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Upper Spokane River Model: Boundary Conditions and Model Setup, 1991 and 2000

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Prepared for the Department of Ecology, Olympia, Washington
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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 location of the region of interest. Figure 2 shows a LANDSAT image of the area, and Figure 3 shows a closer view of 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 (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).

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

- Spokane River flow, water level and water quality data at the upstream system boundary (the State of Idaho boundary)
- Tributary inflows and water quality
- Meteorological conditions
- Bathymetry of the Spokane River, the dam pools along the river, and Long Lake Reservoir
- Point source (wastewater treatment plants, WWTPs) inflows and water quality characteristics

Data have been primarily collected from 1991 to 1992 and again during 2000. This report summarizes the data used in the modeling effort. Information provided in this report was organized in the following sections:

- Previous data gathering and modeling studies in the Spokane River system
- Rationale for using CE-QUAL-W2 Version 3
- Spokane River and Long Lake water quality data
- Model geometry for the Spokane River and reservoirs
- Spokane River flow and water level data
- Meteorological data
- Point Source flow and water quality data
- Tributary inflow and water quality data
- Groundwater flows and water quality data

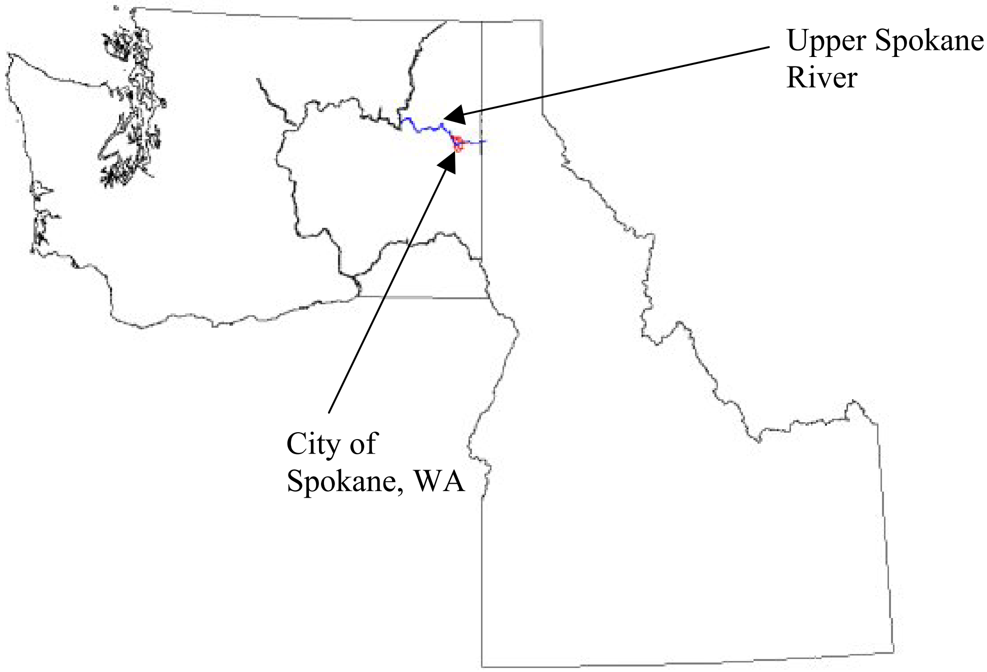


Figure 1. Upper Spokane River in Washington

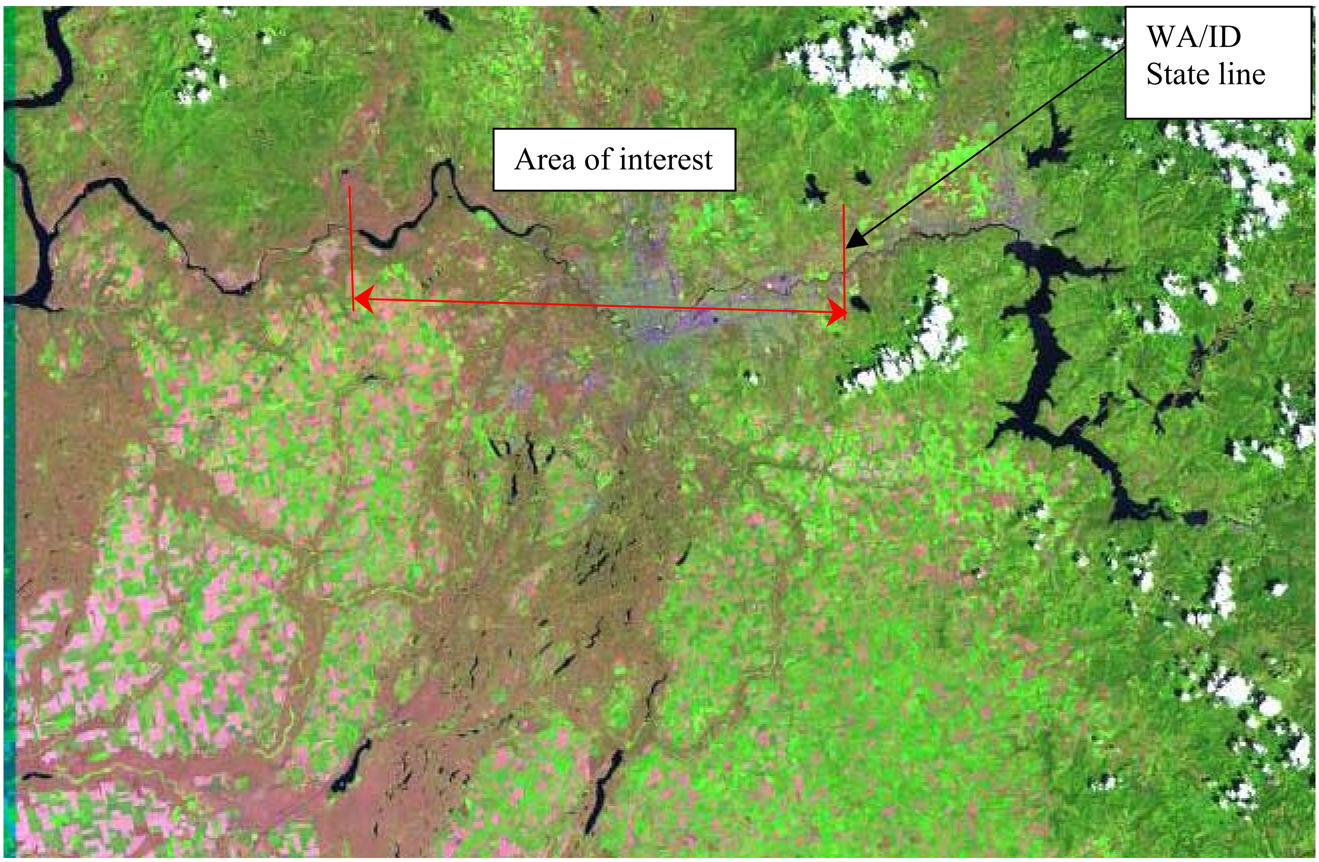


Figure 2. LANDSAT 4 image, June 16, 2000

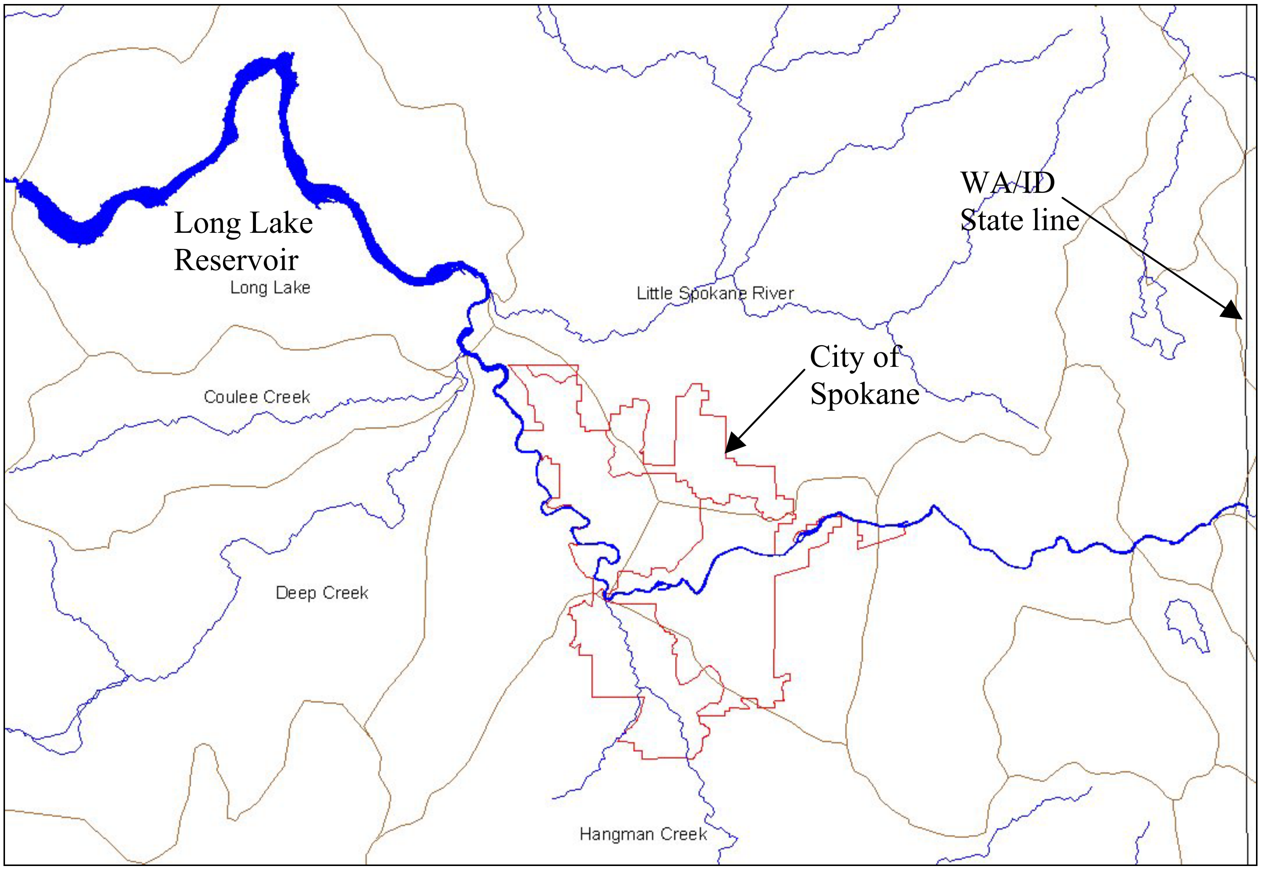


Figure 3. Model domain, WA-ID state line to Long Lake reservoir

Model Selection

Selection of the appropriate water quality model is a function of properly identifying the water quality problem ("conceptualization") and selecting a model which appropriately describes the water quality changes in the water body, is theoretically valid, and can be easily adapted to site-specific physical characteristics of the water body.

The performance of a mathematical model in predicting the existing and future water quality dynamics of a system is dependent on the following steps:

- (i) identification of the problem
- (ii) selection of model type and relationship of model to the problem
- (iii) computational representation
- (iv) model response studies or model sensitivity analyses
- (v) model calibration
- (vi) application of model to evaluate management strategies

Because there are many water quality models available, a choice of the appropriate model would be made after considering the following questions: What physical processes are represented in the model and which are ignored? How are physical processes included in the model? What processes are represented by model coefficients? For example in defining the problem, the following questions could be asked:

