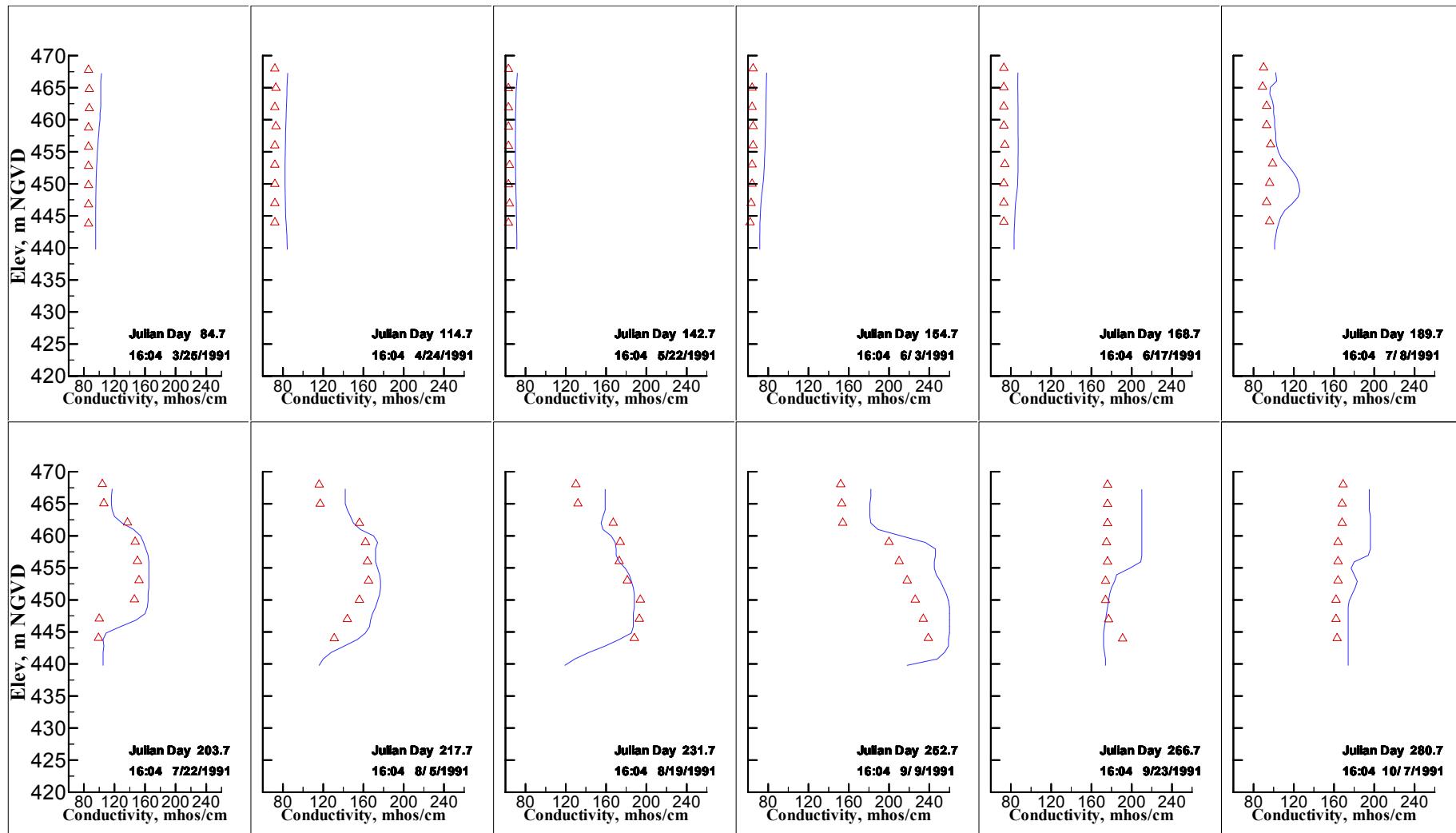


Figure 56. Comparison of model predicted vertical conductivity profiles and 1991 data for Long Lake at Station 2 (Segment 174).

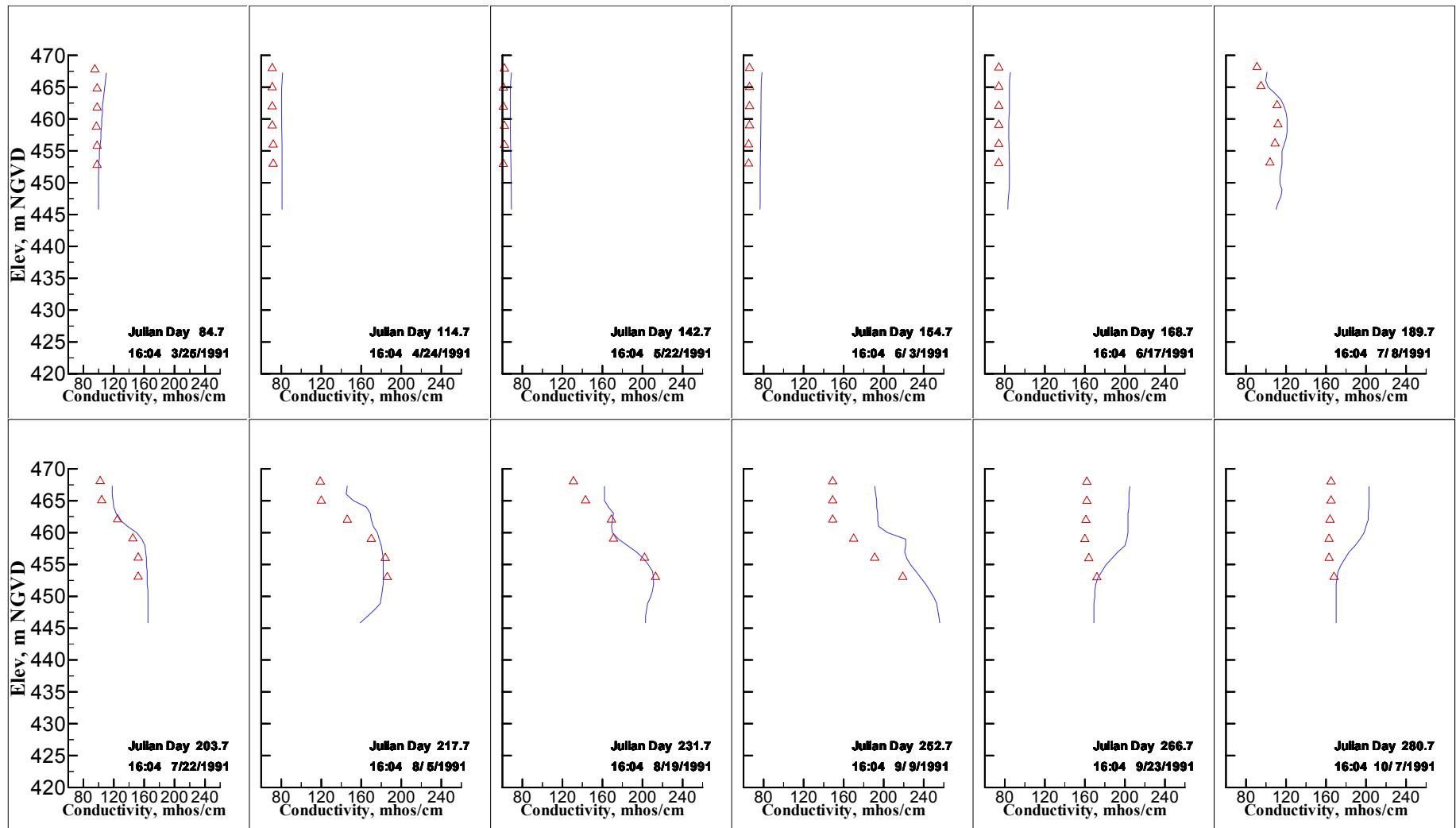


Figure 57. Comparison of model predicted vertical conductivity profiles and 1991 data for Long Lake at Station 3 (Segment 168).

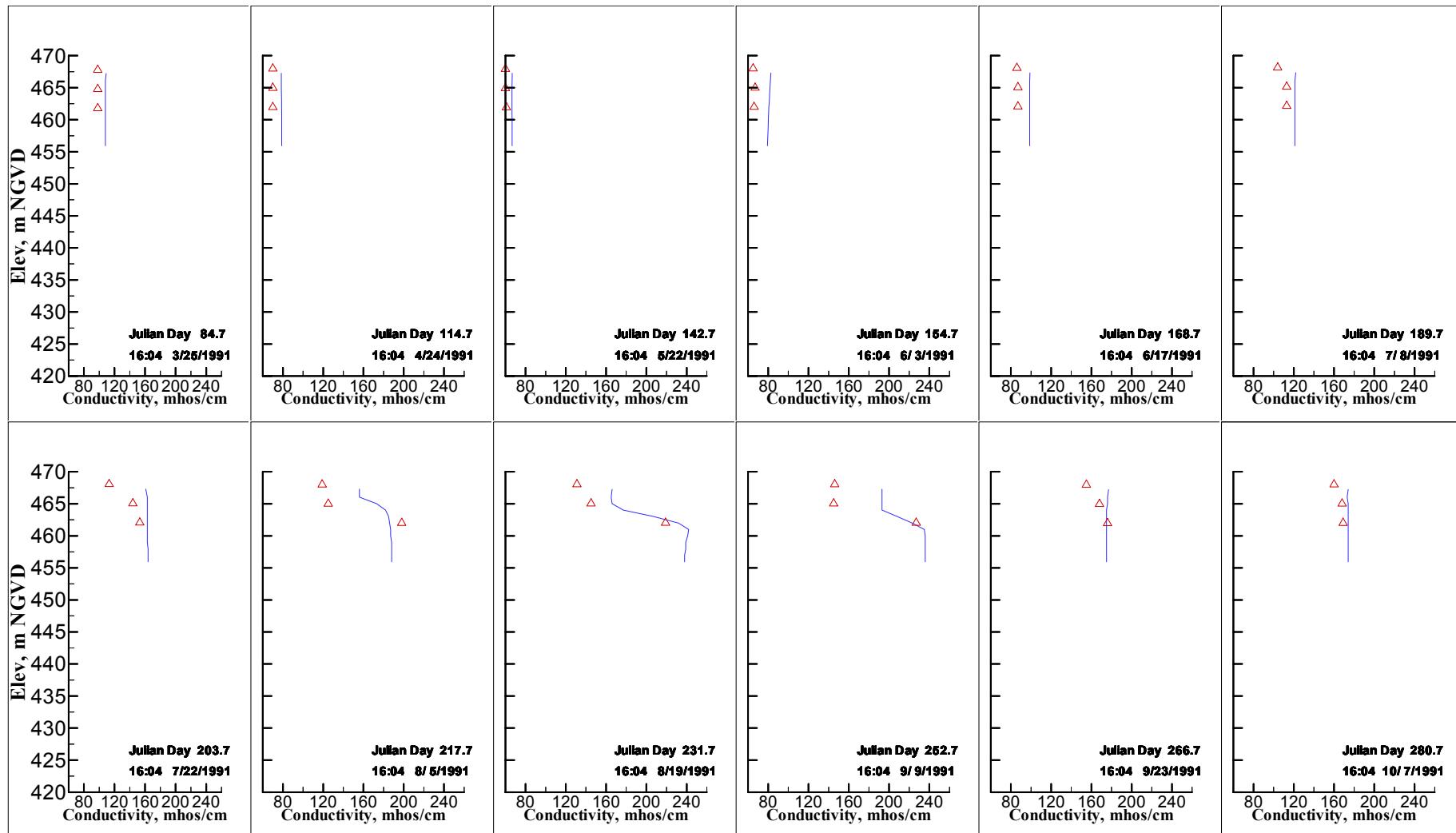


Figure 58. Comparison of model predicted vertical conductivity profiles and 1991 data for Long Lake at Station 4 (Segment 161).

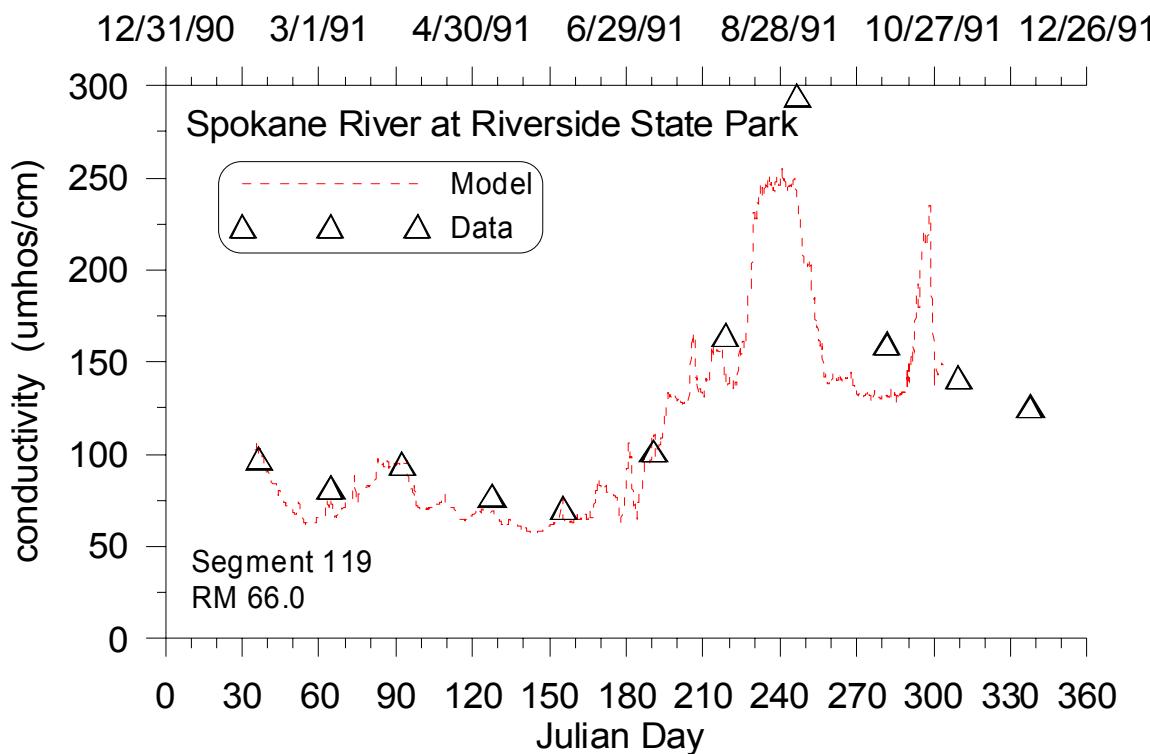


Figure 59. Comparison of model predicted conductivity and 1991 data for the Spokane River at Riverside State Park (Segment 119).

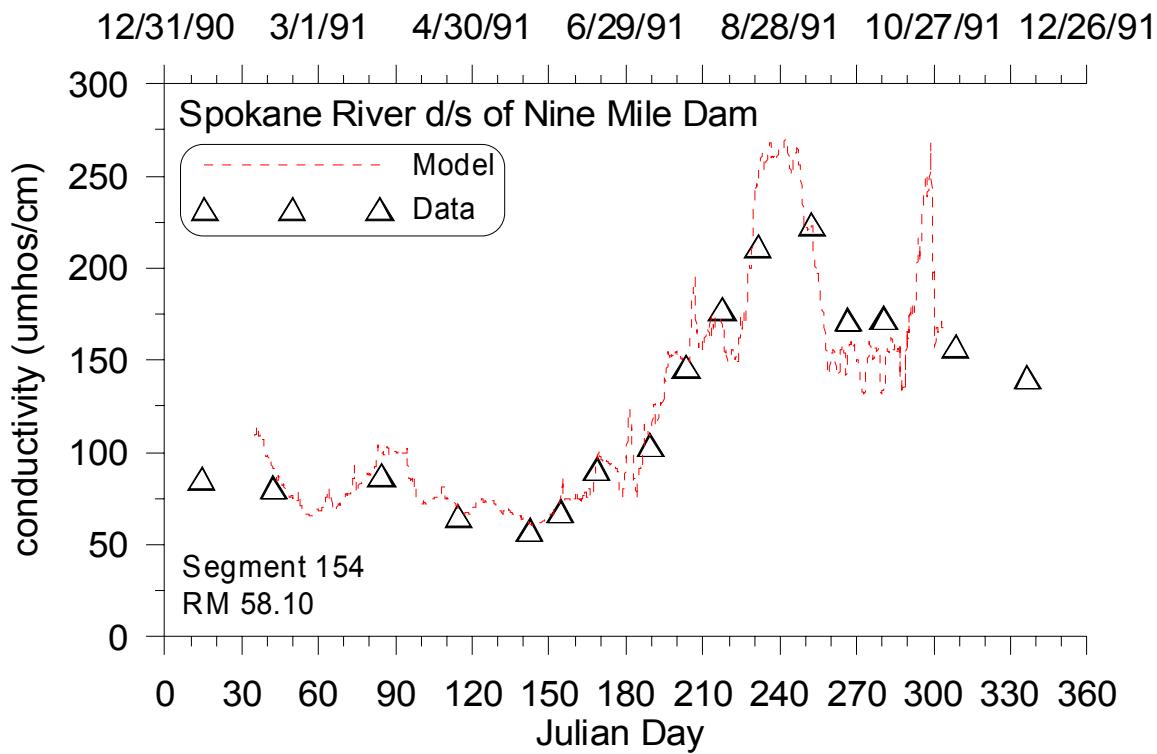


Figure 60. Comparison of model predicted conductivity and 1991 data for the Spokane River downstream of Nine Mile Dam (Segment 154).

Year 2000

Vertical conductivity profiles were collected in Long Lake, Nine Mile Reservoir and Upriver Reservoir in 2000. Figure 61 to Figure 67 show conductivity profile data and model results for seven locations in Long Lake from RM 32.7 to 54.5. As was for the 1991 model simulation, model predictions of conductivity do well in predicting Long Lake vertical profile data. Figure 78 shows conductivity time series data compared with model results for RM 66. Figure 79 shows conductivity time series data compared with model results for RM 58.1. Table 23 shows AME and RMS error statistics for the conductivity vertical profiles and Table 24 includes error statistics for the time series comparisons.

Table 23. Conductivity profile error statistics, 2000

Site	n, # of data profile comparisons	Conductivity model –data error statistics	
		AME, mhos/cm	RMS error, mhos/cm
LL0	3	34.49	52.33
LL0.5	1	46.59	69.75
LL1	7	21.80	27.55
LL2	3	16.21	22.61
LL3	7	16.44	18.38
LL4	3	15.42	17.42
LL5	3	13.96	14.60
SPK58.3	1	5.43	5.49
SPK58.9	1	27.71	27.90
SPK60.2	2	23.23	23.29
SPK60.9	2	26.88	26.96
SPK61.4	2	28.27	28.29
SPK61.9	1	37.91	37.97
SPK80.2	2	60.00	60.05
SPK81.0	2	59.92	59.92
SPK81.6	2	59.63	59.63
SPK82.5	1	65.80	65.97

Table 24. Conductivity time series error statistics, 2000

Site	n, # of data comparisons	Conductivity model –data error statistics	
		AME, mhos/cm	RMS error, mhos/cm
SPK66.0	22	28.81	44.39
SPK58.1	14	18.30	20.12

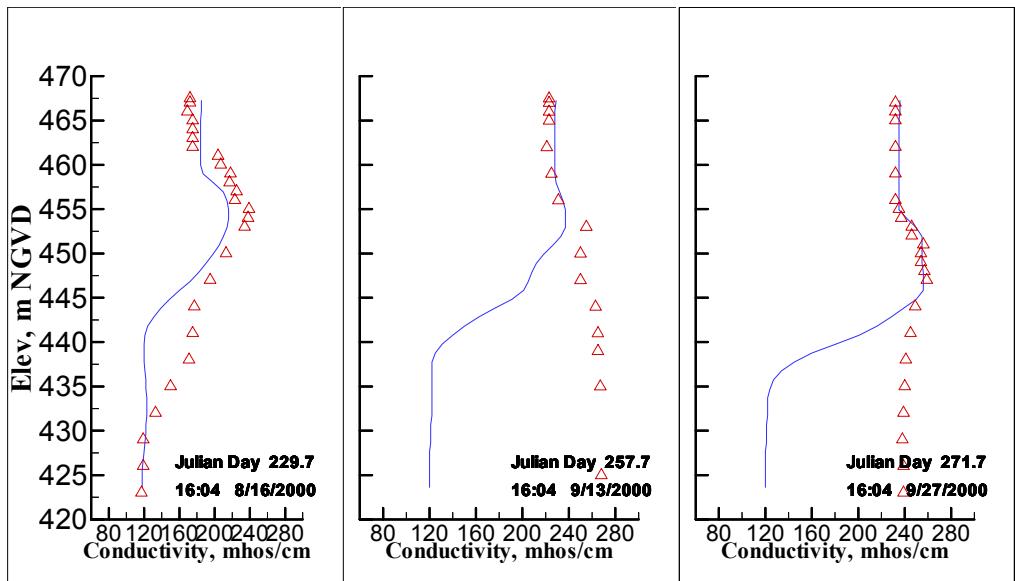


Figure 61. Comparison of model predicted vertical conductivity profiles and 2000 data for Long Lake at Station 0 (Segment 187).

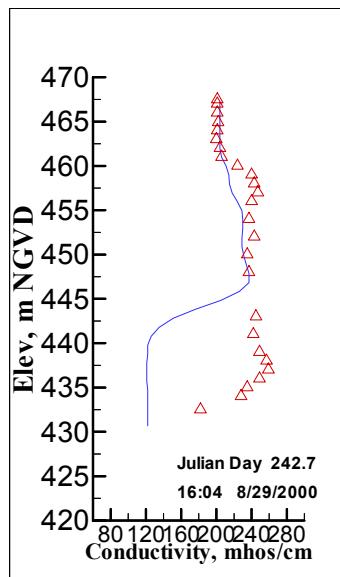


Figure 62. Comparison of model predicted vertical conductivity profiles and 2000 data for Long Lake at Station 0.5 (Segment 183).

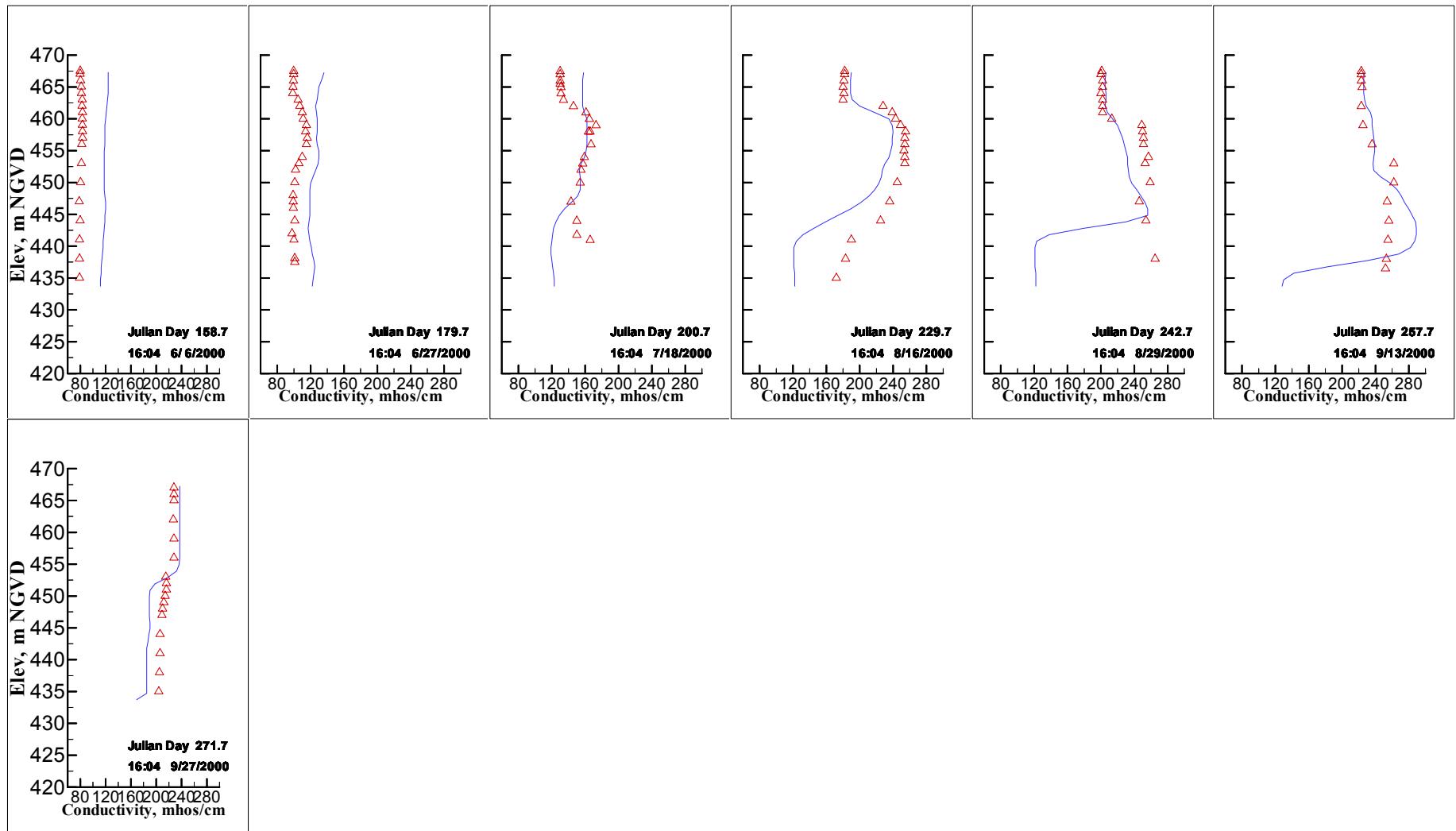


Figure 63. Comparison of model predicted vertical conductivity profiles and 2000 data for Long Lake at Station 1 (Segment 180).

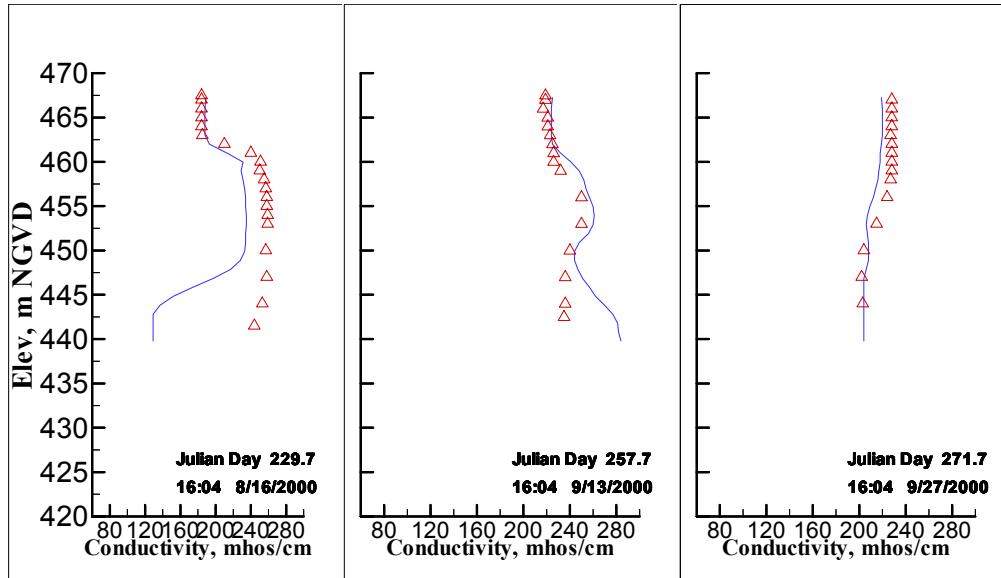


Figure 64. Comparison of model predicted vertical conductivity profiles and 2000 data for Long Lake at Station 2 (Segment 174).

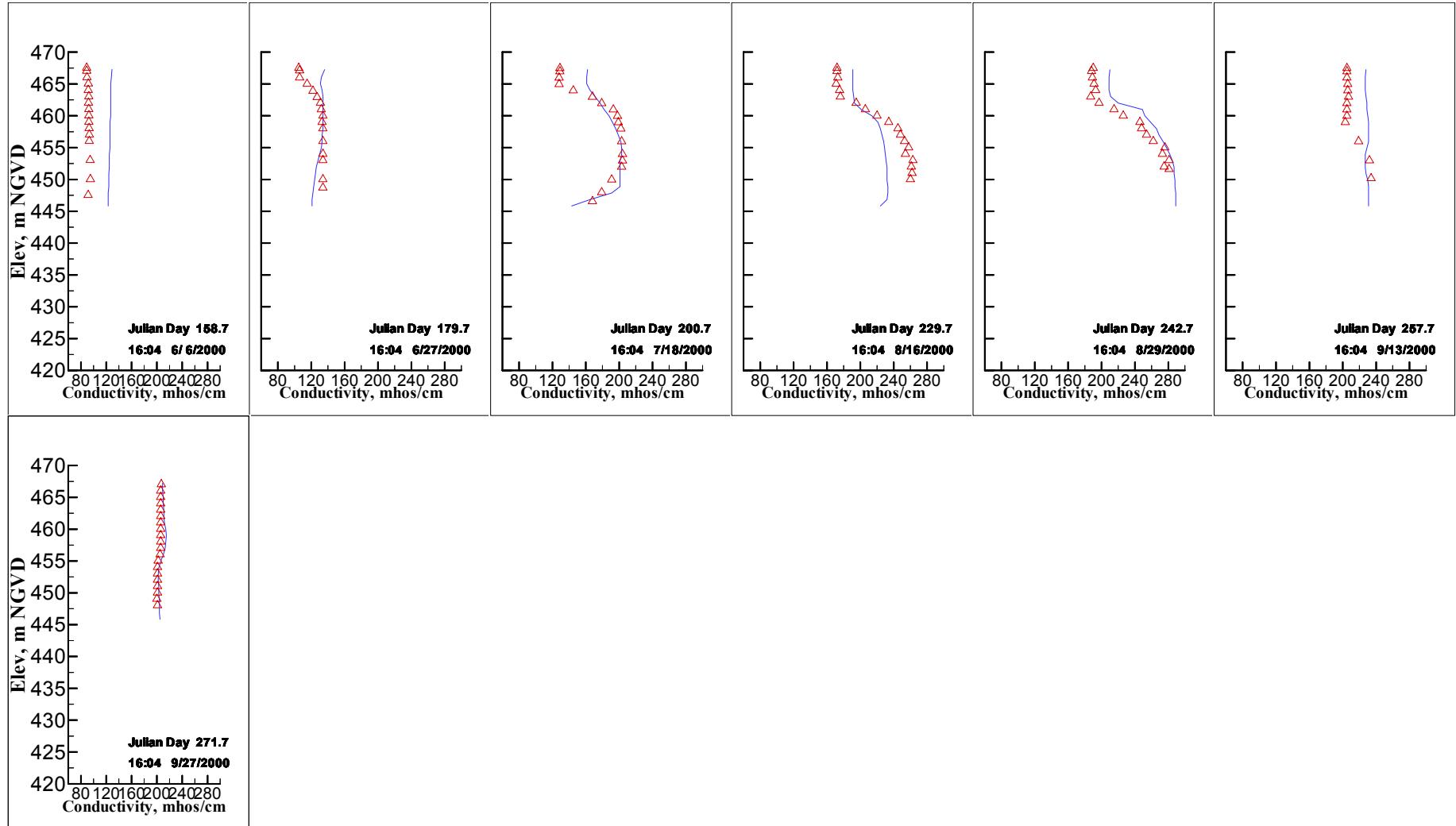


Figure 65. Comparison of model predicted vertical conductivity profiles and 2000 data for Long Lake at Station 3 (Segment 168).

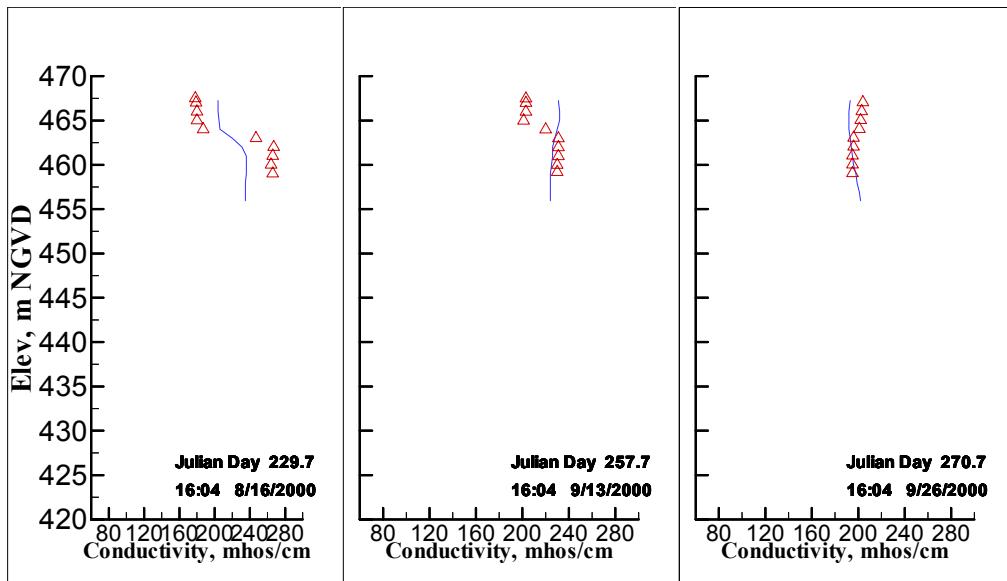


Figure 66. Comparison of model predicted vertical conductivity profiles and 2000 data for Long Lake at Station 4 (Segment 161).

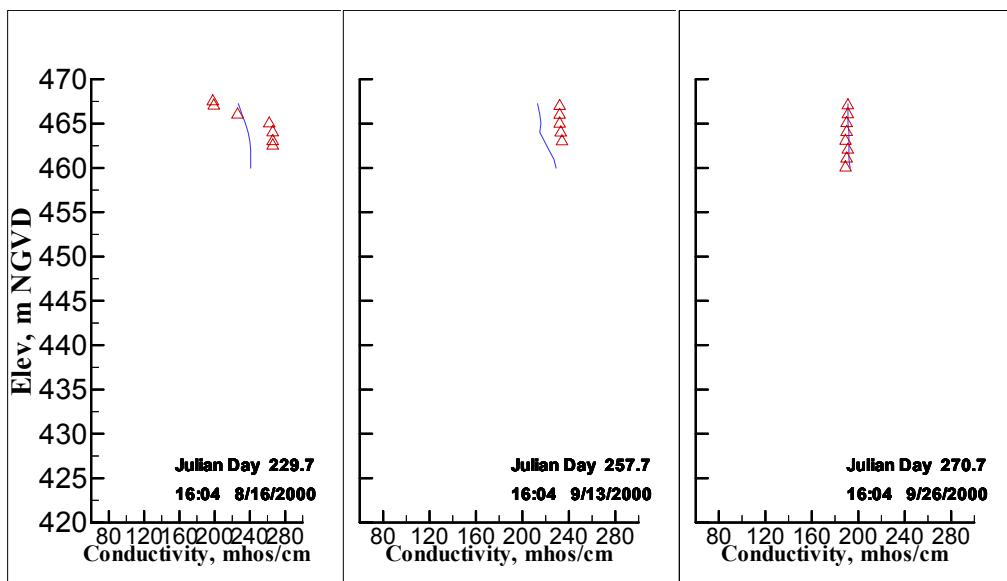


Figure 67. Comparison of model predicted vertical conductivity profiles and 2000 data for Long Lake at Station 5 (Segment 157).

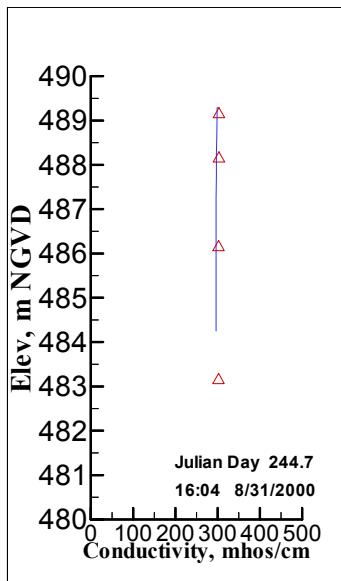


Figure 68. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 0.2 miles upstream of Nine Mile Dam (Segment 150).

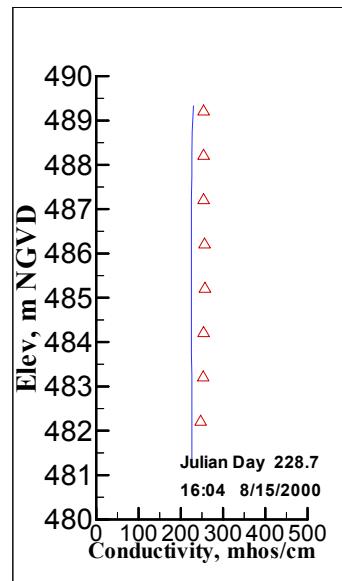


Figure 69. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 0.8 miles upstream of Nine Mile Dam (Segment 147).

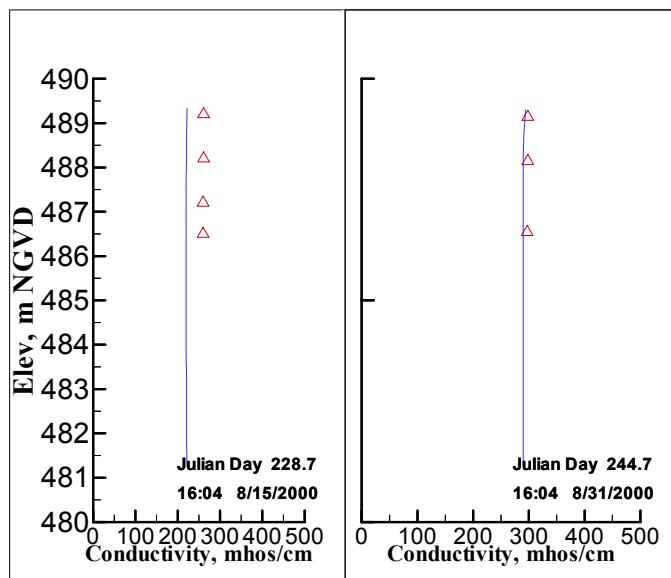


Figure 70. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 2.1 miles upstream of Nine Mile Dam (Segment 143).

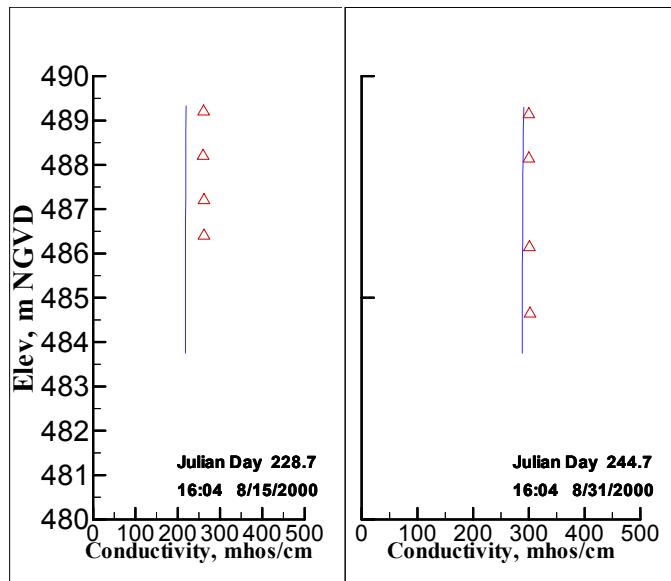


Figure 71. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 2.8 miles upstream of Nine Mile Dam (Segment 141).

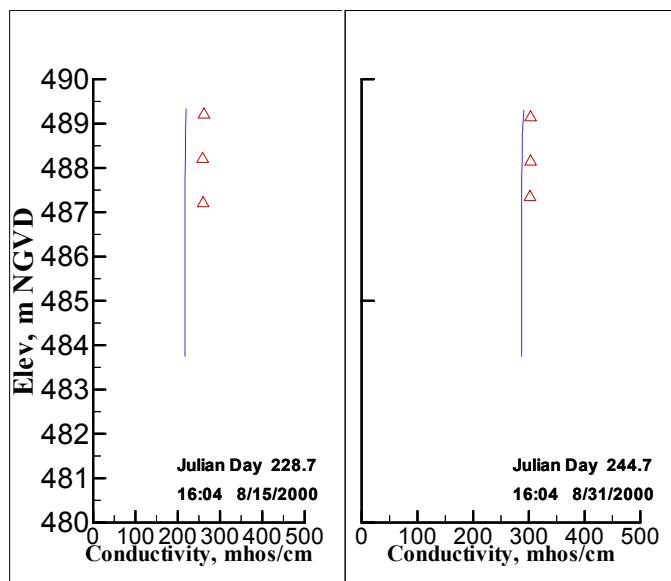


Figure 72. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 3.3 miles upstream of Nine Mile Dam (Segment 139).

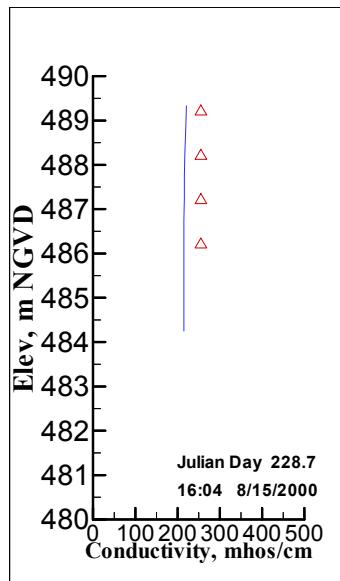


Figure 73. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 3.8 miles upstream of Nine Mile Dam (Segment 135).

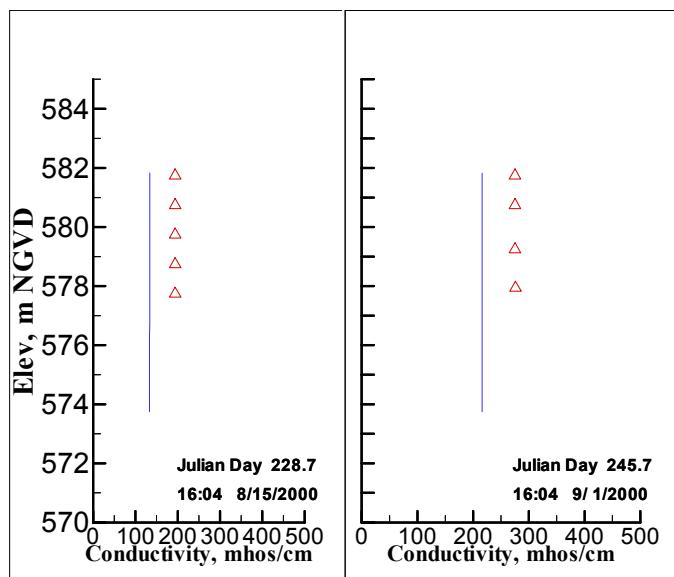


Figure 74. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 0.4 miles upstream of Upriver Dam (Segment 64).

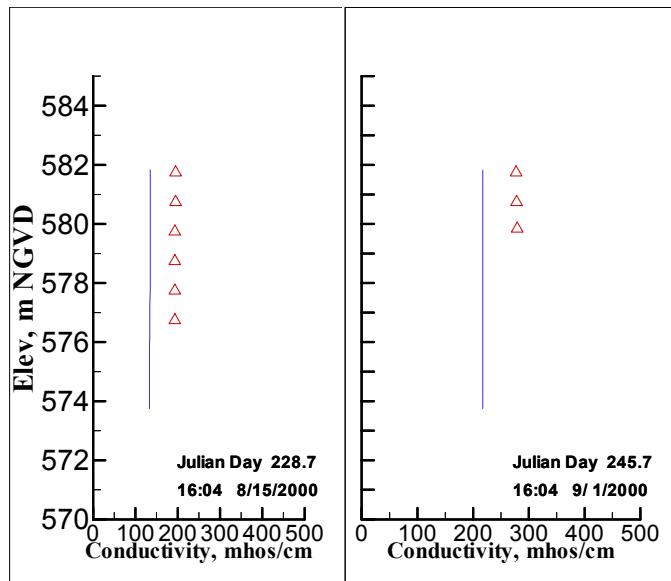


Figure 75. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 1.2 miles upstream of Upriver Dam (Segment 62).

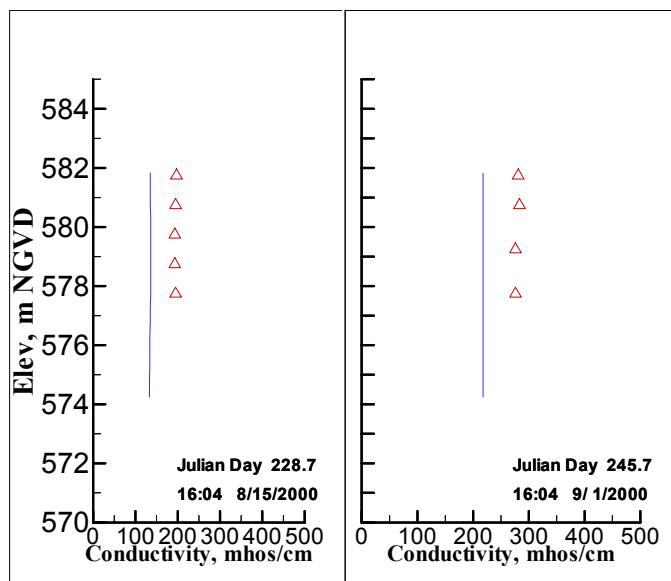


Figure 76. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 1.8 miles upstream of Upriver Dam (Segment 60).

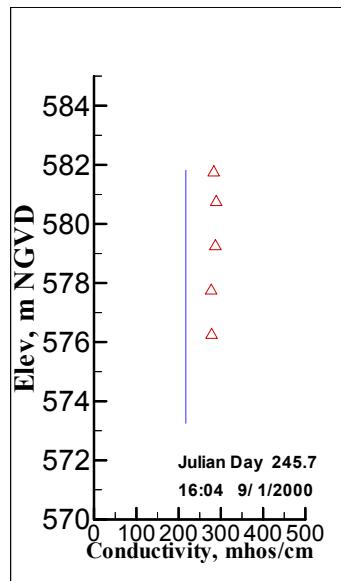


Figure 77. Comparison of model predicted vertical conductivity profiles and 2000 data for Spokane River 2.7 miles upstream of Upriver Dam (Segment 57).

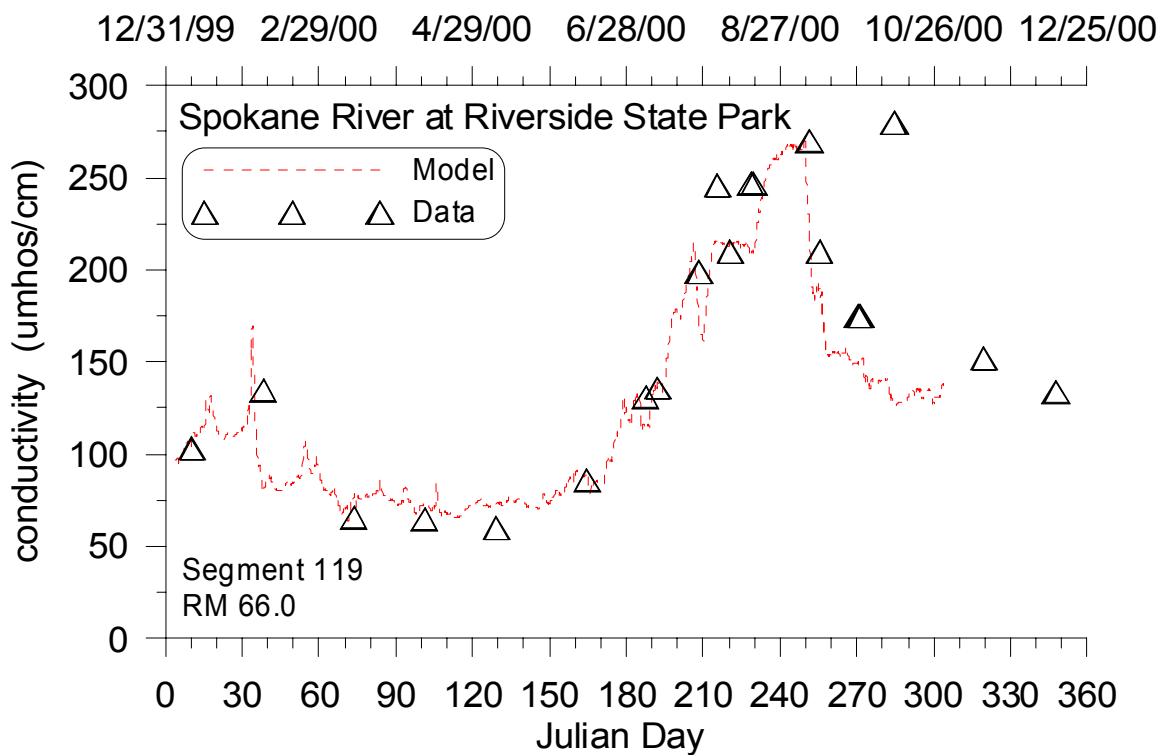


Figure 78. Comparison of model predicted conductivity and 2000 data for the Spokane River at Riverside State Park (Segment 119).

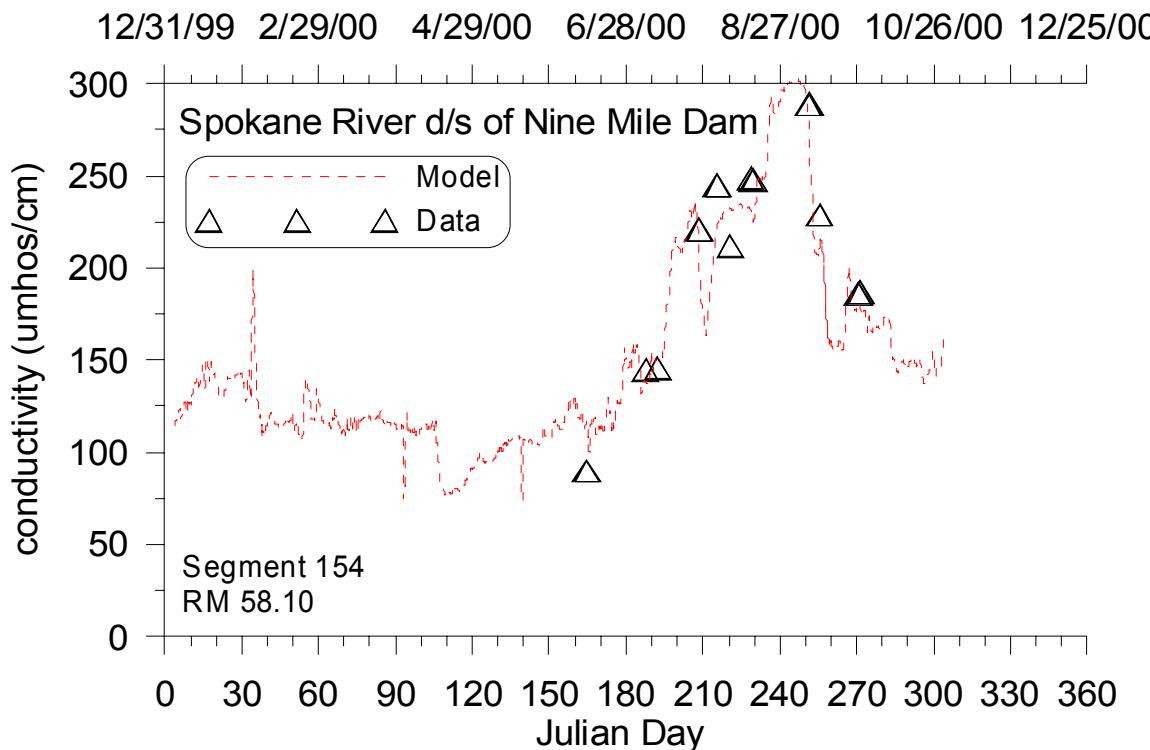


Figure 79. Comparison of model predicted conductivity and 2000 data for the Spokane River downstream of Nine Mile Dam (Segment 154).

Dissolved Oxygen

CE-QUAL-W2 Version 3.1 permits the use of water body specific reaeration equations. For the riverine section between the state line and Islands Foot Bridge (water body 1), the Melching and Flores (1999) equation applicable to pool and riffle streams was used. A fixed reaeration coefficient of 0.05 d^{-1} was applied to the riverine section between Upper Falls Dam and Seven Mile Bridge. Dissolved oxygen concentrations in this section were frequently supersaturated due to periphyton growth, and a fixed value was required to allow the river to be supersaturated. Downstream of wastewater treatment plant outfalls, surfactants can interfere with the reaeration process causing the reaeration rate coefficient to be reduced from expected theoretical or empirical calculations. For the reservoir sections, the Cole and Buchak (1993) equation was applied. Zero order sediment oxygen demand (SOD) rates were set at $0.6 \text{ g m}^{-2} \text{ d}^{-1}$ for Long Lake Reservoir model segments and $0.1 \text{ g m}^{-2} \text{ d}^{-1}$ for riverine segments. For other reservoir segments, SOD was set between $0.5 \text{ g m}^{-2} \text{ d}^{-1}$ to $0.8 \text{ g m}^{-2} \text{ d}^{-1}$, with the value $0.8 \text{ g m}^{-2} \text{ d}^{-1}$ applied to the river section immediately above Upriver Dam. Periphyton growth and phytoplankton growth were important factors for simulation of dissolved oxygen. Phytoplankton photosynthesis contributed to elevated dissolved oxygen concentrations near the surface of Long Lake. In riverine section below Upper Falls dam, supersaturated dissolved oxygen concentrations were likely caused by periphyton populations.

CBOD was modeled using separate CBOD groups for each discharger: Liberty WTP, Kaiser Aluminum, Inland Empire and Spokane WTP. This facilitated accurate simulation of the oxygen demand exerted by effluent originating from each discharger since each CBOD group decayed at its own decay rate. CBOD originating from Coulee Creek, Hangman Creek, Little Spokane River, and the upstream boundary condition were modeled as another single CBOD compartment. The first-order decay rates of the CBOD compartments were developed from laboratory data supplied by the Washington Department of Ecology. Table 25 shows the CBOD decay rates used in the model.

Table 25. Decay rates for each CBOD compartment

CBOD compartment	Description	Decay rate, day ⁻¹
1	Liberty WTP	0.0418
2	Kaiser Aluminum	0.1302
3	Inland Empire Paper	0.0469
4	Spokane WTP	0.0880
5	Coulee Creek, Hangman Creek, Little Spokane River, Upstream Boundary Condition	0.0500

Since organic matter originating from point sources and tributaries was modeled with CBOD compartments, the labile dissolved organic matter (LDOM), refractory dissolved organic matter (RDOM), labile particulate organic matter (LPOM), and refractory particulate organic matter (RPOM) compartments only simulated the by-products of phytoplankton and periphyton decay. A decay rate of 0.1 d⁻¹ was used for labile dissolved organic matter (LDOM).

Year 1991

Dissolved oxygen profiles were collected in Long Lake in 1991 for 12 different days. No profiles were collected in the rest of the Upper Spokane basin. Figure 80 to Figure 84 show dissolved oxygen profile data and model results for five locations in Long Lake from RM 32.7 to 54.5. Figure 85 and Figure 86 show model predictions versus data at Riverside State Park and downstream of Nine Mile Dam. Table 26 shows AME and RMS error statistics for the dissolved oxygen vertical profiles and Table 27 includes error statistics for the time series comparisons.

Table 26. Dissolved oxygen profile error statistics, 1991

Site	n, # of data profile comparisons	DO model –data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	12	1.05	1.24
LL1	12	0.93	1.08
LL2	12	1.08	1.20
LL3	12	0.75	0.84
LL4	12	0.98	1.03

Table 27. Dissolved oxygen time series error statistics, 1991

Site	n, # of data comparisons	DO model –data error statistics	
		AME, mg/L	RMS error, mg/L
SPK66.0	13	1.13	1.24
SPK58.1	17	1.10	1.28

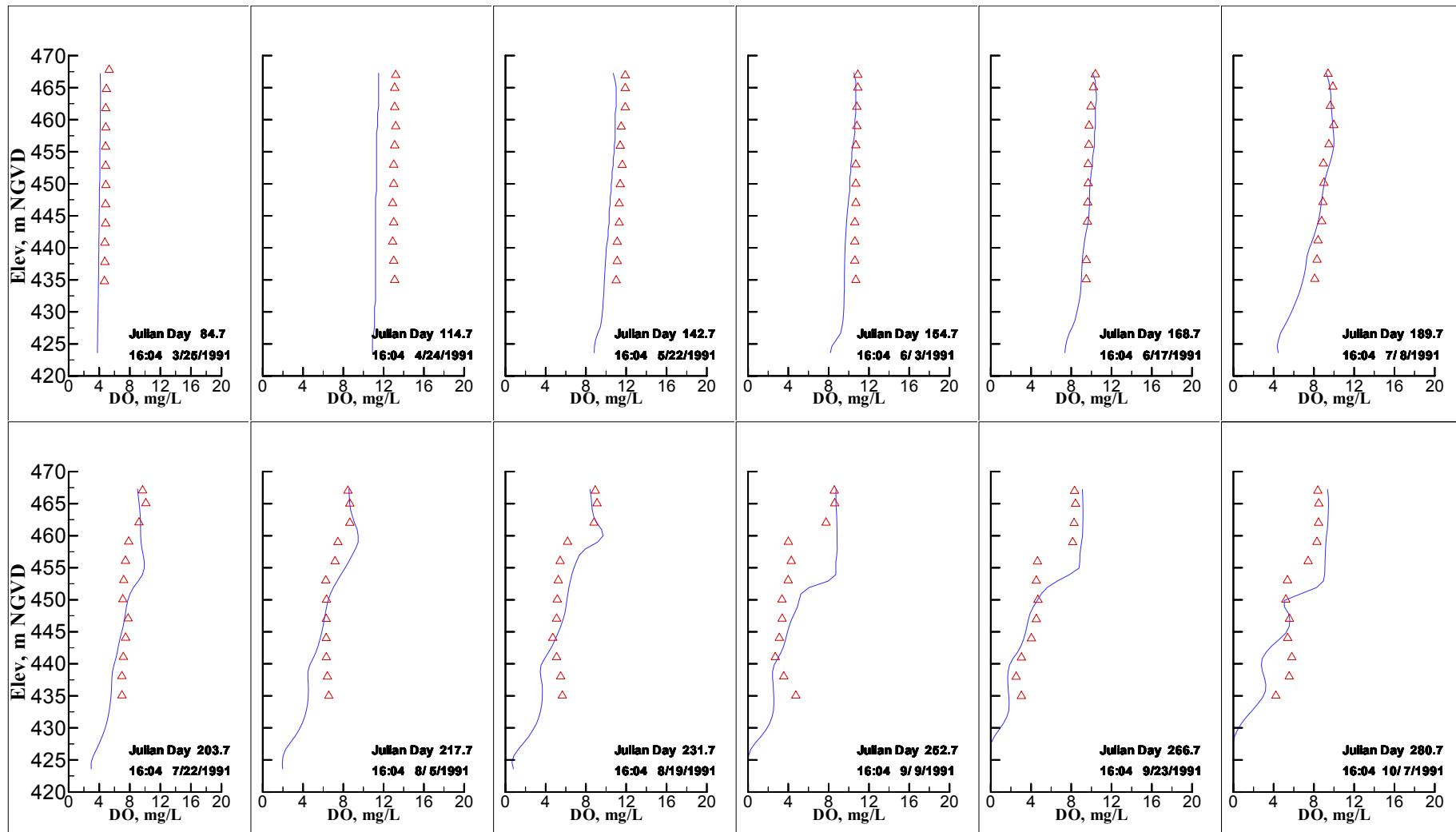


Figure 80. Comparison of model predicted vertical dissolved oxygen profiles and 1991 data for Long Lake at Station 0 (Segment 187).

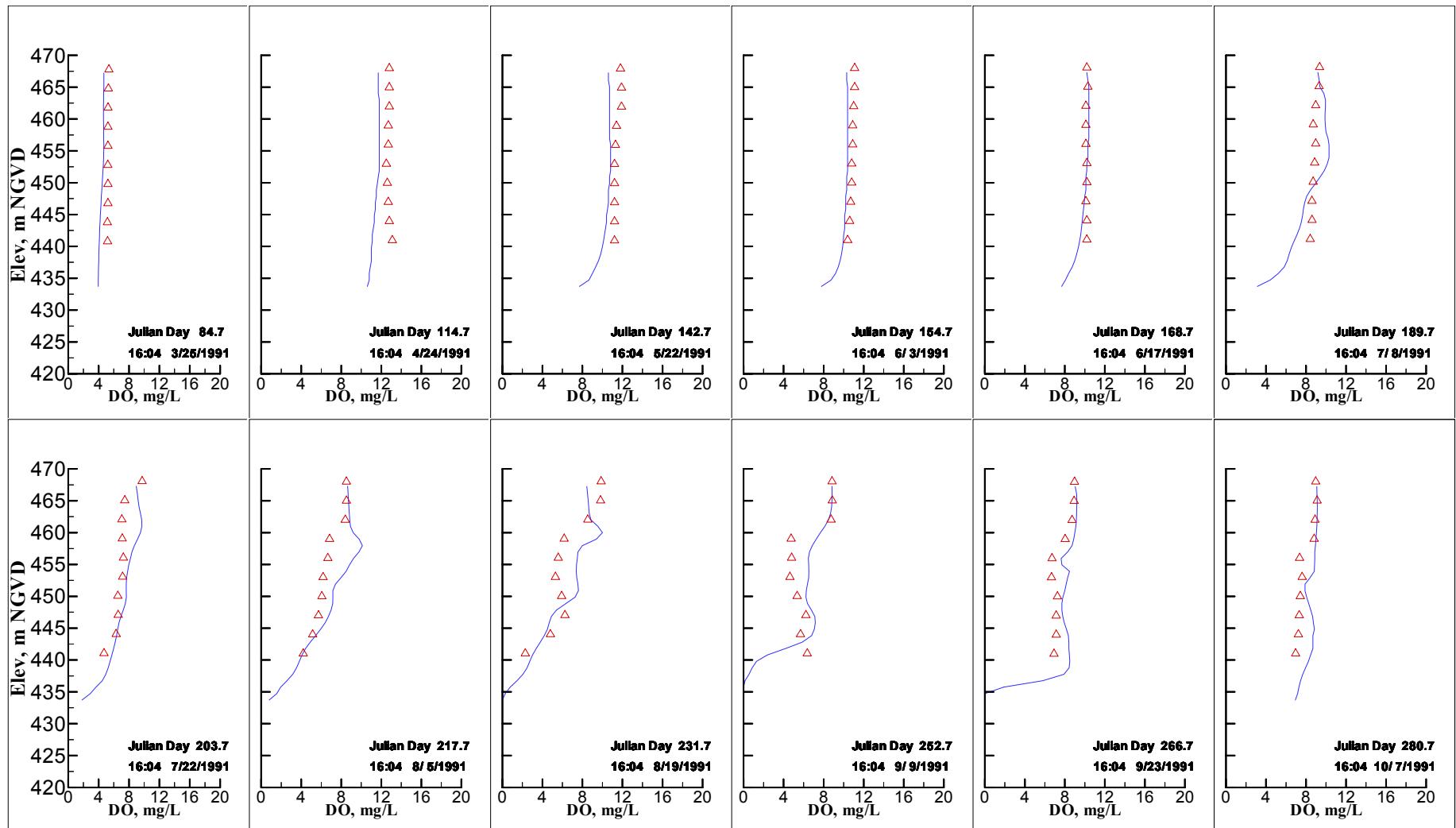


Figure 81. Comparison of model predicted vertical dissolved oxygen profiles and 1991 data for Long Lake at Station 1 (Segment 180).

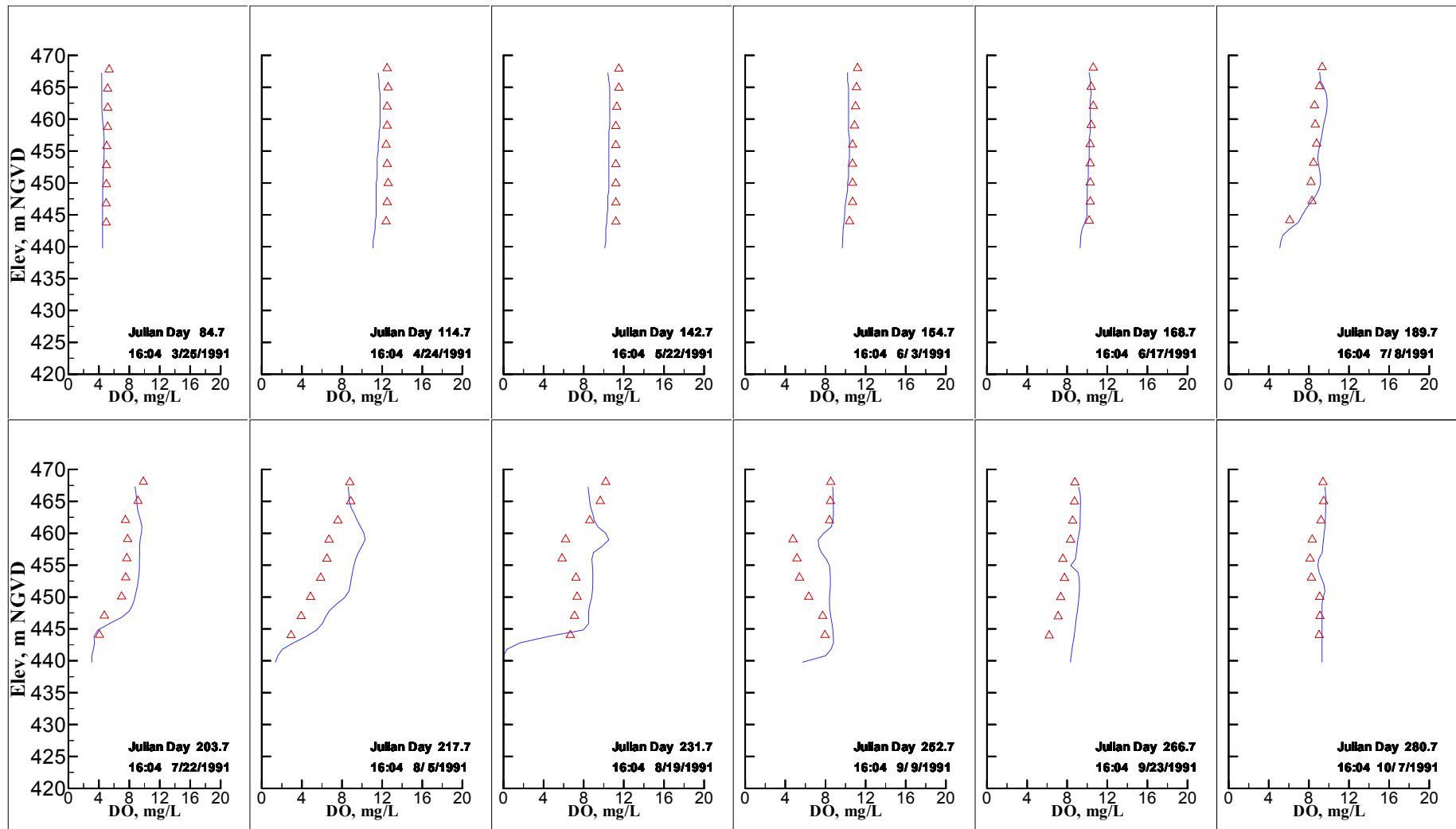


Figure 82. Comparison of model predicted vertical dissolved oxygen profiles and 1991 data for Long Lake at Station 2 (Segment 174).

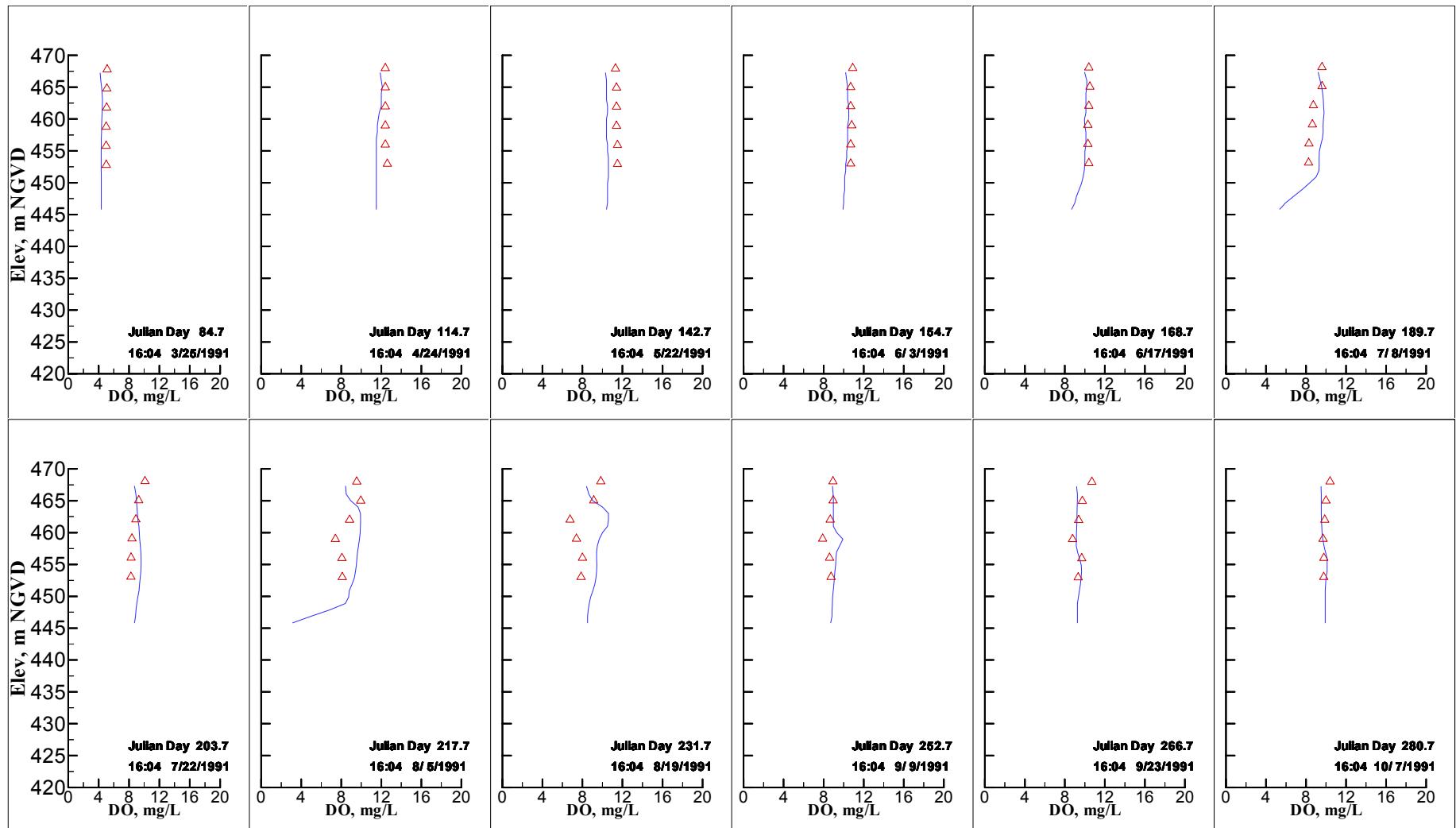


Figure 83. Comparison of model predicted vertical dissolved oxygen profiles and 1991 data for Long Lake at Station 3 (Segment 168).

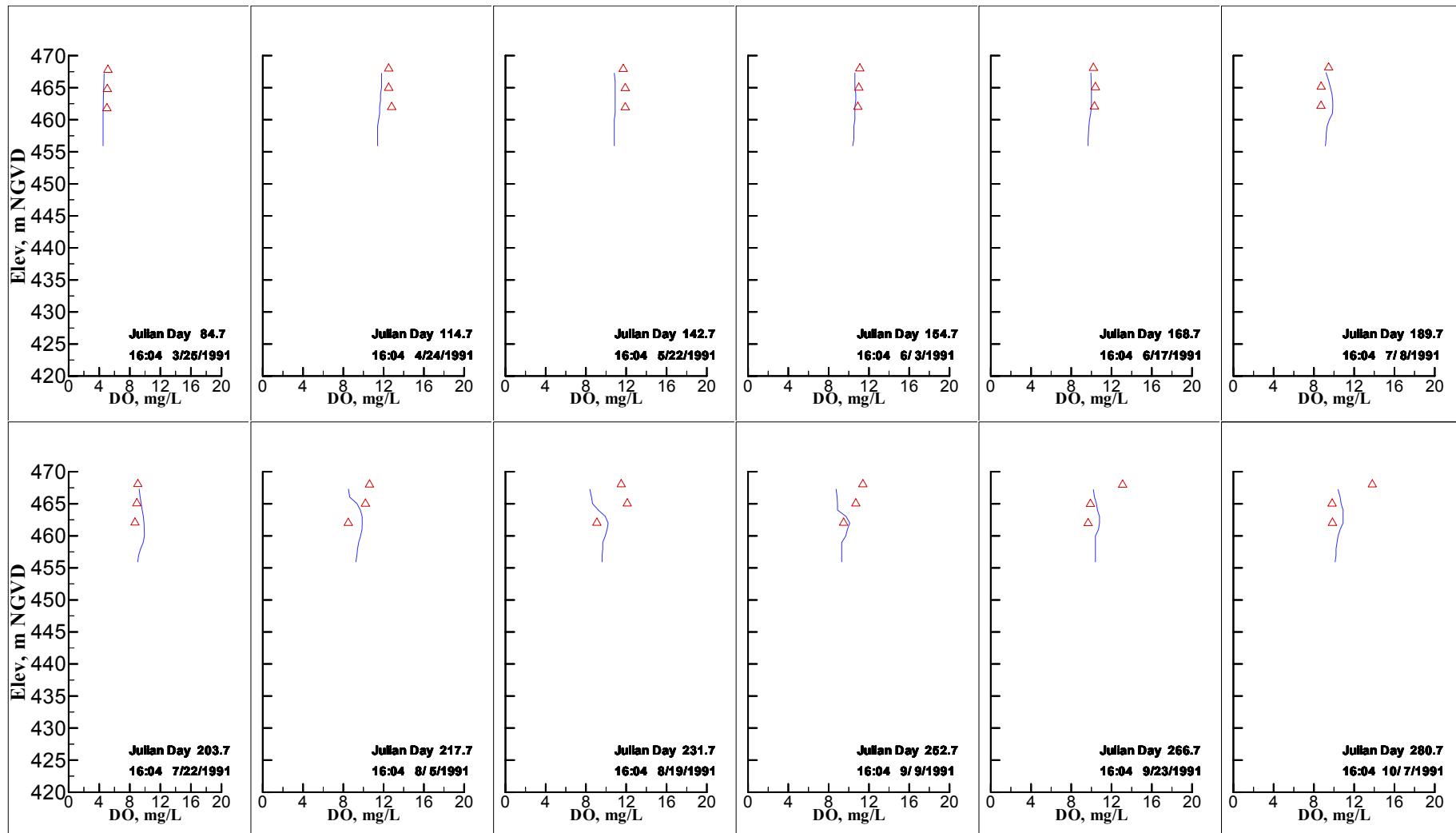


Figure 84. Comparison of model predicted vertical dissolved oxygen profiles and 1991 data for Long Lake at Station 4 (Segment 161).

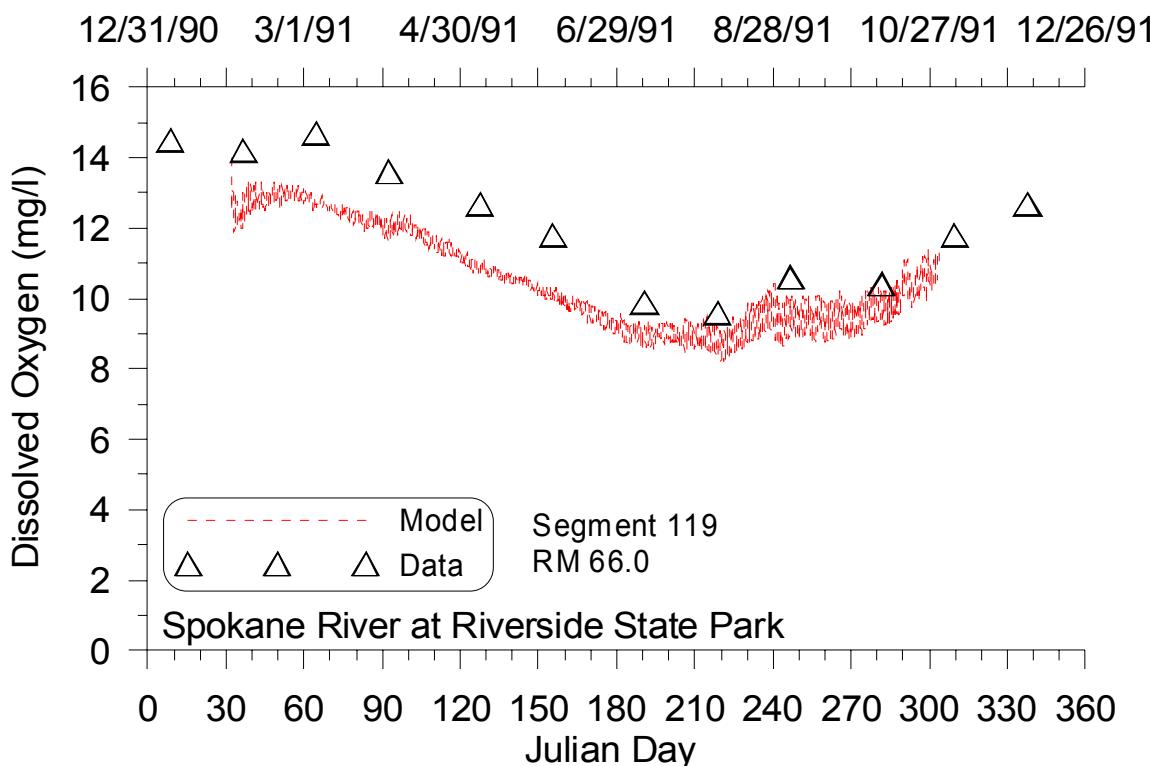


Figure 85. Comparison of model predicted dissolved oxygen and 1991 data for the Spokane River at Riverside State Park (Segment 119).

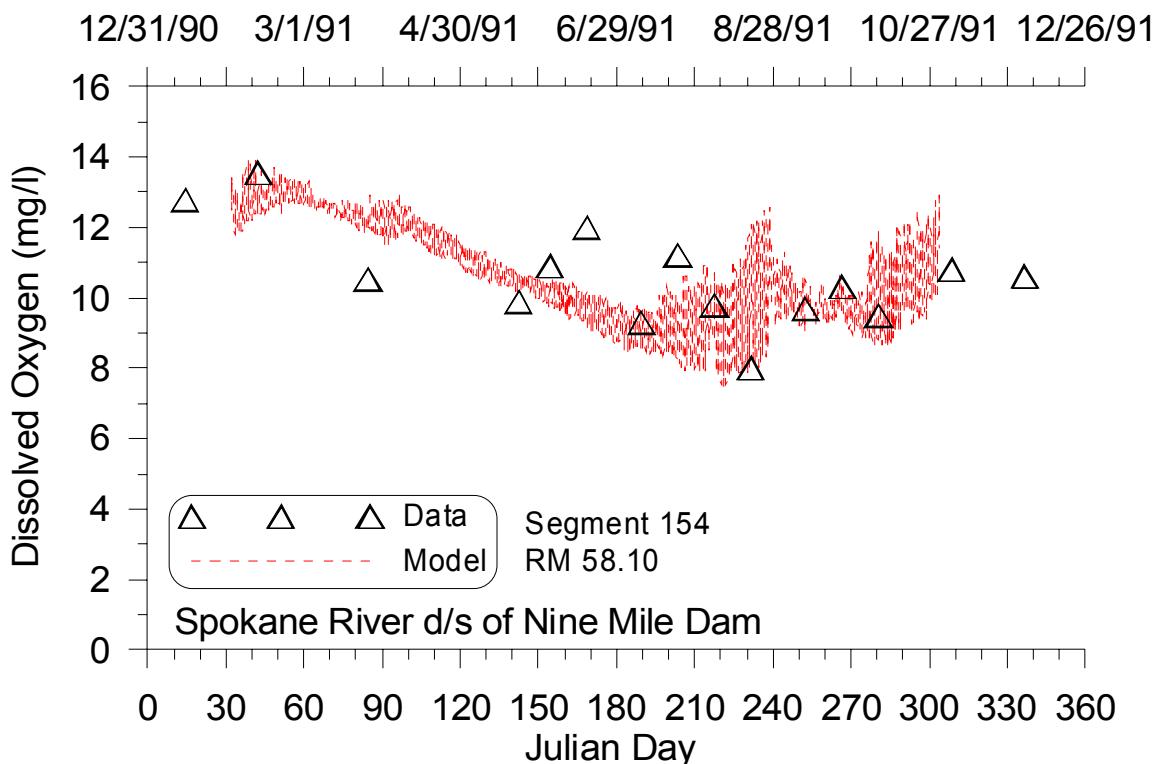


Figure 86. Comparison of model predicted dissolved oxygen concentrations and 1991 data for the Spokane River downstream of Nine Mile Dam (Segment 154).

Year 2000

Vertical dissolved oxygen profiles were collected in Long Lake, Nine Mile Reservoir and Upriver Reservoir in 2000. Figure 87 to Figure 103 show dissolved oxygen profile data and model results for seventeen locations in Long Lake from RM 32.7 to 54.5. Figure 105 and Figure 107 show model predictions versus data at Riverside State Park and downstream of Nine Mile Dam. Figure 104 and Figure 108 show the comparison between continuous data and model predictions above Upriver Dam and below Nine Mile Dam.

Table 28 shows AME and RMS error statistics for the dissolved oxygen vertical profiles and Table 29 includes error statistics for the time series comparisons.

Table 28. Dissolved oxygen profile error statistics, 2000

Site	n, # of data profile comparisons	DO model –data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	3	1.82	2.17
LL0.5	1	1.55	1.81
LL1	7	0.99	1.30
LL2	3	1.23	1.36
LL3	7	0.83	0.96
LL4	3	0.70	0.83
LL5	3	0.76	0.81
SPK58.3	1	0.90	1.06
SPK58.9	1	1.33	1.33
SPK60.2	2	0.51	0.54
SPK60.9	2	0.44	0.44
SPK61.4	2	0.67	0.67
SPK61.9	1	0.77	0.77
SPK80.2	2	0.40	0.43
SPK81.0	2	0.26	0.30
SPK81.6	2	0.46	0.46
SPK82.5	1	0.80	0.81

Table 29. Dissolved oxygen time series error statistics, 2000

Site	n, # of data comparisons	DO model –data error statistics	
		AME, mg/L	RMS error, mg/L
SPK66.0	20	0.51	0.63
SPK58.1	24	0.27	0.38

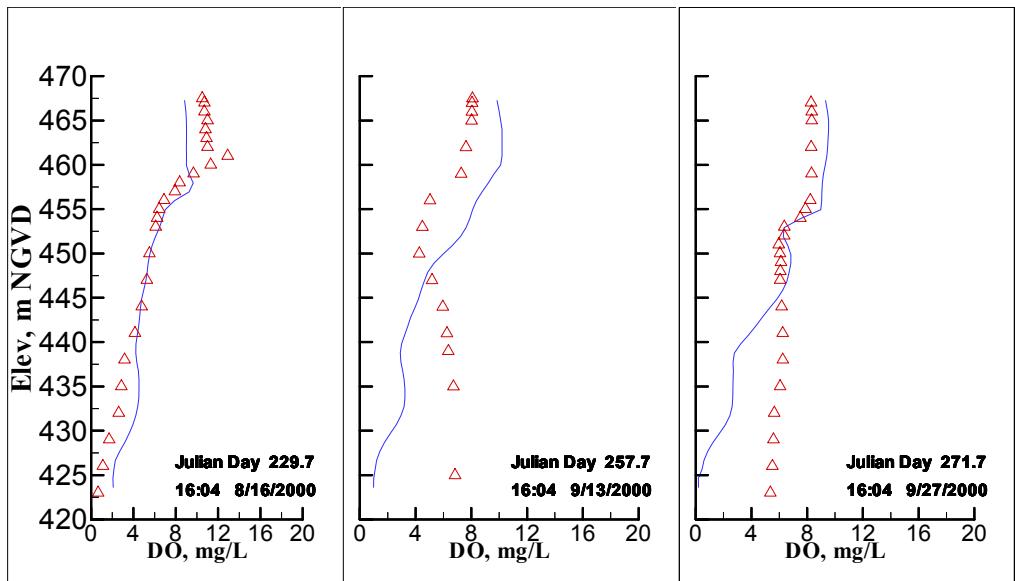


Figure 87. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for Long Lake at Station 0 (Segment 187).

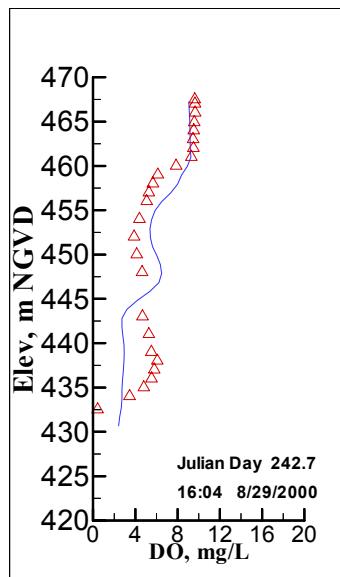


Figure 88. Comparison of model predicted vertical dissolved oxygen profile and 2000 data for Long Lake at Station 0.5 (Segment 183).

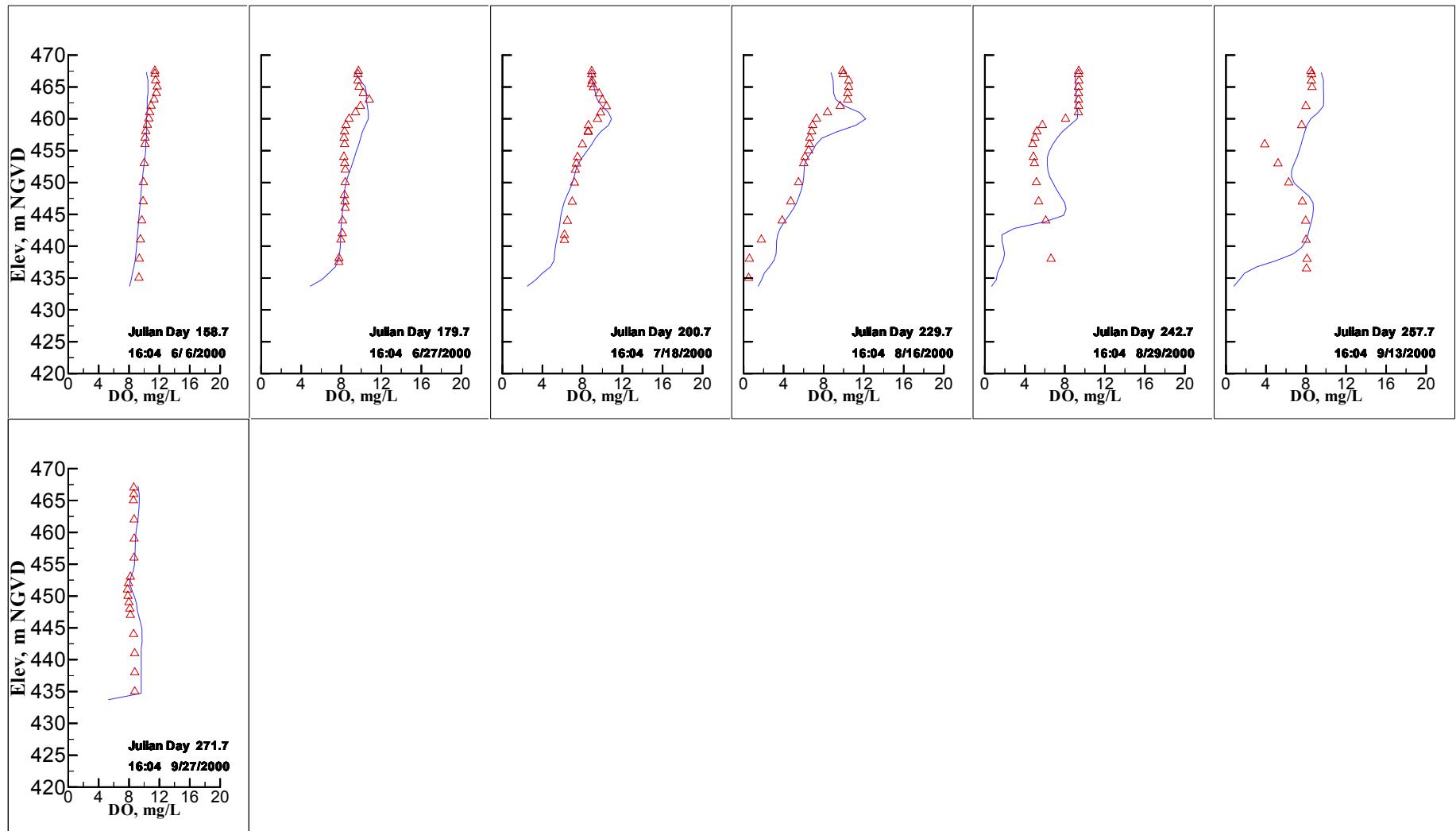


Figure 89. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for Long Lake at Station 1 (Segment 180).

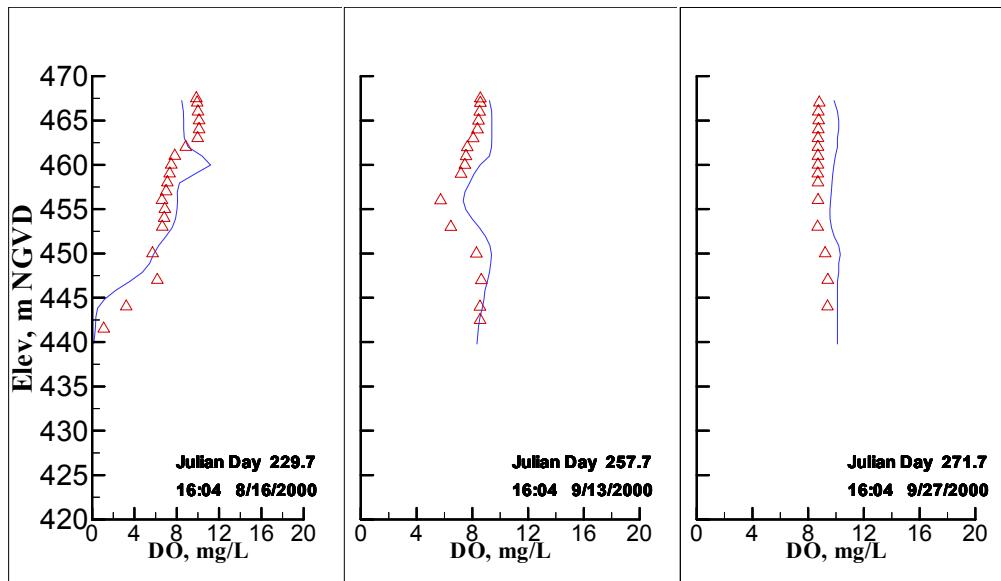


Figure 90. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for Long Lake at Station 2 (Segment 174).

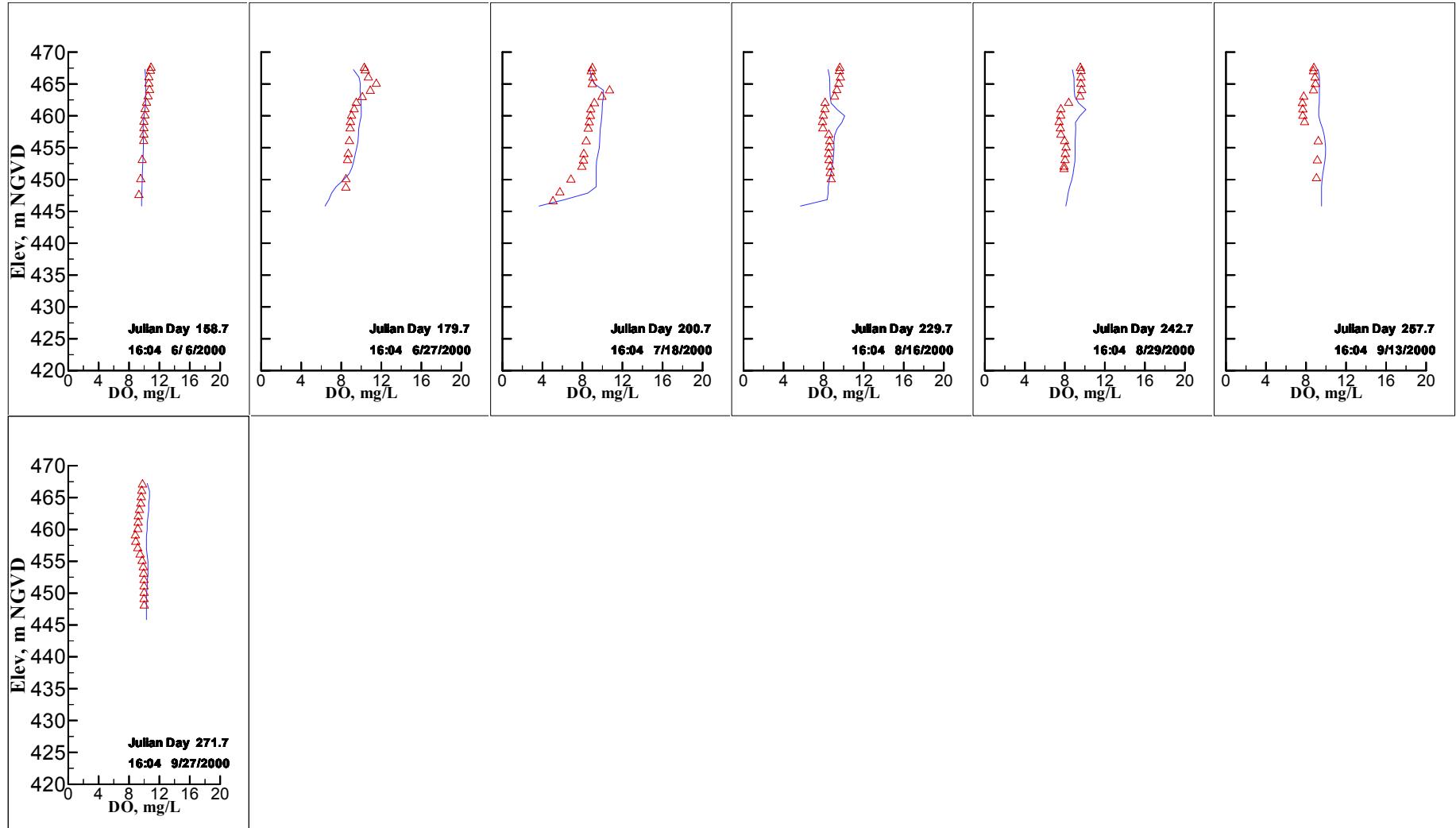


Figure 91. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for Long Lake at Station 3 (Segment 168).

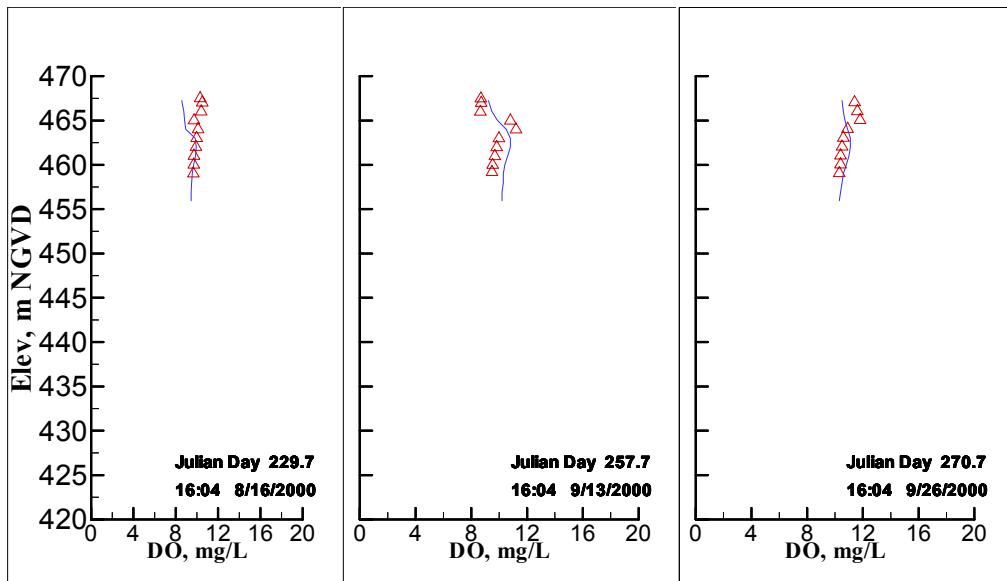


Figure 92. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for Long Lake at Station 4 (Segment 161).

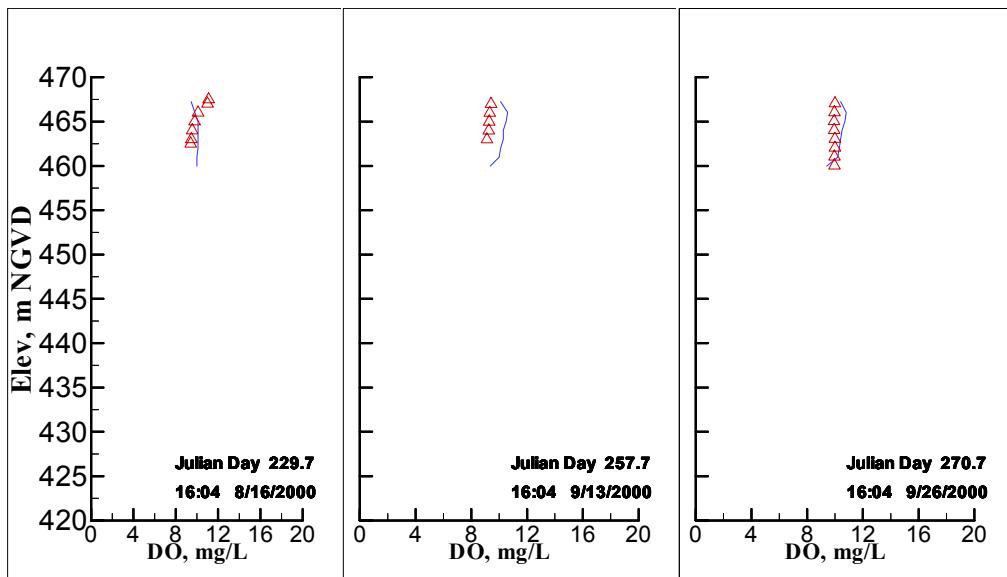


Figure 93. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for Long Lake at Station 5 (Segment 157).

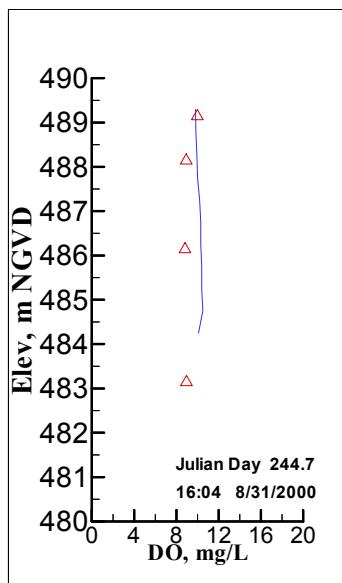


Figure 94. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 0.2 miles upstream of Nine Mile Dam (Segment 150).

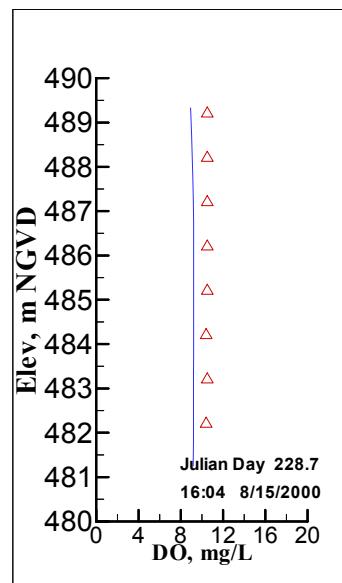


Figure 95. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 0.8 miles upstream of Nine Mile Dam (Segment 147).

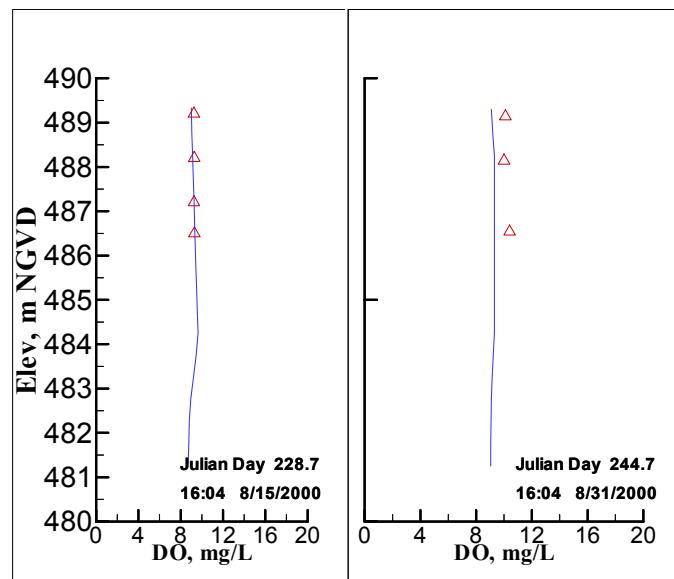


Figure 96. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 2.1 miles upstream of Nine Mile Dam (Segment 143).

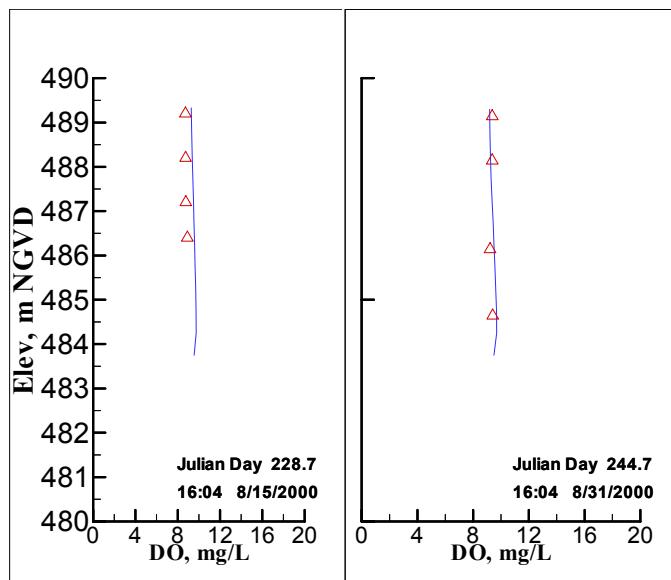


Figure 97. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 2.8 miles upstream of Nine Mile Dam (Segment 141).

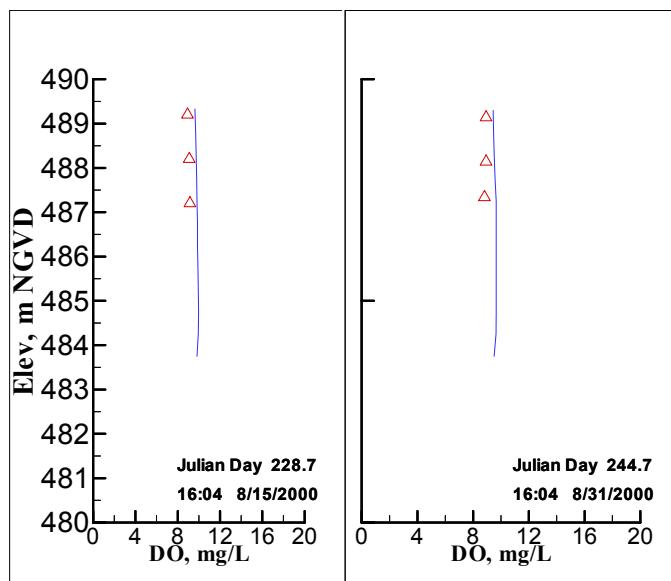


Figure 98. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 3.3 miles upstream of Nine Mile Dam (Segment 139).

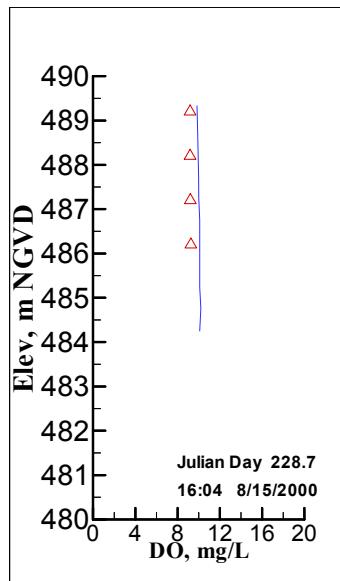


Figure 99. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 3.8 miles upstream of Nine Mile Dam (Segment 135).

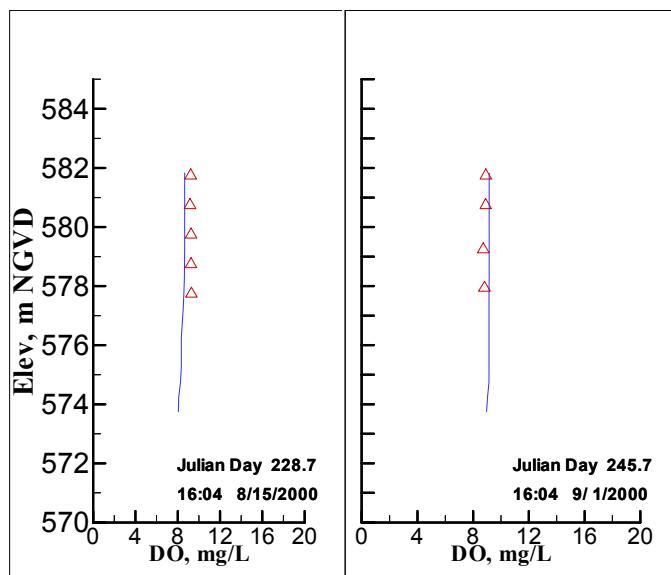


Figure 100. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 0.4 miles upstream of Upriver Dam (Segment 64).

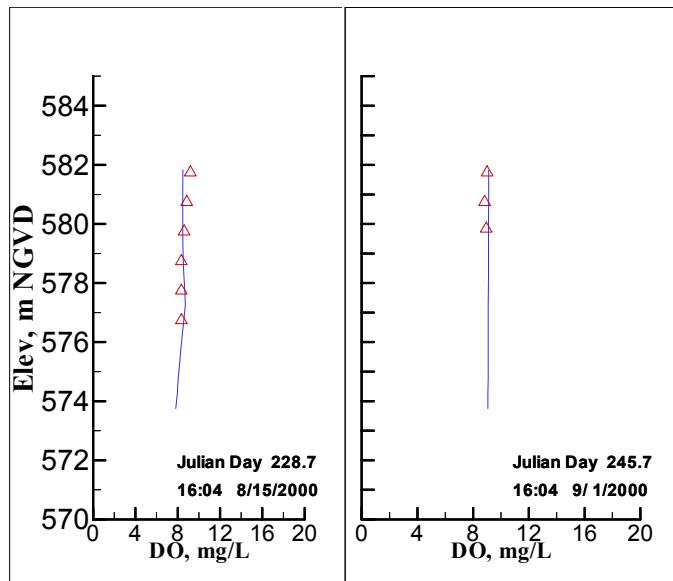


Figure 101. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 1.2 miles upstream of Upriver Dam (Segment 62).

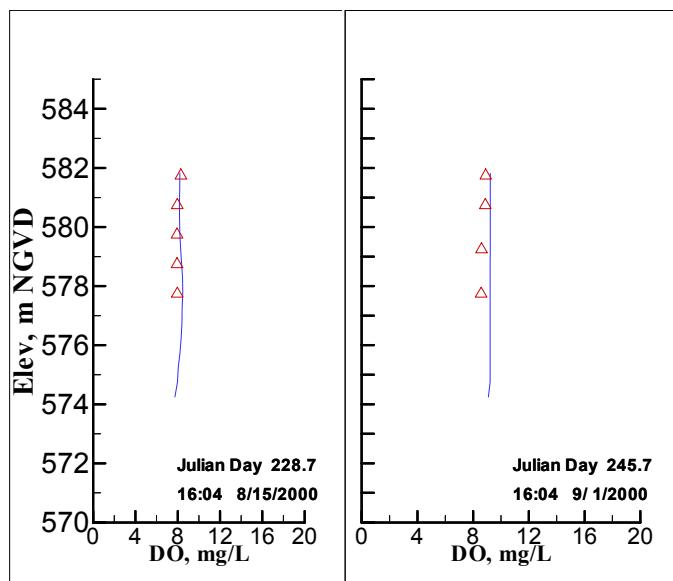


Figure 102. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 1.8 miles upstream of Upriver Dam (Segment 60).

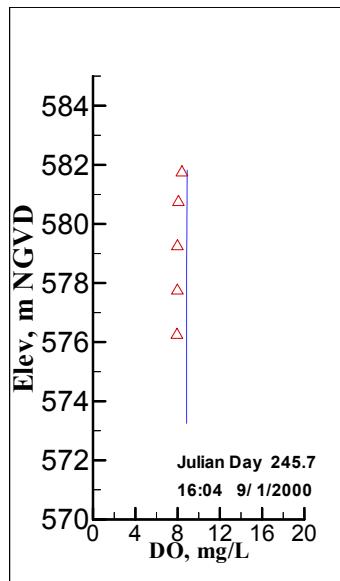


Figure 103. Comparison of model predicted vertical dissolved oxygen profiles and 2000 data for the Spokane River 2.7 miles upstream of Upriver Dam (Segment 57).

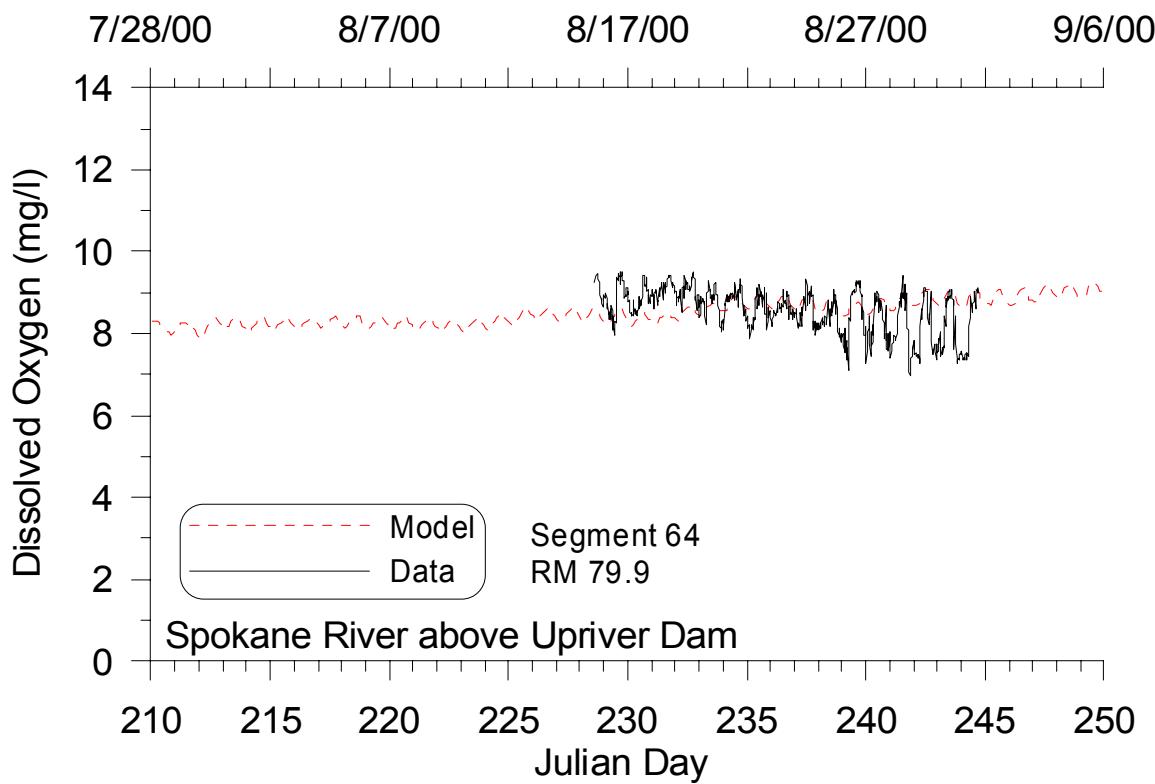


Figure 104. Comparison of model predicted dissolved oxygen concentrations and 2000 continuous data for the Spokane River above Upriver Dam (Segment 64).

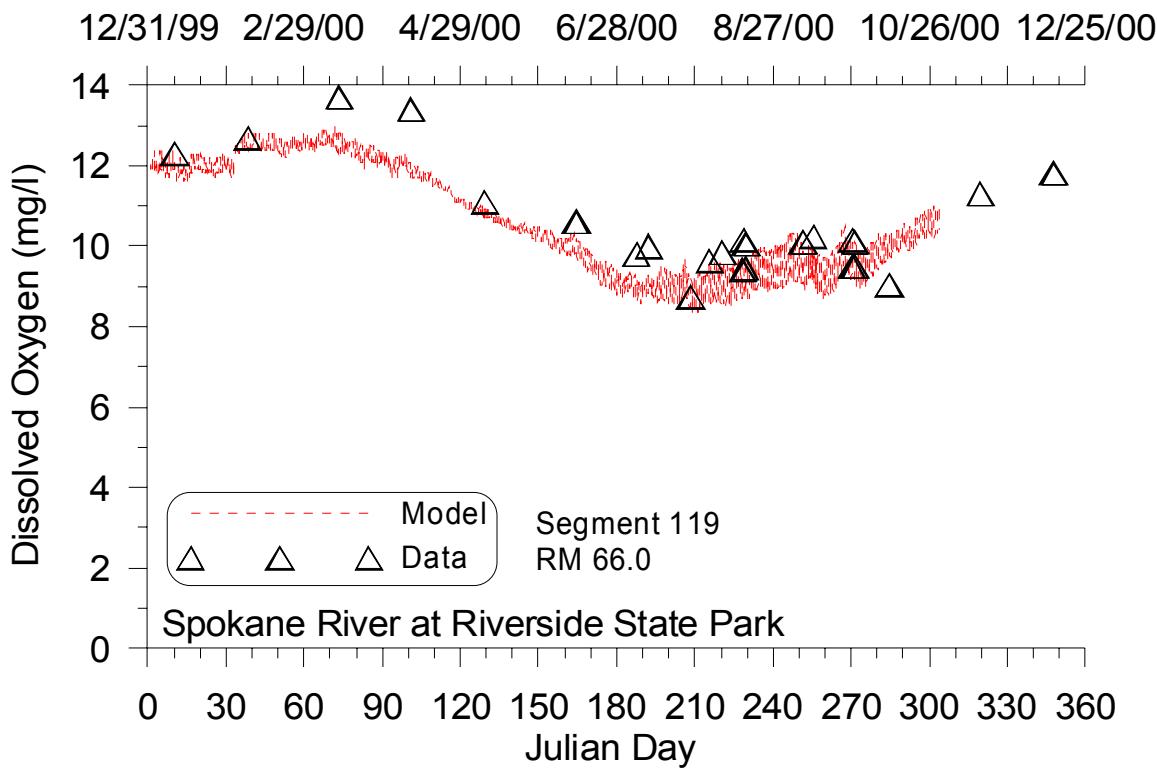


Figure 105. Comparison of model predicted dissolved oxygen concentrations and 2000 data for the Spokane River at Riverside State Park (Segment 119).

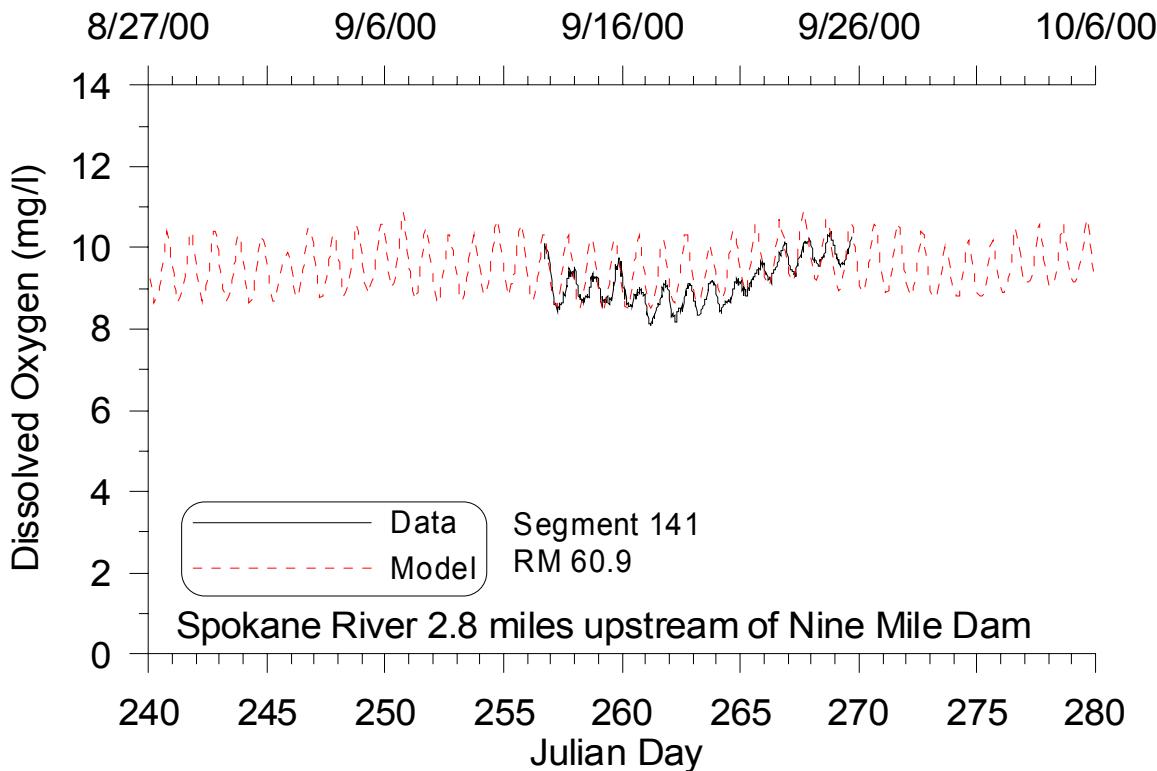


Figure 106. Comparison of model predicted dissolved oxygen concentrations and 2000 data for the Spokane River 2.8 miles upstream of Nine Mile Dam (Segment 141).

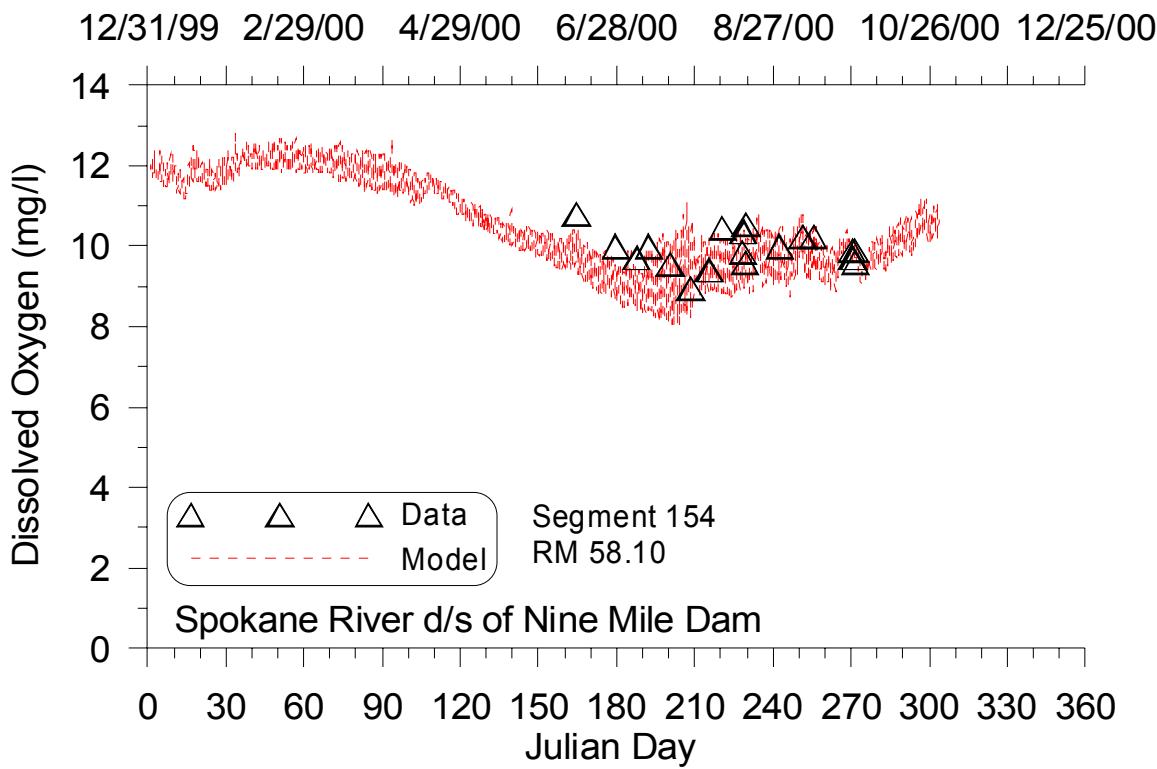


Figure 107. Comparison of model predicted dissolved oxygen concentrations and 2000 data for the Spokane River downstream of Nine Mile Dam (Segment 154).

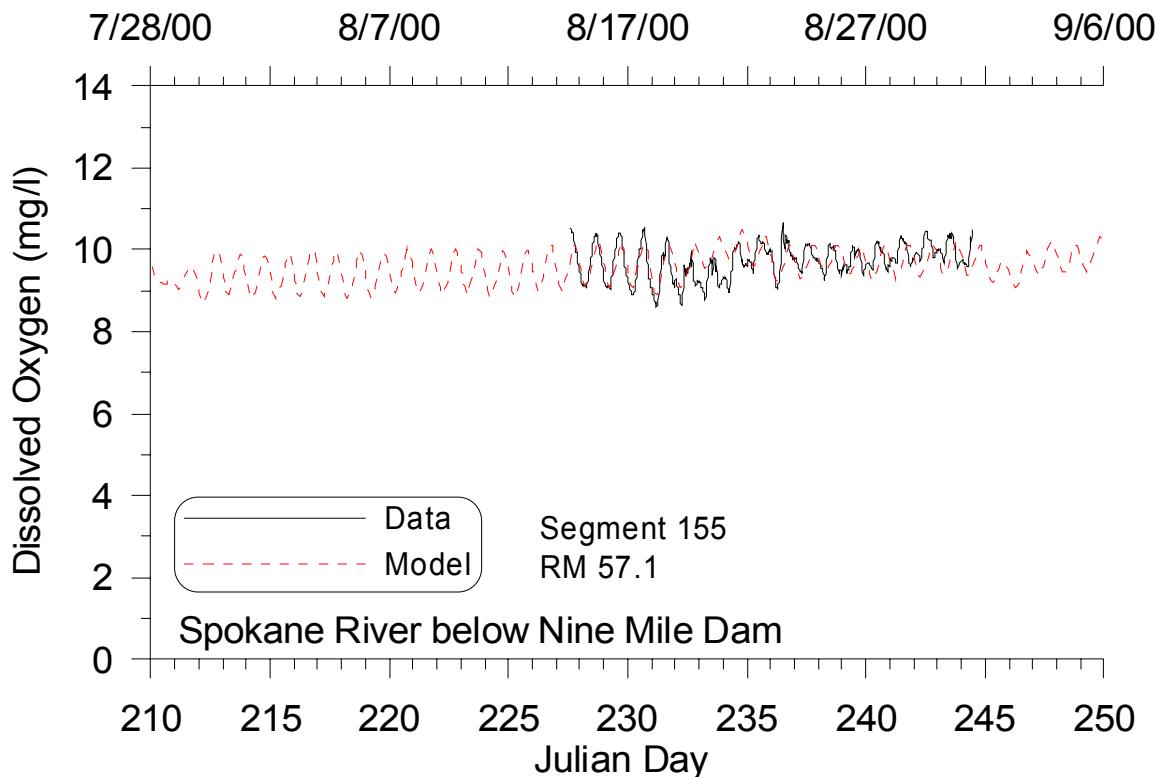


Figure 108. Comparison of model predicted dissolved oxygen concentrations and 2000 continuous data for the Spokane River below Nine Mile Dam (Segment 155).

pH

Year 1991

Vertical pH profiles were collected in Long Lake in 1991 for 12 different days. No additional profiles were collected upstream of Long Lake in 1991. Figure 109 to Figure 113 show pH profile data and model results for five locations in Long Lake from RM 32.7 to 54.5. Table 30 shows AME and RMS error statistics for the pH vertical profiles. Table 31 shows the AME and RMS error statistics for the model-data pH times series. Figure 114 and Figure 115 show the time series plots at model segment 119 (RM 66.0) and 154 (RM 58.1), respectively.

Table 30. pH profile error statistics, 1991

Site	n, # of data profile comparisons	pH model –data error statistics	
		AME	RMS error
LL0	12	0.45	0.51
LL1	12	0.52	0.57
LL2	12	0.57	0.60
LL3	12	0.49	0.52
LL4	12	0.37	0.39

Table 31. pH time series error statistics, 1991

Site	n, # of data comparisons	pH model –data error statistics	
		AME	RMS error
SPK66.0	12	0.20	0.24
SPK58.1	16	0.25	0.34

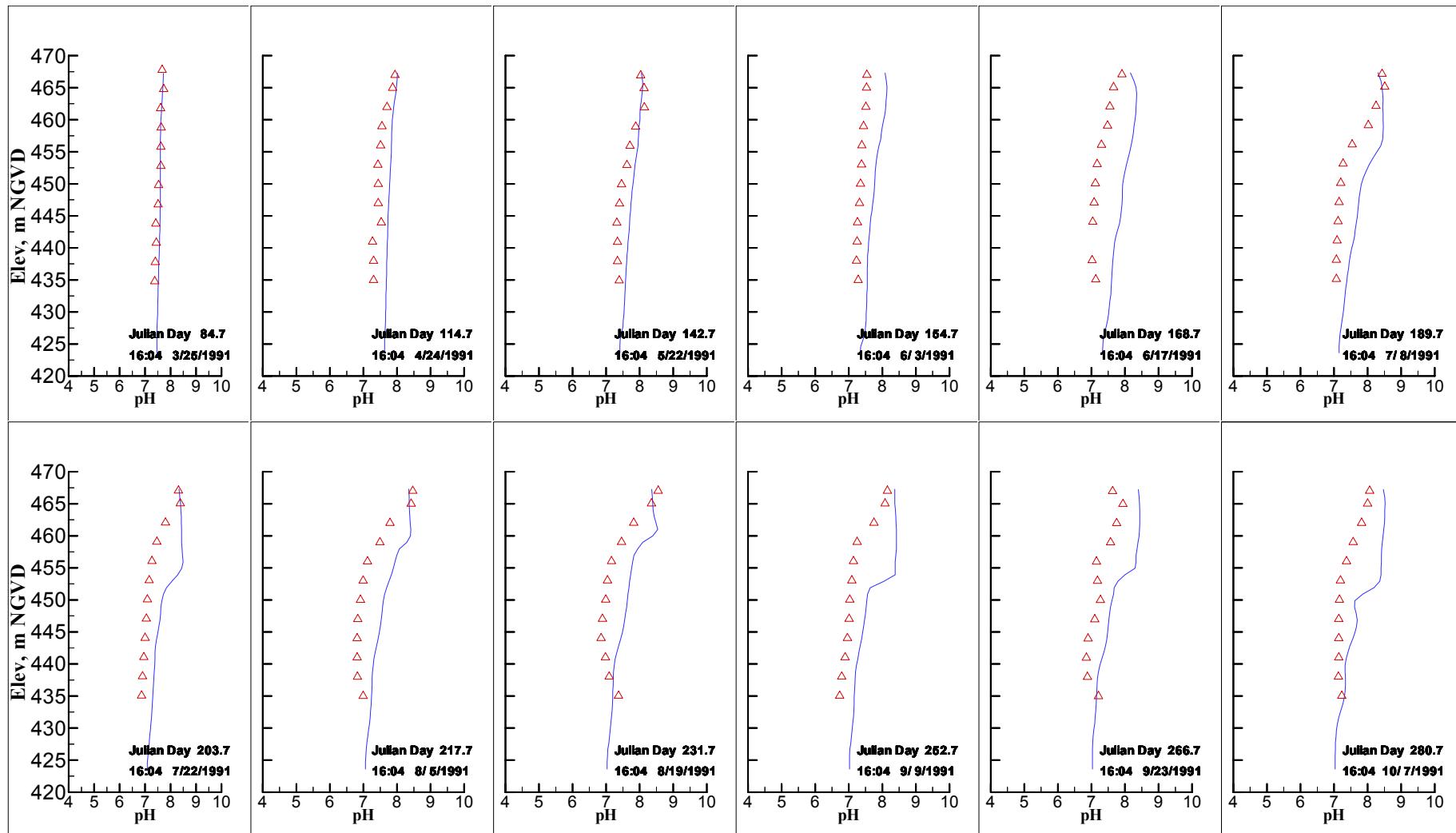


Figure 109. Comparison of model predicted vertical pH profiles and 1991 data for Long Lake at Station 0 (Segment 187).

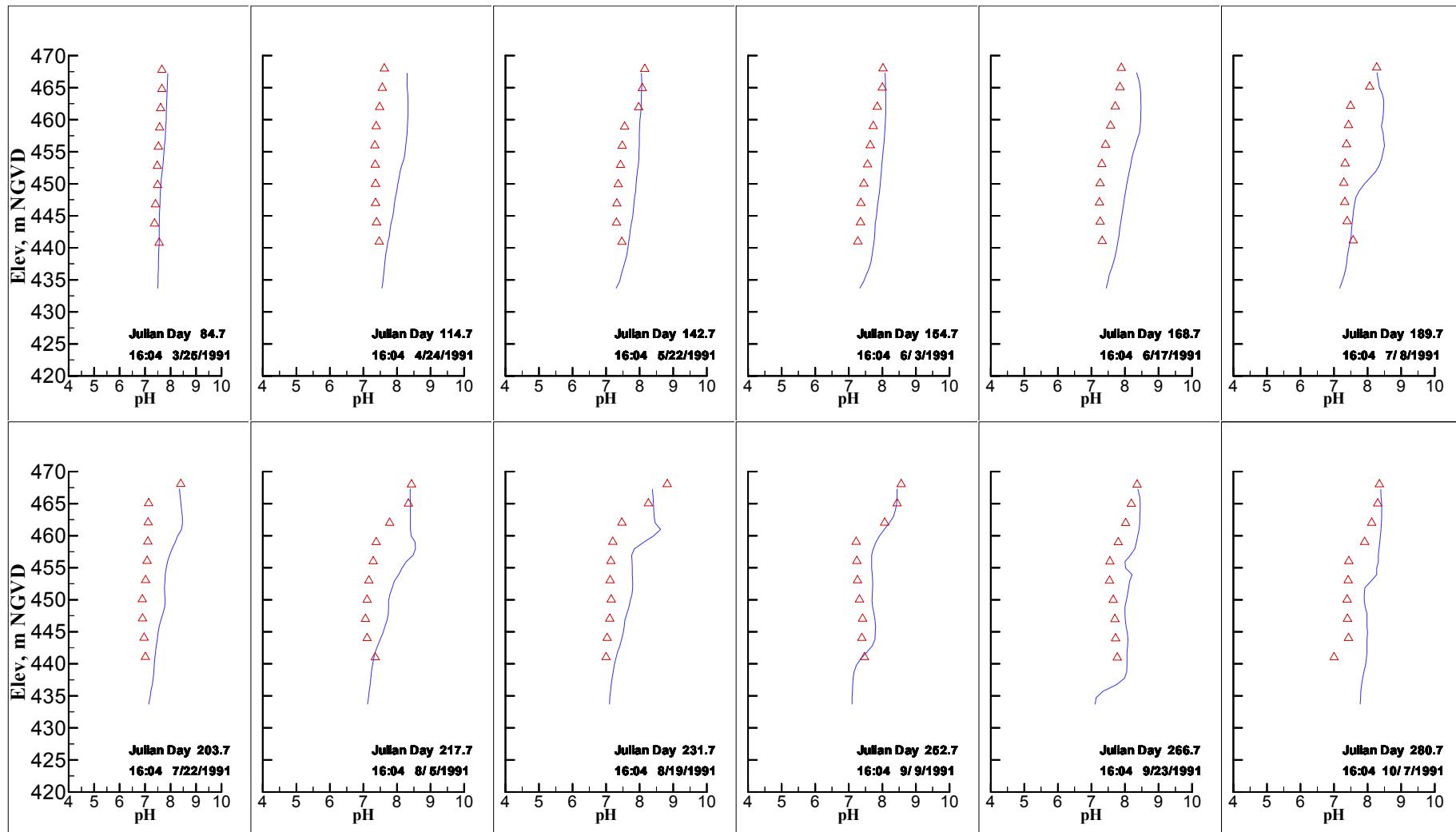


Figure 110. Comparison of model predicted vertical pH profiles and 1991 data for Long Lake at Station 1 (Segment 180).

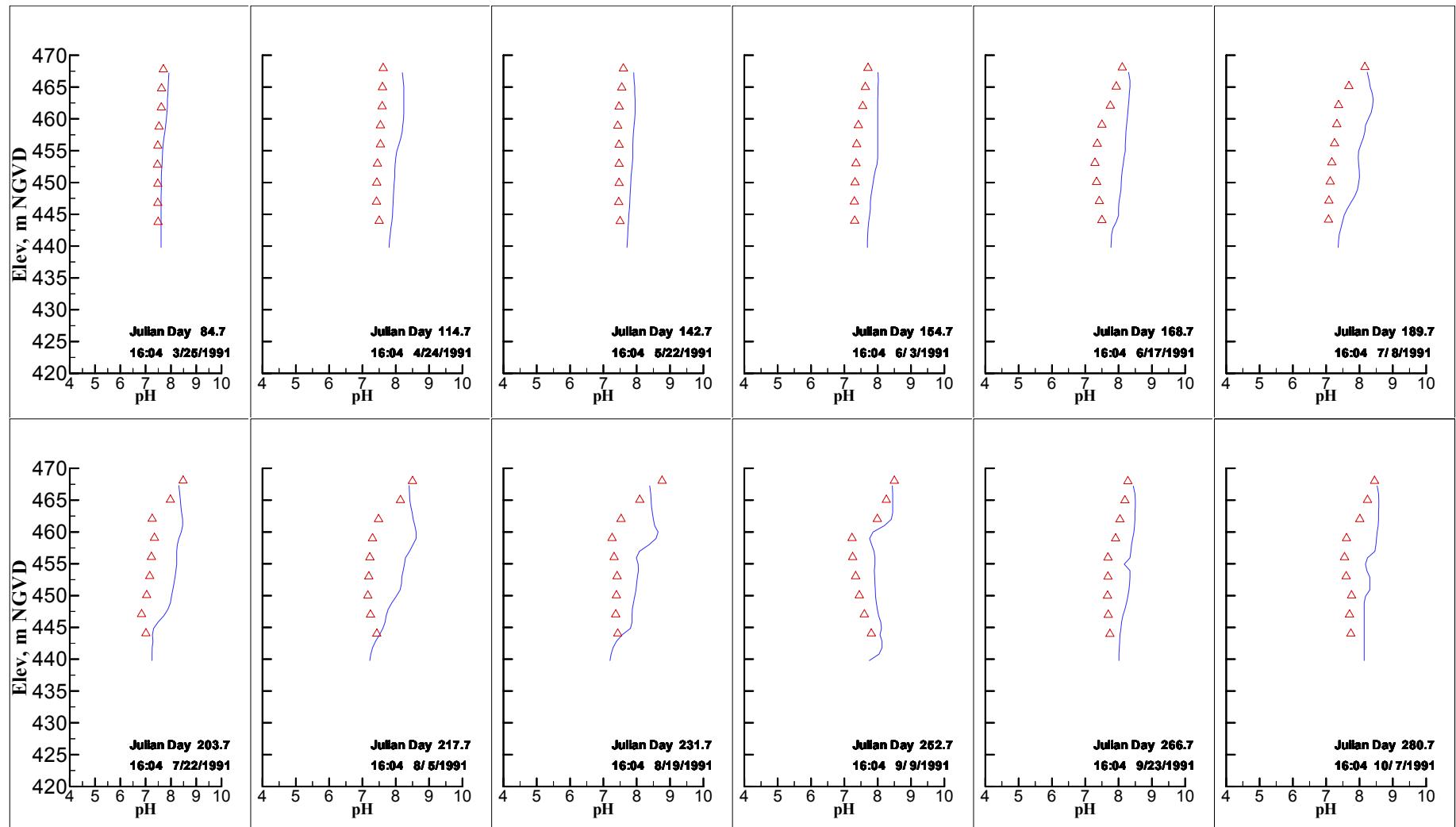


Figure 111. Comparison of model predicted vertical pH profiles and 1991 data for Long Lake at Station 2 (Segment 174).

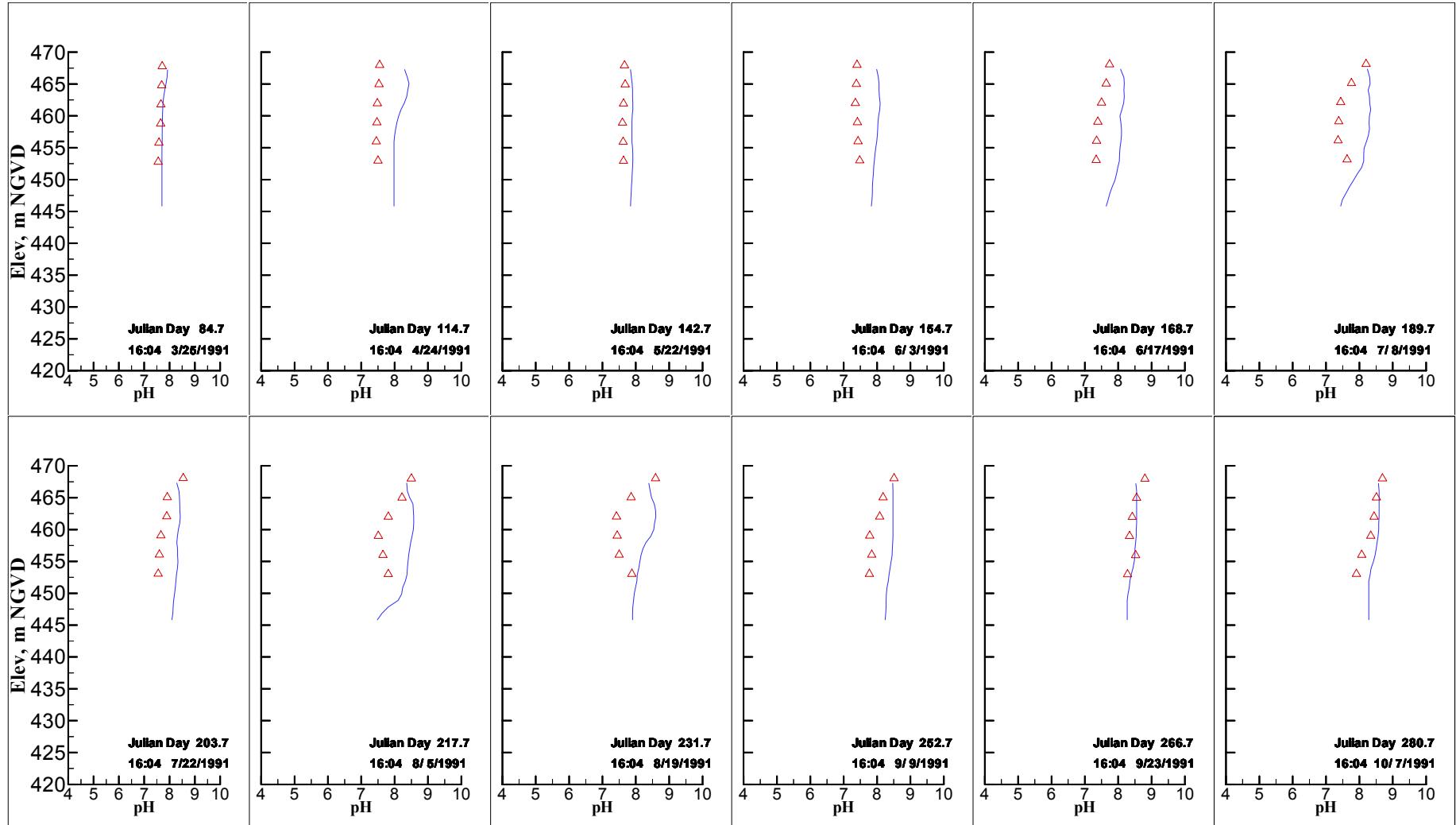


Figure 112. Comparison of model predicted vertical pH profiles and 1991 data for Long Lake at Station 3 (Segment 168).

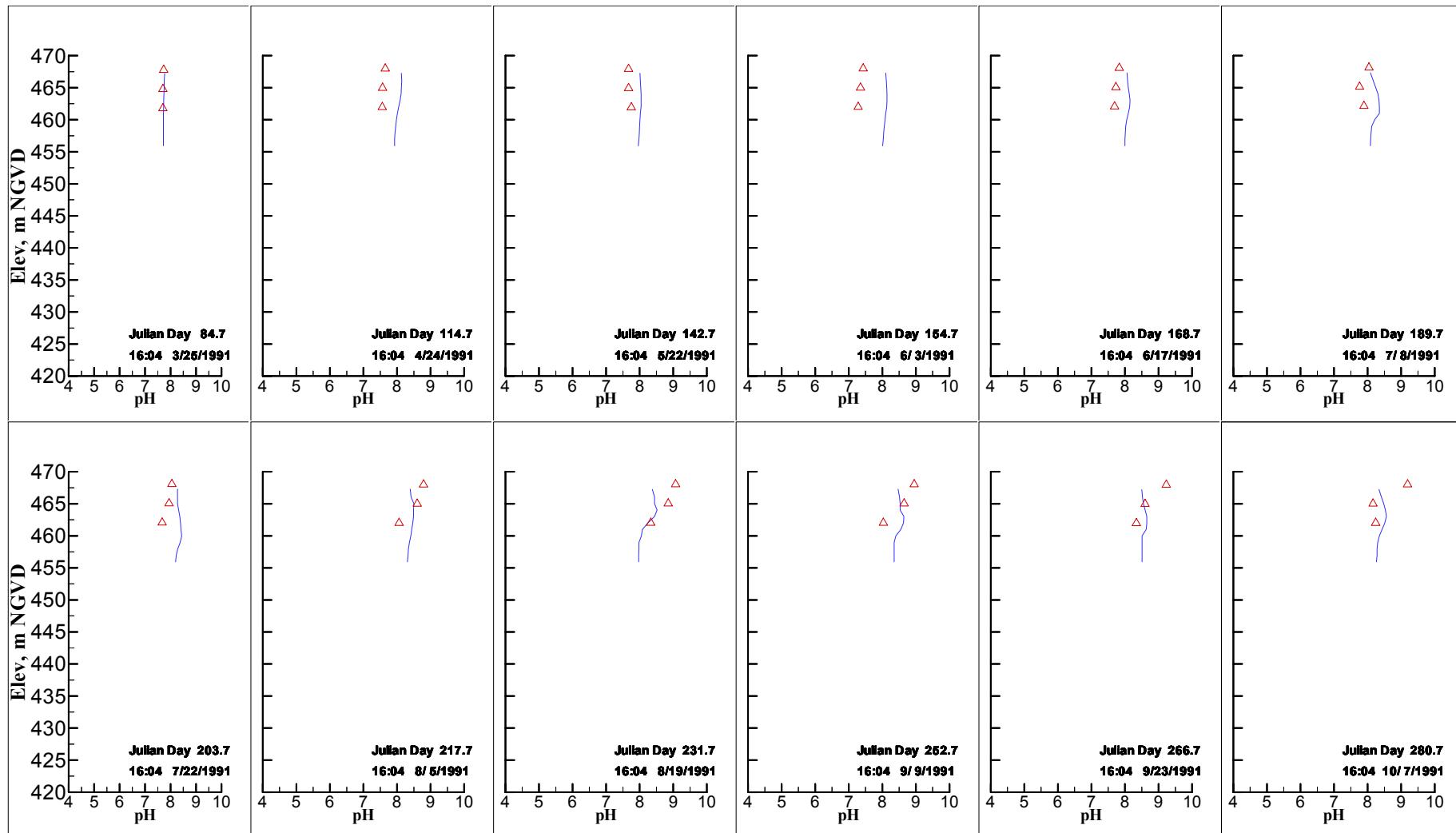


Figure 113. Comparison of model predicted vertical pH profiles and 1991 data for Long Lake at Station 4 (Segment 161).

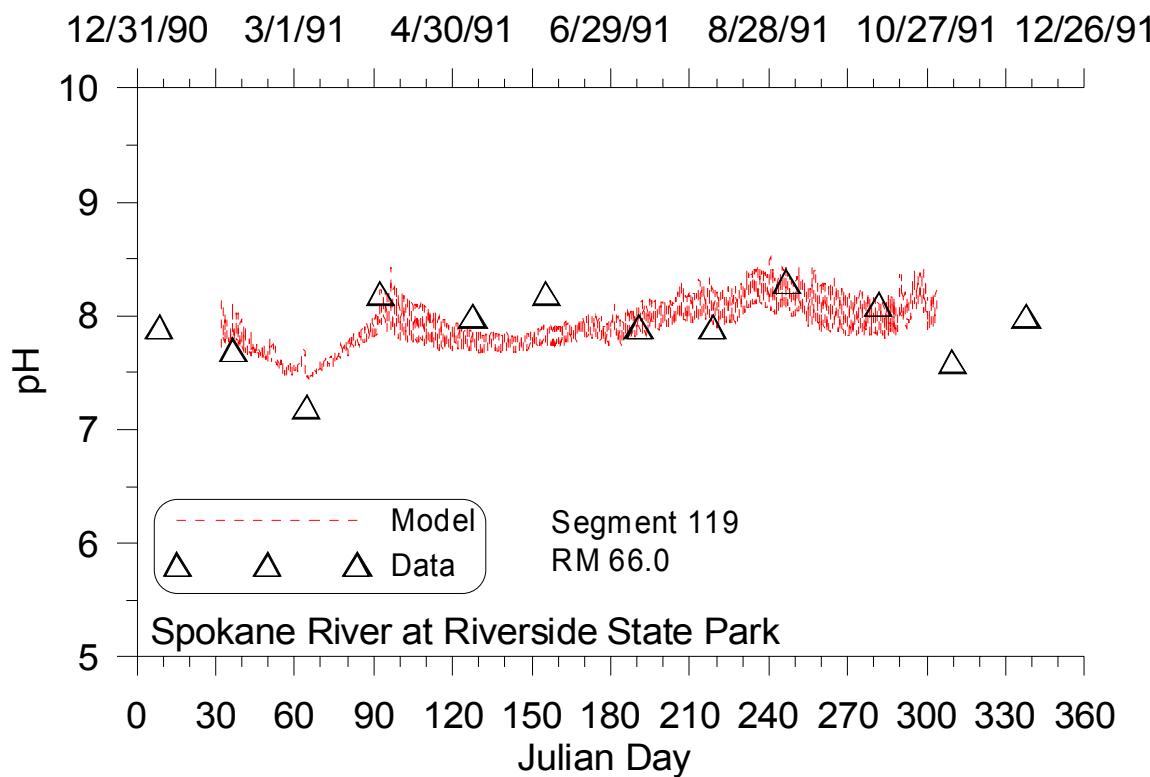


Figure 114. Comparison of model predicted pH and 2000 data for the Spokane River at Riverside State Park (Segment 119).

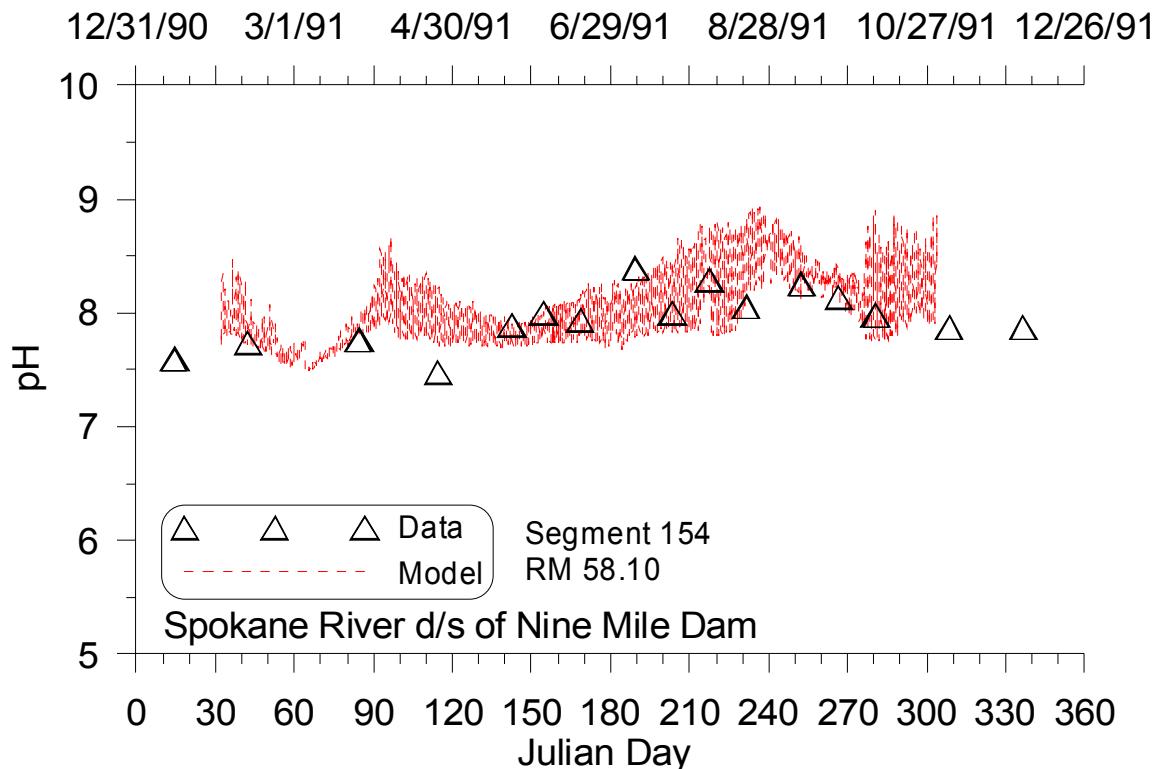


Figure 115. Comparison of model predicted pH and 2000 data for the Spokane River downstream of Nine Mile Dam (Segment 154).

Year 2000

pH profiles were collected in Long Lake, Nine Mile Reservoir and Upriver Reservoir in 2000. Figure 116 to Figure 132 show pH profile data and model results for sixteen locations. Figure 134 shows model pH predictions and data at Riverside Park and Figure 136 show model predictions versus data downstream of Nine Mile Dam. Figure 133, Figure 135, and Figure 137 show the comparison between continuous pH data and model predictions above Upriver Dam, above Nine Mile Dam and below Nine Mile Dam. The model did well in predicting swings in pH caused by diurnal fluctuations in periphyton and phytoplankton growth.

Table 32 shows AME and RMS error statistics for the pH vertical profiles and Table 33 includes error statistics for the time series comparisons.

Table 32. pH profile error statistics, 2000

Site	n, # of data profile comparisons	pH model –data error statistics	
		AME	RMS error
LL0	3	0.30	0.35
LL0.5	1	0.28	0.36
LL1	7	0.35	0.40
LL2	3	0.34	0.38
LL3	7	0.41	0.43
LL4	3	0.18	0.20
LL5	3	0.29	0.30
SPK58.3	1	0.12	0.13
SPK58.9	1	0.04	0.05
SPK60.2	2	0.14	0.15
SPK60.9	2	0.31	0.32
SPK61.4	2	0.32	0.32
SPK61.9	1	0.56	0.56
SPK80.2	2	0.13	0.13
SPK81.0	2	0.16	0.16
SPK81.6	2	0.12	0.12
SPK82.5	1	0.21	0.21

Table 33. pH time series error statistics, 2000

Site	n, # of data comparisons	pH model –data error statistics	
		AME	RMS error
SPK66.0	24	0.24	0.32
SPK58.1	20	0.24	0.34

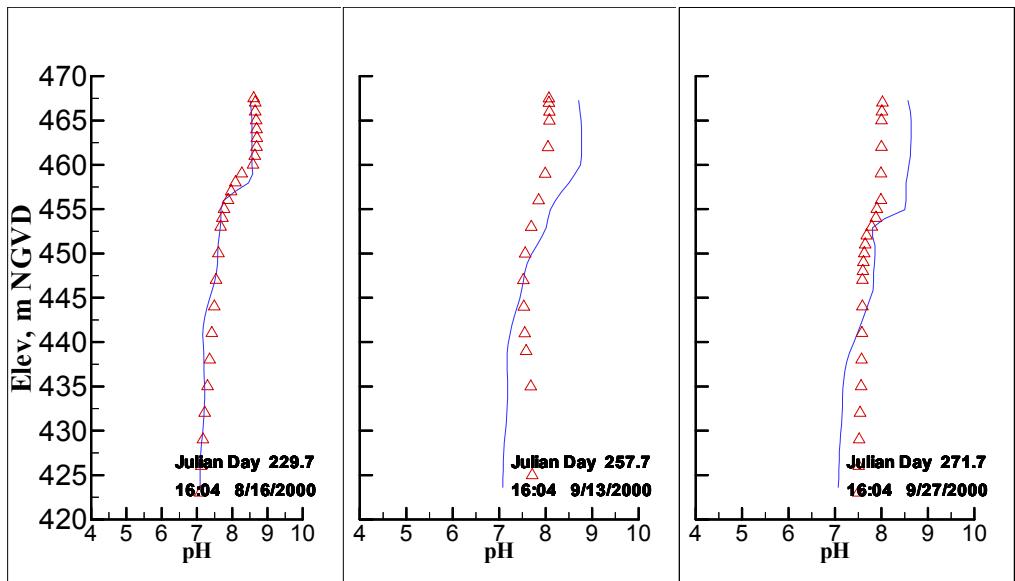


Figure 116. Comparison of model predicted vertical pH profiles and 2000 data for Long Lake at Station 0 (Segment 187).

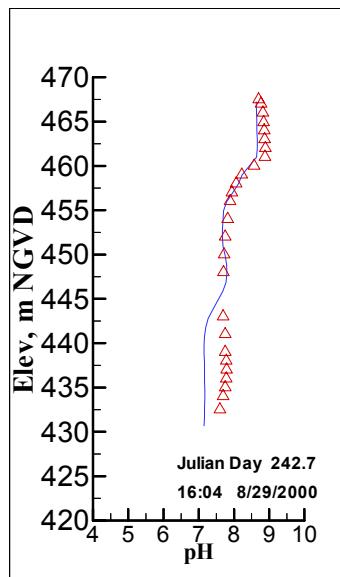


Figure 117. Comparison of model predicted vertical pH profiles and 2000 data for Long Lake at Station 0.5 (Segment 183).

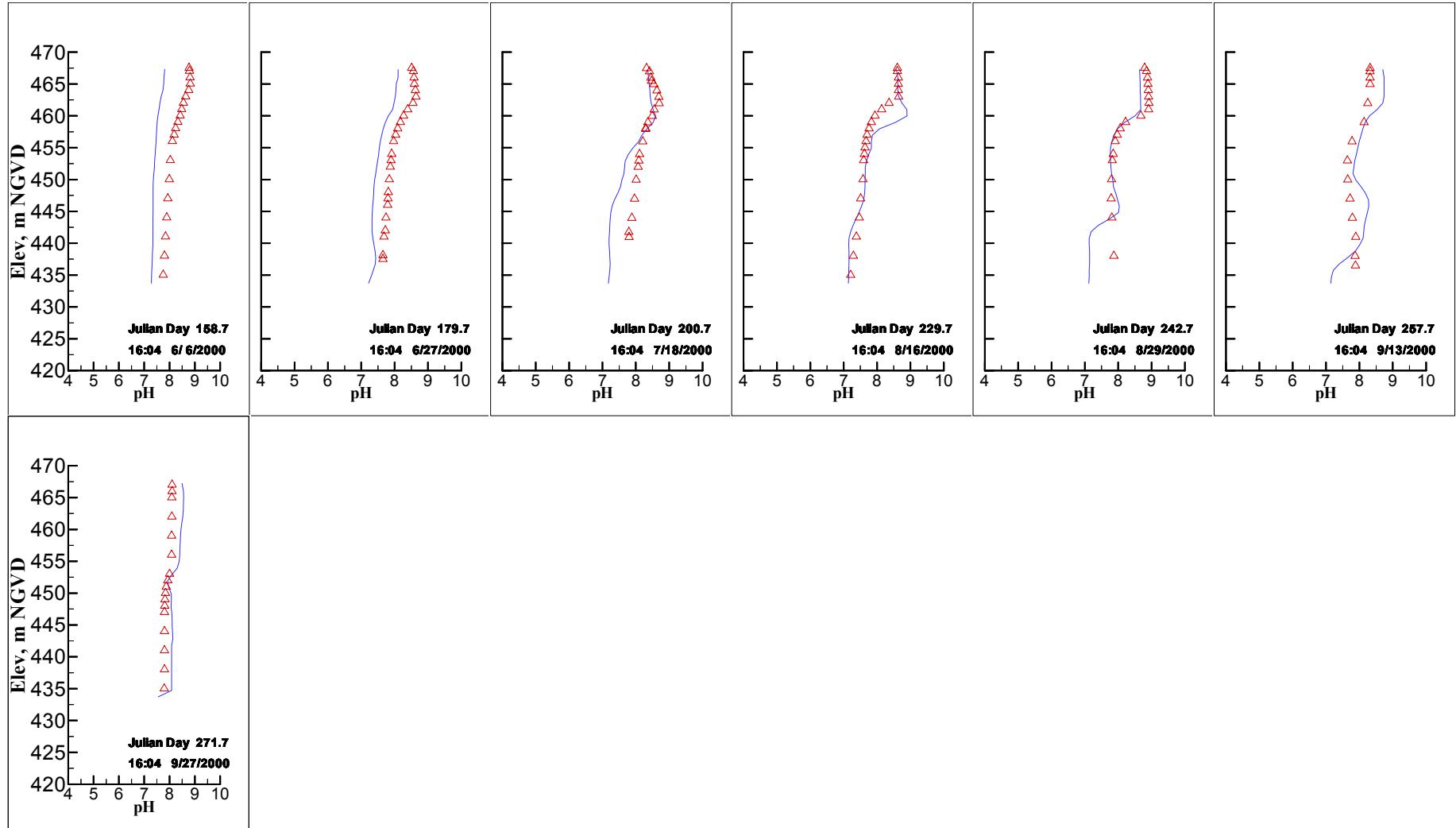


Figure 118. Comparison of model predicted vertical pH profiles and 2000 data for Long Lake at Station 1 (Segment 180).

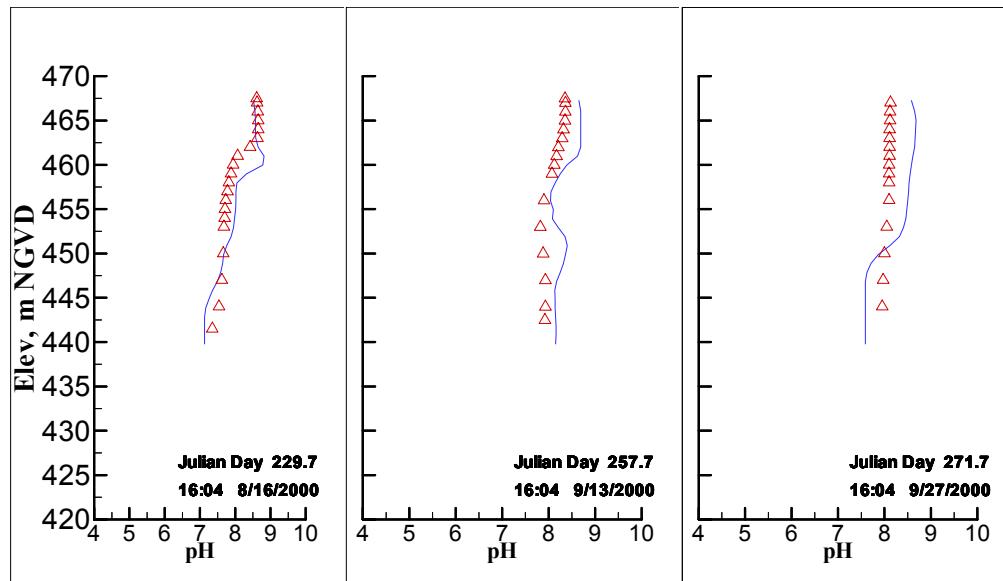


Figure 119. Comparison of model predicted vertical pH profiles and 2000 data for Long Lake at Station 2 (Segment 174).

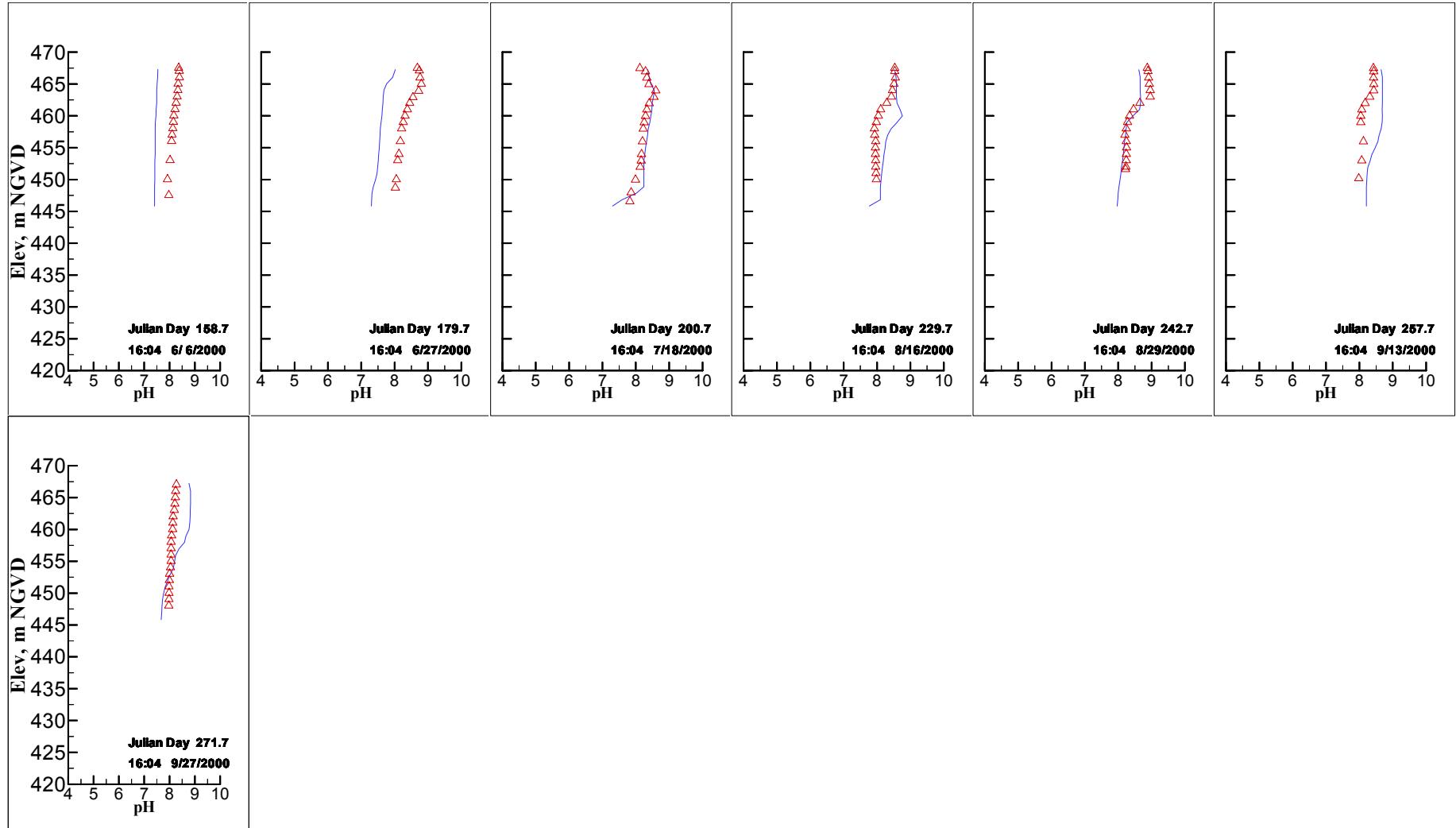


Figure 120. Comparison of model predicted vertical pH profiles and 2000 data for Long Lake at Station 3 (Segment 168).

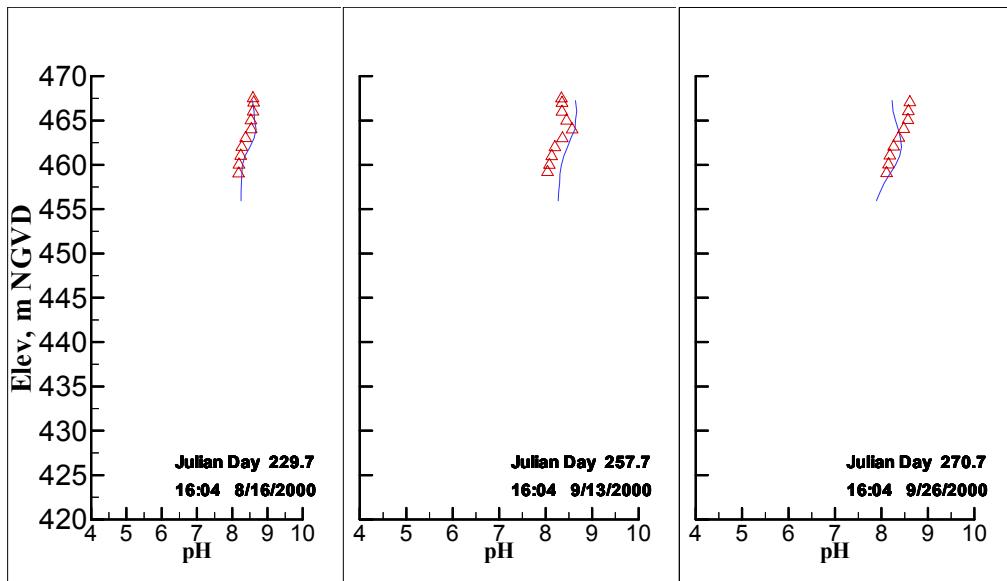


Figure 121. Comparison of model predicted vertical pH profiles and 2000 data for Long Lake at Station 4 (Segment 161).

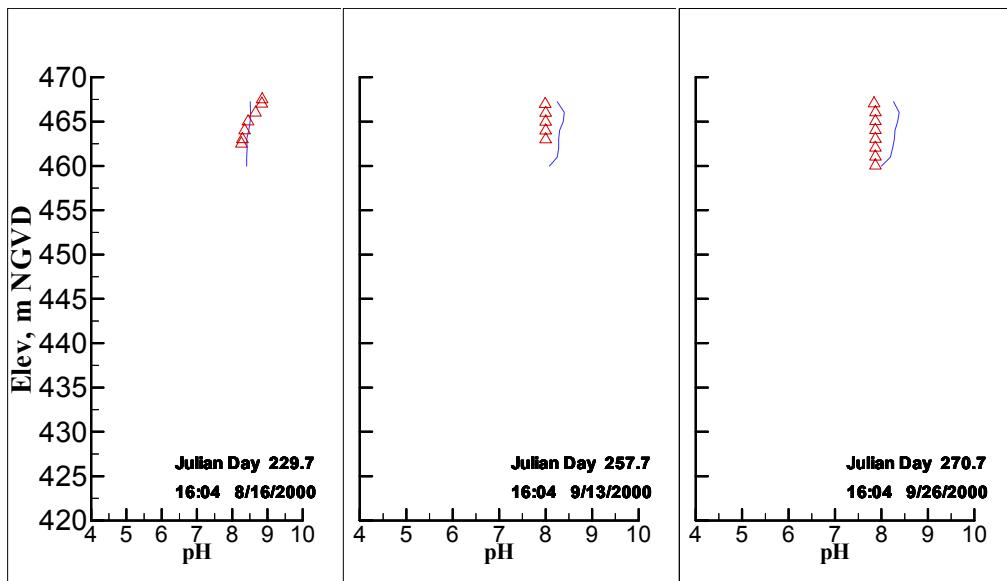


Figure 122. Comparison of model predicted vertical pH profiles and 2000 data for Long Lake at Station 5 (Segment 157).

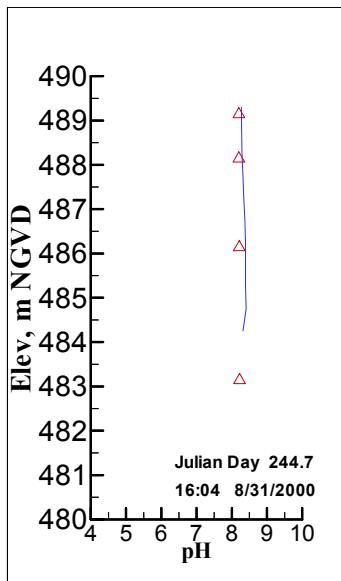


Figure 123. Comparison of model predicted pH profiles and 2000 data for the Spokane River 0.2 miles upstream of Nine Mile Dam (Segment 150).

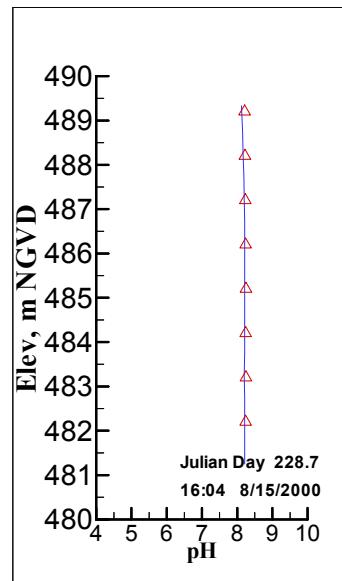


Figure 124. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 0.8 miles upstream of Nine Mile Dam (Segment 147).

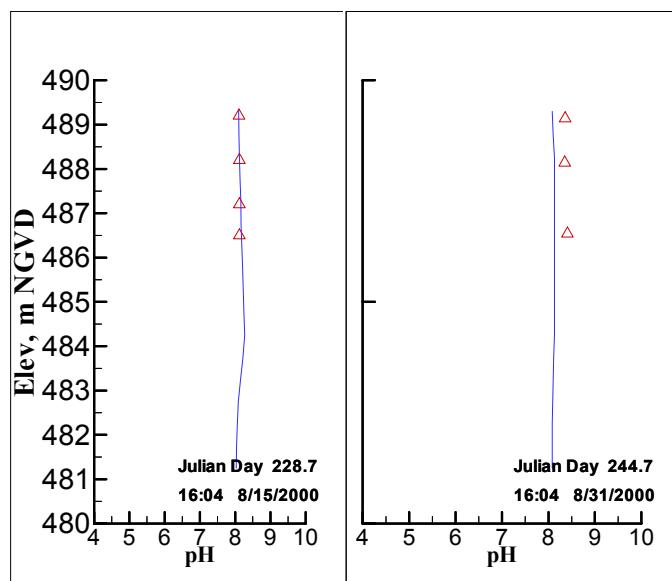


Figure 125. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 2.1 miles upstream of Nine Mile Dam (Segment 143).

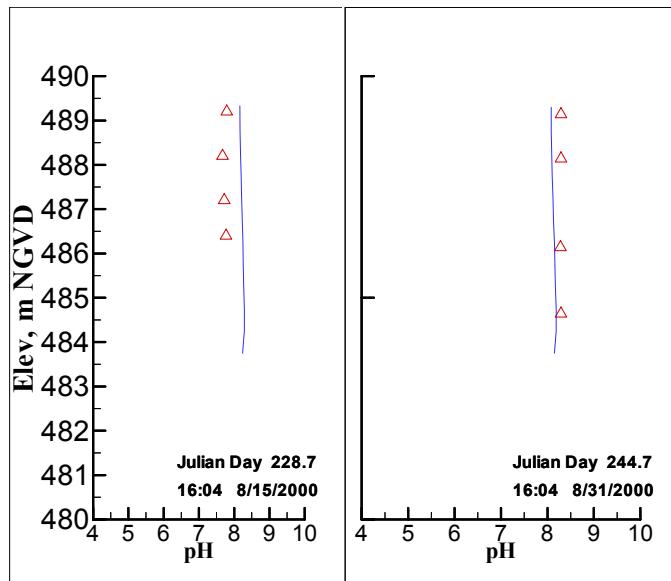


Figure 126. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 2.8 miles upstream of Nine Mile Dam (Segment 141).

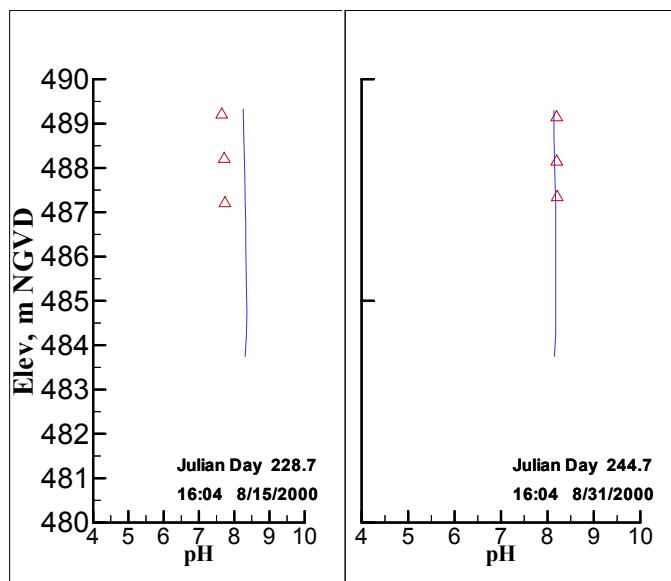


Figure 127. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 3.3 miles upstream of Nine Mile Dam (Segment 139).

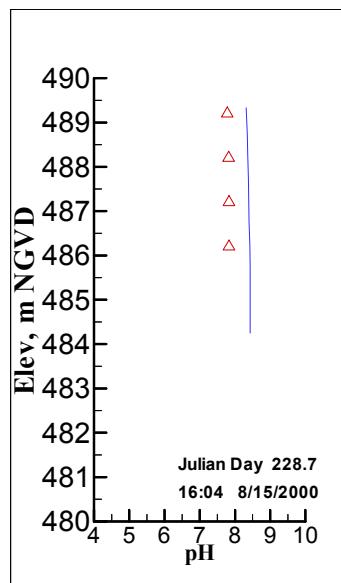


Figure 128. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 3.8 miles upstream of Nine Mile Dam (Segment 135).

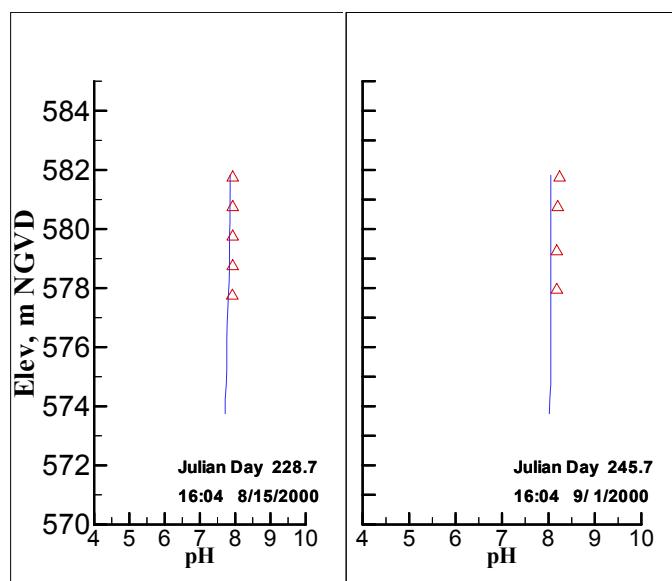


Figure 129. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 0.4 miles upstream of Upriver Dam (Segment 64).

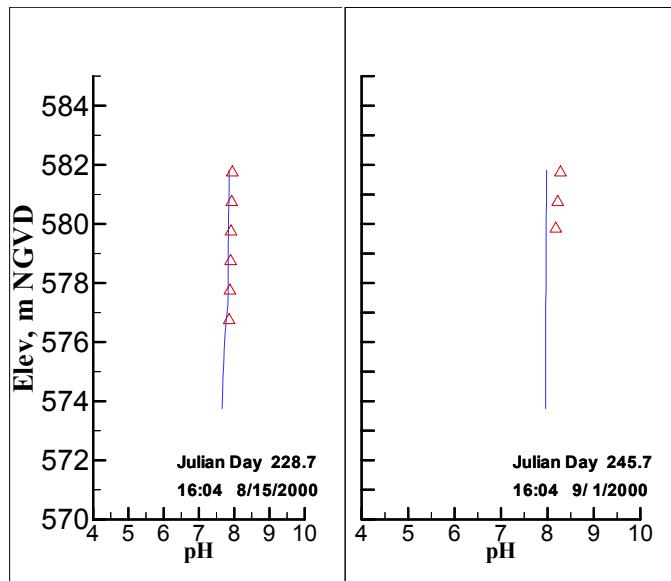


Figure 130. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 1.2 miles upstream of Upriver Dam (Segment 62).

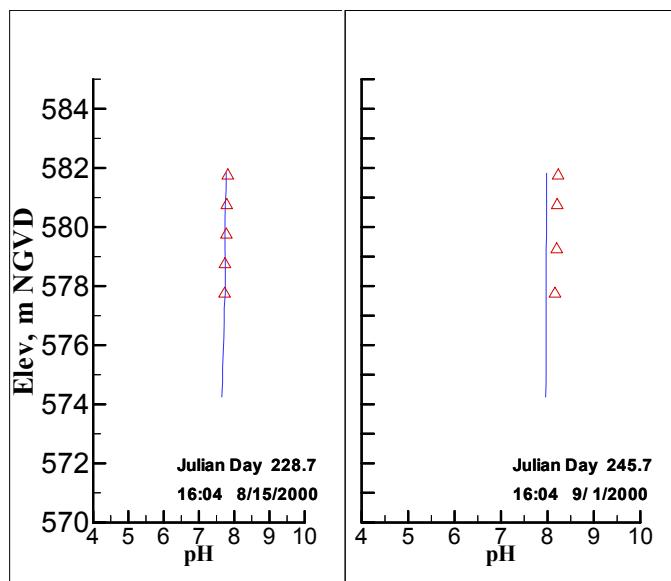


Figure 131. Comparison of model predicted vertical pH profiles and 2000 data for the Spokane River 1.8 miles upstream of Upriver Dam (Segment 60).

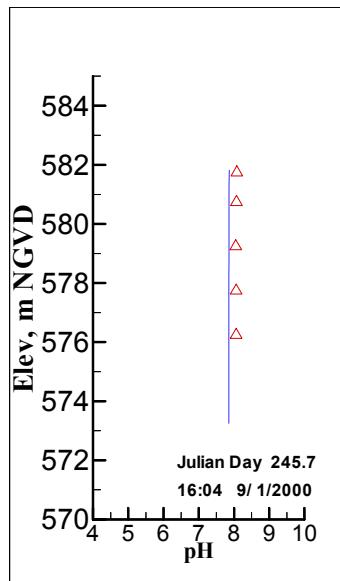


Figure 132. Comparison of model predicted vertical pH profile and 2000 data for the Spokane River 2.7 miles upstream of Upriver Dam (Segment 57).

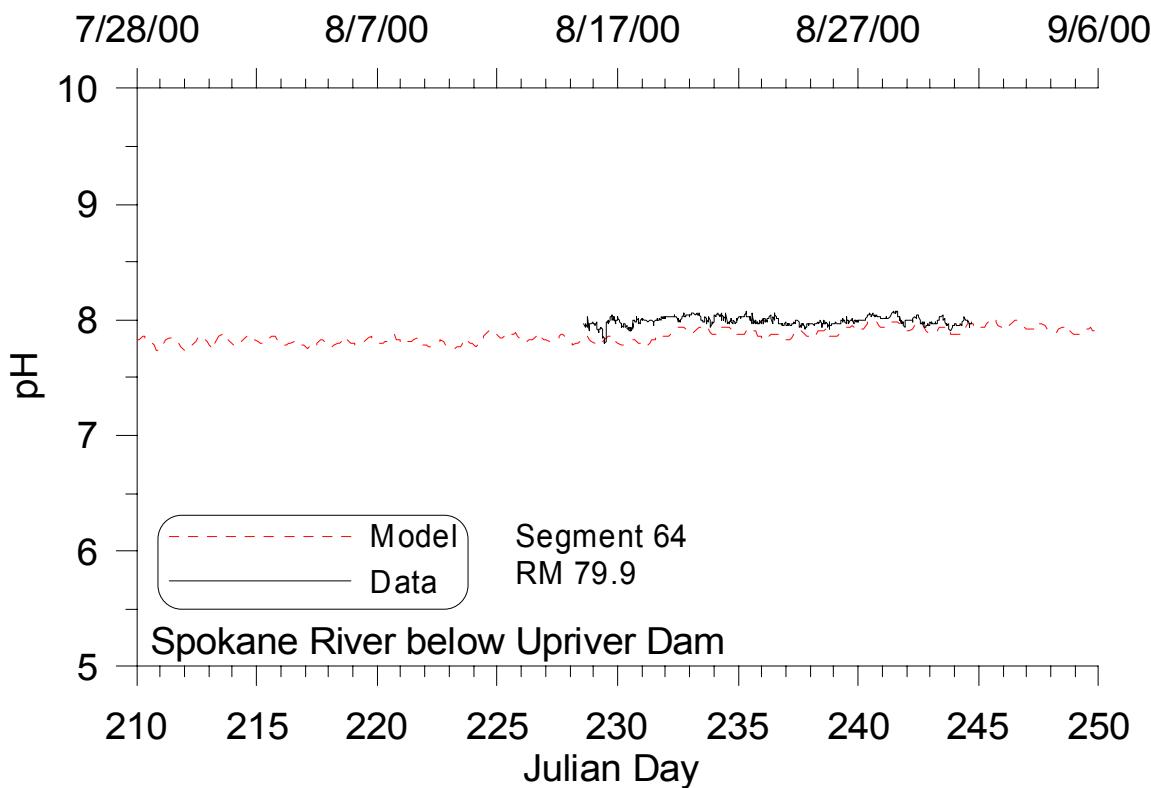


Figure 133. Comparison of model predicted pH and year 2000 continuous data for the Spokane River above Upriver Dam (Segment 64).

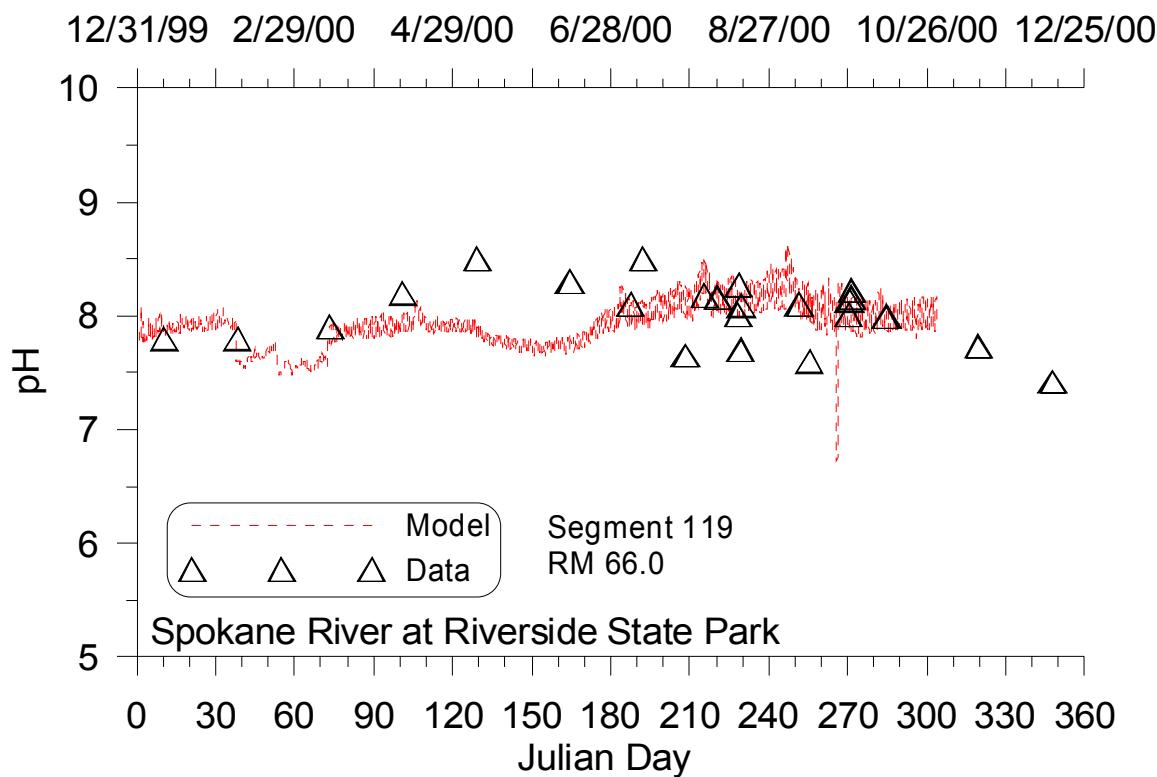


Figure 134. Comparison of model predicted pH and 2000 data for the Spokane River at Riverside State Park (Segment 119).

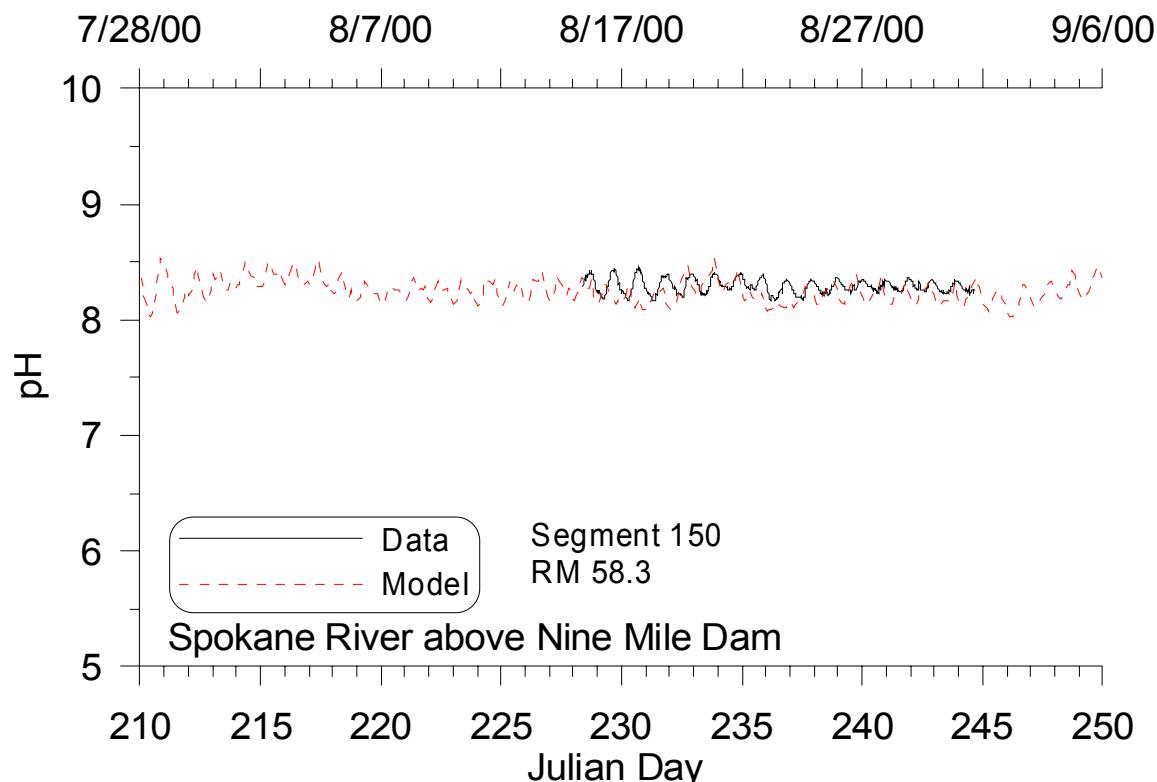


Figure 135. Comparison of model predicted pH and 2000 continuous data for the Spokane River 0.2 miles upstream Nine Mile Dam (Segment 150).

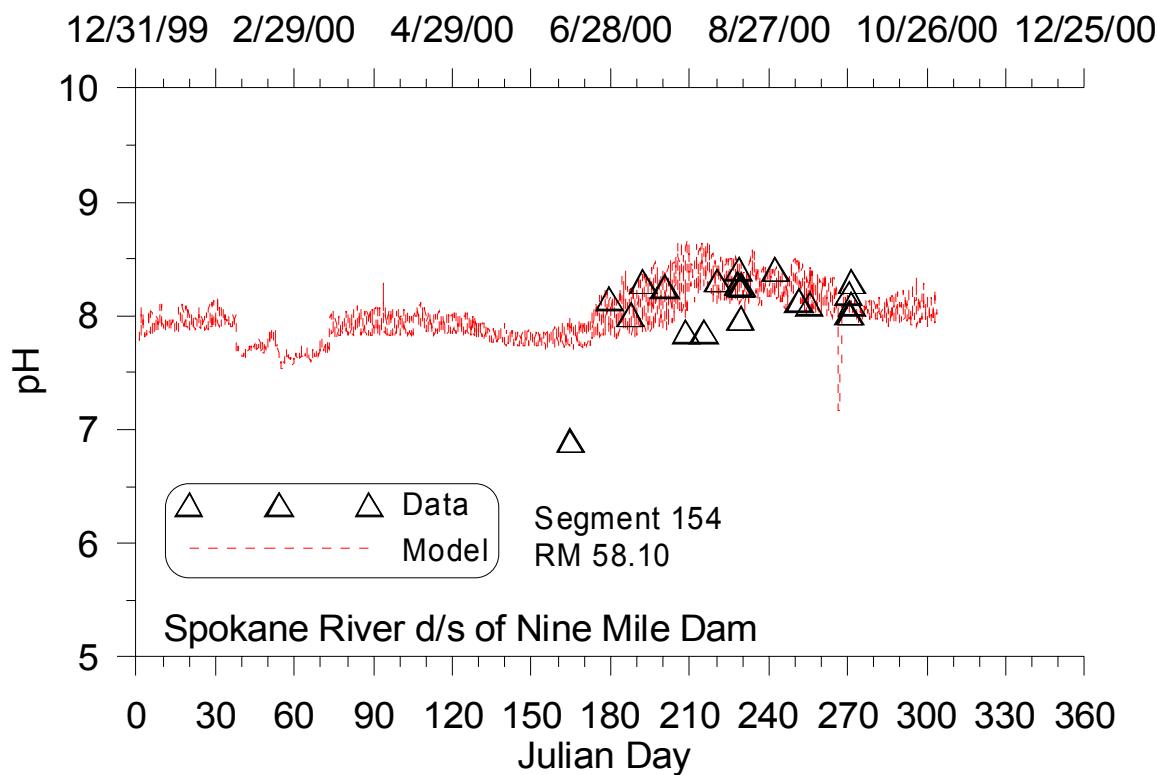


Figure 136. Comparison of model predicted pH and 2000 data for the Spokane River downstream of Nine Mile Dam (Segment 154).

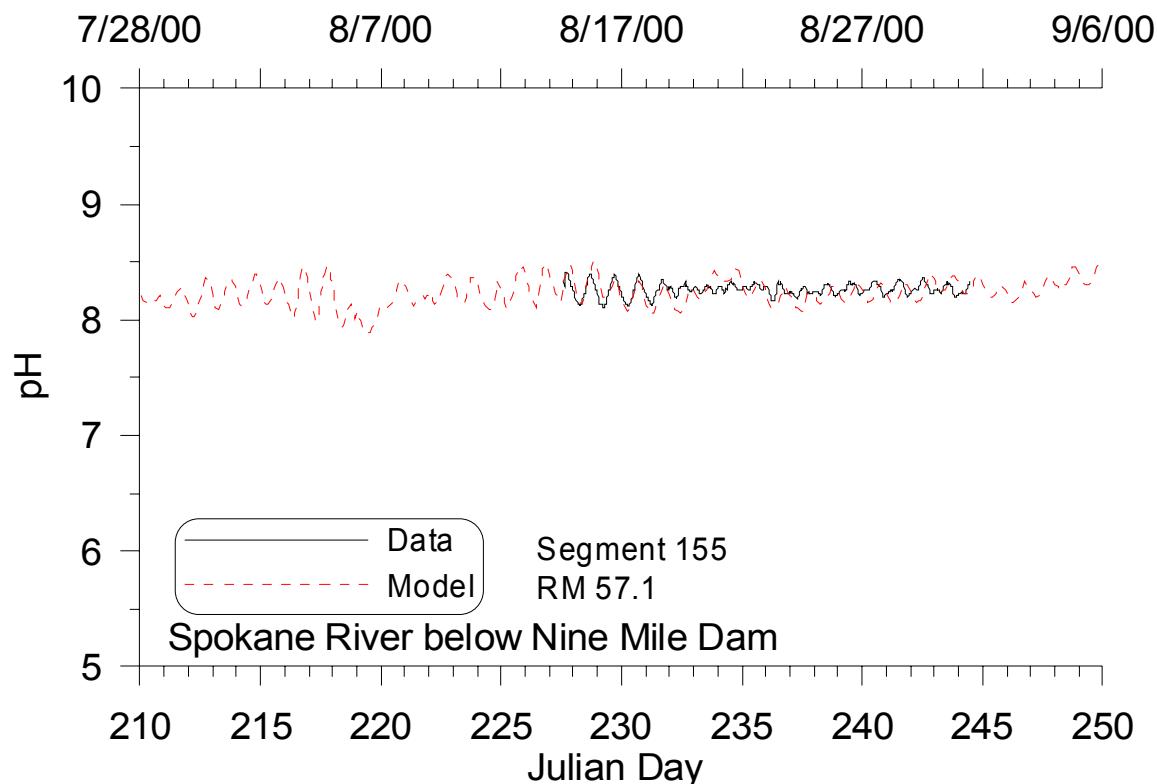


Figure 137. Comparison of model predicted pH and 2000 continuous data for the Spokane River below Nine Mile Dam (Segment 155).

Nitrite-Nitrate Nitrogen

Nitrite-nitrate nitrogen was modeled as a potential source of nitrogen for phytoplankton and periphyton. An ammonia nitrogen preference factor equation was used to predict the amount of nitrite-nitrate nitrogen uptake and ammonia nitrogen uptake of phytoplankton and periphyton. This equation was discussed in further detail in the ammonia nitrogen section.

Year 1991

Nitrite-Nitrate nitrogen vertical profiles were collected in Long Lake in 1991 for 12 different days. Additional profiles were not collected upstream of Long Lake. Figure 138 to Figure 142 show nitrite-nitrate profile data and model results for five locations in Long Lake from RM 32.7 to 54.5. Figure 143 shows nitrite-nitrate time series data compared with model results for RM 66. Figure 144 shows nitrite-nitrate time series data compared with model results for RM 58.1. Table 34 shows AME and RMS error statistics for the nitrite-nitrate vertical profiles and Table 35 includes error statistics for the time series comparisons.

Table 34. Nitrite-Nitrate Nitrogen profile error statistics, 1991

Site	n, # of data profile comparisons	NO2-NO3-N model –data error statistics	
		AME, mg/L	RMS, mg/L
LL0	12	0.10	0.11
LL1	12	0.12	0.13
LL2	12	0.12	0.13
LL3	12	0.21	0.22
LL4	12	0.16	0.18

Table 35. Nitrite-Nitrate Nitrogen time series error statistics, 1991

Site	n, # of data comparisons	NO2-NO3-N model –data error statistics	
		AME, mg/L	RMS error, mg/L
SPK66.0	13	0.10	0.15
SPK58.1	17	0.10	0.12

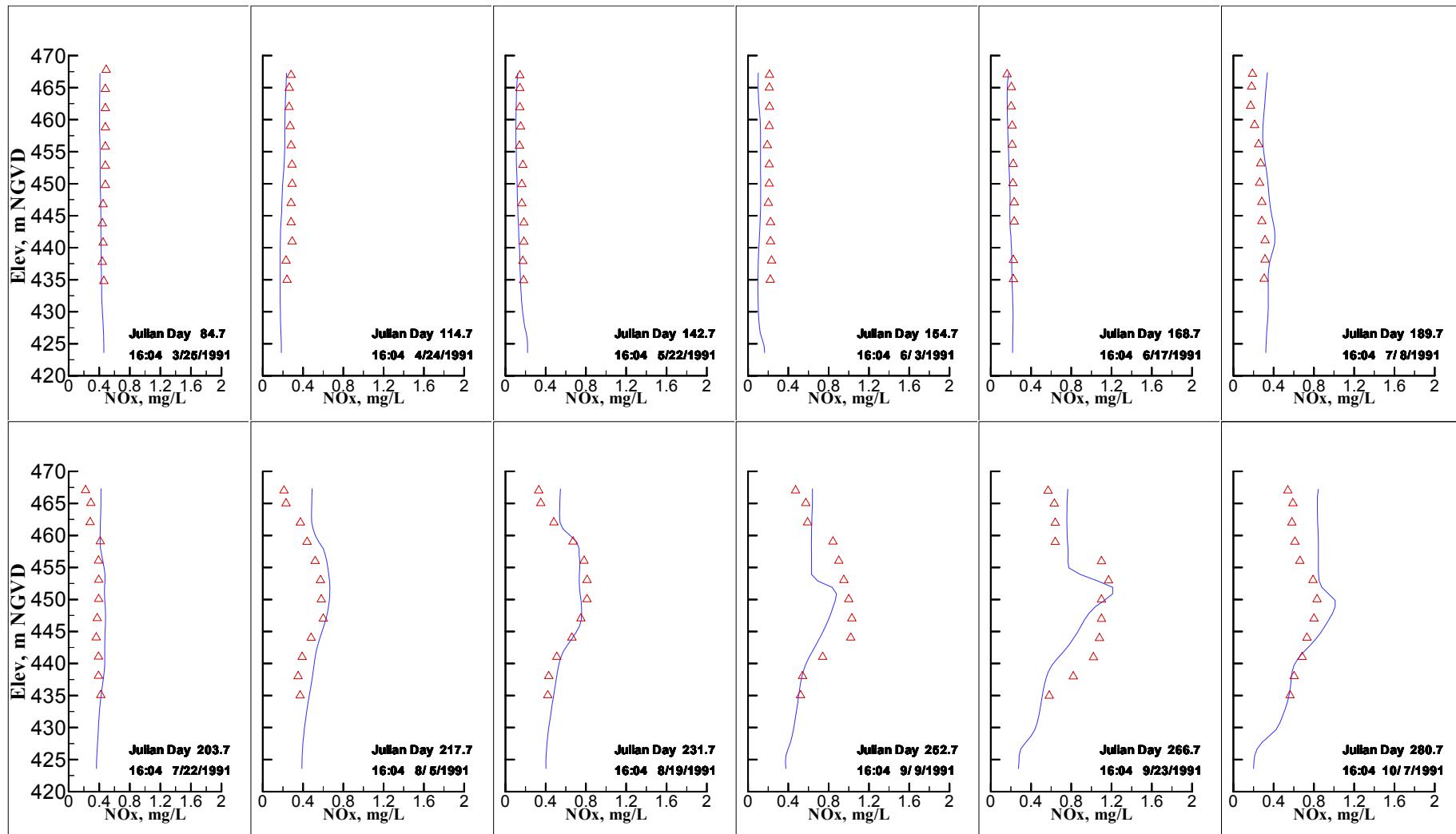


Figure 138. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 1991 data for Long Lake at Station 0 (Segment 187).

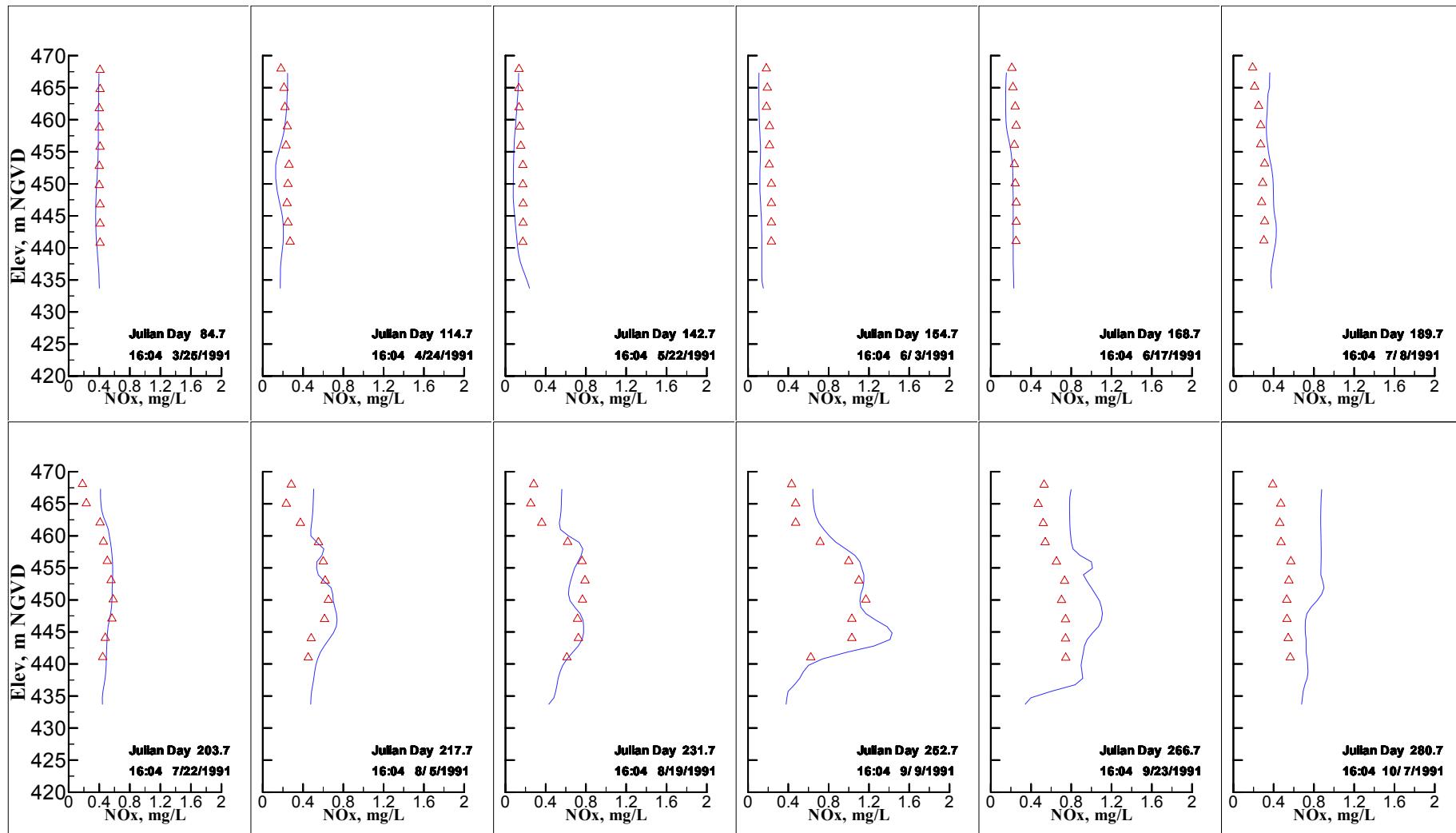


Figure 139. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 1991 data for Long Lake at Station 1 (Segment 180).