(i) What are the dominant physical processes at work and can the chosen model represent those processes? (such as, how does the water move? Is there stratification, wind-driven currents, and/or selective withdrawal?)

(ii) What are the spatial and temporal scales of these processes and can the model represent them? (such as, is steady-state representation adequate, is 1-D, 2-D, or 3-D spatial discretization necessary?)

The choice of the proper model is also based on answering

1. site specific questions (physical characteristics of the each system component - river or reservoir reach, water quality cycles, algal types),
2. management objectives (required accuracy, use for future studies),
3. project resources (data availability, staff constraints, time limitations).

The model chosen for the Spokane River-Long Lake system was the Corps of Engineers model CE-QUAL-W2 Version 3. The Version 2 model was used for Long Lake initially, but this version was not able to simulate the river sections.

CE-QUAL-W2 Version 2 is a dynamic 2-d (x-z) model developed for stratified water-bodies (Cole and Buchak, 1995). This is a Corps of Engineers modification of the Laterally Averaged Reservoir Model (Edinger and Buchak 1978). CE-QUAL-W2, whose grid is shown in Figure 4, consists of directly coupled hydrodynamic and water quality transport models. Hydrodynamic computations are influenced by variable water density caused by temperature, salinity, and dissolved and suspended solids. Developed for reservoirs and narrow, stratified estuaries, CE-QUAL-W2 can handle a branched and/or looped system with flow and/or head boundary conditions. With two dimensions depicted, point and non-point loading can be spatially distributed. Relative to other 2-D models, CE-QUAL-W2 is efficient and cost effective to use. This model allows the user to use the Quickest numerical scheme for constituent transport rather than upwinding.

In addition to temperature, CE-QUAL-W2 Version 2 simulates as many as 20 other water quality variables. Primary physical processes included are surface heat transfer, short-wave and long-wave radiation and penetration, convective mixing, wind and flow induced mixing, entrainment of ambient water by pumped-storage inflows, inflow density stratification as impacted by temperature and dissolved and suspended solids. Major chemical and biological processes in CE-QUAL-W2 include: the effects of DO of atmospheric exchange, photosynthesis, respiration, organic matter decomposition, nitrification, and chemical oxidation of reduced substances; uptake, excretion, and regeneration of phosphorus and nitrogen and nitrification-denitrification under aerobic and anaerobic conditions; carbon cycling and alkalinity-pH-CO_2 interactions; trophic relationships for total phytoplankton; accumulation and decomposition of detritus and organic sediment; and coliform bacteria mortality.

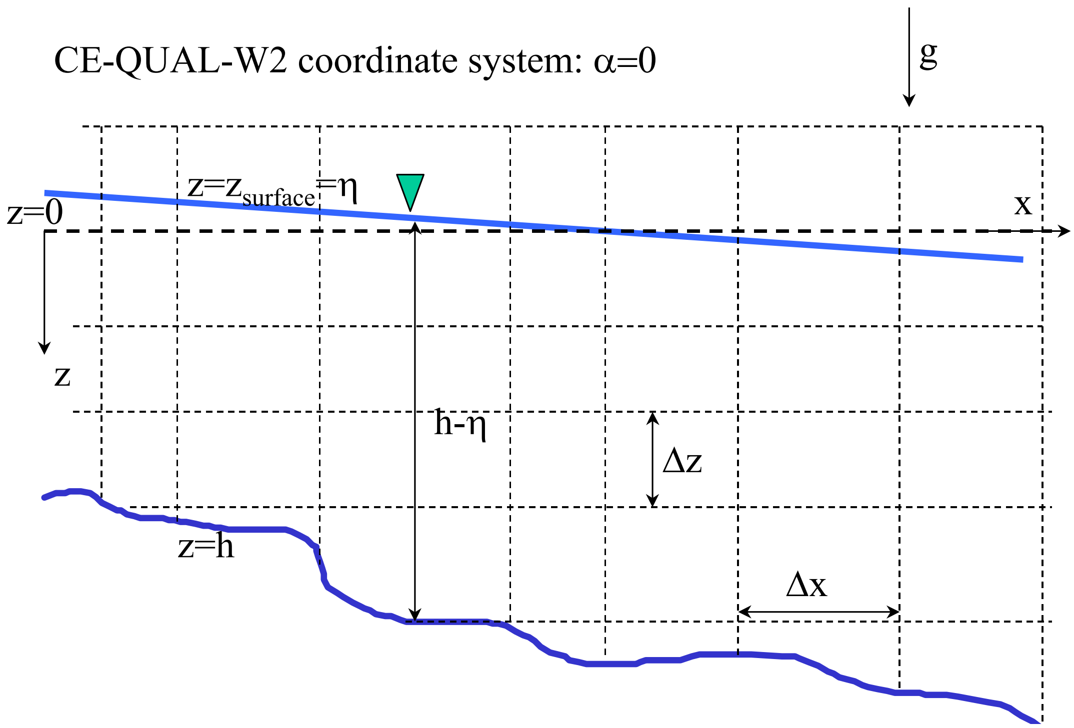


Figure 4. Coordinate system for CE-QUAL-W2 Version 2.

Building on the foundation of Version 2, CE-QUAL-W2 Version 3 is essentially the same as Version 2 except with these following enhancements:

- Ability to specify the channel slope and model sloping river channels in 2-D and use a sloping channel grid (see Figure 5)
- Use of Ultimate Quickest Numerical Scheme for improved numerical accuracy
- Implicit Solution of Vertical Momentum Transfer allowing for water surface solutions in river channels
- Conservation of Longitudinal Momentum at all branch intersections
- Ability to add dams and reservoirs in series with rivers and estuaries
- A user-defined number of water quality model parameters. In addition to Version 2 parameters includes: a user-defined number of algal types, inorganic suspended solids types, dissolved and

particulate silica, labile and refractory particulate organic matter, and arbitrary constituents subject to decay and sedimentation, and BOD groups

- Ability to output numerous model derived variables such as TKN, TSS, TOC that can be compared directly to field data
- In addition to existing sediment oxygen demand and first order sediment decay model, there will be an option to model complex sediment diagenesis
- Choice of model reaeration coefficients and evaporation formulae based on water body type
- Model kinetic coefficients are now variable as a function of water body
- Ability to add hydraulic structures between model branches such as weirs, spillways, pipes, gates, and float-activated pumps
- All withdrawals now use selective withdrawal theory to compute the outflow distribution

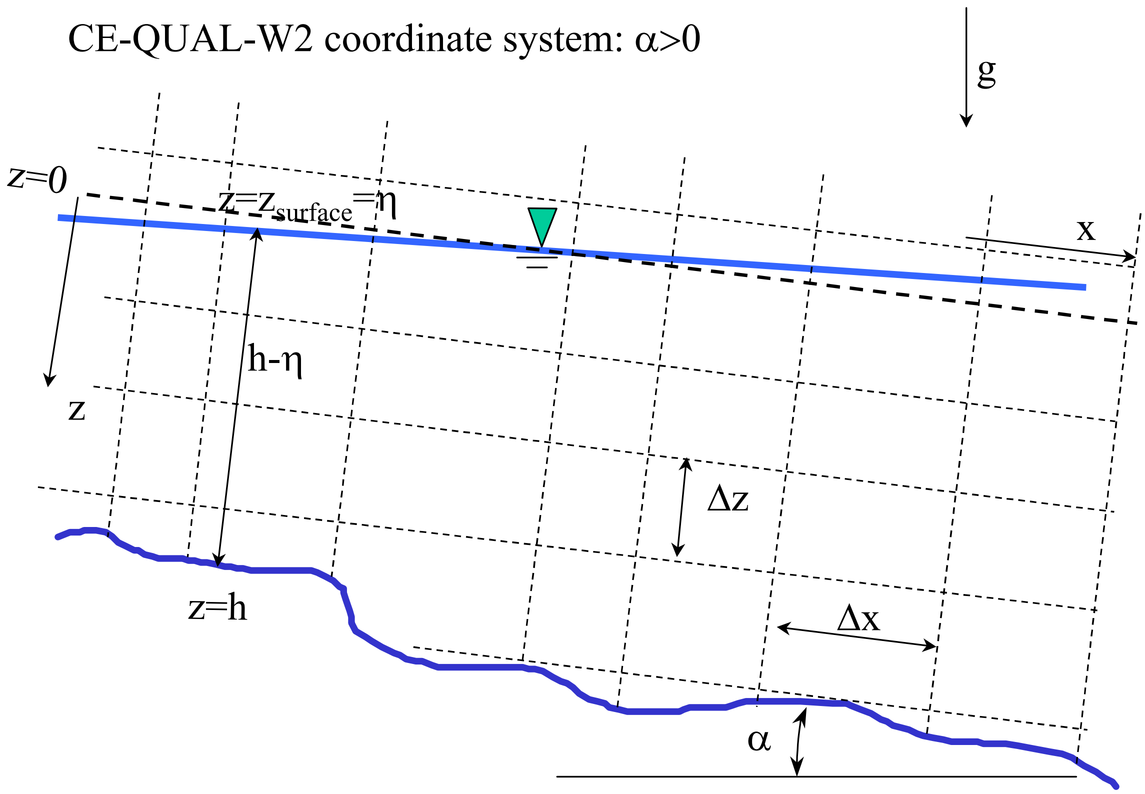


Figure 5. Coordinate system for CE-QUAL-W2 Version 3.

Models, such as WQRSS (Smith 1978), HEC-5Q (Corps of Engineers 1986), and HSPF (Donigian, et al. 1984), have been developed for river basin modeling but have serious limitations. One issue is that the HEC-5Q (similar to WQRSS) and HSPF models incorporate a one-dimensional, longitudinal river model with a one-dimensional, vertical reservoir model (one-dimensional for temperature and water quality and zero dimensional for hydrodynamics). The modeler must choose the location of the transition from 1-D longitudinal to 1-D vertical. Besides the limitation of not solving for the velocity field in the stratified, reservoir system, any point source inputs to the reservoir section are spread over the entire longitudinal distribution of the reservoir layer.

Also, other one-dimensional reservoir models, such as the HEC WQRRS (Water Quality River-Reservoir Simulation) model and the Corps's CE-QUAL-R1, are also not adequate to compute 2-D circulation within reservoir systems. These models conceptualize the reservoir as well mixed in each horizontal slab, i.e., over the length and the width of the system. By making this assumption, the vertical and longitudinal circulation patterns within a reservoir cannot be resolved.

Based on the reservoir field data, a one-dimensional reservoir model of the reservoir system would not be adequate because of both longitudinal and vertical gradients in water quality. Also, because the reservoirs in the Spokane River system are very narrow, lateral homogeneity can be assumed without loss of resolution.

The advantages of CE-QUAL-W2 Version 3 to other river models were illustrated in Wells (1999) where one primary advantage of CE-QUAL-W2 was that the Manning's friction factor did not need to be varied as the river stage increased.

For this project, the CE-QUAL-W2 River Basin Model Version 3 (as schematized in Figure 6) is proposed as the most appropriate for modeling the Spokane River-Long Lake River Basin system since it contains the following elements:

- Two-dimensional, dynamic hydrodynamics and water quality capable of replicating the density stratified environment that exists in Long Lake and some of the other reservoirs along the Spokane River
- Multiple CBOD groups assures that each WWTP discharge is decaying according to its own appropriate decay rate
- The model can be extended by Washington Department of Ecology (DOE) to model the entire Spokane basin including that part of the basin in Idaho including Coeur D'Alene Lake
- The hydraulic elements of the dams along the Spokane River (spillways, gates, and weirs) can be accurately represented
- The model is a state-of-the-art tool with features not found in other models
- The model has a seamless linkage between the river and reservoir