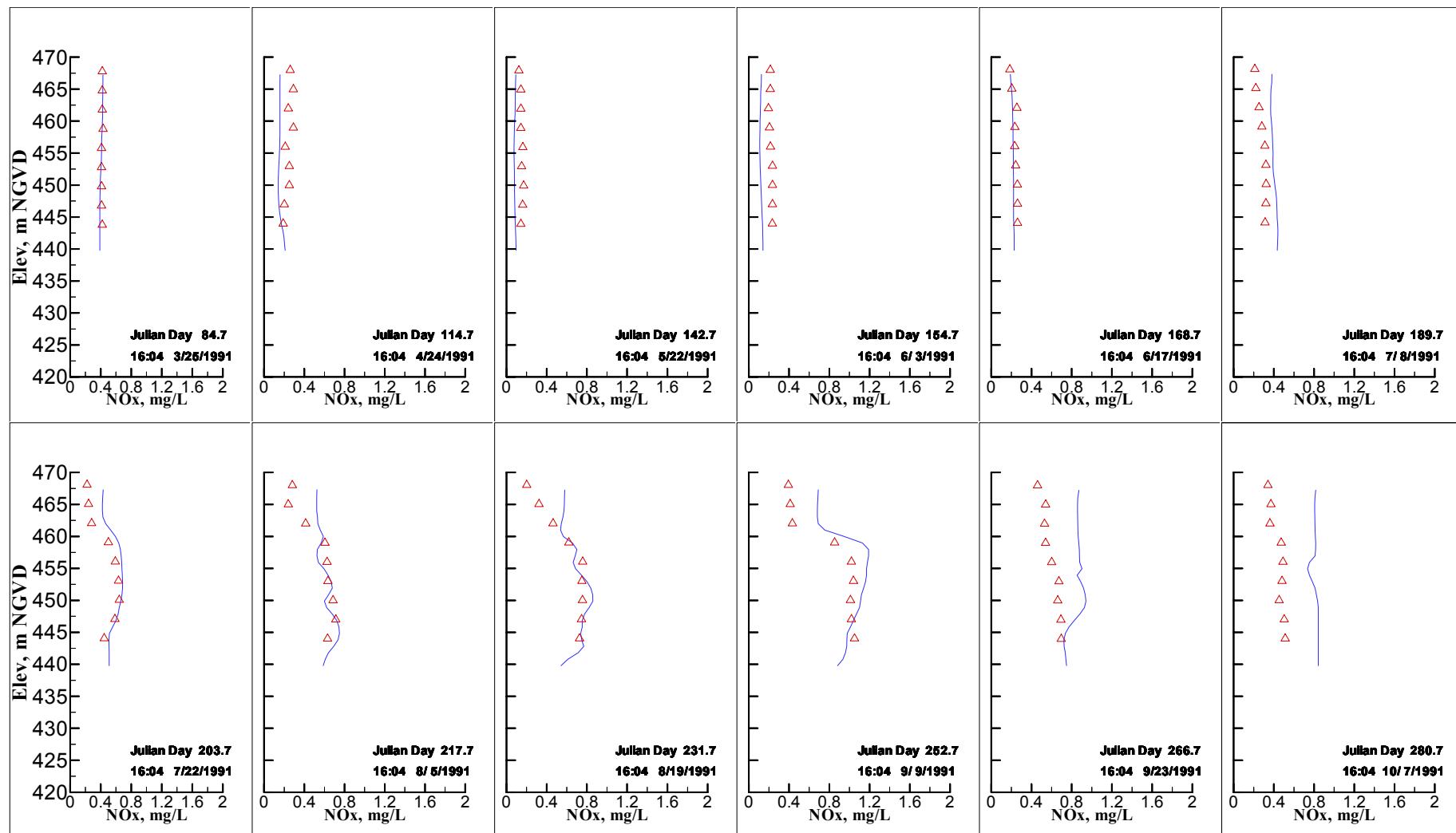


Figure 140. Comparison of model predicted vertical nitrite-nitrate profiles and 1991 data for Long Lake at Station 2 (Segment 174).

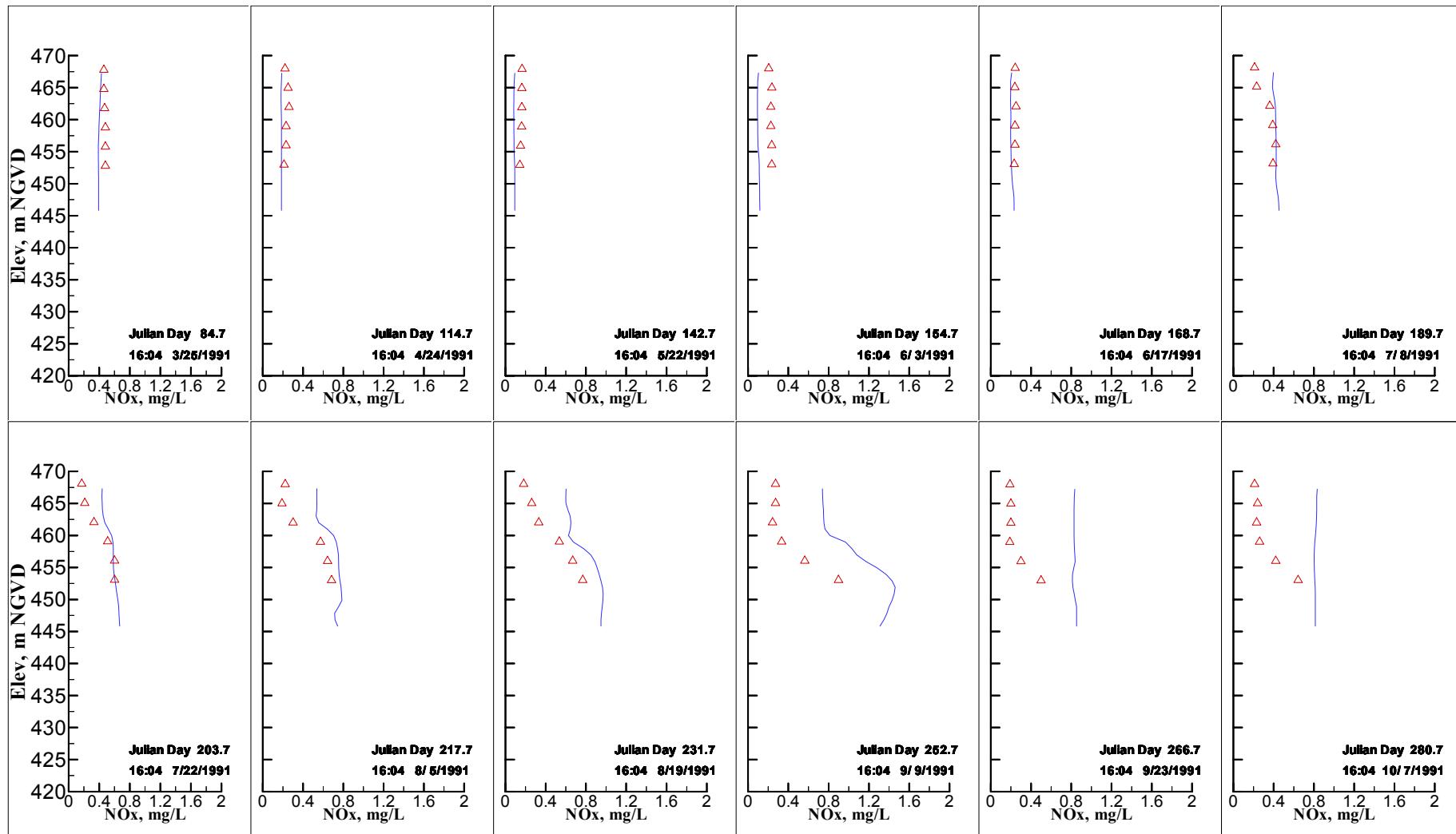


Figure 141. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 1991 data for Long Lake at Station 3 (Segment 168).

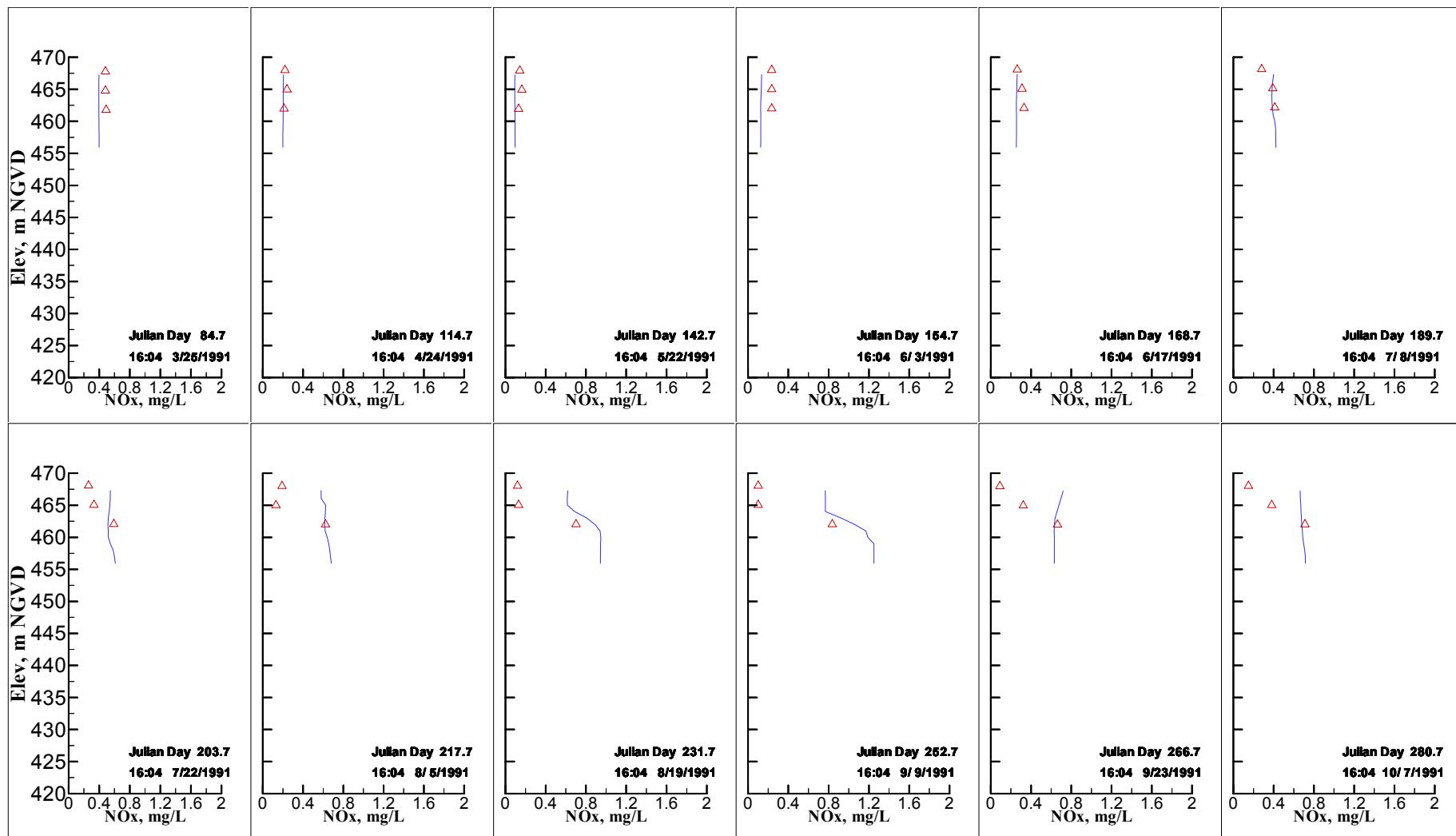


Figure 142. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 1991 data for Long Lake at Station 4 (Segment 161).

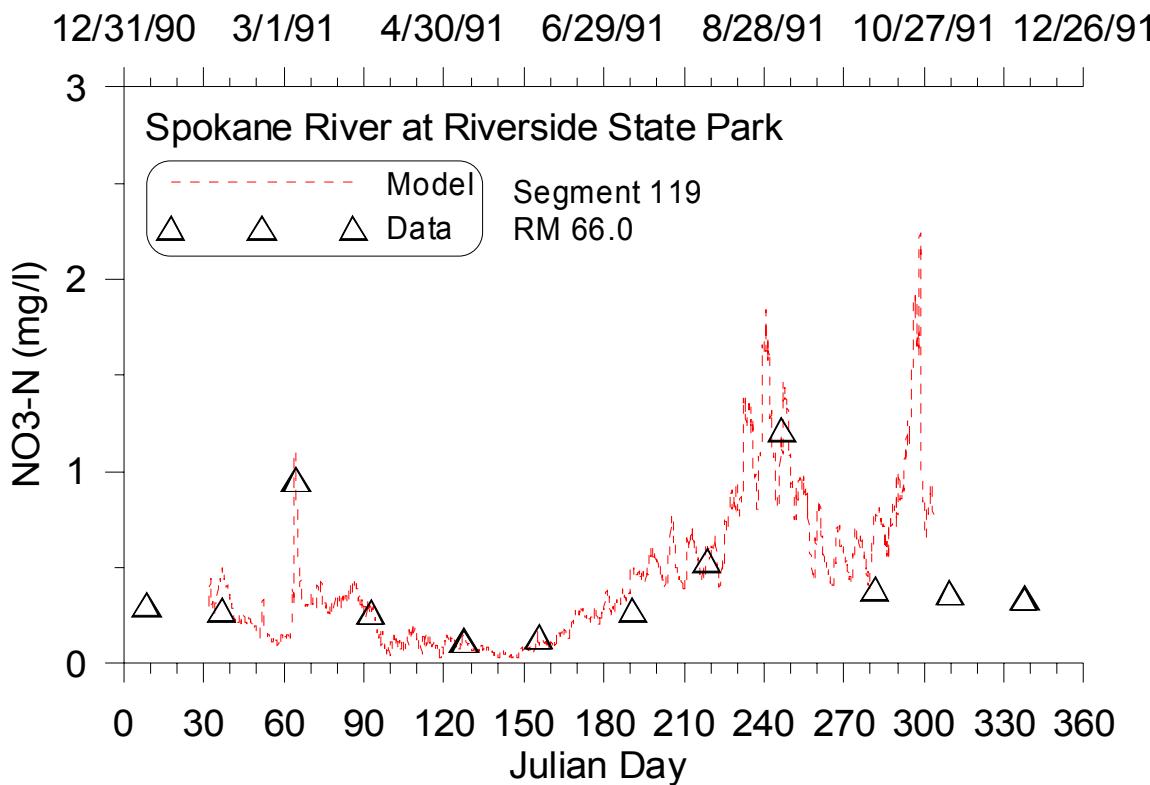


Figure 143. Comparison of model predicted nitrite-nitrate nitrogen and 1991 data for Spokane River at Riverside State Park (Segment 119).

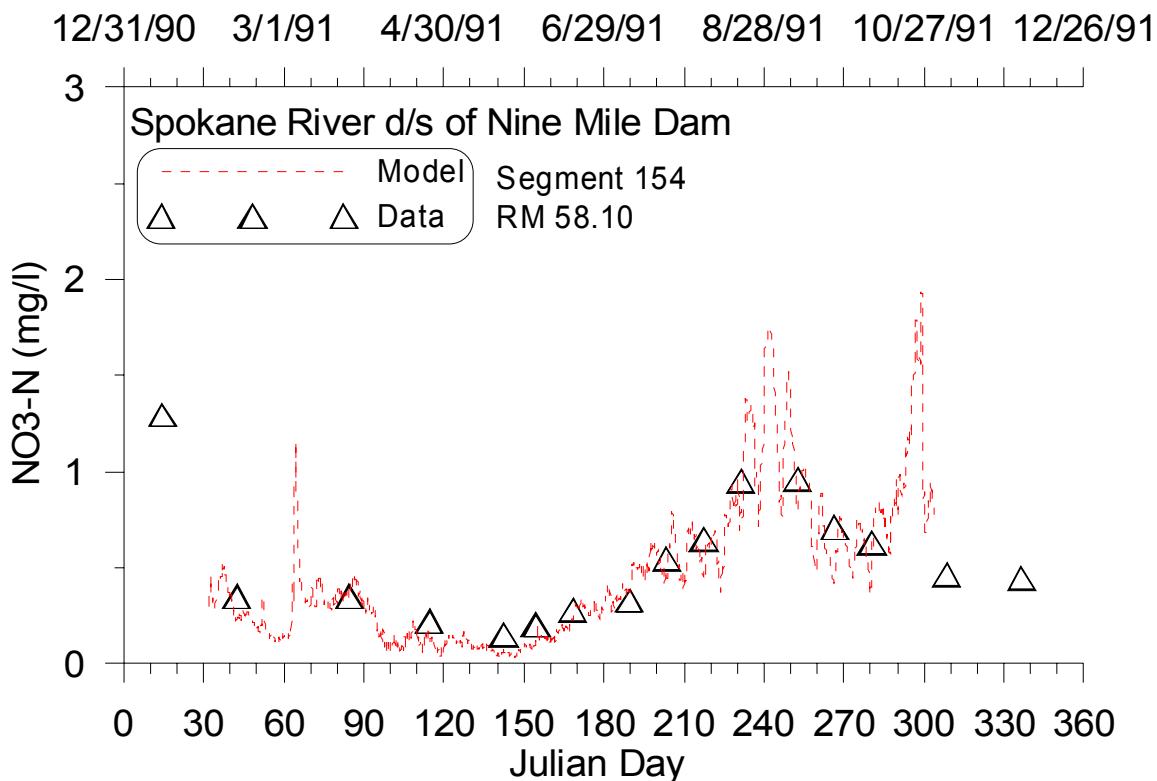


Figure 144. Comparison of model predicted nitrite-nitrate nitrogen and 1991 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Year 2000

Nitrite-Nitrate nitrogen vertical profiles were collected in Long Lake in 2000. Figure 145 to Figure 150 show nitrite-nitrate profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. Figure 151 shows nitrite-nitrate time series data compared with model results for RM 66. Figure 152 shows nitrite-nitrate time series data compared with model results for RM 58.1. Table 36 shows AME and RMS error statistics for the nitrite-nitrate vertical profiles and Table 37 includes error statistics for the time series comparisons.

Table 36. Nitrite-Nitrate nitrogen profile error statistics, 2000

Site	n, # of data profile comparisons	NO ₂ -NO ₃ -N model -data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	2	0.15	0.20
LL1	6	0.12	0.15
LL2	2	0.17	0.20
LL3	6	0.18	0.21
LL4	2	0.42	0.43
LL5	2	0.27	0.28

Table 37. Nitrite-Nitrate nitrogen time series error statistics, 2000

Site	n, # of data comparisons	NO ₂ -NO ₃ -N model -data error statistics	
		AME, mg/L	RMS, mg/L
SPK66.0	24	0.19	0.26
SPK58.1	20	0.26	0.30

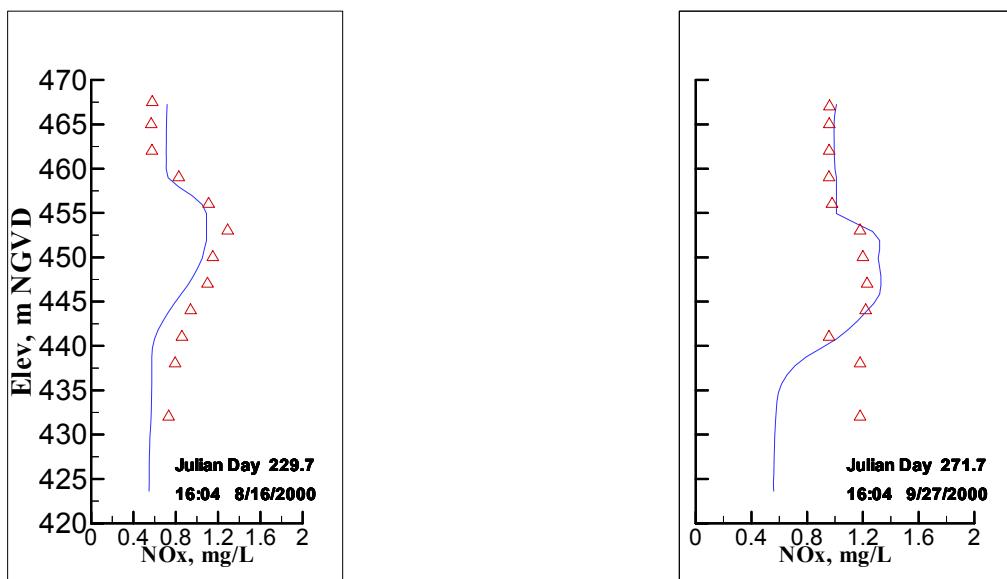


Figure 145. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 2000 data for Long Lake at Station 0 (Segment 187).

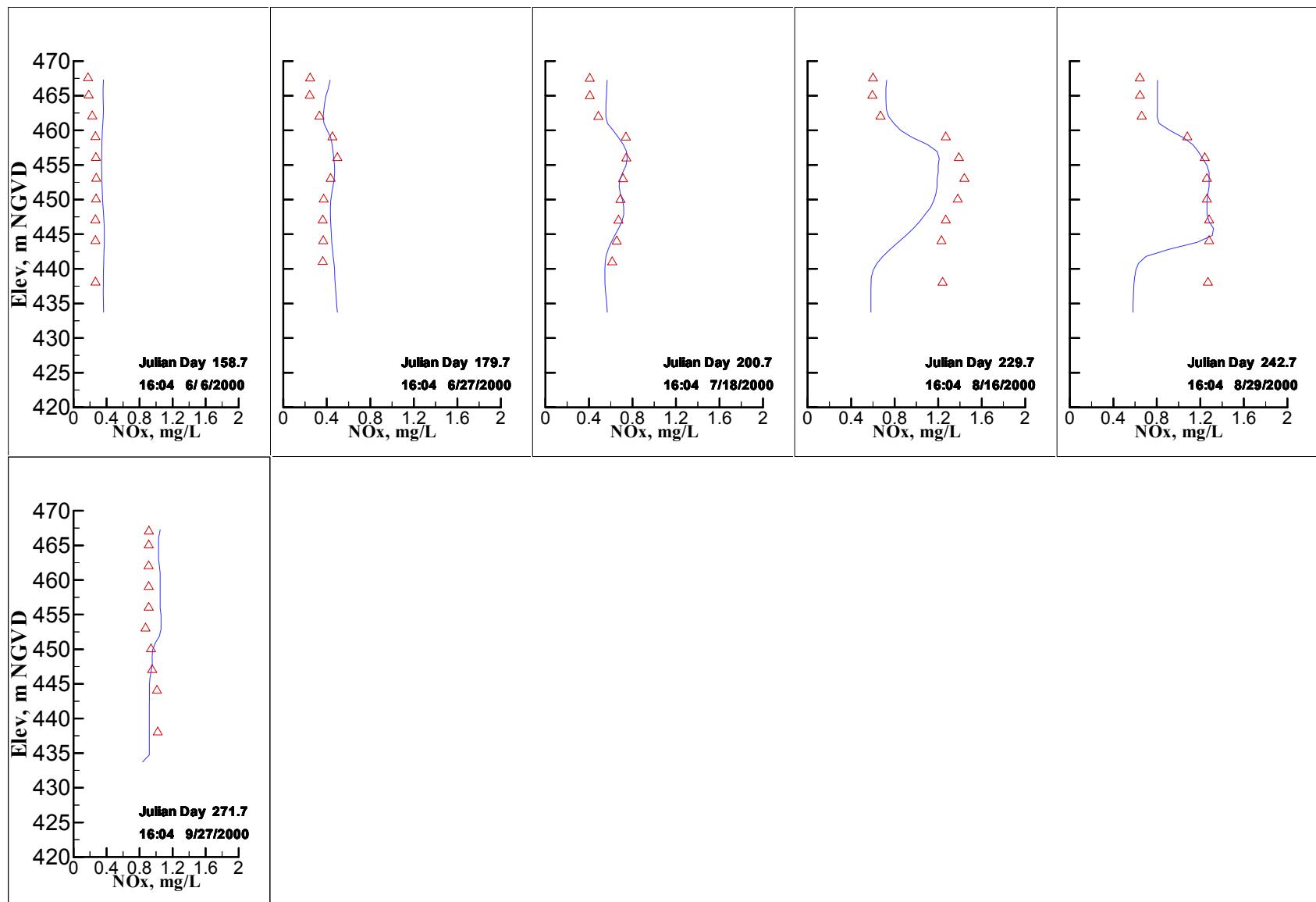


Figure 146. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 2000 data for Long Lake at Station 1 (Segment 180).

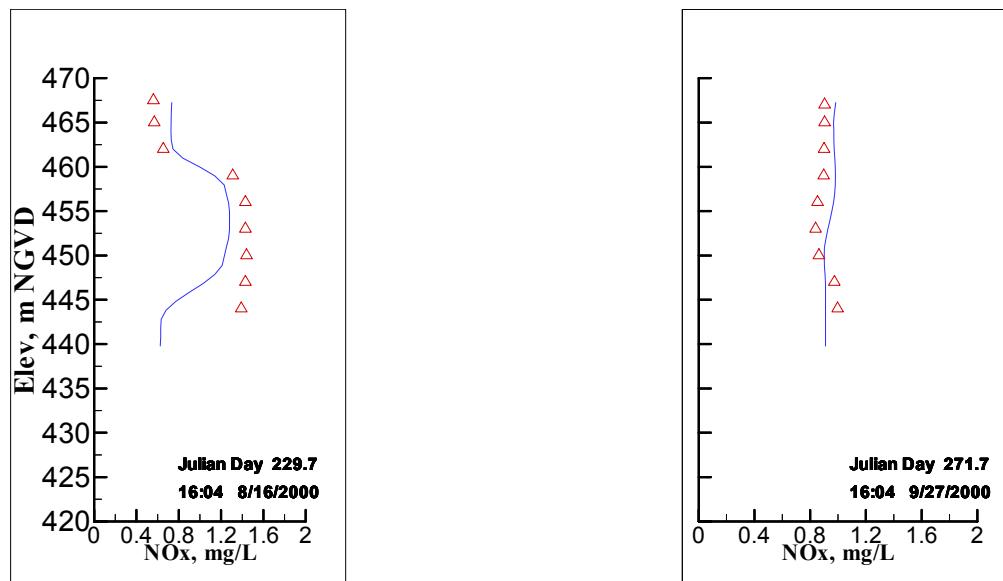


Figure 147. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 2000 data for Long Lake at Station 2 (Segment 174).

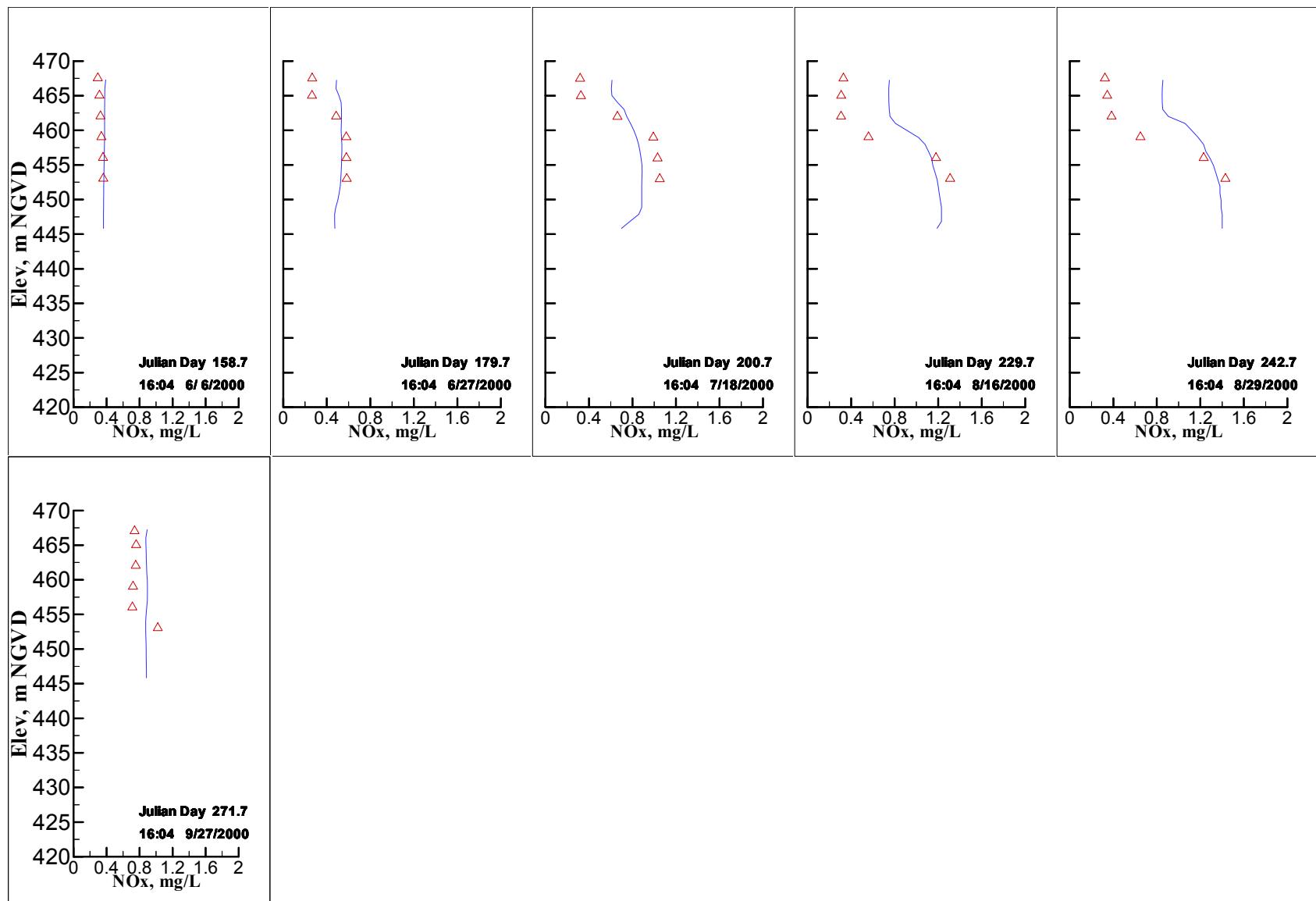


Figure 148. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 2000 data for Long Lake at Station 3 (Segment 168).

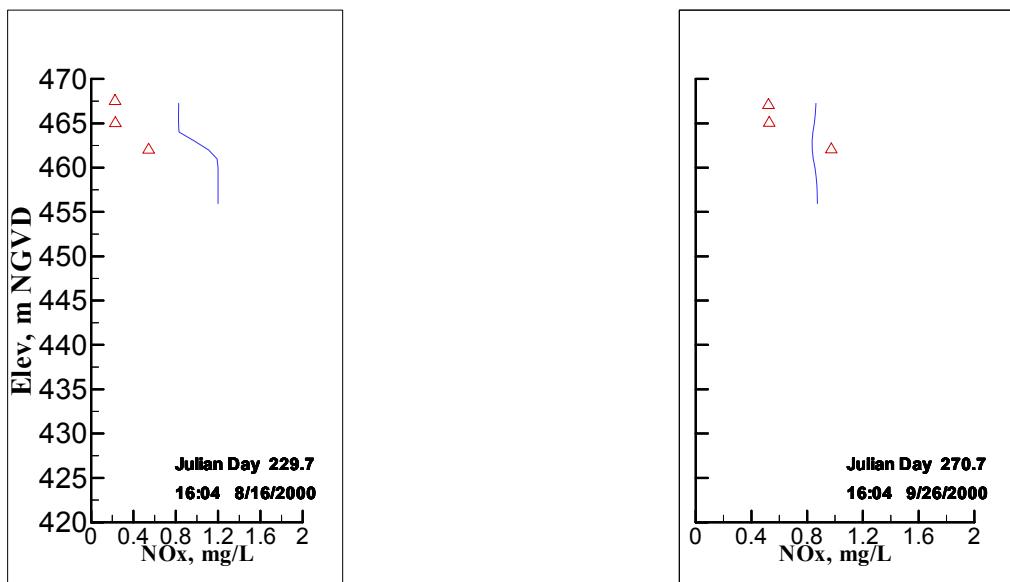


Figure 149. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 2000 data for Long Lake at Station 4 (Segment 161).

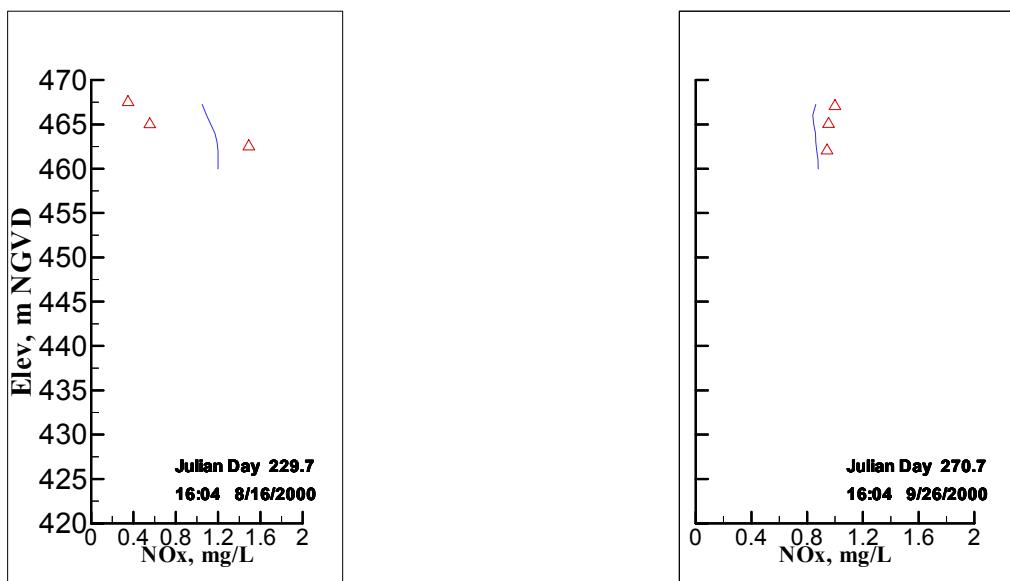


Figure 150. Comparison of model predicted vertical nitrite-nitrate nitrogen profiles and 2000 data for Long Lake at Station 5 (Segment 157).

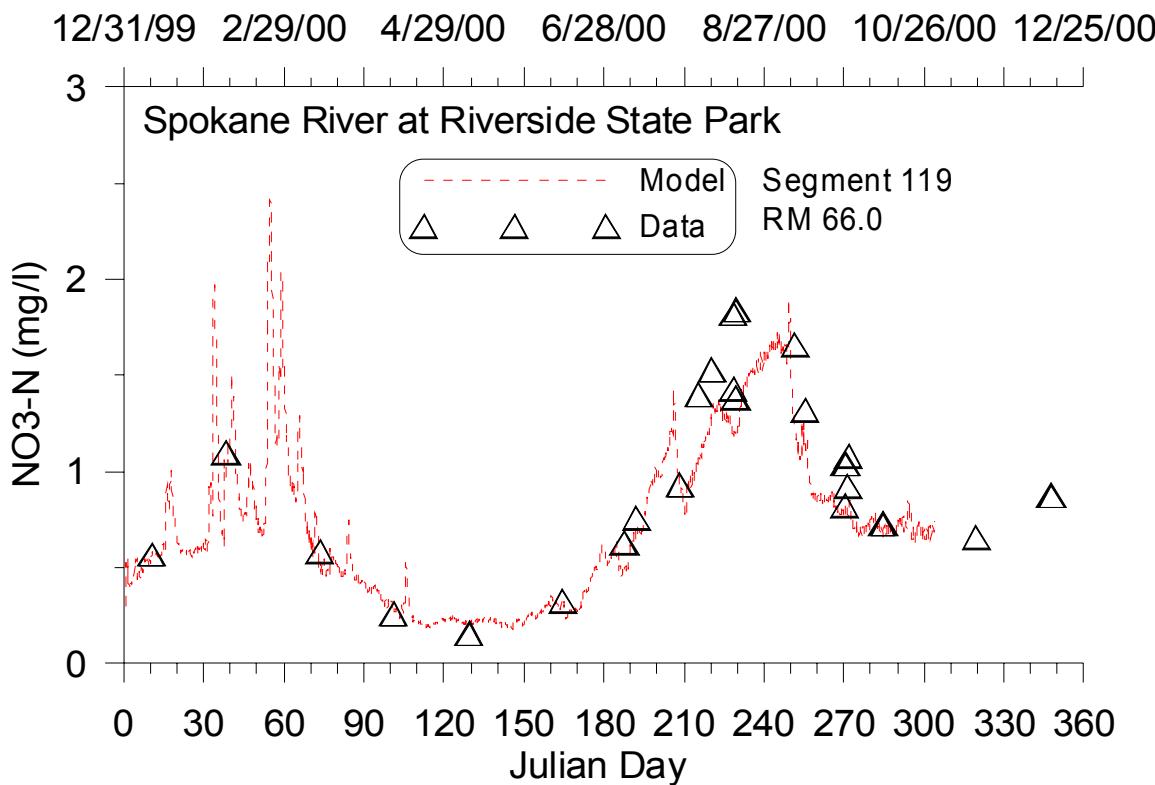


Figure 151. Comparison of model predicted nitrite-nitrate nitrogen and 2000 data for Spokane River at Riverside State Park (Segment 119).

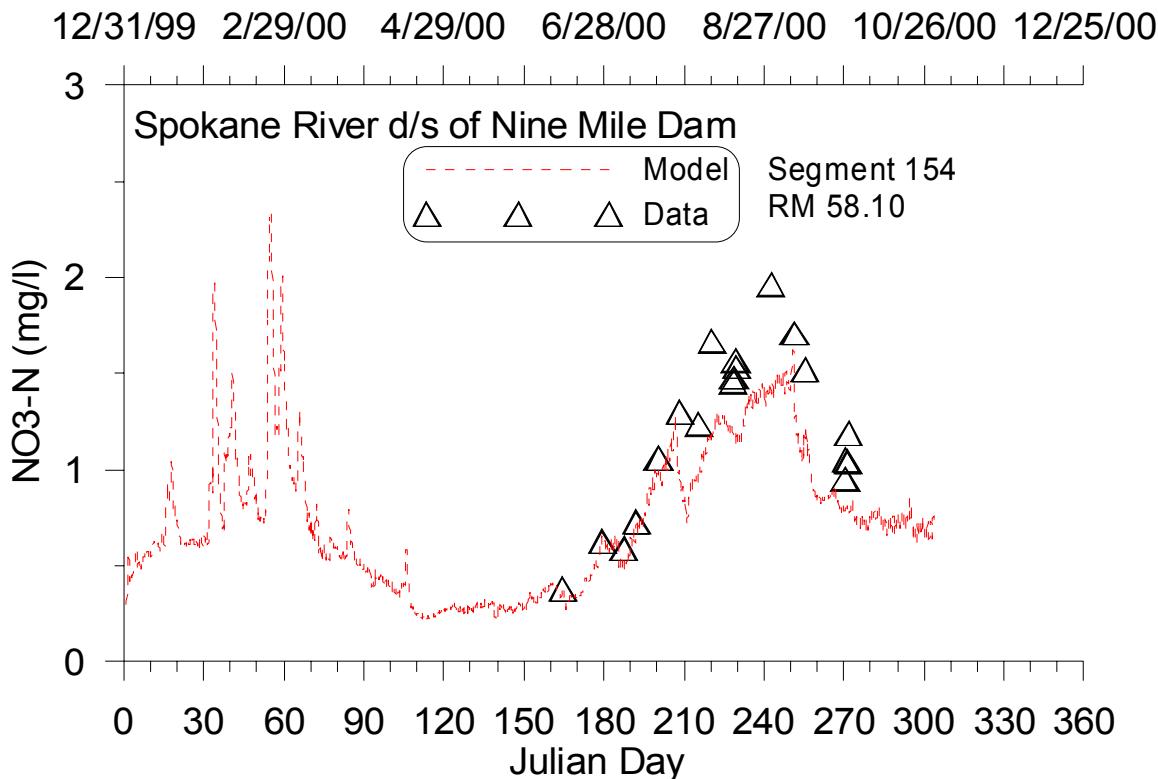


Figure 152. Comparison of model predicted nitrite-nitrate nitrogen and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Ammonia Nitrogen

Ammonia nitrogen was modeled using a nitrification rate of 0.4 d^{-1} . The periphyton and phytoplankton nitrogen preference for ammonia nitrogen was modeled using the following equation from Thomann and Fitzpatrick. (1982)

$$P_{\text{NH}_3} = C_{\text{NH}_3} \frac{C_{\text{NO}_x}}{(K_{\text{mN}} + C_{\text{NH}_3})(K_{\text{mN}} + C_{\text{NO}_x})} + C_{\text{NH}_3} \frac{K_{\text{mN}}}{(C_{\text{NH}_3} + C_{\text{NO}_x})(K_{\text{mN}} + C_{\text{NO}_x})}$$

P_{NH_3} : Ammonia preference factor

K_{mN} : N half-saturation coefficient (mg/l)

C_{NH_3} : Ammonia nitrogen concentration (mg/l)

C_{NO_x} : Nitrate-nitrite nitrogen concentration (mg/l)

The nitrite-nitrate nitrogen preference factor P_{NO_x} was then calculated from:

$$P_{\text{NO}_x} = 1 - P_{\text{NH}_3}$$

Figure 153 shows plots of NH4N preference factors for periphyton with nitrogen half-saturation coefficient values of 0.001 mg/l and 0.002 mg/l and a nitrate-nitrite nitrogen concentration of 0.1 mg/l. The nitrogen half-saturation coefficient used in the ammonia preference equation was 0.001 mg/l.

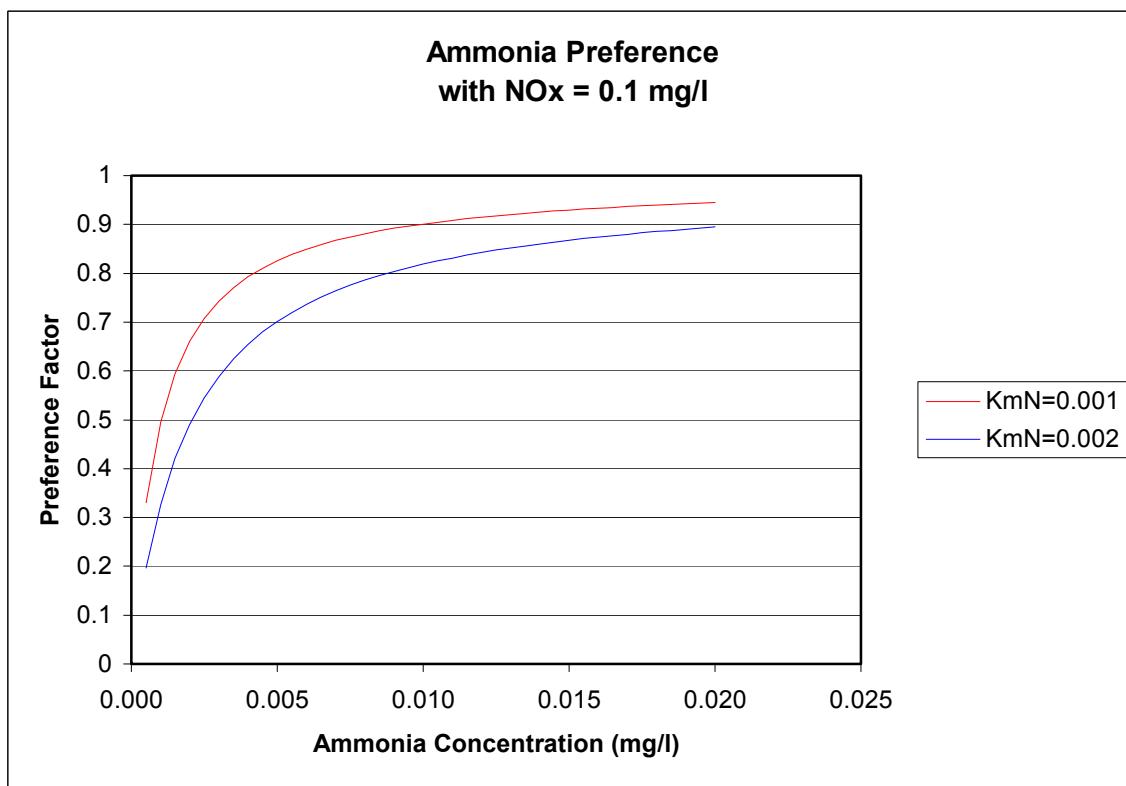


Figure 153. Plot of NH4N preference factor for epiphyton with nitrogen half-saturation coefficient values of 0.001 mg/l and 0.002 mg/l and a nitrate nitrogen concentration of 0.1 mg/l.

Year 1991

Ammonia nitrogen vertical profiles were collected in Long Lake in 1991 for 12 different days. Additional profiles were not collected upstream of Long Lake in 1991. Figure 154 to Figure 158 show ammonia nitrogen profile data and model results for five locations in Long Lake from RM 32.7 to 54.5. Figure 159 shows ammonia nitrogen time series data compared with model results for RM 66. Figure 160 shows ammonia nitrogen time series data compared with model results for RM 58.1. Table 38 shows AME and RMS error statistics for the ammonia nitrogen vertical profiles and Table 39 includes error statistics for the time series comparisons.

Table 38. Ammonia Nitrogen profile error statistics, 1991

Site	n, # of data profile comparisons	NH4-N model –data error statistics	
		AME, mg/L	RMS, mg/L
LL0	12	0.021	0.024
LL1	12	0.036	0.045
LL2	12	0.038	0.046
LL3	12	0.035	0.040
LL4	12	0.029	0.032

Table 39. Ammonia Nitrogen time series error statistics, 1991

Site	n, # of data comparisons	NH4-N model –data error statistics	
		AME, mg/L	RMS error, mg/L
SPK66.0	13	0.048	0.097
SPK58.1	17	0.032	0.039

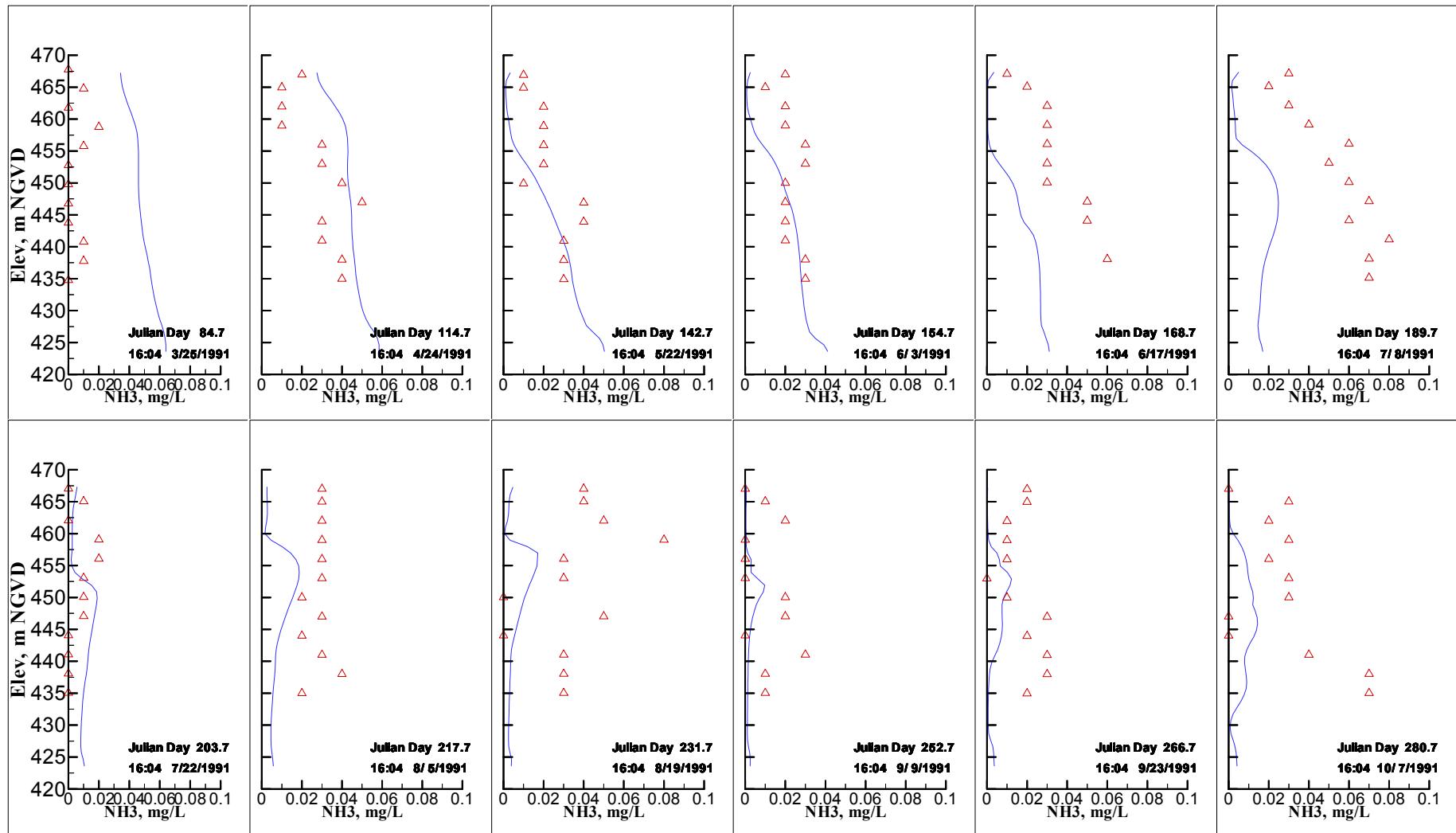


Figure 154. Comparison of model predicted vertical ammonia nitrogen profiles and 1991 data for Long Lake at Station 0 (Segment 187).

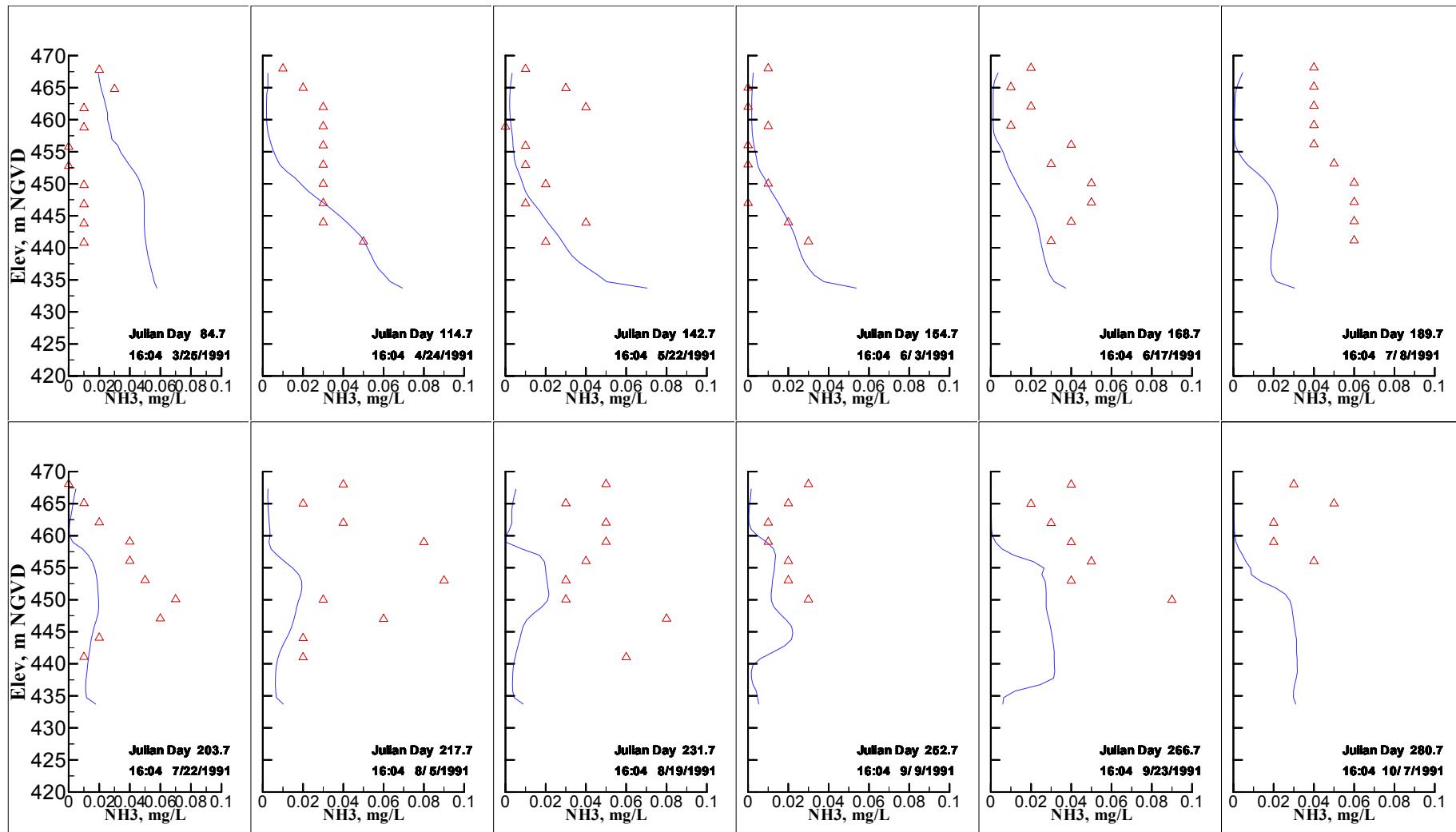


Figure 155. Comparison of model predicted vertical ammonia profiles and 1991 data for Long Lake at Station 1 (Segment 180).

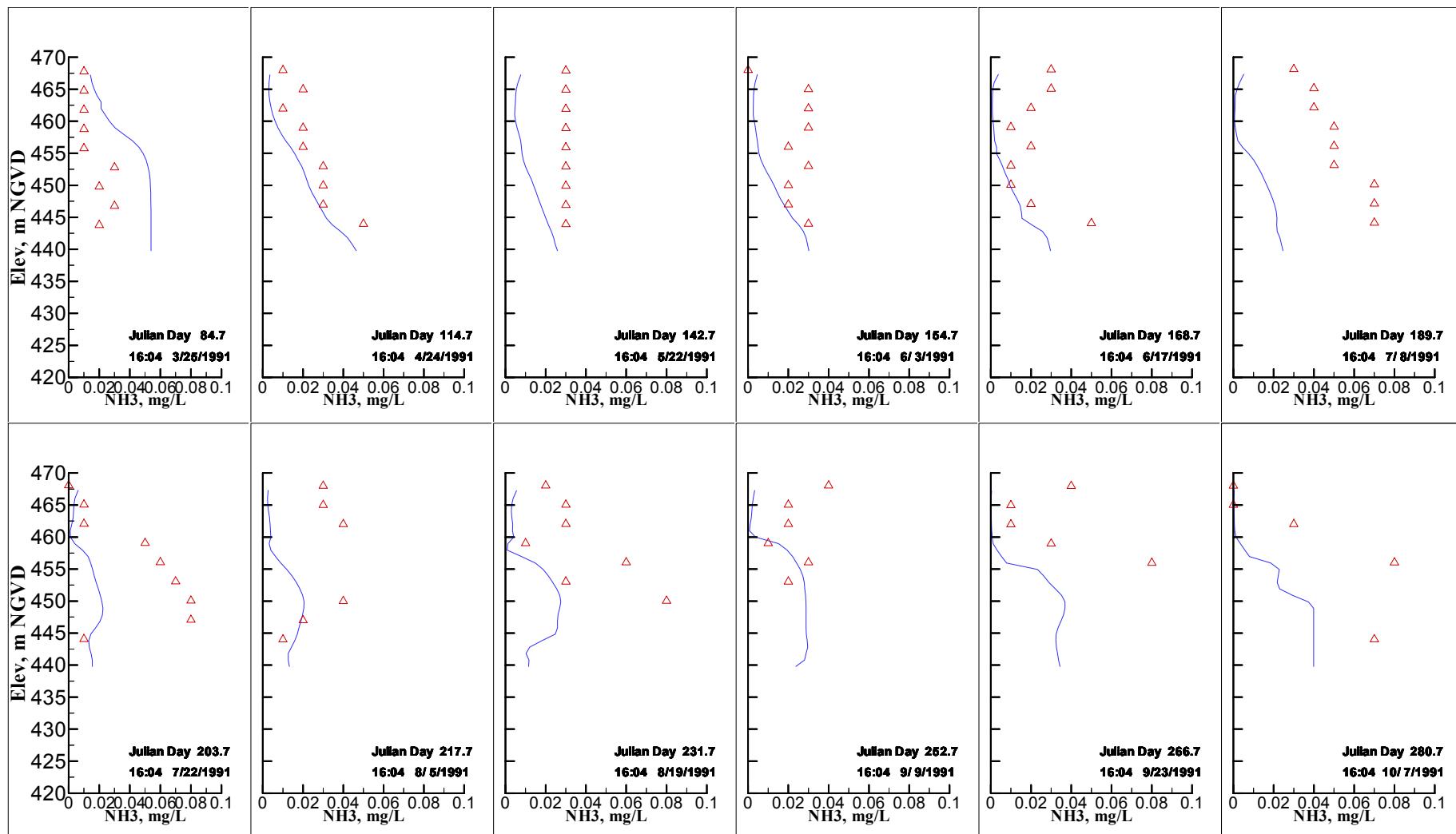


Figure 156. Comparison of model predicted vertical ammonia nitrogen profiles and 1991 data for Long Lake at Station 2 (Segment 174).

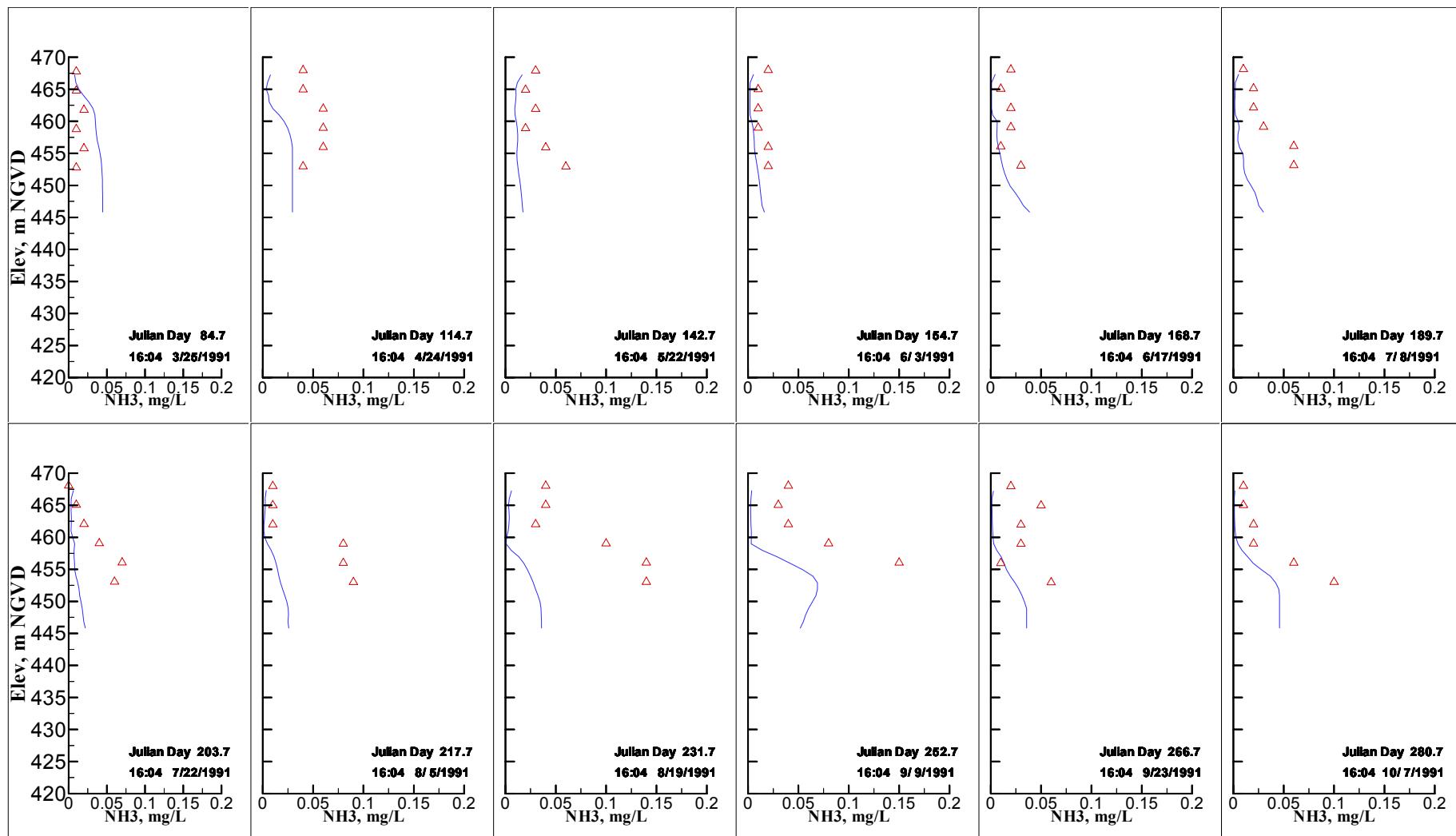


Figure 157. Comparison of model predicted vertical ammonia nitrogen profiles and 1991 data for Long Lake at Station 3 (Segment 168).

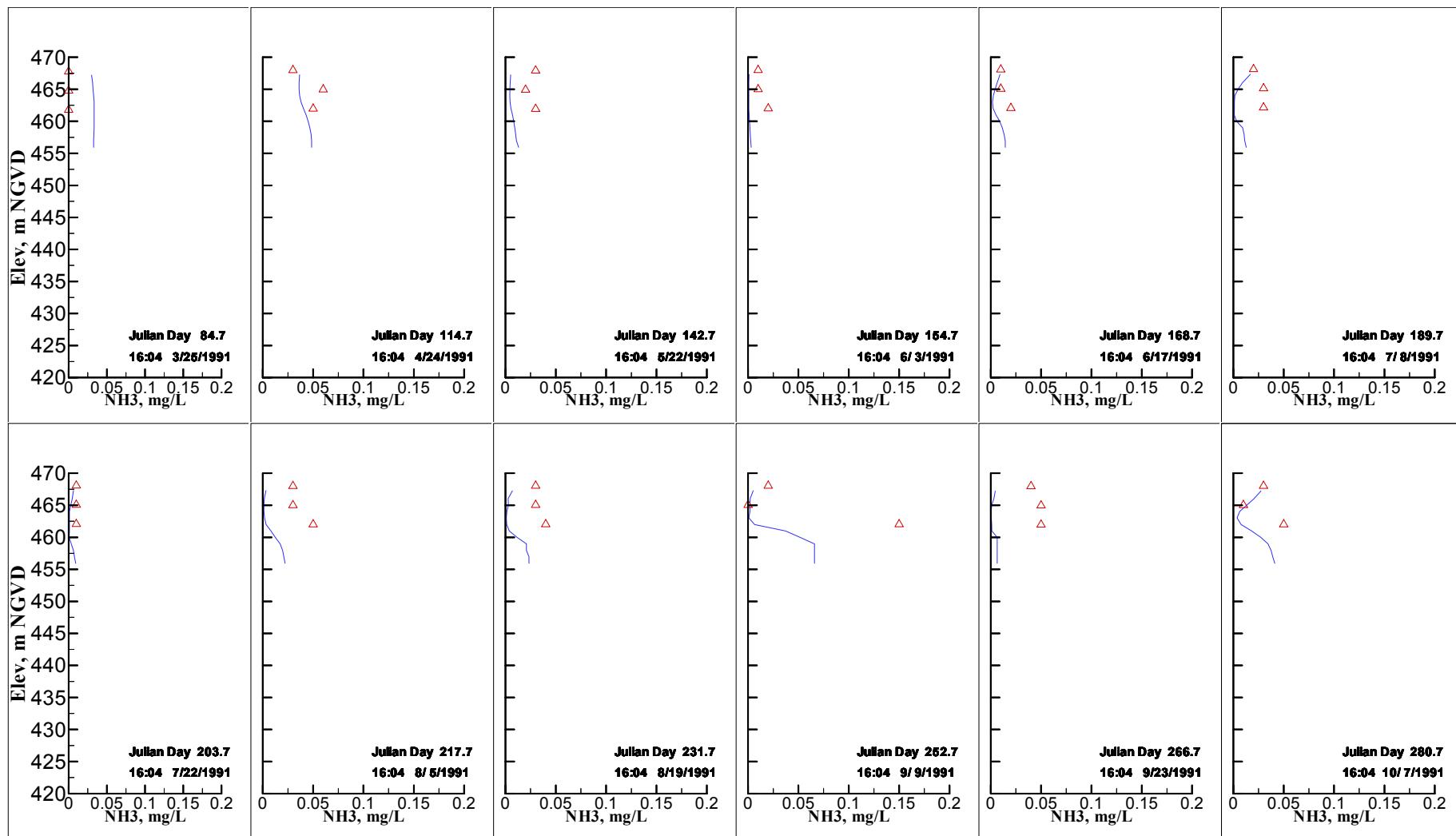


Figure 158. Comparison of model predicted vertical ammonia nitrogen profiles and 1991 data for Long Lake at Station 4 (Segment 161).

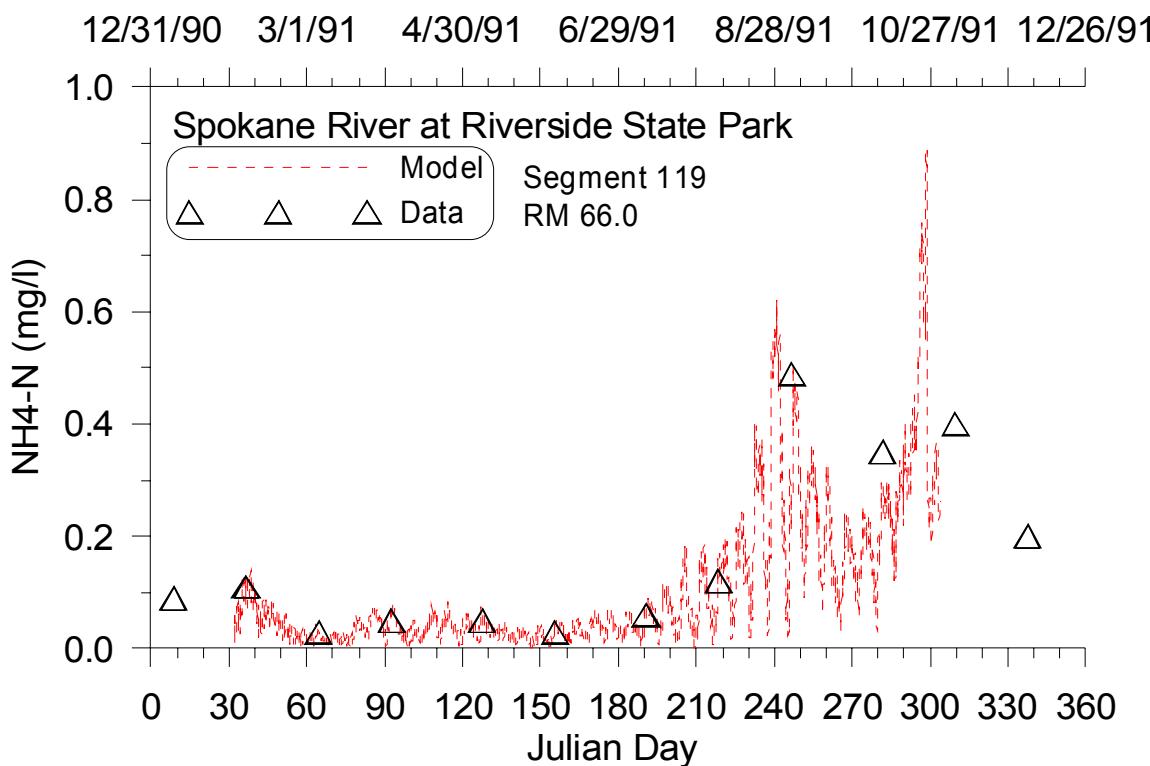


Figure 159. Comparison of model predicted ammonia nitrogen and 1991 data for Spokane River at Riverside State Park (Segment 119).

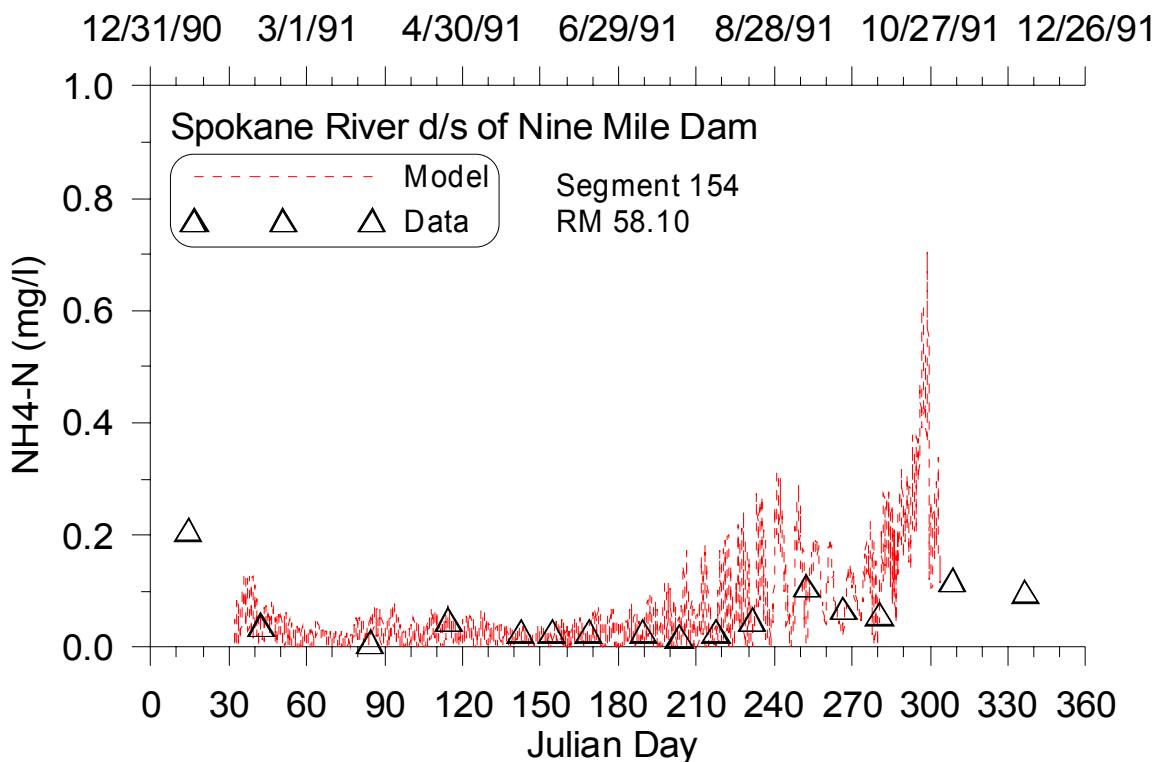


Figure 160. Comparison of model predicted ammonia nitrogen and 1991 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Year 2000

Ammonia nitrogen vertical profiles were collected for Long Lake in 2000. Additional ammonia vertical profiles were not collected upstream of Long Lake in 2000. Figure 161 to Figure 166 show ammonia nitrogen profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. The model generally did well in predicting ammonia nitrogen depletion in the euphotic zone. Figure 167 shows ammonia nitrogen time series data compared with model results for RM 66. Figure 168 shows ammonia nitrogen time series data compared with model results for RM 58.1. Figure 169 shows the nutrient concentrations for the City of Spokane WWTP discharge to the Spokane River at RM 67.4. Table 40 shows AME and RMS error statistics for the ammonia nitrogen vertical profiles and Table 41 includes error statistics for the time series comparisons.

Table 40. Ammonia nitrogen profile error statistics, 2000

Site	n, # of data profile comparisons	NH4-N model –data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	3	0.006	0.008
LL1	7	0.011	0.014
LL2	2	0.013	0.017
LL3	7	0.009	0.011
LL4	2	0.004	0.004
LL5	2	0.004	0.004

Table 41. Ammonia nitrogen time series error statistics, 2000

Site	n, # of data comparisons	NH4-N model –data error statistics	
		AME, mg/L	RMS, mg/L
SPK66.0	24	0.005	0.007
SPK58.1	20	0.005	0.007

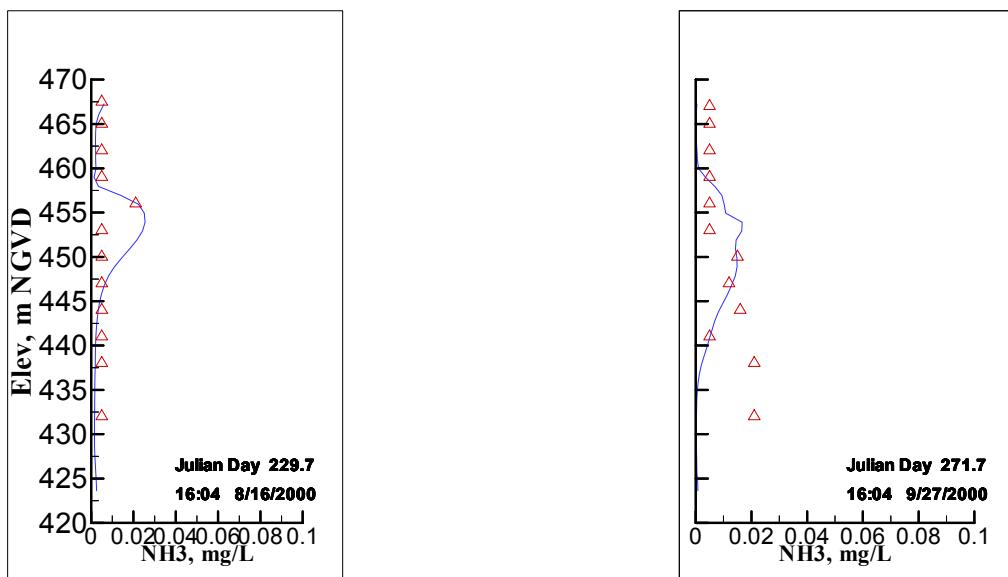


Figure 161. Comparison of model predicted vertical ammonia nitrogen profiles and 2000 data for Long Lake at Station 0 (Segment 187).

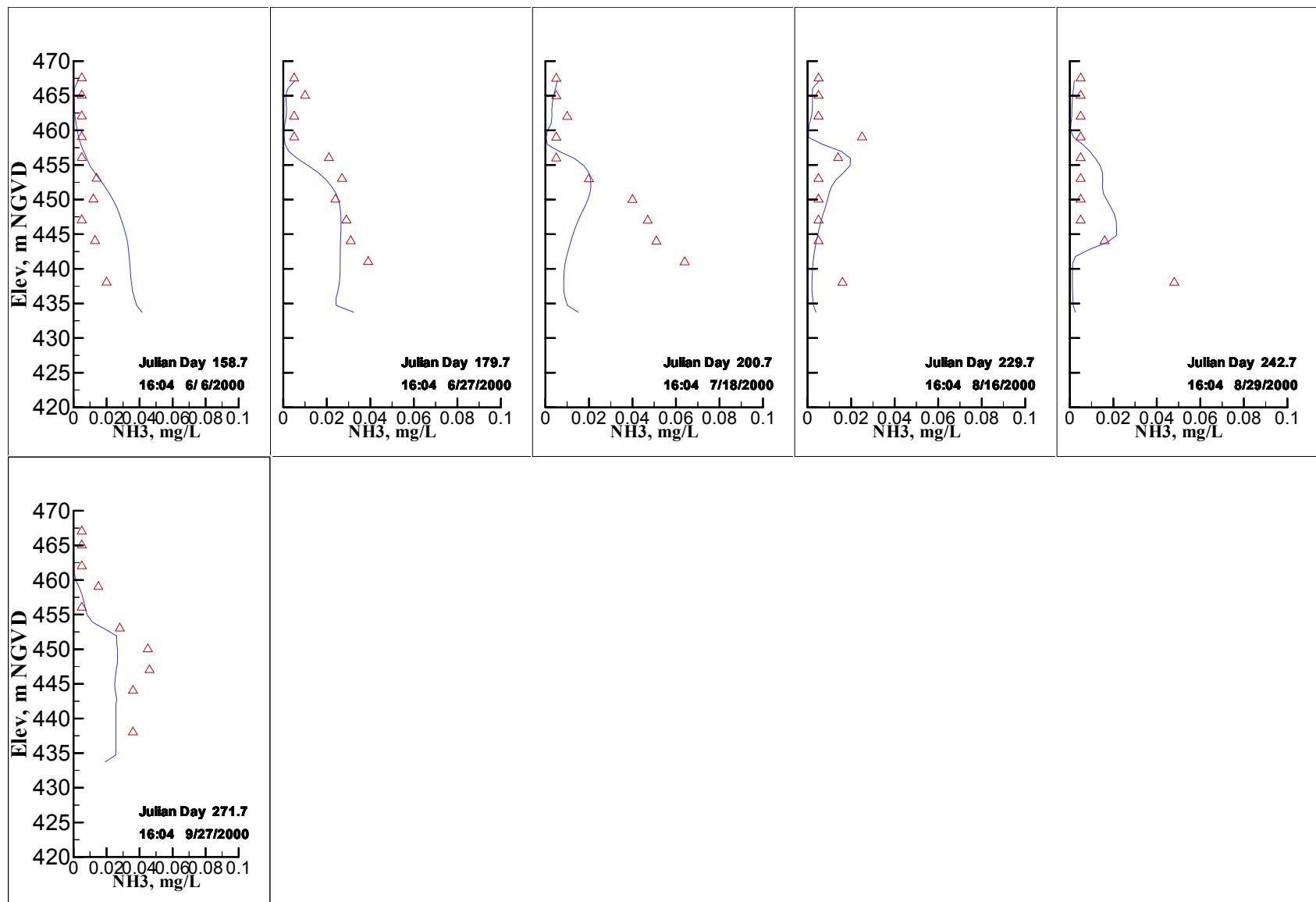


Figure 162. Comparison of model predicted vertical ammonia profiles and 2000 data for Long Lake at Station 1 (Segment 180).

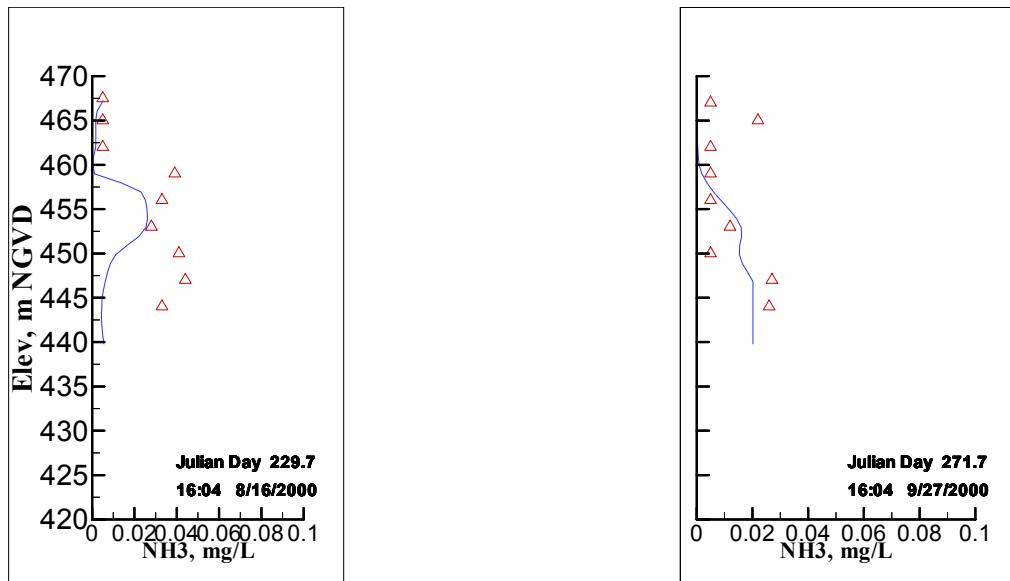


Figure 163. Comparison of model predicted vertical ammonia profiles and 2000 data for Long Lake at Station 2 (Segment 174).

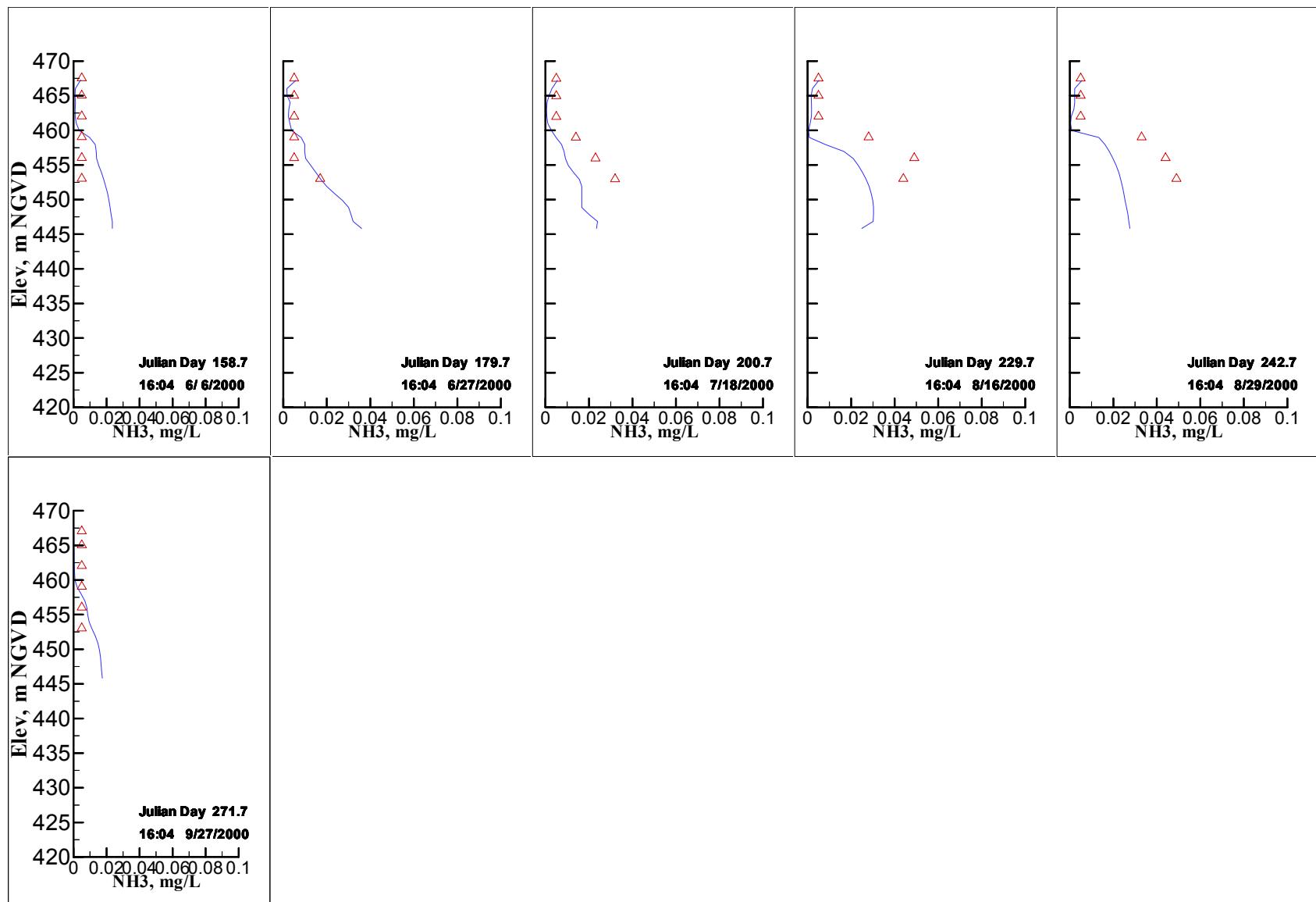


Figure 164. Comparison of model predicted vertical ammonia profiles and 2000 data for Long Lake at Station 3 (Segment 168).

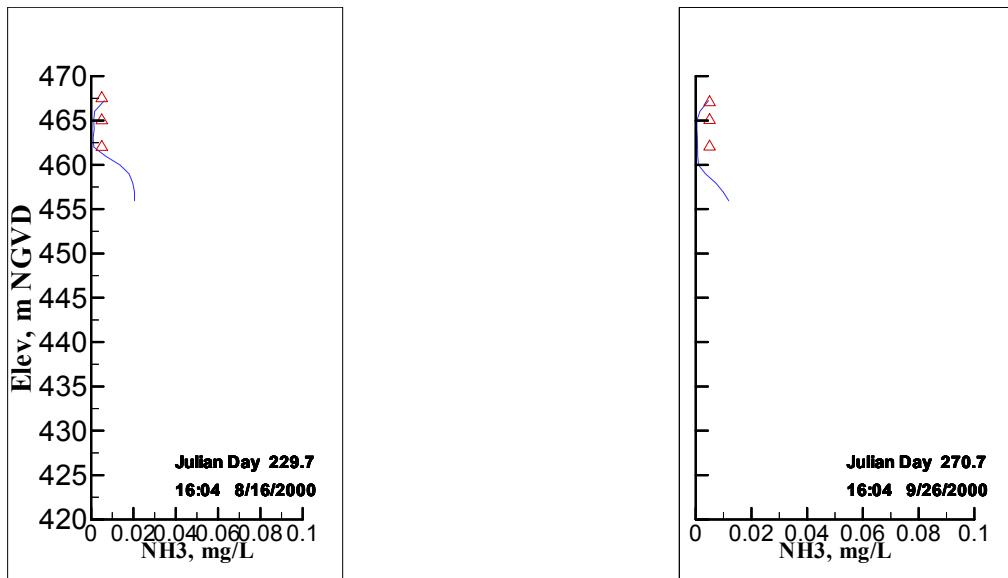


Figure 165. Comparison of model predicted vertical ammonia profiles and 2000 data for Long Lake at Station 4 (Segment 161).

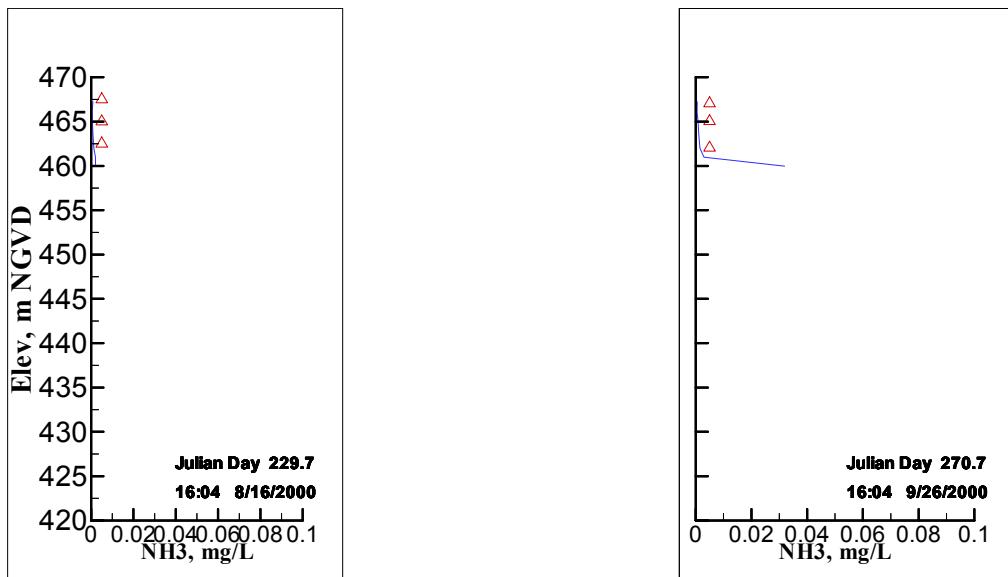


Figure 166. Comparison of model predicted vertical ammonia profiles and 2000 data for Long Lake at Station 5 (Segment 157).

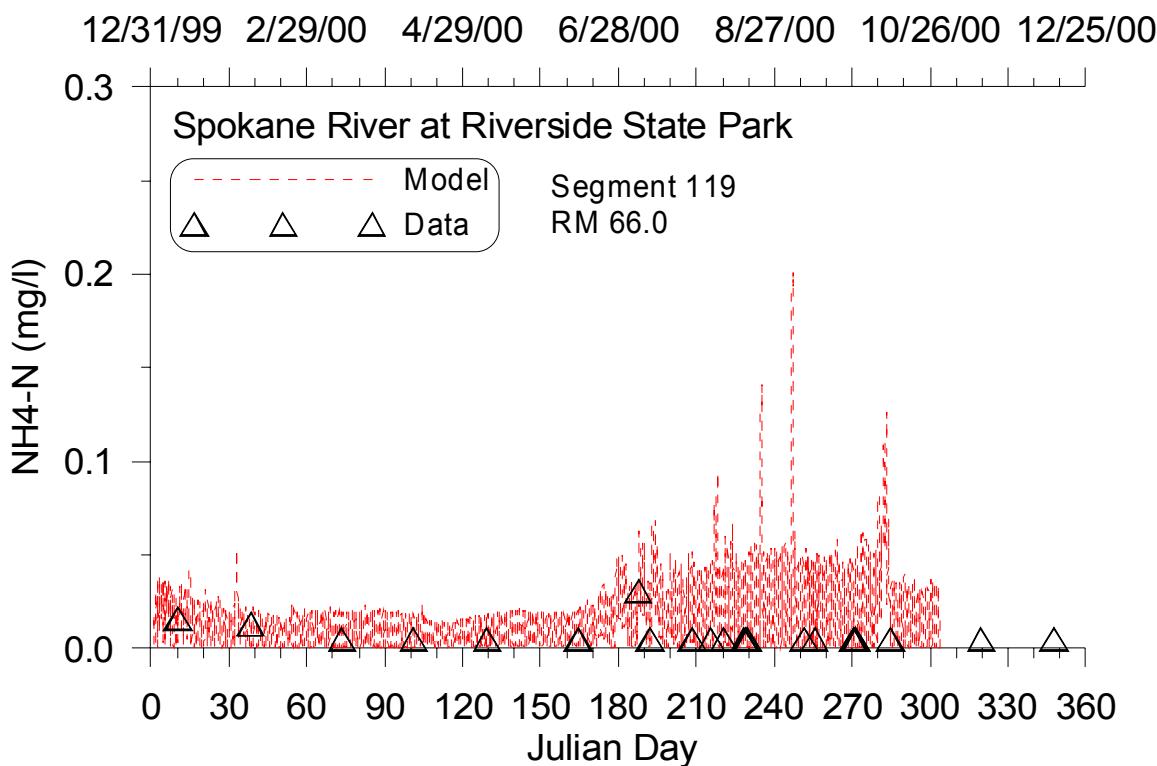


Figure 167. Comparison of model predicted ammonia nitrogen and 1991 data for Spokane River at Riverside Park (Segment 119).

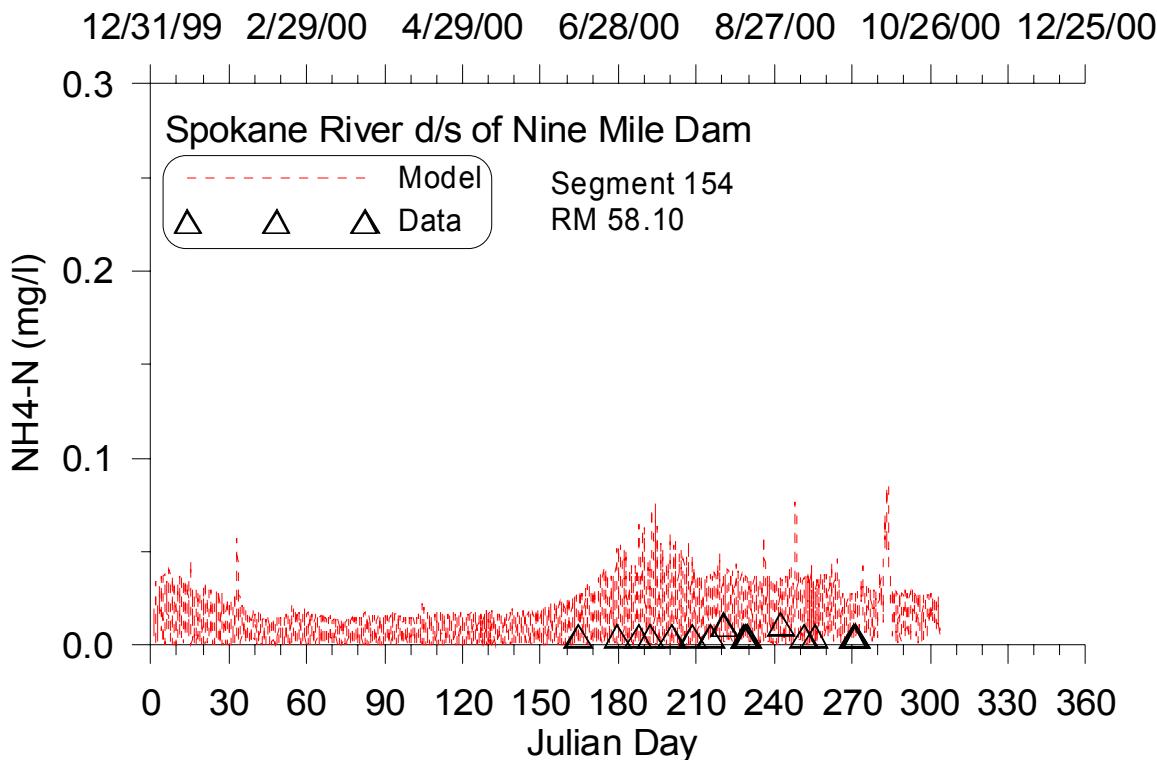


Figure 168. Comparison of model predicted ammonia nitrogen and 2000 data for Spokane River at Nine Mile Dam (Segment 154).

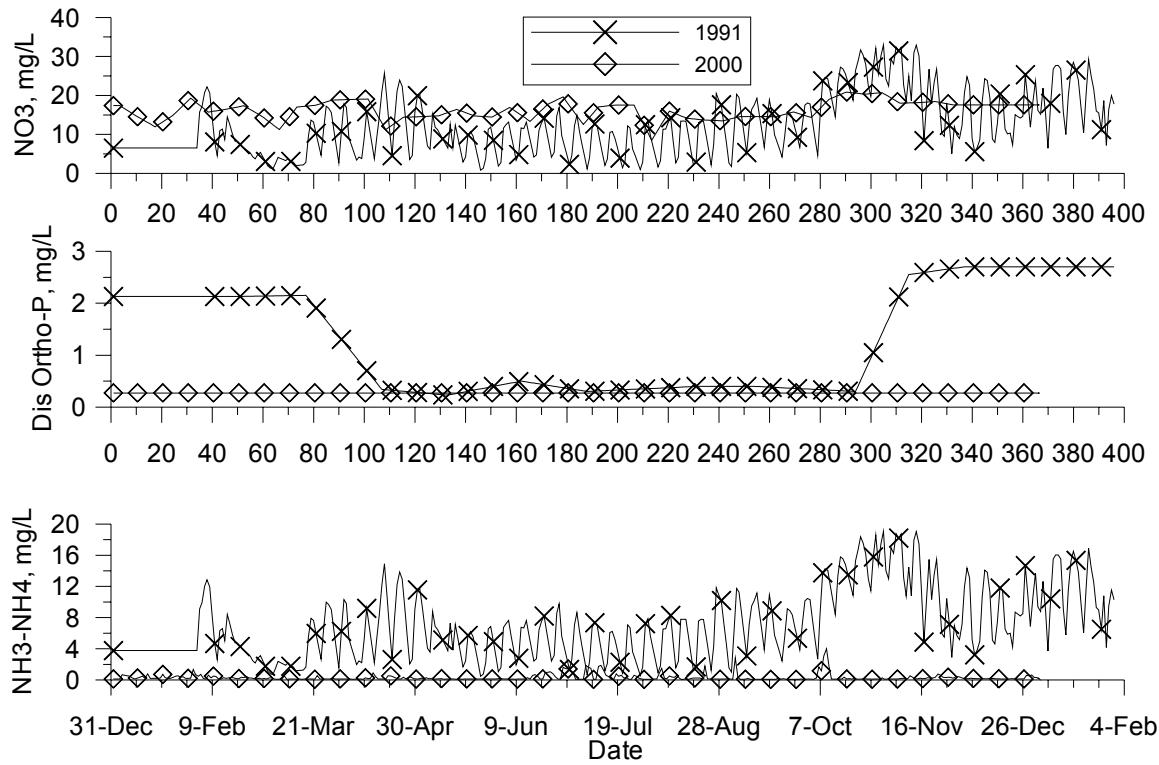


Figure 169. City of Spokane wastewater treatment plant discharge constituents, 1991

Soluble Reactive Phosphorus

The diurnal swings in soluble phosphorus predictions were caused by periphyton and phytoplankton growth. The vertical profile data for Long Lake showed depletion of soluble reactive phosphorus in the euphotic zone, and the model was generally able to reproduce this depletion with phytoplankton production. A phosphorus half-saturation coefficient of 0.003 mg/l was used for phytoplankton and periphyton. The stoichiometric equivalent algal between biomass and phosphorus was set to 0.005.

Year 1991

Soluble reactive phosphorus (SRP) vertical profiles were collected in Long Lake in 1991 for 12 different days. Additional profiles were not collected upstream of Long Lake. Figure 170 to Figure 174 show SRP vertical profile data and model results for five locations in Long Lake from RM 32.7 to 54.5. Figure 175 shows SRP time series data compared with model results for RM 66. Figure 176 shows SRP time series data compared with model results for RM 58.1. Table 42 shows AME and RMS error statistics for the SRP vertical profiles and Table 43 includes error statistics for the time series comparisons.

Table 42. Soluble Reactive Phosphorus profile error statistics, 1991

Site	n, # of data profile comparisons	SRP model –data error statistics	
		AME, mg/L	RMS, mg/L
LL0	12	0.004	0.005
LL1	12	0.004	0.004
LL2	12	0.004	0.004
LL3	12	0.003	0.003
LL4	12	0.003	0.003

Table 43. Soluble Reactive Phosphorus time series error statistics, 1991

Site	n, # of data comparisons	SRP model –data error statistics	
		AME, mg/L	RMS error, mg/L
SPK66.0	13	0.003	0.003
SPK58.1	17	0.004	0.004

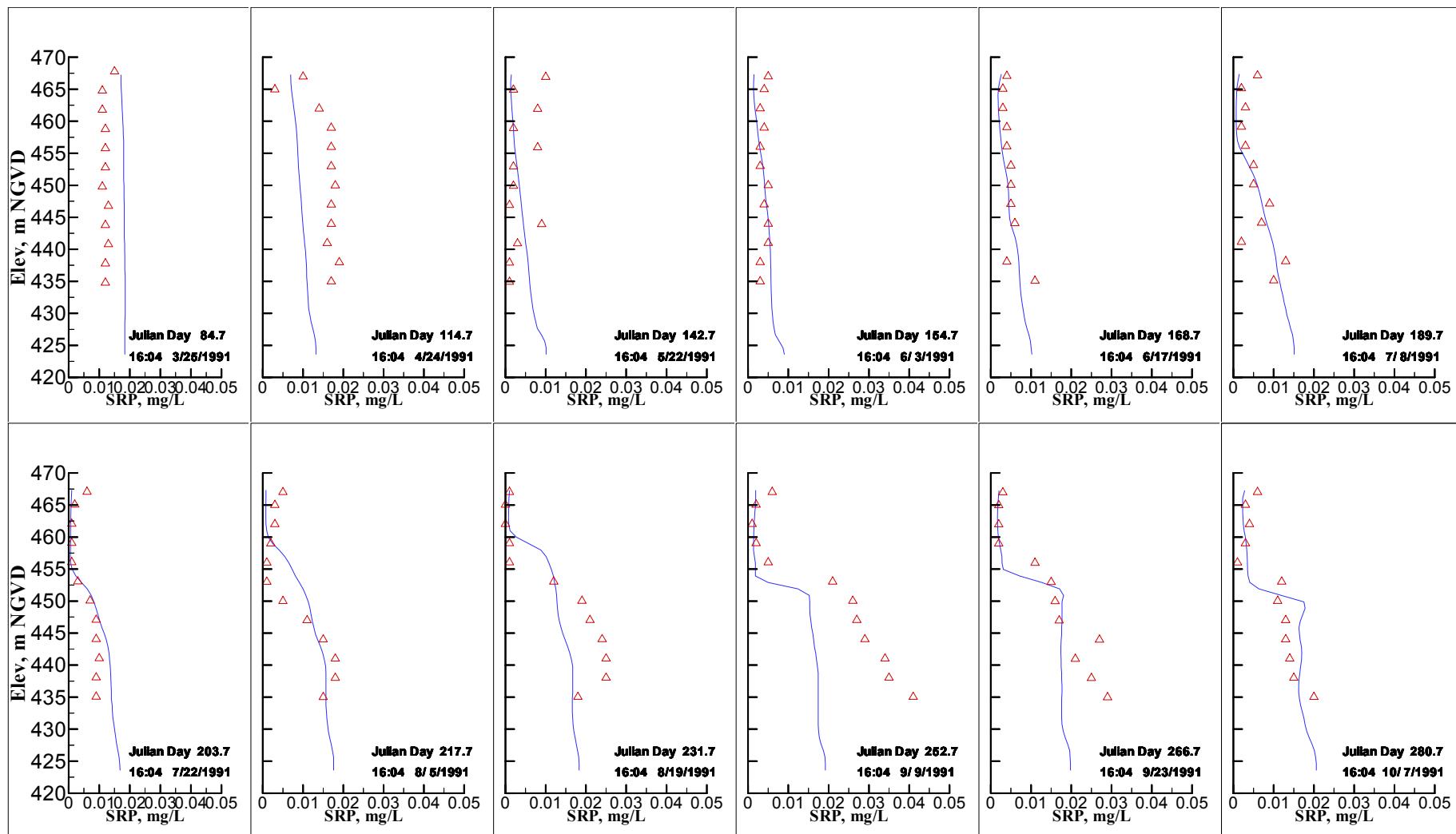


Figure 170. Comparison of model predicted vertical soluble reactive phosphorus profiles and 1991 data for Long Lake at Station 0 (Segment 187).

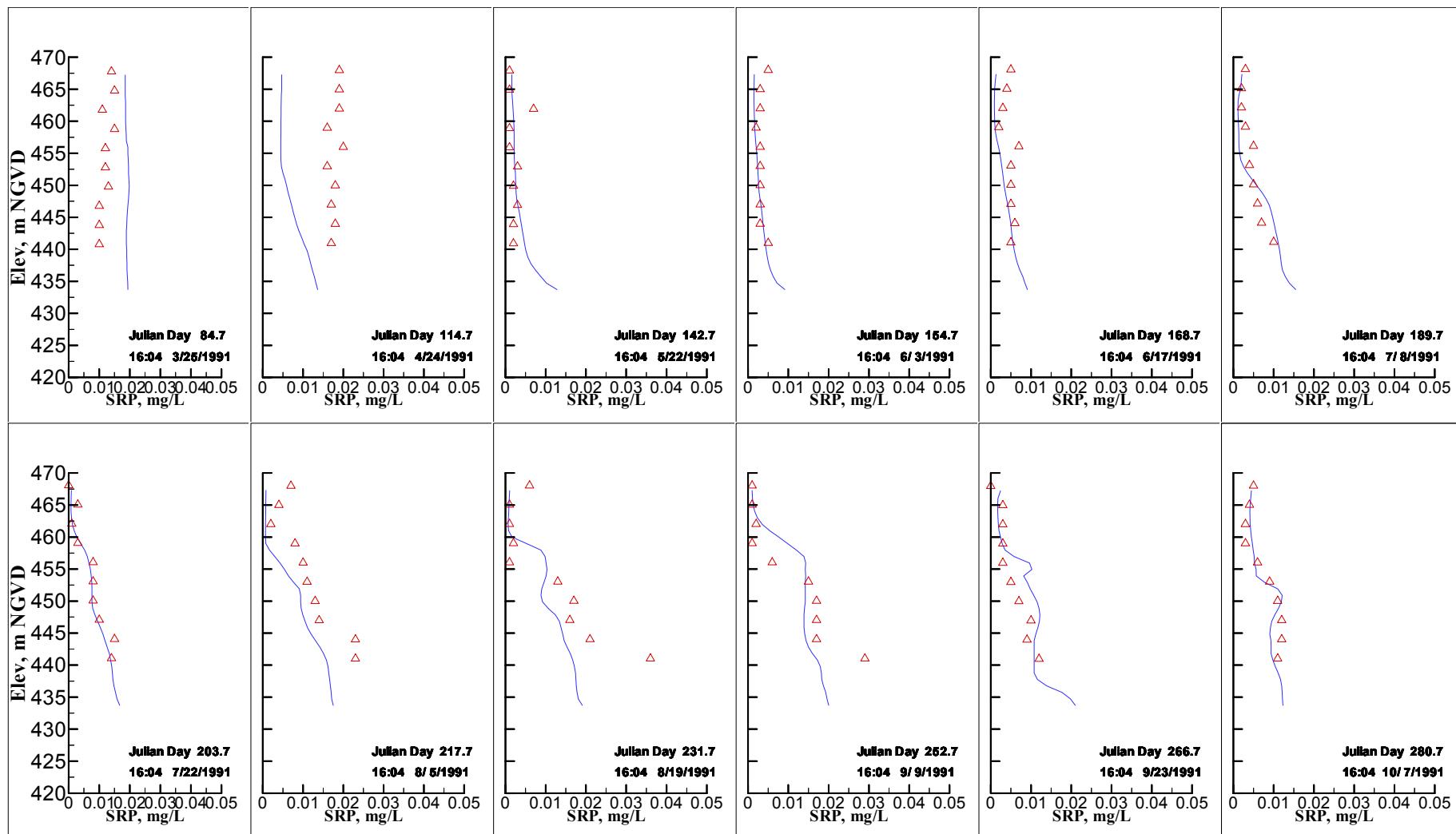


Figure 171. Comparison of model predicted vertical soluble reactive phosphorus profiles and 1991 data for Long Lake at Station 1 (Segment 180).

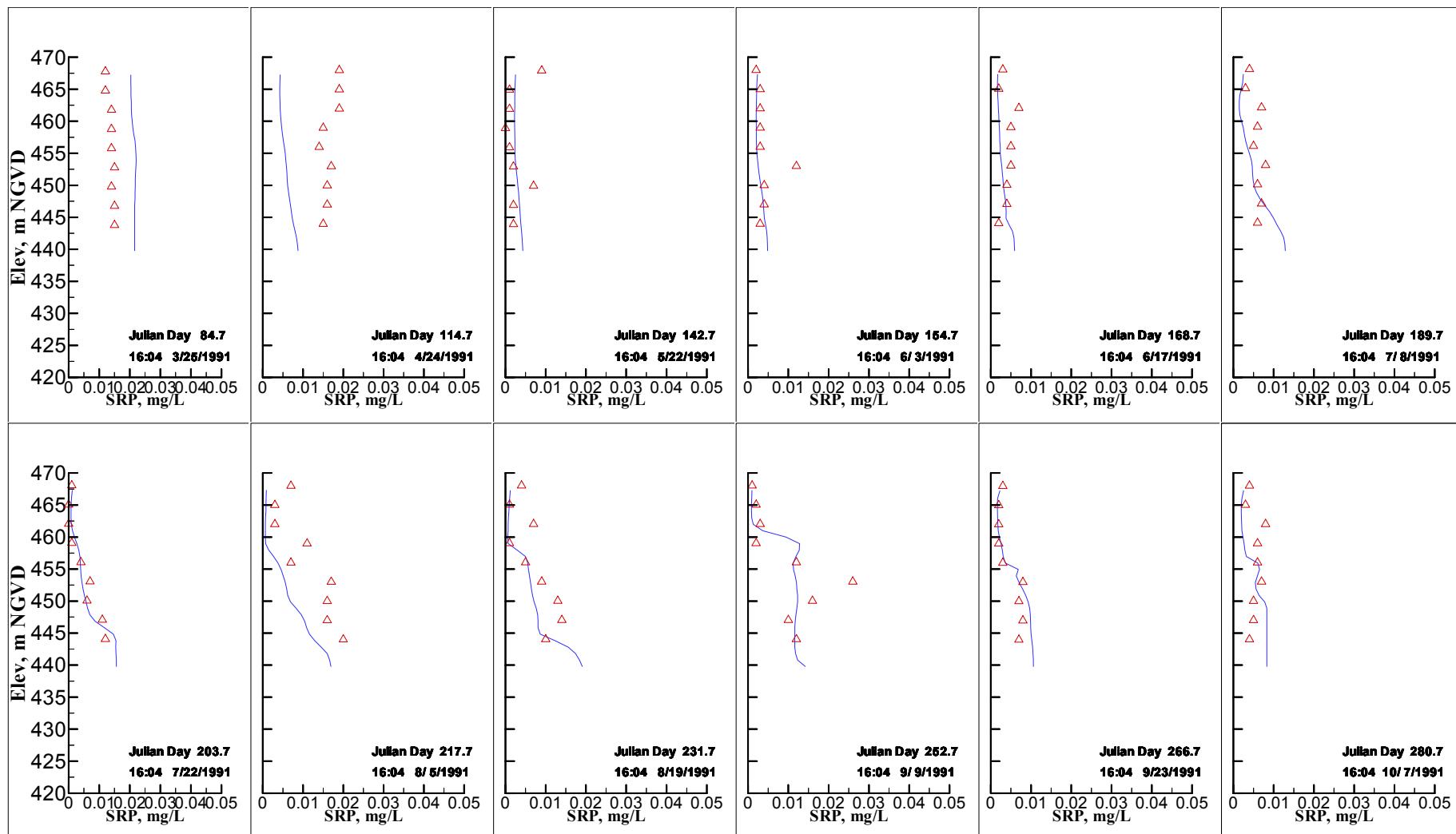


Figure 172. Comparison of model predicted vertical soluble reactive phosphorus profiles and 1991 data for Long Lake at Station 2 (Segment 174).

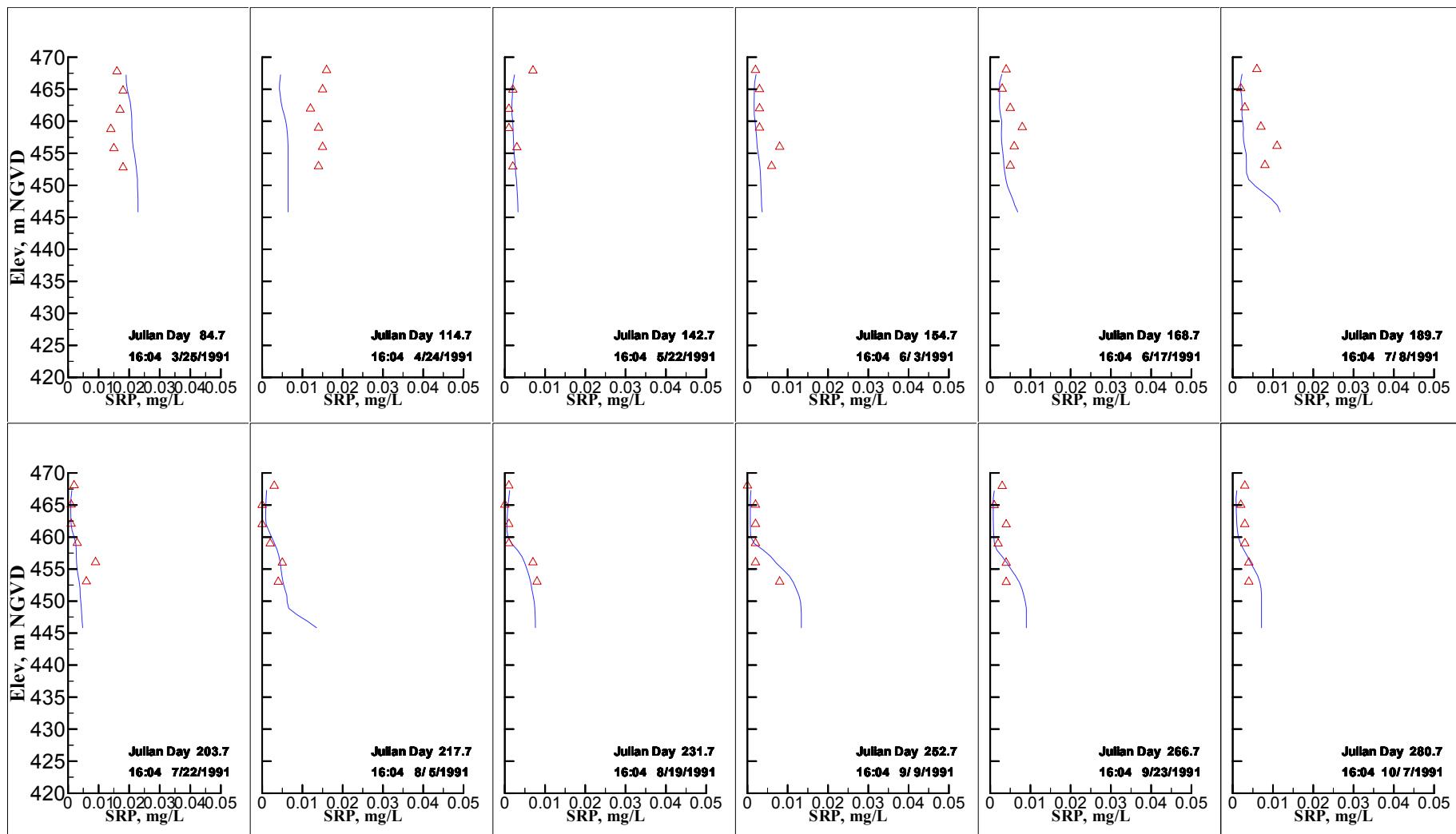


Figure 173. Comparison of model predicted vertical soluble reactive phosphorus profiles and 1991 data for Long Lake at Station 3 (Segment 168).

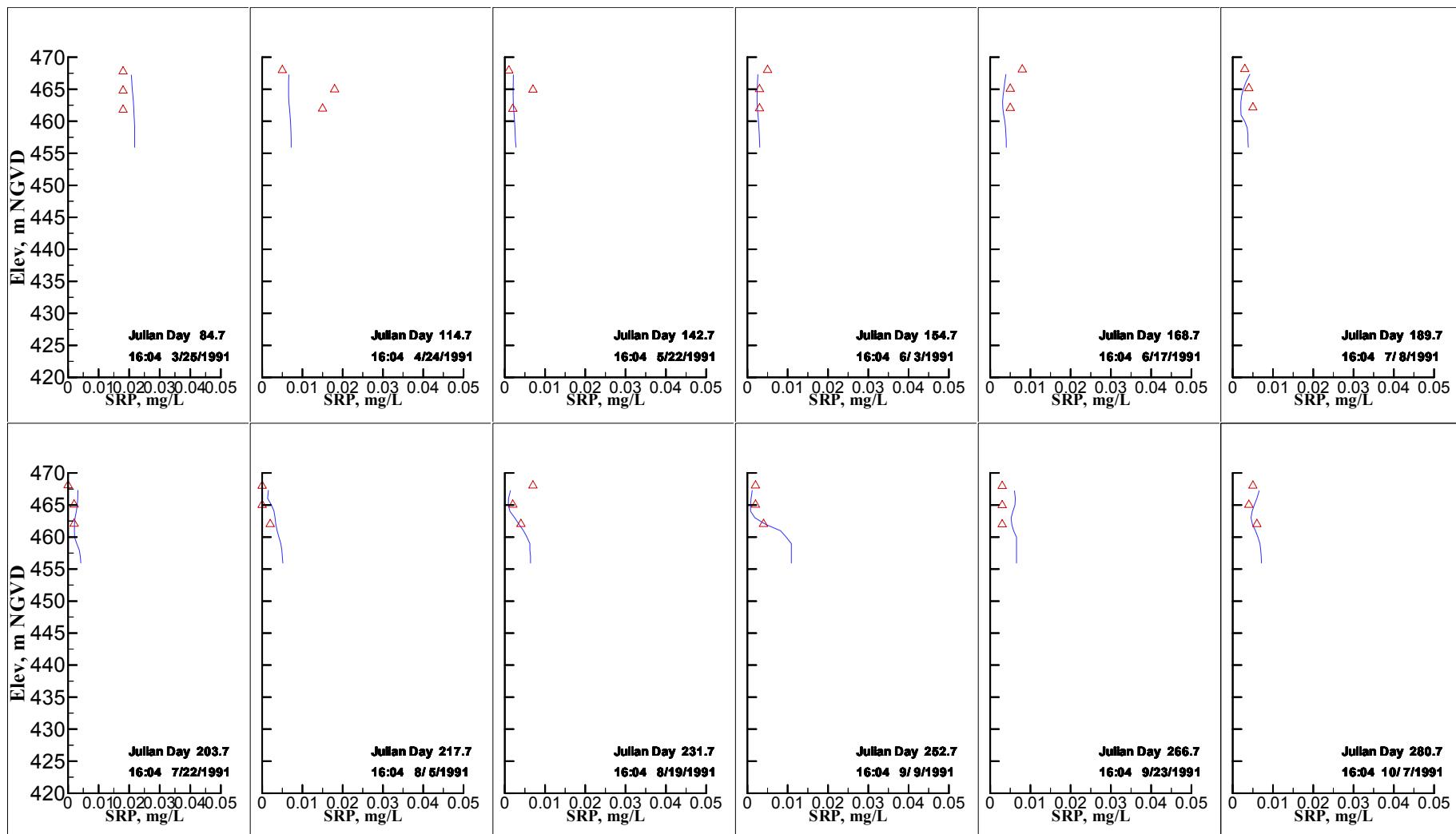


Figure 174. Comparison of model predicted vertical soluble reactive phosphorus profiles and 1991 data for Long Lake at Station 4 (Segment 161).

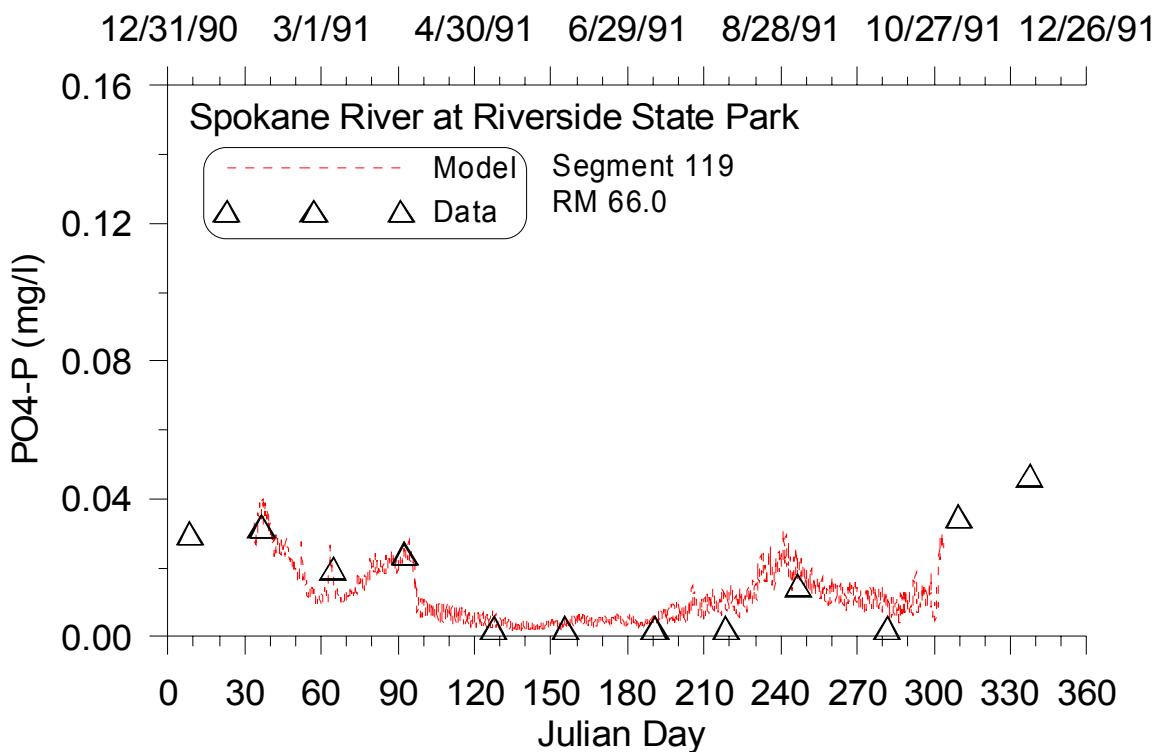


Figure 175. Comparison of model predicted soluble reactive phosphorus profiles and 1991 data for Spokane River at Riverside State Park (Segment 119).

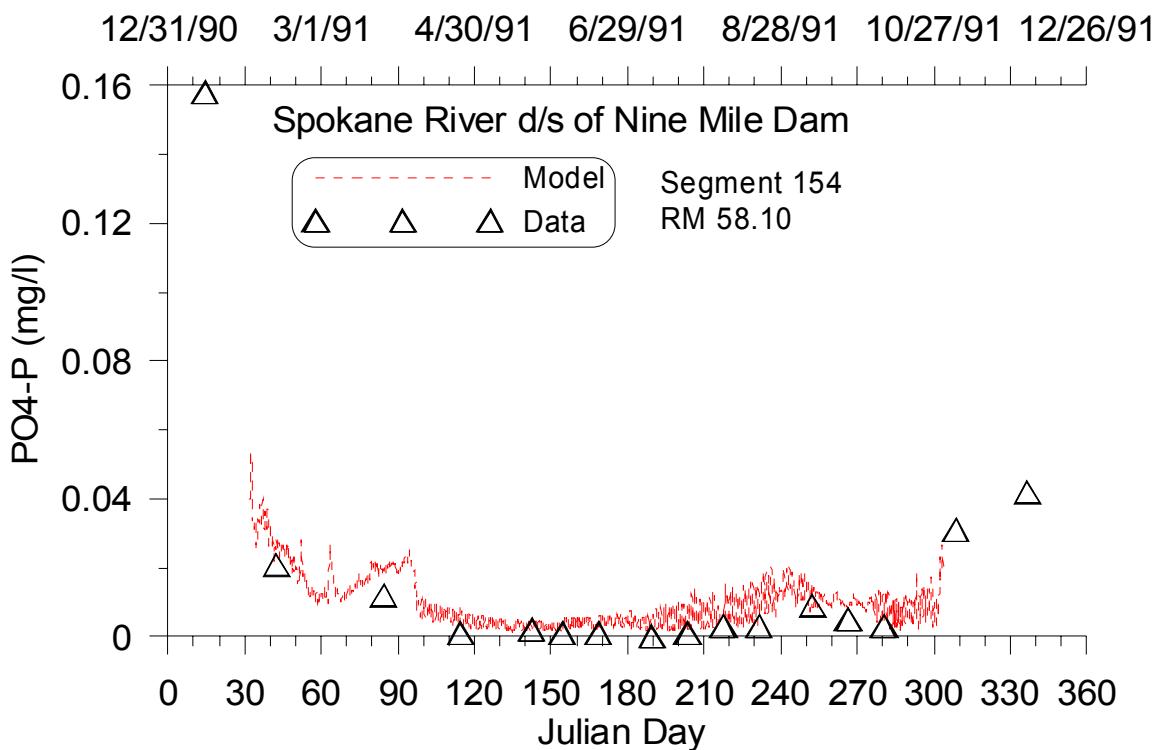


Figure 176. Comparison of model predicted soluble reactive phosphorus profiles and 1991 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Year 2000

Soluble reactive phosphorus (SRP) vertical profiles were collected in Long Lake in 2000. Additional SRP vertical profiles were not collected upstream of Long Lake in 2000. Figure 177 to Figure 182 show SRP profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. Figure 183 shows SRP time series data compared with model results for RM 66. Figure 184 shows SRP time series data compared with model results for RM 58.1. Table 44 shows AME and RMS error statistics for the SRP vertical profiles and Table 45 includes error statistics for the time series comparisons.

Table 44. Soluble Reactive Phosphorus profile error statistics, 2000

Site	n, # of data profile comparisons	SRP model –data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	2	0.006	0.007
LL1	6	0.004	0.005
LL2	2	0.004	0.004
LL3	6	0.002	0.002
LL4	2	0.004	0.004
LL5	2	0.003	0.003

Table 45. Soluble Reactive Phosphorus time series error statistics, 2000

Site	n, # of data comparisons	SRP model –data error statistics	
		AME, mg/L	RMS, mg/L
SPK66.0	24	0.002	0.003
SPK58.1	20	0.002	0.003

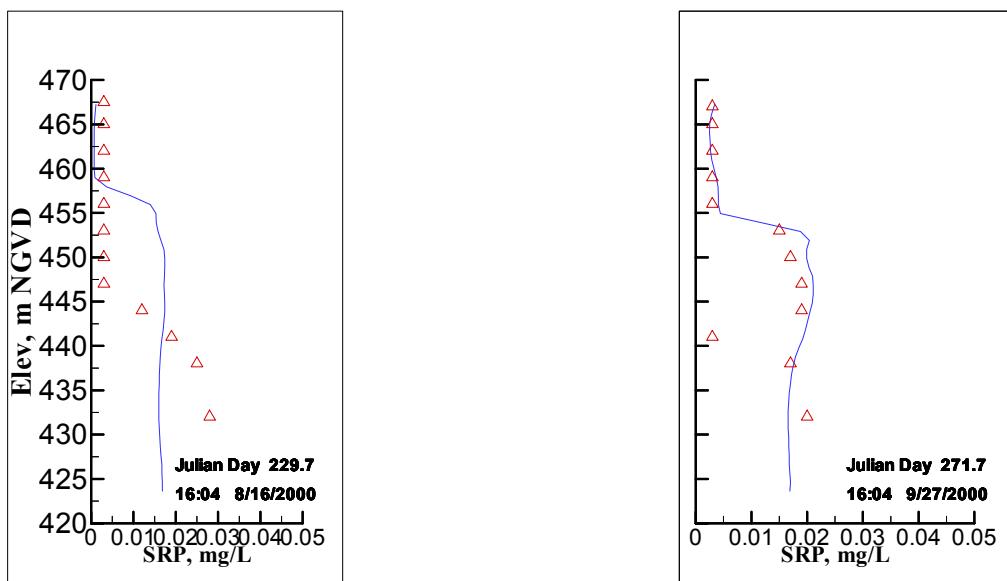


Figure 177. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 0 (Segment 187).

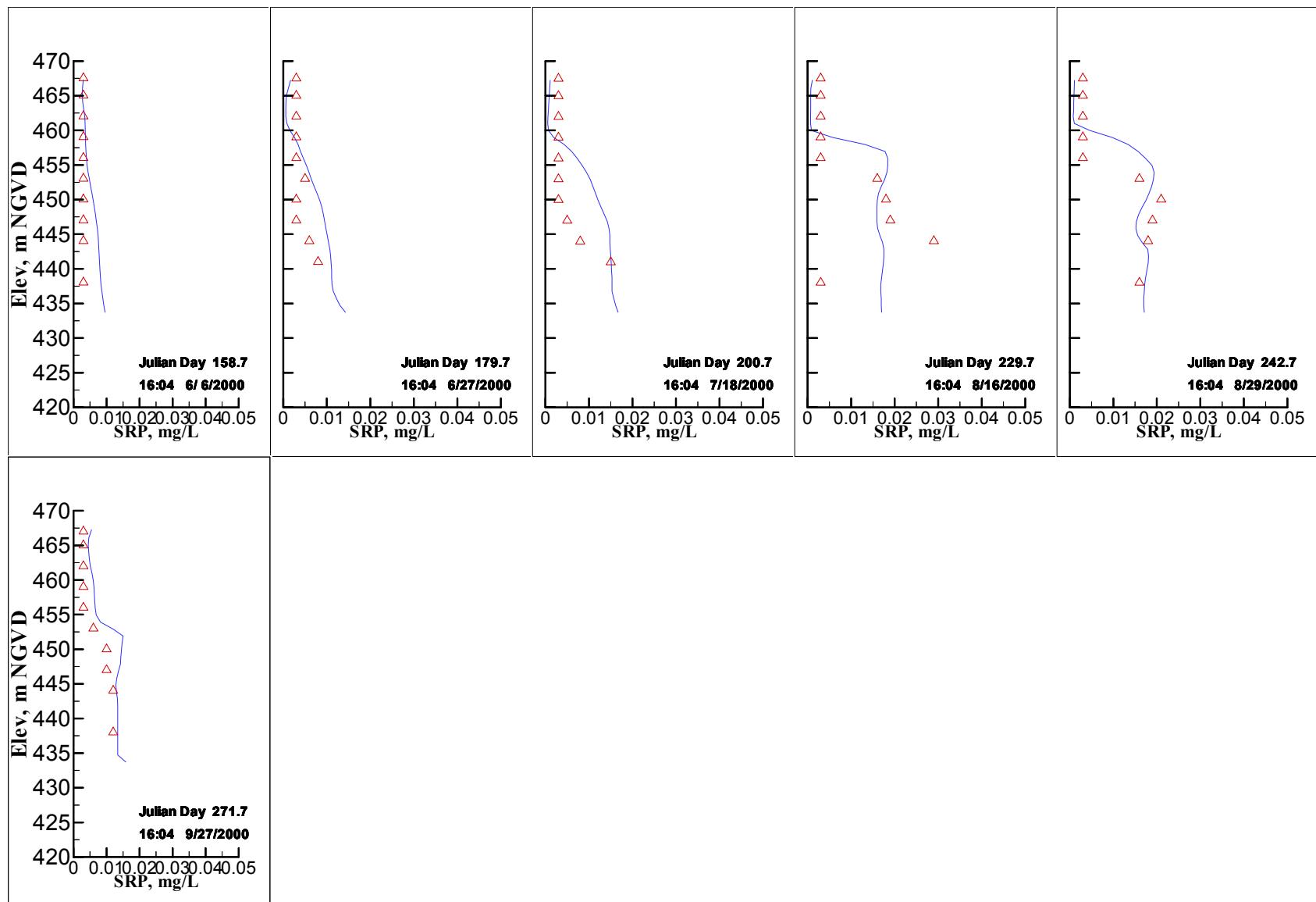


Figure 178. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 1 (Segment 180).

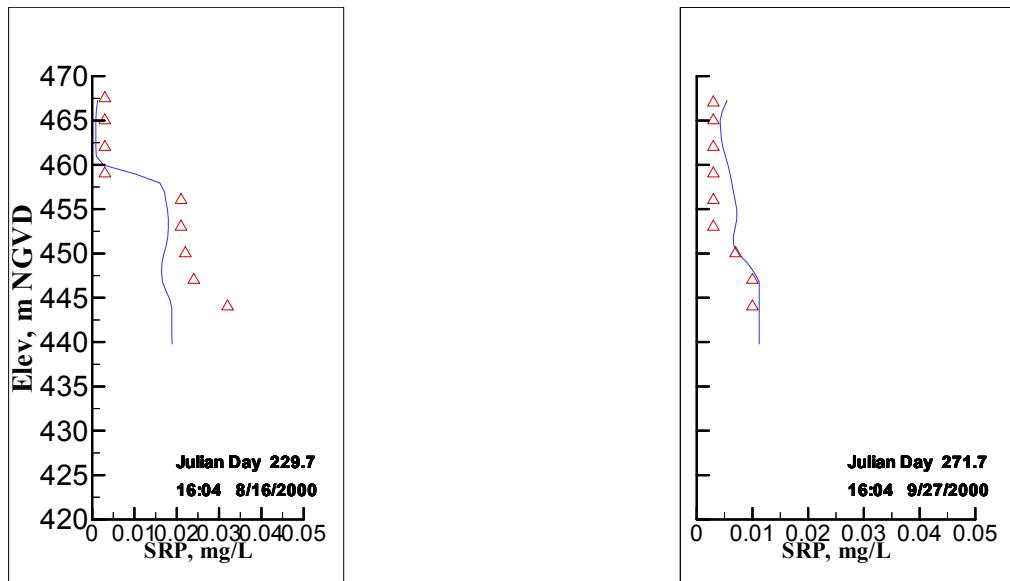


Figure 179. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 2 (Segment 174).

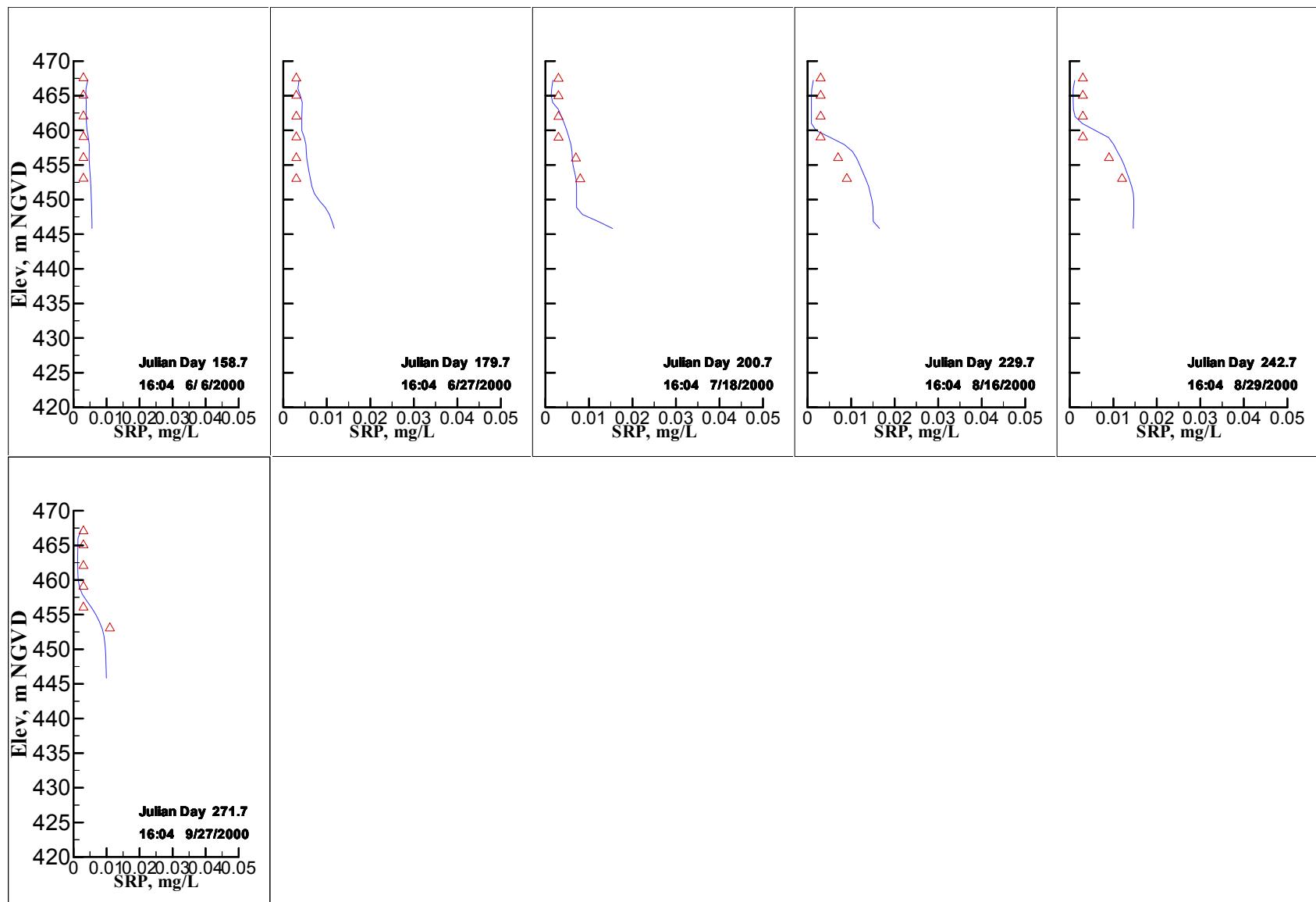


Figure 180. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 3 (Segment 168).

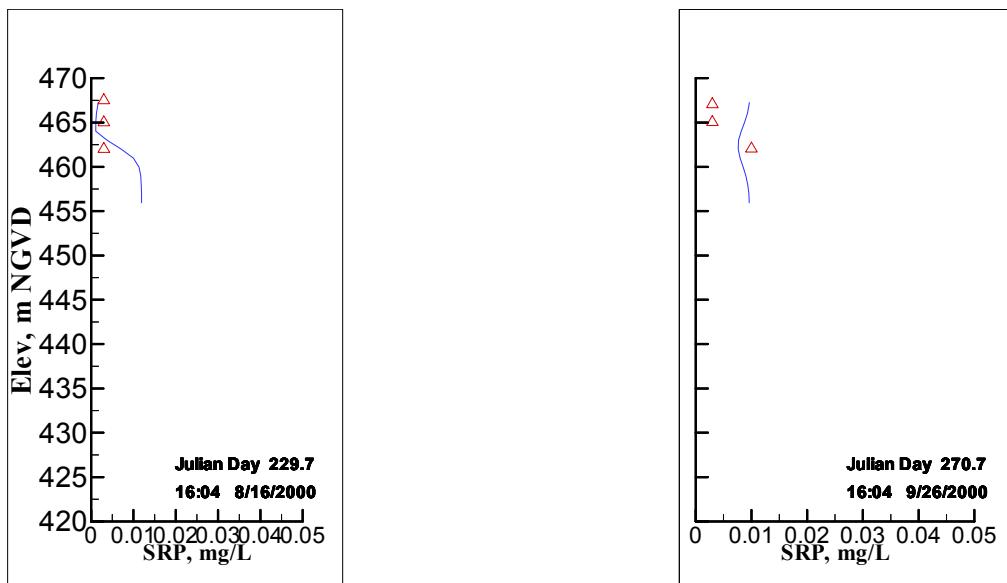


Figure 181. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 4 (Segment 161).

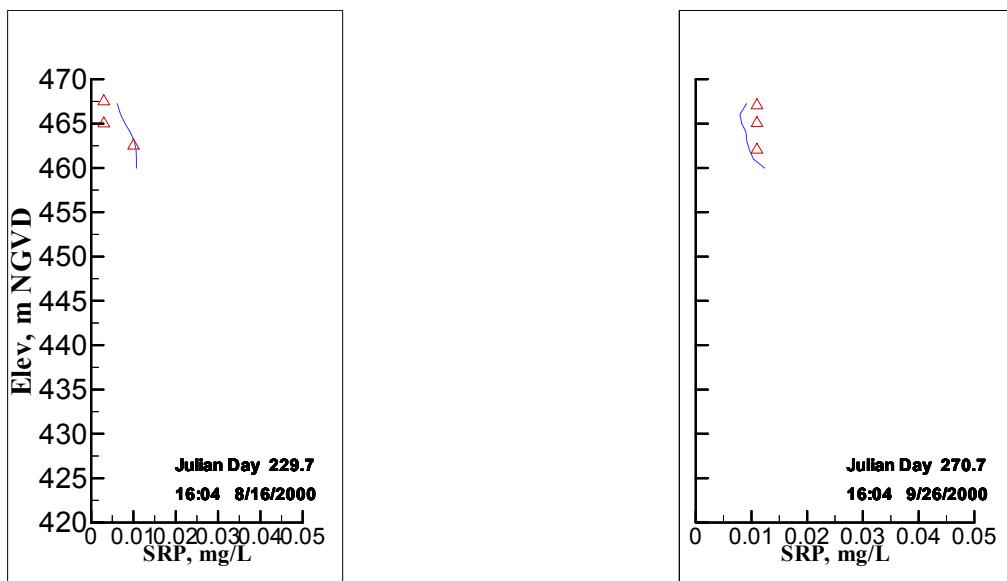


Figure 182. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 5 (Segment 157).

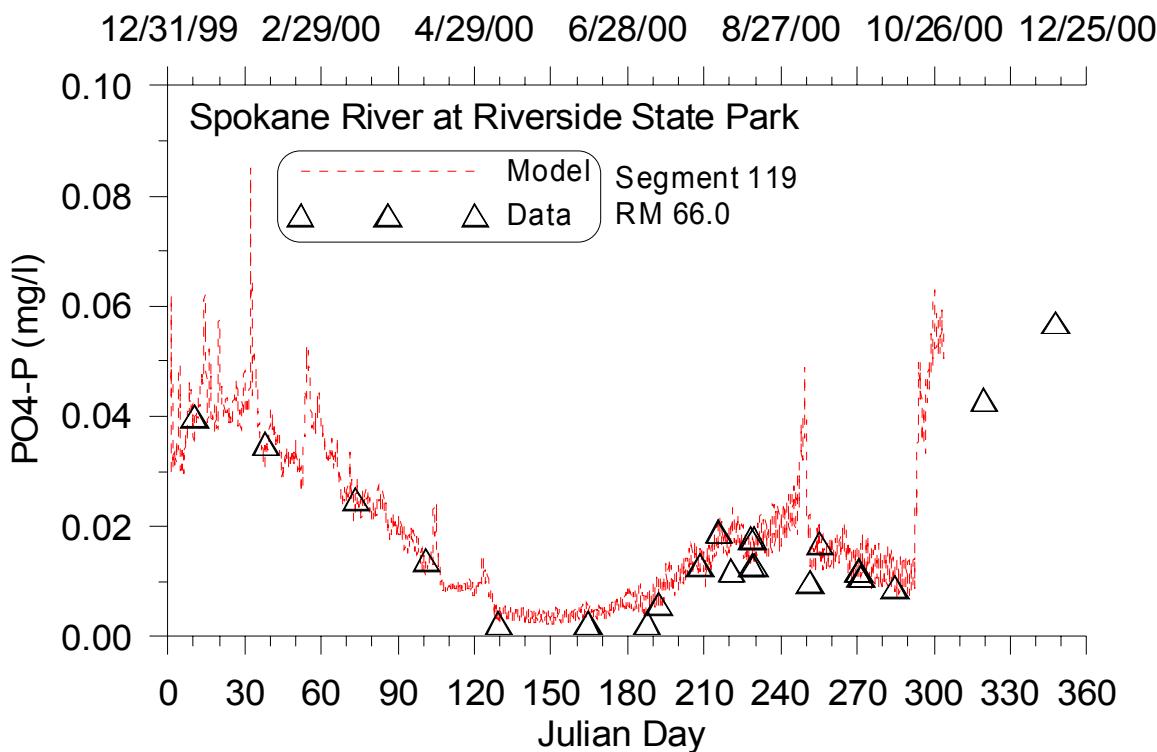


Figure 183. Comparison of model predicted soluble reactive phosphorus and 2000 data for Spokane River at Riverside State Park (Segment 119).

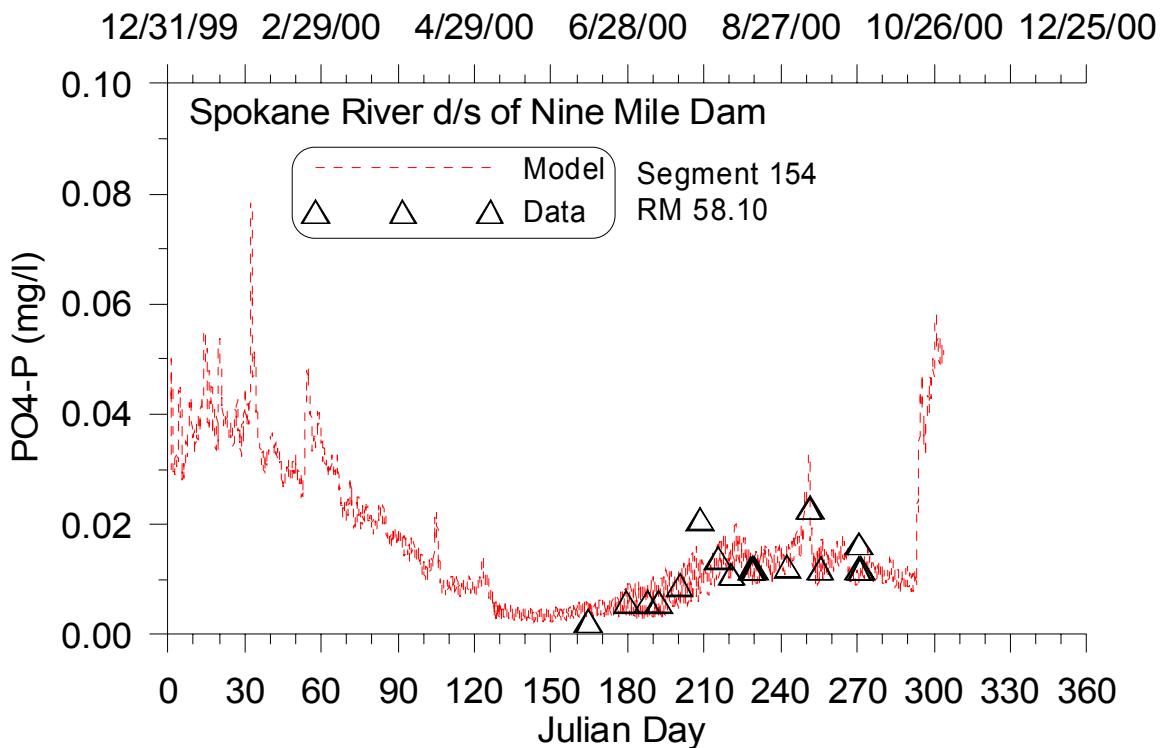


Figure 184. Comparison of model predicted soluble reactive phosphorus and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Alkalinity

Alkalinity is a conservative constituent in CE-QUAL-W2 and was used with inorganic carbon to determine pH. Since it is conservative, it provided another check to the model's water balance and hydrodynamics. No analysis was conducted with model results for 1991 because there were no alkalinity data.

Year 2000

Alkalinity vertical profiles were collected in Long Lake in 2000. Model predictions and data were in good agreement. Additional alkalinity vertical profiles were not collected upstream of Long Lake. Figure 185 to Figure 190 show alkalinity profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. Table 46 shows AME and RMS error statistics for the alkalinity vertical profiles and Table 47 includes error statistics for the time series comparisons. Figure 191 and Figure 192 show the alkalinity model – data time series comparisons for segment 119 and segment 154, respectively.

Table 46. Alkalinity profile error statistics, 2000

Site	n, # of data profile comparisons	ALK model –data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	2	14.16	18.23
LL1	1	9.36	11.66
LL2	2	14.45	18.49
LL3	2	5.67	6.24
LL4	2	9.26	9.26
LL5	2	5.49	5.49

Table 47. Alkalinity time series error statistics, 2000

Site	n, # of data comparisons	ALK model –data error statistics	
		AME, mg/L	RMS, mg/L
SPK66.0	11	8.4	9.4
SPK58.1	16	8.8	9.7

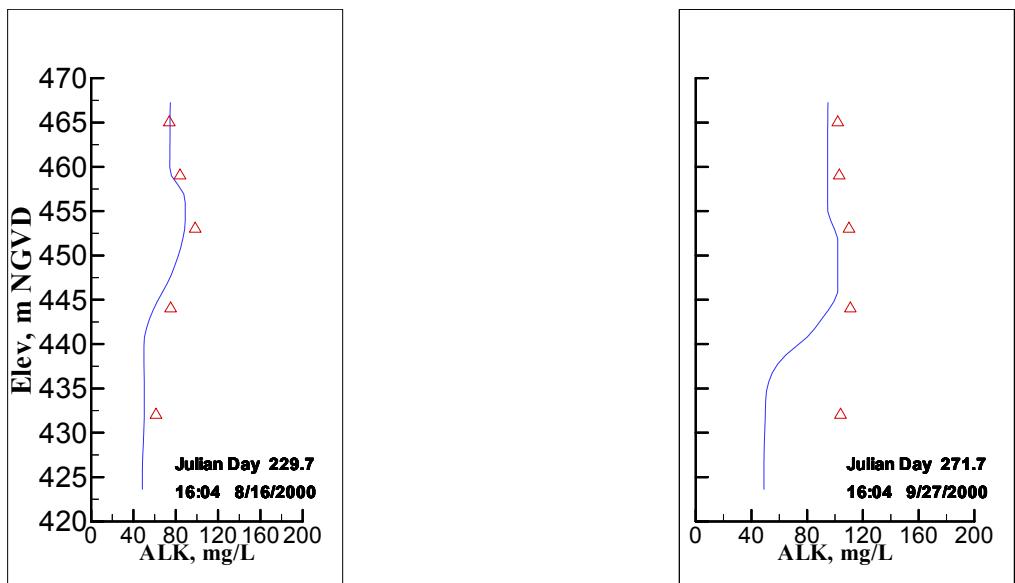


Figure 185. Comparison of model predicted vertical alkalinity profiles and 2000 data for Long Lake at Station 0 (Segment 187).

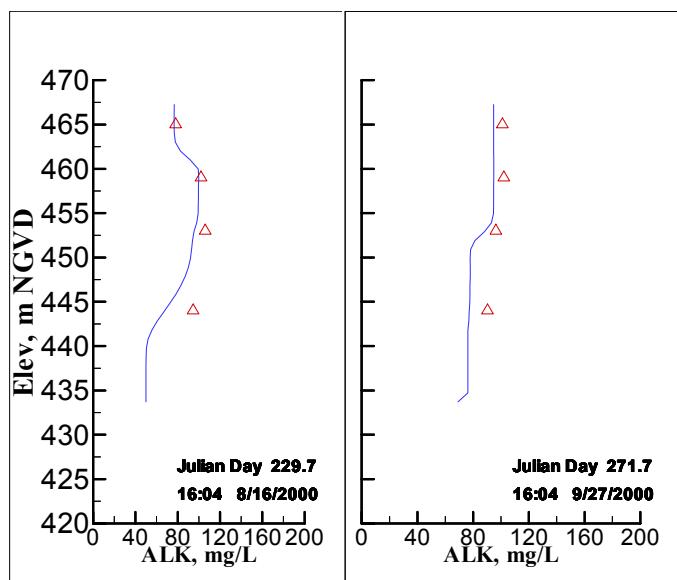


Figure 186. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 1 (Segment 180).

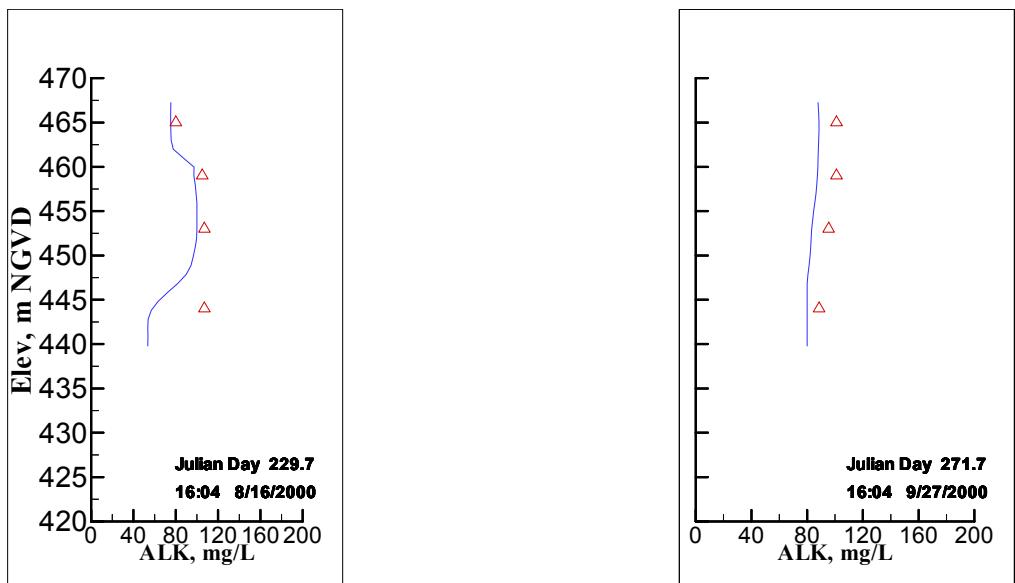


Figure 187. Comparison of model predicted vertical soluble reactive phosphorus profiles and 2000 data for Long Lake at Station 2 (Segment 174).

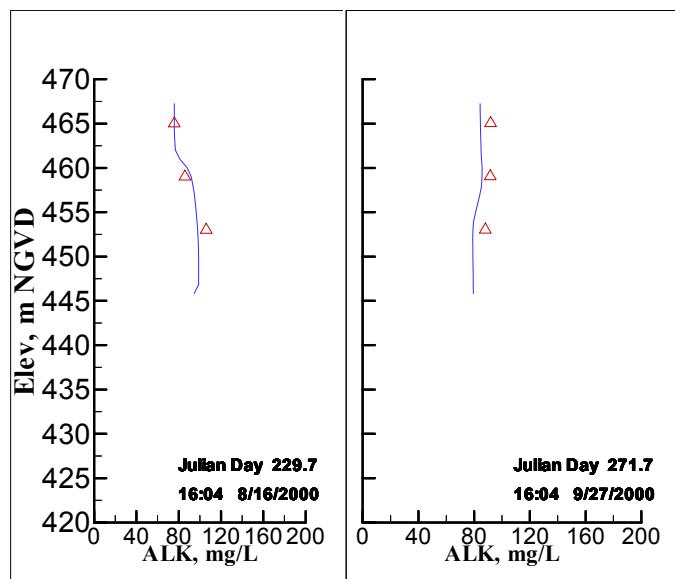


Figure 188. Comparison of model predicted vertical alkalinity profiles and 1991 data for Long Lake at Station 3 (Segment 168).

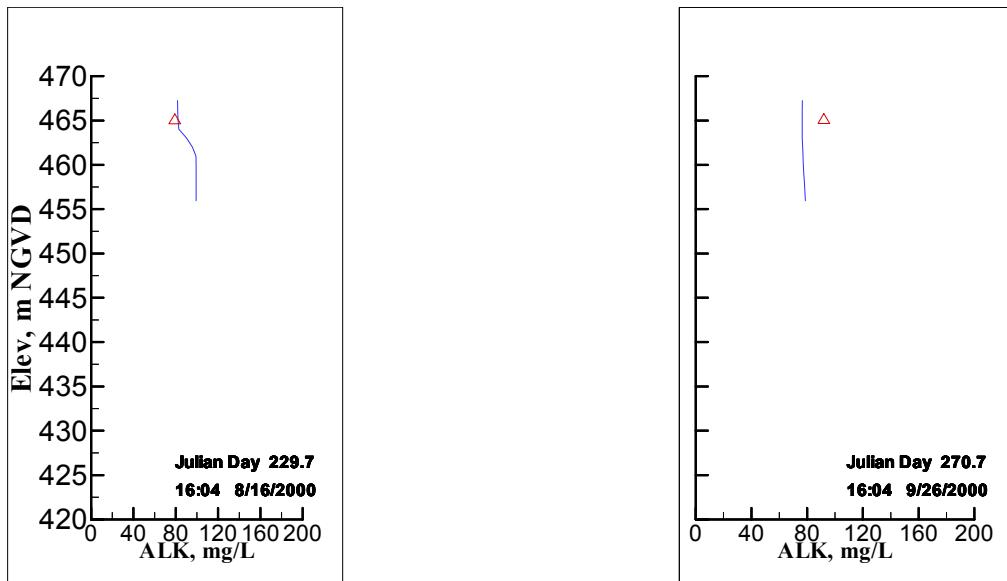


Figure 189. Comparison of model predicted vertical alkalinity profiles and 1991 data for Long Lake at Station 4 (Segment 161).

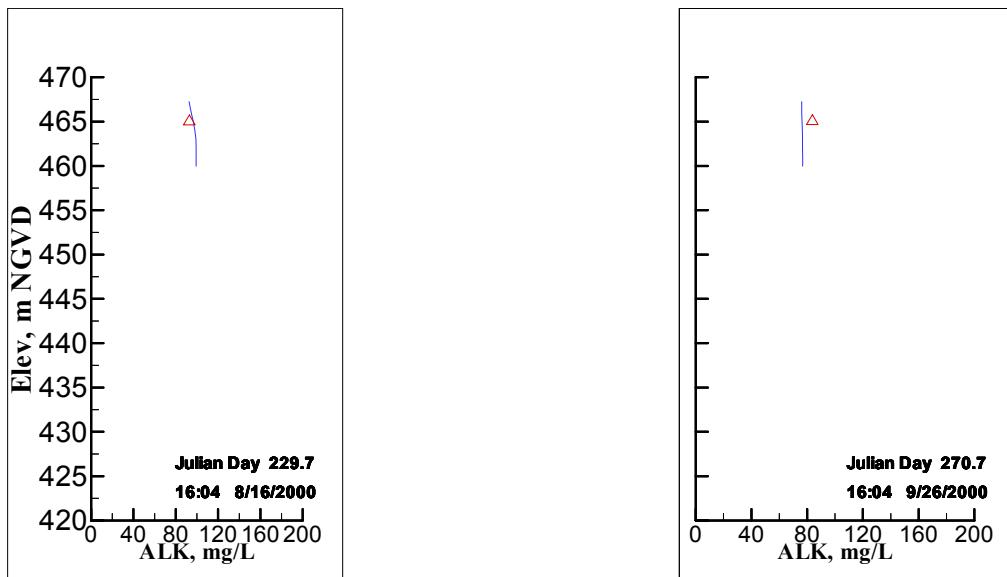


Figure 190. Comparison of model predicted vertical alkalinity profiles and 1991 data for Long Lake at Station 5 (Segment 157).

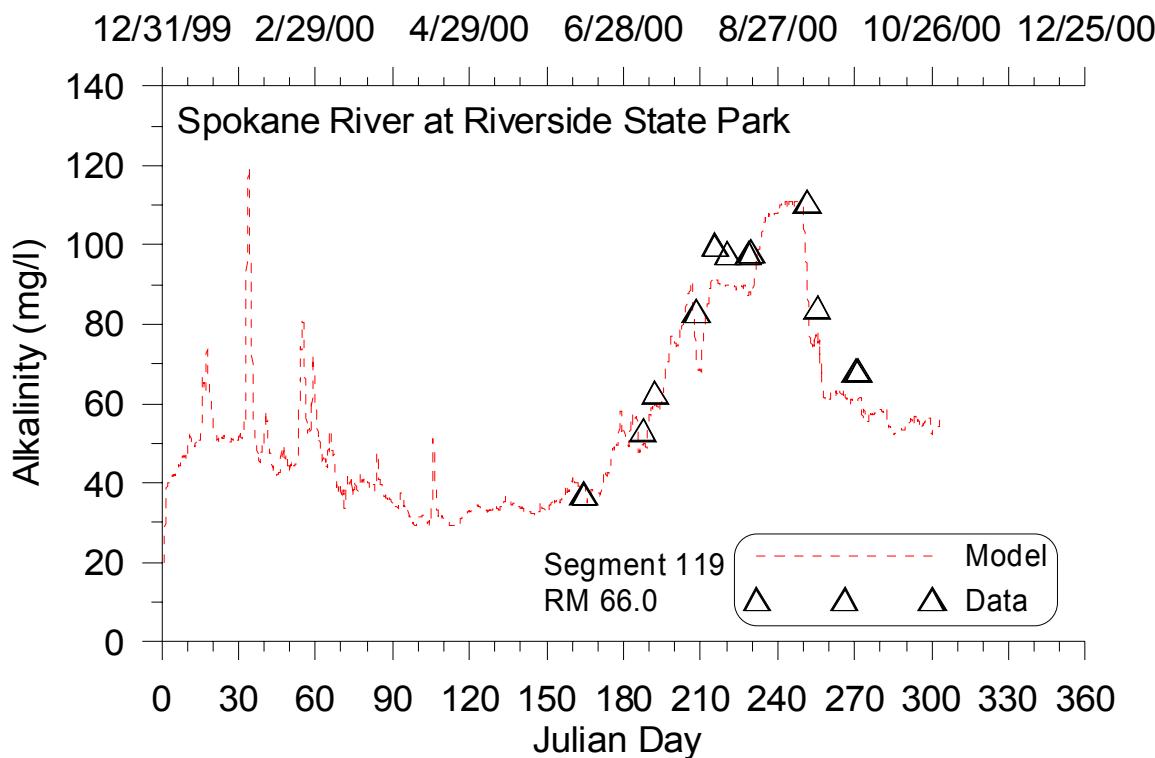


Figure 191. Comparison of model predicted alkalinity and 2000 data for Spokane River at Riverside State Park (Segment 119).

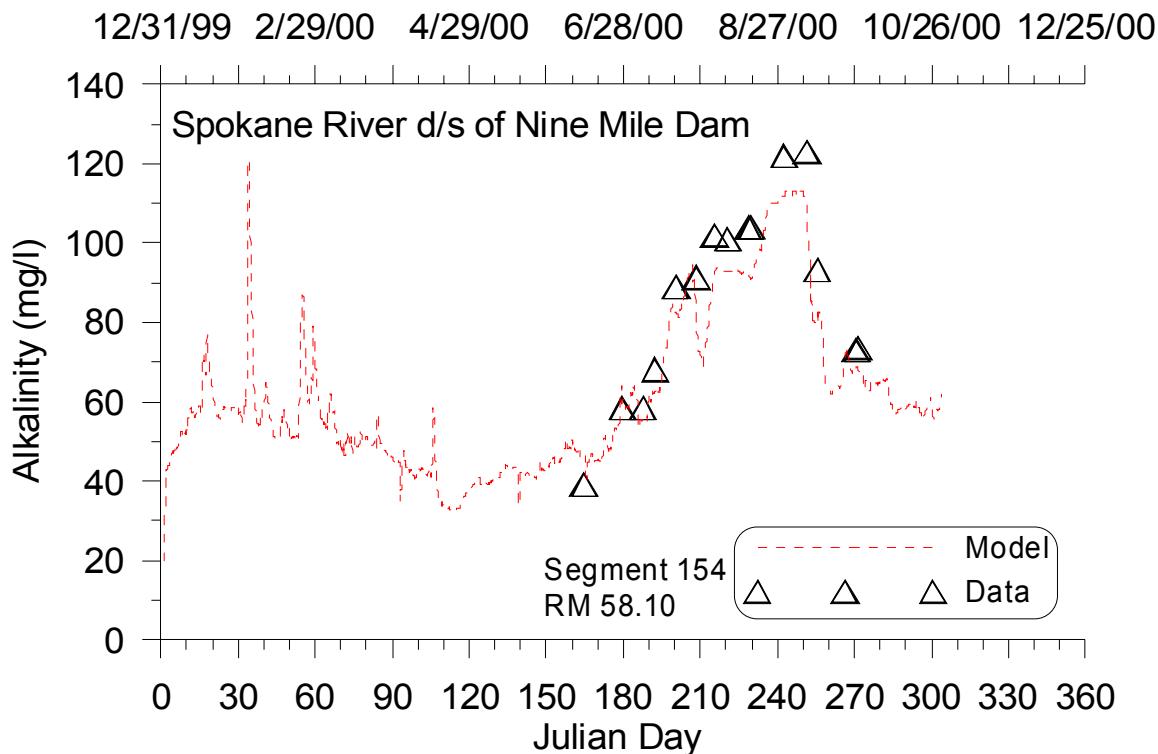


Figure 192. Comparison of model predicted alkalinity and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Chlorophyll a

Model predicted algal biomass was compared to chlorophyll a data by assuming an algal biomass to chlorophyll a ratio of 130. Phytoplankton maximum growth rate was calibrated to 1.5 d^{-1} . Of special importance was the calibration of maximum light saturation coefficient to 40 W/m^2 , which permitted more accurate predictions of phytoplankton growth over depth.

Algae growth in Long Lake was complicated. In spring and early summer, growth was confined to near the dam. As summer progressed, the zone of phytoplankton growth expanded to include more upstream locations in the reservoir. Phytoplankton growth was greatly affected by hydrodynamics occurring in Long Lake. Plunging inflows created a zone near the surface of greater residence time where phytoplankton flourished. Figure 193 shows contour plots of algae concentration and residence time during early summer. Note that the initial bloom is located near the dam and decreased upstream, which was consistent with 1991 phytoplankton data (Soltero, 1991), but cannot be compared to 2000 data because there were only a few sampling dates later in the summer at the upstream sites LL5 and LL4.

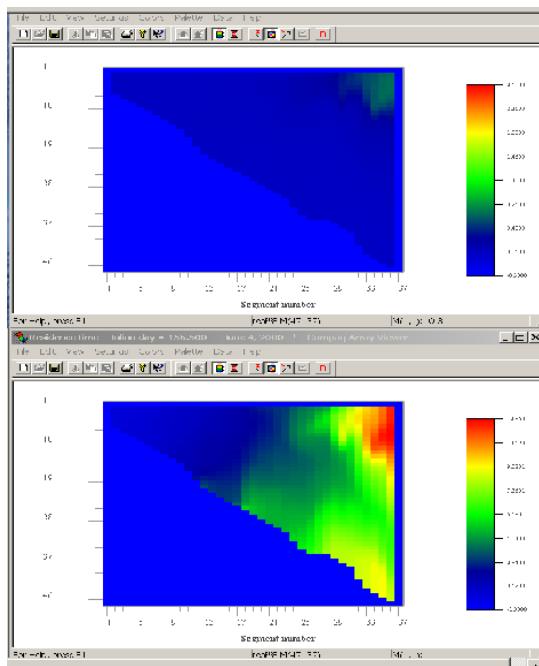


Figure 193. Plots illustrating residence time and algae concentration during early summer in Long Lake. Residence time is shown in the lower plot. Algae growth is shown in the upper plot. Both plots are side views of the reservoir with the dam to the right.

Algae growth and residence time during mid to late summer was illustrated in Figure 194. The bloom has extended upstream and the maximum concentration was located in the transition zone, which was in agreement with the data. Phytoplankton growth was clearly a function of residence time.

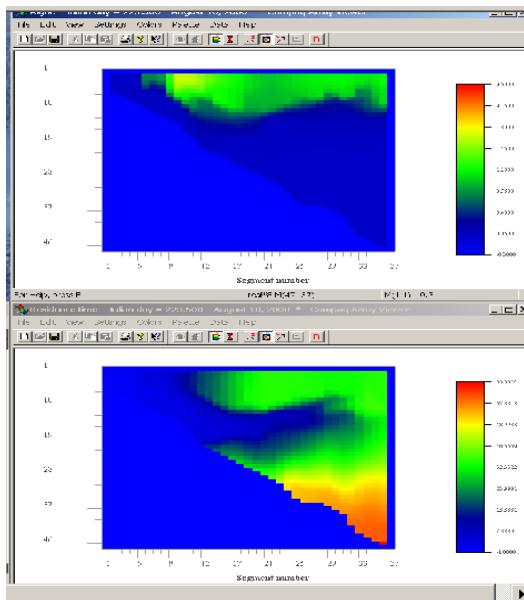


Figure 194. Plots illustrating residence time and algae concentration during late summer in Long Lake. Residence time is shown in the lower plot. Algae growth is shown in the upper plot.

In Figure 195 the model was reproducing the end of the bloom near the dam and the persistence upstream, which was qualitatively in agreement with the data. However, the model was not in quantitative agreement with the data at LL4, not because the model has missed the overall pattern of the algal bloom; it has just missed the upstream extent by a couple of kilometers. Model results must be carefully interpreted on a station by station and a day-by-day basis.

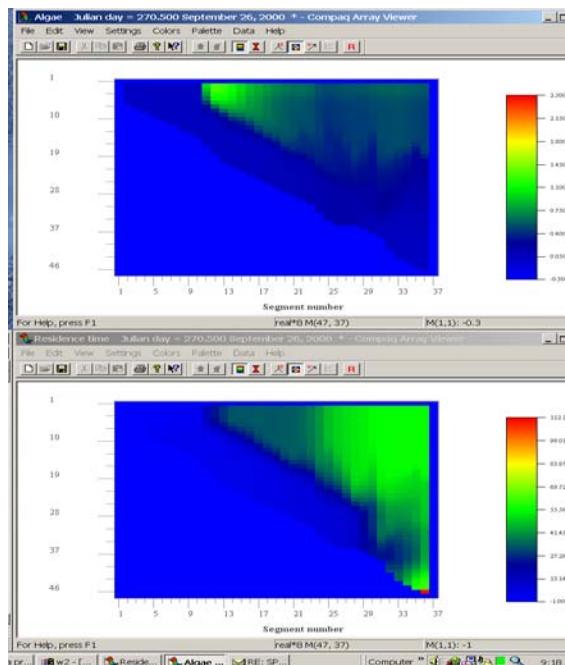


Figure 195 Plots illustrating residence time and algae concentration during early fall in Long Lake. Residence time is shown in the lower plot. Algae growth is shown in the upper plot.

Year 2000

Chlorophyll a vertical profiles were collected in Long Lake in 2000. Figure 196 to Figure 201 show Chlorophyll a profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. Figure 202 shows chlorophyll a time series data compared with model results for RM 66. Figure 203 shows chlorophyll a time series data compared with model results for RM 58.1. Table 48 shows AME and RMS error statistics for the chlorophyll a vertical profiles and Table 49 includes error statistics for the time series comparisons.

Table 48. Chlorophyll a profile error statistics, 2000

Site	n, # of data profile comparisons	Chlorophyll a model –data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	2	0.005	0.005
LL1	6	0.005	0.005
LL2	2	0.006	0.007
LL3	6	0.004	0.004
LL4	2	0.010	0.012
LL5	1	0.004	0.006

Table 49. Chlorophyll a time series error statistics, 2000

Site	n, # of data comparisons	Chlorophyll a model –data error statistics	
		AME, mg/L	RMS, mg/L
SPK66.0	8	0.001	0.001
SPK58.1	12	0.001	0.001

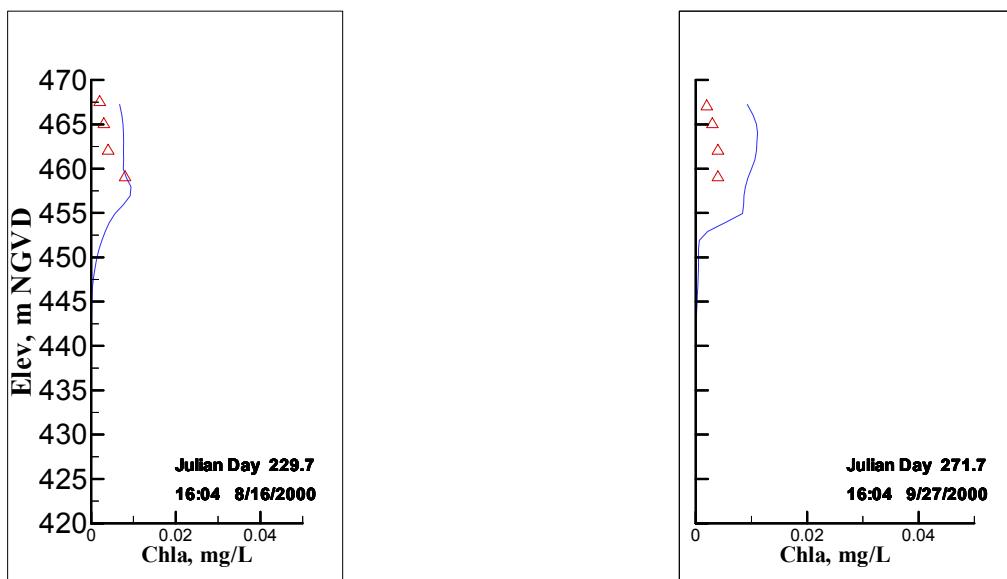


Figure 196. Comparison of model predicted vertical chlorophyll a profiles and 2000 data for Long Lake at Station 0 (Segment 187).

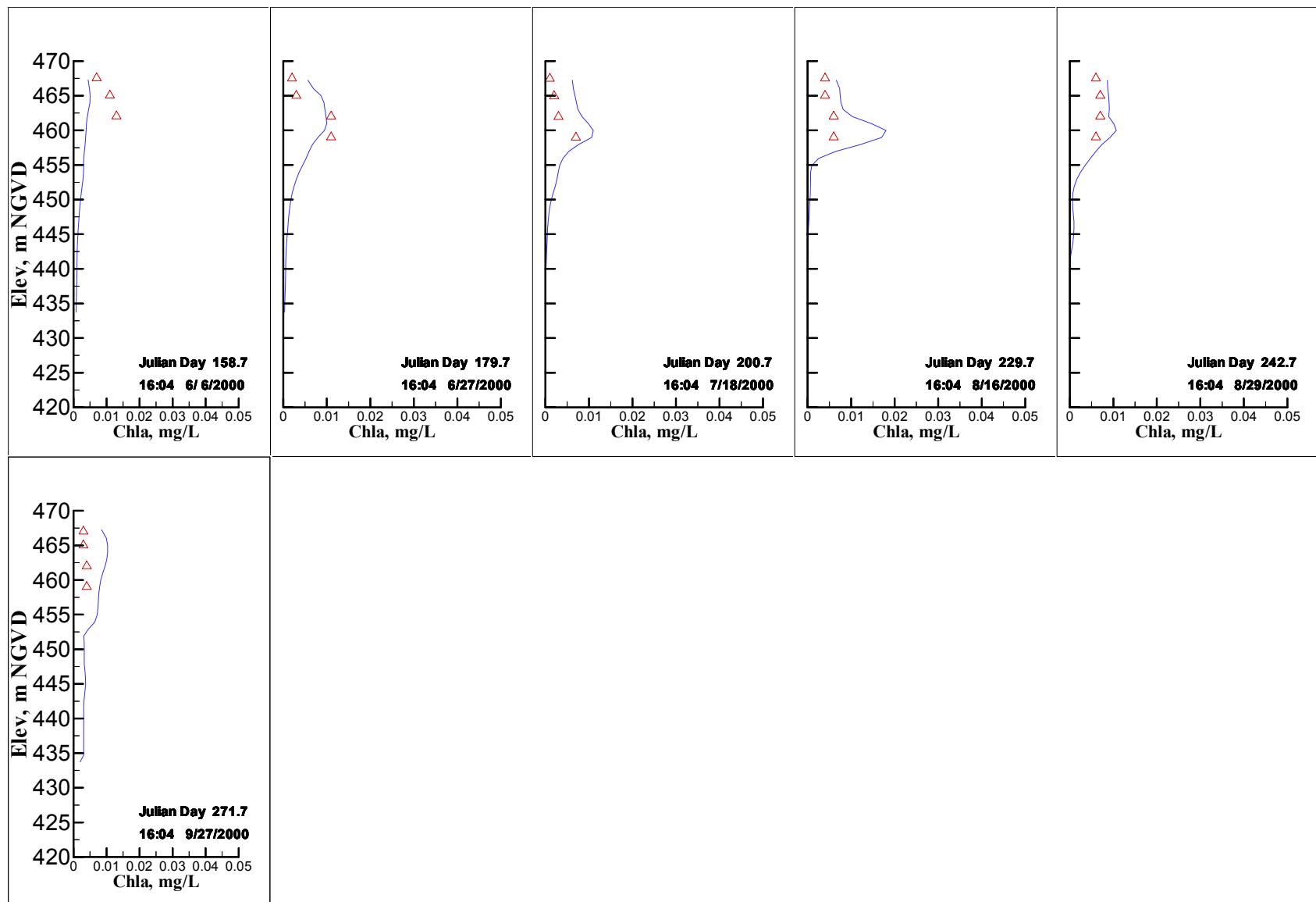


Figure 197. Comparison of model predicted vertical chlorophyll a profiles and 2000 data for Long Lake at Station 1 (Segment 180).

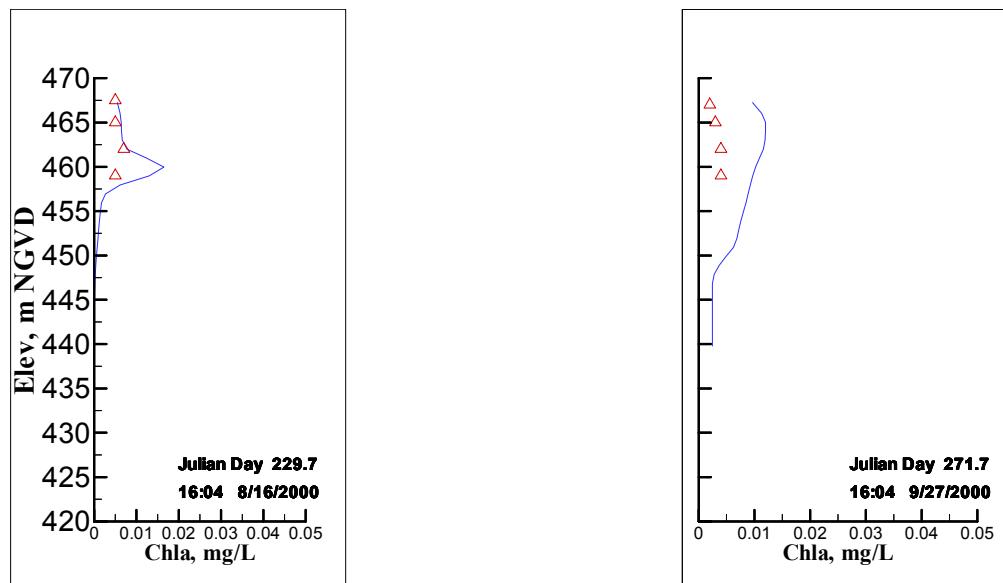


Figure 198. Comparison of model predicted vertical chlorophyll a profiles and 2000 data for Long Lake at Station 2 (Segment 174).

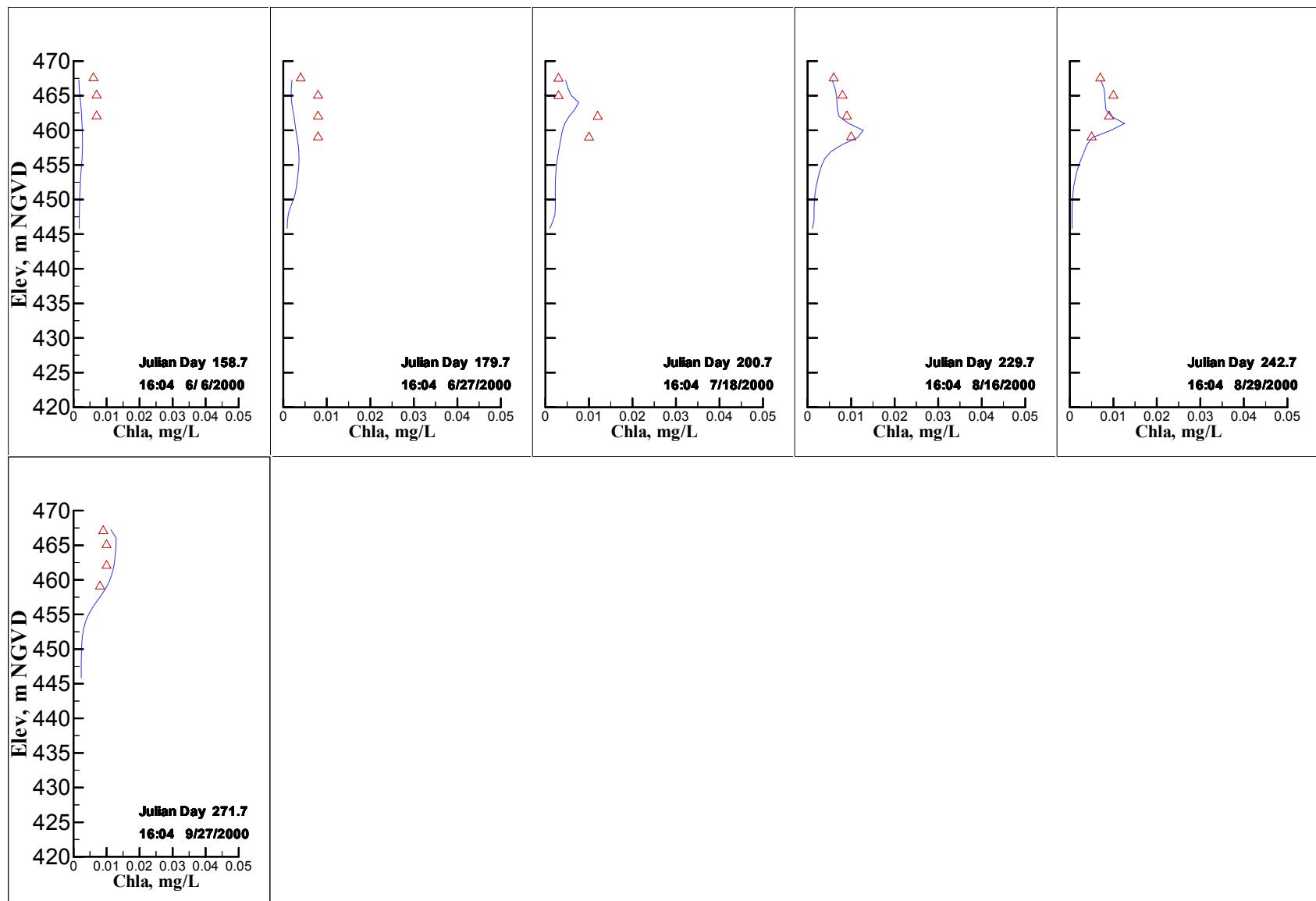


Figure 199. Comparison of model predicted vertical chlorophyll a profiles and 2000 data for Long Lake at Station 3 (Segment 168).

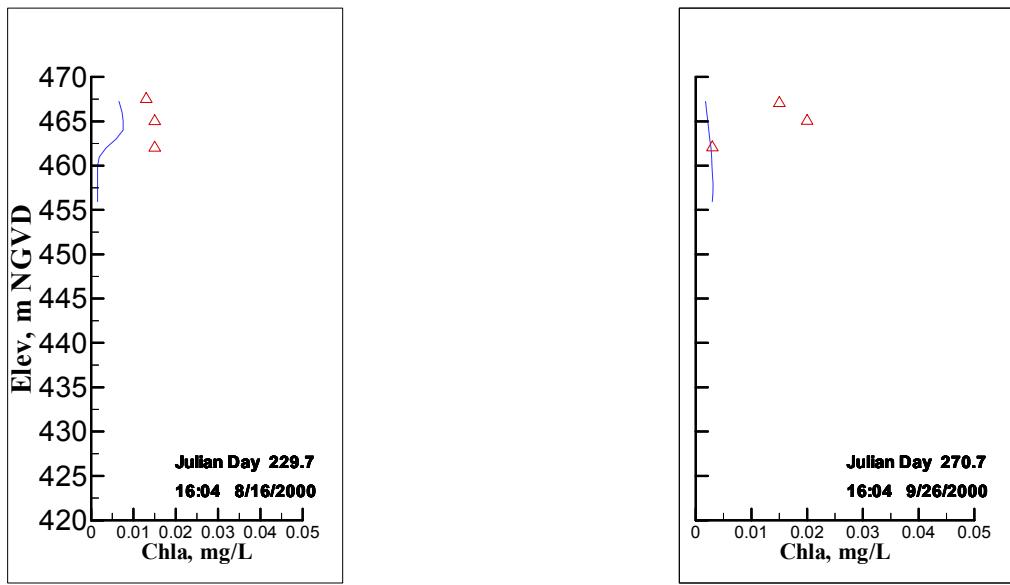


Figure 200. Comparison of model predicted vertical chlorophyll a profiles and 2000 data for Long Lake at Station 4 (Segment 161).

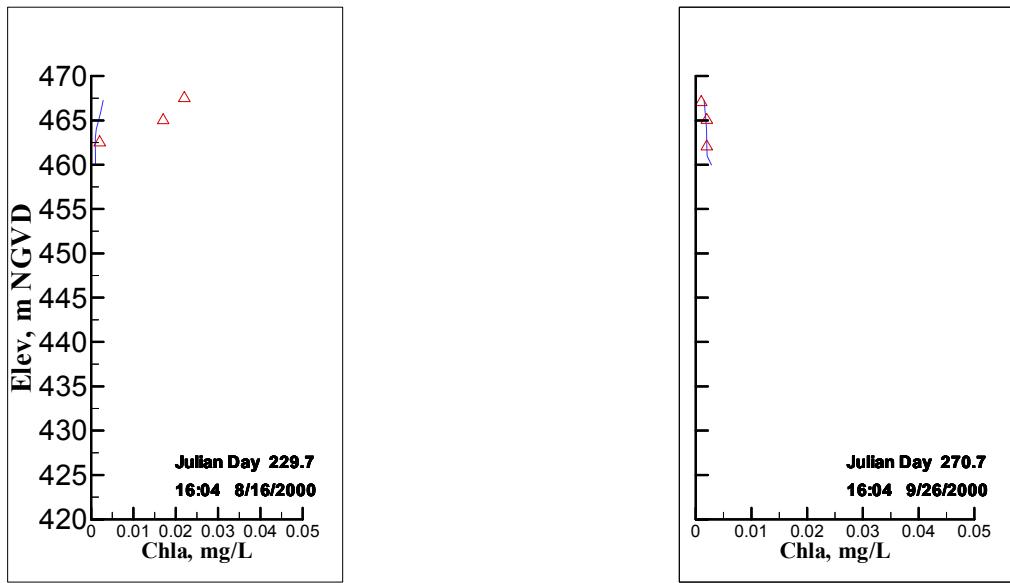


Figure 201. Comparison of model predicted vertical chlorophyll a profiles and 2000 data for Long Lake at Station 5 (Segment 157).

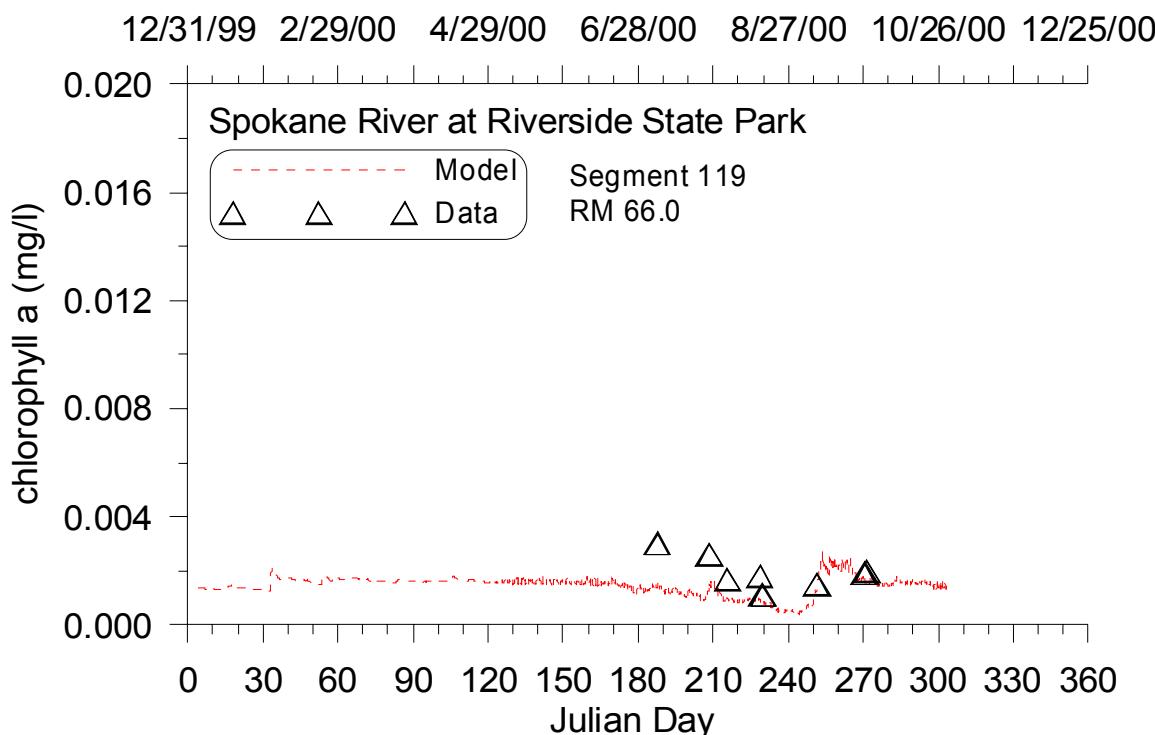


Figure 202. Comparison of model predicted chlorophyll a and 2000 data for Spokane River at Riverside State Park (Segment 119).

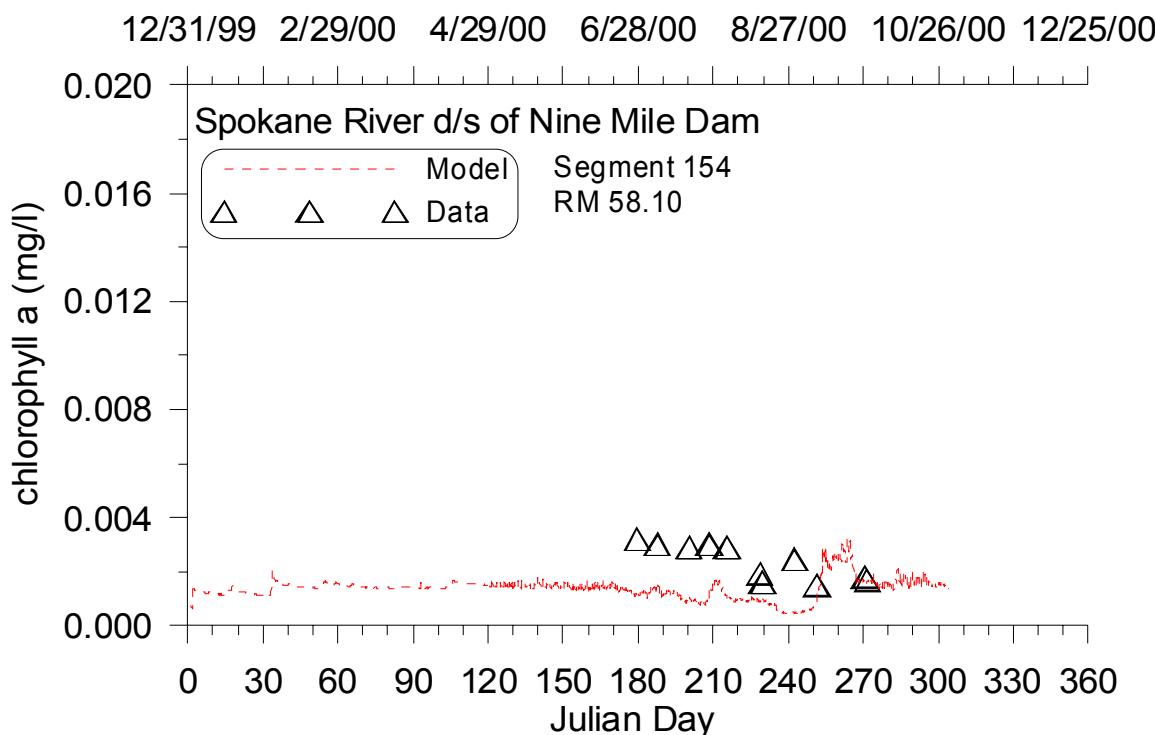


Figure 203. Comparison of model predicted chlorophyll a and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Total Organic Carbon

Model predicted total organic carbon concentrations were compared with data providing a means to determine if correct amounts organic matter were being simulated. In CE-QUAL-W2 total organic

carbon is a derived variable and is total of all CBOD, phytoplankton, and organic matter compartments. Vertical profile and time series data existed for 2000 and model predictions generally agreed with data.

Year 2000

Total organic carbon vertical profiles were collected in Long Lake in 2000 only. Figure 204 to Figure 209 show total organic carbon profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. Figure 210 shows total organic carbon time series data compared with model results for RM 66. Figure 211 shows total organic carbon time series data compared with model results for RM 58.1. Table 50 shows AME and RMS error statistics for the total organic carbon vertical profiles and Table 51 includes error statistics for the time series comparisons.

Table 50. Total organic carbon profile error statistics, 2000

Site	n, # of data profile comparisons	Total organic carbon model – data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	2	0.50	0.58
LL1	6	0.35	0.41
LL2	2	0.38	0.43
LL3	6	0.29	0.33
LL4	2	0.44	0.44
LL5	1	0.44	0.44

Table 51. Total organic carbon time series error statistics, 2000

Site	n, # of data comparisons	Total Organic C model – data error statistics	
		AME, mg/L	RMS, mg/L
SPK66.0	12	0.54	0.64
SPK58.1	16	0.38	0.43

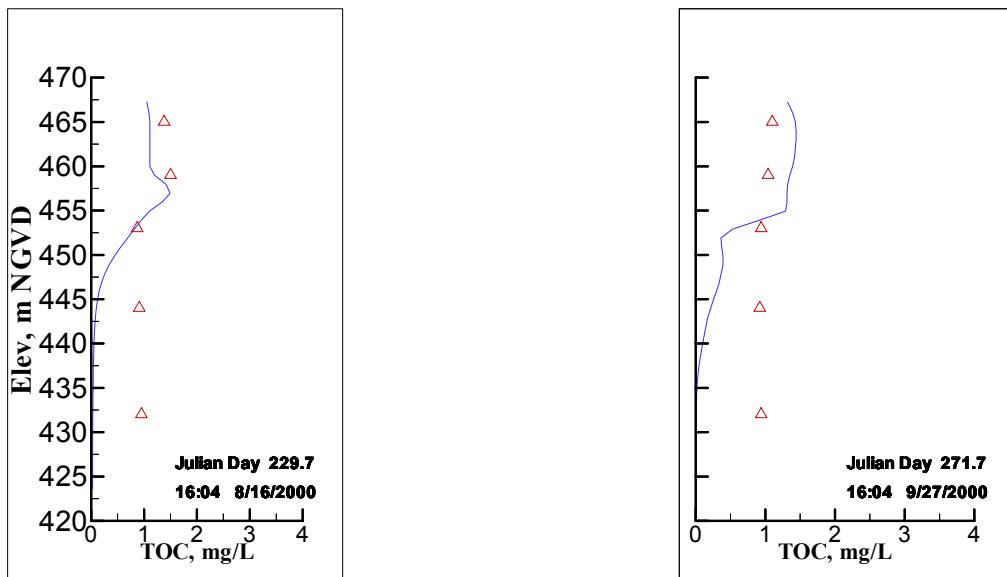


Figure 204. Comparison of model predicted vertical total organic carbon profiles and 2000 data for Long Lake at Station 0 (Segment 187).

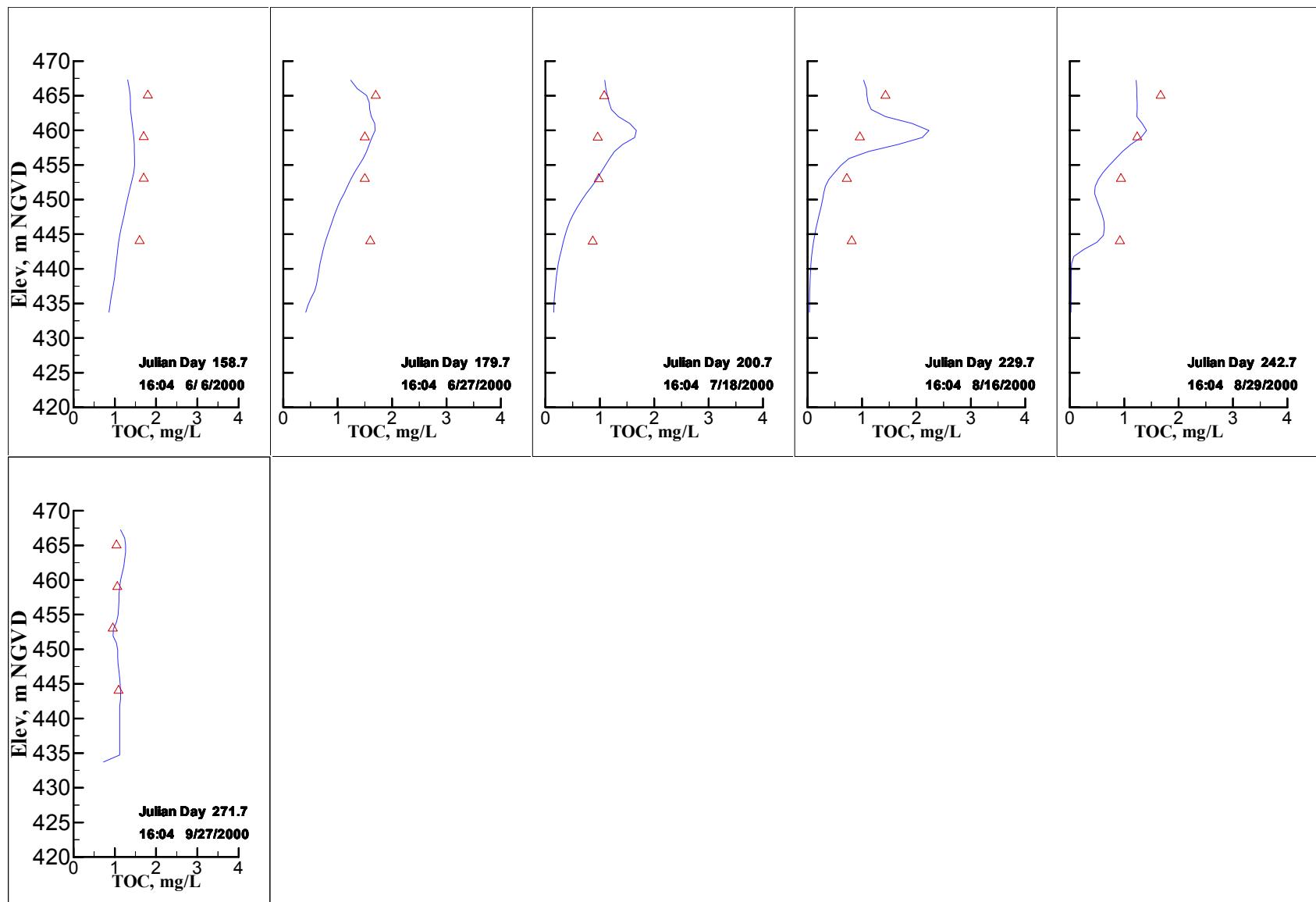


Figure 205. Comparison of model predicted vertical total organic carbon profiles and 2000 data for Long Lake at Station 1 (Segment 180).

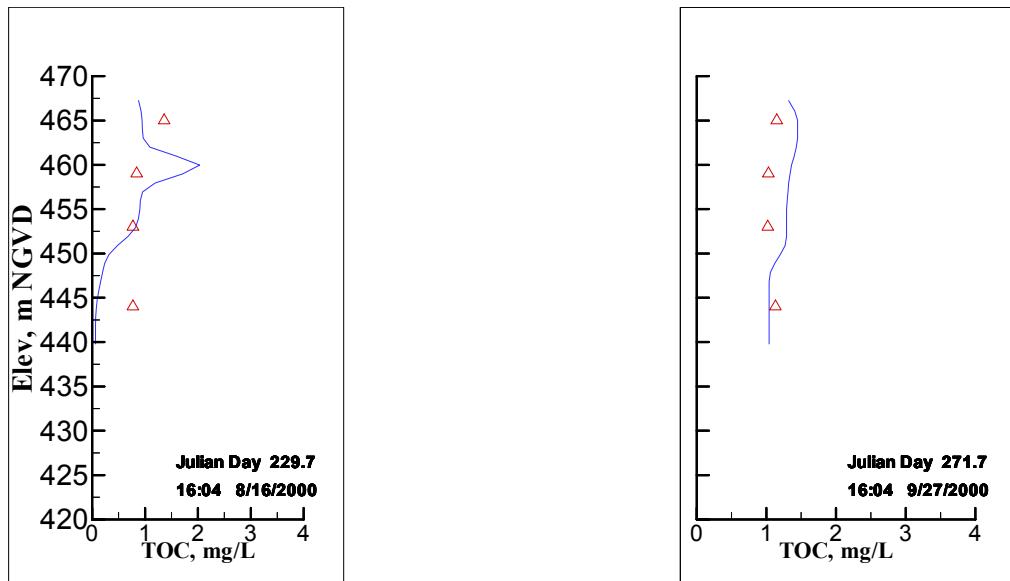


Figure 206. Comparison of model predicted vertical total organic carbon profiles and 2000 data for Long Lake at Station 2 (Segment 174).

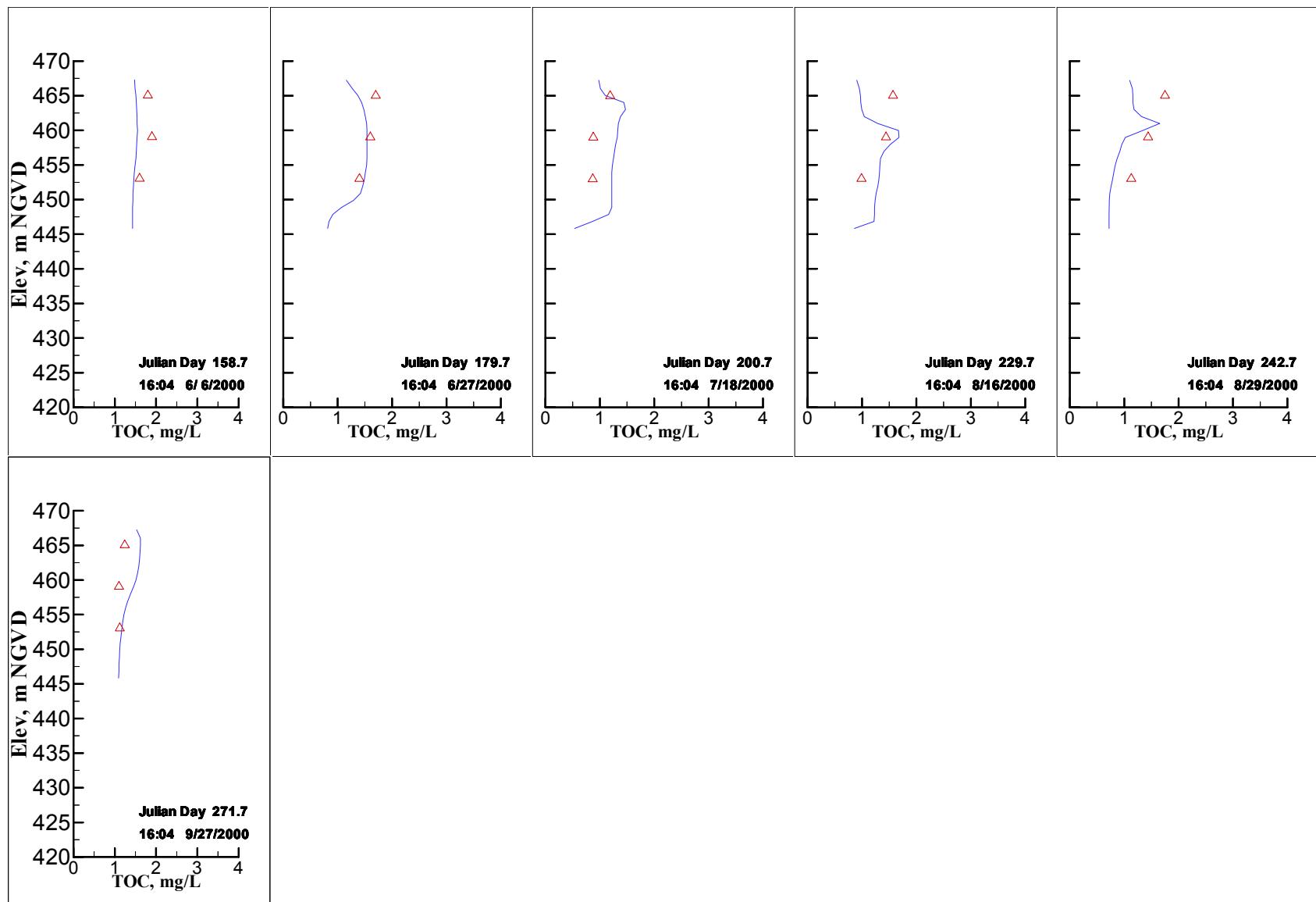


Figure 207. Comparison of model predicted vertical total organic carbon profiles and 2000 data for Long Lake at Station 3 (Segment 168).

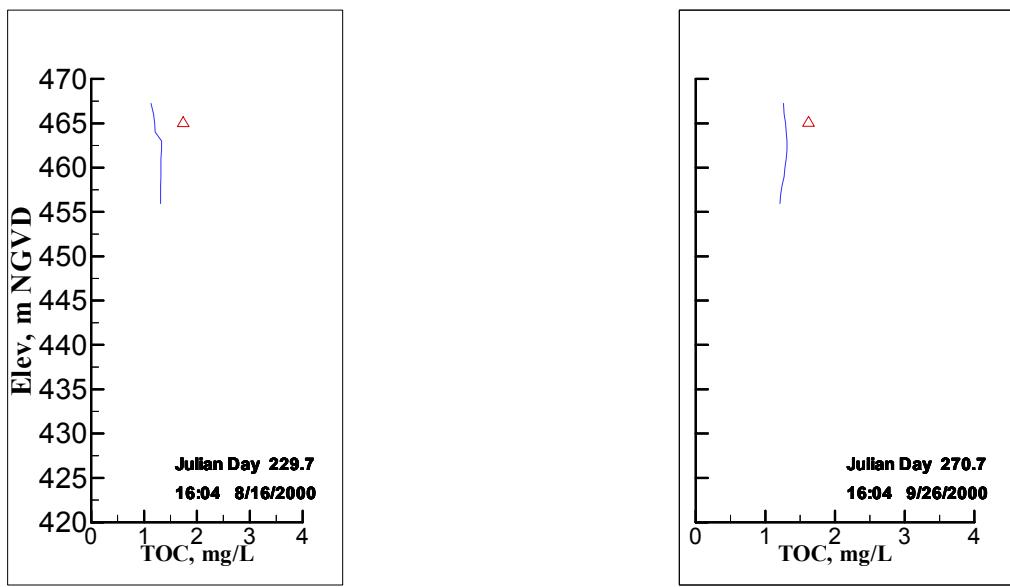


Figure 208. Comparison of model predicted vertical total organic carbon profiles and 2000 data for Long Lake at Station 4 (Segment 161).

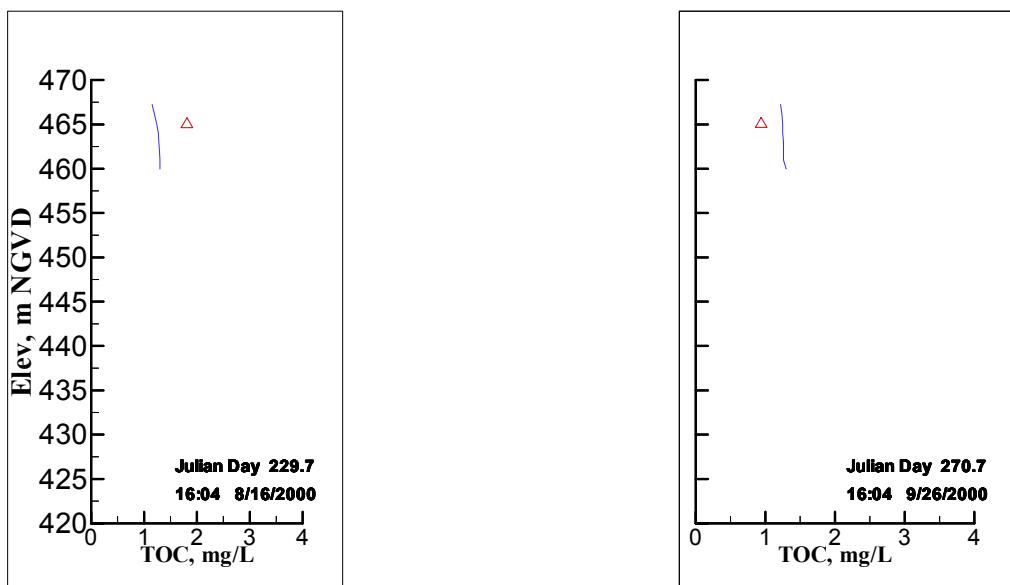


Figure 209. Comparison of model predicted vertical total organic carbon profiles and 2000 data for Long Lake at Station 5 (Segment 157).