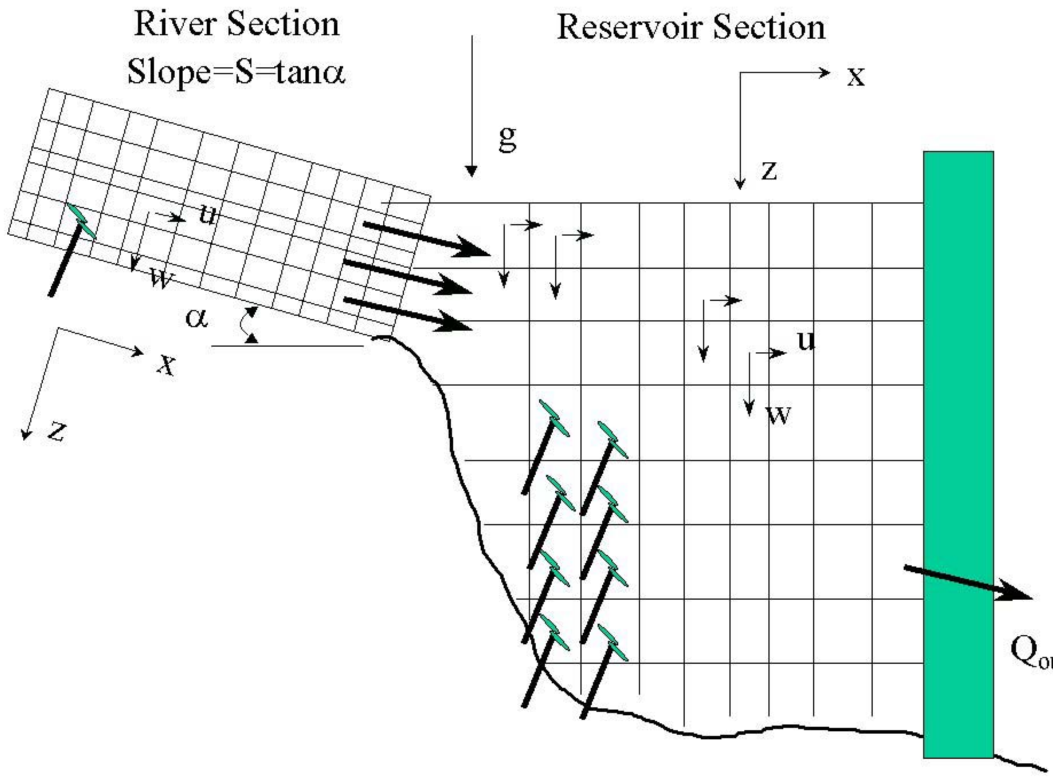


Figure 6. **Conceptual schematic of river-reservoir connection in CE-QUAL-W2 Version 3.**

This model has been under development for many years and is a public-domain code maintained by the Corps of Engineers, Waterways Experiments Station (WES), located in Vicksburg, Mississippi. The current version, Version 2 (Cole and Buchak, 1995), has been superceded by Version 3 developed by WES and Wells (1997). Version 3 has and is undergoing rigorous testing and has been successfully applied to many river basin systems. Further information about CE-QUAL-W2 Version 3 is shown at http://www.ce.pdx.edu/w2.

Water Quality Data

Water quality data were provided primarily by the Washington State Department of Ecology (DOE). Additional flow, temperature and water quality data were provided by the USGS in WA and ID, a discharger along the Spokane River and operators of some of the dam facilities. The majority of the data were collected from Febraury1991 to January 1992 and January 2000 to December 2000. These data were stored in several Microsoft Access databases. Figure 7 shows a map of the upper Spokane region with all of the water quality monitoring sites identified. Figure 8 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 9. Spokane River monitoring sites just below and above the Upriver dam facilities are shown in Figure 10. Figure 11 shows the remaining monitoring sites above Upriver dam to the state line with Idaho. Table 1 has a list of 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.

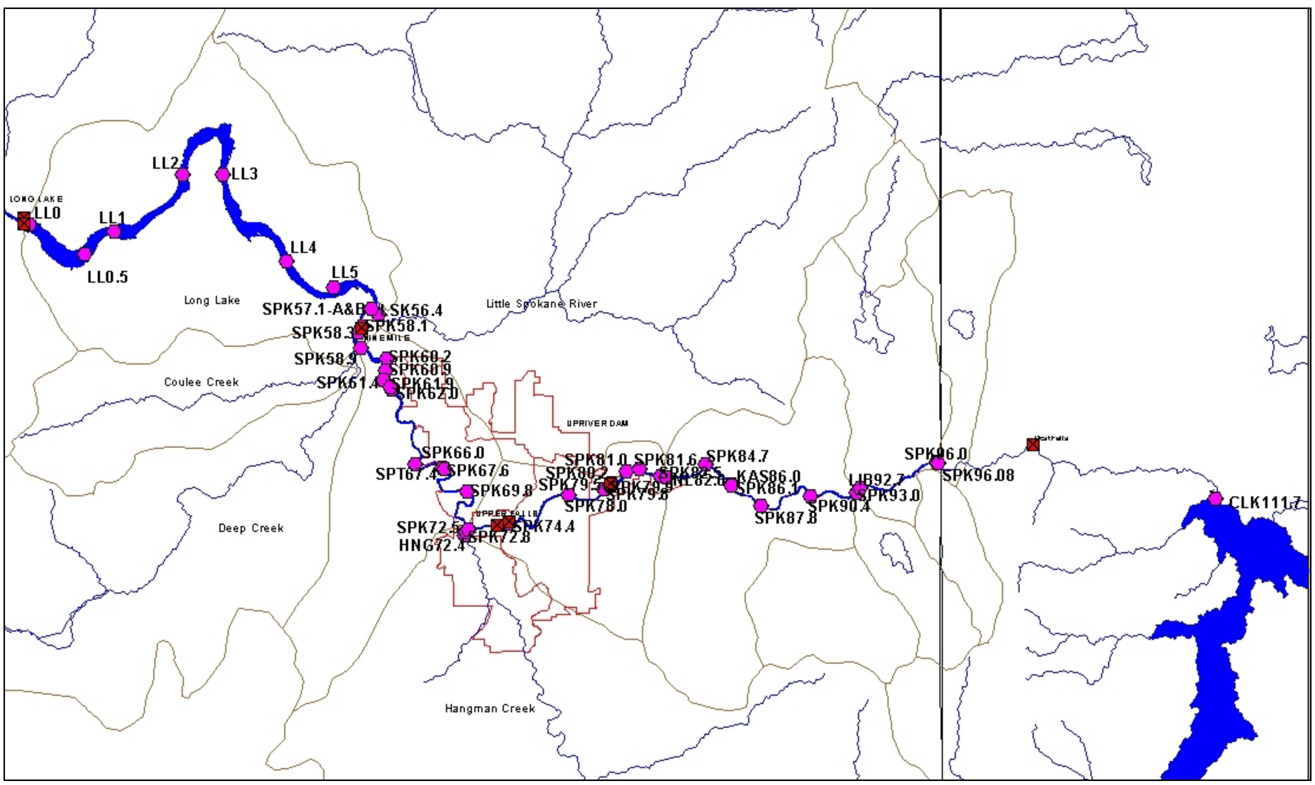


Figure 7. Water quality monitoring sites along the Spokane River and Long Lake reservoir