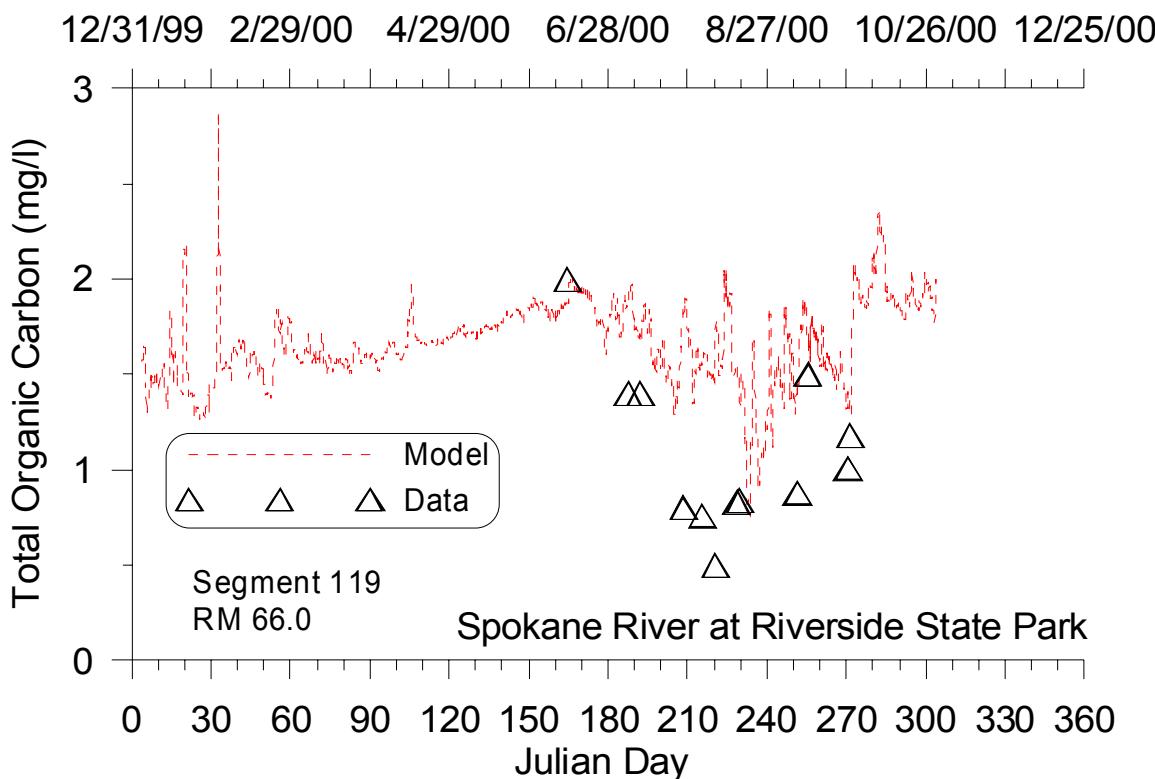


Figure 210. Comparison of model predicted total organic carbon and 2000 data for Spokane River at Riverside State Park (Segment 119).

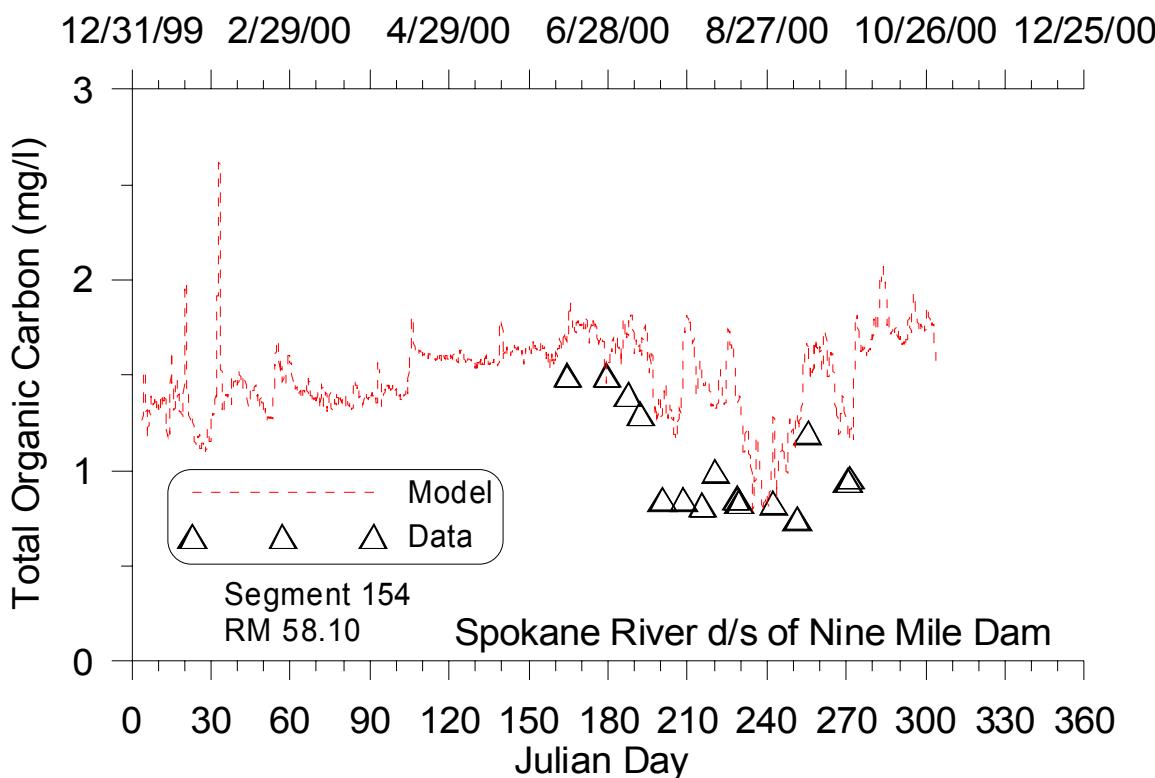


Figure 211. Comparison of model predicted total organic carbon and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Total Nitrogen

Total nitrogen is a derived variable in CE-QUAL-W2 and is the sum of all nitrogen contained in ammonia nitrogen, nitrite-nitrate nitrogen, the CBOD compartments, phytoplankton, and organic matter compartments. Year 2000 time series and vertical profile data were available and the model predictions were consistent with data.

Year 2000

Total nitrogen vertical profiles were collected in Long Lake in 2000. Figure 212 to Figure 217 show total nitrogen profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. Figure 218 and Figure 219 show total nitrogen time series data compared with model results for RM 66 and RM 58, respectively. Table 52 shows AME and RMS error statistics for the total nitrogen vertical profiles and Table 53 includes error statistics for the time series comparisons. Model predictions of total nitrogen were generally best in Long Lake at the downstream sampling sites.

Table 52. Total nitrogen profile error statistics, 2000

Site	n, # of data profile comparisons	Total nitrogen model –data error statistics	
		AME, mg/L	RMS error, mg/L
LL0	2	0.18	0.24
LL1	6	0.16	0.20
LL2	2	0.19	0.23
LL3	6	0.24	0.27
LL4	2	0.46	0.48
LL5	1	0.21	0.26

Table 53. Total nitrogen time series error statistics, 2000

Site	n, # of data comparisons	Total nitrogen model –data error statistics	
		AME, mg/L	RMS, mg/L
SPK66.0	24	0.14	0.19
SPK58.1	20	0.18	0.22

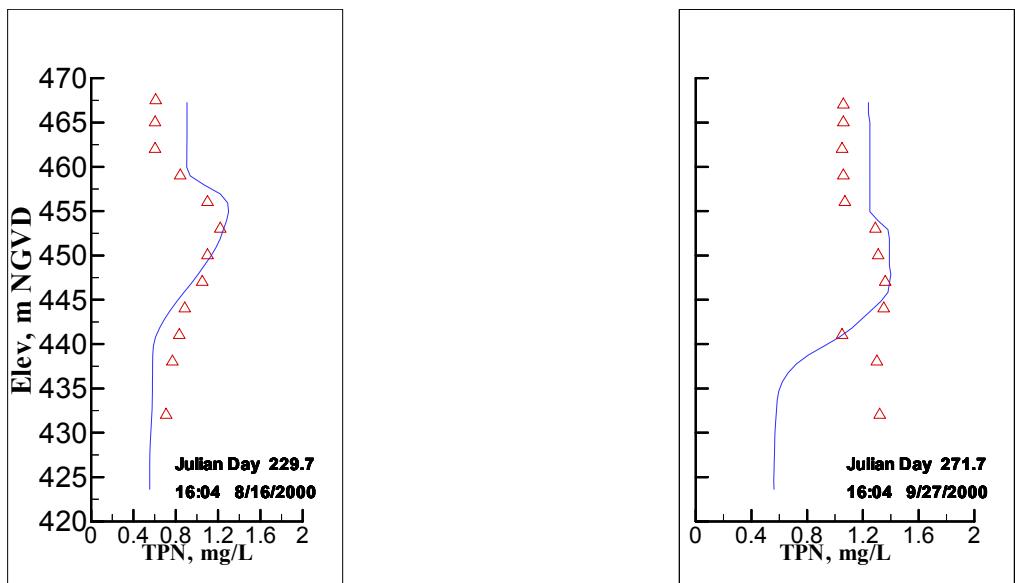


Figure 212. Comparison of model predicted vertical total nitrogen profiles and 2000 data for Long Lake at Station 0 (Segment 187).

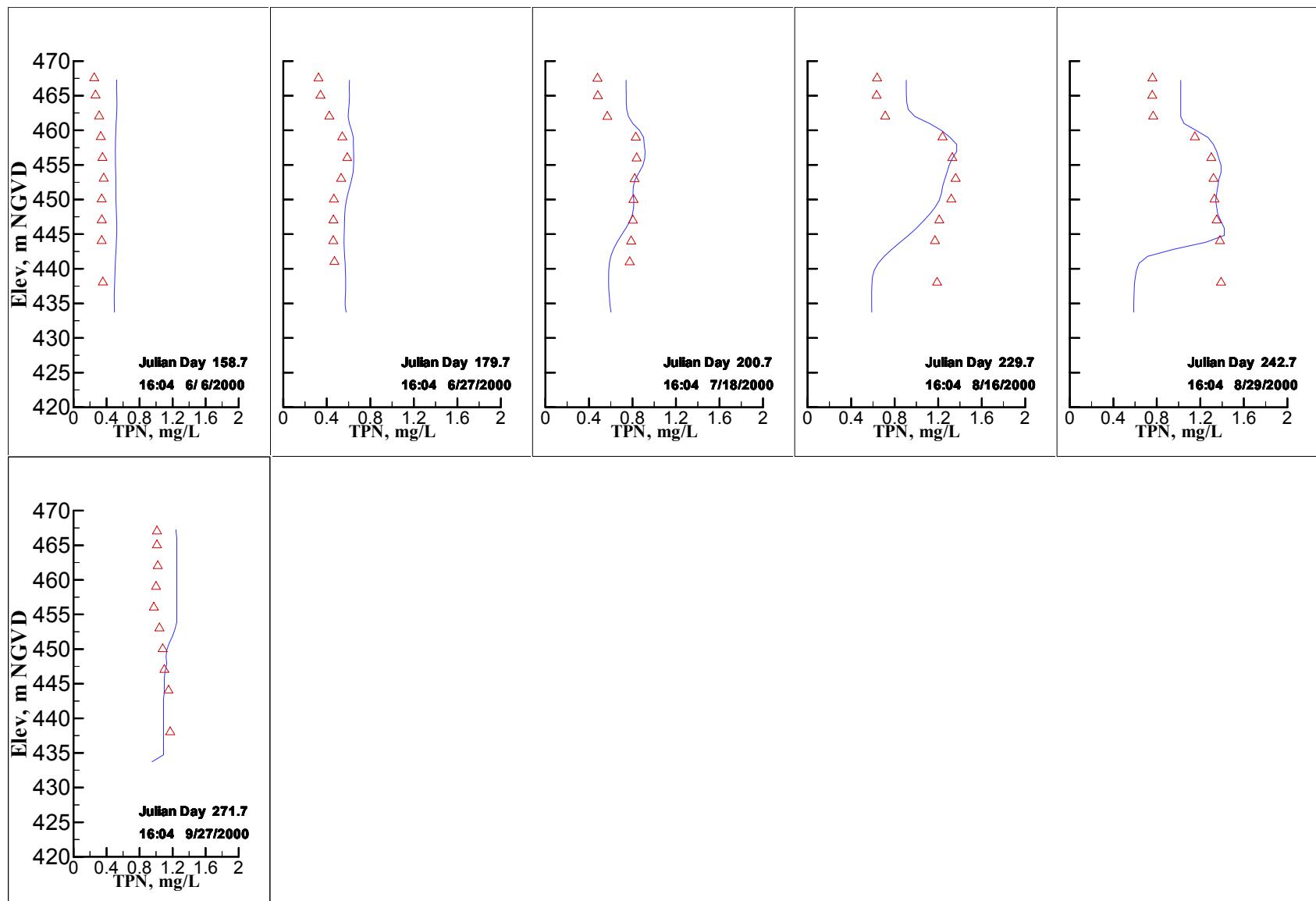


Figure 213. Comparison of model predicted vertical total nitrogen profiles and 2000 data for Long Lake at Station 1 (Segment 180).

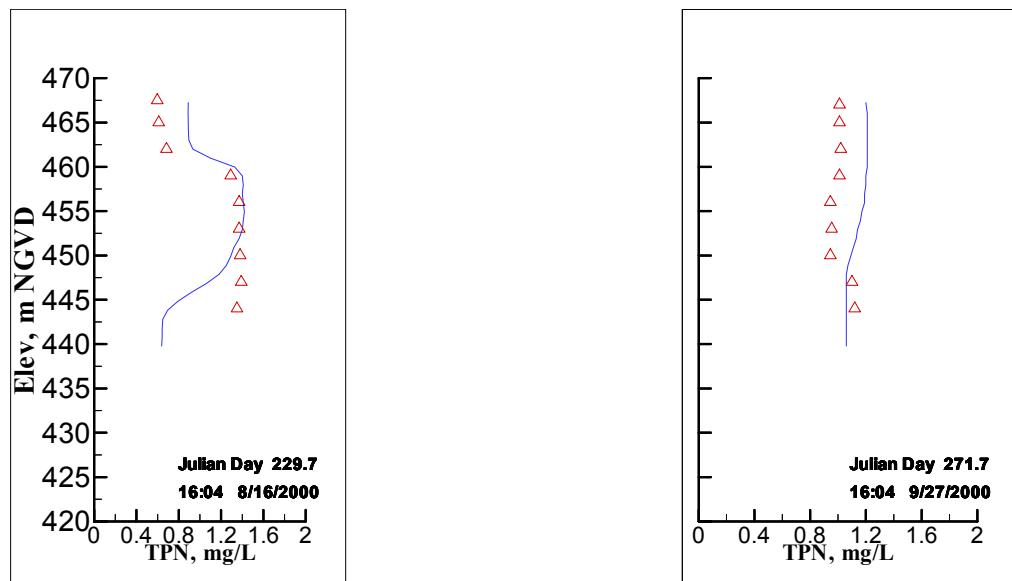


Figure 214. Comparison of model predicted vertical total nitrogen profiles and 2000 data for Long Lake at Station 2 (Segment 174).

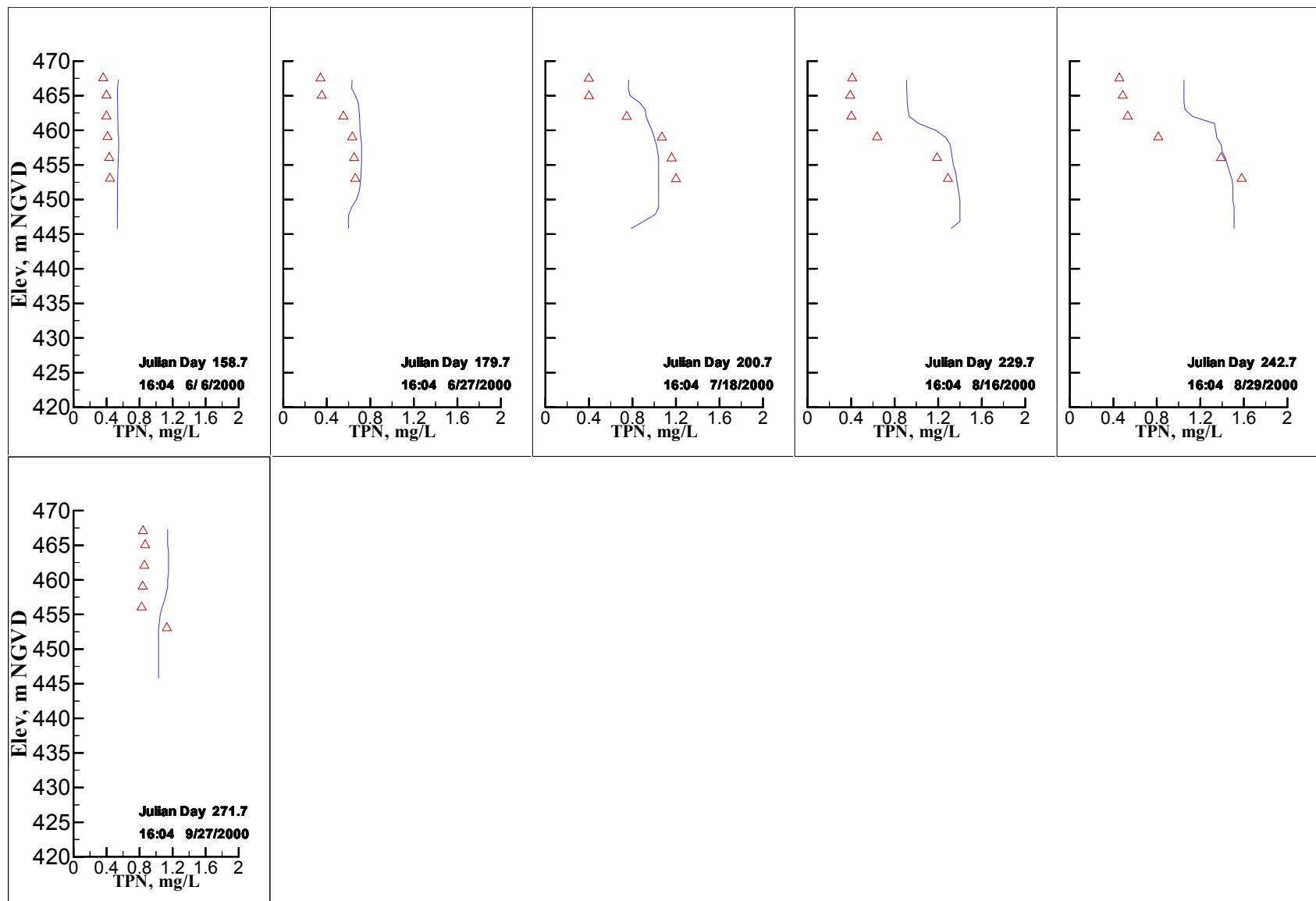


Figure 215. Comparison of model predicted vertical total nitrogen profiles and 2000 data for Long Lake at Station 3 (Segment 168).

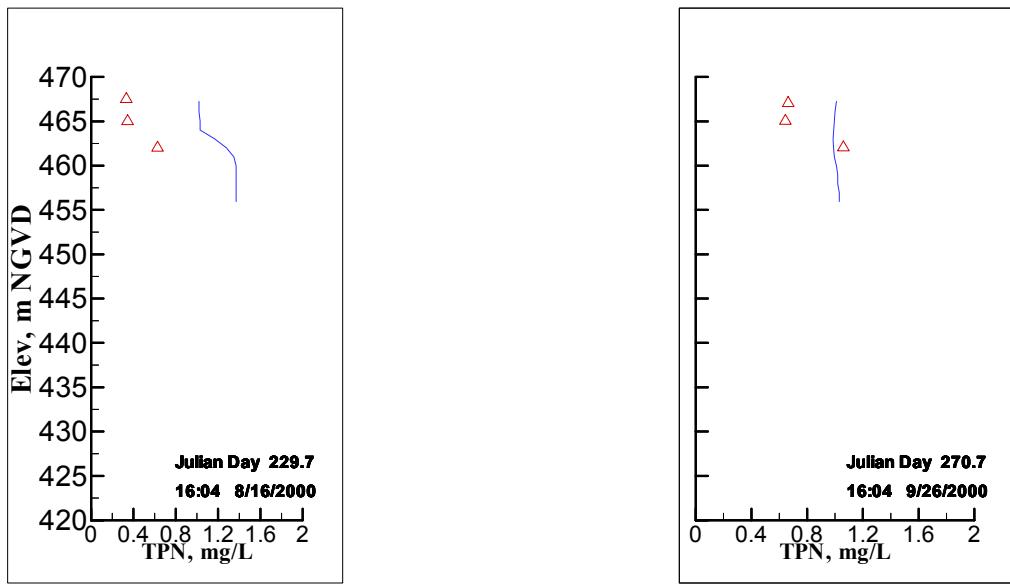


Figure 216. Comparison of model predicted vertical total nitrogen profiles and 2000 data for Long Lake at Station 4 (Segment 161).

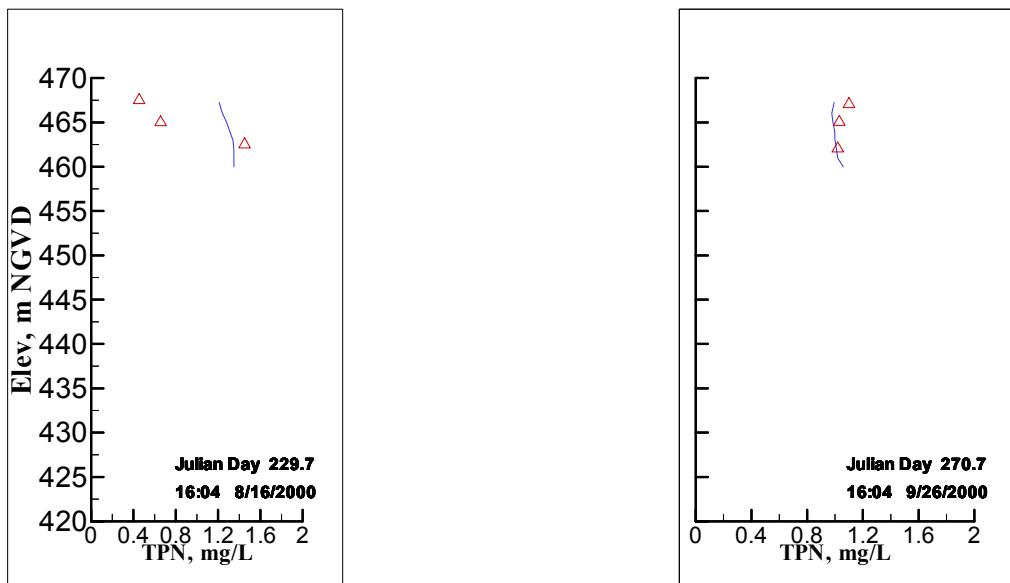


Figure 217. Comparison of model predicted vertical total nitrogen profiles and 2000 data for Long Lake at Station 5 (Segment 157).

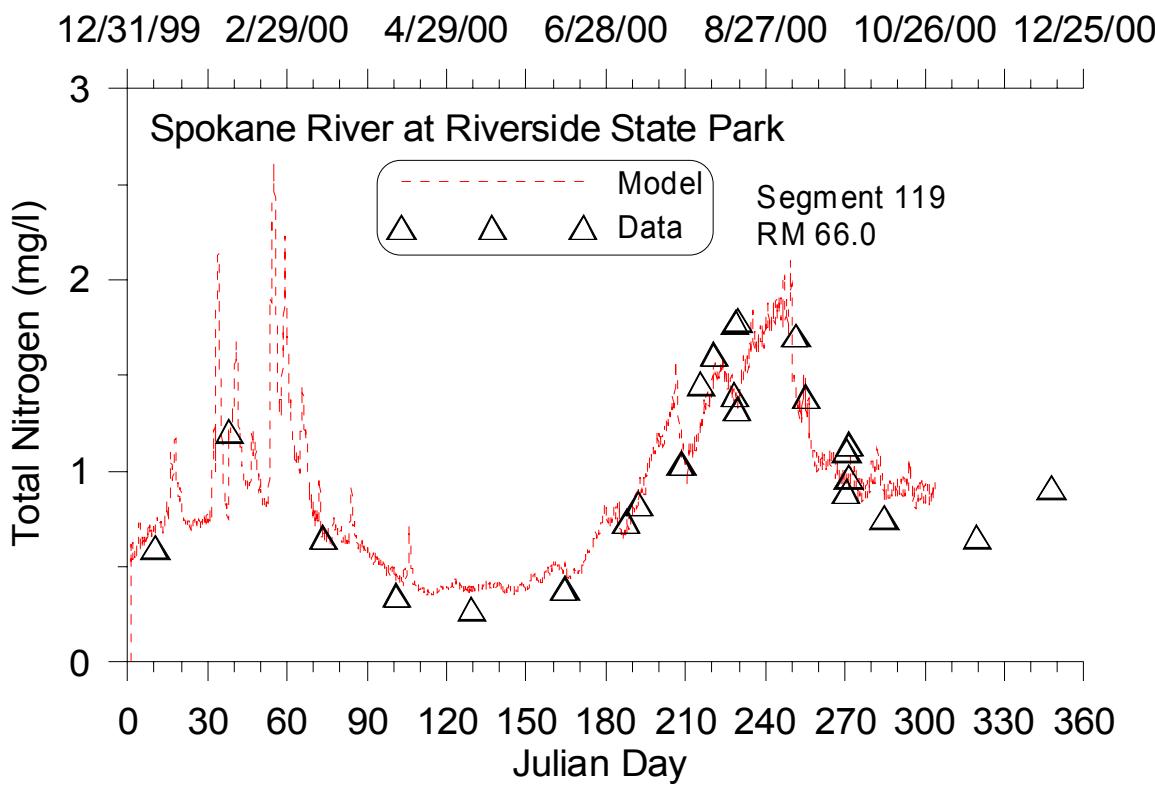


Figure 218. Comparison of model predicted total nitrogen and 2000 data for Spokane River at Riverside State Park (Segment 119).

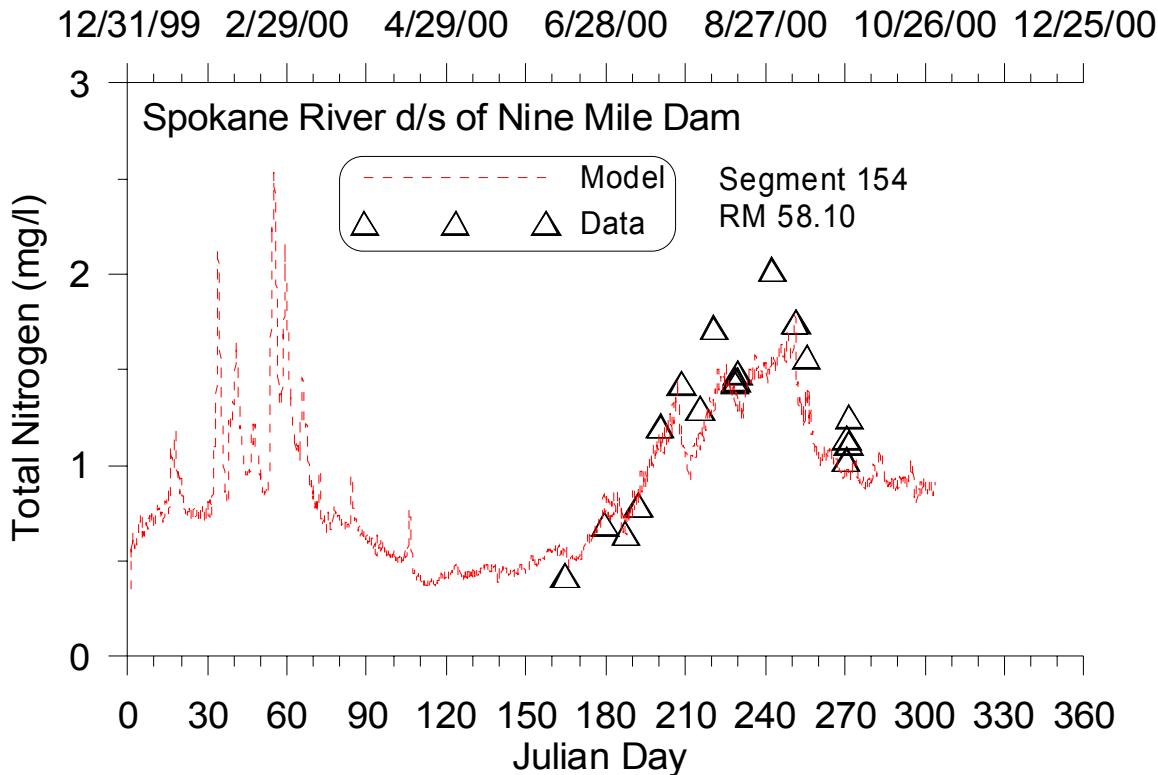


Figure 219. Comparison of model predicted total nitrogen and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Total Kjeldahl Nitrogen

The model predicted total Kjeldahl nitrogen (TKN) was compared with 1991 data in Figure 220 for the sampling site downstream of Nine Mile Dam (RM 58.10). TKN is the total of all organic and ammonia nitrogen and is a derived variable in CE-QUAL-W2.

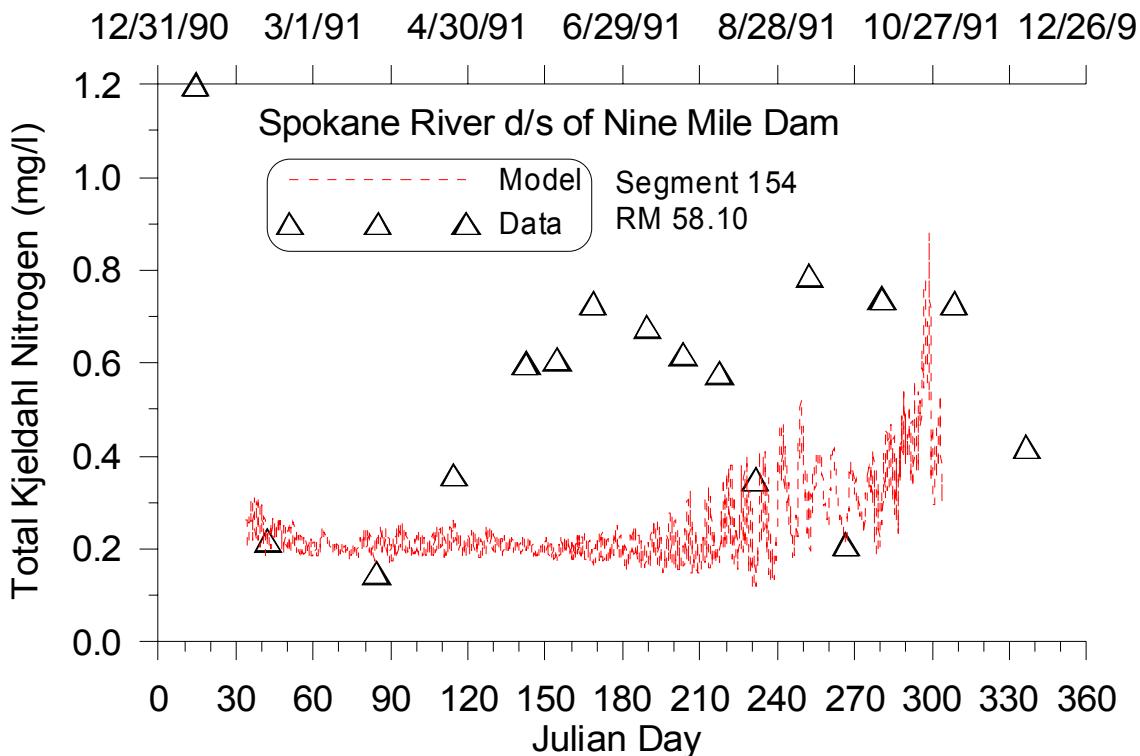


Figure 220. Comparison of model predicted TKN and 1991 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Total Phosphorus

Total phosphorus is a derived variable in CE-QUAL-W2 and is the sum of all phosphorus model compartments. 1991 and 2000 time series and vertical profile data were available and the model predictions were consistent with data.

Year 1991

Total phosphorus (TP) vertical profiles were collected in Long Lake in 1991 for 12 different days. Additional profiles were not collected upstream of Long Lake. Figure 221 to Figure 225 show TP vertical profile data and model results for five locations in Long Lake from RM 32.7 to 54.5. Table 54 shows AME and RMS error statistics for the TP vertical profiles.

Table 54. Total Phosphorus profile error statistics, 1991

Site	n, # of data profile comparisons	TP model -data error statistics	
		AME, mg/L	RMS, mg/L
LL0	12	0.007	0.008
LL1	12	0.007	0.009
LL2	12	0.007	0.008
LL3	12	0.010	0.011
LL4	12	0.009	0.010

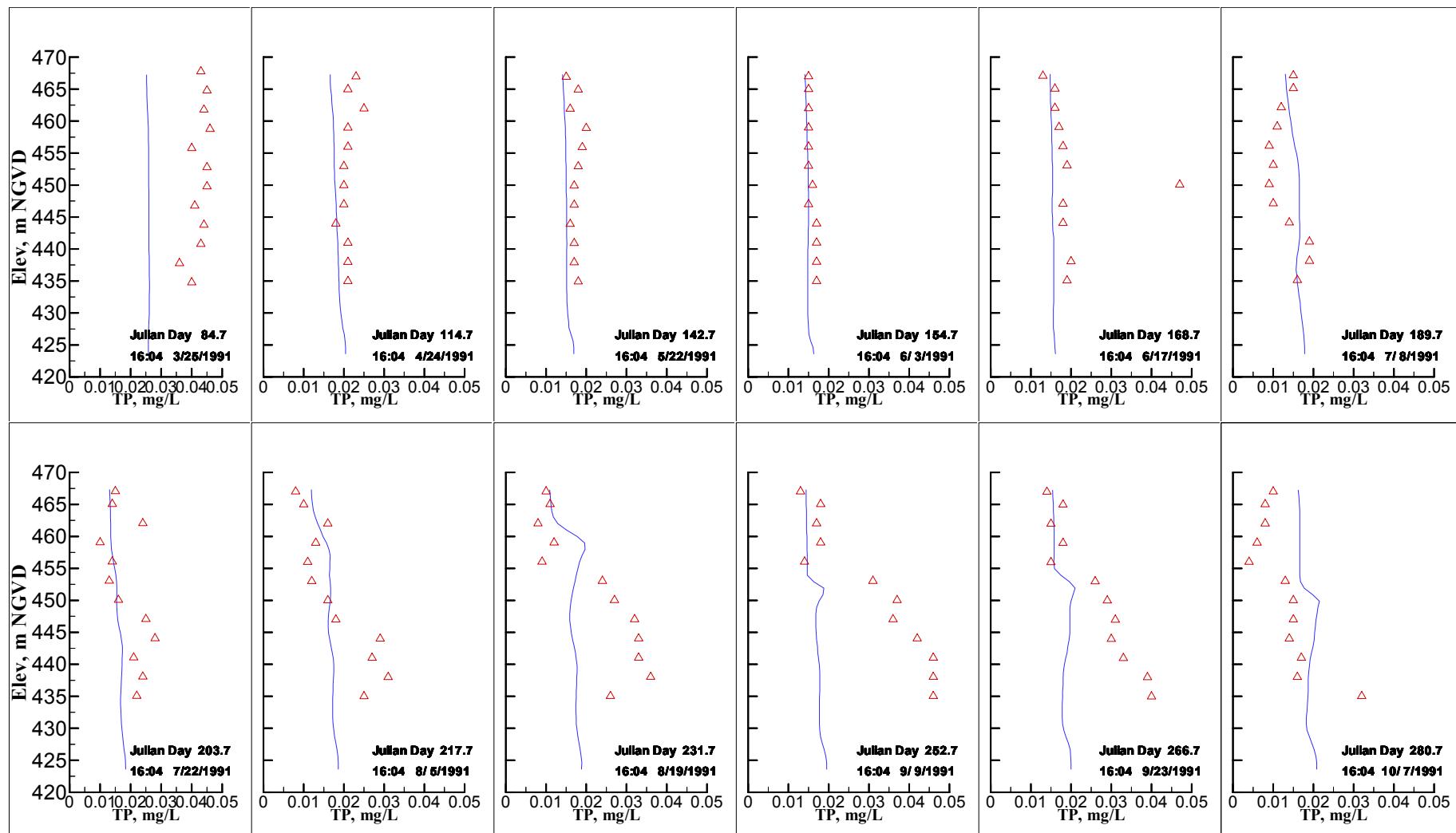


Figure 221. Comparison of model predicted vertical total phosphorus profiles and 1991 data for Long Lake at Station 0 (Segment 187).

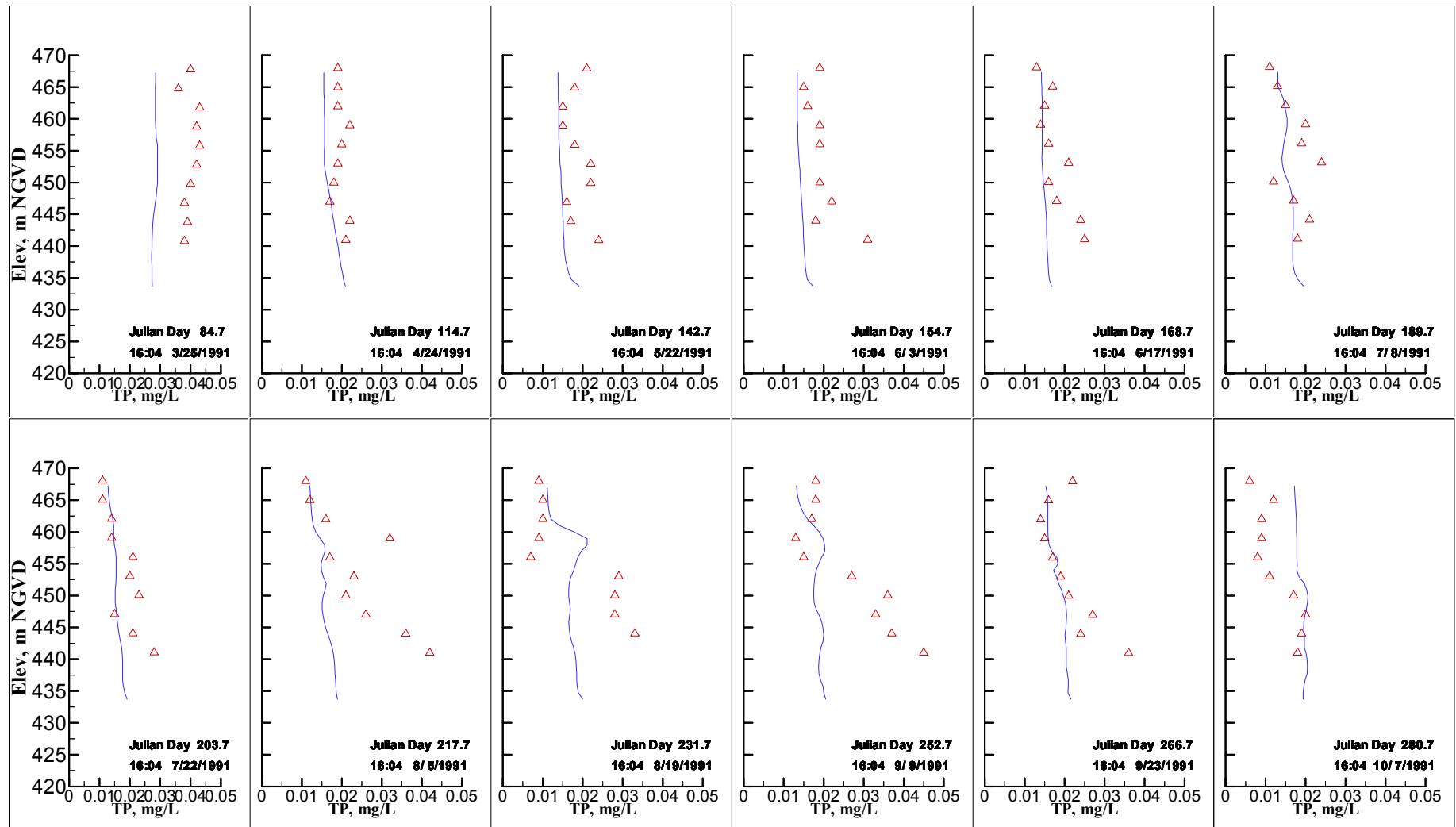


Figure 222. Comparison of model predicted vertical total phosphorus profiles and 1991 data for Long Lake at Station 1 (Segment 180).

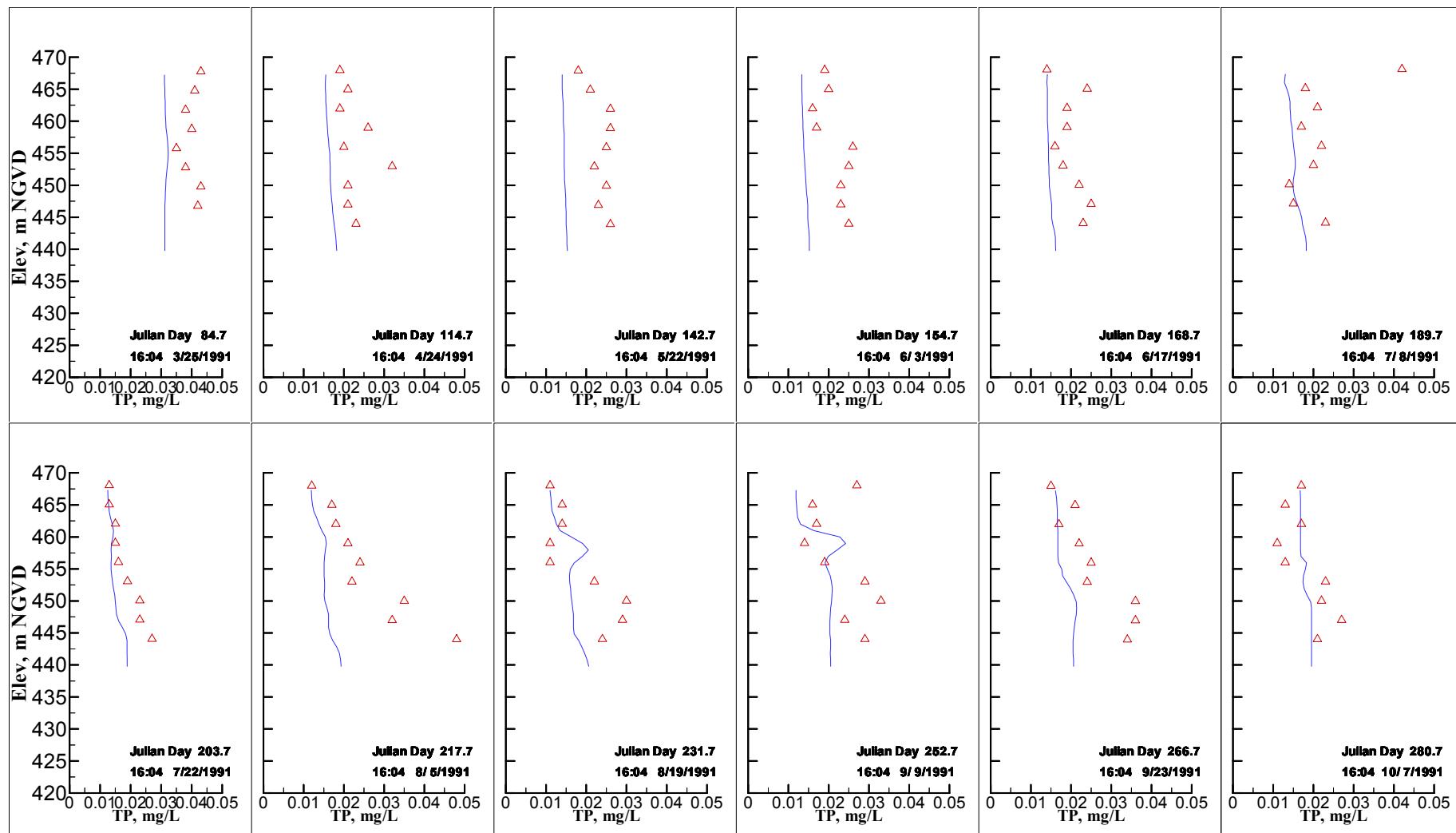


Figure 223. Comparison of model predicted vertical total phosphorus profiles and 1991 data for Long Lake at Station 2 (Segment 174).

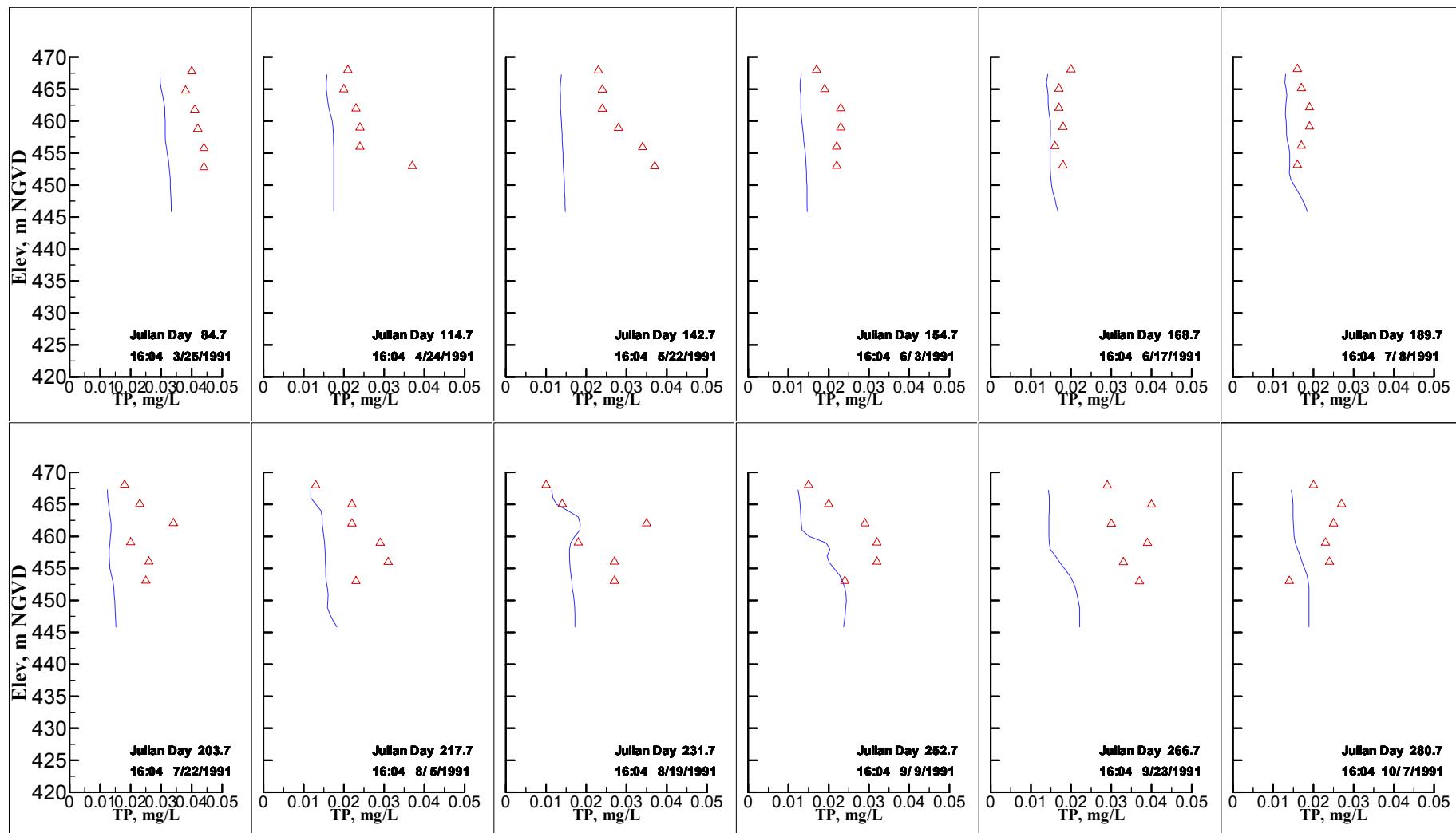


Figure 224. Comparison of model predicted vertical total phosphorus profiles and 1991 data for Long Lake at Station 3 (Segment 168).

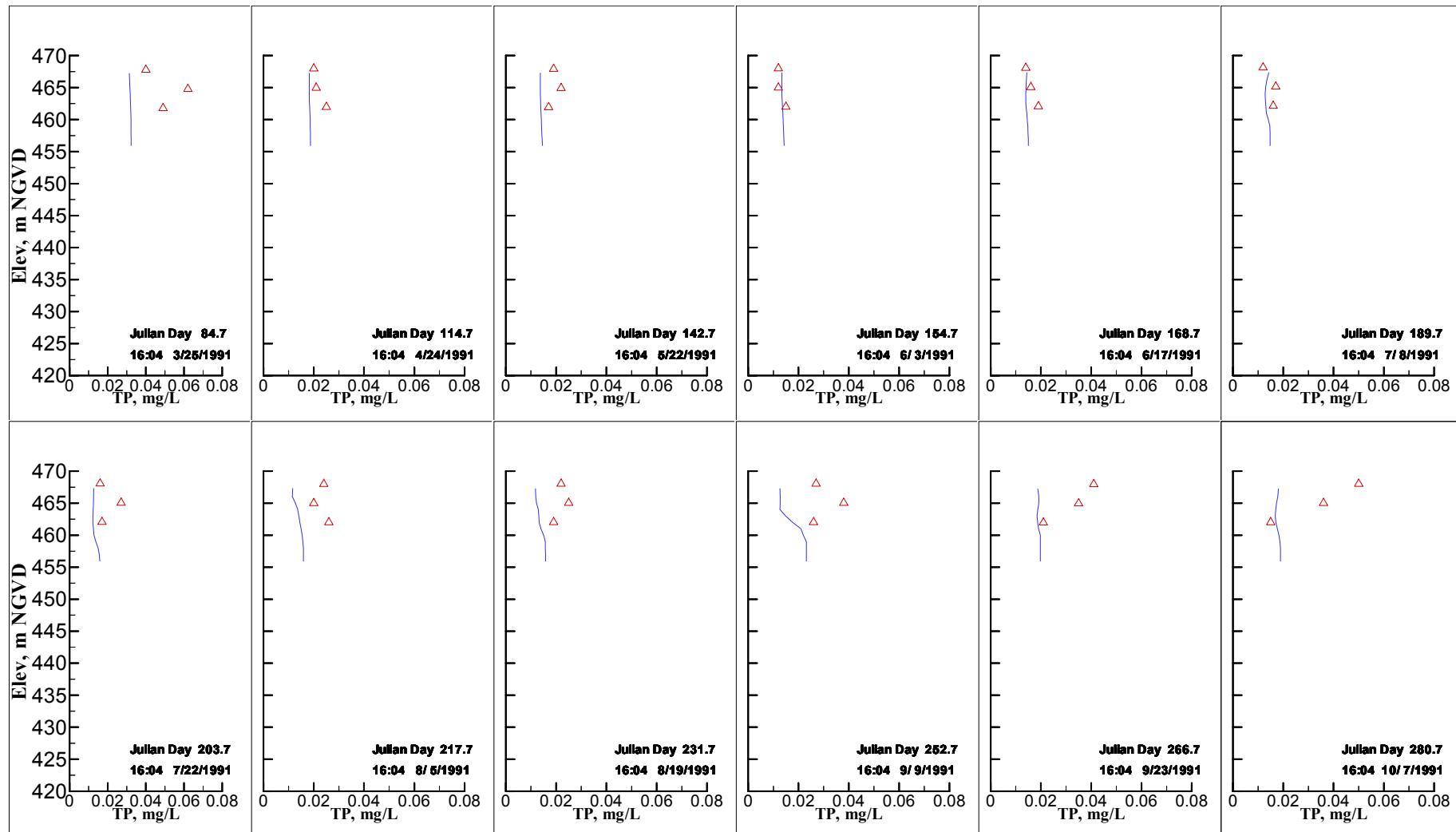


Figure 225. Comparison of model predicted vertical total phosphorus profiles and 1991 data for Long Lake at Station 4 (Segment 161).

Year 2000

Total phosphorus (TP) vertical profiles were collected in Long Lake in 1991 for 7 different days. Additional profiles were not collected upstream of Long Lake. Figure 226 to Figure 231 show TP vertical profile data and model results for six locations in Long Lake from RM 32.7 to 54.5. Figure 232 shows TP time series data compared with model results for RM 66. Figure 233 shows TP time series data compared with model results for RM 58.1. Table 55 shows AME and RMS error statistics for the TP vertical profiles and Table 56 includes error statistics for the time series comparisons.

Table 55. Total Phosphorus profile error statistics, 2000

Site	n, # of data profile comparisons	TP model -data error statistics	
		AME, mg/L	RMS, mg/L
LL0	3	0.008	0.010
LL1	7	0.006	0.007
LL2	3	0.011	0.013
LL3	7	0.005	0.006
LL4	3	0.005	0.006
LL5	3	0.007	0.007

Table 56. Total Phosphorus time series error statistics, 2000

Site	n, # of data comparisons	TP model -data error statistics	
		AME, mg/L	RMS error, mg/L
SPK66.0	24	0.014	0.039
SPK58.1	20	0.004	0.005

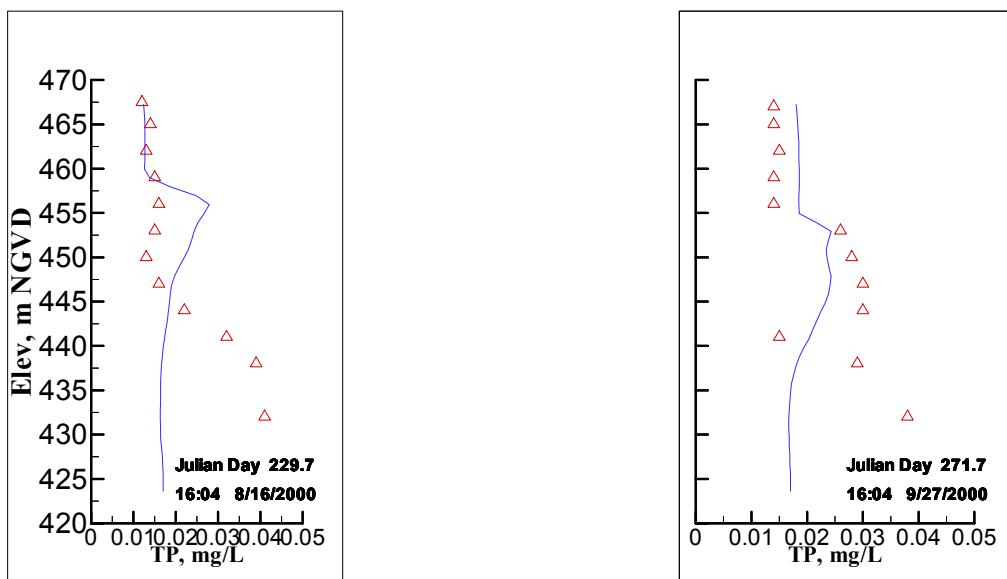


Figure 226. Comparison of model predicted vertical total phosphorus profiles and 2000 data for Long Lake at Station 0 (Segment 187).

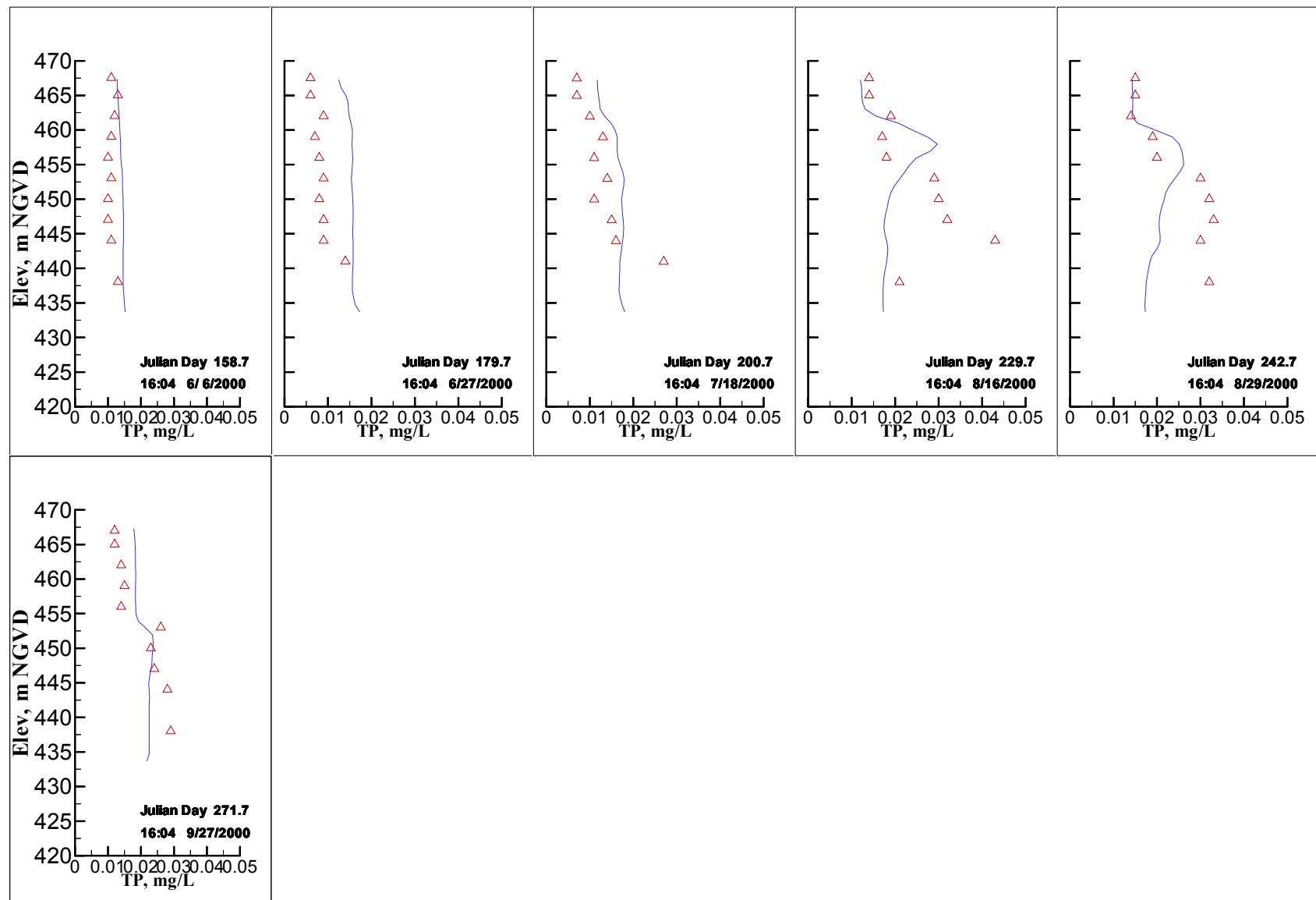


Figure 227. Comparison of model predicted vertical total phosphorus profiles and 2000 data for Long Lake at Station 1 (Segment 180).

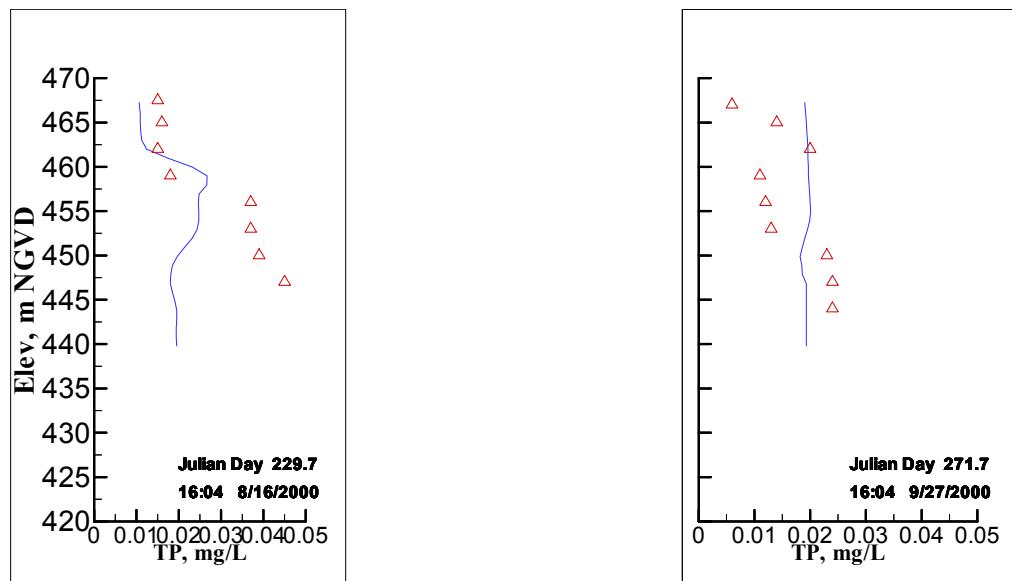


Figure 228. Comparison of model predicted vertical total phosphorus profiles and 2000 data for Long Lake at Station 2 (Segment 174).

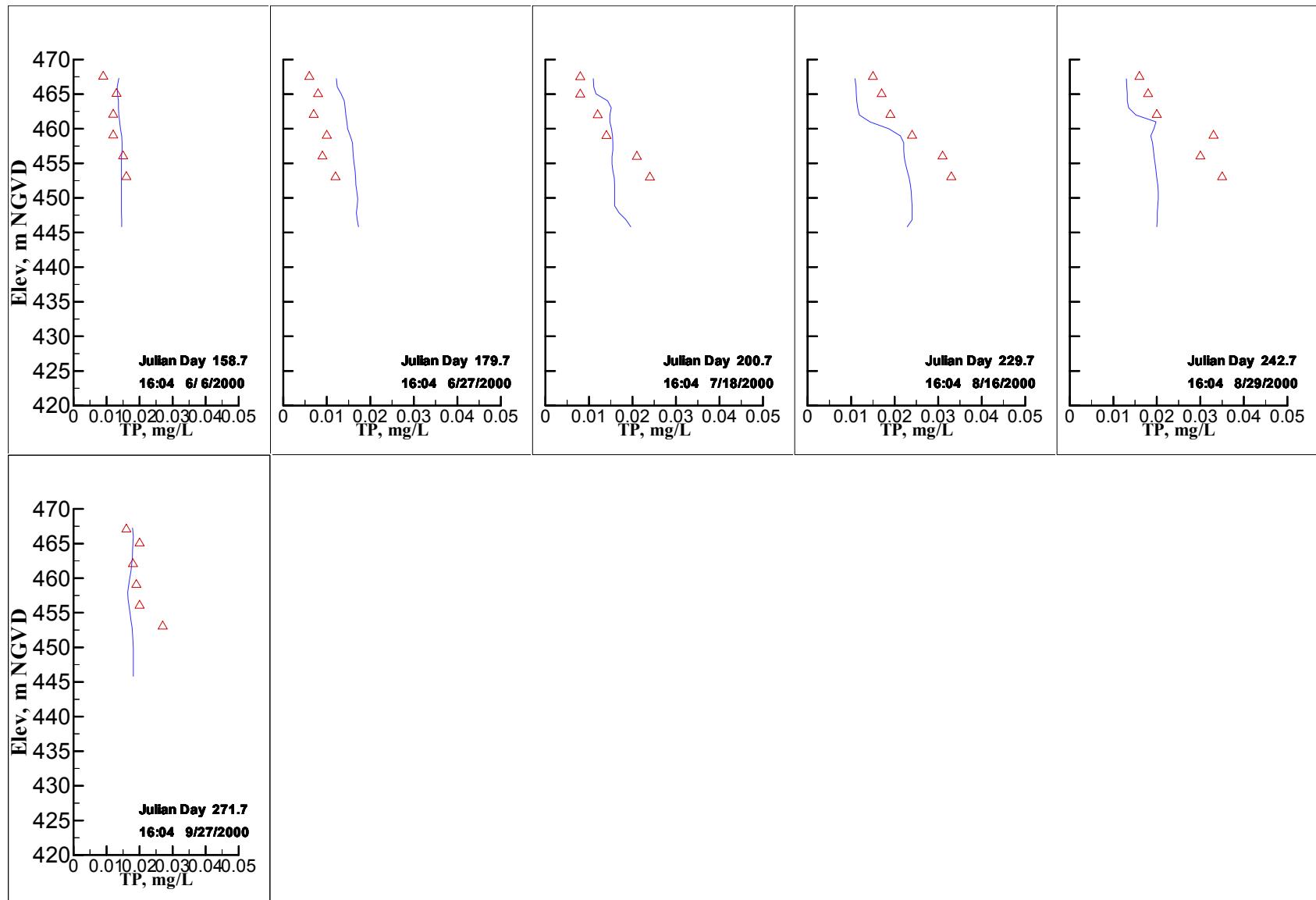


Figure 229. Comparison of model predicted vertical total phosphorus profiles and 2000 data for Long Lake at Station 3 (Segment 168).

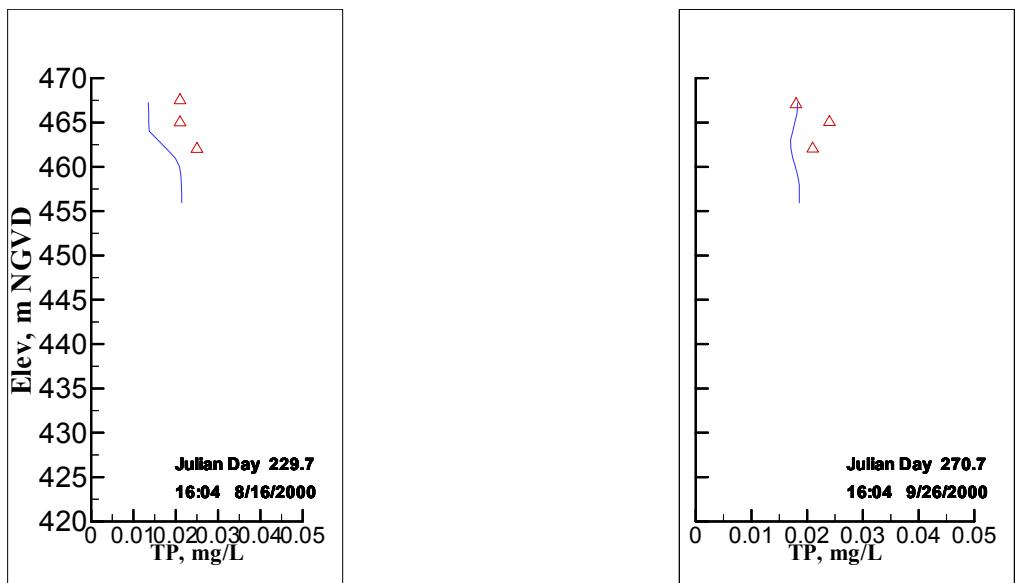


Figure 230. Comparison of model predicted vertical total phosphorus profiles and 2000 data for Long Lake at Station 4 (Segment 161).

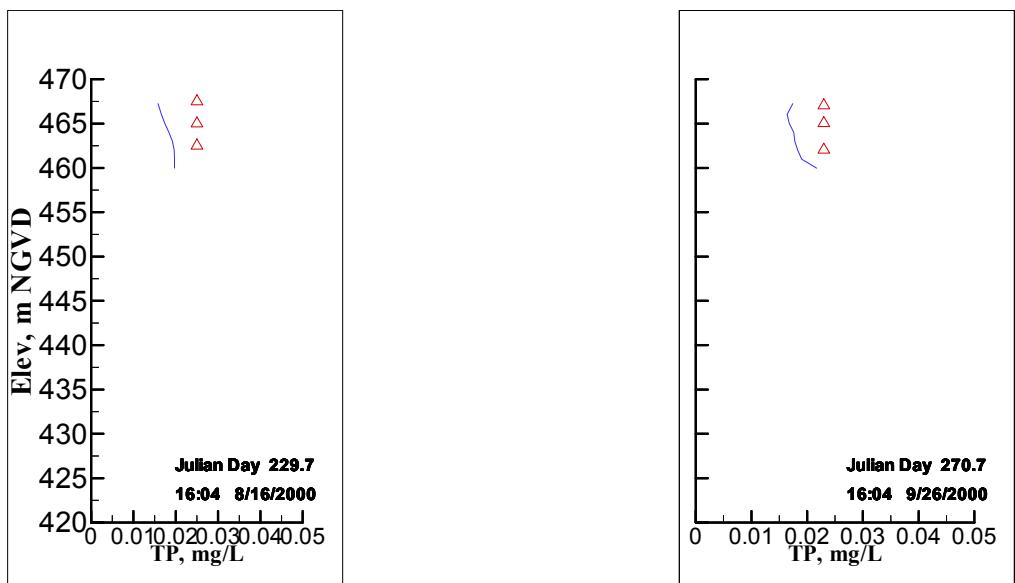


Figure 231. Comparison of model predicted vertical total phosphorus profiles and 2000 data for Long Lake at Station 5 (Segment 157).

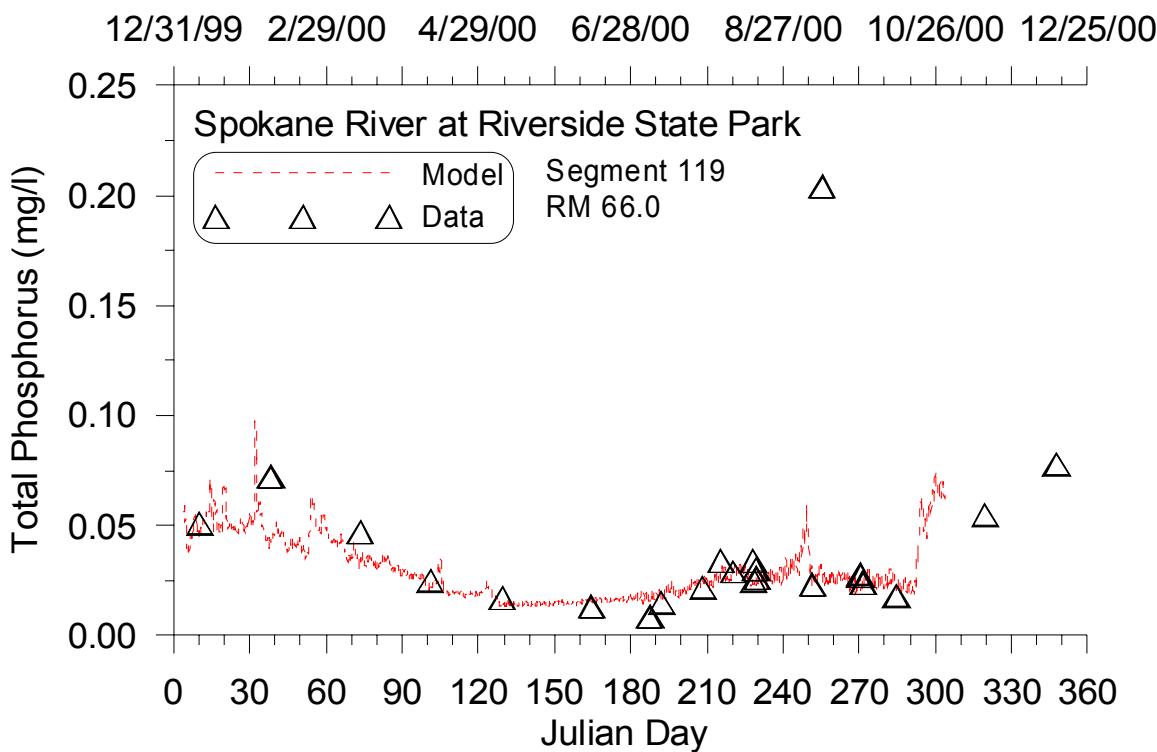


Figure 232. Comparison of model predicted total phosphorus and 2000 data for Spokane River at Riverside State Park (Segment 119).

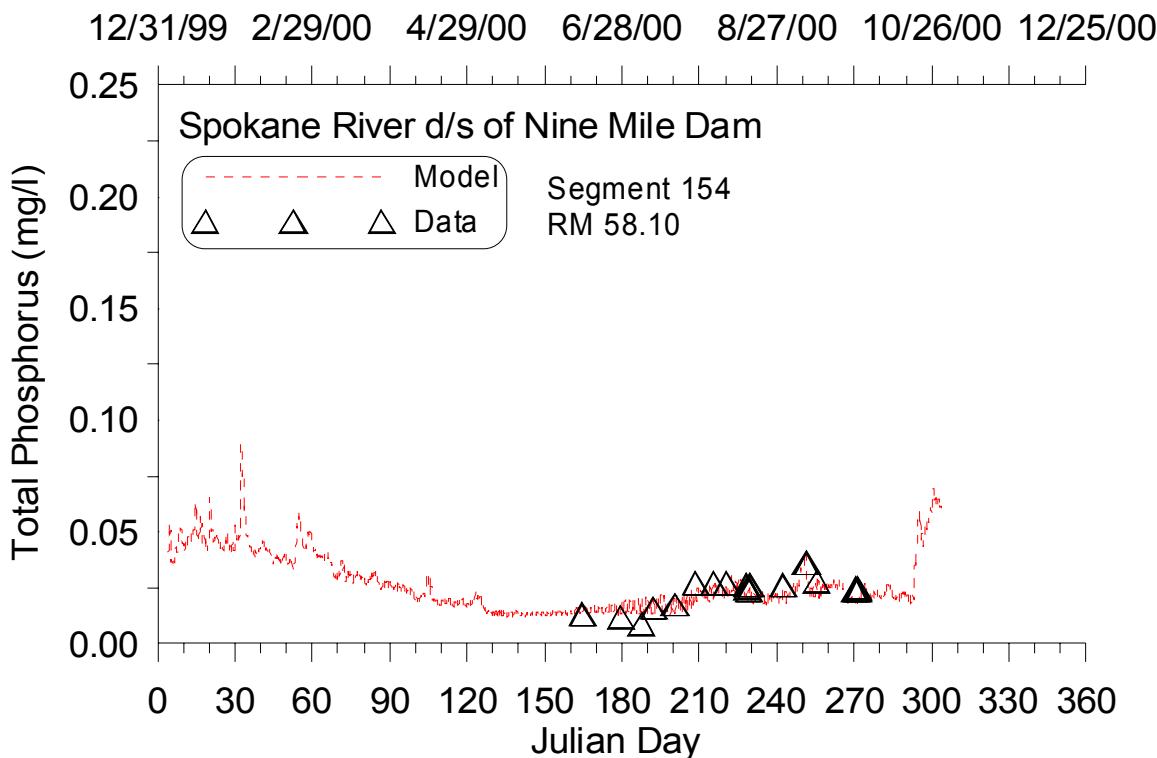


Figure 233. Comparison of model predicted total phosphorus and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Ultimate Carbonaceous Biochemical Oxygen Demand (CBOD_U)

Year 2000

Ultimate carbonaceous biochemical oxygen demand data were available for 2 sample sites in the year 2000. Figure 234 shows the comparison between model predicted CBOD ultimate and data for the Spokane River site above Kaiser Aluminum (RM 86.1).

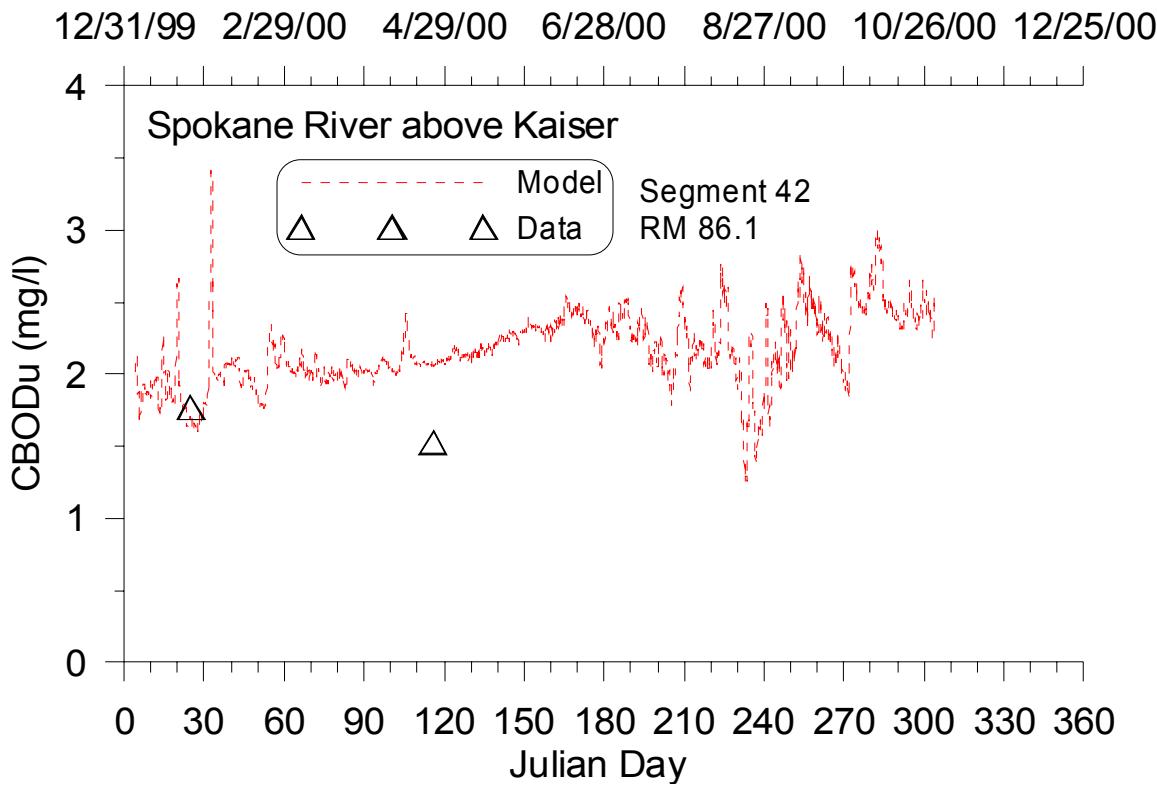


Figure 234. Comparison of model predicted CBOD ultimate and 2000 data for Spokane River above Kaiser Aluminum (Segment 42).

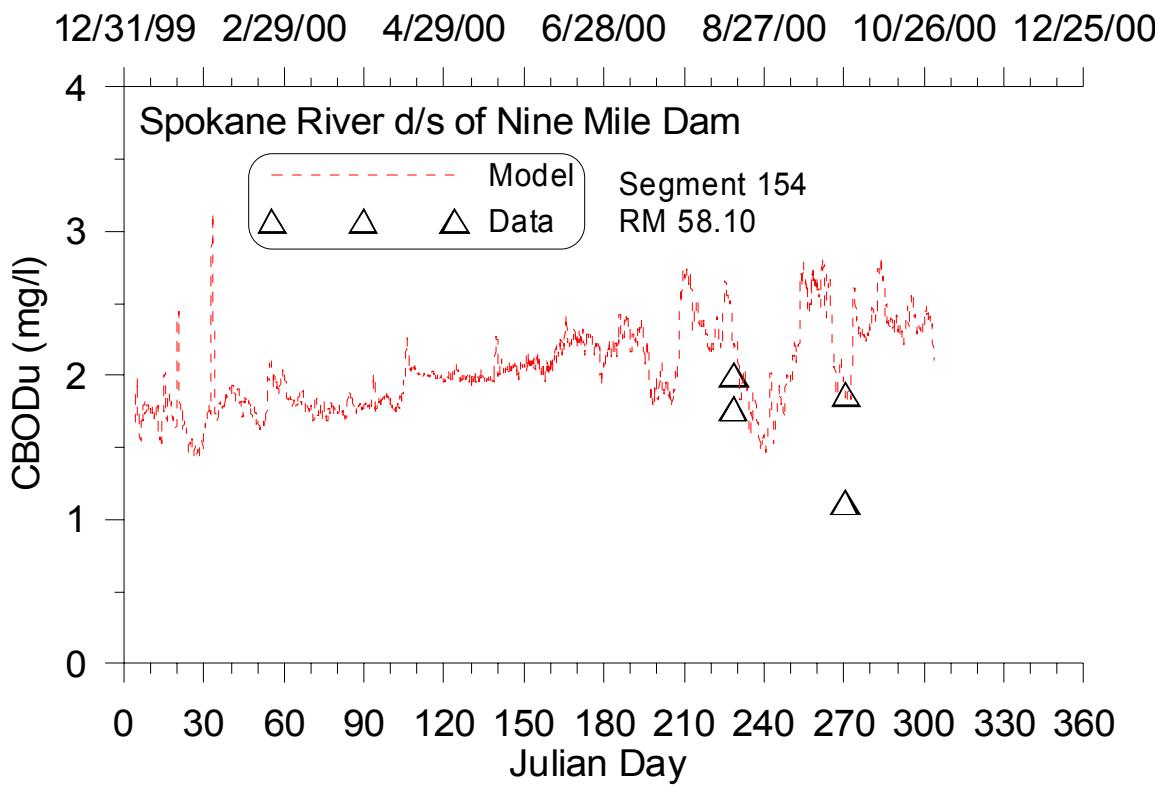


Figure 235. Comparison of model predicted CBOD ultimate and 2000 data for Spokane River downstream of Nine Mile Dam (Segment 154).

Extinction Coefficient

Year 1991

The comparison between year 1991 model predicted light extinction coefficients and data were shown in Figure 236. Light extinction data were calculated from light intensity data measured by Soltero (1992). Model predictions generally matched data except during the spring and at the more upstream sampling locations.

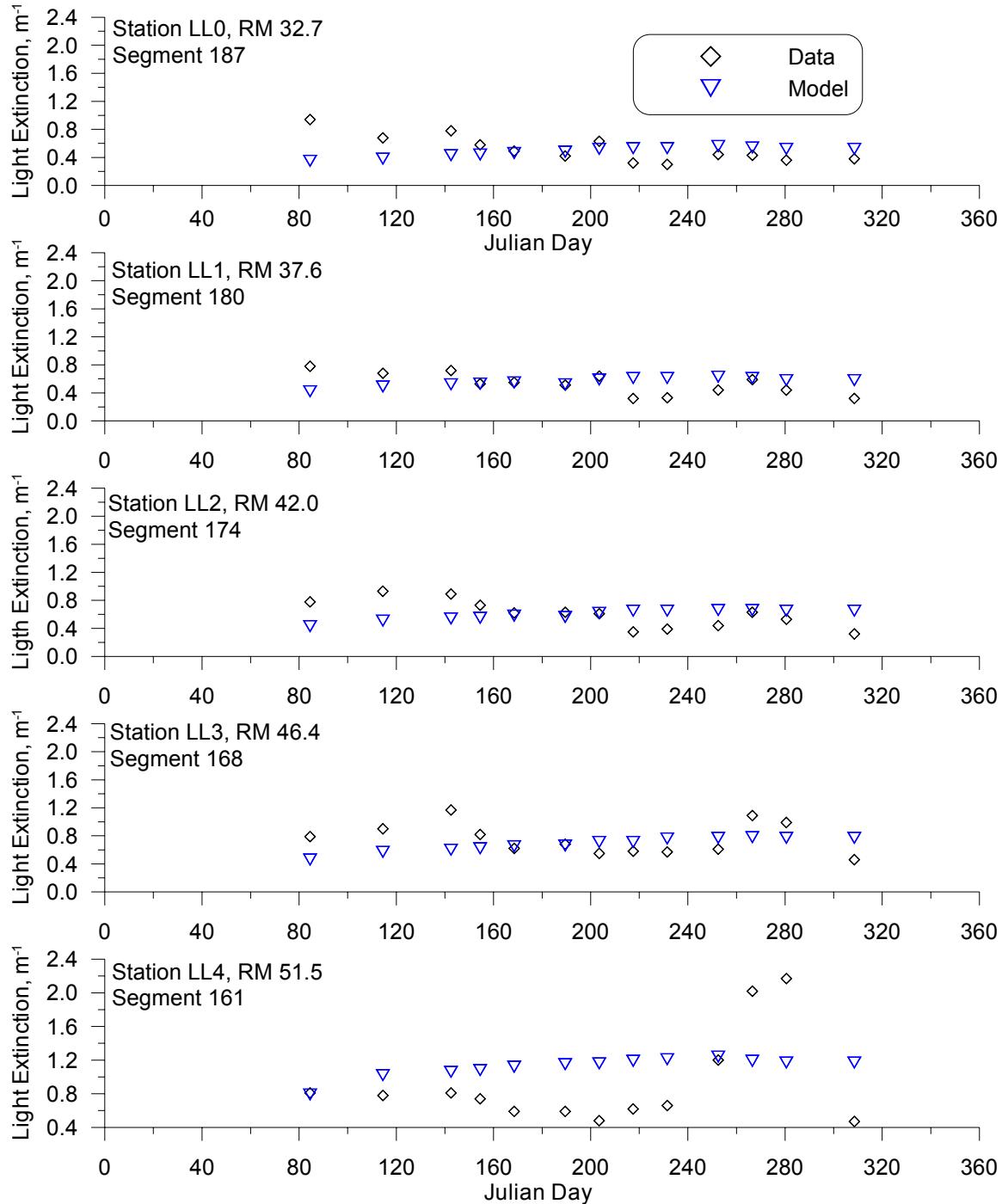


Figure 236. Comparison between model predicted light extinction coefficients and 1991 data.

Year 2000

The comparison between year 2000 model predicted light extinction coefficients and data were shown in Figure 237. The extinction coefficient data were calculated using 2000 secchi disk depth data and a regression developed from 1991 light extinction data (Soltero, 1991). Model results match fairly well with data (predicted from Secchi disk depth) except at the 2 most upstream sample sites LL4 and LL5.

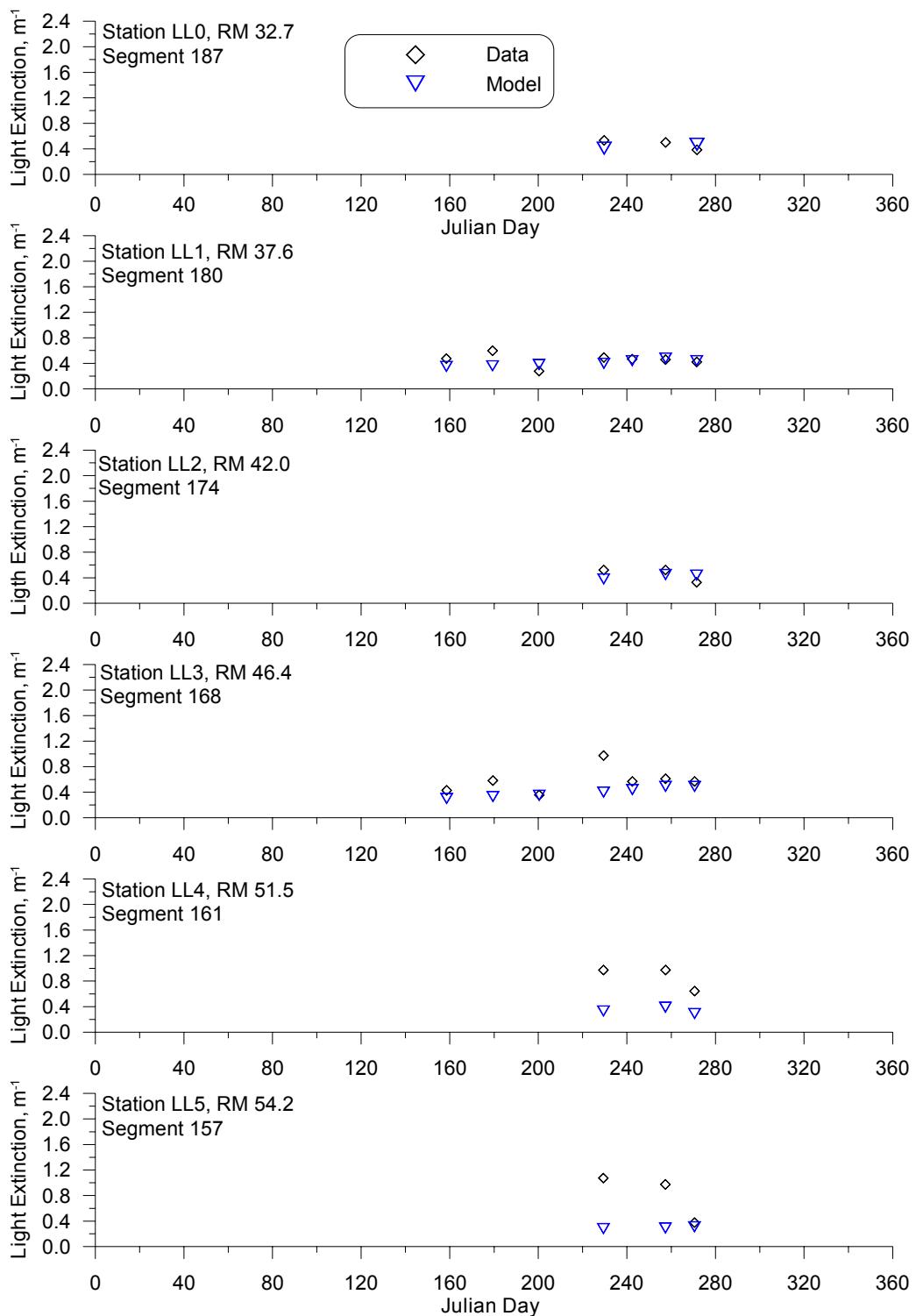


Figure 237. Comparison between model predicted light extinction coefficients and 2000 data.

Sensitivity Analysis

A sensitivity analysis was conducted for Long Lake and a section of the Spokane River, below Upper Falls to the headwaters of Nine Mile Pool. Comparisons were made to determine the sensitivity of the model predictions of dissolved oxygen, temperature, chlorophyll a, and periphyton biomass to model

parameter values. Model results were compared by evaluating time series of the model predictions as well as computing a sensitivity coefficient, defined as

$$S = \frac{\Delta c / \bar{c}}{\Delta \mu / \bar{\mu}}$$

where $\bar{\mu}$ is the mean parameter value and $\Delta\mu$ is the change in the parameter value, \bar{c} is the mean value of the constituent evaluated at $\bar{\mu}$ and Δc is the change in the constituent.

Because of the long computational time of the entire model, analyses were done for just two sections of the CE-QUAL-W2 model: Long Lake and a riverine stretch from RM 74.6 to RM 63. This allowed evaluation of model sensitivity for both riverine and lacustrine environments.

Long Lake

The Long Lake sensitivity analysis simulations were run from March 27th to September 30th, 2000. Time series results were compared at two locations in the reservoir; site LL4 at RM 51.5 and site LL0, RM 32.7, near the dam fore bay. Vertical profiles were compared at the LL0 site for each parameter evaluated. Figure 238 shows the Long Lake grid layout.

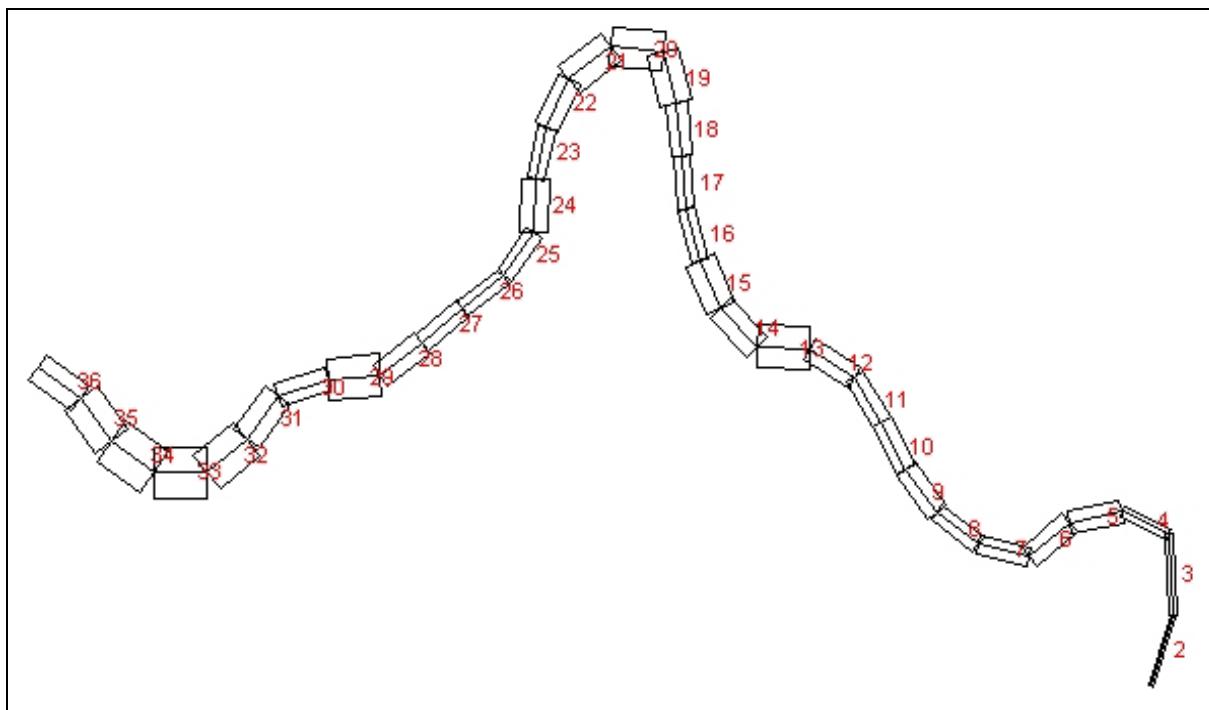


Figure 238. Long Lake model grid layout

Meteorological data

The final calibration of the reservoir used meteorological data from the Spokane International Airport and Spokane Felts Field with the cloud cover estimated based on incoming short-wave solar radiation from Odessa, Washington. To show the sensitivity of the model to this computed cloud cover data, the model was run with the same meteorological data including cloud cover data recorded at the Spokane International Airport. Table 57 shows the mean temperature, dissolved oxygen, and chlorophyll a for the three simulations. The table shows that using the cloud cover data results in cooler temperatures (less than 1.0°C), slightly higher dissolved oxygen, and similar chlorophyll a concentrations. Figure 239

compares vertical profiles for August 14, 2000 and shows there is negligible difference between the two simulations. Figure 240 and Figure 241 show time series plots of temperature, dissolved oxygen, and chlorophyll a at LL4 and LL0, respectively. Figure 240 shows at LL4, which is closer to the upstream boundary condition, there is not much difference between the two simulations. In mid July and early September there are slightly cooler temperatures and higher dissolved oxygen concentrations than the final calibration. The chlorophyll a concentration varies also during mid July and early September but fluctuates around the final calibration concentrations resulting in a similar overall mean concentrations. Figure 241 shows similar variability between the two simulations in mid-July and early September except for chlorophyll a, which more closely resembles the final calibration. Overall the cloud cover data at Spokane International Airport results in cooler temperatures in the Long Lake system (at most close to 1°C) with minor influences on dissolved oxygen and chlorophyll a concentrations in the reservoir.

Table 57. Long Lake meteorological sensitivity analysis, mean statistics

Description	Cloud Cover	Location	Mean Temp., °C	Mean DO, mg/L	Mean Chl a, mg/L
Final Calibration, Spokane International Airport with cloud cover based on solar radiation data at Odessa, WA	Based on Solar Radiation	LL4	18.84	9.21	0.0016
		LL0	19.29	9.12	0.0058
Spokane International Airport using Cloud Cover data	Based on Data	LL4	18.17	9.37	0.0017
		LL0	18.40	9.29	0.0057

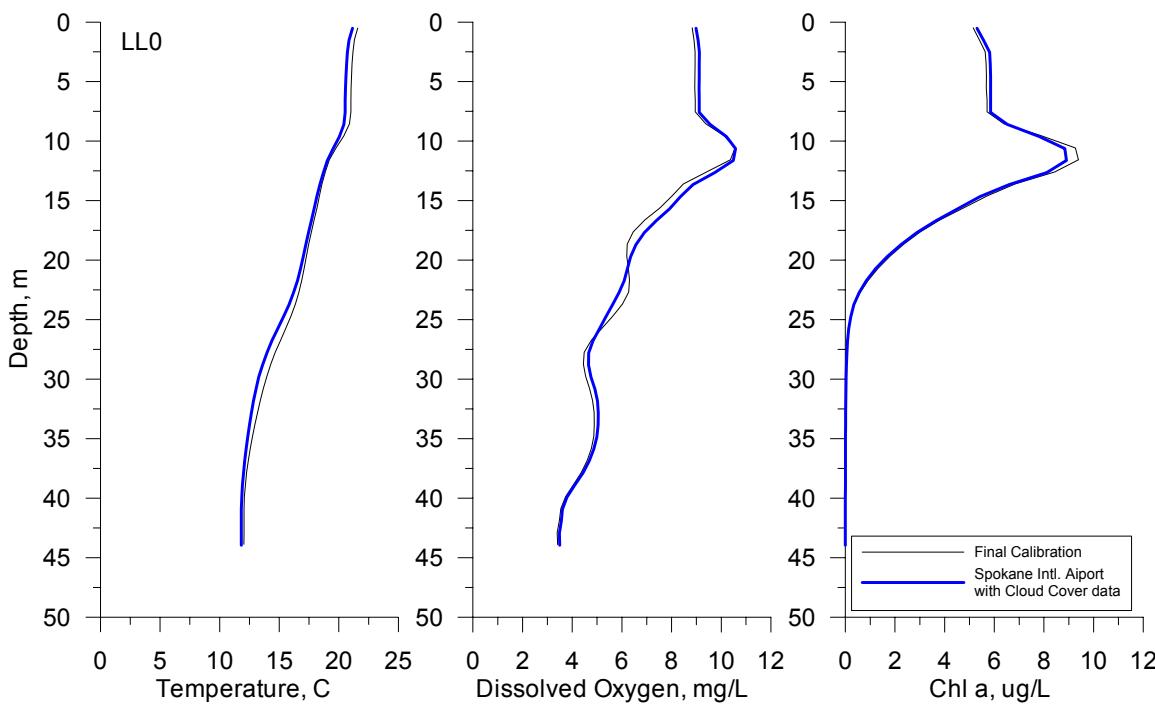


Figure 239. Long Lake site LL0 (RM 32.7) meteorology sensitivity, vertical profile, August 14, 2000

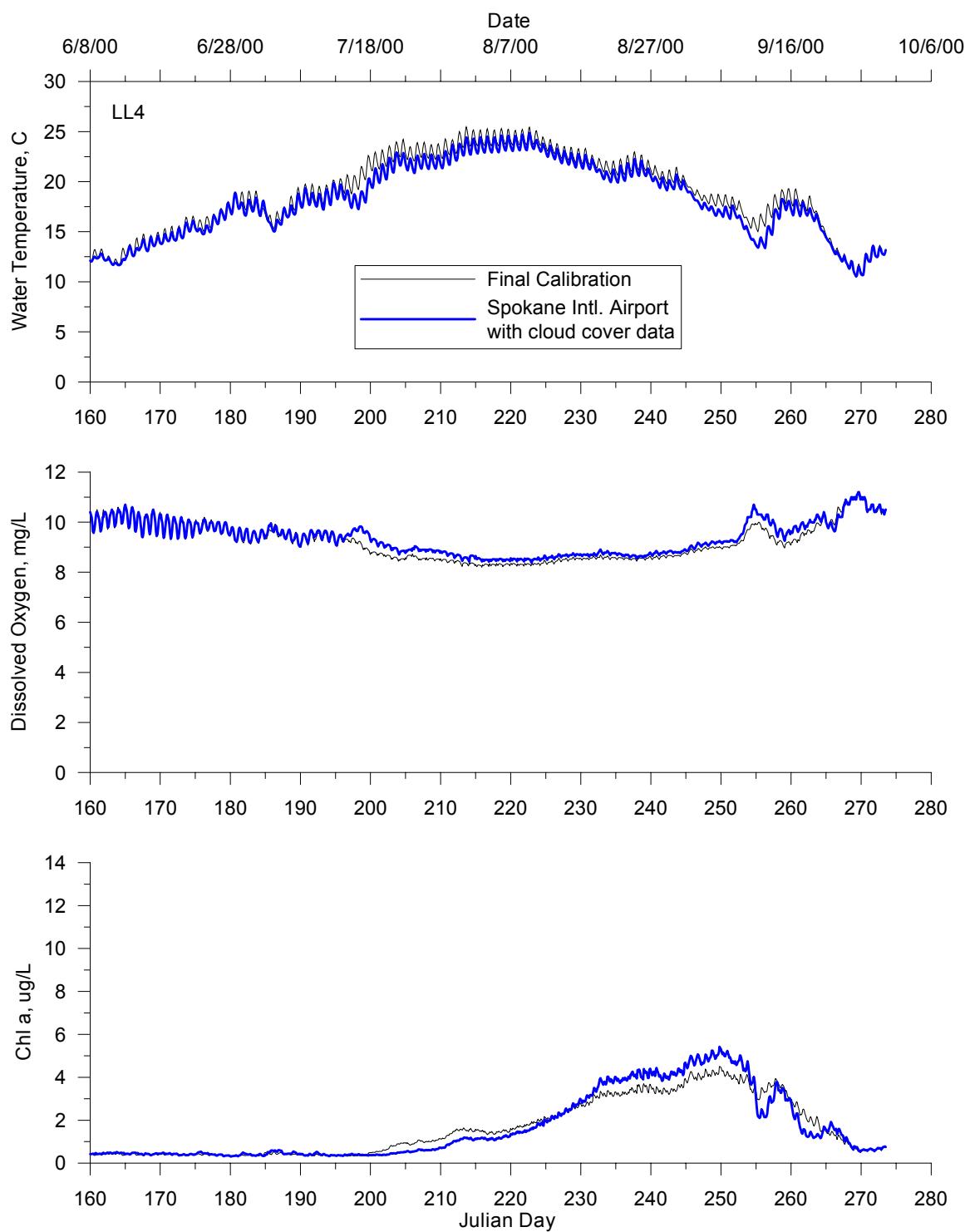


Figure 240. Long Lake site LL4 (RM 51.5) meteorology sensitivity, time series

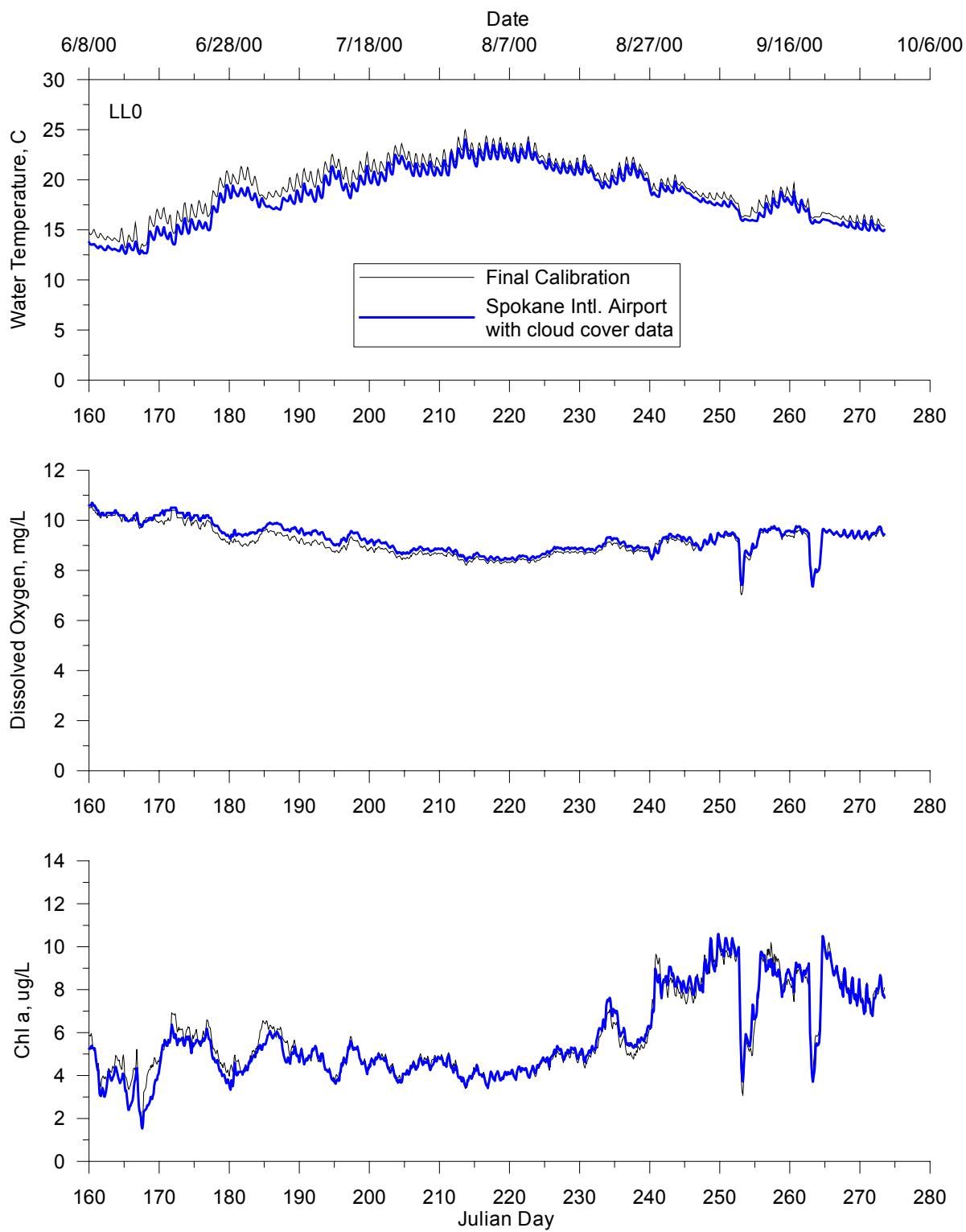


Figure 241. Long Lake site LL0 (RM 32.7) meteorology sensitivity, time series

Reaeration Formulation

The final calibration of the reservoir used a lake reaeration by Cole and Buchak (1993):

$K_a = \frac{0.5 + 0.05W^2}{H}$ where H is the average depth and W is the wind speed measured 10 m above the surface. Two additional equations were used to investigate their influence on the lake: Banks and Herrera (1977) model: $K_a = \frac{0.728W^{0.5} - 0.317W + 0.0372W^2}{H}$ and Smith (1978) (see Cole and Wells, 2001): $K_a = \frac{0.64 + 0.128W^2}{H}$

Table 58 shows the mean temperature, dissolved oxygen, and chlorophyll a for the simulations. The table shows there is no change in the mean temperature or chlorophyll a concentration between the three simulations. There are small deviations in the mean dissolved oxygen concentration between the three simulations (at most 0.3 mg/l).

Figure 242 compares vertical profiles for August 14, 2000 and shows there is no difference between the simulations for the temperature and chlorophyll a concentrations profiles. The dissolved oxygen profiles show slight differences in the surface region as expected, but the remainder of the profiles are the same. Figure 243 and Figure 244 show time series plots of temperature, dissolved oxygen and chlorophyll a at LL4 and LL0, respectively. The time series plots at LL4 show the different reaeration formulas have almost no influence on the temperature, dissolved oxygen and chlorophyll a compared to the final calibration. The time series plots at LL0 also show almost no influence for the different reaeration formulas compared to the final calibration with the exception of dissolved oxygen. The two different reaeration formulas vary from the final calibration by approximately 0.5 mg/L. Much of this variation can also be ascribed to uncertainties in wind data since these formulations are dependent on wind speed.

Table 58. Long Lake reaeration sensitivity analysis, mean statistics

Description	Lake Reaeration Formula	Location	Mean Temp., °C	Mean DO, mg/L	Mean Chl a, mg/L
Final Calibration, Equation #6	Cole and Buchak (1993)	LL4	18.84	9.21	0.0016
		LL0	19.29	9.12	0.0058
Reaeration Formulation, Equation #3	Banks and Herrera (1977)	LL4	18.84	9.23	0.0016
		LL0	19.29	9.29	0.0058
Reaeration Formulation, Equation #8	Smith (1978)	LL4	18.84	9.15	0.0016
		LL0	19.29	8.93	0.0058

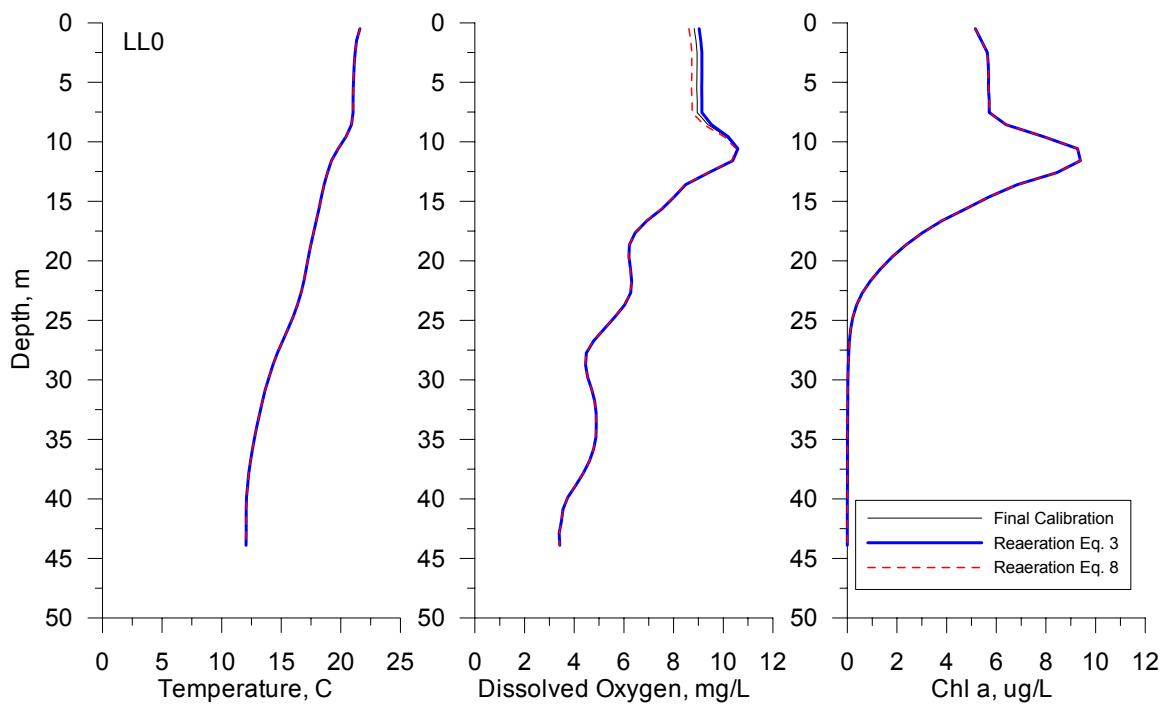


Figure 242. Long Lake site LL0 (RM 32.7) reaeration sensitivity, vertical profile, August 14, 2000

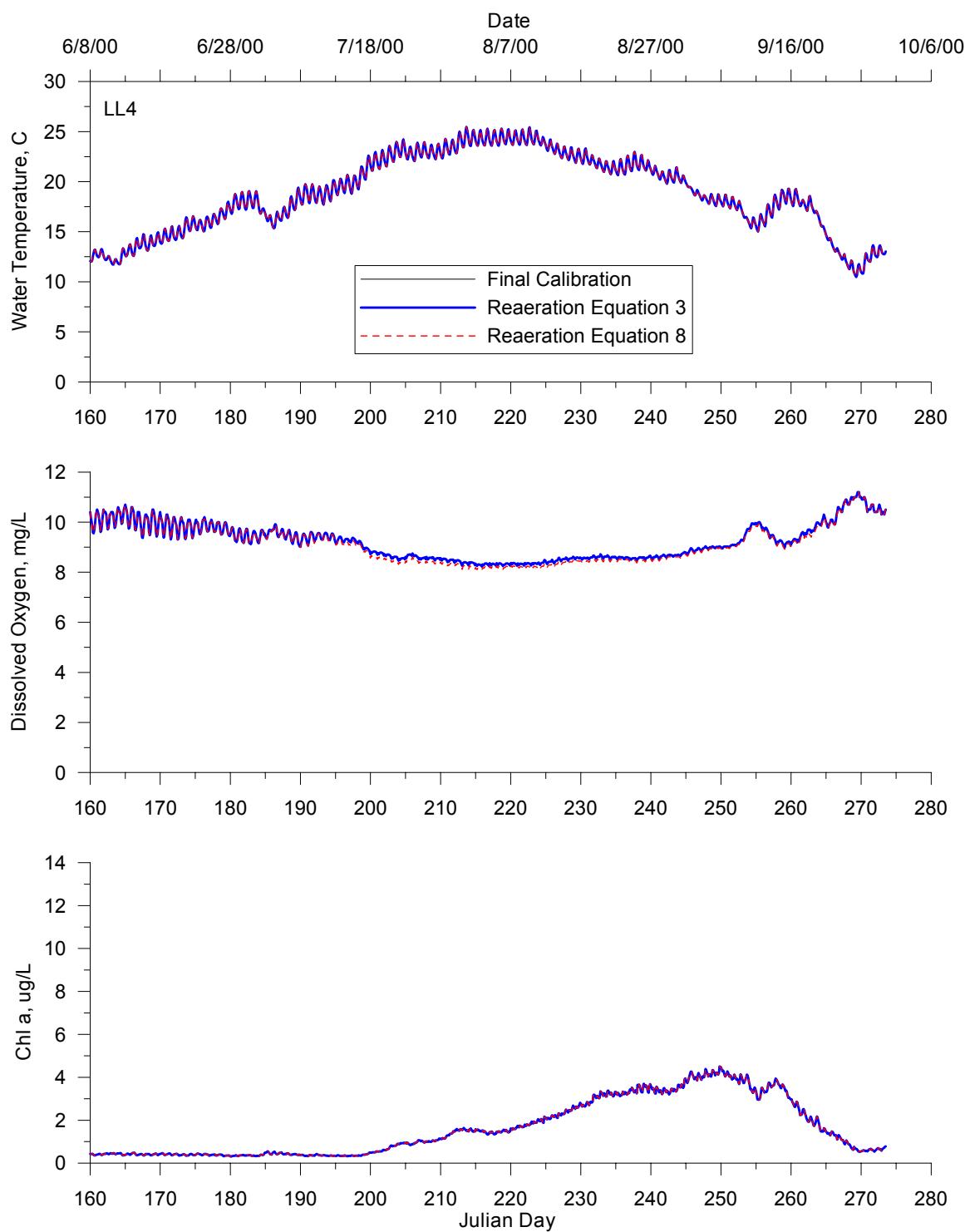


Figure 243. Long Lake site LL4 (RM 51.5) reaeration sensitivity, time series

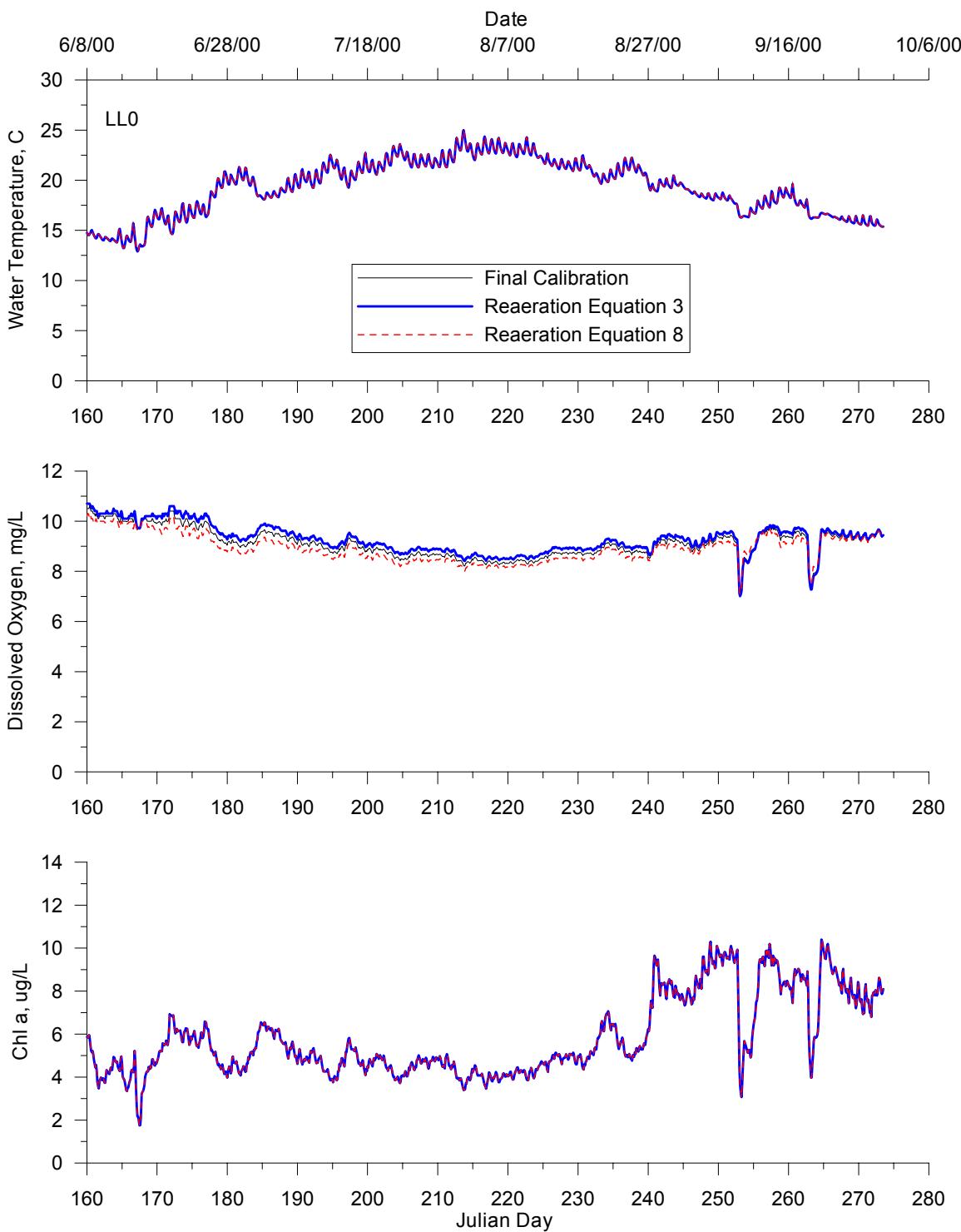


Figure 244. Long Lake site LL0 (RM 32.7) reaeration sensitivity, time series

Wind Sheltering

Wind sheltering is used in model calibration to “correct” wind data measured off-site to the lake surface. This wind sheltering correction in CE-QUAL-W2 can be a function of time and space (each model segment). In the model calibration the wind sheltering was varied over each segment but was constant over time. Two simulations were run with the wind sheltering set at 100% and 85% for all segments, setting the effective wind (measured at the Spokane International Airport) at 100% and 85% of the

measured wind data. The overall average wind sheltering used in the model calibration was 43%. Figure 245 shows the wind sheltering values for each model segment and simulation. Table 59 shows the mean temperature, dissolved oxygen, and chlorophyll a concentration for these simulations. Figure 246 provides a vertical profile comparison for the three simulations. Figure 247 and Figure 248 show time series plots for sites LL4 and LL0, respectively. As the mean statistics and plots indicate, the higher wind sheltering results in lower lake temperatures, higher dissolved oxygen concentrations and lower chlorophyll a concentrations. This also affects the vertical distribution of chlorophyll a showing the hydrodynamic impact of the wind. To improve the Long Lake model calibration, measurement of wind as a function of longitudinal location would be useful.

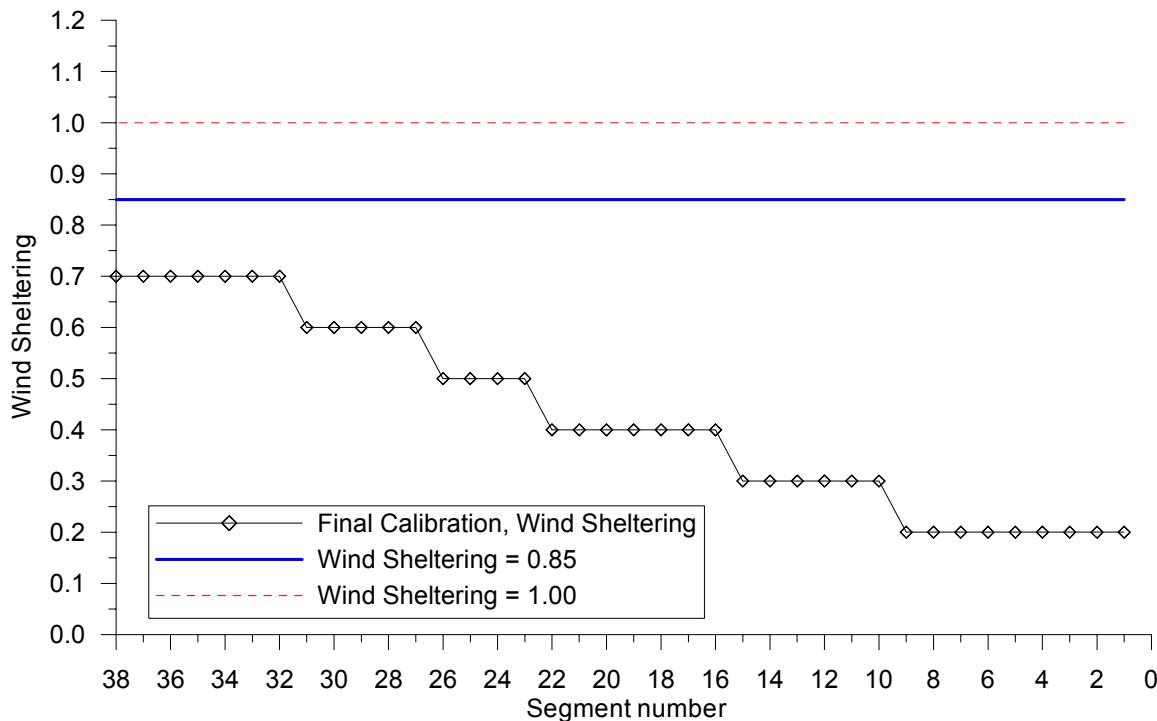


Figure 245. Wind sheltering values for each Long Lake model segment

Table 59. Long Lake wind sheltering sensitivity analysis, mean statistics

Description	Wind Sheltering Coefficient	Location	Mean Temp., °C	Mean DO, mg/L	Mean Chl a, mg/L
Final Calibration	Variable over time	LL4	18.84	9.21	0.0016
		LL0	19.29	9.12	0.0058
Set wind sheltering to 100%	1.00	LL4	16.20	9.86	0.0009
		LL0	17.85	9.16	0.0062
Set wind sheltering to 85%	0.85	LL4	16.56	9.79	0.0011
		LL0	18.39	9.17	0.0063

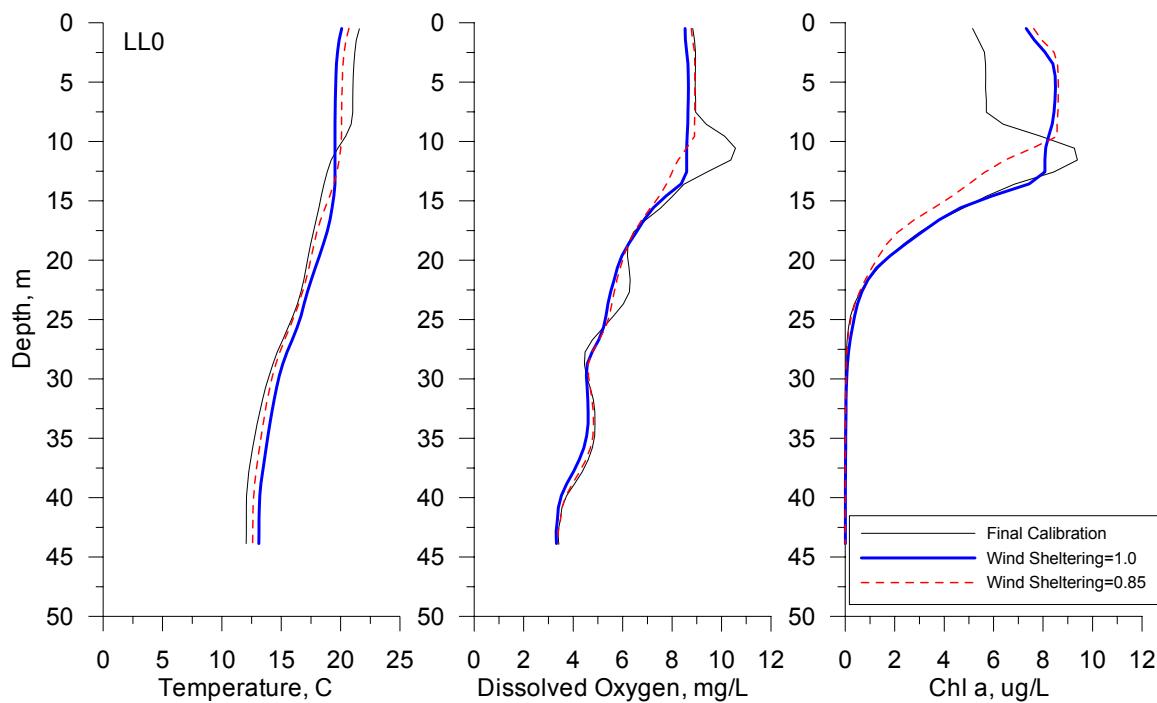


Figure 246. Long Lake site LL0 (RM 32.7) wind sheltering sensitivity, vertical profile, August 14, 2000

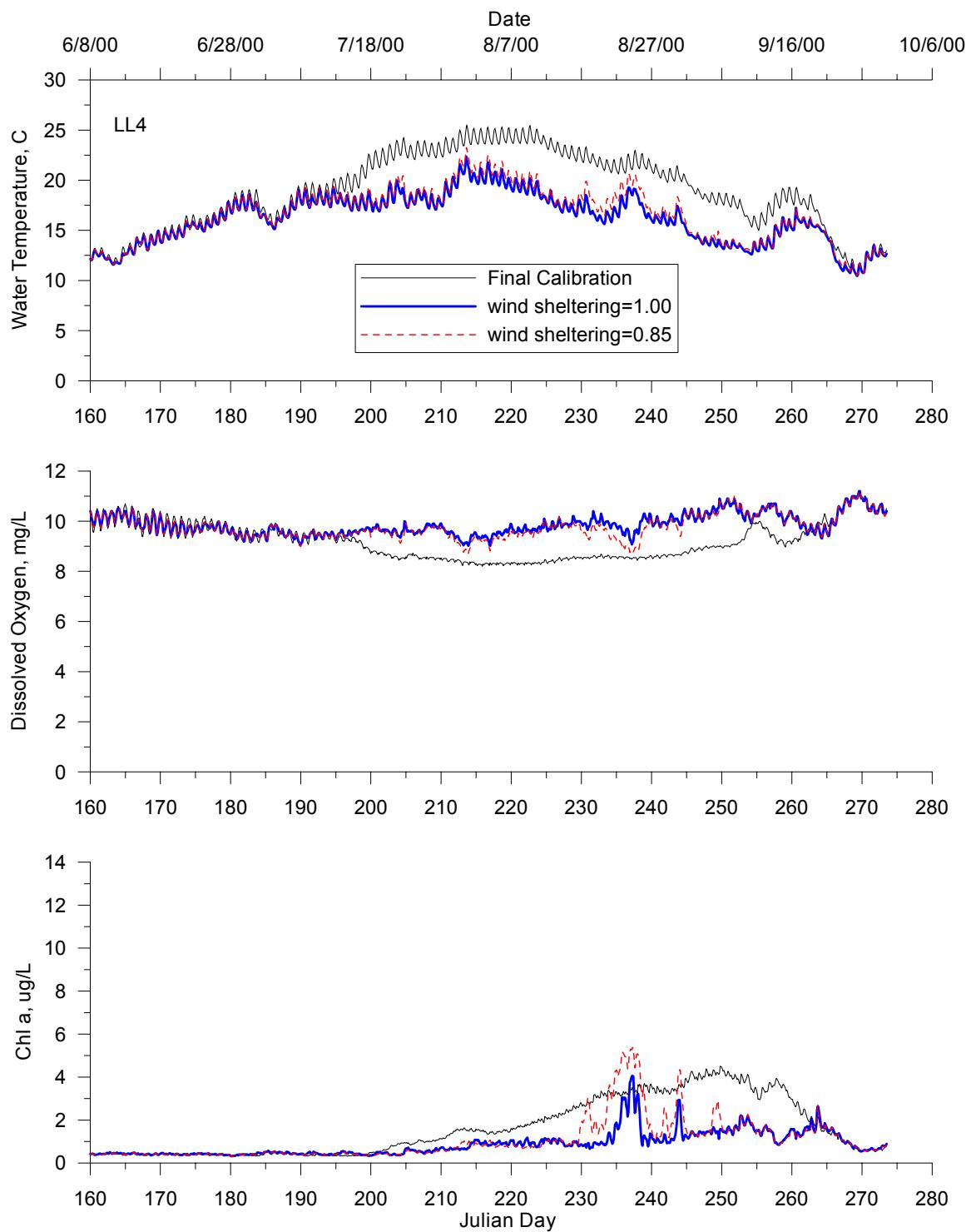


Figure 247. Long Lake site LL4 (RM 51.5) wind sheltering sensitivity, time series

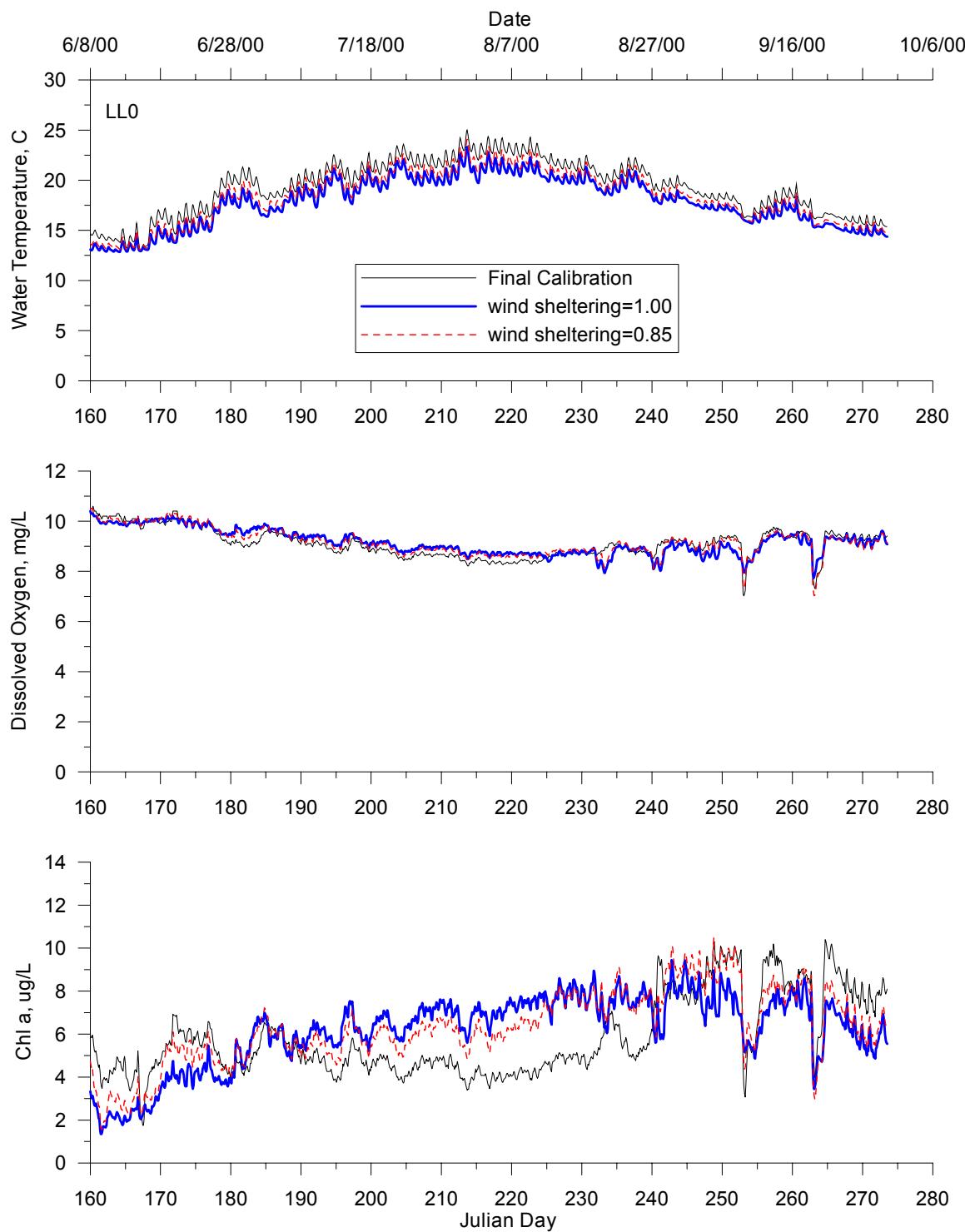


Figure 248. Long Lake site LL0 (RM 32.7) wind sheltering sensitivity, time series

Wind Direction

The wind direction measured at Spokane International Airport was used in the Long Lake model calibration. But since these data may not be appropriate for Long Lake, a sensitivity analysis was performed evaluating wind direction on temperature, dissolved oxygen and chlorophyll a. The wind

direction data were modified so all the winds were either going up or down the western-most lake axis. If the wind direction has an influence on the lake's water quality, then it would have the maximum effect when the wind is blowing along the fetch of the lake. Table 60 shows the mean temperature, dissolved oxygen, and chlorophyll a at two locations, LL4 and LL0. Figure 249 provides vertical profiles of the three constituents at LL0. Figure 250 and Figure 251 provide surface layer time series plots of the three constituents at LL4 and LL0, respectively. The table indicates there is little difference in the three constituents when comparing the two simulations. The time series plots show the same results with the exception of chlorophyll a at both LL4 and LL0. The chlorophyll a concentration seems to be slightly lower for the wind following the lake fetch than the final calibration with a small difference at LL4 and a slightly larger difference at LL0. This sensitivity was analyzed using the same wind sheltering as the final model calibration.

Table 60. Long Lake wind direction sensitivity analysis, mean statistics

Description	Wind Direction	Location	Mean Temp., °C	Mean DO, mg/L	Mean Chl a, mg/L
Final Calibration	Based on Data	LL4	18.84	9.21	0.0016
		LL0	19.29	9.12	0.0058
Wind direction set to only upstream and downstream directions for the western-most part of the lake	Set to lake orientation	LL4	18.80	9.24	0.0016
		LL0	19.52	9.02	0.0054

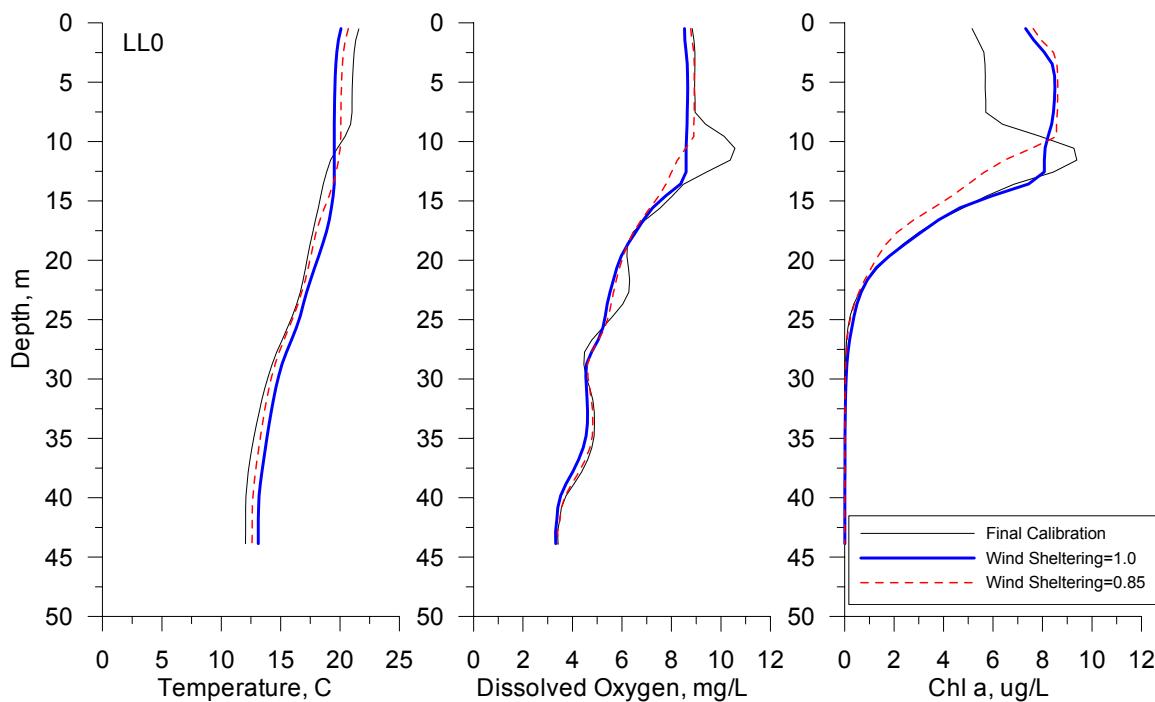


Figure 249. Long Lake site LL0 (RM 32.7) wind direction sensitivity, vertical profile, August 14, 2000

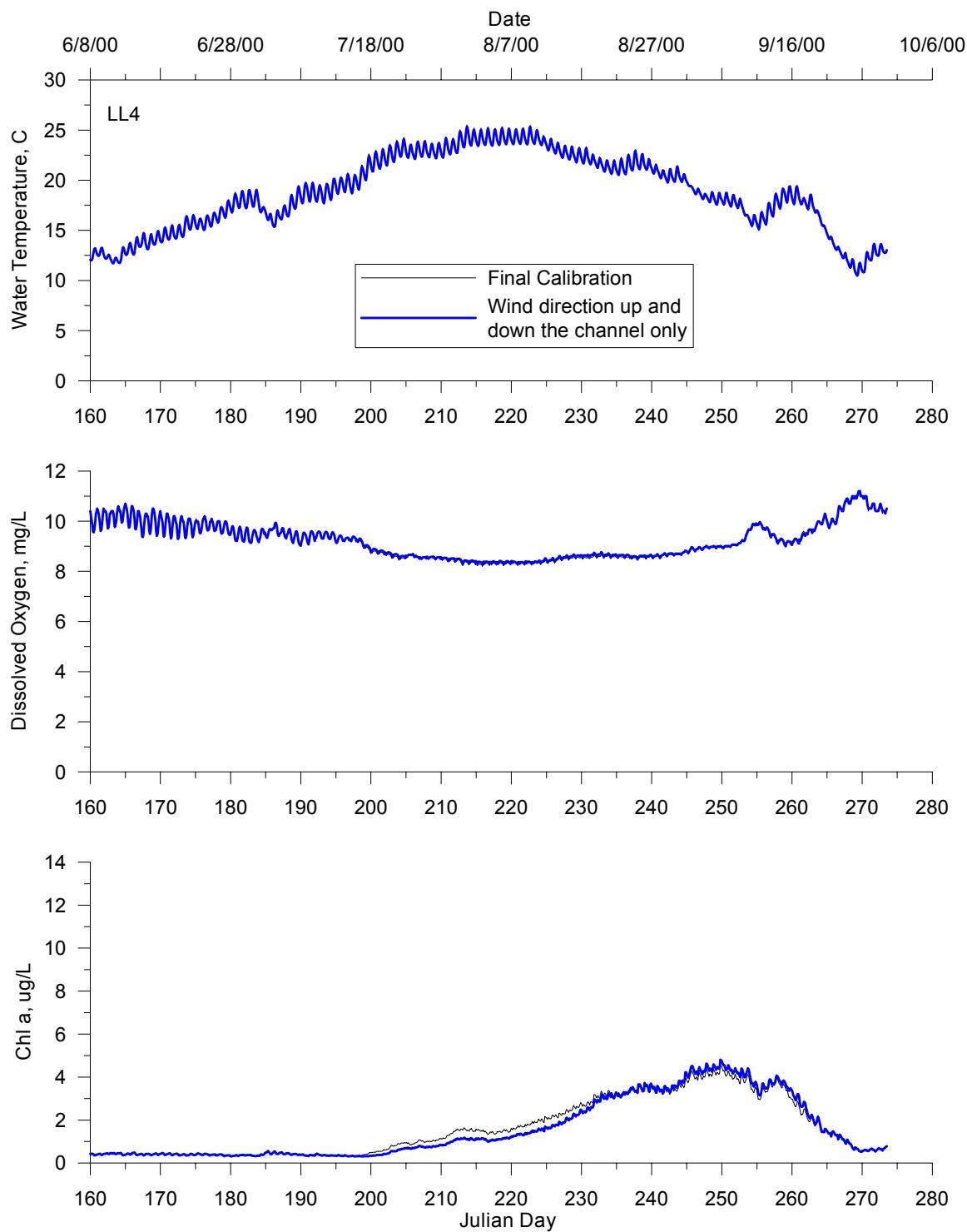


Figure 250. Long Lake site LL4 (RM 51.5) wind direction sensitivity, time series

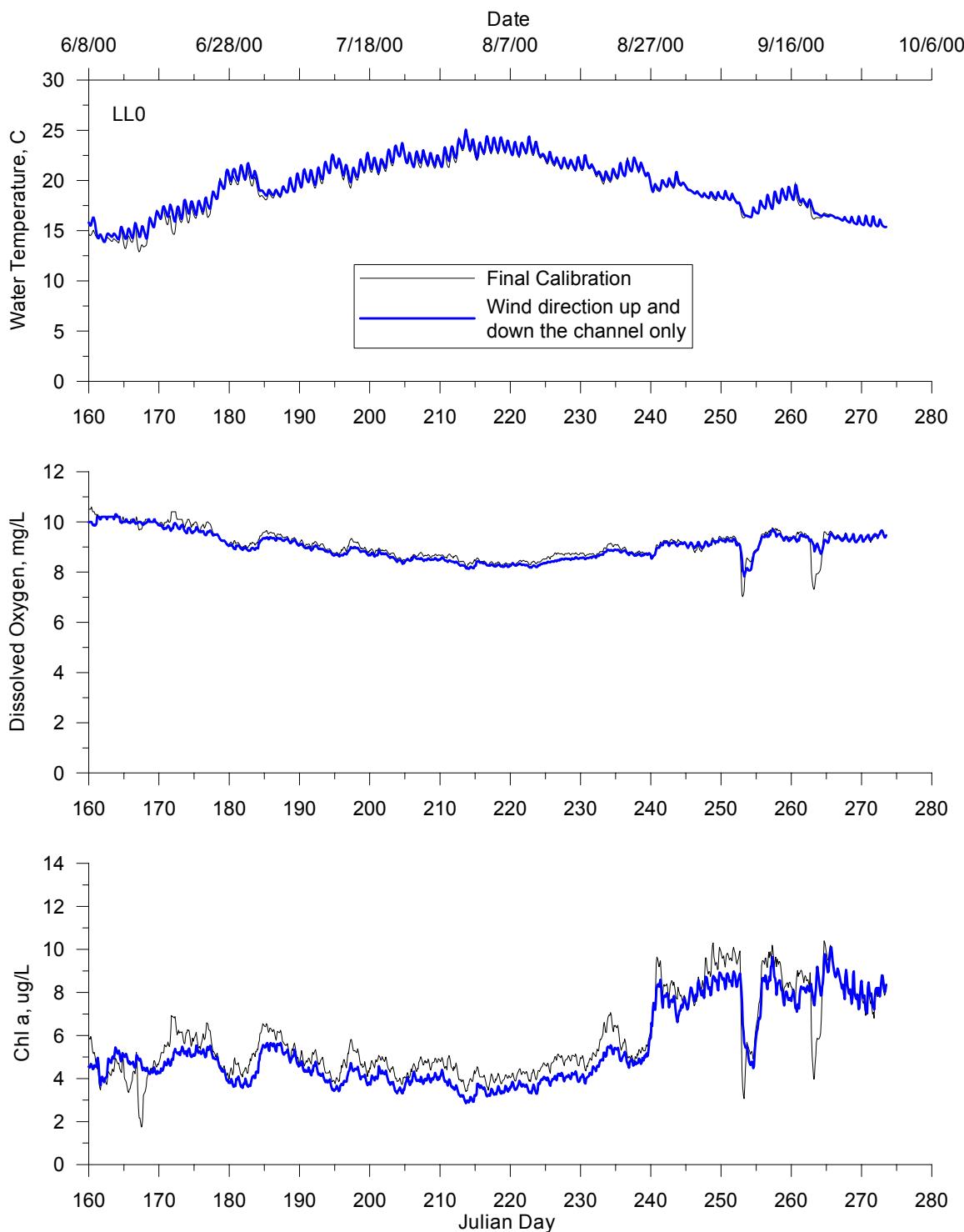


Figure 251. Long Lake site LL0 (RM 32.7) wind direction sensitivity, time series

Algal Growth Rate

The maximum algal growth rate determines how fast algae can grow in the lake which influences dissolved oxygen and nutrients. The growth rate was increased by 50% and decreased by 50% to determine how much influence it would have on temperature, dissolved oxygen and chlorophyll a. Table 61 shows the sensitivity of each constituent to changes in the algal growth rate. Figure 252 provides vertical profiles of the three constituents. Figure 253 and Figure 254 show the time series plots

of the three constituents at LL4 and LL0, respectively. The time series plots show there is not much difference between the final calibration and 50% higher algal growth rate for the chlorophyll a concentration. There is a clear difference between the final calibration and the algal growth rate reduced by 50%. The algae growth rate is a critical model parameter for predicting dissolved oxygen and algae dynamics.

Table 61. Long Lake algal growth rate sensitivities

Description	Algal Growth Rate day ⁻¹	Location	Temperature Sensitivity	DO Sensitivity	Chl a Sensitivity
Final Calibration	1.50	LL4	NA	NA	NA
		LL0	NA	NA	NA
Increase algal growth rate by 50%	2.25	LL4	-0.011	-0.002	-1.765
		LL0	0.000	-0.013	-0.251
Decrease algal growth rate by 50%	0.75	LL4	-0.016	0.015	-1.717
		LL0	-0.016	-0.090	-1.646

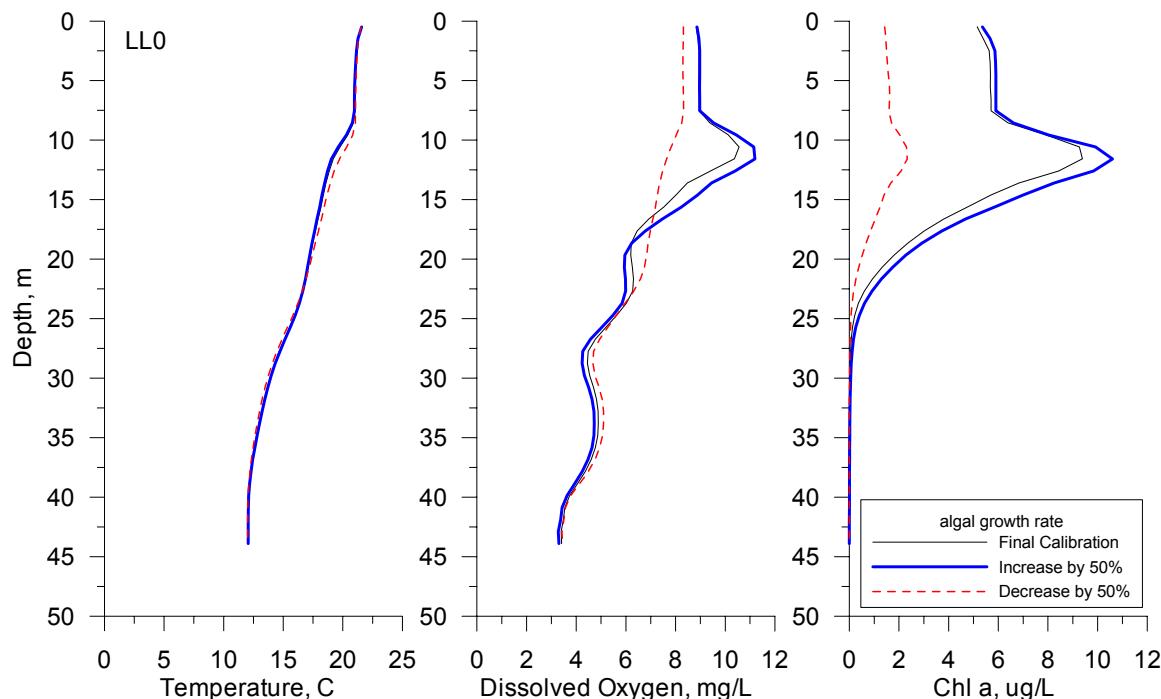


Figure 252. Long Lake site LL0 (RM 32.7) algal growth rate sensitivity, vertical profile, August 14, 2000

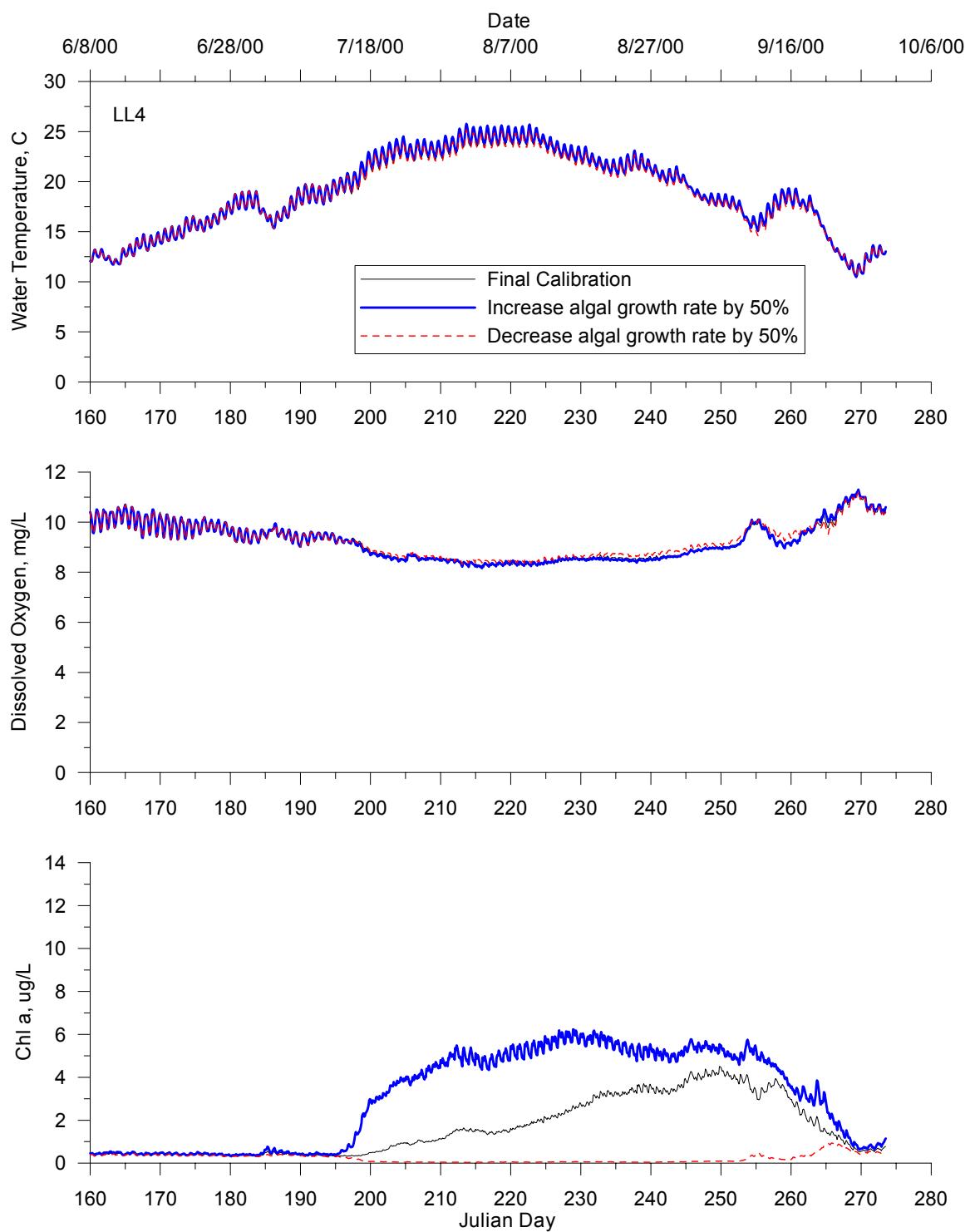


Figure 253. Long Lake site LL4 (RM 51.5) algal growth rate sensitivity, time series

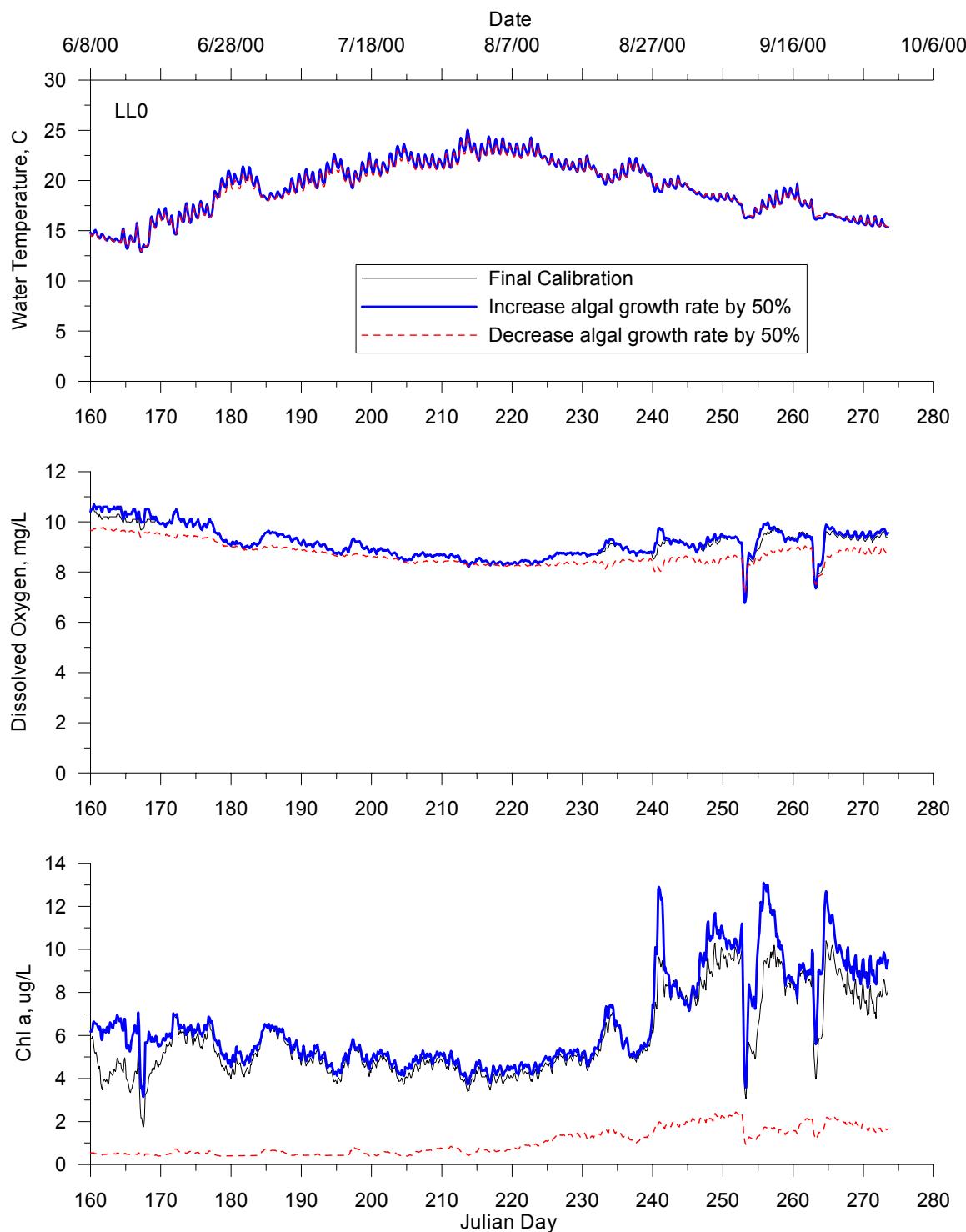


Figure 254. Long Lake site LL0 (RM 32.7) algal growth rate sensitivity, time series

Algal half-saturation for phosphorus limited growth

Similar to the algal growth rate, the algal half-saturation for phosphorus limited growth was increased by 50% and decreased by 50% from the final calibration value. Table 62 provides the constituent sensitivities for temperature, dissolved oxygen, and chlorophyll a. The table shows on a gross scale that

temperature and dissolved oxygen are not sensitive to changes in the half-saturation constant for phosphorus limited growth. Chlorophyll a was shown to be sensitive to changes in the half-saturation constant for phosphorus limited growth. Figure 255 provides vertical profiles for the three constituents, comparing the final calibration to the changes in the half-saturation parameter. The figure shows there is some variation in the chlorophyll a concentration in the photic zone. Figure 256 and Figure 257 show time series plots for temperature, dissolved oxygen, and chlorophyll a concentration at LL4 and LL0, respectively. Figure 256 show that once summer occurs, even at the upstream end of the lake, the half-saturation constant can have an influence on the chlorophyll a concentration. Downstream at site LL0 the chlorophyll a concentration is still influenced by the changes in the half-saturation constant but the effects are muted by the higher overall concentrations.

Table 62. Long Lake algal half-saturation for phosphorus limited growth sensitivities

Description	Algal ½ sat. P limited growth rate g/m ³	Location	Temperature Sensitivity	DO Sensitivity	Chl a Sensitivity
Final Calibration	0.0030	LL4	NA	NA	NA
		LL0	NA	NA	NA
Increase algal half-saturation for phosphorus limited growth by 50%	0.0045	LL4	0.006	-0.007	0.872
		LL0	0.001	0.007	0.241
Decrease algal half-saturation for phosphorus limited growth by 50%	0.0015	LL4	0.009	-0.002	1.444
		LL0	0.000	0.007	0.278

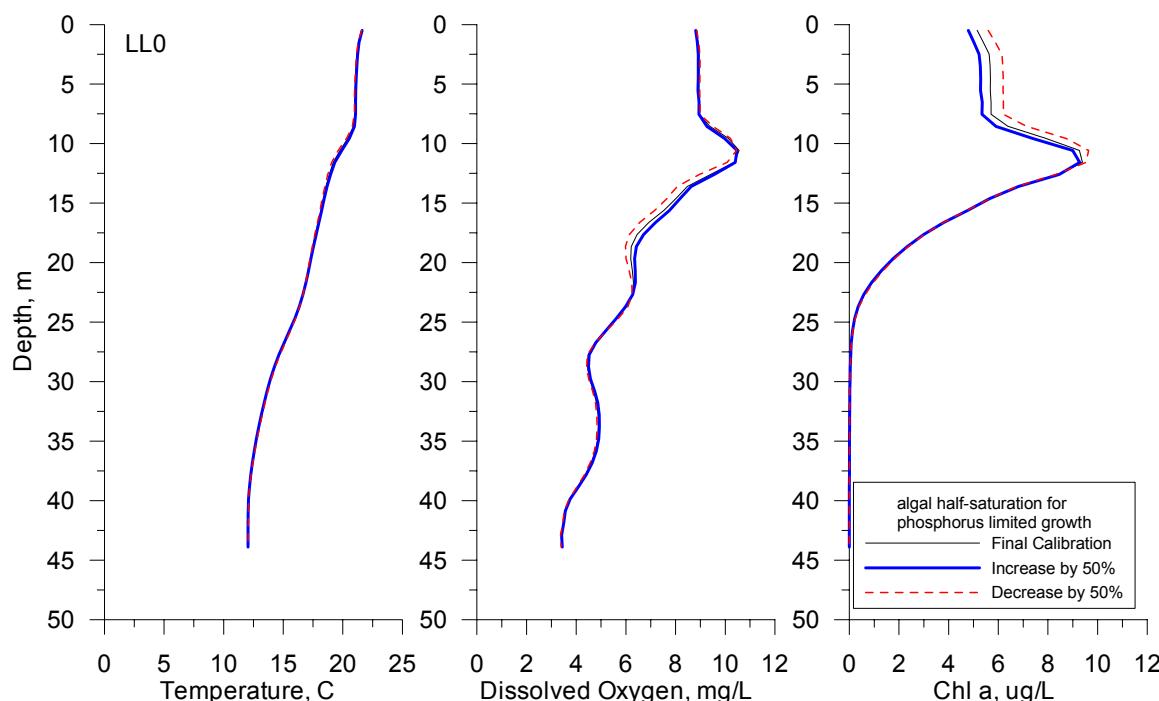


Figure 255. Long Lake site LL0 (RM 32.7) algal half-saturation for phosphorus limited growth sensitivity, vertical profile, August 14, 2000

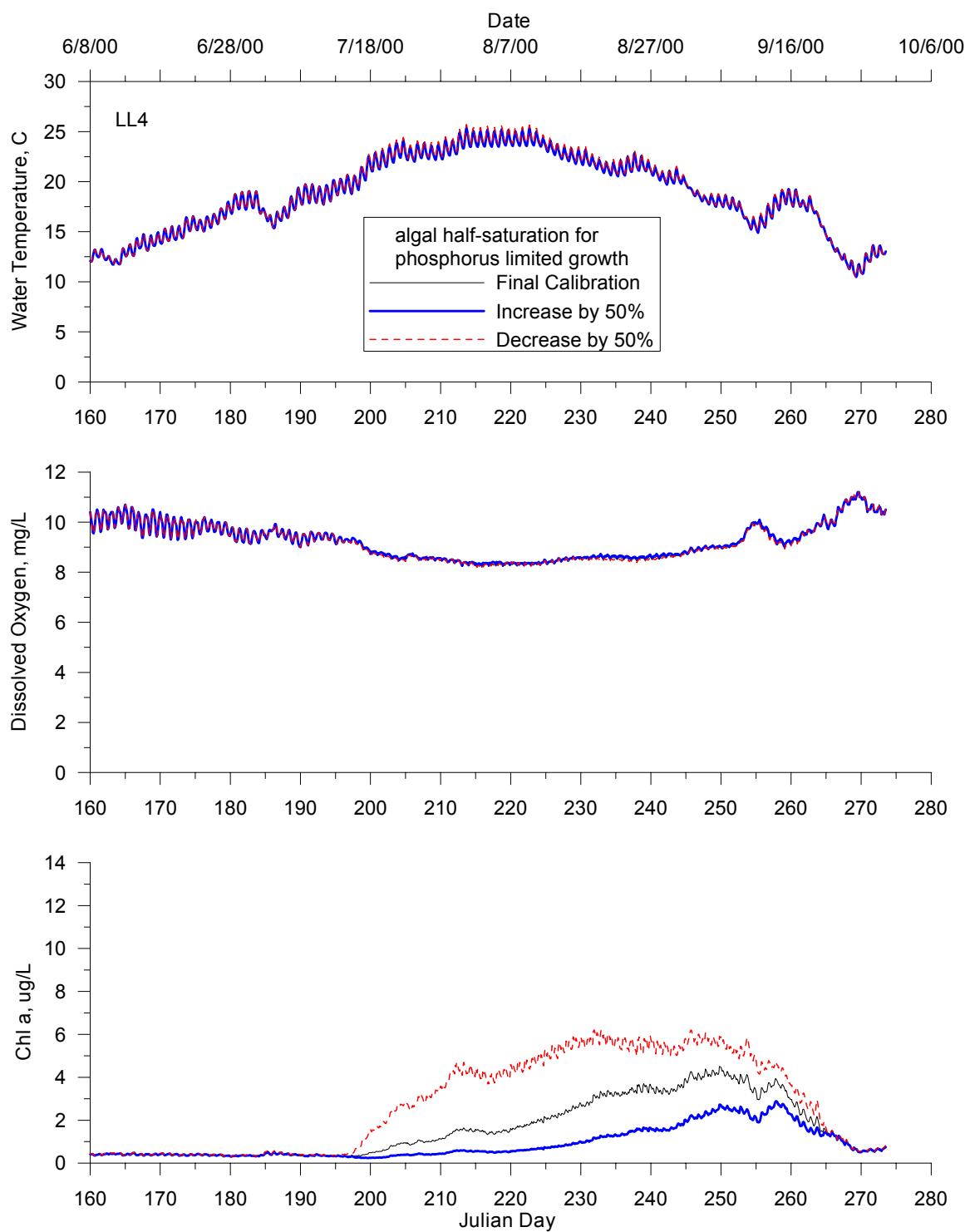


Figure 256. Long Lake site LL4 (RM 51.5) algal half-saturation for phosphorus limited growth sensitivity, time series

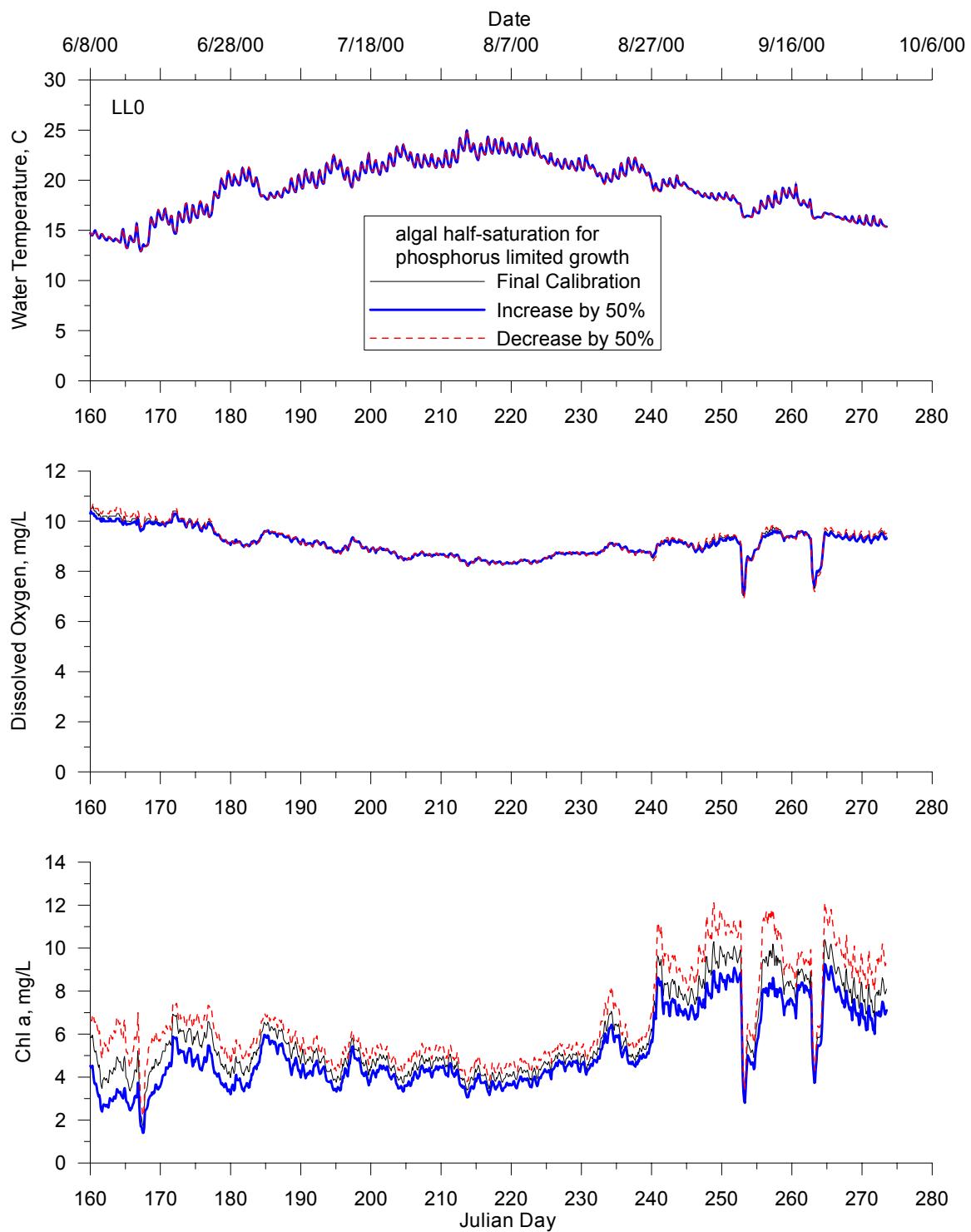


Figure 257. Long Lake site LL0 (RM 32.7) algal half-saturation for phosphorus limited growth sensitivity, time series

Spokane River

Spokane River sensitivity analysis simulations were run from August 7th to September 6th, 2000 with temperature, dissolved oxygen and periphyton biomass compared between simulations. Time series results were compared at RM 72.5, just below the Upper Falls Dam and at RM 66.0, the headwaters to Nine Mile Dam pool.

Meteorological data

The final calibration of the Spokane River model used meteorological data from the Spokane International Airport with cloud cover estimated from the incoming short-wave solar radiation at Odessa, Washington. The river model was evaluated with meteorological data from near-by Spokane Felts Field, meteorological data at the Spokane International Airport using cloud cover computed from Odessa, and meteorological data at the Spokane International Airport using existing cloud cover. Table 63 shows mean temperature, dissolved oxygen, and periphyton biomass concentration values for these 3 comparisons. The table shows there is negligible difference between the mean values for each simulation indicating the changes in the meteorological data have little influence on these constituents overall primarily because of the short travel time between model sections. Figure 258 and Figure 259 show time series plots at the upstream end of the river section (RM 72.5) and the lower end of the river (RM 66.0), respectively. The differences in meteorological data have a negligible influence on the temperature, dissolved oxygen and periphyton biomass in the river.

Table 63. Spokane River section meteorological sensitivity analysis, mean statistics

Description	Cloud Cover	Location	Mean Temp., °C	Mean DO, mg/L	Mean Periphyton Biomass, mg/L
Final Calibration, Spokane International Airport with cloud cover based on solar radiation	Based on Solar Radiation	SPK72.5	14.97	8.62	20.4
		SPK66.0	15.45	9.09	31.4
Spokane International Airport using Cloud Cover data	Based on Data	SPK72.5	14.96	8.62	20.2
		SPK66.0	15.40	9.08	31.3
Felts Field using Cloud Cover data	Based on Data	SPK72.5	14.98	8.62	20.3
		SPK66.0	15.52	9.08	31.3

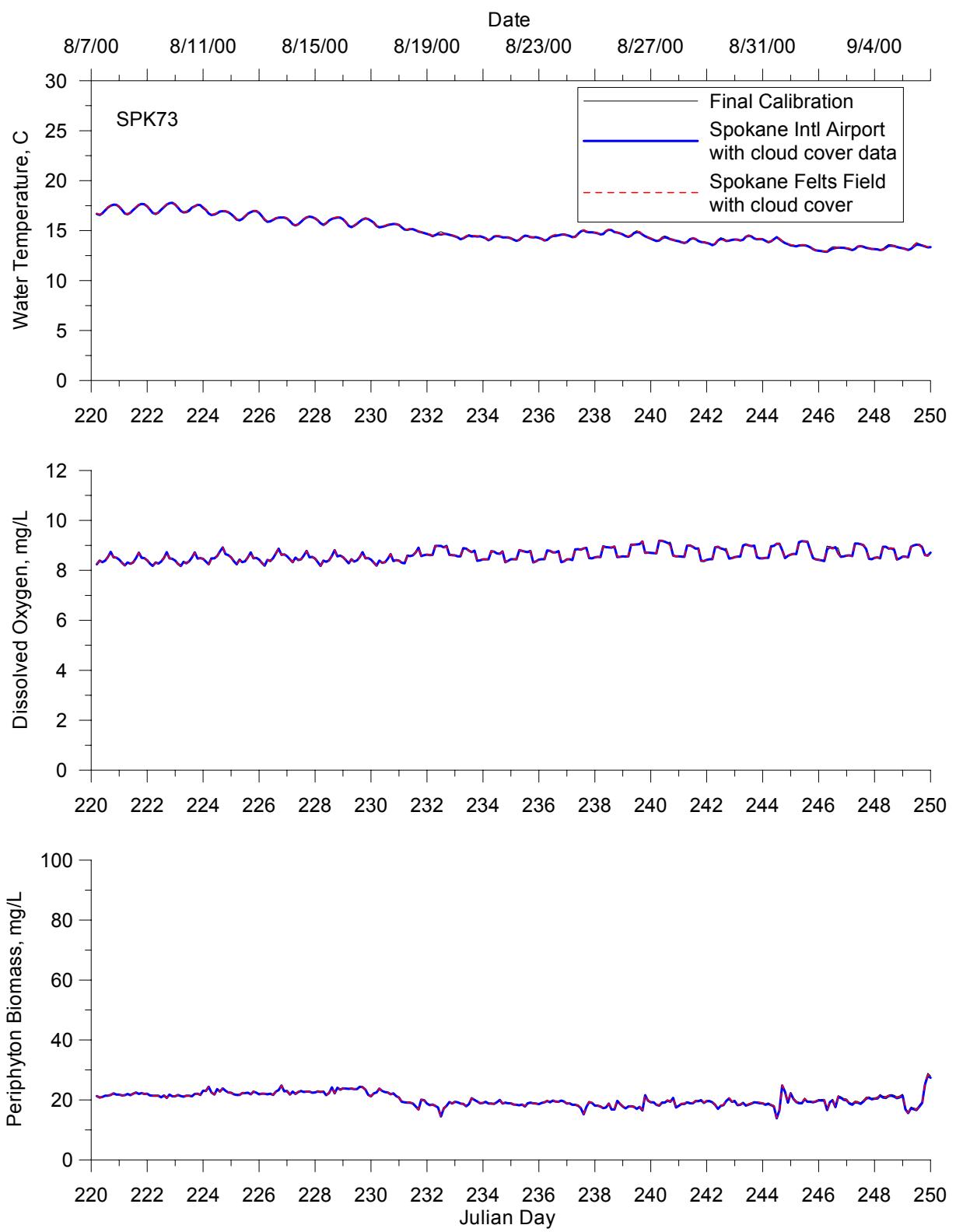


Figure 258. Spokane River at RM 72.5 meteorology sensitivity, time series

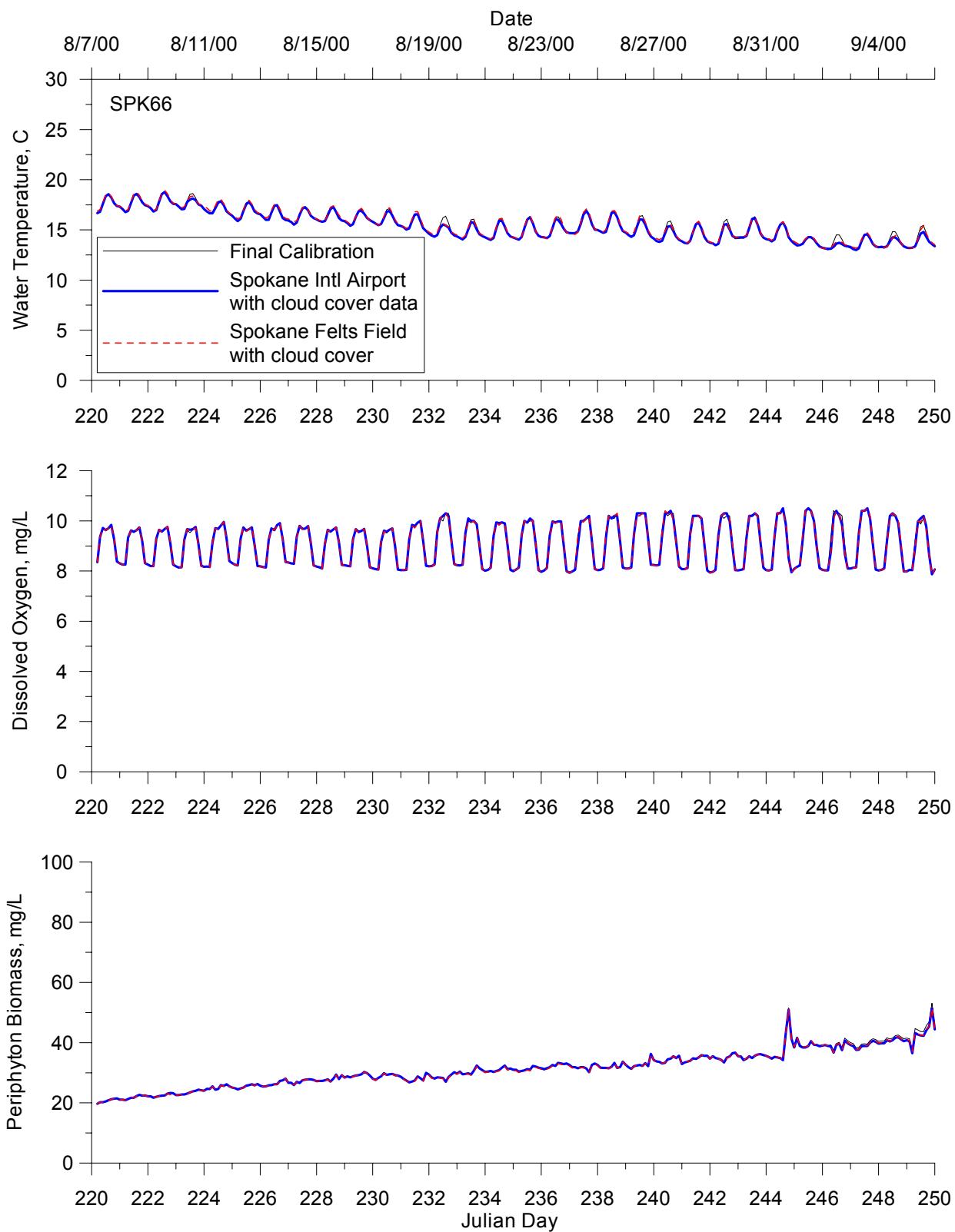


Figure 259. Spokane River at RM 66.0 meteorology sensitivity, time series

Reaeration Formulation

The final calibration of the river used a river reaeration equation, which allows the user to define the relationship. The equation used in the final calibration was: $K_a = COEF1U^{COEF2}H^{COEF3}$ where COEF1

=0.04, COEF2=0.0, COEF3=0.0, U is the average velocity, and H is the average depth. This reaeration equation was compared with a reaeration equation from Thackston and Krenkel (1966): $K_a = \frac{7.62U}{H^{1.33}}$

and with an equation from Melching and Flores (1999): $K_a = 596(US)^{0.528} Q^{-0.136}$ for $Q > 0.556 m^3/s$ where S is the slope. The user-defined reaeration relationship was used for this river section in order to match field data of supersaturation. This supersaturation may be a result of photosynthetic production from periphyton and low surface gas transfer because of surfactants in the effluent from the wastewater treatment discharge. Table 64 shows the mean temperature, dissolved oxygen, and periphyton biomass for the three simulations. Figure 260 and Figure 261 provide time series of the three constituents at RM 72.5 and 66.0, respectively. The plots show there are negligible differences for the temperature and periphyton time series between simulations and at both locations. The different reaeration equations influence the dissolved oxygen at the surface as shown in the time series plot. The time series plots furthest downstream show more influence from the reaeration equations than the upstream site as expected. The dissolved oxygen concentration at the surface varied by approximately 0.5 mg/L between the different simulations.

Table 64. Spokane River section reaeration sensitivity analysis, mean statistics

Description	River Reaeration Formula	Location	Mean Temp., °C	Mean DO, mg/L	Mean Periphyton Biomass, mg/L
Final Calibration, Equation #9	User defined	SPK72.5	14.97	8.62	20.4
		SPK66.0	15.45	9.09	31.4
Reaeration Formulation 1, Equation #5	Thackston and Krenkel (1966)	SPK72.5	14.97	8.99	20.4
		SPK66.0	15.45	9.52	31.4
Reaeration Formulation 2, Equation #7	Melching and Flores (1999)	SPK72.5	14.97	8.84	20.4
		SPK66.0	15.45	9.44	31.4

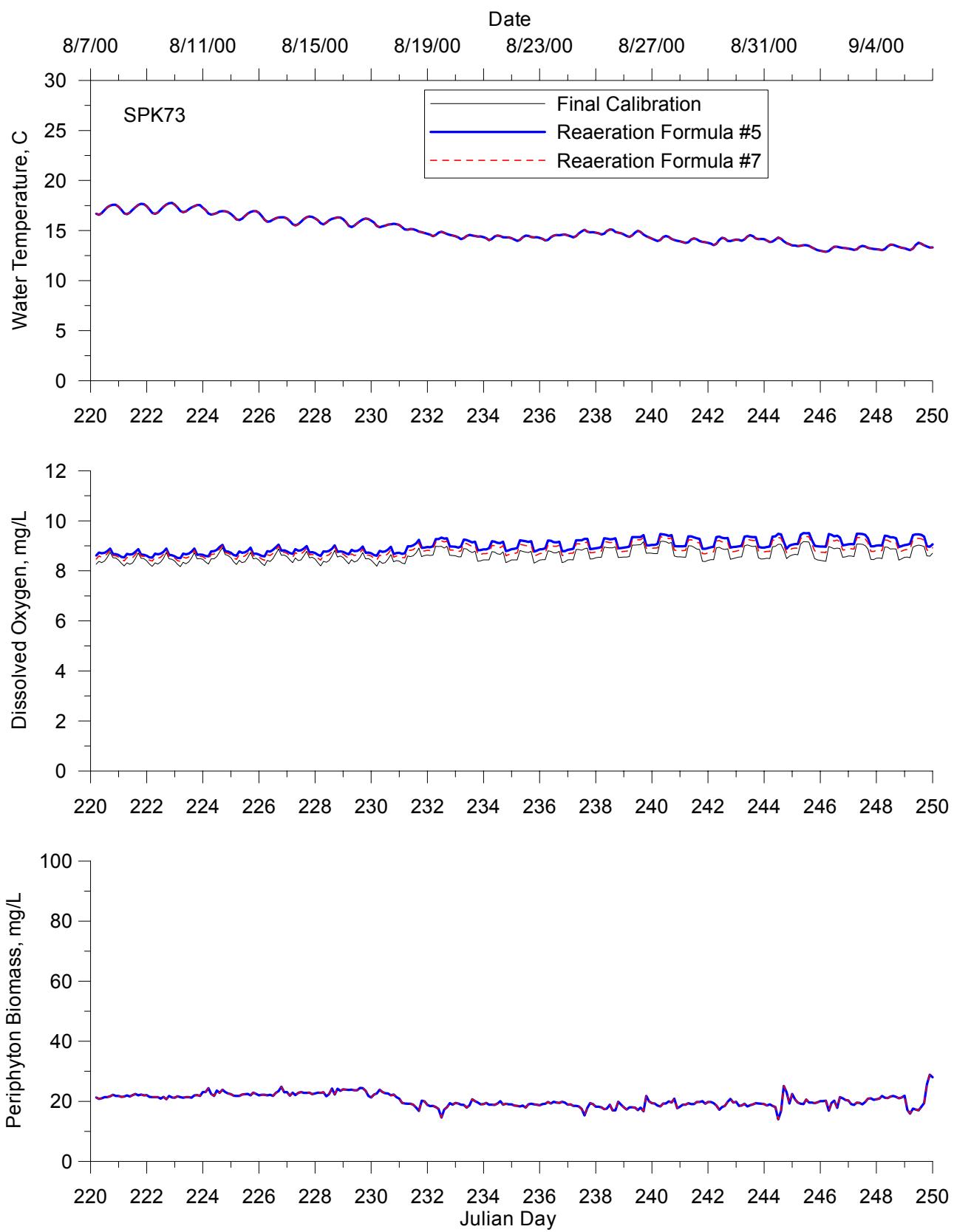


Figure 260. Spokane River at RM 72.5 reaeration sensitivity, time series

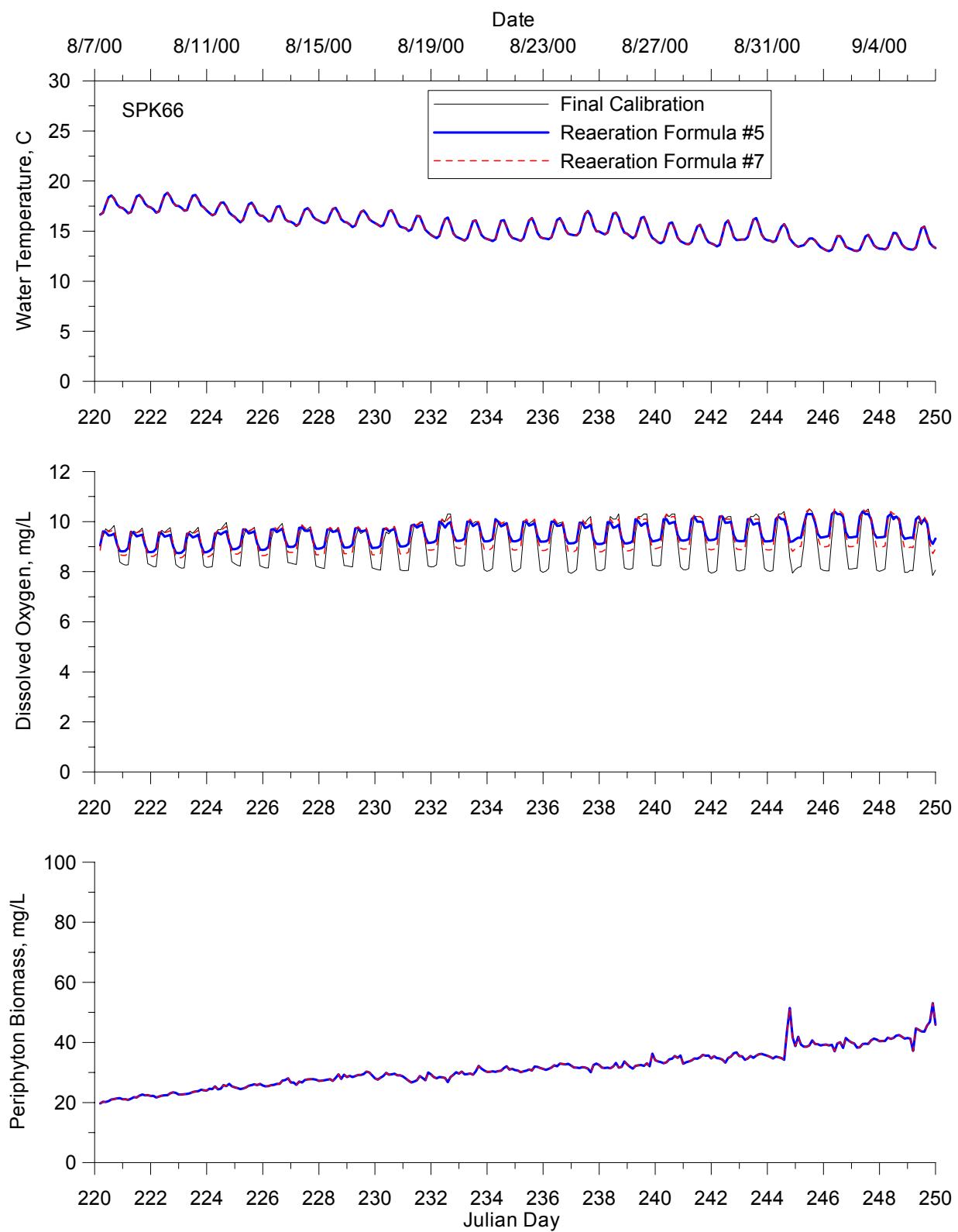


Figure 261. Spokane River at RM 66.0 reaeration sensitivity, time series

Wind Sheltering

Wind sheltering does not play a significant role in influencing water quality in a swift moving river like the Spokane River because the detention time in riverine sections is usually much shorter than in a lake and the reaeration is a function of boundary shear rather than wind induced turbulence. The final calibration of the river model used varying wind sheltering for the river sections. For the river section used in the sensitivity analysis the wind sheltering was 85% for all the model segments. The wind sheltering was set 65% and 100% in two simulations to compare with the final calibration. Table 65 shows the mean temperature, dissolved oxygen, and periphyton biomass. Figure 262 and Figure 263 show time series plots of the three constituents at RM 72.5 and RM 66.0, respectively. These results show negligible differences between the different wind sheltering simulations.

Table 65. Spokane River section wind sheltering sensitivity analysis, mean statistics

Description	Wind Sheltering Coefficient	Location	Mean Temp., °C	Mean DO, mg/L	Mean Periphyton Biomass, mg/L
Final Calibration	0.85	SPK72.5	14.97	8.62	20.4
		SPK66.0	15.45	9.09	31.4
Set wind sheltering to 100%	1.00	SPK72.5	14.96	8.62	20.4
		SPK66.0	15.42	9.09	31.4
Set wind sheltering to 65%	0.65	SPK72.5	14.98	8.62	20.4
		SPK66.0	15.49	9.09	31.4

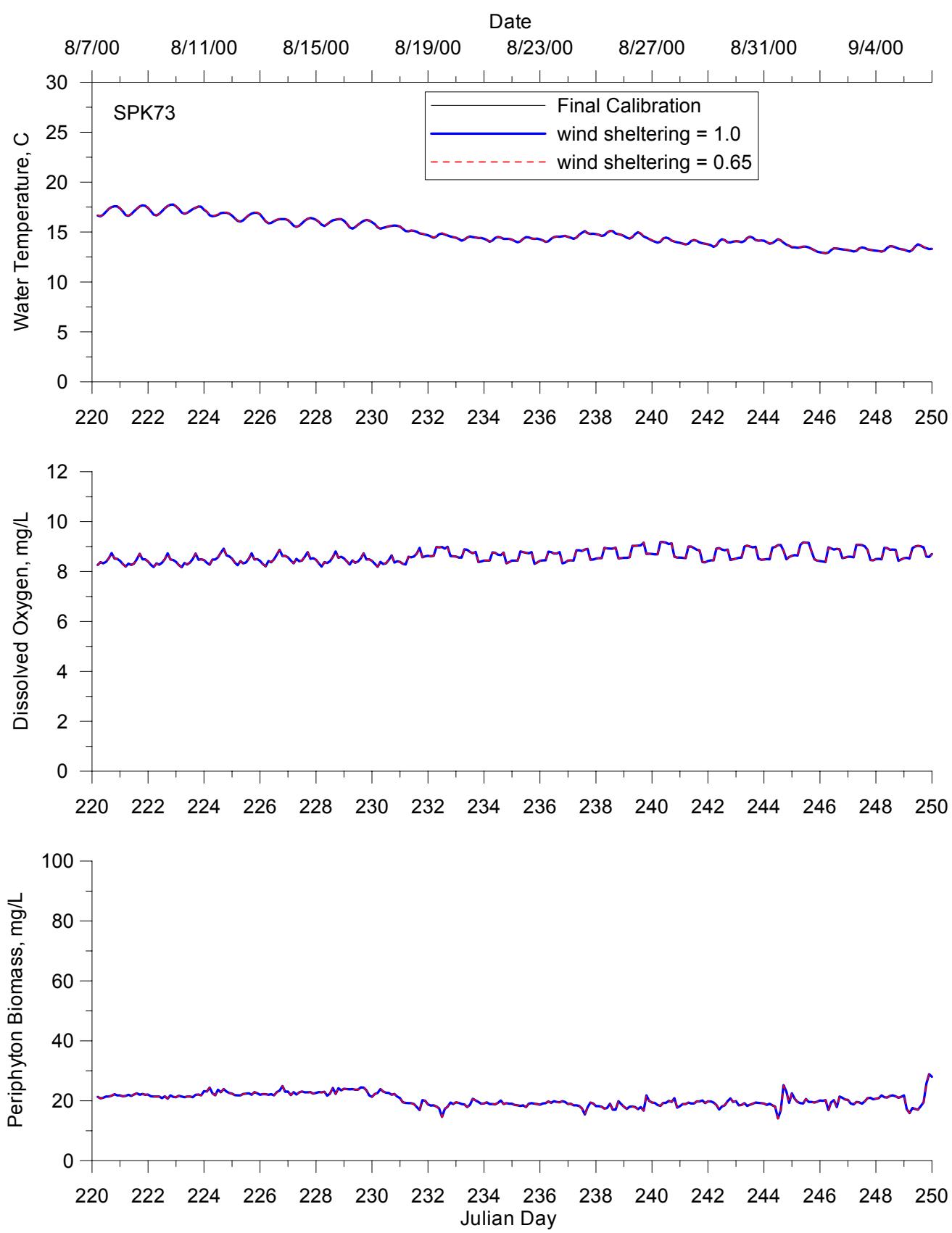


Figure 262. Spokane River at RM 72.5 wind sheltering sensitivity, time series

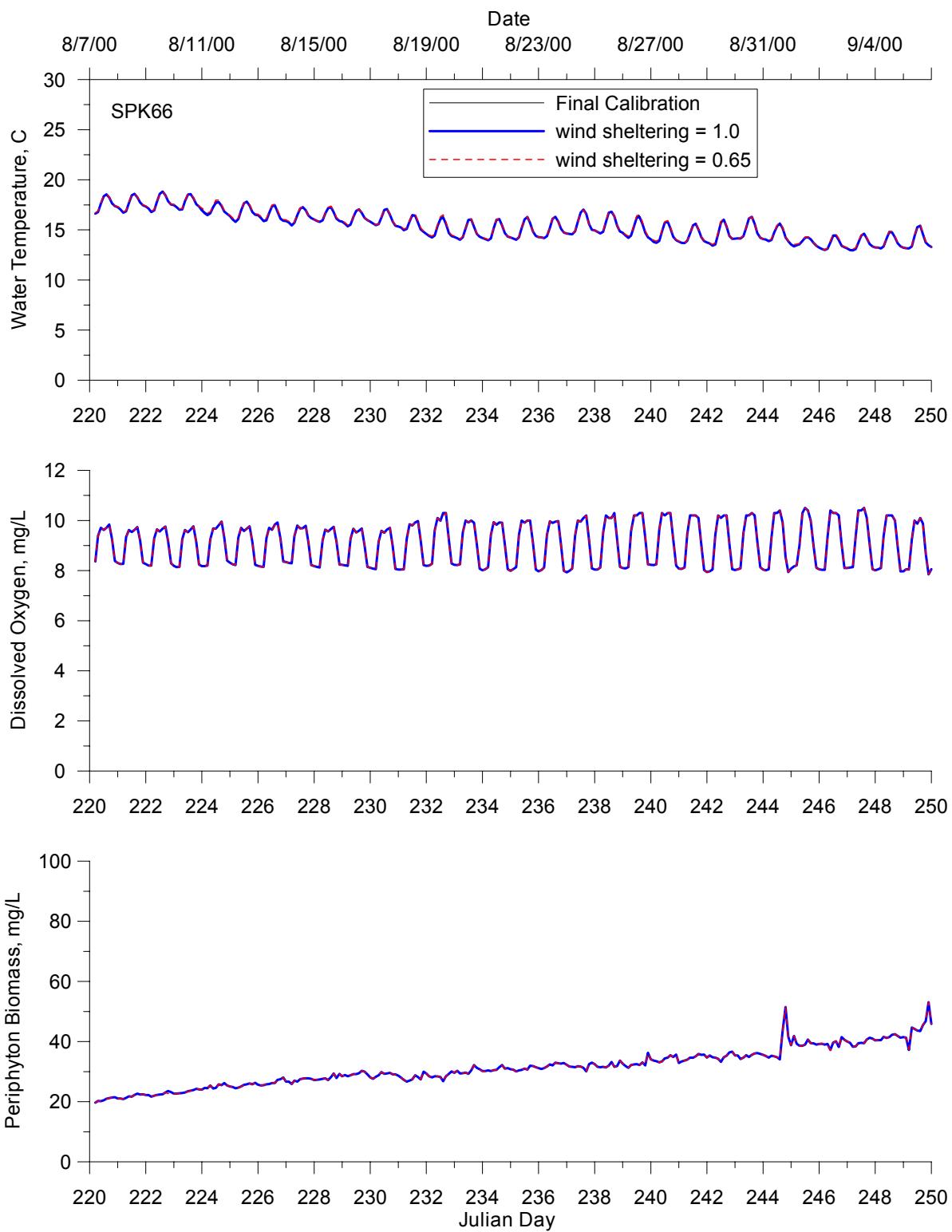


Figure 263. Spokane River at RM 66.0 wind sheltering sensitivity, time series

Wind Direction

The final model calibration used wind direction data from the Spokane International Airport. The results were compared with running the river model with the wind direction set to the orientation of the river so

the wind was always blowing up or down the river channel. Table 66 provides the mean temperature, dissolved oxygen, and periphyton biomass for each simulation. The table shows no difference between the mean values, indicating the wind direction does not influence the three constituents. Figure 264 and Figure 265 provide time series plots for the three constituents, comparing the two simulations. The two figures show no differences in the temperature, dissolved oxygen, and periphyton biomass concentration between the two simulations.

Table 66. Spokane River section wind direction sensitivity analysis, mean statistics

Description	Wind Direction	Location	Mean Temp., °C	Mean DO, mg/L	Mean Periphyton Biomass, mg/L
Final Calibration	Based on Data	SPK72.5	14.97	8.62	20.4
		SPK66.0	15.45	9.09	31.4
Wind direction set to only upstream and downstream directions for the last half of river	Set to river orientation	SPK72.5	14.97	8.62	20.4
		SPK66.0	15.45	9.09	31.4

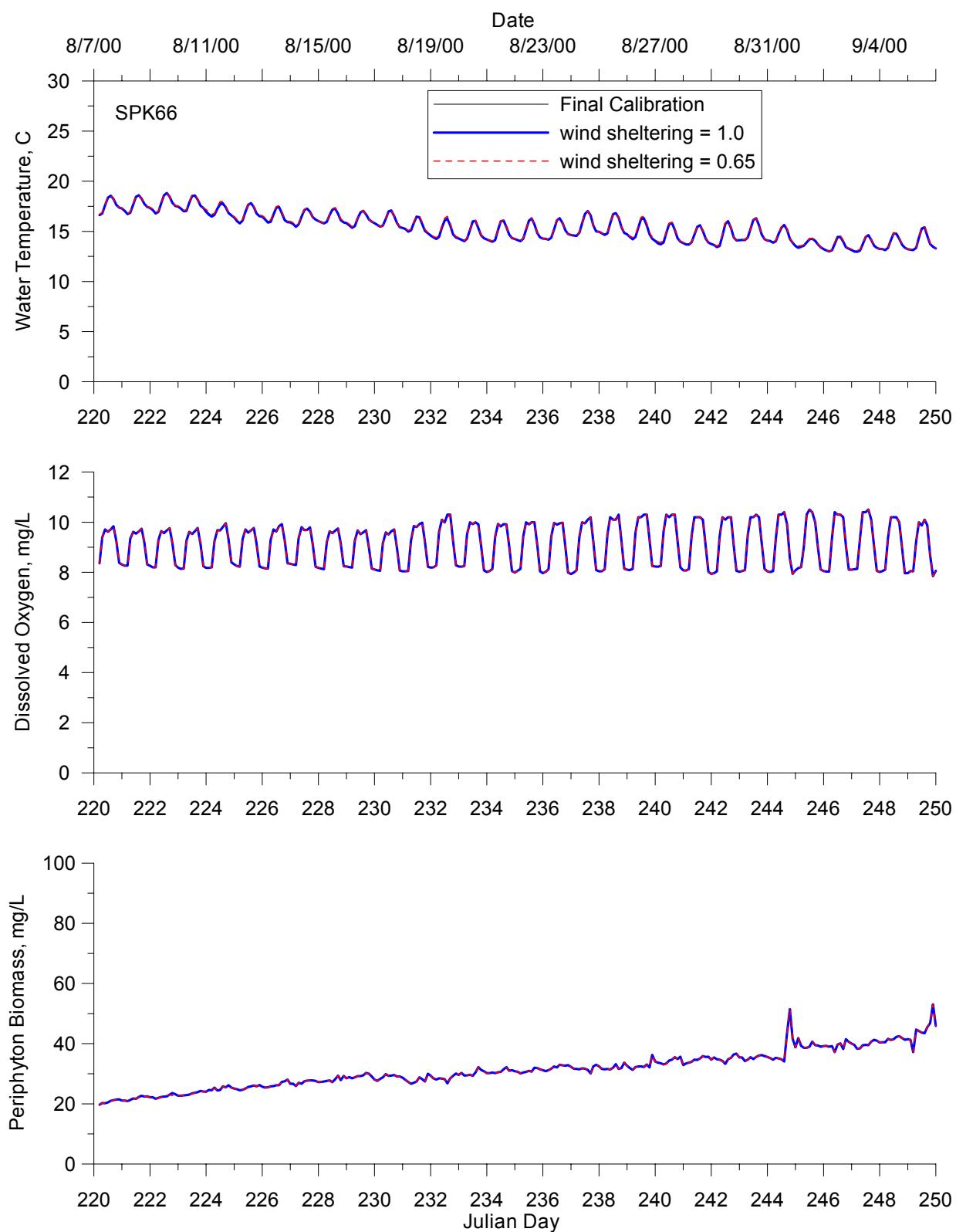


Figure 264. Spokane River at RM 72.5 wind direction sensitivity, time series

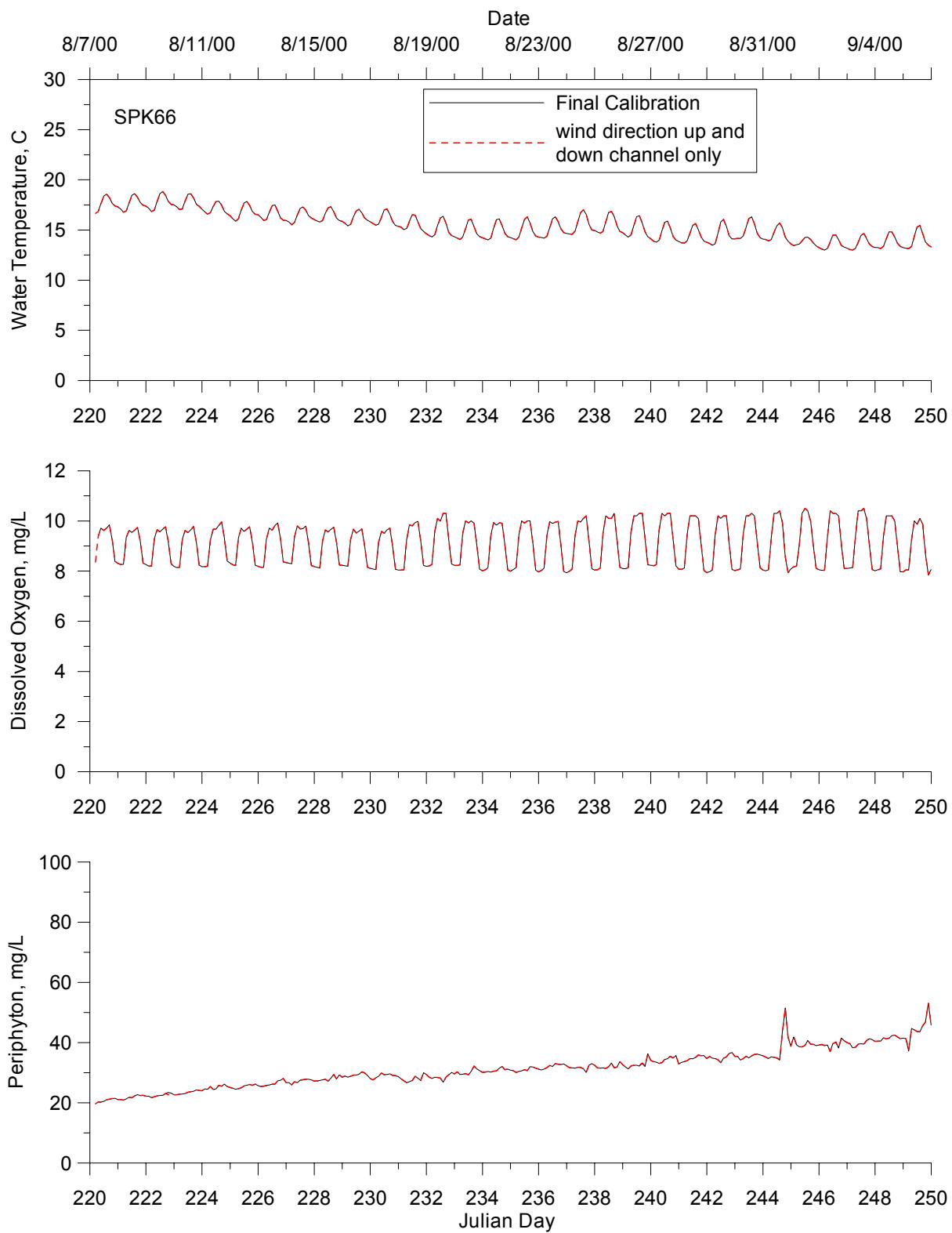


Figure 265. Spokane River at RM 66.0 wind direction sensitivity, time series

Periphyton Growth Rate

The sensitivity of the periphyton growth rate to temperature, dissolved oxygen and periphyton biomass in the river was investigated by increasing and decreasing the periphyton growth rate by 50% from the

final calibration value. Table 67 provides the sensitivities for each constituent and shows that dissolved oxygen is slightly sensitive and the periphyton biomass is more sensitive to the growth rate changes. Figure 266 and Figure 267 are time series plots for each constituent at RM 72.5 and RM 66.0, respectively. The plots show the temperature at both sites is not sensitive to the periphyton growth rate changes. The dissolved oxygen concentration does show variability from the final calibration values with differences occurring during the day. The effects are more pronounced downstream on the river at RM 66.0 than at RM 72.5. The dissolved oxygen differences between simulations are less than 0.5 mg/L compared to the final calibration. Periphyton biomass concentration time series plots show the biomass increasing over time at both locations.