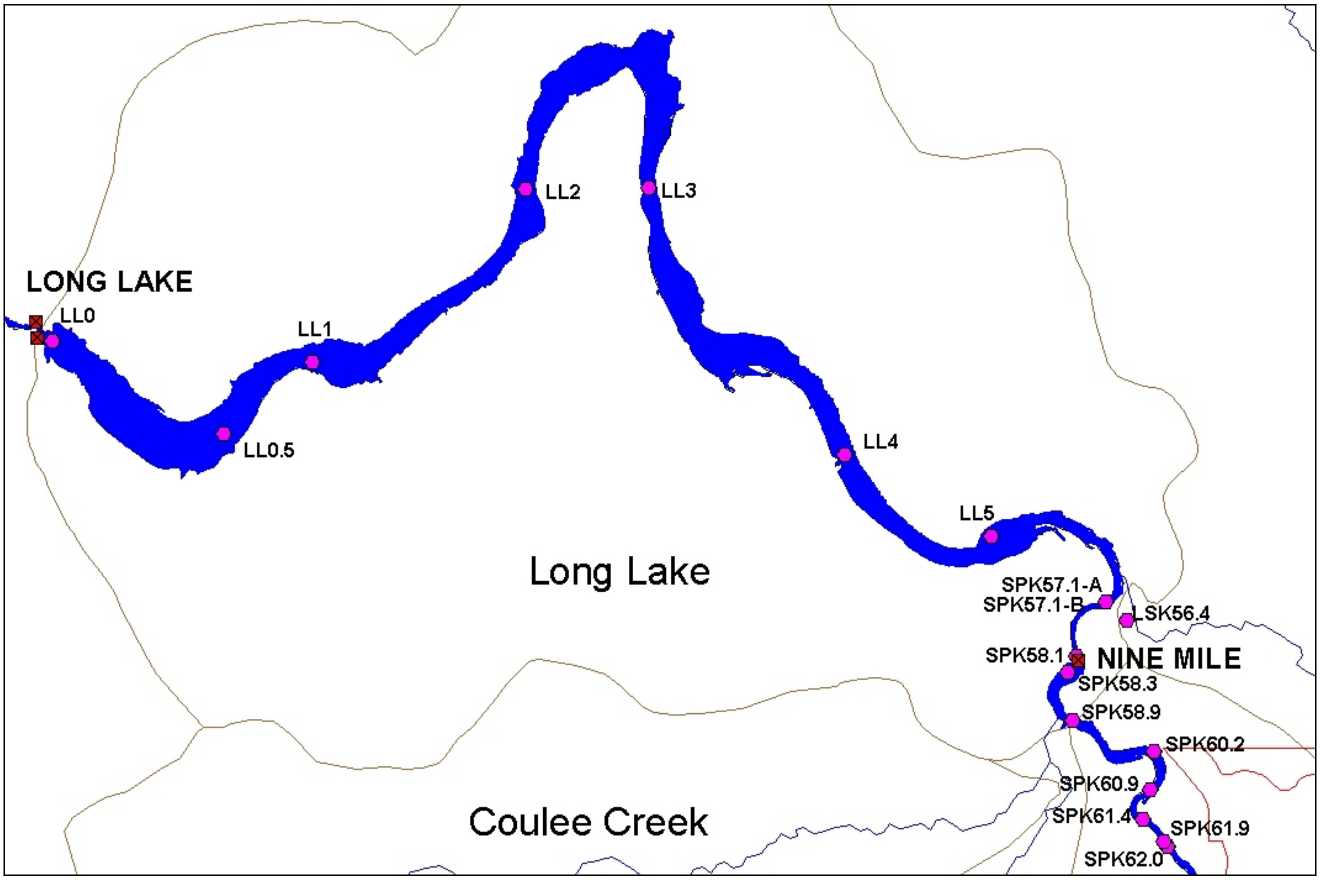


Figure 8. Water quality monitoring sites at Long Lake Reservoir

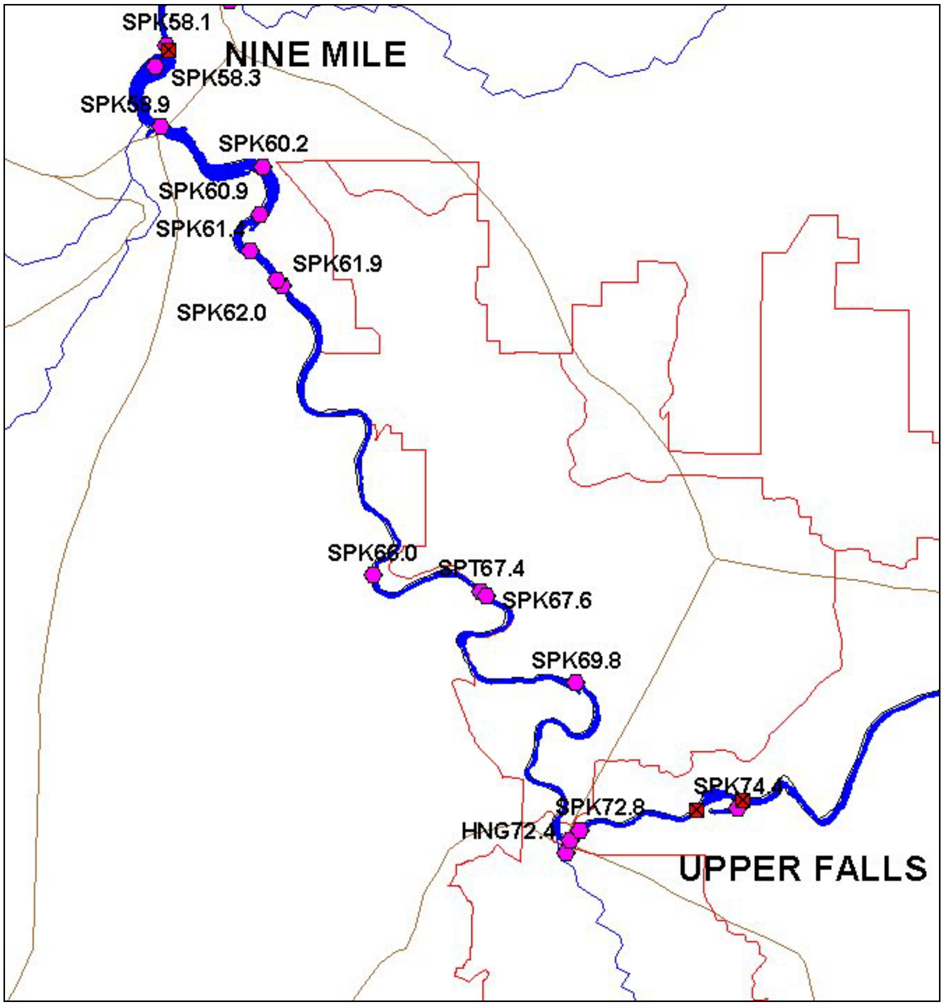


Figure 9. Water quality monitoring sites along Nine Mile Reservoir

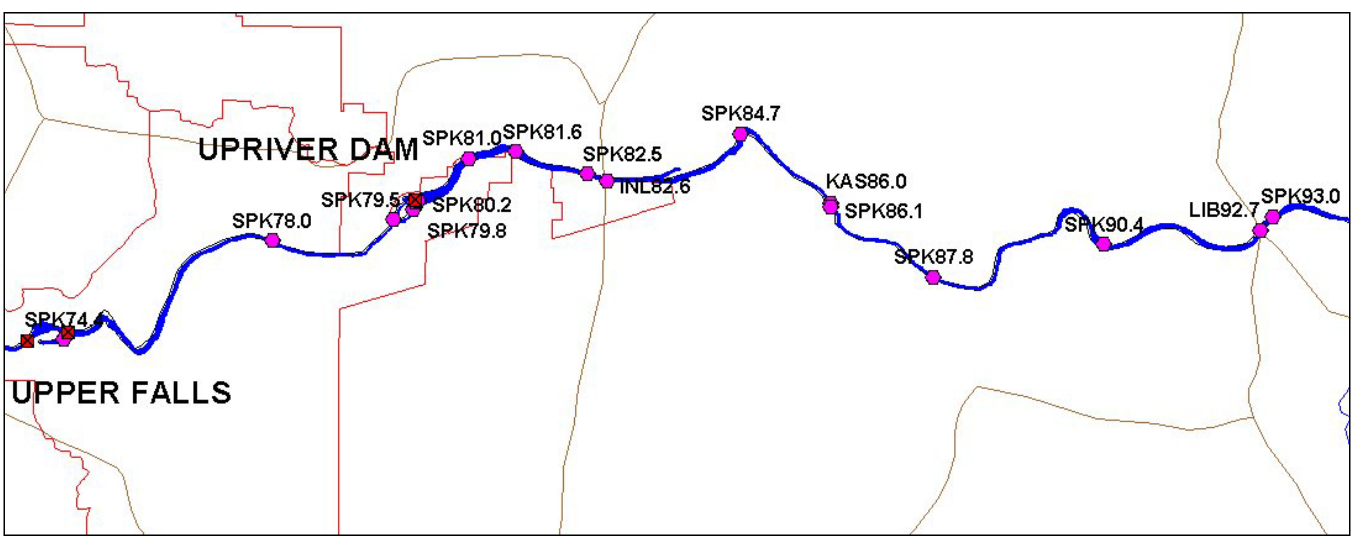


Figure 10. Water quality monitoring sites along the Spokane River near Upriver Dam

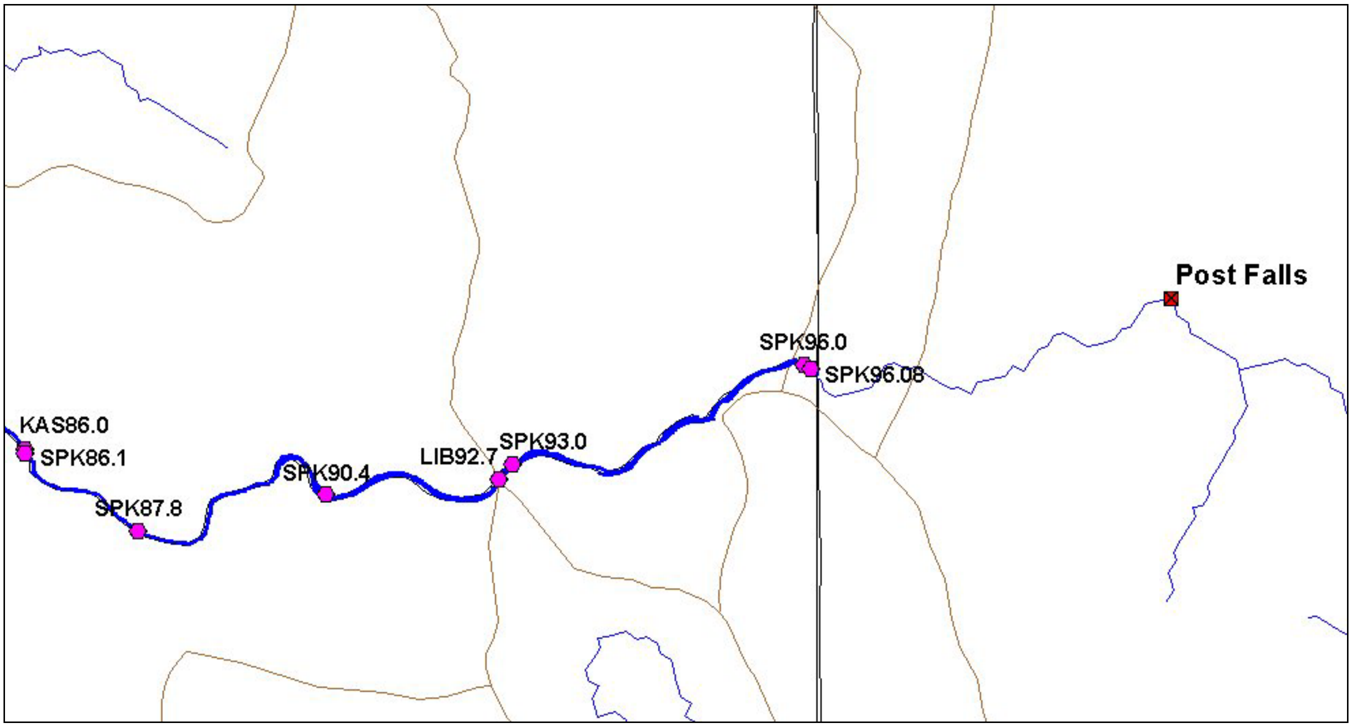


Figure 11. Water quality monitoring sites near the WA-ID state line

Table 1. 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

Table 1. Water Quality Monitoring sites		
Site ID	**Description**	**RM**
SPK79.5	Downstream of Upriver Dam Powerhouse	79.50
SPK79.8	Spokane R Upstream Upriver Dam Powerhouse	79.80
SPK79.9	Spokane River 0.1 mi above Upriver Dam	79.90
SPK80.2	Spokane River 0.4 mi above Upriver Dam	80.20
SPK81.0	Spokane River 1.2 mi above Upriver Dam	81.00
SPK81.6	Spokane River 1.8 mi above Upriver Dam	81.60
SPK82.5	Spokane River 2.7 mi above Upriver Dam	82.50
INL82.6	Inland Empire Paper Co discharge	82.60
SPK84.7	Spokane R Foot Bridge @ Plantes Ferry Park	84.70
KAS86.0	Kaiser Aluminum	86.00
SPK86.1	Spokane R Upstream Kaiser IWTP	86.10
SPK87.8	Spokane R @ Sullivan Rd. Bridge	87.80
SPK90.4	Spokane R @ Barker Rd. Bridge	90.40
LIB92.7	Liberty Lake WTP	92.70
SPK93.0	Spokane R @ Harvard Rd. Bridge	93.00
SPK96.08	Spokane River about 400 feet upstream of Stateline Bridge.	96.40
CLK111.7	Lake Coeur d'Alene outlet	111.70

Longitudinal Profiles in 1991

In 1991 grab samples were collected along the length of the Spokane River between the state line and Long Lake dam. Table 2 shows the list of the water quality constituents monitored from the grab samples collected and plotted in longitudinal profiles. Figure 12 shows an example of one longitudinal plot for water temperature. The figure also includes another plot indicating the location of specific features such as the location of incoming tributaries, discharges and breaks in the river geometry. Additional figures for the remaining constituents listed in Table 2 can be found in Appendix A: 1991 Longitudinal Profiles.

Table 2. Longitudinal profile constituents plotted, 1991			
Constituent	**Constituent Name**	**Constituent**	**Constituent Name**
Temp	Temperature, C	Turb	Turbidity, NTU
Conductivity	Conductivity, umhos/cm	TSS	Total Suspended Solids, mg/L
PH	pH	Fecal Coliform	Fecal Coliform MPN/100 ml
DO	Dissolved Oxygen, mg/L	Chl a	Chlorophyll a, ug/L
NO3	Nitrate, mg/L	HCO3	Carbonate, mg/L
NO2	Nitrite, mg/L	Ca	Calcium, mg/L
NH4	Ammonium	Mg	Magnesium, mg/L
TKN	Total Kheldal Nitrogen, mg/L	Na & K	Sodium and Potassium, mg/L
TON	Total Organic Nitrogen	Cl	Chloride, mg/L
SRP	Soluble Reactive Phosphorus, mg/L	SO4	Sulfate, mg/L
TP	Total Phosphorus, mg/L	SiO2	Silicon Dioxide, mg/L
TOP	Total organic		

Table 2. Longitudinal profile constituents plotted, 1991			
Constituent	**Constituent Name**	**Constituent**	**Constituent Name**
	Phosphorus, mg/L		

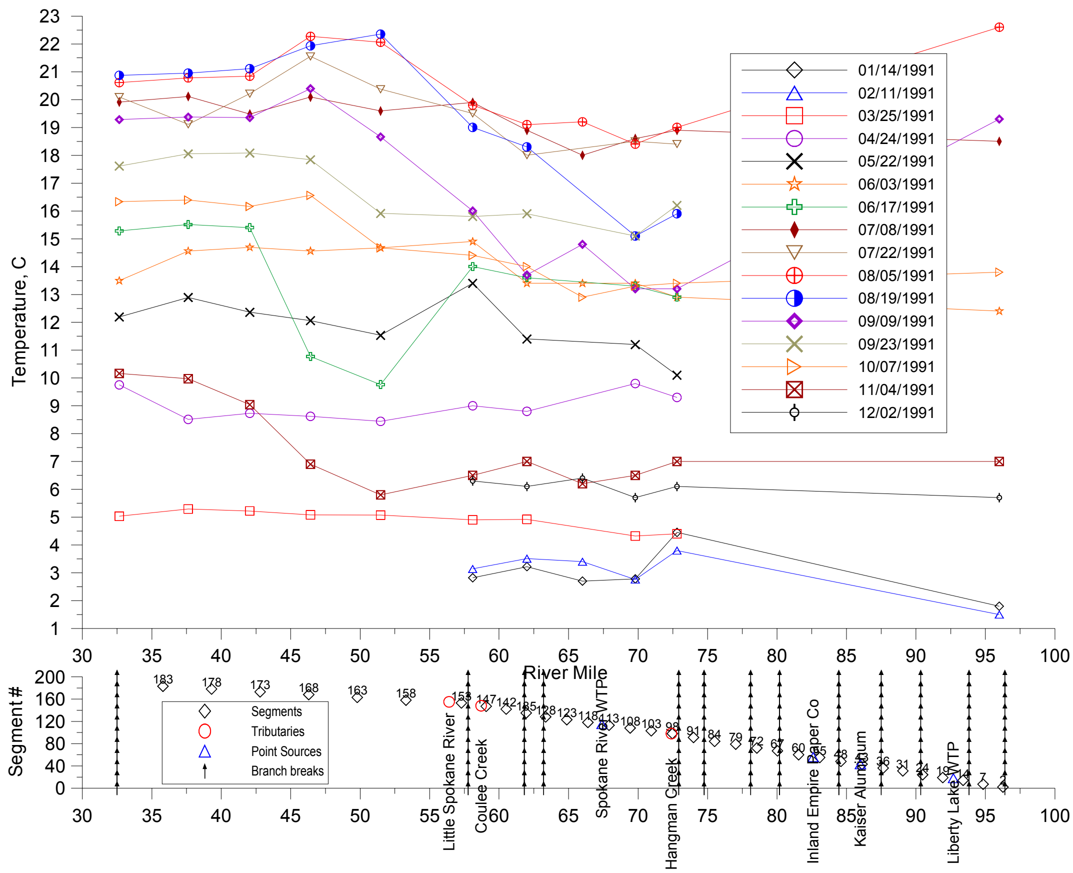


Figure 12. Temperature longitudinal profile, 1991

Long Lake Vertical Profiles in 1991

In addition to grab samples collected in 1991, vertical profiles were also collected in Long Lake. The vertical profiles were collected at several locations in the lake on a given day and then repeated for several days over the course of the year. Table 3 indicates a list of the water quality constituents monitored in the vertical profiles, and Figure 13 shows an example of the water temperature profiles taken in Long Lake on March 25, 1991. Vertical profiles for additional dates and water quality constituents can be found in Appendix C: 1991 Long Lake Vertical Profiles.