Table 67. Spokane River section periphyton growth rate sensitivities

Description	Periphyton Growth Rate day^{-1}	Location	Temperature Sensitivity	DO Sensitivity	Periphyton Biomass Sensitivity
Final Calibration	1.50	SPK72.5	NA	NA	NA
		SPK66.0	NA	NA	NA
Increase periphyton growth rate by 50%	2.25	SPK72.5	0.000	-0.021	-0.429
		SPK66.0	0.000	-0.068	-0.915
Decrease periphyton growth rate by 50%	0.75	SPK72.5	0.000	-0.021	-0.478
		SPK66.0	0.000	-0.092	-0.854

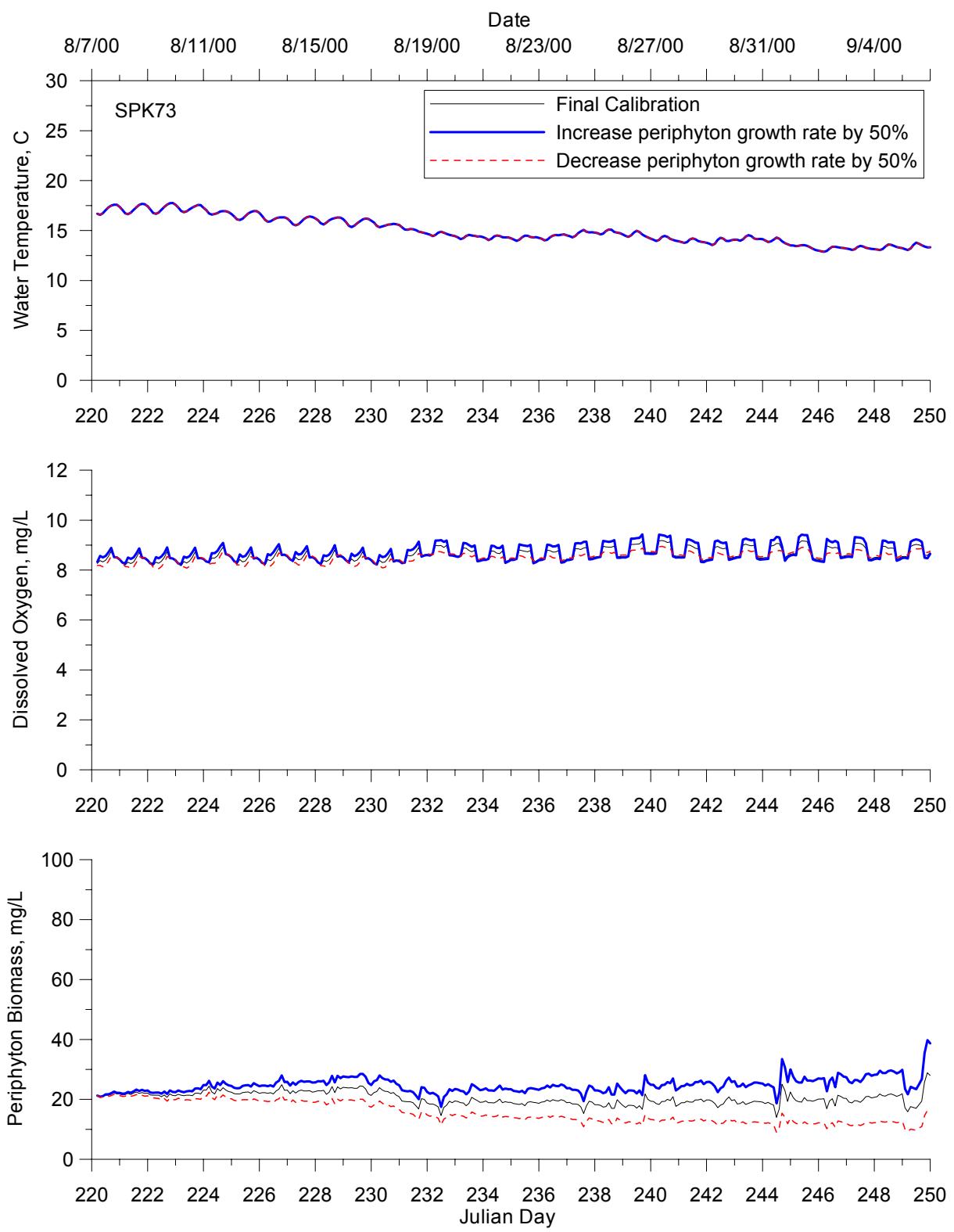


Figure 266. Spokane River at RM 72.5 periphyton growth rate sensitivity, time series

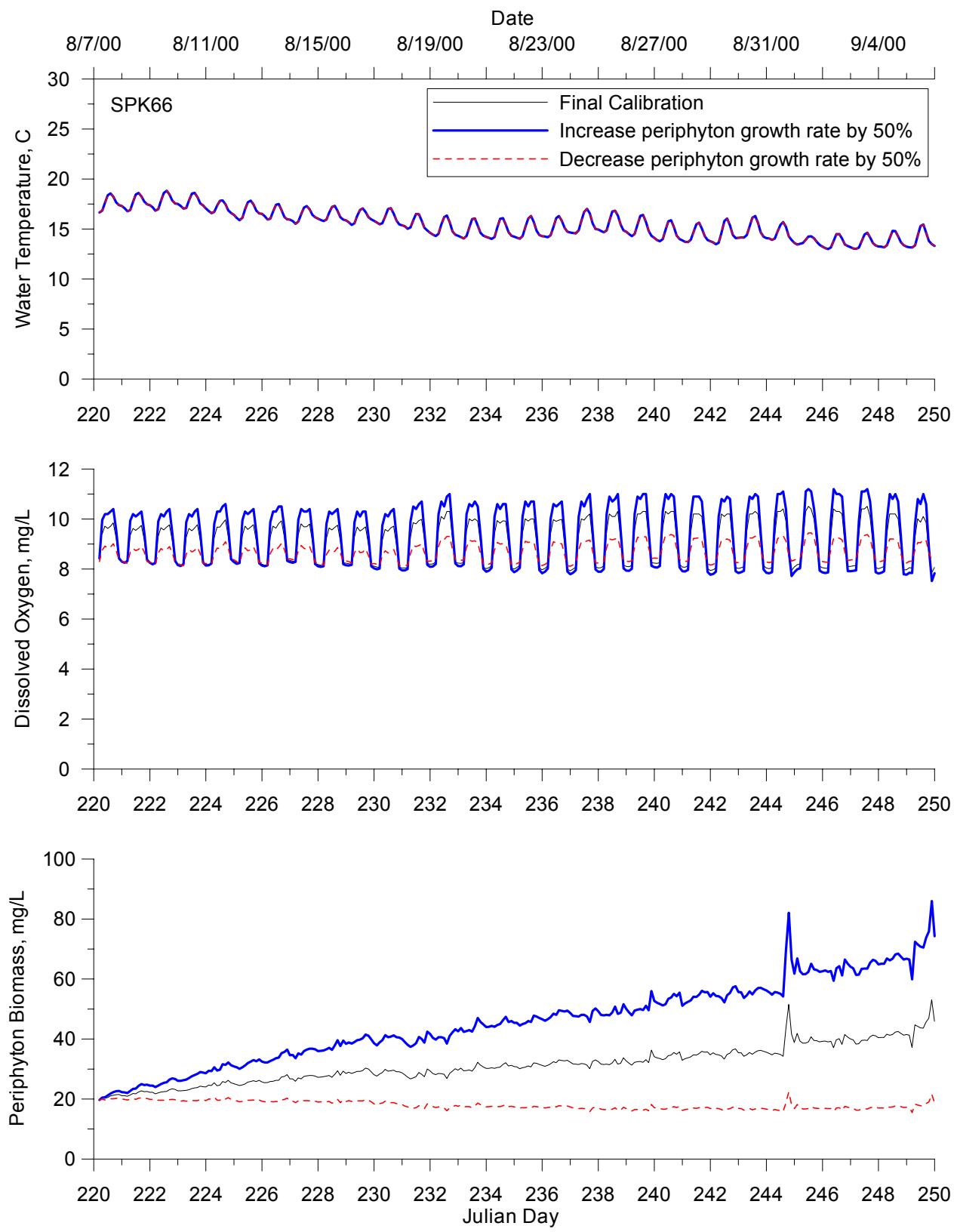


Figure 267. Spokane River at RM 66.0 periphyton growth rate sensitivity, time series

Periphyton half-saturation for phosphorus limited growth

The sensitivity of the periphyton half saturation for phosphorus limited growth to temperature, dissolved oxygen, and periphyton biomass were investigated by increasing and decreasing the half-saturation value by 50% from the final calibration value. Table 68 provides the sensitivities for each constituent and shows that temperature and dissolved oxygen are not sensitive to the changes in the half-saturation constant on a gross time scale. Periphyton biomass concentration does show some sensitivity to changes in the half-saturation constant. Figure 268 and Figure 269 are time series plots for each constituent at RM 72.5 and RM 66.0, respectively. The plots show temperature at both sites is not sensitive to the half-saturation constant changes. The dissolved oxygen concentrations show some differences from the final calibration during each day. The effects are more pronounced downstream at RM 66.0 rather than at RM 72.5 but differences are usually less than 0.5 mg/L. The periphyton biomass concentration time series shows gradual increases in concentration over time.

Table 68. Spokane River section periphyton half-saturation for phosphorus limited growth rate sensitivities

Description	Periphyton $\frac{1}{2}$ sat. P limited growth rate g/m ³	Location	Temperature Sensitivity	DO Sensitivity	Periphyton Biomass Sensitivity
Final Calibration	0.003	SPK72.5	NA	NA	NA
		SPK66.0	NA	NA	NA
Increase periphyton half-saturation for phosphorus limited growth by 50%	0.0045	SPK72.5	0.000	0.007	0.142
		SPK66.0	0.000	0.020	0.068
Decrease periphyton half-saturation for phosphorus limited growth by 50%	0.0015	SPK72.5	0.000	0.009	0.220
		SPK66.0	0.000	0.026	0.063

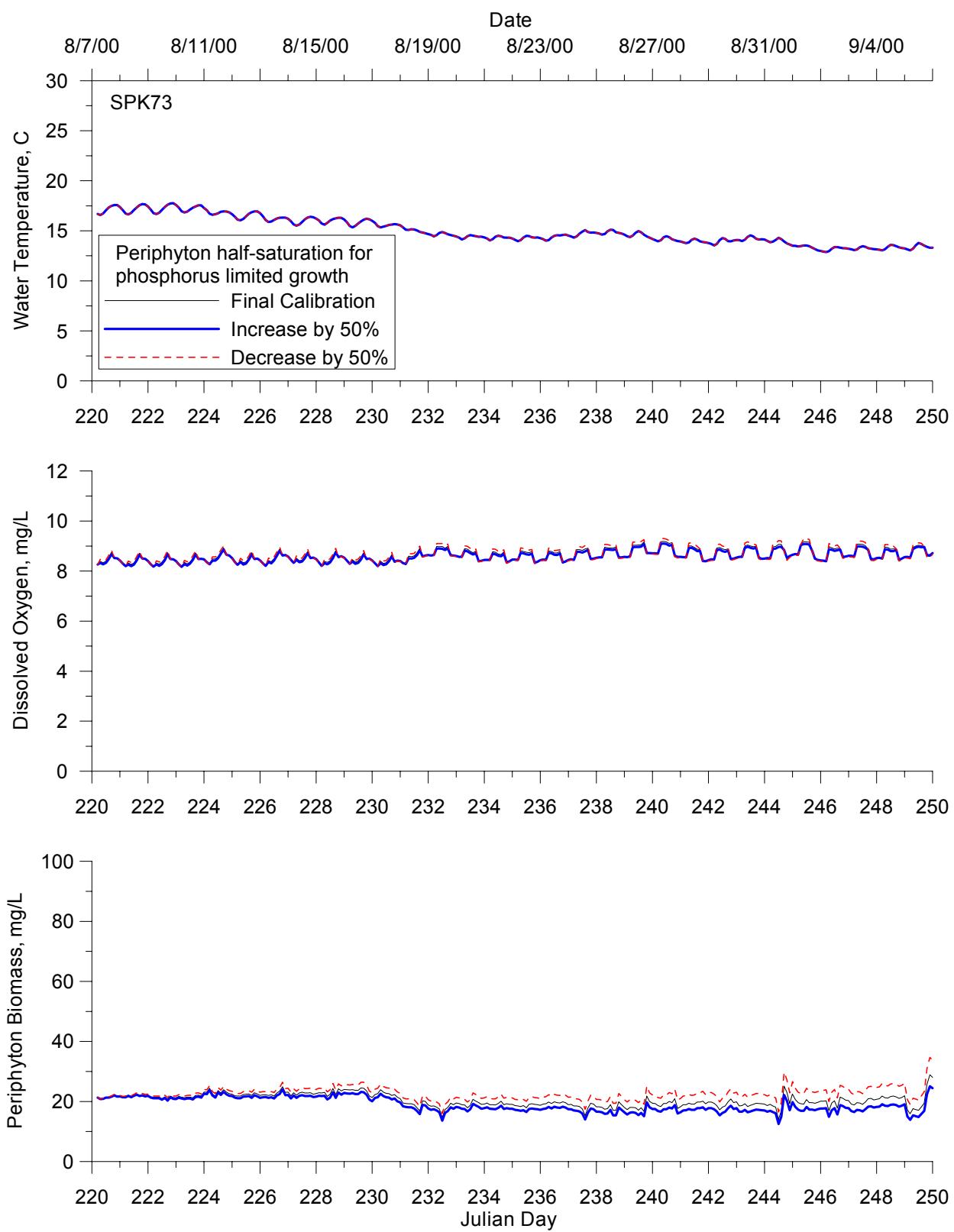


Figure 268. Spokane River at RM 72.5 periphyton half-saturation for phosphorus limited growth sensitivity, time series

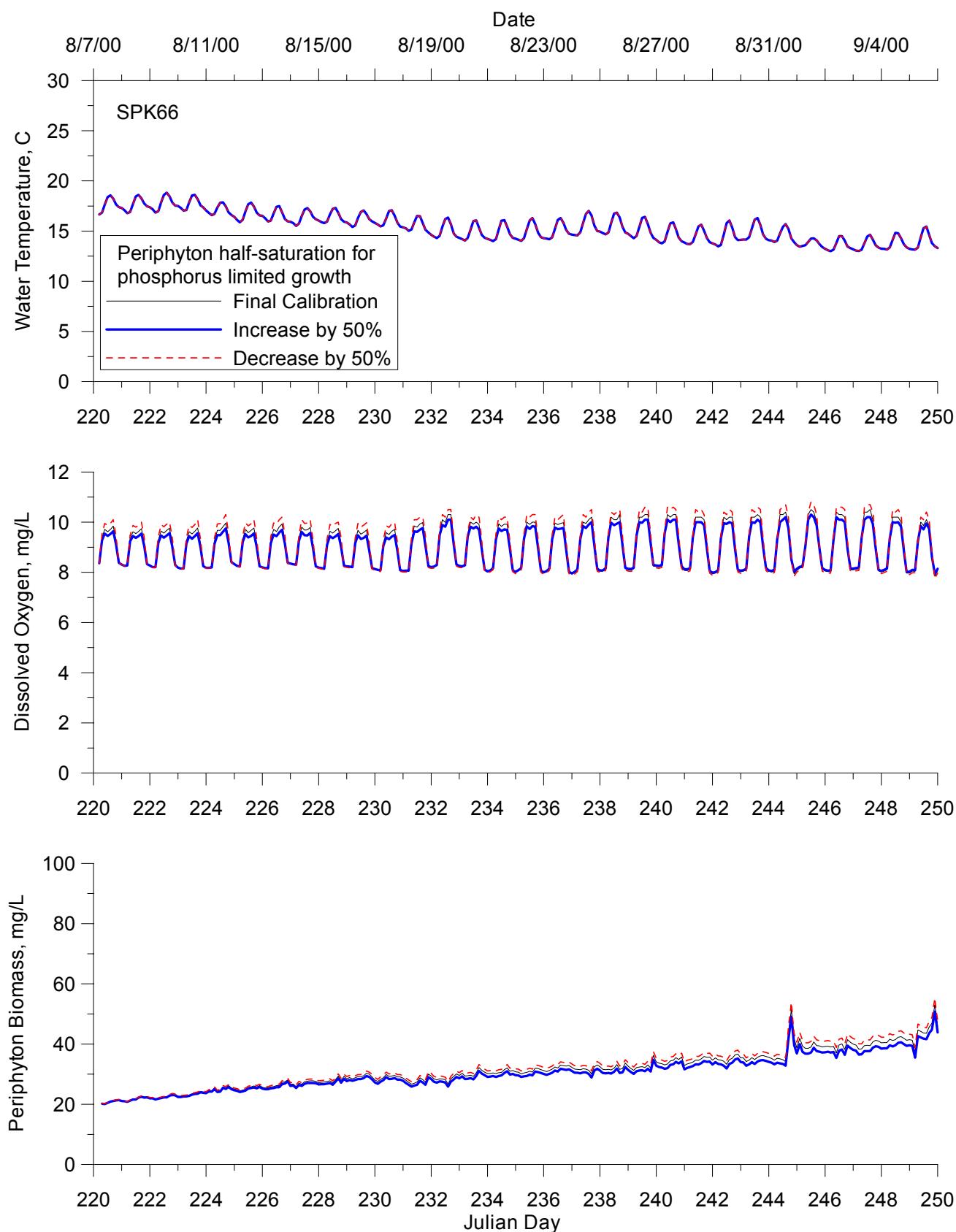


Figure 269. Spokane River at RM 66.0 periphyton half-saturation for phosphorus limited growth sensitivity, time series

Summary

A water quality and hydrodynamic model, CE-QUAL-W2 Version 3.1 (Cole and Wells, 2001), was applied to the Spokane River from the Washington State line to the outlet of Long Lake in Washington. This model was calibrated to field data from the years 1991 and 2000. A description of the field data used in the model and the model set-up was described in Annear et al. (2001). This report detailed the calibration of hydrodynamic, temperature and water quality variables. Model predictions were compared to field data for the following parameters:

- Water level
- Temperature
- pH
- $\text{NO}_3\text{-N} + \text{NO}_2\text{-N}$ – nitrate + nitrite
- SRP – soluble reactive phosphorus
- Chlorophyll a
- Flow rate
- Dissolved oxygen
- Conductivity
- $\text{NH}_4\text{-N}$ - ammonia
- Periphyton biomass
- Alkalinity

Field data used in the model-data comparisons included near-surface grab sample data, continuous Hydrolab data, and vertical profiles data. Grab sample data were compared to field measurements at over 13 river-reservoir locations along the Spokane River. Vertical profiles comparisons were made at 15 locations (including the 5 Long Lake profile stations).

In general, the model reproduces the river and reservoir responses to the known boundary conditions. Table 69 shows a summary of model errors for each parameter of interest in the Long Lake – Spokane model domain.

Table 69. Typical model errors in the Long Lake Spokane system from vertical profile and time series comparisons

Parameter	Overall Average Absolute Mean Error	Typical range in Absolute Mean Error
Water level, m	0.09	0.03 – 0.30
Flow rate, m^3/s	3.4	1.9 – 5.3
Temperature, $^{\circ}\text{C}$	0.95	0.28 – 3.49
Dissolved oxygen, mg/l	0.85	0.26 – 1.82
Chlorophyll a, ug/l	0.004	0.001 – 0.010
pH	0.29	0.04 – 0.57
$\text{PO}_4\text{-P}$, mg/l	0.003	0.002 – 0.006
Total P, mg/l	0.008	0.004 - 0.014
Ammonia-N, mg/l	0.020	0.004 – 0.048
Nitrate-N, mg/l	0.18	0.10 – 0.42
TPN, mg/l	0.22	0.14 – 0.46
TOC, mg/l	0.41	0.29 – 0.54

The model is well suited for evaluating the impacts of management strategies to improve water quality in the Spokane River Long Lake region.

References

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Appendix 1: W2 Control File

Spokane River Model Version 3.1

TITLE CTITLE.....
 Version 3.1 Spokane R. Model
 WB 1 : Sloping branches between State line and Upriver Pool
 WB 2 : Pool of Upriver DAM
 Wb 3 : Pool of Upper Falls Dam
 WB 4 : 2 sloping branches above 9-mile dam pool
 WB 5 : Nine Mile dam pool
 WB 6 : Long Lake
 Tom Cole, WES; Scott Wells, PSU; Rob Annear, PSU; Chris Berger, PSU

GRID	NWB 6	NBR 12	IMX 189	KMX 47					
IN/OUTFLOW	NTR 7	NST 7	NIW 0	NWD 0	NGT 0	NSP 6	NPI 0	NPU 0	
CONSTITUENTS	NCG 5	NSS 1	NAL 1	NEP 1	NBOD 5				
MISCELL	NDAY 100 1.0402 303.89								
TIME CON	TMSTRRT 1.0402	TMEND 303.89	YEAR 2000						
DLT CON	NDLT 6	DLTMIN 0.1							
DLT DATE	DLTD 1.00	DLTD 1.2	DLTD 105.0	DLTD 200.0	DLTD 229.0	DLTD 251.0	DLTD	DLTD	DLTD
DLT MAX	DLTMAX 5.0	DLTMAX 65.0	DLTMAX 65.0	DLTMAX 10.0	DLTMAX 5.0	DLTMAX 10.0	DLTMAX	DLTMAX	DLTMAX
DLT FRN	DLTF 0.90	DLTF 0.60	DLTF 0.60	DLTF 0.60	DLTF 0.60	DLTF 0.90	DLTF	DLTF	DLTF
DLT LIMIT	VISC	CELC							
Wb 1	ON	ON							
Wb 2	ON	ON							
Wb 3	ON	ON							
Wb 4	ON	ON							
Wb 5	ON	ON							
Wb 6	ON	ON							
BRANCH G	US	DS	UHS	DHS	UQB	DQB	NL	SLOPE	
Br 1	2	10	0	13	0	0	1	0.00181	
Br 2	13	24	10	27	0	0	1	0.00152	
Br 3	27	36	24	39	0	0	1	0.00328	
Br 4	39	48	36	0	0	0	1	0.00142	
Br 5	51	64	0	0	0	0	1	0.00000	
Br 6	67	73	-64	76	0	0	1	0.00000	
Br 7	76	86	73	0	0	0	1	0.00000	
Br 8	89	94	-86	97	0	0	1	0.00256	
Br 9	97	128	94	0	0	0	1	0.00208	
Br 10	131	135	0	138	0	0	1	0.00000	
Br 11	138	151	135	0	0	0	1	0.00000	
Br 12	154	188	-151	0	0	0	1	0.00000	
LOCATION	LAT	LONG	EBOT	BS	BE	JBDN			
Jr 1	47.8	117.8	578.72	1	4	4			
Jr 2	47.8	117.8	571.00	5	5	5			
Jr 3	47.8	117.8	560.00	6	7	7			
Jr 4	47.8	117.8	485.51	8	9	9			
Jr 5	47.8	117.8	481.00	10	11	11			
Jr 6	47.8	117.8	422.10	12	12	12			

INIT	CND	T2I	ICEI	WTYPEC							
wb	1	4.0	0.0	FRESH							
wb	2	4.0	0.0	FRESH							
wb	3	4.0	0.0	FRESH							
wb	4	4.0	0.0	FRESH							
wb	5	4.0	0.0	FRESH							
wb	6	4.0	0.0	FRESH							
CALCULAT		VBC	EBC	MBC	PQC	EVC	PRC				
Wb	1	ON	ON	ON	OFF	ON	OFF				
Wb	2	ON	ON	ON	OFF	ON	OFF				
Wb	3	ON	ON	ON	OFF	ON	OFF				
Wb	4	ON	ON	ON	OFF	ON	OFF				
Wb	5	ON	ON	ON	OFF	ON	OFF				
Wb	6	ON	ON	ON	OFF	ON	OFF				
DEAD	SEA	WINDC	QINC	QOUTC	HEATC						
Wb	1	ON	ON	ON	ON						
Wb	2	ON	ON	ON	ON						
Wb	3	ON	ON	ON	ON						
Wb	4	ON	ON	ON	ON						
Wb	5	ON	ON	ON	ON						
Wb	6	ON	ON	ON	ON						
INTERPOL		QINIC	DTRIC	HDIC							
Br	1	ON	OFF	ON							
Br	2	ON	OFF	ON							
Br	3	ON	OFF	ON							
Br	4	ON	OFF	ON							
Br	5	ON	OFF	ON							
Br	6	ON	OFF	ON							
Br	7	ON	OFF	ON							
Br	8	ON	OFF	ON							
Br	9	ON	OFF	ON							
Br	10	ON	OFF	ON							
Br	11	ON	OFF	ON							
Br	12	ON	OFF	ON							
HEAT	EXCH	SLHTC	SROC	RHEVAP	METIC	FETCHC	AFW	BFW	CFW	WINDH	
Wb	1	TERM	OFF	OFF	ON	OFF	9.2	0.46	2.0	2.0	
Wb	2	TERM	OFF	OFF	ON	OFF	9.2	0.46	2.0	2.0	
Wb	3	TERM	OFF	OFF	ON	OFF	9.2	0.46	2.0	2.0	
Wb	4	TERM	OFF	OFF	ON	OFF	9.2	0.46	2.0	2.0	
Wb	5	TERM	OFF	OFF	ON	OFF	9.2	0.46	2.0	2.0	
Wb	6	TERM	OFF	OFF	ON	OFF	9.2	0.46	2.0	2.0	
ICE	COVER	ICEC	SLICEC	ALBEDO	HWICE	BICE	GICE	ICEMIN	ICET2		
Wb	1	OFF	DETAIL	0.25	10.0	0.6	0.07	0.05	3.0		
Wb	2	OFF	DETAIL	0.25	10.0	0.6	0.07	0.05	3.0		
Wb	3	OFF	DETAIL	0.25	10.0	0.6	0.07	0.05	3.0		
Wb	4	OFF	DETAIL	0.25	10.0	0.6	0.07	0.05	3.0		
Wb	5	OFF	DETAIL	0.25	10.0	0.6	0.07	0.05	3.0		
Wb	6	OFF	DETAIL	0.25	10.0	0.6	0.07	0.05	3.0		
TRANSPORT	SLTRC	THETA									
Wb	1	ULTIMATE		0.55							
Wb	2	ULTIMATE		0.55							
Wb	3	ULTIMATE		0.55							
Wb	4	ULTIMATE		0.55							
Wb	5	ULTIMATE		0.55							
Wb	6	ULTIMATE		0.55							
HYD	COEF	AX	DX	CBHE	TSED	FI	TSEDF	FRIICC			
Wb	1	1.0	1.0	7.0E-8	11.5	0.01	1.00	MANN			
Wb	2	1.0	1.0	7.0E-8	11.5	0.01	1.00	MANN			
Wb	3	1.0	1.0	7.0E-8	11.5	0.01	1.00	MANN			
Wb	4	1.0	1.0	7.0E-8	11.5	0.01	1.00	MANN			
Wb	5	1.0	1.0	7.0E-8	11.5	0.01	1.00	MANN			
Wb	6	1.0	1.0	7.0E-8	11.5	0.01	1.00	MANN			
EDDY	VISC	AZC	AZSLC	AZMAX							
jrl		W2N	IMP	1.0							
jr2		W2	IMP	1.0							
jr3		W2	IMP	1.0							

Br 1									
Br 2									
Br 3									
Br 4									
Br 5	579.50	577.1							
Br 6									
Br 7	565.15	567.25							
Br 8									
Br 9									
Br 10									
Br 11	485.00	489.0							
Br 12		456.9							

STR	WIDTH	WSTR							
-----	-------	------	------	------	------	------	------	------	------

Br 1									
Br 2									
Br 3									
Br 4									
Br 5		70.0							
Br 6									
Br 7		50.0							
Br 8									
Br 9									
Br 10									
Br 11									
Br 12									

PIPS	IUPI	IDPI	EUPI	EDPI	WPI	DLXPI	FPI	FMINPI	LATPIC
Pi 1	24	28	28.0	27.0	0.5	230.0	0.065	0.1	DOWN

PIPE UP	PUPIC	ETUPI	EBUPI	KTUPI	KBUPI				
Pi 1	DISTR			2	23				

PIPE DOWN	PDPIC	ETDPI	EBDPI	KTDPI	KBDPI				
Pi 1	DISTR			2	23				

SPILLWAY	IUSP	IDSP	ESP	A1SP	B1SP	A2SP	B2SP	LATSPC	
upriver	64	67	592.14	10000.0	1.5	20.00	1.5		DOWN
upperfal	86	89	580.14	7000.0	1.5	20.00	1.5		DOWN
9mile	151	154	497.00	10000.0	1.5	20.00	1.5		DOWN
longlake	188	0	469.00	20000.0	1.5	20.00	1.5		DOWN
48_51	48	51	579.80	80.00	1.5	30.00	1.5		DOWN
128_131	128	131	486.50	60.00	1.5	30.00	1.5		DOWN

SPILL UP	PUSPC	ETUSP	EBUSP	KTUSP	KBUSP				
spill1	DISTR			2	41				
spill2	DISTR			2	38				
spill3	DISTR			2	39				
spill4	DISTR			2	46				
spill5	DISTR			2	45				
spill6	DISTR			2	46				

SPILL DOWN	PDSPC	ETDSP	EBDSP	KTDSP	KBDSP				
spill1	DISTR			2	36				
spill2	DISTR			2	45				
spill3	DISTR			2	6				
spill4	DISTR			2	46				
spill5	DISTR			2	43				
spill6	DISTR			2	39				

SPILL GAS	GASSP	EQSP	ASP	BSP	CSP				
spill1	OFF								
spill2	OFF								
spill3	OFF								
spill4	OFF								
spill5	OFF								
spill6	OFF								

GATES	IUGT	IDGT	EGT	A1GT	B1GT	G1GT	A2GT	B2GT	G2GT	LATGTC
Gt 1	27	33	44.0	10.00	1.0	1.0	10.0	2.5	0.0	DOWN

GATE WEIR	GA1	GB1	GA2	GB2	DYNGTC					
Gt 1	10.0	1.5	10.0	1.5	B					

GATE UP	PUGTC	ETUGT	EBUGT	KTUGT	KBUGT					
---------	-------	-------	-------	-------	-------	--	--	--	--	--

Gt 1	DISTR			3	23					
GATE DOWN Gt 1	PDGTG DISTR	ETDGT	EBDGT	KTDGT 3	KBDGT 23					
GATE GAS Gt 1	GASGT ON	EQGT 1	AGASG 10.0	BGASG 120.00	CGASG 1.0					
PUMPS 1 Wl 1	IUPU 30	IDPU 33	EPU 2.4	STRTPU 1.0	ENDPU 900.0	EONPU 3.0	EOFFPU 2.4	QPU 3.0	LATPUC DOWN	
PUMPS 2 Wl 1	PPUC DISTR	ETPU	EBPU	KTPU 4	KBPU 23					
WEIR SEG Wr 1	IWR 27	IWR	IWR	IWR	IWR	IWR	IWR	IWR	IWR	
WEIR TOP Wr 1	KTWR 9	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	
WEIR BOT Wr 1	KBWR 23	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	
WD INT Wd 1	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	
WD SEG Wd 1	IWD	IWD	IWD	IWD	IWD	IWD	IWD	IWD	IWD	
WD ELEV Wd 1	EWD	EWD	EWD	EWD	EWD	EWD	EWD	EWD	EWD	
WD TOP Wd 1	ETWD	ETWD	ETWD	ETWD	ETWD	ETWD	ETWD	ETWD	ETWD	
WD BOT Wd 1	EBWD	EBWD	EBWD	EBWD	EBWD	EBWD	EBWD	EBWD	EBWD	
TRIB PLACE	PTRC DISTR	PTRC DISTR	PTRC DISTR	PTRC DISTR	PTRC DISTR	PTRC DISTR	PTRC DISTR	PTRC	PTRC	
TRIB INT Tr 1	TRIC OFF	TRIC OFF	TRIC OFF	TRIC OFF	TRIC OFF	TRIC OFF	TRIC OFF	TRIC	TRIC	
TRIB SEG	ITR 15	ITR 43	ITR 56	ITR 98	ITR 114	ITR 147	ITR 155	ITR	ITR	
TRIB TOP	ETRT	ETRT	ETRT	ETRT	ETRT	ETRT	ETRT	ETRT	ETRT	
TRIB BOT	ETRB	ETRB	ETRB	ETRB	ETRB	ETRB	ETRB	ETRB	ETRB	
DST TRIB Br 1	DTRE ON	DTRIC OFF								no check for DTRIC
Br 2	ON	OFF								
Br 3	ON	OFF								
Br 4	ON	OFF								
Br 5	ON	OFF								
Br 6	ON	OFF								
Br 7	ON	OFF								
Br 8	ON	OFF								
Br 9	ON	OFF								
Br10	ON	OFF								
Br11	ON	OFF								
Br12	ON	OFF								
PUMPBACK	JBG	KTG	KBG	JBP	KTP	KBP				
PRINTER	LJC IV									
HYD PRINT NVIOL	HPRWBC ON	HPRWBC ON	HPRWBC ON	HPRWBC ON	HPRWBC ON	HPRWBC ON	HPRWBC ON	HPRWBC ON	HPRWBC ON	

U	ON	ON	ON	ON	ON	ON
W	ON	ON	ON	ON	ON	ON
T	ON	ON	ON	ON	ON	ON
RHO	OFF	OFF	OFF	OFF	OFF	OFF
AZ	OFF	OFF	OFF	OFF	OFF	OFF
SHEAR	OFF	OFF	OFF	OFF	OFF	OFF
ST	OFF	OFF	OFF	OFF	OFF	OFF
SB	OFF	OFF	OFF	OFF	OFF	OFF
ADMX	OFF	OFF	OFF	OFF	OFF	OFF
DM	OFF	OFF	OFF	OFF	OFF	OFF
HDG	OFF	OFF	OFF	OFF	OFF	OFF
ADMZ	OFF	OFF	OFF	OFF	OFF	OFF
HPG	OFF	OFF	OFF	OFF	OFF	OFF
GRAV	OFF	OFF	OFF	OFF	OFF	OFF
SNP PRINT	SNPC	NSNP	NISNP			
WB 1	ON	2	16			
WB 2	ON	2	8			
WB 3	ON	2	3			
WB 4	ON	2	6			
WB 5	ON	2	5			
WB 6	ON	2	6			
SNP DATE	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD
jr 1	1.00	1.6				
jr 2	1.00	1.6				
jr 3	1.00	1.6				
jr 4	1.00	1.6				
jr 5	1.00	1.6				
jr 6	1.00	1.6				
SNP FREQ	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF
WB 1	0.1000	7.0				
WB 2	0.1000	7.0				
WB 3	0.1000	7.0				
WB 4	0.1000	7.0				
WB 5	0.1000	7.0				
WB 6	0.1000	7.0				
SNP SEG	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP
WB 1	2	10	13	24	27	36
	42	43	44	45	46	47
WB 2	51	53	55	57	59	61
WB 3	84	85	86			
WB 4	89	90	92	122	123	124
WB 5	131	138	139	148	151	
WB 6	154	155	156	175	187	188
SCR PRINT	SCRC	NSCR				
WB 1	OFF	1				
WB 2	OFF	1				
WB 3	OFF	1				
WB 4	OFF	1				
WB 5	OFF	1				
WB 6	ON	1				
SCR DATE	SCRD	SCRD	SCRD	SCRD	SCRD	SCRD
WB 1	1.0					
WB 2	1.0					
WB 3	1.0					
WB 4	1.0					
WB 5	1.0					
WB 6	1.0					
SCR FREQ	SCRF	SCRF	SCRF	SCRF	SCRF	SCRF
WB 1	0.0500					
WB 2	0.1000					
WB 3	0.1000					
WB 4	0.1000					
WB 5	0.1000					
WB 6	0.1000					
PRF PLOT	PRFC	NPRF	NIPRF			
jr 1	OFF	0	0			
jr 2	ON	12	4			

jr 3	OFF	0	0						
jr 4	OFF	0	0						
jr 5	ON	12	6						
jr 6	ON	12	7						
PRF DATE	PRFD								
jr 1									
jr 2	158.5	179.5	200.5	228.5	229.5	242.5	244.5	245.5	249.5
	257.5	270.5	271.5						
jr 3									
jr 4									
jr 5	158.5	179.5	200.5	228.5	229.5	242.5	244.5	245.5	249.5
	257.0	270.0	271.0						
jr 6	158.67	179.67	200.67	228.67	229.67	242.67	244.67	245.67	249.67
	257.67	270.67	271.67						
PRF FREQ	PRFF								
jr 1									
jr 2	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0						
jr 3									
jr 4									
jr 5	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0						
jr 6	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0						
PRF SEG	IPRF								
jr 1									
jr 2	57	60	62	64					
jr 3									
jr 4									
jr 5	135	139	141	143	147	150			
jr 6	157	161	168	174	180	183	187		
SPR PLOT	SPRC	NSPR	NISPR						
WB 1	OFF	0	0						
WB 2	OFF	0	0						
WB 3	OFF	0	0						
WB 4	OFF	0	0						
WB 5	OFF	0	0						
WB 6	OFF	0	0						
SPR DATE	SPRD								
WB 1									
WB 2									
WB 3									
WB 4									
WB 5									
WB 6									
SPR FREQ	SPRF								
WB 1									
WB 2									
WB 3									
WB 4									
WB 5									
WB 6									
SPR SEG	ISPR								
WB 1									
WB 2									
WB 3									
WB 4									
WB 5									
WB 6									
VPL PLOT	VPLC	NVPL							
WB 1	OFF	1							
WB 2	OFF	1							
WB 3	OFF	1							
WB 4	OFF	1							
WB 5	OFF	1							
WB 6	OFF	1							

VPL DATE	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD
WB 1	63.5								
WB 2	63.5								
WB 3	63.5								
WB 4	63.5								
WB 5	63.5								
WB 6	63.5								
VPL FREQ	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF
WB 1	1.0								
WB 2	1.0								
WB 3	1.0								
WB 4	1.0								
WB 5	1.0								
WB 6	1.0								
CPL PLOT	CPLC	NCPL							
WB 1	ON	24							
WB 2	ON	24							
WB 3	ON	24							
WB 4	ON	24							
WB 5	ON	24							
WB 6	ON	24							
CPL DATE	CPLD	CPLD	CPLD	CPLD	CPLD	CPLD	CPLD	CPLD	CPLD
jr 1	9.67	37.67	72.75	100.6	128.67	163.75	187.6	191.6	208.4
	215.5	219.75	228.4	228.6	229.4	229.6	251.5	254.75	270.4
	270.6	271.4	271.6	284.4	319.35	347.35			
jr 2	9.67	37.67	72.75	100.6	128.67	163.75	187.6	191.6	208.4
	215.5	219.75	228.4	228.6	229.4	229.6	251.5	254.75	270.4
	270.6	271.4	271.6	284.4	319.35	347.35			
jr 3	9.67	37.67	72.75	100.6	128.67	163.75	187.6	191.6	208.4
	215.5	219.75	228.4	228.6	229.4	229.6	251.5	254.75	270.4
	270.6	271.4	271.6	284.4	319.35	347.35			
jr 4	9.67	37.67	72.75	100.6	128.67	163.75	187.6	191.6	208.4
	215.5	219.75	228.4	228.6	229.4	229.6	251.5	254.75	270.4
	270.6	271.4	271.6	284.4	319.35	347.35			
jr 5	9.67	37.67	72.75	100.6	128.67	163.75	187.6	191.6	208.4
	215.5	219.75	228.4	228.6	229.4	229.6	251.5	254.75	270.4
	270.6	271.4	271.6	284.4	319.35	347.35			
jr 6	9.67	37.67	72.75	100.6	128.67	163.75	187.6	191.6	208.4
	215.5	219.75	228.4	228.6	229.4	229.6	251.5	254.75	270.4
	270.6	271.4	271.6	284.4	319.35	347.35			
CPL FREQ	CPLF	CPLF	CPLF	CPLF	CPLF	CPLF	CPLF	CPLF	CPLF
jr 1	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
jr 2	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
jr 3	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
jr 4	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
jr 5	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
jr 6	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
FLUXES	FLXC	NFLX							
WB 1	OFF	0							
WB 2	OFF	0							
WB 3	OFF	0							
WB 4	OFF	0							
WB 5	OFF	0							
WB 6	OFF	0							
FLX DATE	FLXD	FLXD	FLXD	FLXD	FLXD	FLXD	FLXD	FLXD	FLXD
WB 1									
WB 2									

WB 3									
WB 4									
WB 5									
WB 6									
FLX FREQ	FLXF	FLXF	FLXF	FLXF	FLXF	FLXF	FLXF	FLXF	FLXF
WB 1									
WB 2									
WB 3									
WB 4									
WB 5									
WB 6									
TSR PLOT	TSRC ON	NTSR 1	NIKTSR 31						
TSR DATE	TSRD 1.0	TSRD	TSRD	TSRD	TSRD	TSRD	TSRD	TSRD	TSRD
TSR FREQ	TSRF 0.10	TSRF	TSRF	TSRF	TSRF	TSRF	TSRF	TSRF	TSRF
TSR SEG	ITSR 2	ITSR 13	ITSR 17	ITSR 24	ITSR 36	ITSR 48	ITSR 64	ITSR 67	ITSR 73
	86	89	94	97	106	114	119	135	141
	150	151	154	155	161	168	174	180	181
	188	128	131	157					
TSR LAYER	ETSR 0.1	ETSR 0.1	ETSR 0.1	ETSR 0.1	ETSR 0.1	ETSR 0.1	ETSR 0.1	ETSR 0.1	ETSR 0.1
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	0.1	0.1	0.1	0.1					
WITH OUT	WDOC ON	NWDO 1	NIWDO 7						
WITH DATE	WDOD 1.0000	WDOD	WDOD	WDOD	WDOD	WDOD	WDOD	WDOD	WDOD
WITH FREQ	WDOF 0.100	WDOF	WDOF	WDOF	WDOF	WDOF	WDOF	WDOF	WDOF
WITH SEG	IWDO 64	IWDO 86	IWDO 151	IWDO 188	IWDO 13	IWDO 24	IWDO 97	IWDO	IWDO
RESTART	RSOC OFF	NRSO 0	RSIC OFF						
RSO DATE	RSOD	RSOD	RSOD	RSOD	RSOD	RSOD	RSOD	RSOD	RSOD
RSO FREQ	RSOF	RSOF	RSOF	RSOF	RSOF	RSOF	RSOF	RSOF	RSOF
CST COMP	CCC ON	LIMC ON	CUF 10						
CST ACTIVE	CAC								
TDS	ON								!1
AGE	ON								!2
TRACER	ON								!3
COLIFORM	ON								!4
Conduct	ON								!5
Chlorine	ON								!6
ISS1	ON								!7
PO4	ON								!8
NH4	ON								!9
NOx	ON								!10
DSi	OFF								!11
PSi	OFF								!12
TFe	OFF								!13
LDOM	ON								!14
RDOM	ON								!15
LPOM	ON								!16

RPOM	ON										!17
1CBOD	ON										!18
2CBOD	ON										!19
3CBOD	ON										!20
4CBOD	ON										!21
5CBOD	ON										!22
ALG1	ON										!23
DO	ON										!24
TIC	ON										!25
ALK	ON										!26

| CST | DERIV | CDWBC | |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| DOC | ON | !1 |
| POC | OFF | !2 |
| TOC | ON | !3 |
| DON | OFF | !4 |
| PON | OFF | !5 |
| TON | ON | !6 |
| TKN | ON | !7 |
| TN | ON | !8 |
| DOP | OFF | !9 |
| POP | OFF | !10 |
| TOP | ON | !11 |
| TP | ON | !12 |
| APR | OFF | !13 |
| CHLA | ON | !14 |
| ATOT | OFF | !15 |
| %DO | OFF | !16 |
| TSS | ON | !17 |
| TISS | OFF | !18 |
| CBODU | ON | !19 |
| pH | ON | !20 |
| CO2 | OFF | !21 |
| HCO3 | OFF | !22 |
| CO3 | OFF | !23 |

CST	FLUX	CFWBC									
TISSIN	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	1
TISSOUT	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	2
PO4AR	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	3
PO4AG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	4
PO4AP	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	5
PO4ER	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	6
PO4EG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	7
PO4EP	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	8
PO4POM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	9
PO4DOM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	10
PO4OM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	11
PO4SED	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	12
PO4SOD	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	13
PO4SET	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	14
NH4NITR	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	15
NH4AR	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	16
NH4AG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	17
NH4AP	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	18
NH4ER	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	19
NH4EG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	20
NH4EP	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	21
NH4POM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	22
NH4DOM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	23
NH4OM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	24
NH4SED	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	25
NH4SOD	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	26
NO3DEN	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	27
NO3AG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	28
NO3EG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	29
NO3SED	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	30
DSIAG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	31
DSIEG	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	32
DSIPIS	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	33
DSISED	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	34
DSISOD	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	35
DSISET	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	36
PSIAM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	37
PSINET	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	38

PSIDK	OFF	OFF	OFF	OFF	OFF	OFF		39
FESET	OFF	OFF	OFF	OFF	OFF	OFF		40
FESED	OFF	OFF	OFF	OFF	OFF	OFF		41
LDOMDK	OFF	OFF	OFF	OFF	OFF	OFF		42
LRDOM	OFF	OFF	OFF	OFF	OFF	OFF		43
RDOMDK	OFF	OFF	OFF	OFF	OFF	OFF		44
LDOMAP	OFF	OFF	OFF	OFF	OFF	OFF		45
LDOMEP	OFF	OFF	OFF	OFF	OFF	OFF		46
LPOMDK	OFF	OFF	OFF	OFF	OFF	OFF		47
LRPOM	OFF	OFF	OFF	OFF	OFF	OFF		48
RPOMDK	OFF	OFF	OFF	OFF	OFF	OFF		49
LPOMAP	OFF	OFF	OFF	OFF	OFF	OFF		50
LPOMEPE	OFF	OFF	OFF	OFF	OFF	OFF		51
LPOMSET	OFF	OFF	OFF	OFF	OFF	OFF		52
RPOMSET	OFF	OFF	OFF	OFF	OFF	OFF		53
CBODDK	OFF	OFF	OFF	OFF	OFF	OFF		54
DOAP	OFF	OFF	OFF	OFF	OFF	OFF		55
DOAR	OFF	OFF	OFF	OFF	OFF	OFF		56
DOEP	OFF	OFF	OFF	OFF	OFF	OFF		57
DOER	OFF	OFF	OFF	OFF	OFF	OFF		58
DOPOM	OFF	OFF	OFF	OFF	OFF	OFF		59
DODOM	OFF	OFF	OFF	OFF	OFF	OFF		60
DOOM	OFF	OFF	OFF	OFF	OFF	OFF		61
DONITR	OFF	OFF	OFF	OFF	OFF	OFF		62
DOC BOD	OFF	OFF	OFF	OFF	OFF	OFF		63
DOREAR	OFF	OFF	OFF	OFF	OFF	OFF		64
DOSED	OFF	OFF	OFF	OFF	OFF	OFF		65
DOSOD	OFF	OFF	OFF	OFF	OFF	OFF		66
TICAG	OFF	OFF	OFF	OFF	OFF	OFF		67
TICEG	OFF	OFF	OFF	OFF	OFF	OFF		68
SEDDK	OFF	OFF	OFF	OFF	OFF	OFF		69
SEDAS	OFF	OFF	OFF	OFF	OFF	OFF		70
SEDL POM	OFF	OFF	OFF	OFF	OFF	OFF		71
SEDSET	OFF	OFF	OFF	OFF	OFF	OFF		72
SODDK	OFF	OFF	OFF	OFF	OFF	OFF		73

CST	ICON	C2IWB						
TDS	0.0	0.0	0.0	0.0	0.0	0.0		!1
AGE	0.0	0.0	0.0	0.0	0.0	0.0		!2
TRACER	0.0	0.0	0.0	0.0	0.0	0.0		!3
COL1	0.0	0.0	0.0	0.0	0.0	0.0		!4
Conduct	0.0	0.0	0.0	0.0	0.0	0.0		!5
Chlorine	0.0	0.0	0.0	0.0	0.0	0.0		!6
ISS1	0.0	0.0	0.0	0.0	0.0	0.0		!7
PO4	0.03	0.03	0.03	0.03	0.03	0.03		!8
NH4	0.01	0.01	0.01	0.01	0.01	0.01		!9
NOx	0.3	0.3	0.3	0.3	0.3	0.3		!10
DSi	0.0	0.0	0.0	0.0	0.0	0.0		!11
PSi	0.0	0.0	0.0	0.0	0.0	0.0		!12
TFe	0.0	0.0	0.0	0.0	0.0	0.0		!13
LDOM	0.1	0.1	0.1	0.1	0.1	0.1		!14
RDOM	0.1	0.1	0.1	0.1	0.1	0.1		!15
LPOM	0.1	0.1	0.1	0.1	0.1	0.1		!16
RPOM	0.1	0.1	0.1	0.1	0.1	0.1		!17
1CBOD	0.0	0.0	0.0	0.0	0.0	0.0		!18
2CBOD	0.0	0.0	0.0	0.0	0.0	0.0		!19
3CBOD	0.0	0.0	0.0	0.0	0.0	0.0		!20
4CBOD	0.0	0.0	0.0	0.0	0.0	0.0		!21
4CBOD	0.0	0.0	0.0	0.0	0.0	0.0		!22
ALG1	0.1	0.1	0.1	0.1	0.1	0.1		!23
DO	12.0	12.0	12.0	12.0	12.0	12.0		!24
TIC	5.0	5.0	5.0	5.0	5.0	5.0		!25
ALK	19.8	19.8	19.8	19.8	19.8	19.8		!26

CST	PRINT	CPRWBC						
TDS	ON	ON	ON	ON	ON	ON		!1
AGE	ON	ON	ON	ON	ON	ON		!2
TRACER	ON	ON	ON	ON	ON	ON		!3
COL1	ON	ON	ON	ON	ON	ON		!4
Conduct	ON	ON	ON	ON	ON	ON		!5
Chlorine	ON	ON	ON	ON	ON	ON		!6
ISS1	ON	ON	ON	ON	ON	ON		!7
PO4	ON	ON	ON	ON	ON	ON		!8
NH4	ON	ON	ON	ON	ON	ON		!9
NOx	ON	ON	ON	ON	ON	ON		!10

DSi	OFF	OFF	OFF	OFF	OFF	OFF				!11
PSi	OFF	OFF	OFF	OFF	OFF	OFF				!12
TFe	OFF	OFF	OFF	OFF	OFF	OFF				!13
LDOM	ON	ON	ON	ON	ON	ON				!14
RDOM	ON	ON	ON	ON	ON	ON				!15
LPOM	ON	ON	ON	ON	ON	ON				!16
RPOM	ON	ON	ON	ON	ON	ON				!17
1CBOD	ON	ON	ON	ON	ON	ON				!18
2CBOD	ON	ON	ON	ON	ON	ON				!19
3CBOD	ON	ON	ON	ON	ON	ON				!20
4CBOD	ON	ON	ON	ON	ON	ON				!21
5CBOD	ON	ON	ON	ON	ON	ON				!22
ALG1	ON	ON	ON	ON	ON	ON				!23
DO	ON	ON	ON	ON	ON	ON				!24
TIC	ON	ON	ON	ON	ON	ON				!25
ALK	ON	ON	ON	ON	ON	ON				!26

CIN CON	CINBRC									
TDS	ON	!1								
TDS	ON	!2								
AGE	OFF	!3								
AGE	OFF	!4								
TRACER	ON	!5								
TRACER	ON	!6								
COL1	ON	!7								
COL1	ON	!8								
Conduct	ON	!9								
Conduct	ON	!10								
Chlorine	ON	!11								
Chlorine	ON	!12								
ISS1	ON	!13								
ISS1	ON	!14								
PO4	ON	!15								
PO4	ON	!16								
NH4	ON	!17								
NH4	ON	!18								
NOx	ON	!19								
NOx	ON	!20								
DSi	OFF	!21								
DSi	OFF	!22								
PSi	OFF	!23								
TFe	OFF	!24								
TFe	OFF	!25								
LDOM	ON	!26								
LDOM	ON	!27								
RDOM	ON	!28								
RDOM	ON	!29								
LPOM	ON	!30								
LPOM	ON	!31								
RPOM	ON	!32								
RPOM	ON	!33								
1CBOD	ON	!34								
1CBOD	ON	!35								
2CBOD	ON	!36								
2CBOD	ON	!37								
3CBOD	ON	!38								
3CBOD	ON	!39								
4CBOD	ON	!40								
4CBOD	ON	!41								
5CBOD	ON	!42								
5CBOD	ON	!43								
ALG1	ON	!44								
ALG1	ON	!45								
DO	ON	!46								
DO	ON	!47								
TIC	ON	!48								
TIC	ON	!49								
ALK	ON	!50								
ALK	ON	!51								

CTR CON	CTRTRC									
TDS	ON	!1								
AGE	OFF	!2								
TRACER	ON	!3								

ALK	ON	!26										
ALK	ON	ON	ON	ON								
CPR CON	CPRBRC	!1										
TDS	ON											
TDS	ON	ON	ON	ON								
AGE	OFF	!2										
AGE	OFF	OFF	OFF	OFF								
TRACER	ON	!3										
TRACER	ON	ON	ON	ON								
COL1	ON	!4										
COL1	ON	ON	ON	ON								
Conduct	ON	!5										
Conduct	ON	ON	ON	ON								
Chlorine	ON	!6										
Chlorine	ON	ON	ON	ON								
ISS1	ON	!7										
ISS1	ON	ON	ON	ON								
PO4	ON	!8										
PO4	ON	ON	ON	ON								
NH4	ON	!9										
NH4	ON	ON	ON	ON								
NOx	ON	!10										
NOx	ON	ON	ON	ON								
DSi	OFF	!11										
DSi	OFF	OFF	OFF	OFF								
PSi	OFF	!12										
PSi	OFF	OFF	OFF	OFF								
TFe	OFF	!13										
TFe	OFF	OFF	OFF	OFF								
LDOM	ON	!14										
LDOM	ON	ON	ON	ON								
RDOM	ON	!15										
RDOM	ON	ON	ON	ON								
LPOM	ON	!16										
LPOM	ON	ON	ON	ON								
RPOM	ON	!17										
RPOM	ON	ON	ON	ON								
1CBOD	ON	!18										
1CBOD	ON	ON	ON	ON								
2CBOD	ON	!19										
2CBOD	ON	ON	ON	ON								
3CBOD	ON	!20										
3CBOD	ON	ON	ON	ON								
4CBOD	ON	!21										
4CBOD	ON	ON	ON	ON								
5CBOD	ON	!22										
5CBOD	ON	ON	ON	ON								
ALG1	ON	!23										
ALG1	ON	ON	ON	ON								
DO	ON	!24										
DO	ON	ON	ON	ON								
TIC	ON	!25										
TIC	ON	ON	ON	ON								
ALK	ON	!26										
ALK	ON	ON	ON	ON								
EX COEF	EXH2O	EXSS	EXOM	BETA	EXC	EXIC						
Wb 1	0.25	0.01	0.10	0.45	OFF	OFF						
Wb 2	0.25	0.01	0.10	0.45	OFF	OFF						
Wb 3	0.25	0.01	0.10	0.45	OFF	OFF						
Wb 4	0.25	0.01	0.10	0.45	OFF	OFF						
Wb 5	0.25	0.01	0.10	0.45	OFF	OFF						
Wb 6	0.25	0.01	0.10	0.45	OFF	OFF						
ALG EX	EXA	EXA	EXA	EXA	EXA	EXA						
	0.10	0.1	0.1	0.1	0.1	0.1						
GENERIC	CGQ10	CG0DK	CG1DK	CGS								
Age	0.00	-1.0	0.0	0.0								
TRACER	0.00	0.0	0.0	0.0								
Colfrm1	1.04	0.0	0.5	0.0								
CONDUCT	0.00	0.0	0.0	0.0								
Chloride	0.00	0.0	0.0	0.0								

S SOLIDS	SSS 1.5	SSS 1.0	SSS 0.5	SSS	SSS	SSS	SSS	SSS	SSS
ALGAL RATE Alg 1	AG 1.5	AR 0.04	AE 0.04	AM 0.10	AS 0.20	AHSP 0.003	AHSN 0.014	AHSSI 0.000	ASAT 40.0
ALGAL TEMP Alg 1	AT1 8.0	AT2 10.0	AT3 20.0	AT4 30.0	AK1 0.1	AK2 0.99	AK3 0.99	AK4 0.10	
ALG STOICH Alg 1	ALGP 0.005	ALGN 0.08	ALGC 0.45	ALGSI 0.00	ACHLA 130.00	APOM 0.8	ANEQN 2	ANPR 0.001	
EPIPHYTE Epi 1	EPIC ON	EPIC ON	EPIC ON	EPIC ON	EPIC ON	EPIC ON	EPIC ON	EPIC ON	EPIC
EPI PRINT Epi 1	EPRC ON	EPRC ON	EPRC ON	EPRC ON	EPRC ON	EPRC ON	EPRC ON	EPRC ON	EPRC
EPI INIT Epi 1	EPICI 20.0	EPICI -1.0	EPICI -1.0	EPICI 40.0	EPICI -1.0	EPICI -1.0	EPICI -1.0	EPICI -1.0	EPICI
EPI RATE Epi 1	EG 1.500	ER 0.040	EE 0.040	EM 0.100	EB 0.001	EHSP 0.003	EHSN 0.014	EHSSI 0.000	
EPI HALF Epi 1	ESAT 150.00	EHS 15.0	ENEQN 2	ENPR 0.001					
EPI TEMP Epi 1	ET1 1.000	ET2 3.000	ET3 20.000	ET4 30.000	EK1 0.100	EK2 0.990	EK3 0.990	EK4 0.100	
EPI STOICH Epi 1	EP 0.005	EN 0.080	EC 0.450	ESI 0.000	ECHLA 65.000	EPOM 0.800			
DOM	LDOMDK	RDOMDK	LRDDK						
Wb 1	0.10	0.001	0.001						
Wb 2	0.10	0.001	0.001						
Wb 3	0.10	0.001	0.001						
Wb 4	0.10	0.001	0.001						
Wb 5	0.10	0.001	0.001						
Wb 6	0.10	0.001	0.001						
POM	LPOMDK	RPOMDK	LRPDK	POMS					
Wb 1	0.08	0.001	0.001	0.1					
Wb 2	0.08	0.001	0.001	0.1					
Wb 3	0.08	0.001	0.001	0.1					
Wb 4	0.08	0.001	0.001	0.1					
Wb 5	0.08	0.001	0.001	0.1					
Wb 6	0.08	0.001	0.001	0.1					
OM STOICH	ORG 0.005	ORG 0.08	ORG 0.45	ORGSI 0.18					
Wb 1	0.005	0.08	0.45	0.18					
Wb 2	0.005	0.08	0.45	0.18					
Wb 3	0.005	0.08	0.45	0.18					
Wb 4	0.005	0.08	0.45	0.18					
Wb 5	0.005	0.08	0.45	0.18					
Wb 6	0.005	0.08	0.45	0.18					
OM RATE	OMT1 4.0	OMT2 30.0	OMK1 0.1	OMK2 0.99					
Wb 1	4.0	30.0	0.1	0.99					
Wb 2	4.0	30.0	0.1	0.99					
Wb 3	4.0	30.0	0.1	0.99					
Wb 4	4.0	30.0	0.1	0.99					
Wb 5	4.0	30.0	0.1	0.99					
Wb 6	4.0	30.0	0.1	0.99					
CBOD	KBOD	TBOD	RBOD						
1CBOD	0.0418	1.0147	1.00						
2CBOD	0.1302	1.0147	1.00						
3CBOD	0.0469	1.0147	1.00						
4CBOD	0.0880	1.0147	1.00						
5CBOD	0.050	1.0147	1.00						
CBOD STOIC	BODP 0.005	BODN 0.08	BODC 0.45	BODSI 0.18					
1CBOD	0.005	0.08	0.45	0.18					
2CBOD	0.005	0.08	0.45	0.18					

3CBOD	0.005	0.08	0.45	0.18
4CBOD	0.005	0.08	0.45	0.18
5CBOD	0.005	0.08	0.45	0.18

PHOSPHOR	PO4R	PARTP	
Wb 1	0.001	0.0	
Wb 2	0.001	0.0	
Wb 3	0.001	0.0	
Wb 4	0.001	0.0	
Wb 5	0.001	0.0	
Wb 6	0.001	0.0	

AMMONIUM	NH4R	NH4DK	
Wb 1	0.001	0.40	
Wb 2	0.001	0.40	
Wb 3	0.001	0.40	
Wb 4	0.001	0.40	
Wb 5	0.001	0.40	
Wb 6	0.001	0.40	

NH4 RATE	NH4T1	NH4T2	NH4K1	NH4K2
Wb 1	5.0	25.0	0.1	0.99
Wb 2	5.0	25.0	0.1	0.99
Wb 3	5.0	25.0	0.1	0.99
Wb 4	5.0	25.0	0.1	0.99
Wb 5	5.0	25.0	0.1	0.99
Wb 6	5.0	25.0	0.1	0.99

NITRATE	NO3DK	
Wb 1	0.05	
Wb 2	0.05	
Wb 3	0.05	
Wb 4	0.05	
Wb 5	0.05	
Wb 6	0.05	

NO3 RATE	NO3T1	NO3T2	NO3K1	NO3K2
Wb 1	5.0	25.0	0.1	0.99
Wb 2	5.0	25.0	0.1	0.99
Wb 3	5.0	25.0	0.1	0.99
Wb 4	5.0	25.0	0.1	0.99
Wb 5	5.0	25.0	0.1	0.99
Wb 6	5.0	25.0	0.1	0.99

SILICA	DSIR	PSIS	PSIDK	PARTSI
Wb 1	0.1	0.0	0.3	0.2
Wb 2	0.1	0.0	0.3	0.2
Wb 3	0.1	0.0	0.3	0.2
Wb 4	0.1	0.0	0.3	0.2
Wb 5	0.1	0.0	0.3	0.2
Wb 6	0.1	0.0	0.3	0.2

IRON	FER	FES	
Wb 1	0.1	0.0	
Wb 2	0.1	0.0	
Wb 3	0.1	0.0	
Wb 4	0.1	0.0	
Wb 5	0.1	0.0	
Wb 6	0.1	0.0	

SED CO2	CO2R	
Wb 1	0.1	
Wb 2	0.1	
Wb 3	0.1	
Wb 4	0.1	
Wb 5	0.1	
Wb 6	0.1	

STOICH 1	O2NH4	O2OM	
Wb 1	4.570	1.400	
Wb 2	4.570	1.400	
Wb 3	4.570	1.400	
Wb 4	4.570	1.400	
Wb 5	4.570	1.400	
Wb 6	4.570	1.400	

STOICH 2 O2AR O2AG
Alg 1 1.100 1.400

STOICH 3 O2ER O2EG
Epi 1 1.100 1.400

O2 LIMIT O2LIM
0.1

SEDIMENT	SEDC	PRNSC	SEDCI	SEDK	FSOD	FSED
Wb 1	ON	ON	0.0	0.1	1.0	1.0
Wb 2	ON	ON	0.0	0.1	1.0	1.0
Wb 3	ON	ON	0.0	0.1	1.0	1.0
Wb 4	ON	ON	0.0	0.1	1.0	1.0
Wb 5	ON	ON	0.0	0.1	1.0	1.0
Wb 6	ON	ON	0.0	0.1	1.0	1.0

SOD RATE	SODT1	SODT2	SODK1	SODK2
Wb 1	4.0	30.0	0.1	0.99
Wb 2	4.0	30.0	0.1	0.99
Wb 3	4.0	30.0	0.1	0.99
Wb 4	4.0	30.0	0.1	0.99
Wb 5	4.0	30.0	0.1	0.99
Wb 6	4.0	30.0	0.1	0.99

S DEMAND	SOD							
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5
0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8
0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
0.5	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.5	0.5	0.5	0.5	0.5	0.5
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

REAERATION	TYPE	EQN#	COEF1	COEF2	COEF3	COEF4
jr1	RIVER	7				
jr2	LAKE	6				
jr3	LAKE	6				
jr4	RIVER	9	0.04	0.0	0.0	0.0
jr5	LAKE	6				
jr6	LAKE	6				

RSI FILE.....RSIFN.....
rsi.npt

QWD FILE.....QWDFN.....
qwd.npt

QGT FILE.....QGTFN.....
qgt.npt

WSC FILE.....WSCFN.....
wsc.npt

SHD FILE.....SHDFN.....
shade.npt

BTH FILE.....BTHFN.....
bth1.npt
bth2.npt

```

Wb 3     bth3.npt
Wb 4     bth4.npt
Wb 5     bth5.npt
Wb 6     bth6.npt

MET FILE.....METFN.....
Wb 1     met00j1f.npt
Wb 2     met00j2f.npt
Wb 3     met00j3f.npt
Wb 4     met00jr4.npt
Wb 5     met00jr5.npt
Wb 6     met00jr6.npt

EXT FILE.....EXTFN.....
Wb 1     ext_wb1.npt - not used
Wb 2     ext_wb2.npt - not used
Wb 3     ext_wb3.npt - not used
Wb 4     ext_wb3.npt - not used
Wb 5     ext_wb3.npt - not used
Wb 6     ext_wb3.npt - not used

VPR FILE.....VPRFN.....
Wb 1     vpr00wb1.npt
Wb 2     vpr00wb2.npt
Wb 3     vpr00wb3.npt
Wb 4     vpr00wb4.npt
Wb 5     vpr00wb5.npt
Wb 6     vpr00wb6.npt

LPR FILE.....LPRFN.....
Wb 1     lpr_wb1.npt - not used
Wb 2     lpr_wb2.npt - not used
Wb 3     lpr_wb3.npt - not used
Wb 4
Wb 5
Wb 6

QIN FILE.....QINFN.....
Br 1     stateq00.npt
Br 2
br 3
br 4
Br 5     qin_br5.npt
Br 6     qin_br6.npt
br 7
br 8     qin_br8.npt
Br 9
Br 10    qin_br10.npt
br 11
br 12    qin_br12.npt

TIN FILE.....TINFN.....
Br 1     statet00.npt
Br 2
Br 3
Br 4
Br 5     tin_br5.npt
Br 6     tin_br6.npt
br 7
br 8     tin_br8.npt
Br 9
Br 10    tin_br10.npt
br 11
br 12    tin_br12.npt

CIN FILE.....CINFN.....
Br 1     statec00.npt
Br 2
Br 3
Br 4
Br 5     Cin_br5.npt
Br 6     cin_br6.npt
br 7
br 8     cin_br8.npt
Br 9

```

```

Br 10  cin_br10.npt
br 11
br 12  cin_br11.npt

QOT FILE.....QOTFN.....
Br 1  qot1.npt
Br 2  qot2.npt
Br 3  qot3.npt
Br 4  qot4.npt
Br 5  qur_00r.npt
Br 6  qot6.npt
br 7  quf_00r.npt
br 8  qot8.npt
Br 9  qot9.npt
Br 10  qot10.npt
br 11  q9m_00r.npt
br 12  qll_00r.npt

QTR FILE.....QTRFN.....
tr1  libertyq00.npt
tr2  kaisq00.npt
tr3  IEPCq00.npt
tr4  hangq00.npt
tr5  spkwwtpq00.npt
tr6  couleeq00.npt
tr7  lspkq00.npt

TTR FILE.....TTRFN.....
tr1  libertyt00.npt
tr2  kaist00.npt
tr3  IEP Ct00.npt
tr4  hangt00.npt
tr5  spkwwtp00.npt
tr6  couleet00.npt
tr7  lspkt00.npt

CTR FILE.....CTRFN.....
tr1  libertyc00.npt
tr2  kaisc00.npt
tr3  IEPCc00.npt
tr4  hangc00.npt
tr5  spkwwtpc00.npt
tr6  couleec00.npt
tr7  lspkc00.npt

QDT FILE.....QDTFN.....
Br 1  qdt_br1.npt
Br 2  qdt_br2.npt
Br 3  qdt_br3.npt
Br 4  qdt_br4.npt
Br 5  qdt_br5.npt
Br 6  qdt_br6.npt
br 7  qdt_br7.npt
br 8  qdt_br8.npt
Br 9  qdt_br9.npt
Br 10  qdt_br10.npt
br 11  qdt_br11.npt
br 12  LLkdisq00.npt

TDT FILE.....TDTFN.....
Br 1  tdt_br1.npt
Br 2  tdt_br2.npt
Br 3  tdt_br3.npt
Br 4  tdt_br4.npt
Br 5  tdt_br5.npt
Br 6  tdt_br6.npt
br 7  tdt_br7.npt
br 8  tdt_br8.npt
Br 9  tdt_br9.npt
Br 10  tdt_br10.npt
br 11  tdt_br11.npt
br 12  LLkdist00.npt

CDT FILE.....CDTFN.....
Br 1  cdt_br1.npt

```

```
Br 2      cdt_br2.npt  
Br 3      cdt_br3.npt  
Br 4      cdt_br4.npt  
Br 5      cdt_br5.npt  
Br 6      cdt_br6.npt  
br 7      cdt_br7.npt  
br 8      cdt_br8.npt  
Br 9      cdt_br9.npt  
Br 10     cdt_br10.npt  
br 11     cdt_br11.npt  
br 12     cdt_br12.npt
```

PRE FILE.....PREFN.....
Br 1 pre_brl.npt - not used

```
Br 2  
Br 3  
Br 4  
Br 5  
Br 6  
br 7  
br 8  
Br 9  
Br 10  
br 11  
br 12
```

TPR FILE.....TPRFN.....

```
Br 1      tpr_brl.npt - not used  
Br 2  
Br 3  
Br 4  
Br 5  
Br 6  
br 7  
br 8  
Br 9  
Br 10  
br 11  
br 12
```

CPR FILE.....CPRFN.....

```
Br 1      cpr_brl.npt - not used  
Br 2  
Br 3  
Br 4  
Br 5  
Br 6  
br 7  
br 8  
Br 9  
Br 10  
br 11  
br 12
```

EUH FILE.....EUHFN.....

```
Br 1  
Br 2  
Br 3  
Br 4  
Br 5  
Br 6  
br 7  
br 8  
Br 9  
Br 10  
br 11  
br 12
```

TUH FILE.....TUHFN.....

```
Br 1  
Br 2  
Br 3  
Br 4  
Br 5  
Br 6
```

```

br 7
br 8
Br 9
Br 10
br 11
br 12

CUH FILE.....CUHFN.....
Br 1
Br 2
Br 3
Br 4
Br 5
Br 6
br 7
br 8
Br 9
Br 10
br 11
br 12

EDH FILE.....EDHFN.....
Br 1
Br 2
Br 3
Br 4
Br 5
Br 6
br 7
br 8
Br 9
Br 10
br 11
br 12

TDH FILE.....TDHFN.....
Br 1
Br 2
Br 3
Br 4
Br 5
Br 6
br 7
br 8
Br 9
Br 10
br 11
br 12

CDH FILE.....CDHFN.....
Br 1
Br 2
Br 3
Br 4
Br 5
Br 6
br 7
br 8
Br 9
Br 10
br 11
br 12

SNP FILE.....SNPFN.....
jr 1   .snp1.opt
jr 2   .snp2.opt
jr 3   .snp3.opt
jr 4   .snp4.opt
jr 5   .snp5.opt
jr 6   .snp6.opt

PRF FILE.....PRFFN.....
jr 1    prf1.opt
jr 2    prf2.opt
jr 3    prf3.opt

```

```
jr 4      prf4.opt
jr 5      prf5.opt
jr 6      prf6.opt

VPL FILE.....VPLFN.....  
jr 1      vpl1.opt
jr 2      vpl2.opt
jr 3      vpl3.opt
jr 4      vpl4.opt
jr 5      vpl5.opt
jr 6      vpl6.opt

CPL FILE.....CPLFN.....  
jr 1      cpl1.opt
jr 2      cpl2.opt
jr 3      cpl3.opt
jr 4      cpl4.opt
jr 5      cpl5.opt
jr 6      cpl6.opt

SPR FILE.....SPRFN.....  
jr 1      spr1.opt
jr 2      spr2.opt
jr 3      spr3.opt
jr 4      spr4.opt
jr 5      spr5.opt
jr 6      spr6.opt

FLX FILE.....KFLFN.....  
jr 1      kfl1.opt
jr 2      kfl2.opt
jr 3      kfl3.opt
jr 4      kfl4.opt
jr 5      kfl5.opt
jr 6      kfl6.opt

TSR FILE.....TSRFN.....  
tsr.opt

WDO FILE.....WDOFN.....  
wdo.opt
```