Table 3. Long Lake vertical profile constituents plotted, 1991			
Constituent	**Constituent Name**	**Constituent**	**Constituent Name**
Temp	Temperature, C	NH4	Ammonium
Conductivity	Conductivity, umhos/cm	SRP	Soluble Reactive Phosphorus, mg/L
pH	pH	TP	Total Phosphorus, mg/L

Table 3. Long Lake vertical profile constituents plotted, 1991			
Constituent	**Constituent Name**	**Constituent**	**Constituent Name**
DO	Dissolved Oxygen, mg/L	TOP	Total organic Phosphorus, mg/L
NO3	Nitrate, mg/L	Turb	Turbidity, NTU
NO2	Nitrite, mg/L		

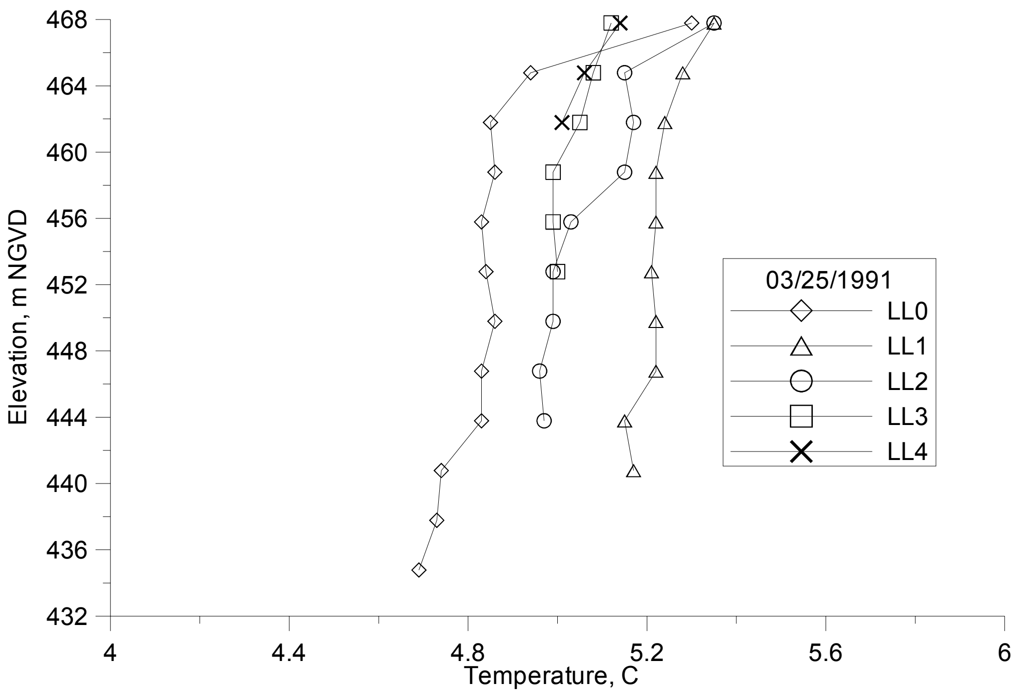


Figure 13. Temperature vertical profile in Long Lake

Longitudinal Profiles in 2000

Grab samples were collected throughout 2000 at many locations along the Spokane River and included the constituents listed in Table 4. Similar to figures for 1991, Figure 14 shows a longitudinal temperature profile for water temperature and indicates the location of tributaries, dischargers and breaks in the channel geometry. Additional longitudinal profiles for the remaining water quality constituents can be found in Appendix B: 2000 Longitudinal Profiles.

Table 4. Longitudinal profile constituents plotted, 2000			
Constituent	**Constituent Name**	**Constituent**	**Constituent Name**
Temp	Temperature, C	Turb	Turbidity, NTU
Conductivity	Conductivity, μmhos/cm	TSS	Total Suspended Solids, mg/L
PH	pH	Fecal Coliform	Fecal Coliform MPN/100 ml
DO	Dissolved Oxygen, mg/L	ALK	Alkalinity, mg/L
NO3-NO2	Nitrate-Nitrite, mg/L	TDS	Total Dissolved Solids, mg/L
NH4	Ammonium	Cl	Chloride, mg/L

Table 4. Longitudinal profile constituents plotted, 2000			
Constituent	**Constituent Name**	**Constituent**	**Constituent Name**
TPN	Total Persulfate Nitrogen, mg/L	TOC	Total Organic Carbon, mg/L
TON	Total Organic Nitrogen	DOC	Dissolved Organic Carbon, mg/L
SRP	Soluble Reactive Phosphorus, mg/L	BOD	Biochemical Oxygen Demand, 5 day, mg/L
SRP (uncensored)*	Soluble Reactive Phosphorus (uncensored), mg/L	CBODu	Ultimate Carbonaceous Biochemical Oxygen Demand, mg/L
TP	Total Phosphorus, mg/L	Chl a	Chlorophyll a, ug/L
TOP	Total organic Phosphorus, mg/L		
* Uncensored values are results that are below the laboratory reporting limit			

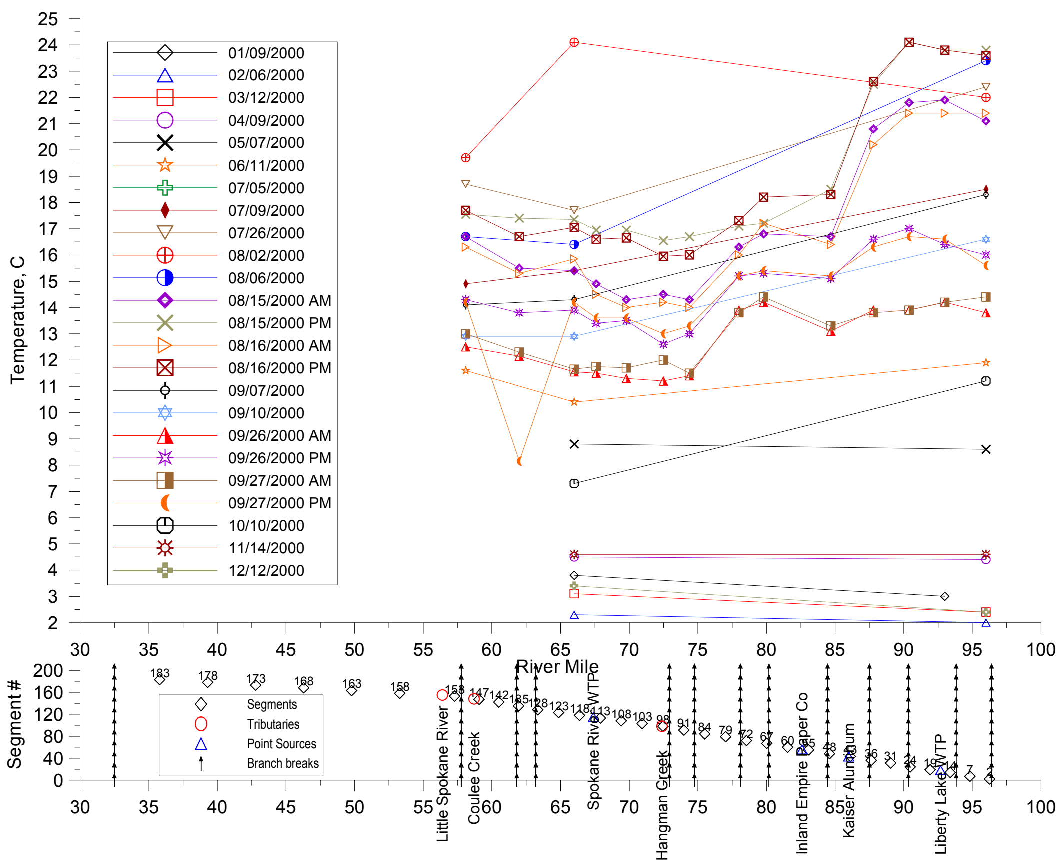


Figure 14. Temperature longitudinal profile, 2000

Long Lake Vertical Profiles in 2000

Vertical profiles were collected in Long Lake in 2000. The constituents monitored in the lake are listed in Table 5 and Figure 15 provides an example of water temperature vertical profiles collected on August

16, 2000. Additional vertical profiles for the remaining constituents can be found in Appendix D: 2000 Long Lake Vertical Profiles.