Appendix 2: Longitudinal Profiles

Year 1991

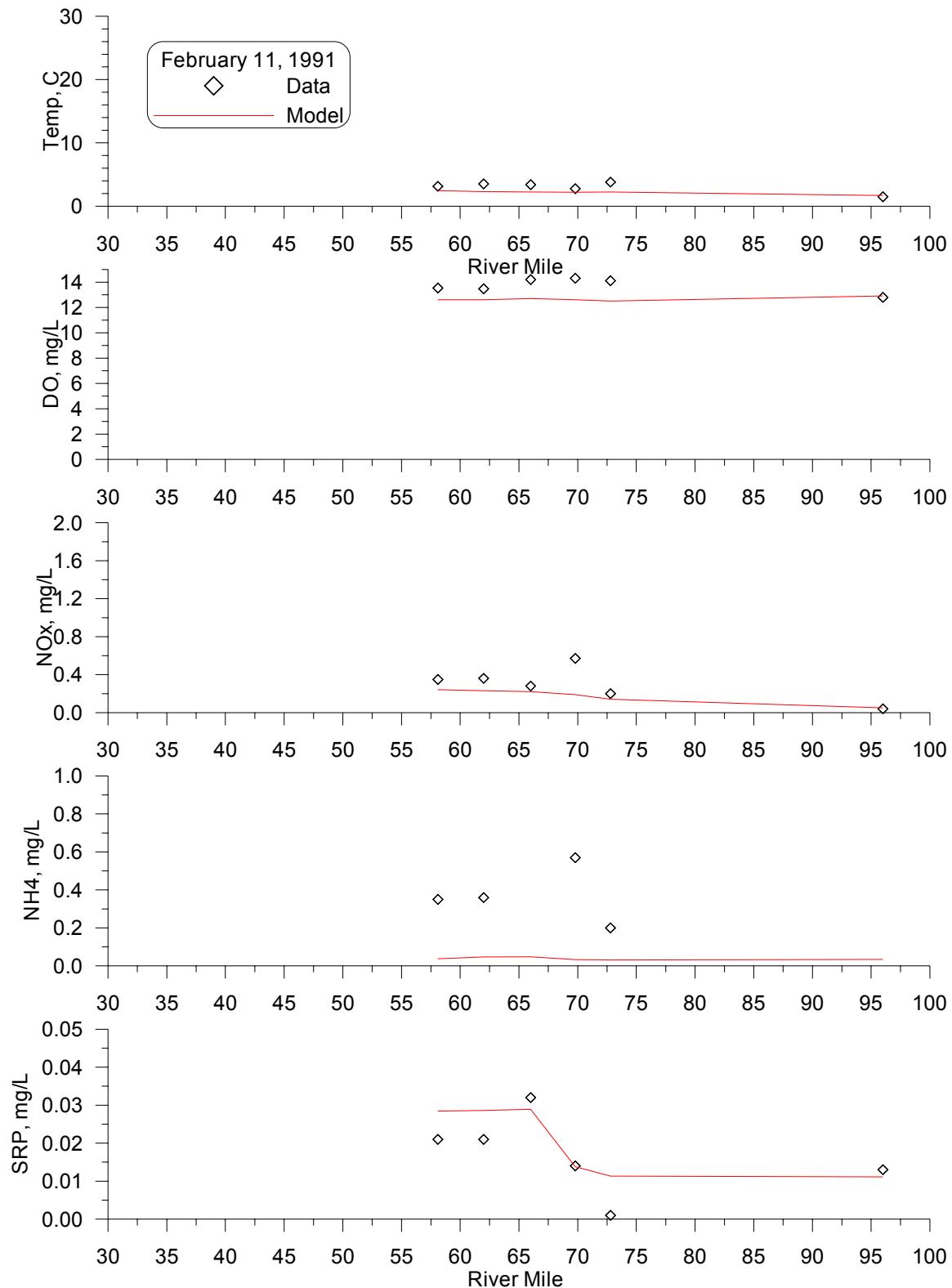


Figure 270. Longitudinal profile, February 11, 1991

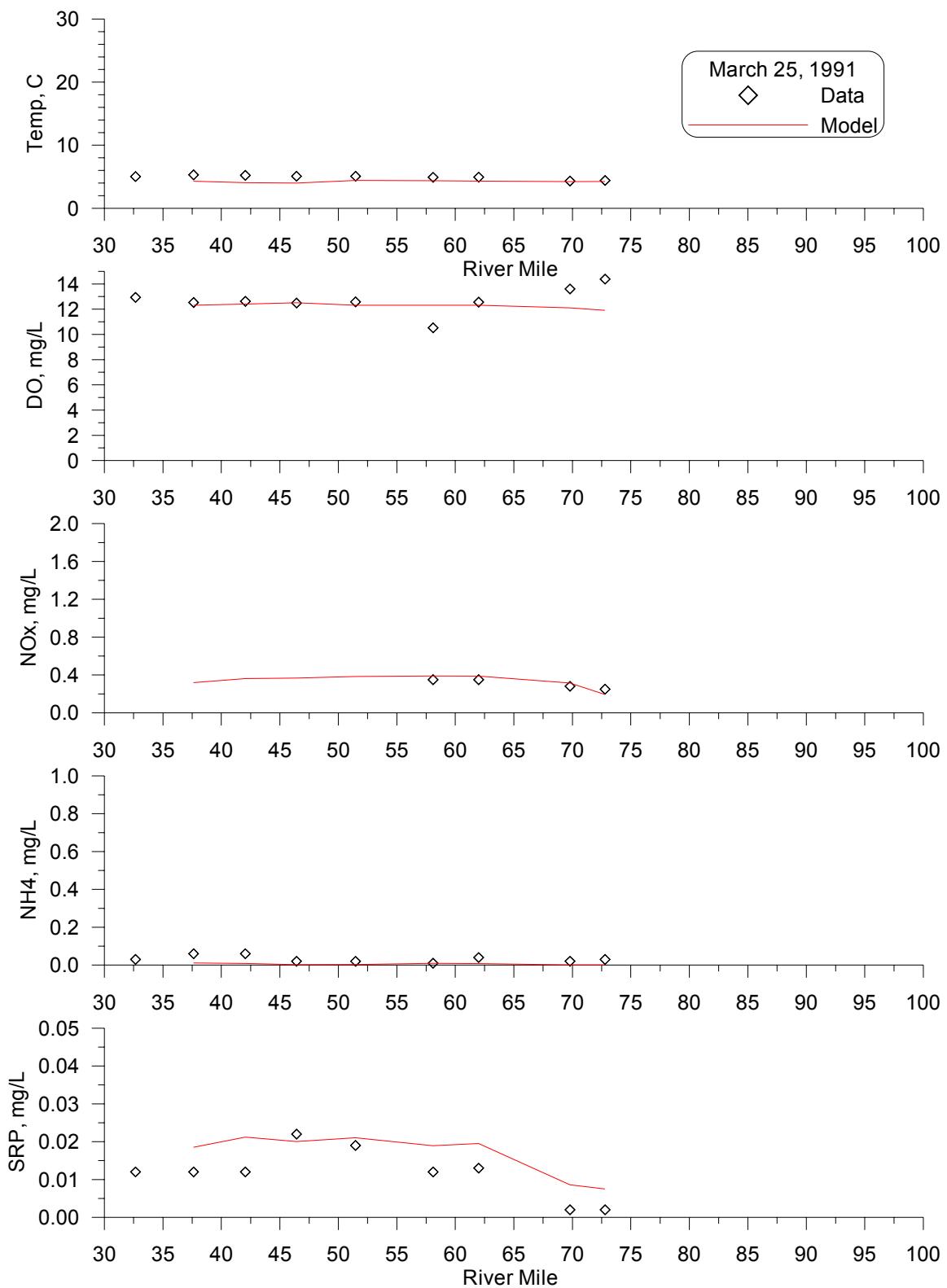


Figure 271. Longitudinal profile, March 25, 1991

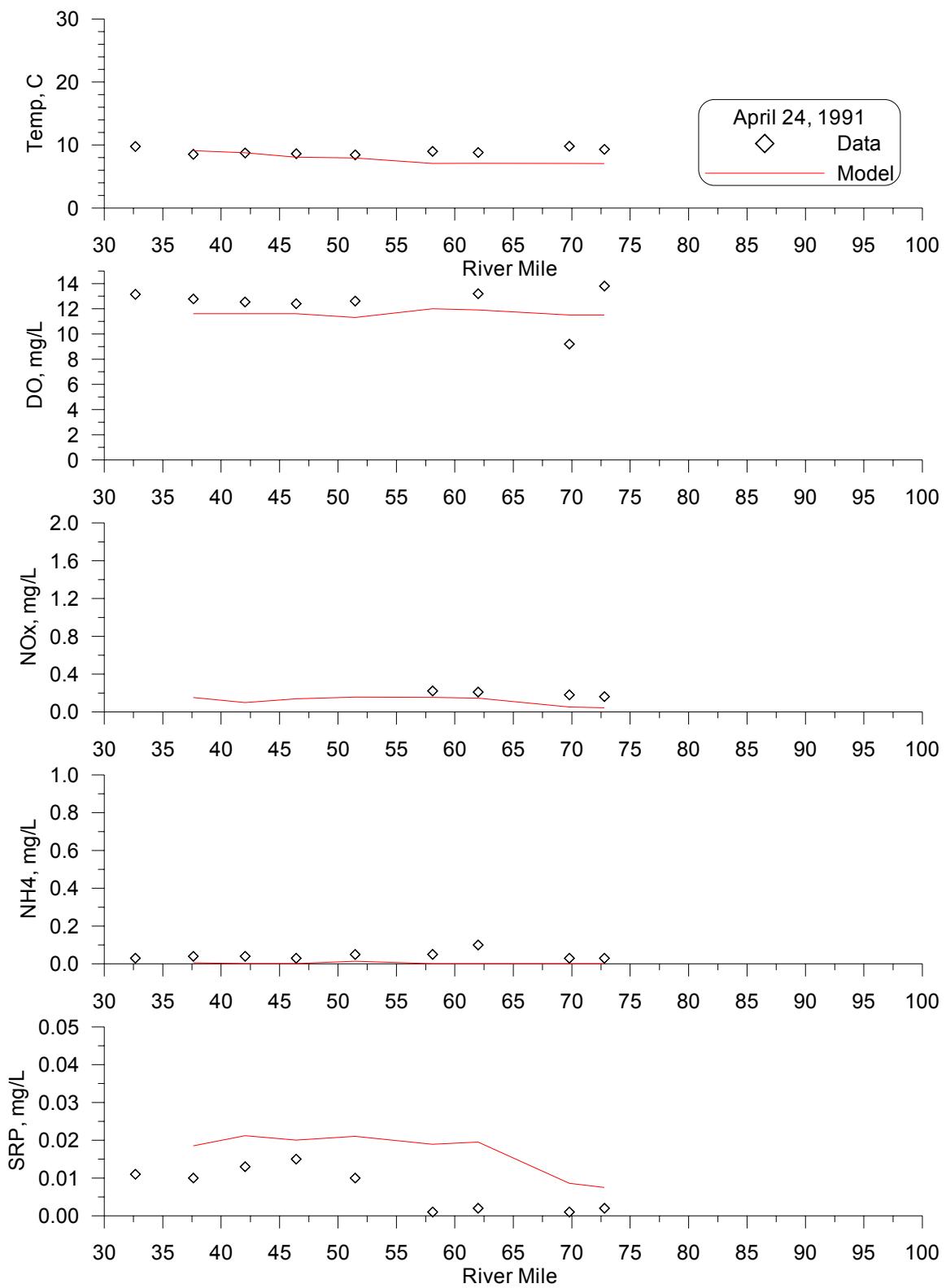


Figure 272. Longitudinal profile, April 24, 1991

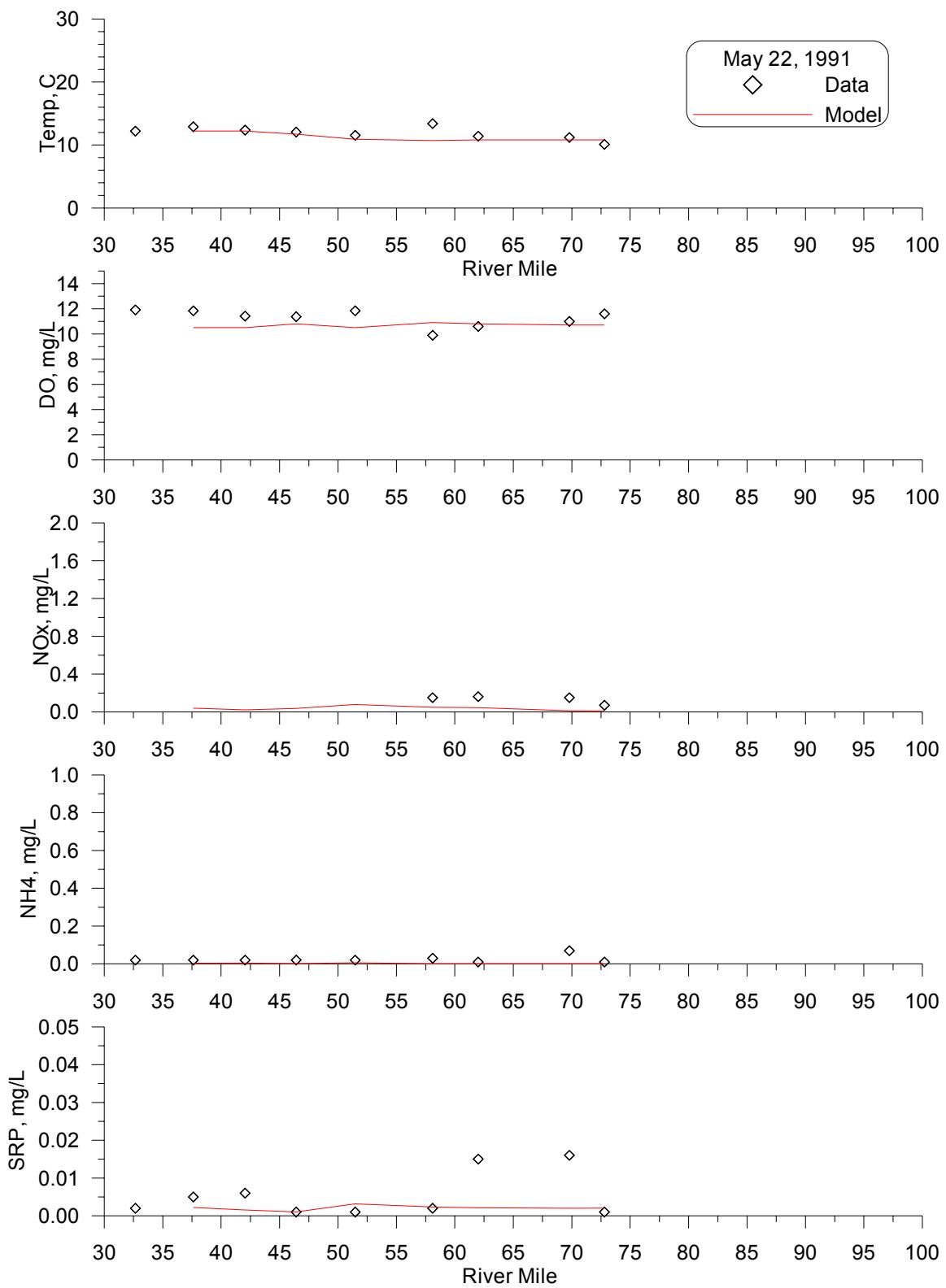


Figure 273. Longitudinal profile, May 22, 1991

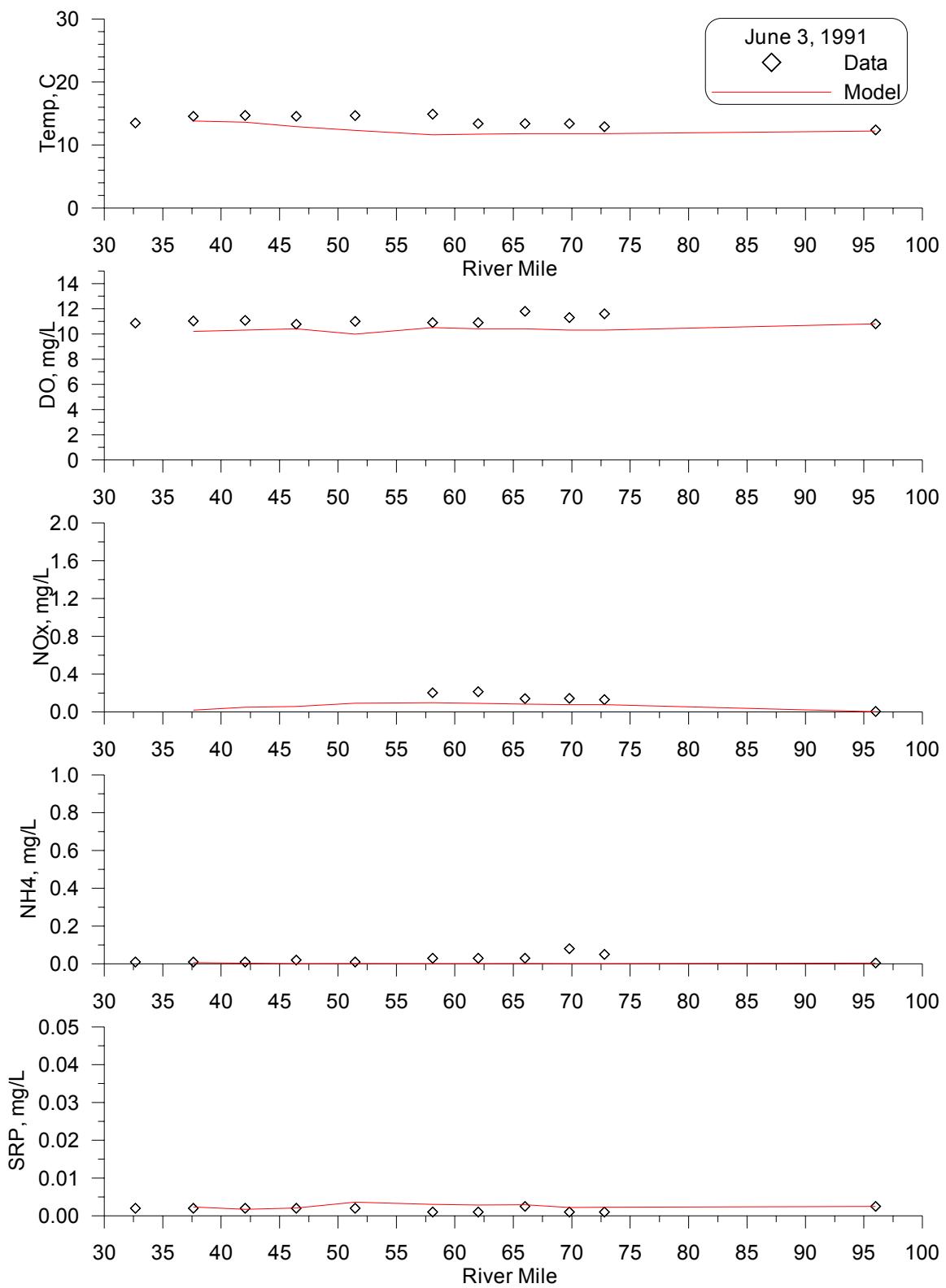


Figure 274, Longitudinal profile, June 3, 1991

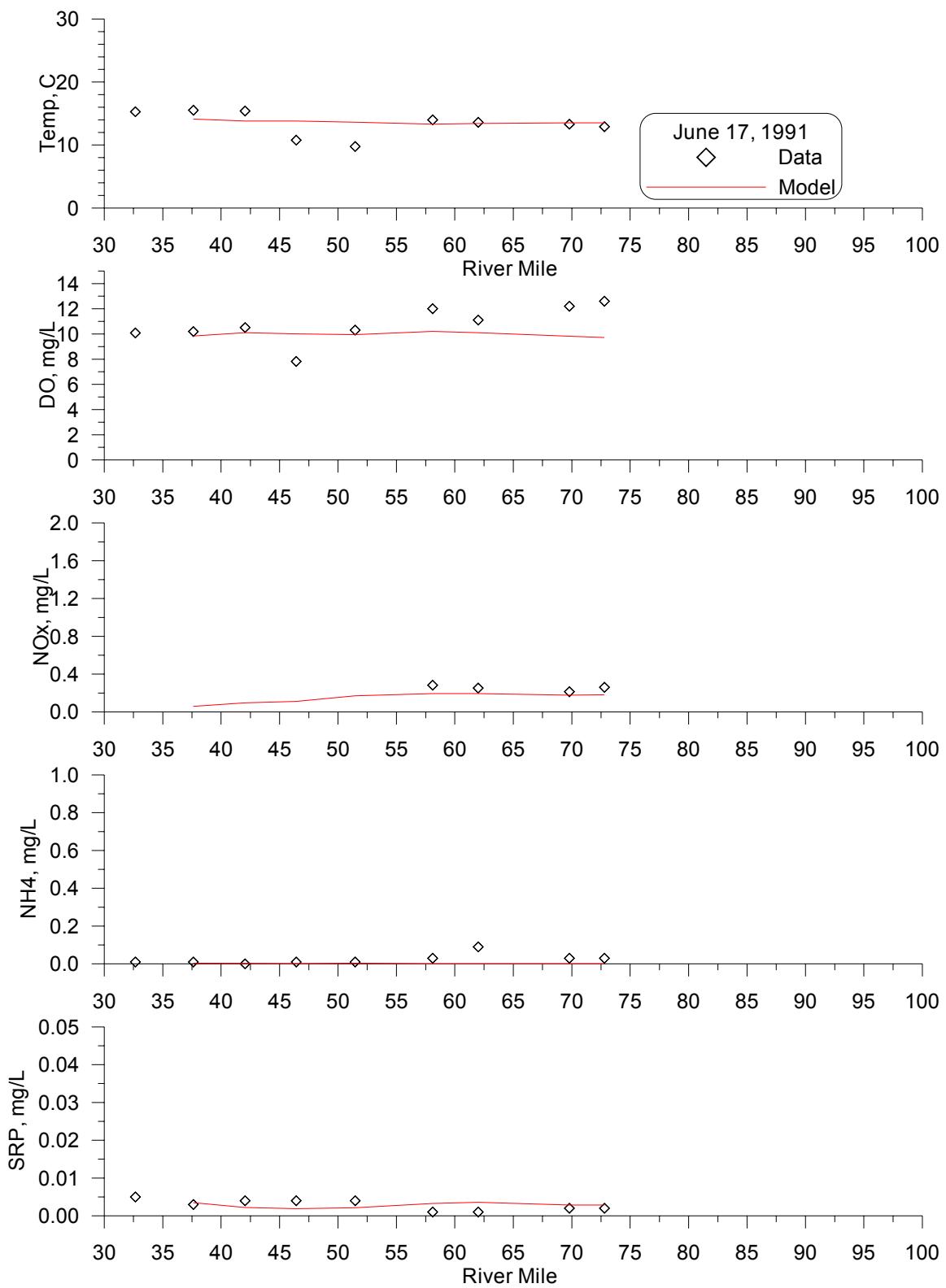


Figure 275. Longitudinal profile, June 17, 1991

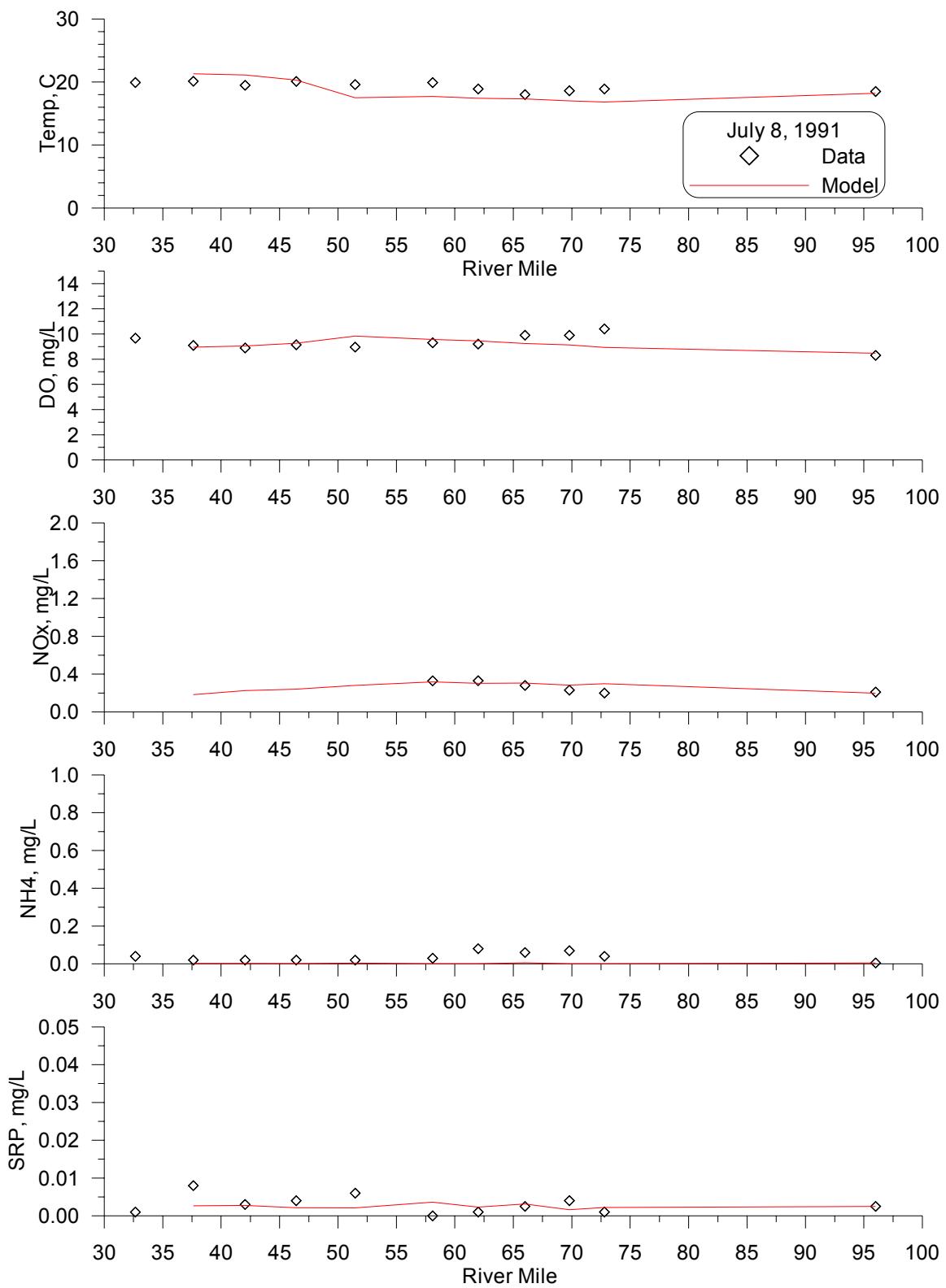


Figure 276. Longitudinal profile, July 8, 1991

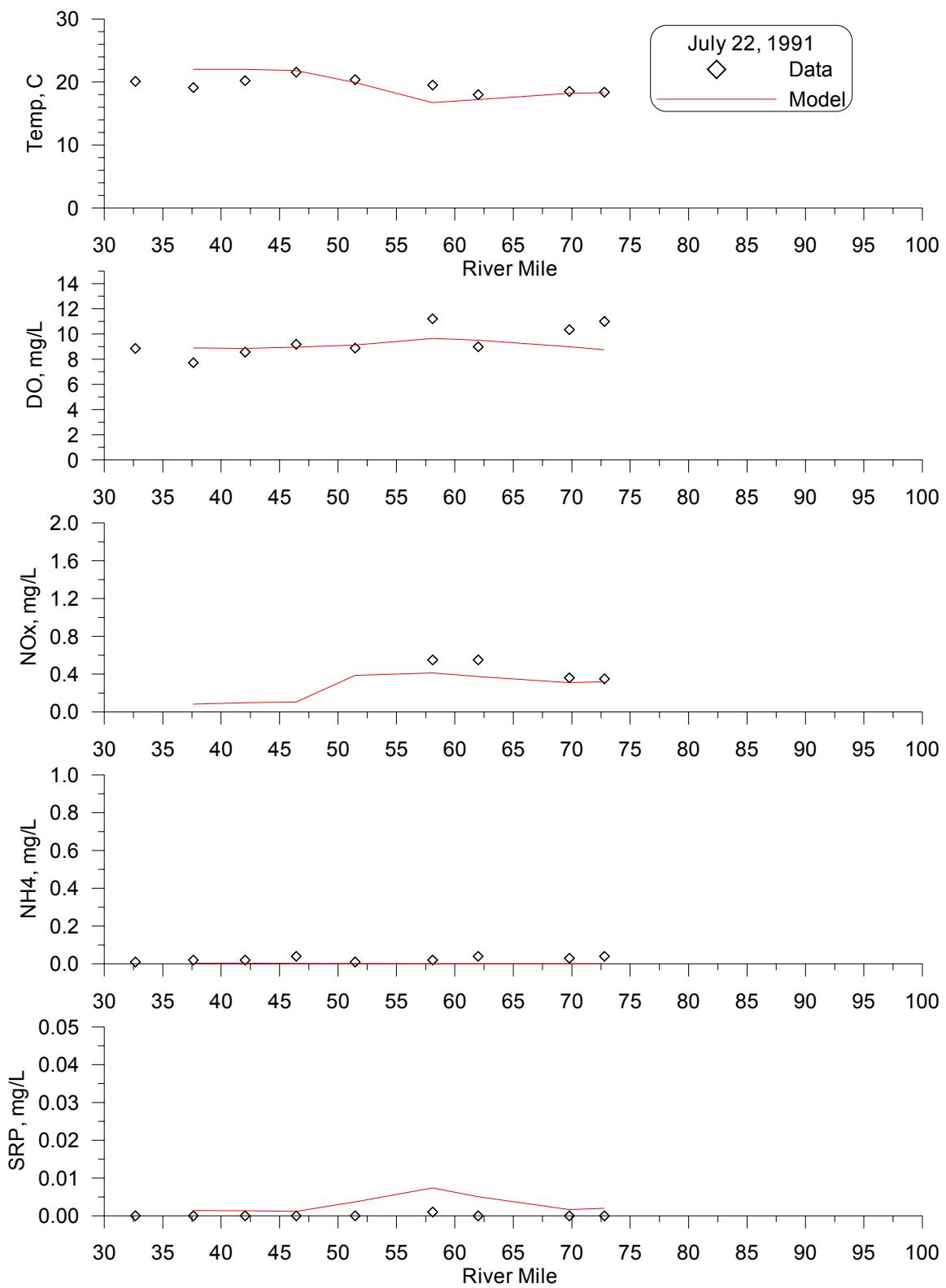


Figure 277. Longitudinal profile, July 22, 1991

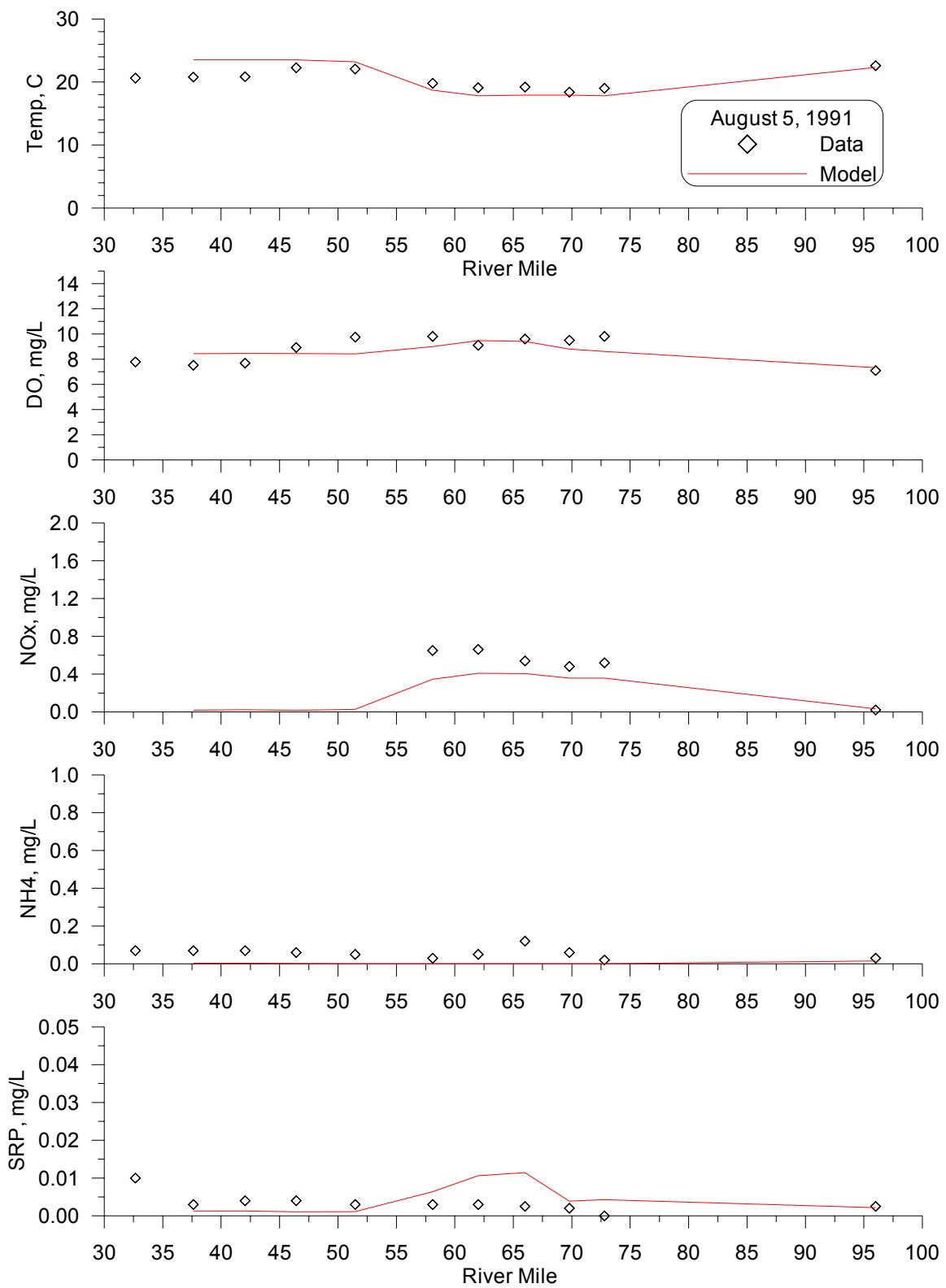


Figure 278. Longitudinal profile, August 5, 1991

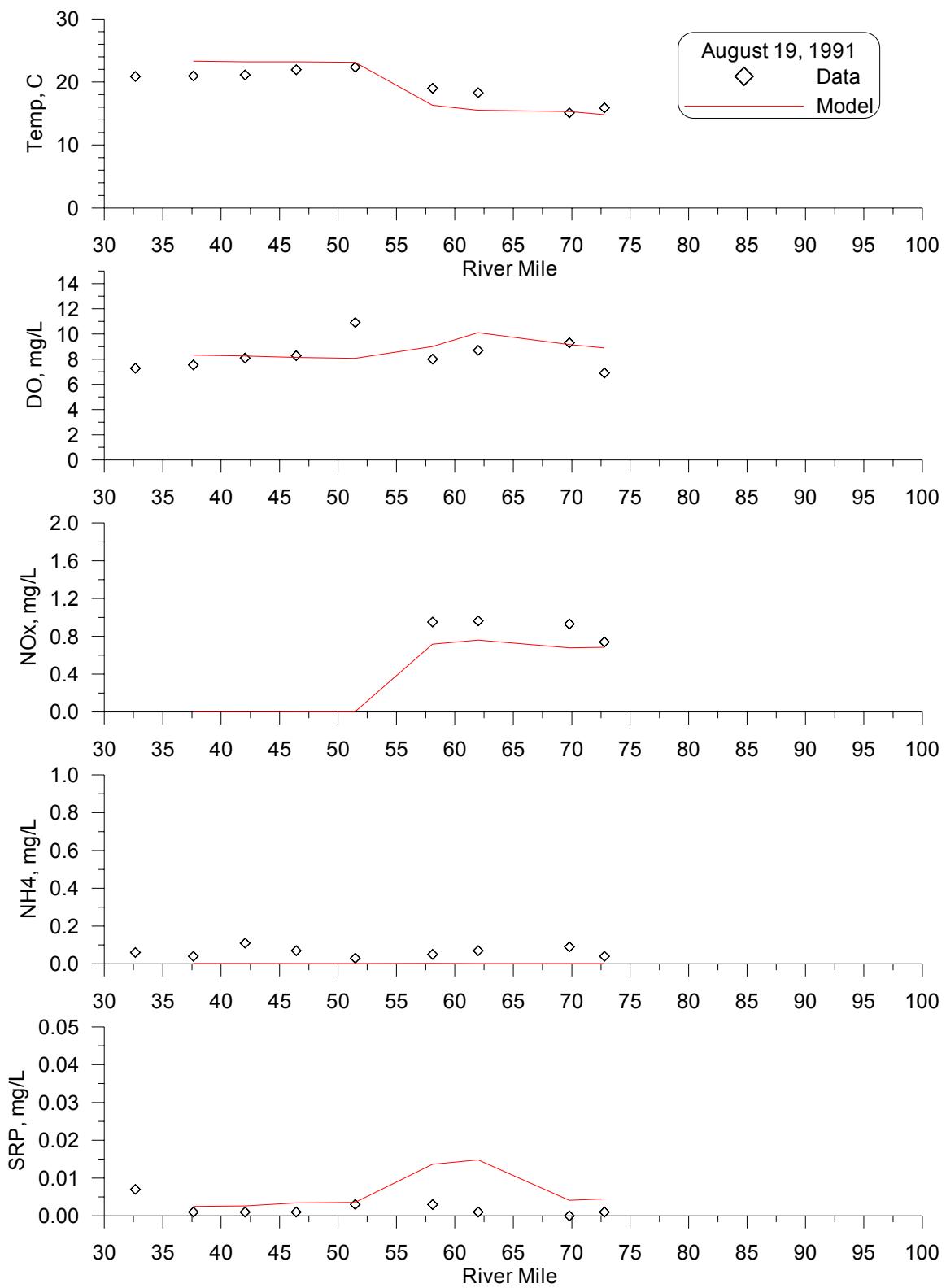


Figure 279. Longitudinal profile, August 19, 1991

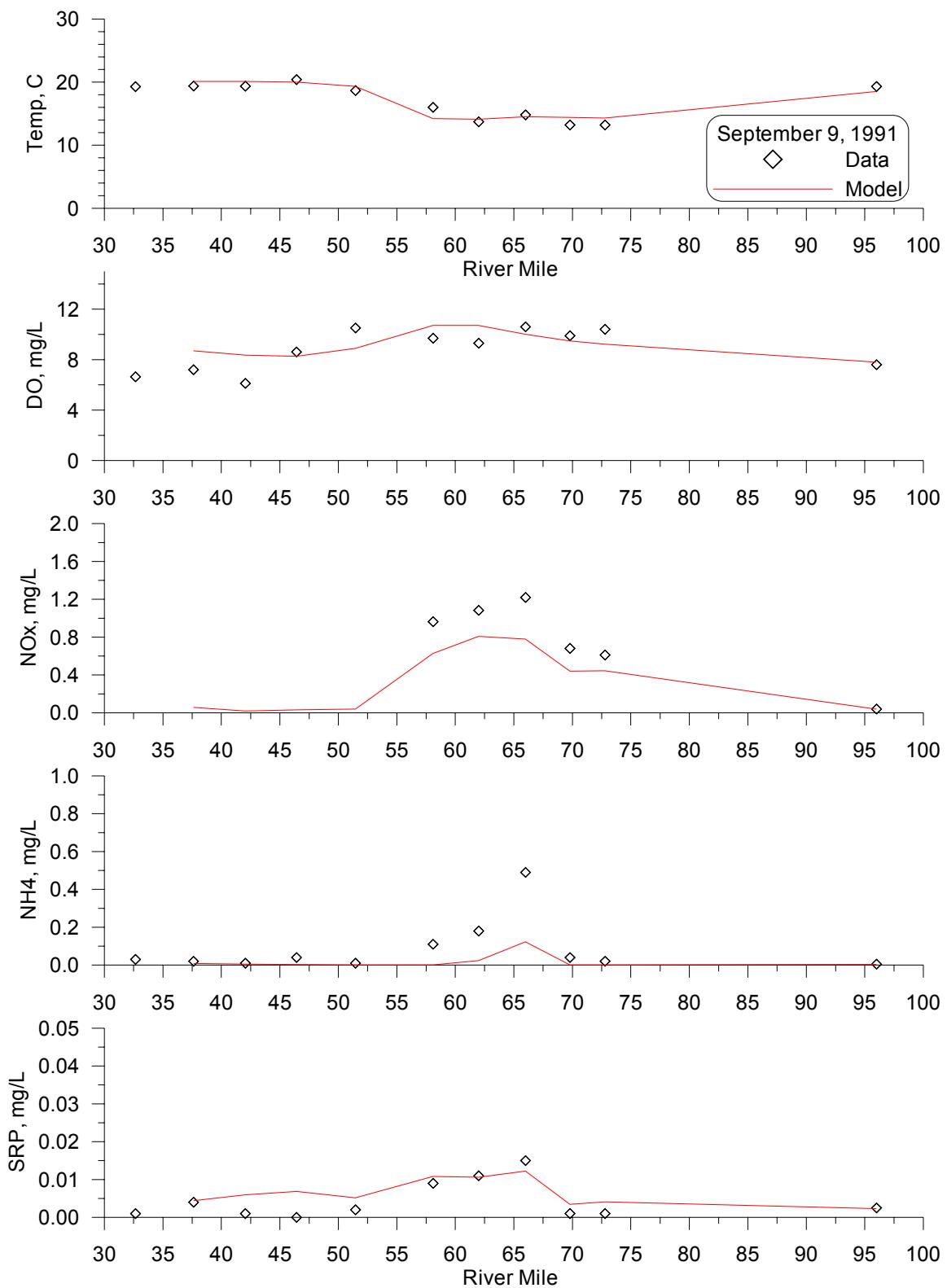


Figure 280. Longitudinal profile, September 9 1991

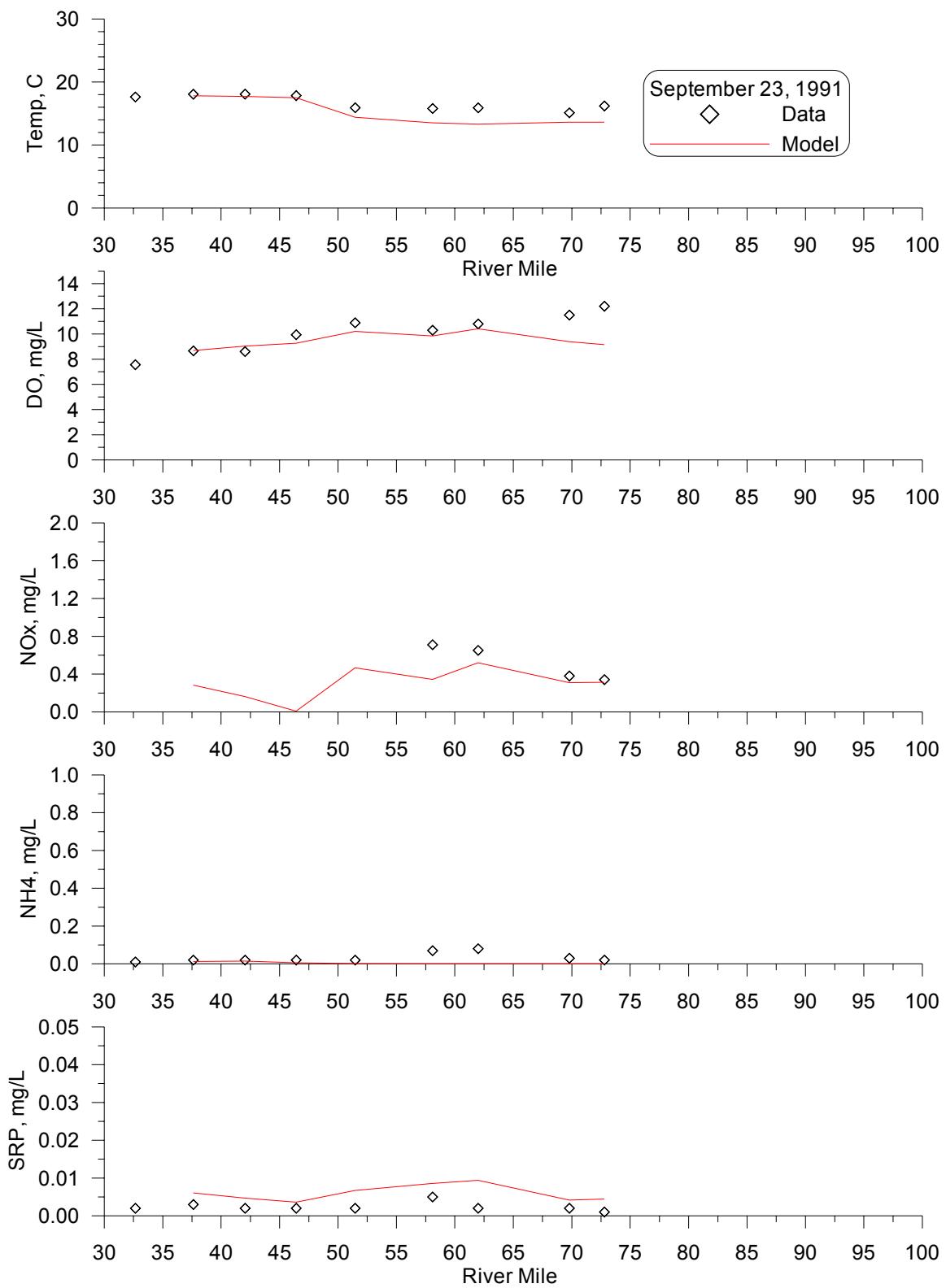


Figure 281. Longitudinal profile, September 23, 1991

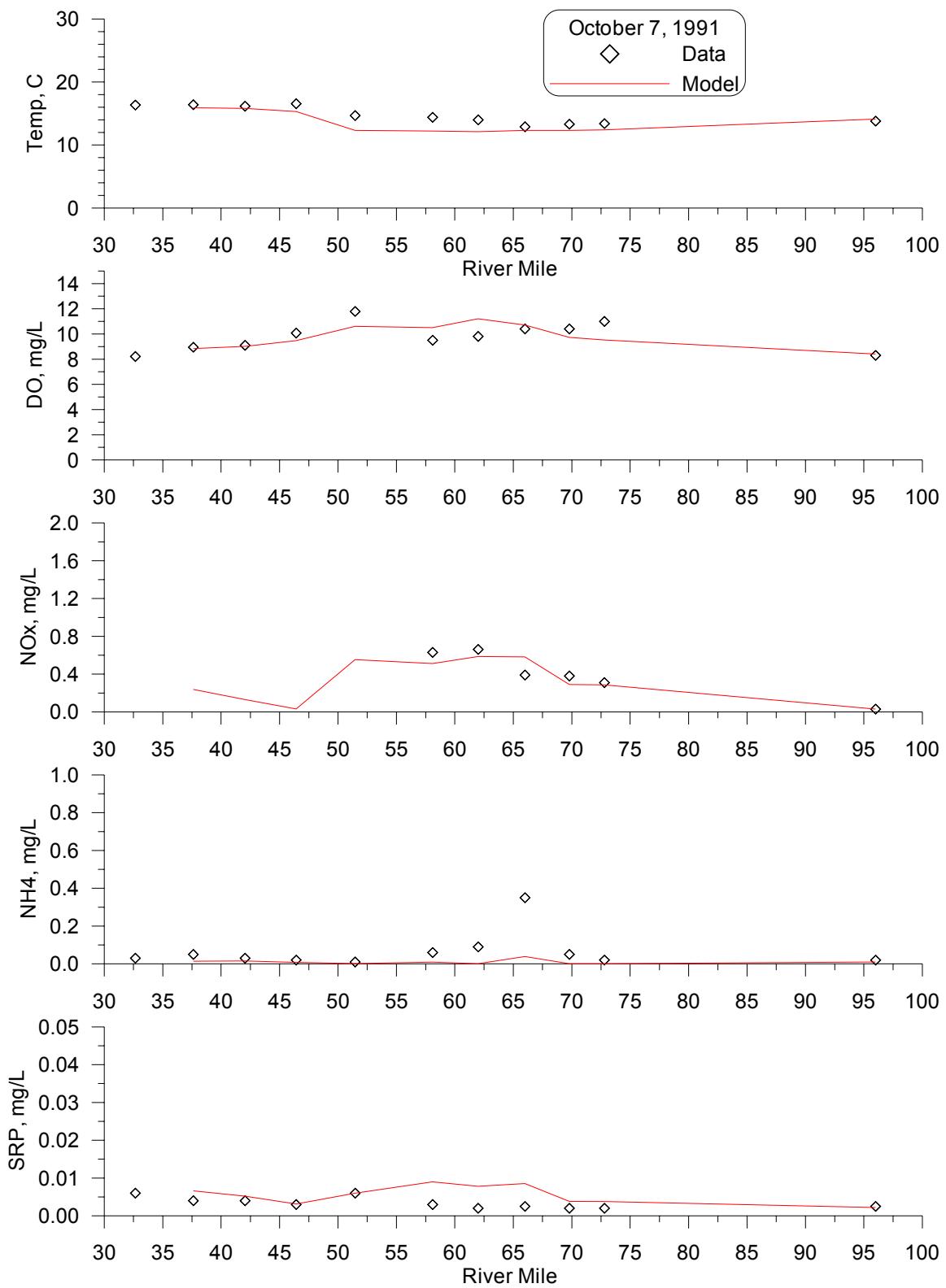


Figure 282. Longitudinal profile, October 7, 1991

Year 2000

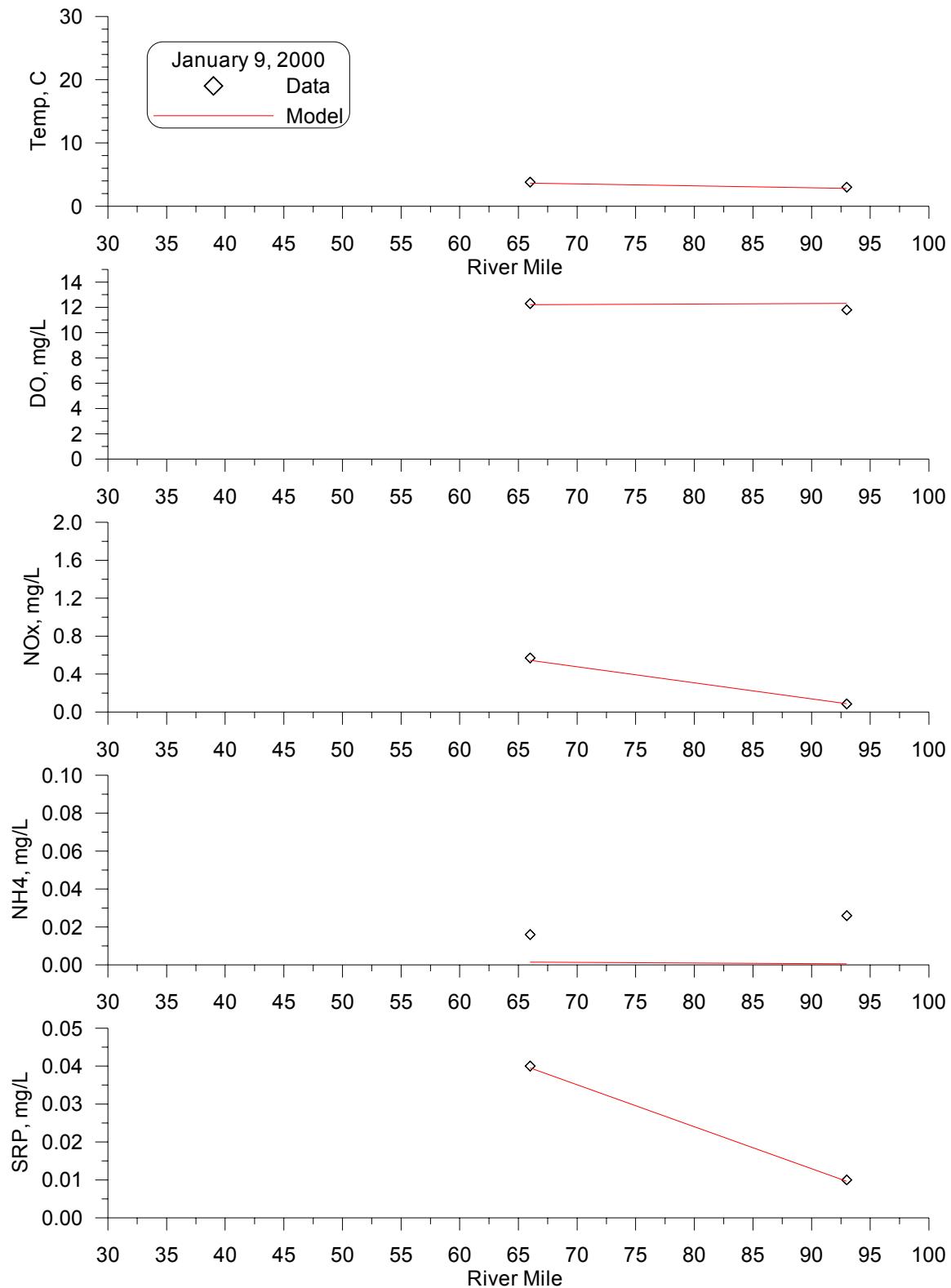


Figure 283. Longitudinal profile, January 9, 2000

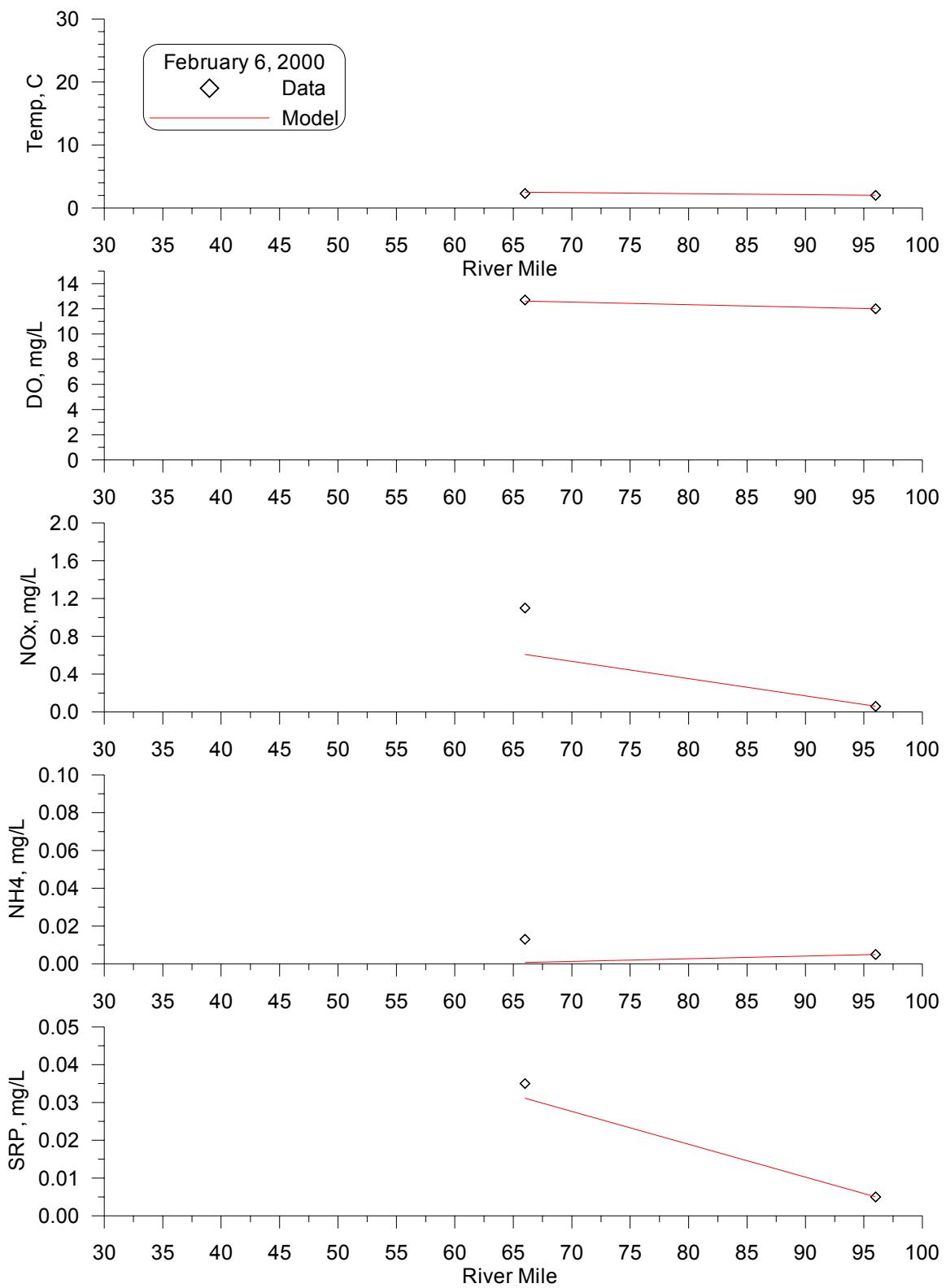


Figure 284. Longitudinal profile, February 6, 2000

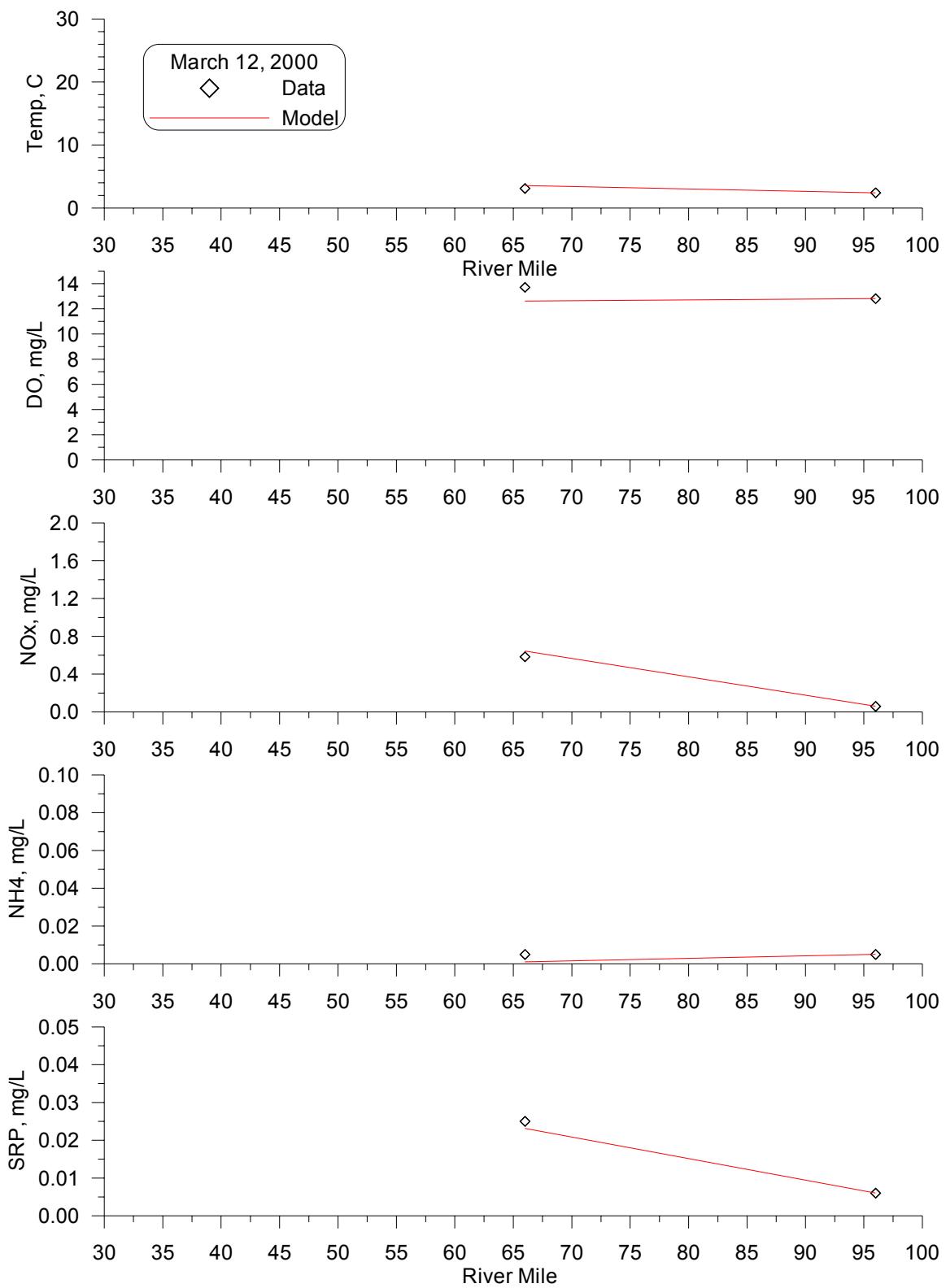


Figure 285. Longitudinal profile, March 12 2000

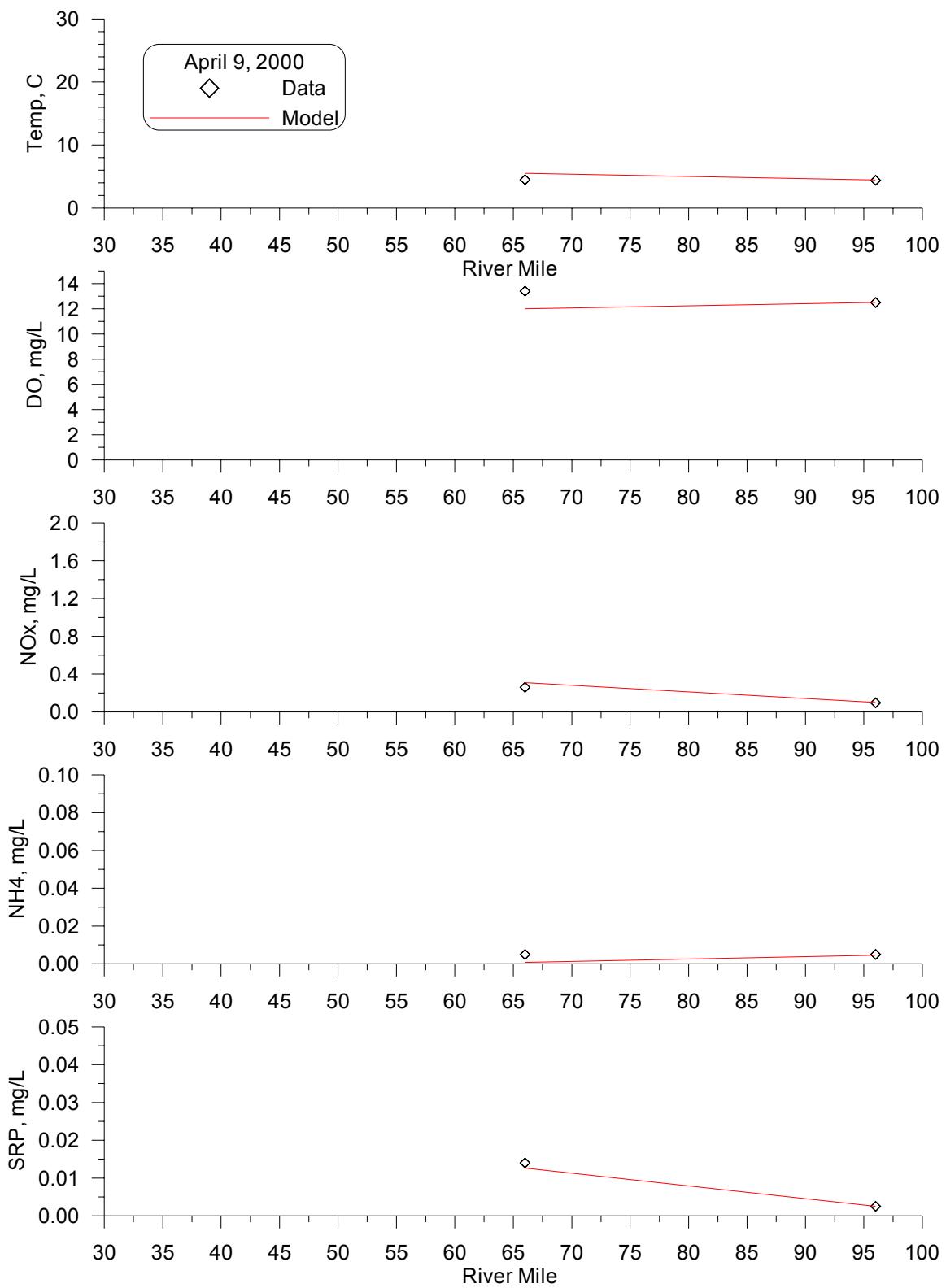


Figure 286. Longitudinal profile, April 9, 2000

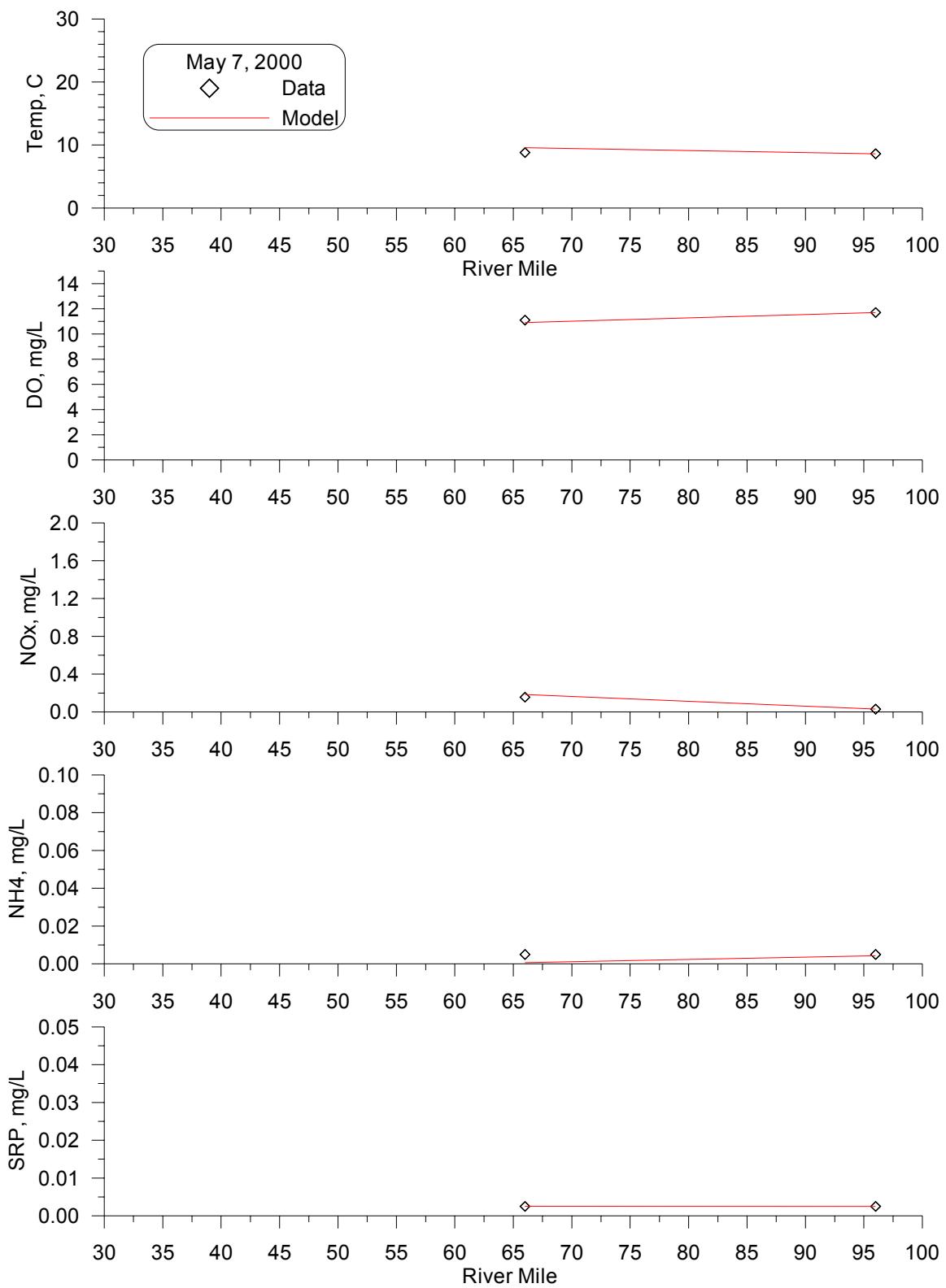


Figure 287. Longitudinal profile, May 7, 2000

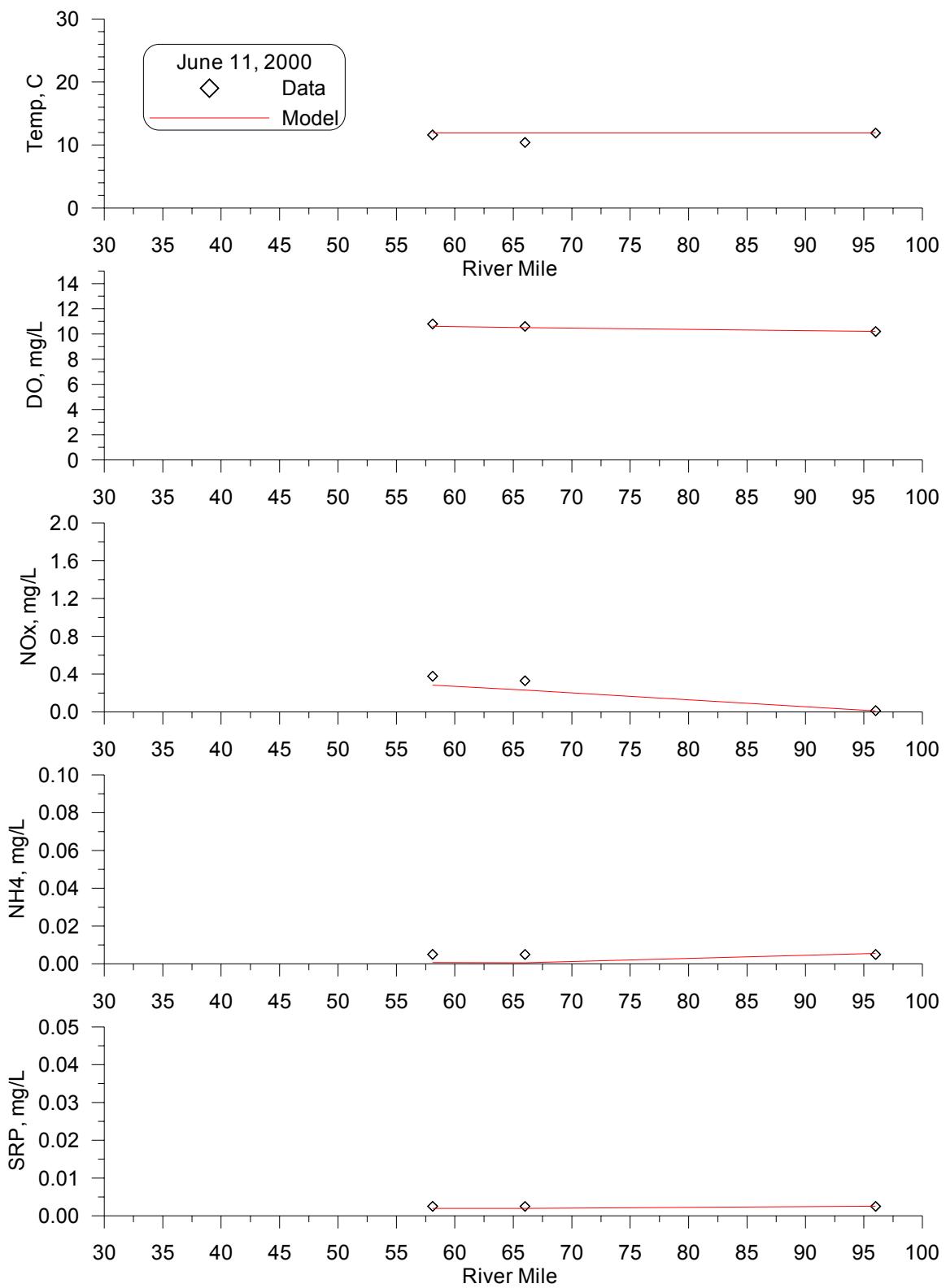


Figure 288. Longitudinal profile, June 11, 2000

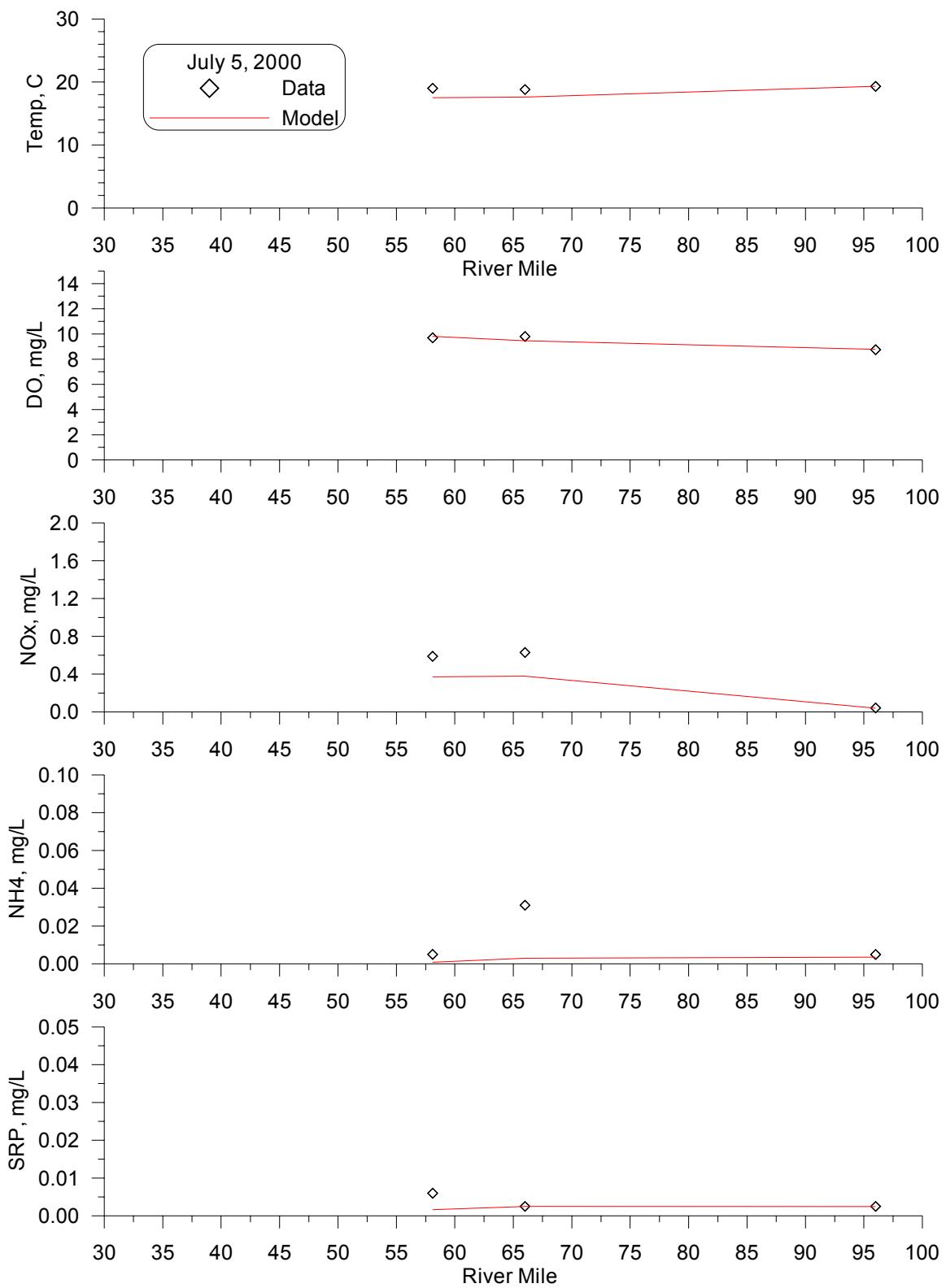


Figure 289. Longitudinal profile, July 5, 2000

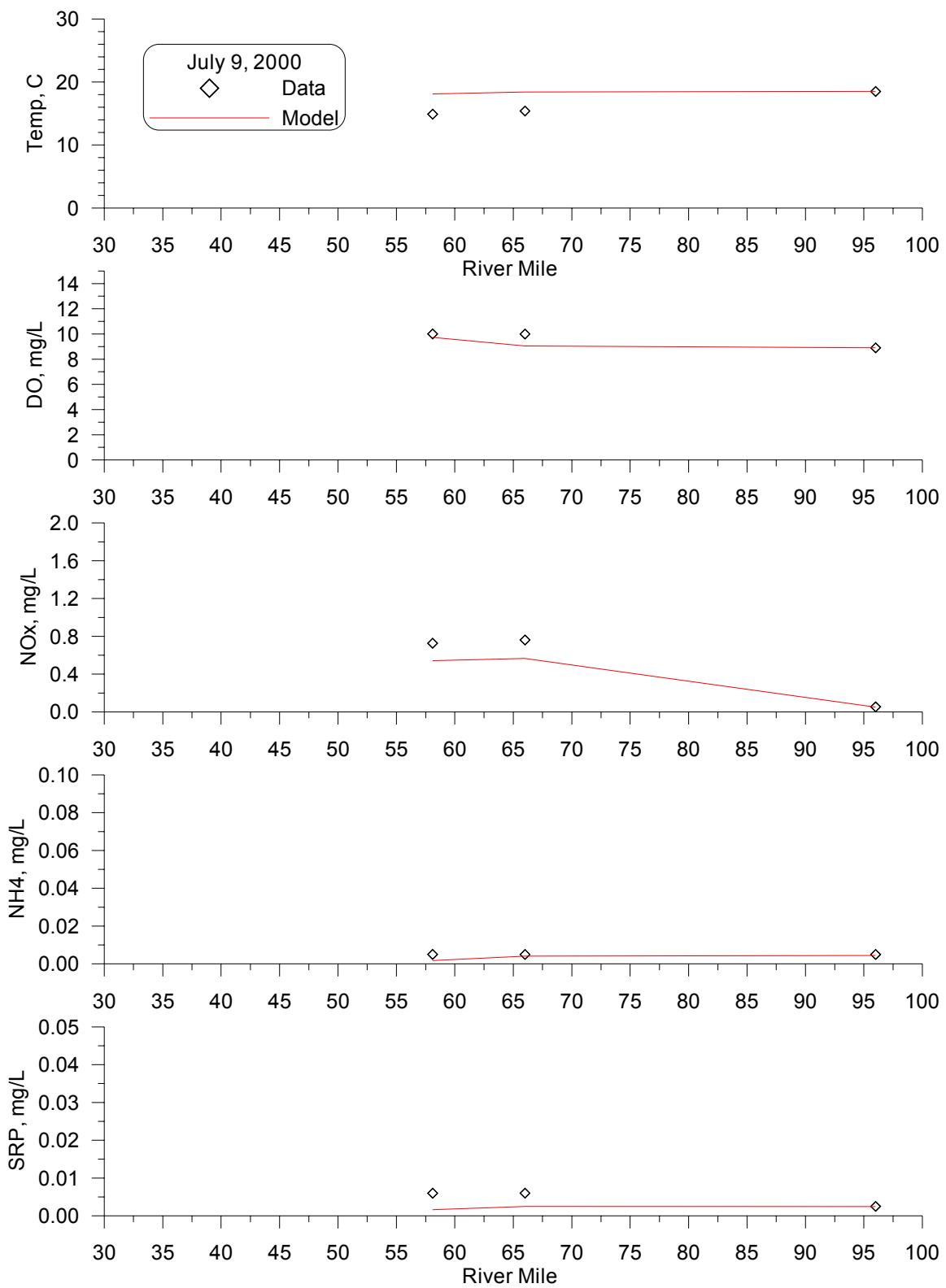


Figure 290. Longitudinal profile, July 9, 2000

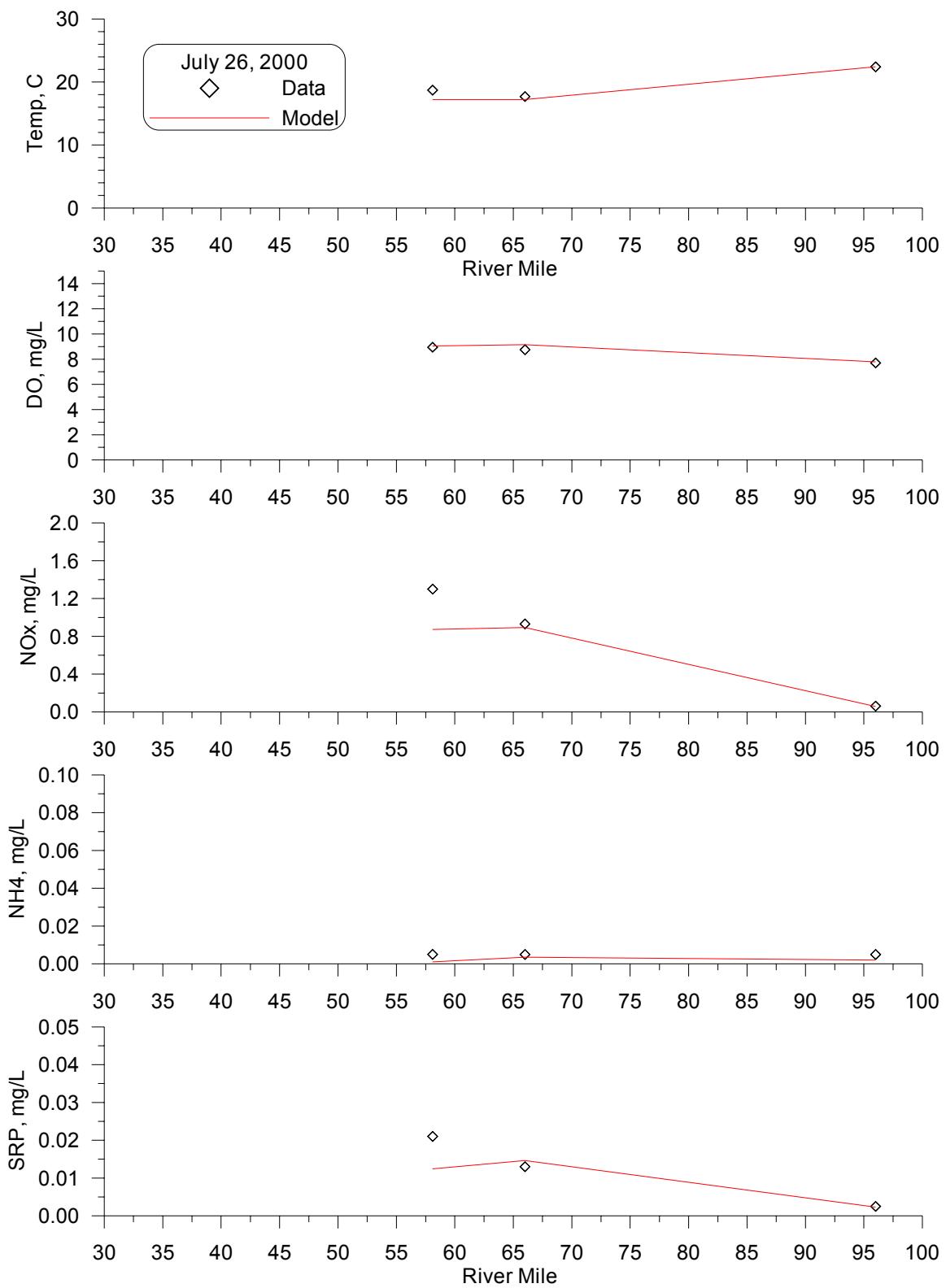


Figure 291. Longitudinal profile, July 26, 2000

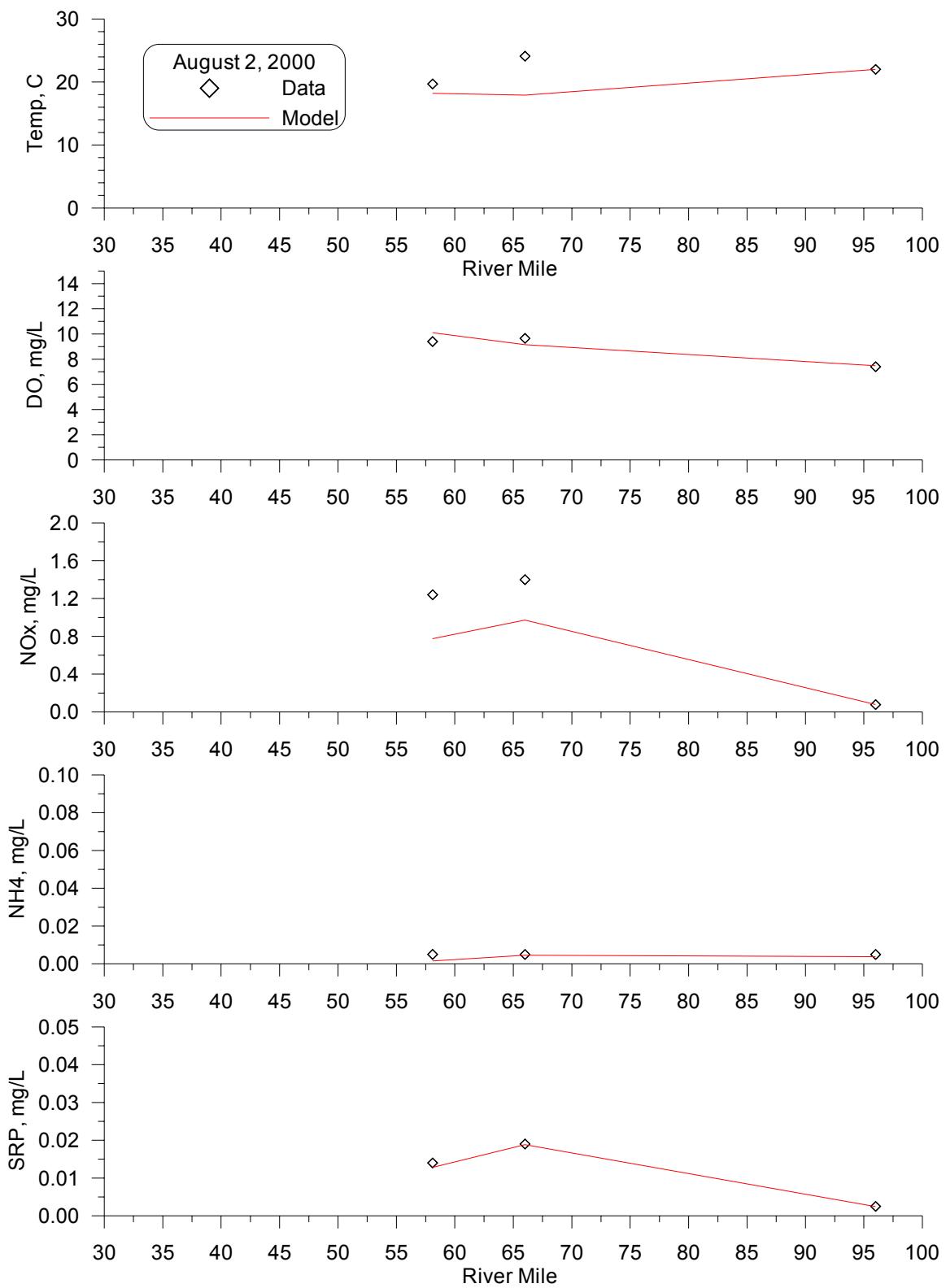


Figure 292. Longitudinal profile, August 2, 2000

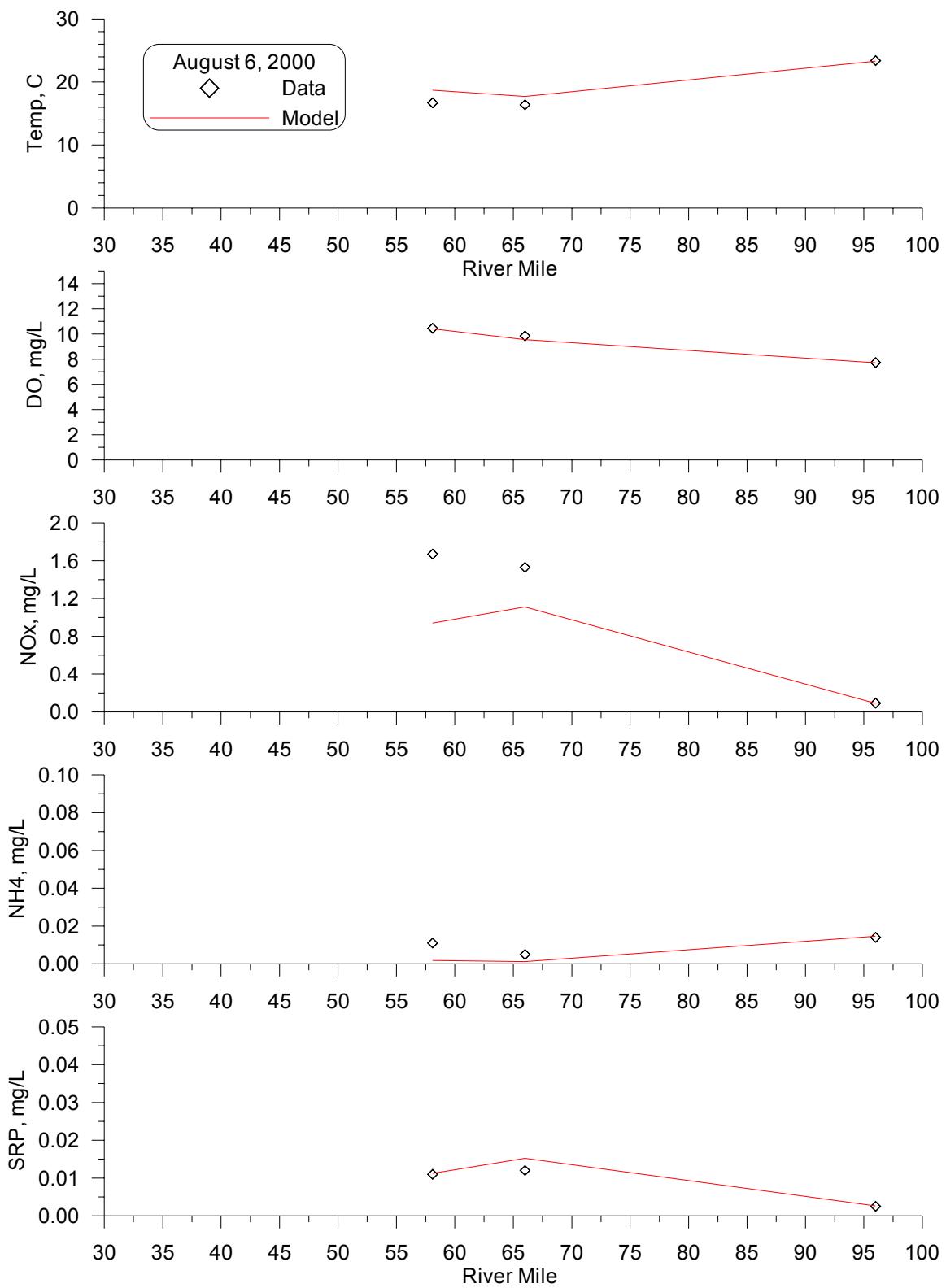


Figure 293. Longitudinal profile, August 6, 2000

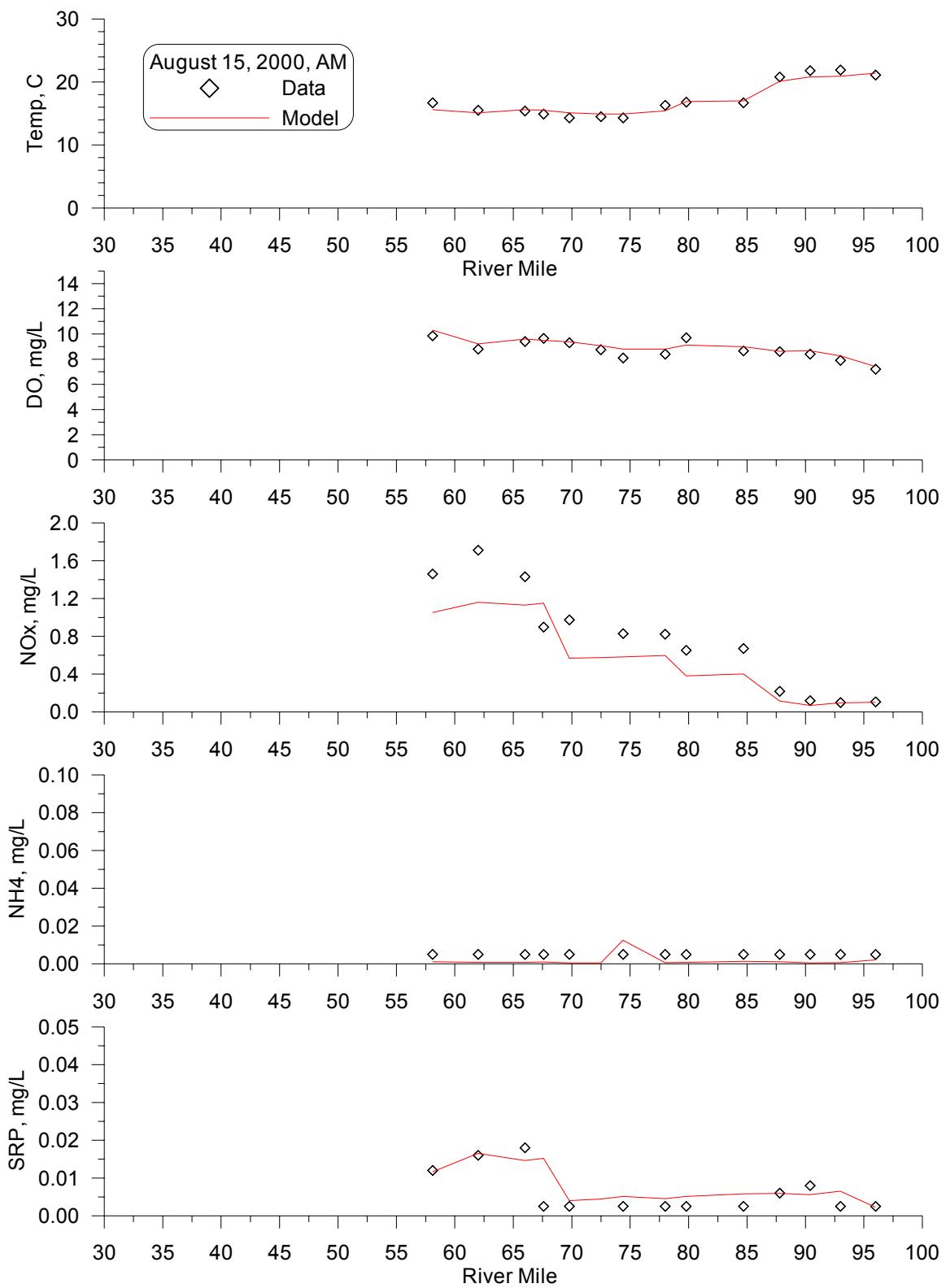


Figure 294. Longitudinal profile, August 15, 2000 AM

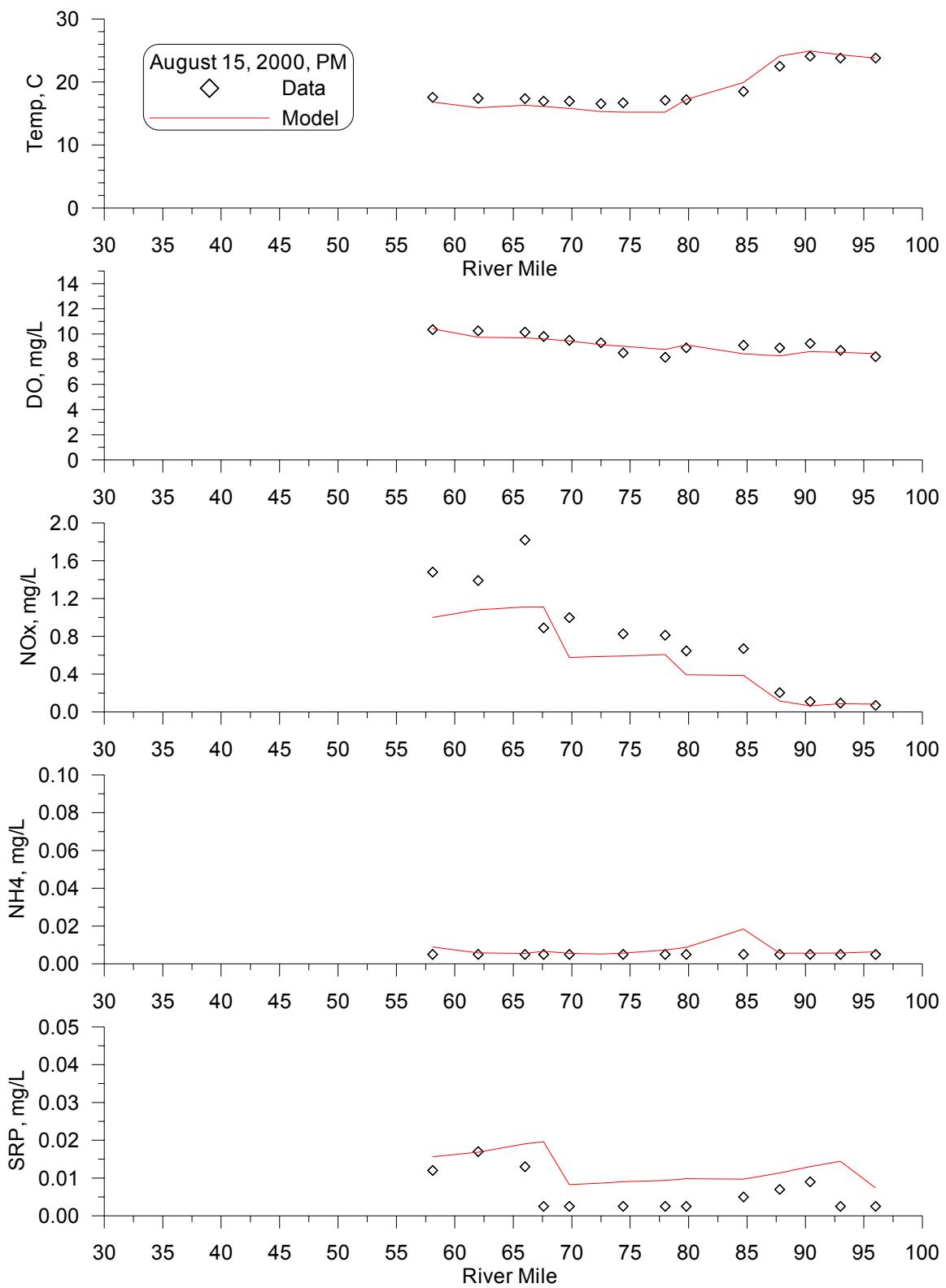


Figure 295. Longitudinal profile, August 15, 2000 PM

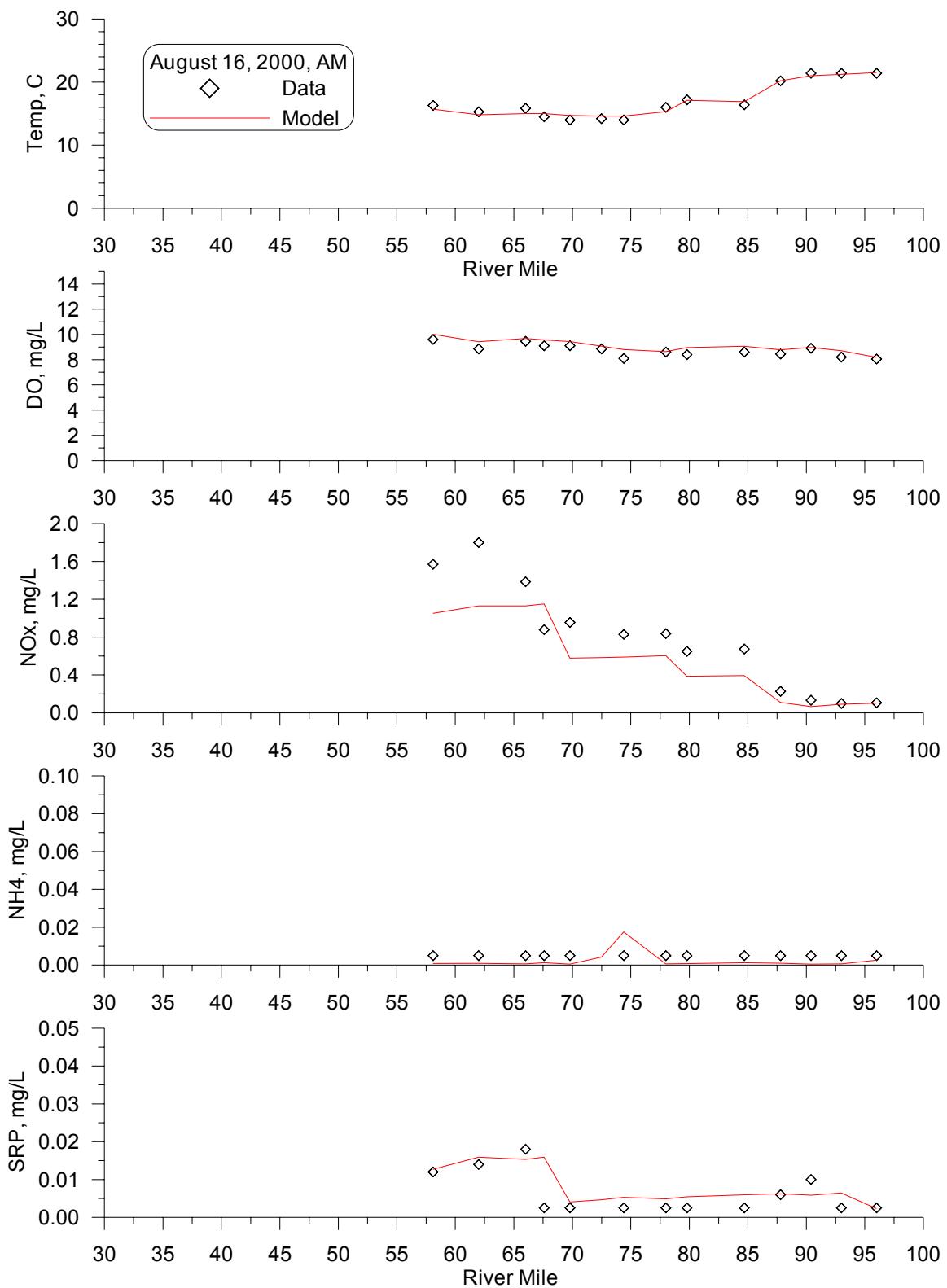


Figure 296. Longitudinal profile, August 16, 2000 AM

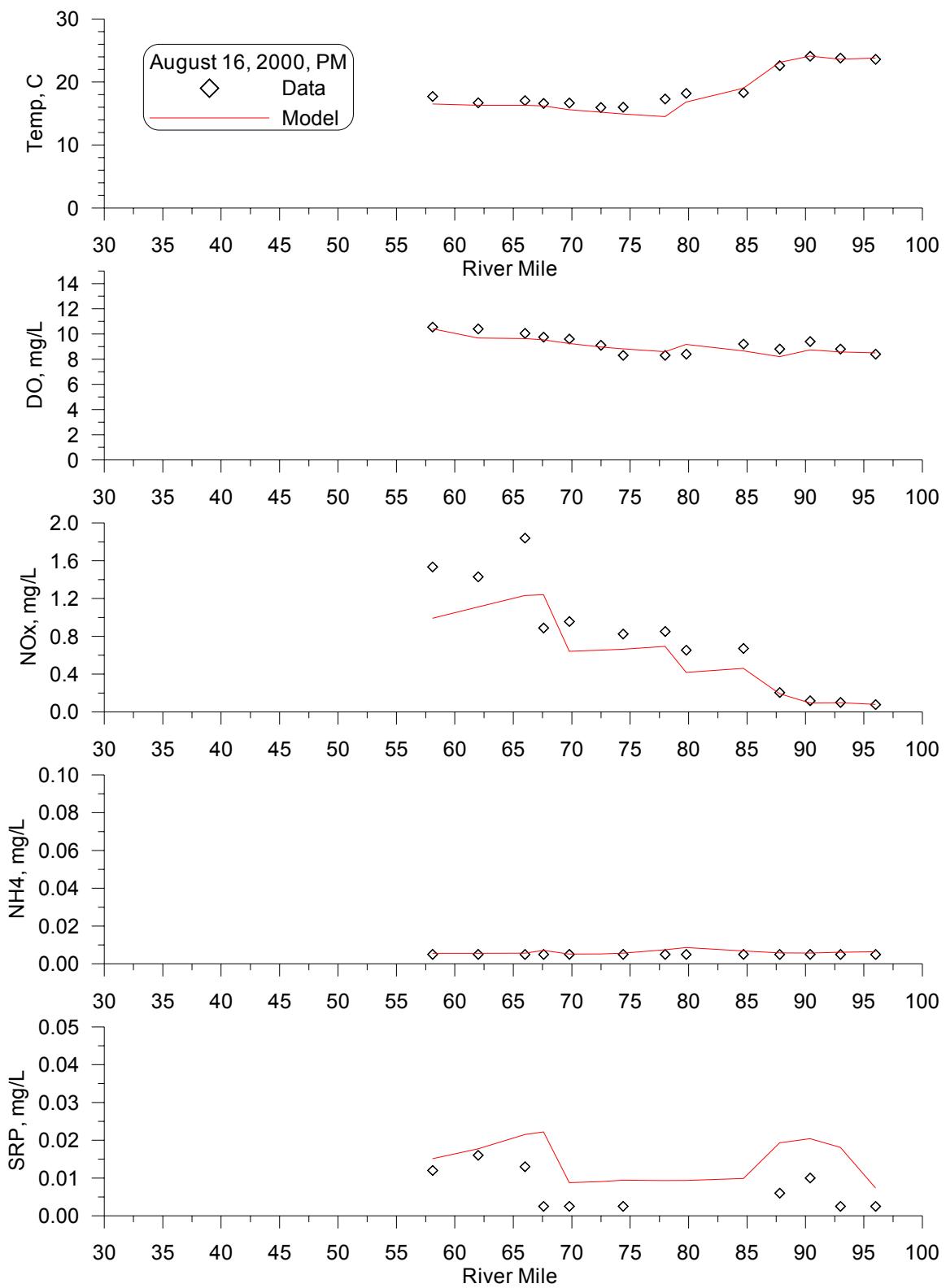


Figure 297. Longitudinal profile, August 16, 2000 PM

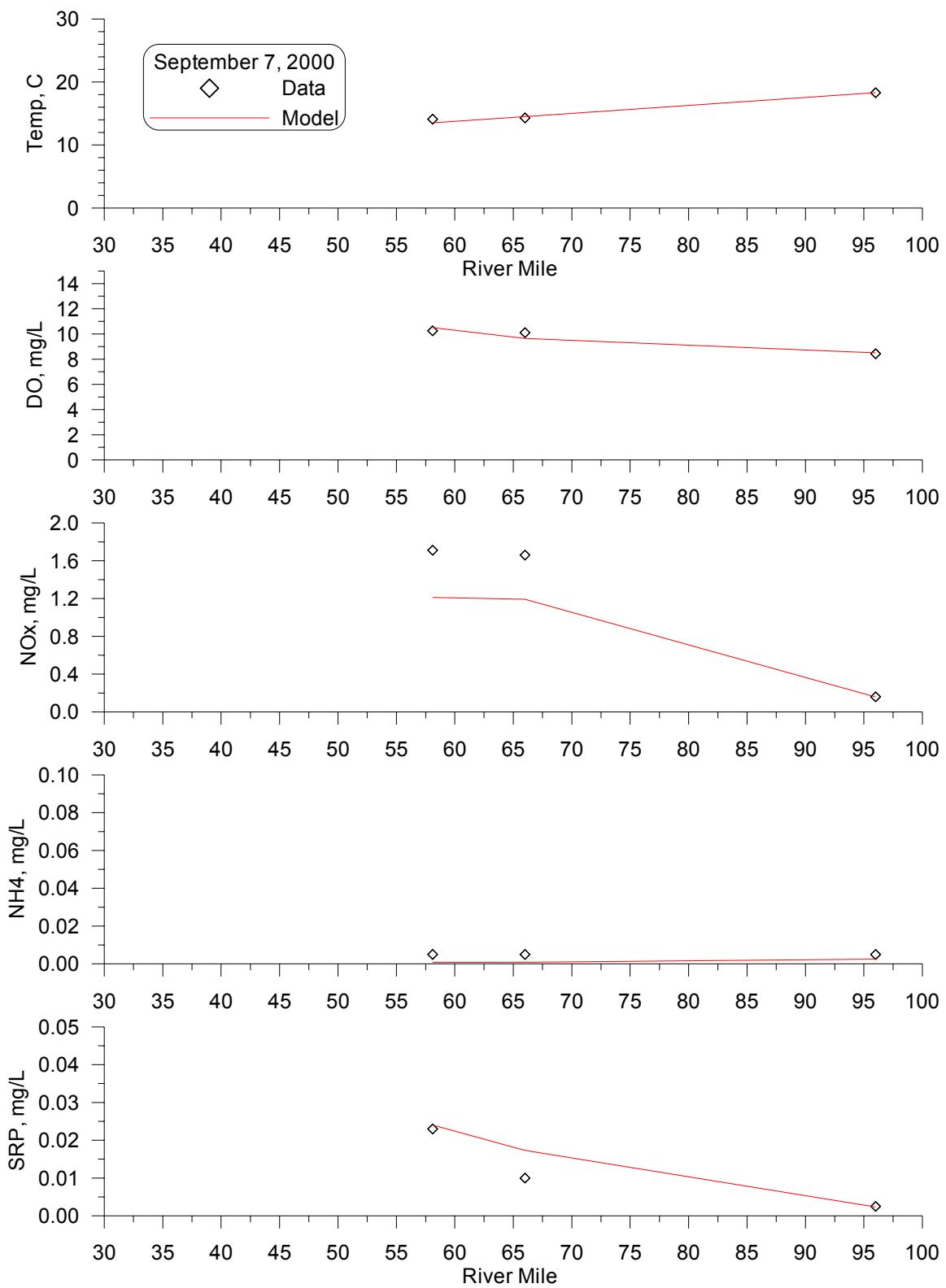


Figure 298. Longitudinal profile, September 7, 2000

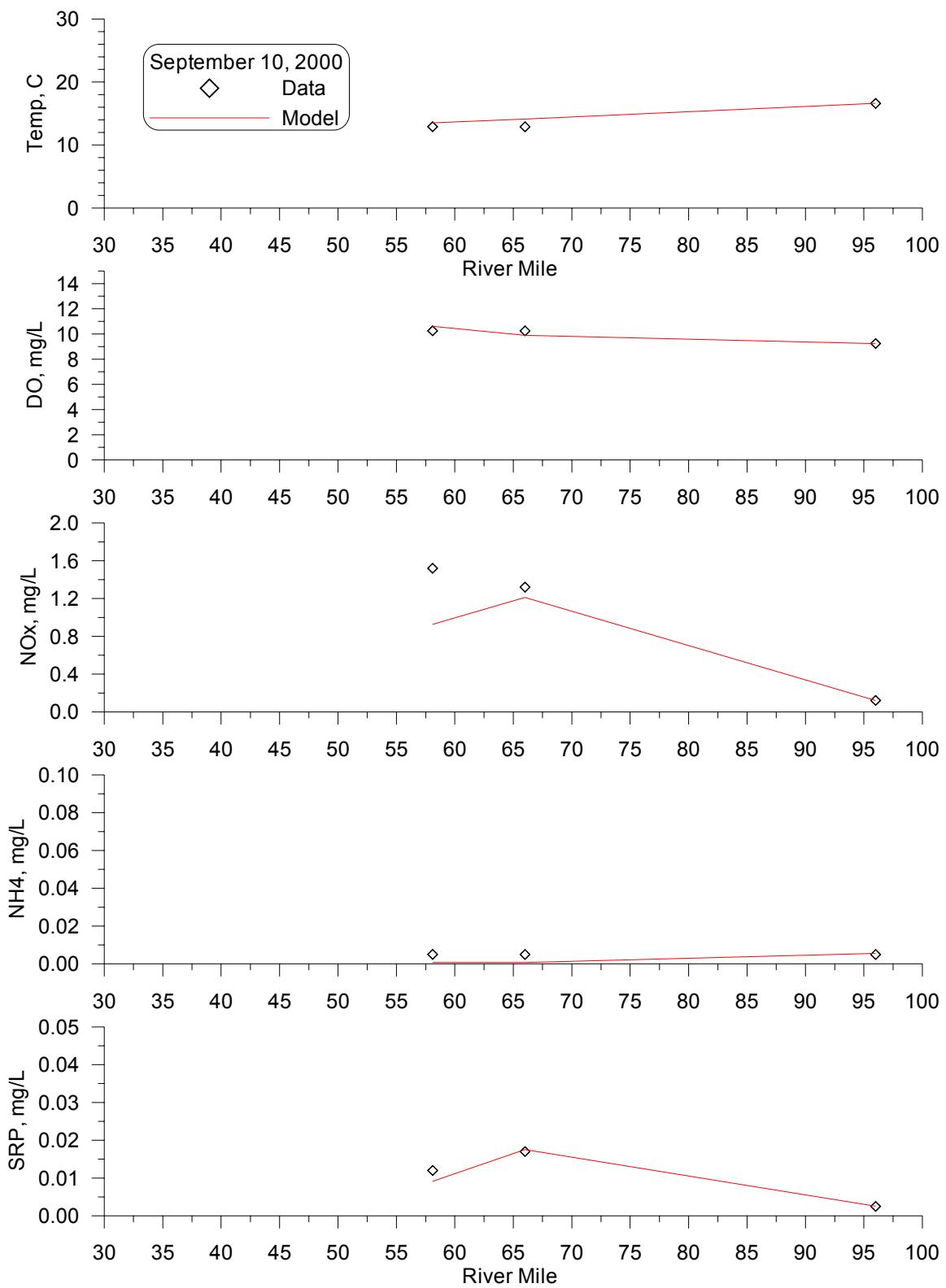


Figure 299. Longitudinal profile, September 10, 2000

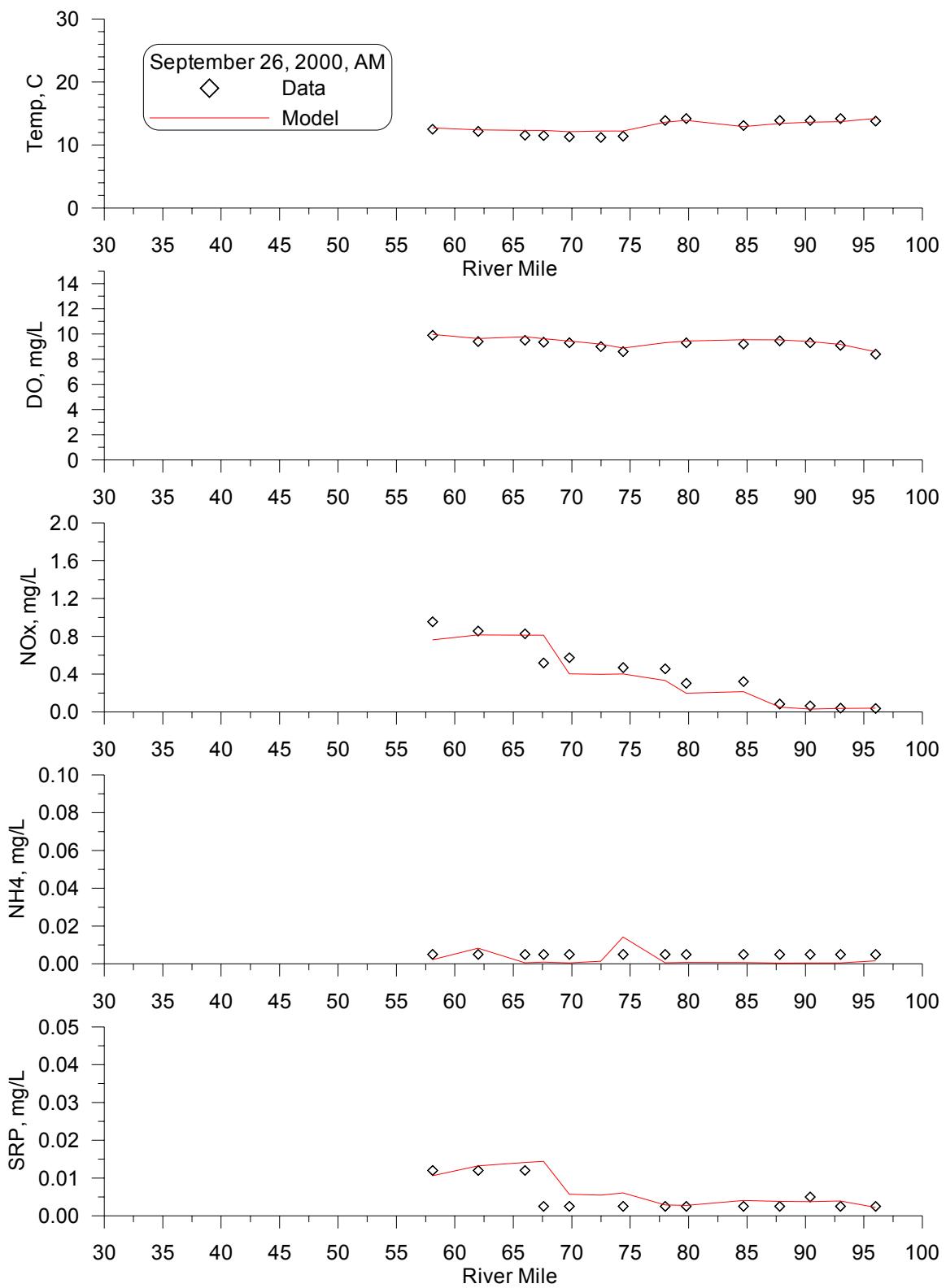


Figure 300. Longitudinal profile, September 26, 2000 AM

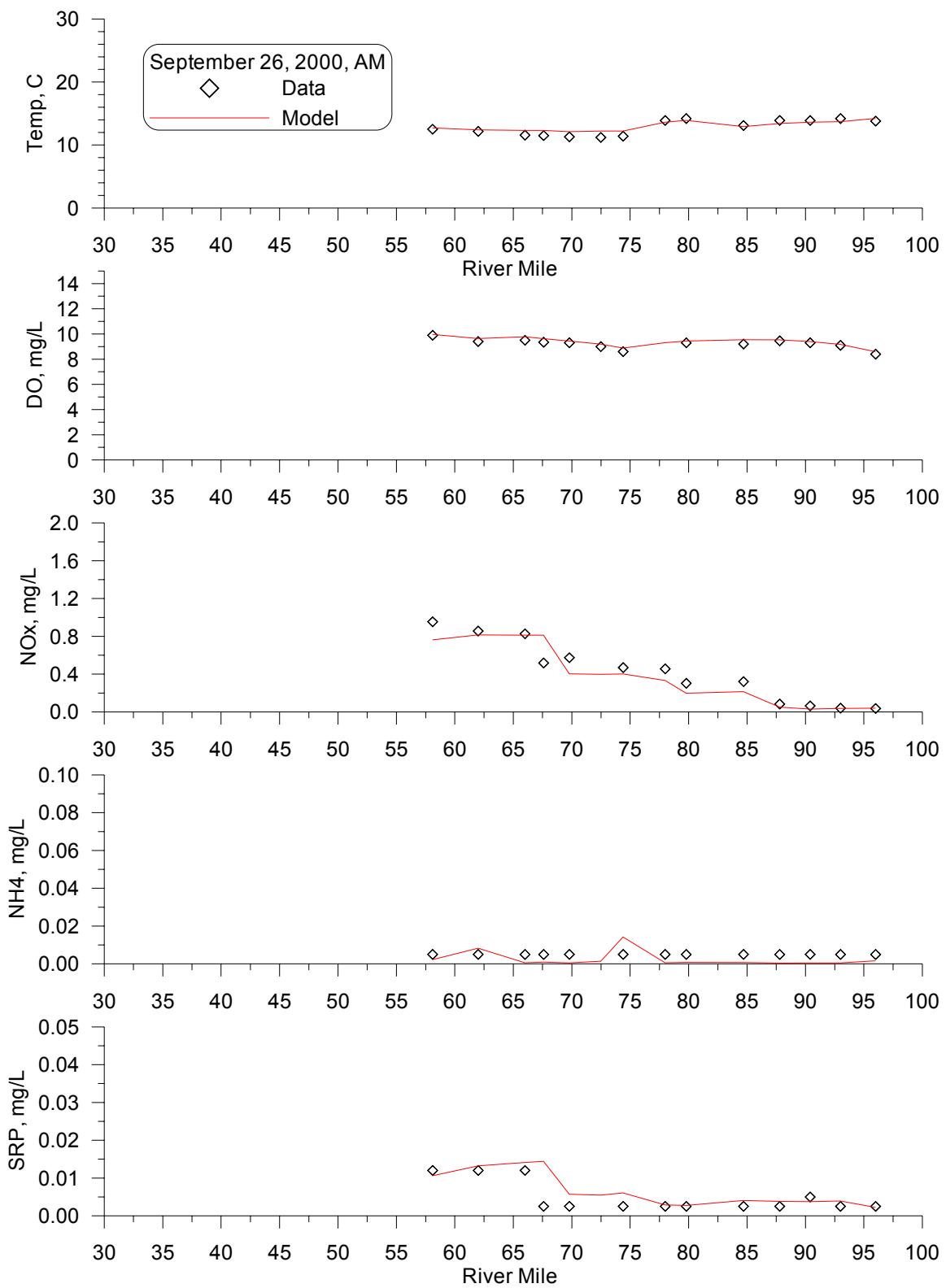


Figure 301. Longitudinal profile, September 26, 2000 PM

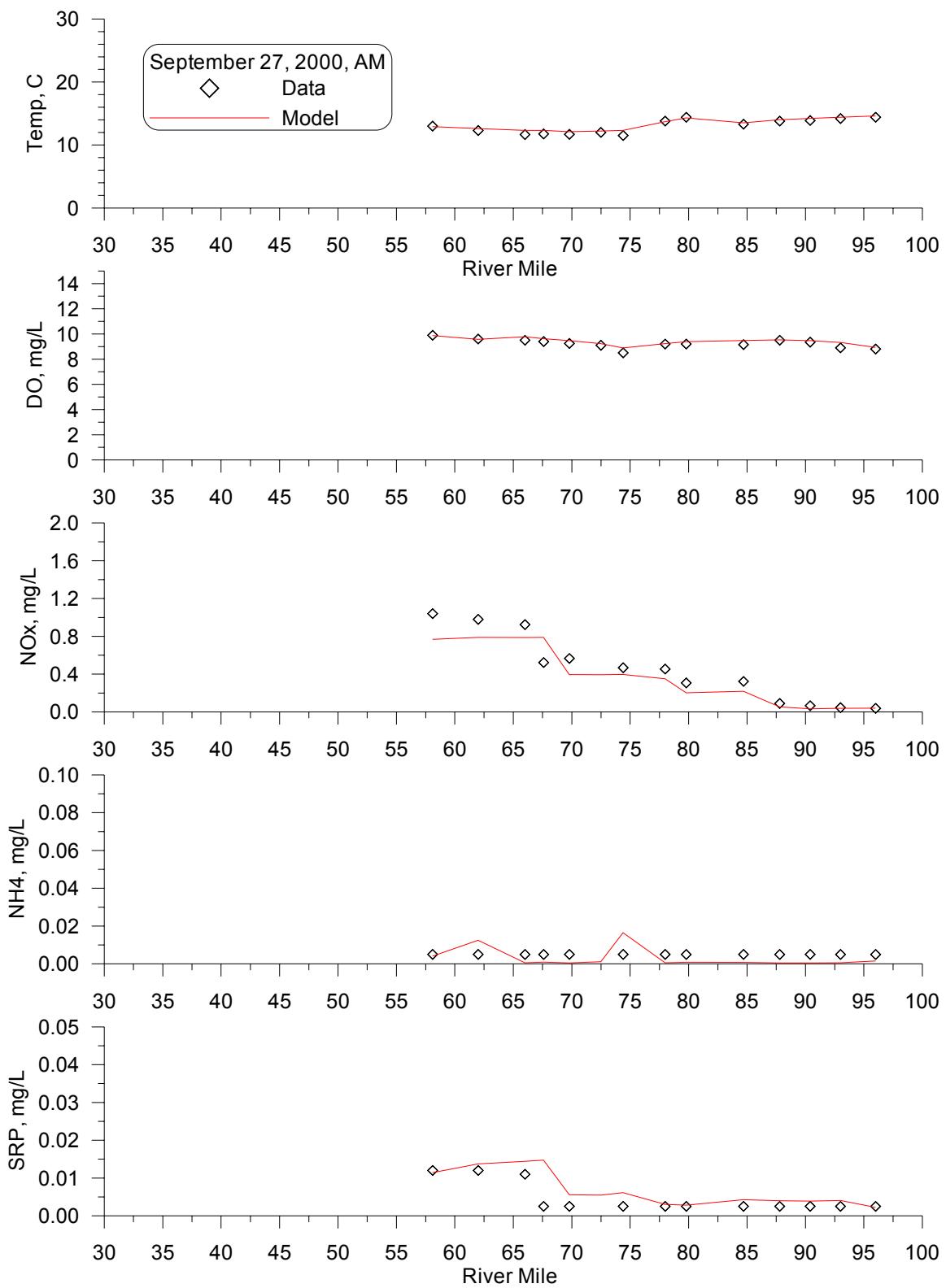


Figure 302. Longitudinal profile, September 27, 2000 AM

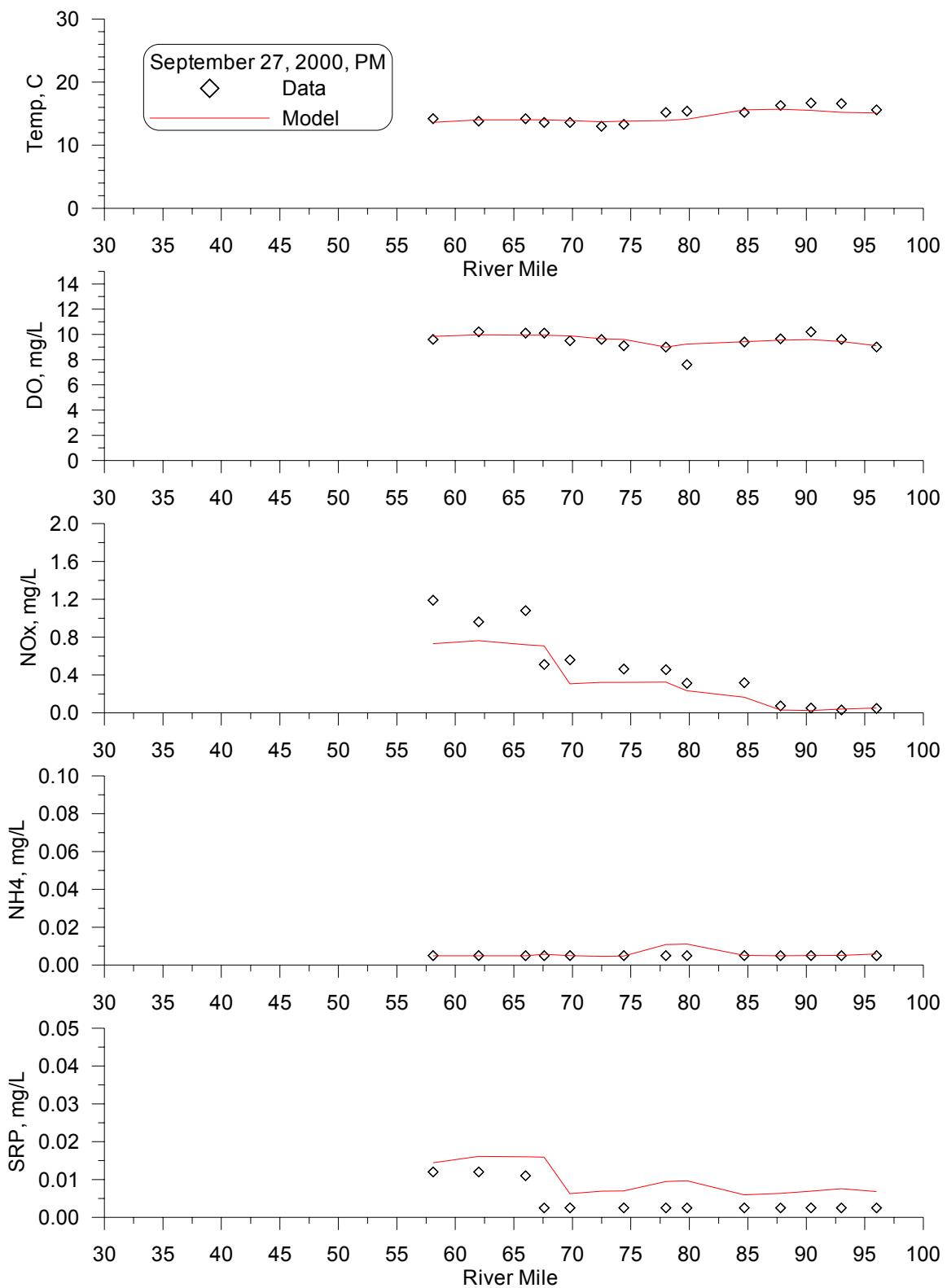


Figure 303. Longitudinal profile, September 27, 2000 PM

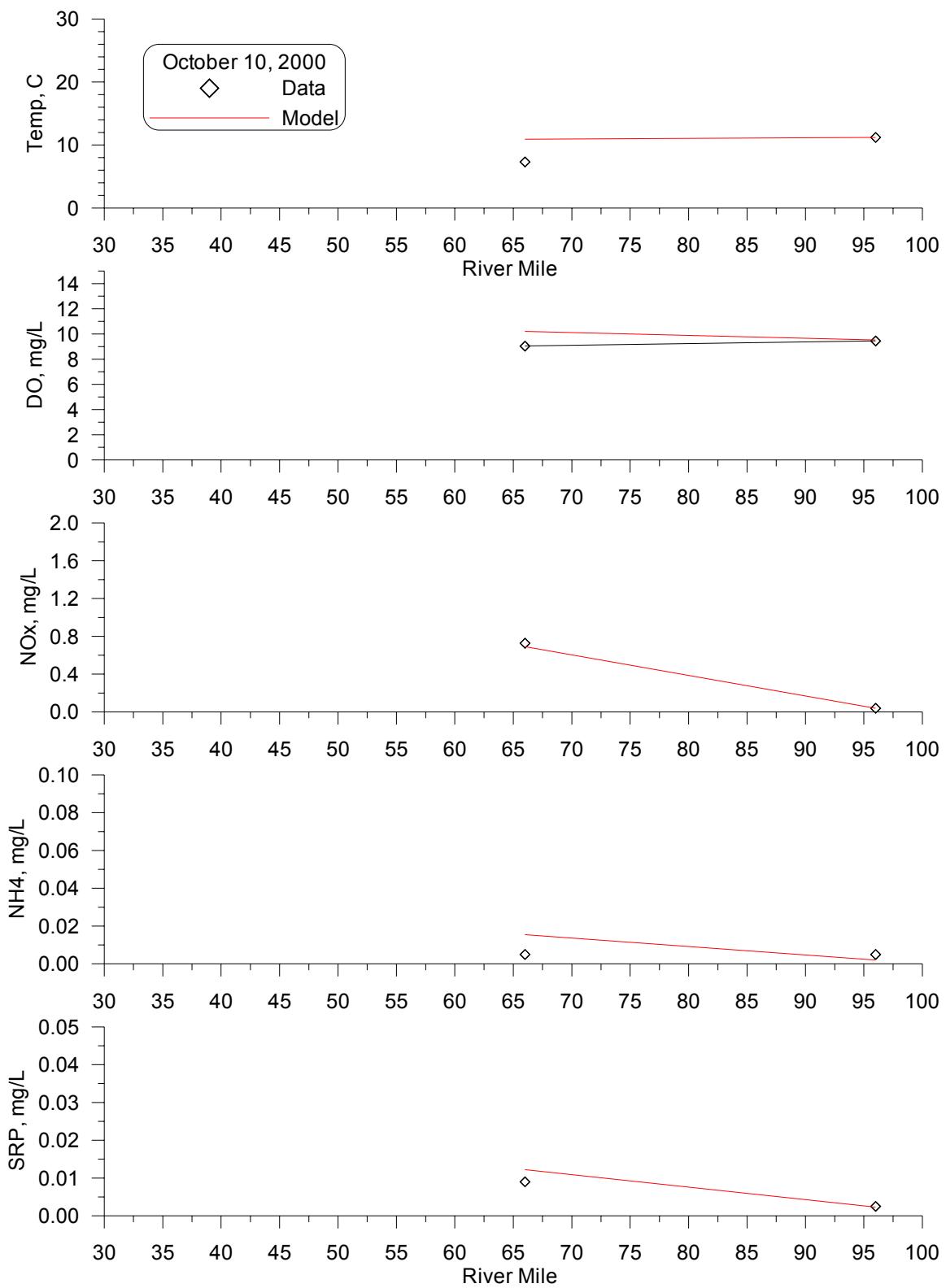


Figure 304. Longitudinal profile, October 10, 2000