Table 5. Long Lake vertical profile constituents plotted, 2000			
Constituent	**Constituent Name**	**Constituent**	**Constituent Name**
Temp	Temperature, C	SRP (uncensored)	Soluble Reactive Phosphorus (uncensored), mg/L
Conductivity	Conductivity, umhos/cm	TP	Total Phosphorus, mg/L
PH	pH	TOP	Total organic Phosphorus, mg/L
DO	Dissolved Oxygen, mg/L	ALK	Alkalinity, mg/L
NO3-NO2	Nitrate-Nitrite, mg/L	TDS	Total Dissolved Solids, mg/L
NH4	Ammonium	Cl	Chloride, mg/L
TPN	Total Persulfate Nitrogen, mg/L	TOC	Total Organic Carbon, mg/L
TON	Total Organic Nitrogen	DOC	Dissolved Organic Carbon, mg/L
SRP	Soluble Reactive Phosphorus, mg/L	Chl a	Chlorophyll a, ug/L

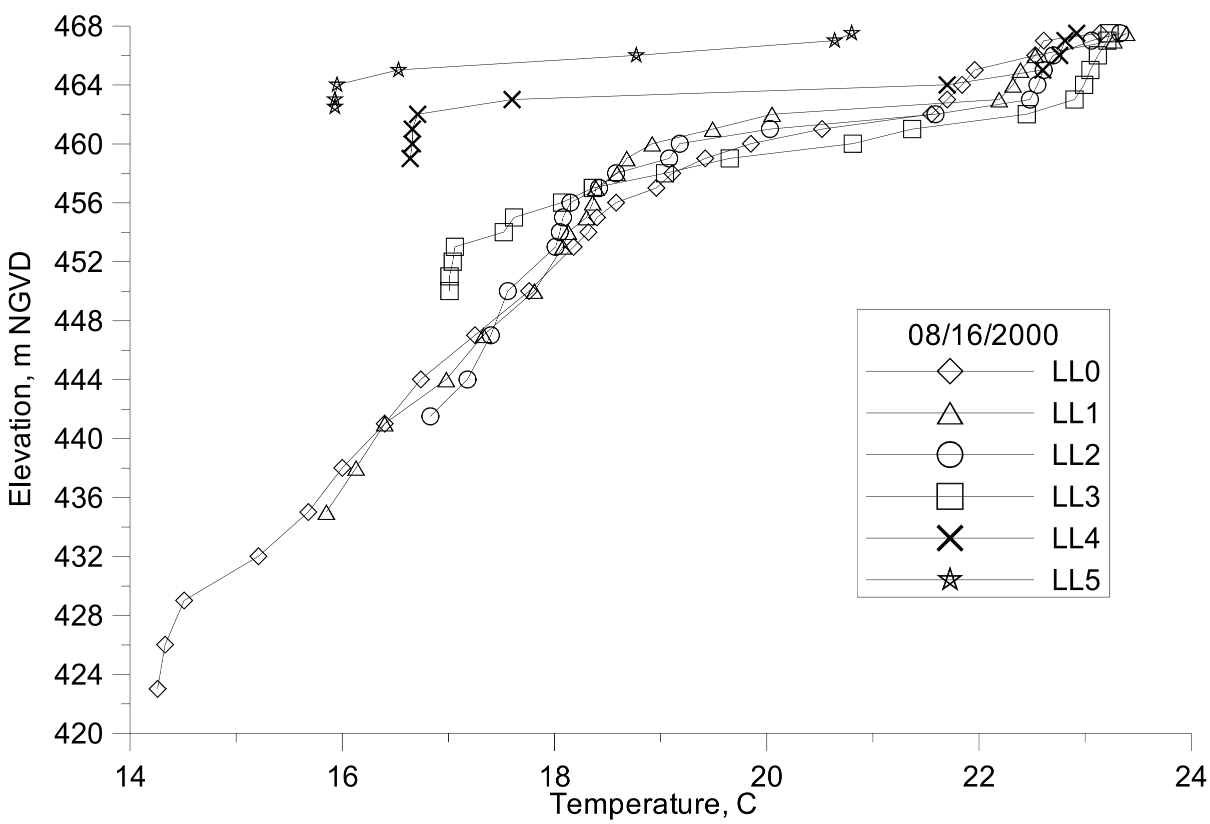


Figure 15. Temperature vertical profile in Long Lake, 2000

Spokane River Vertical Profiles in 2000

Unlike in 1991 vertical profiles were also collected at several other locations along the Spokane River in 2000. Vertical profiles were collected in the pools behind Upriver dam and Nine Mile dam as indicated for water temperature in Figure 16 and Figure 17, respectively. Table 6 shows a list of the additional constituents monitored in the vertical profiles. The remaining profiles can be found in Appendix E: 2000 Spokane River Vertical Profiles.

Table 6. Spokane River vertical profile constituents plotted, 2000

Constituent	Constituent Name
Temp	Temperature, C
Conductivity	Conductivity, umhos/cm
pH	pH
DO	Dissolved Oxygen, mg/L

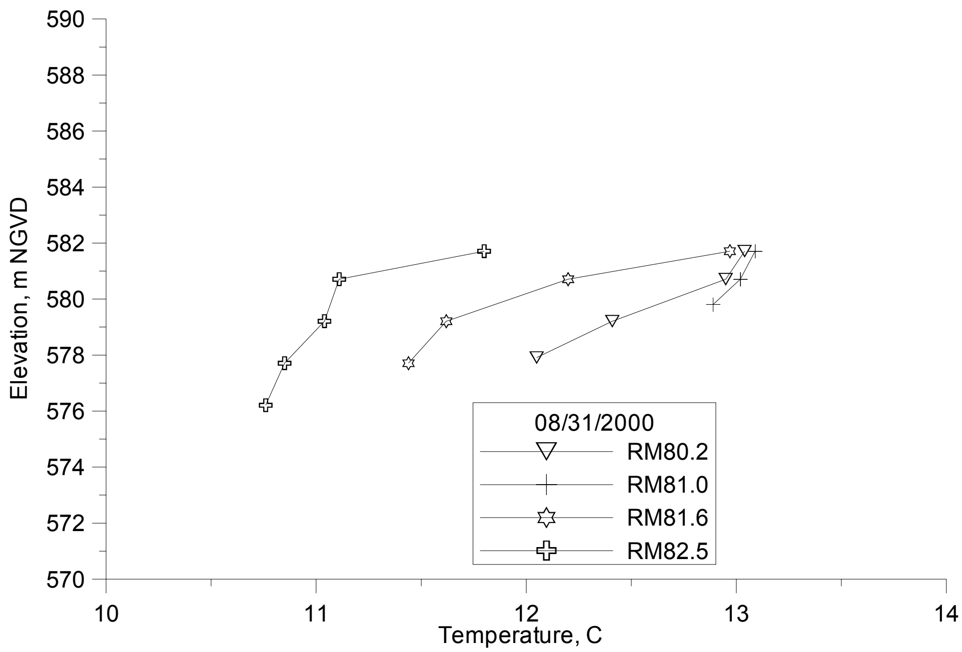


Figure 16. Upriver Dam Pool temperature profile, 2000

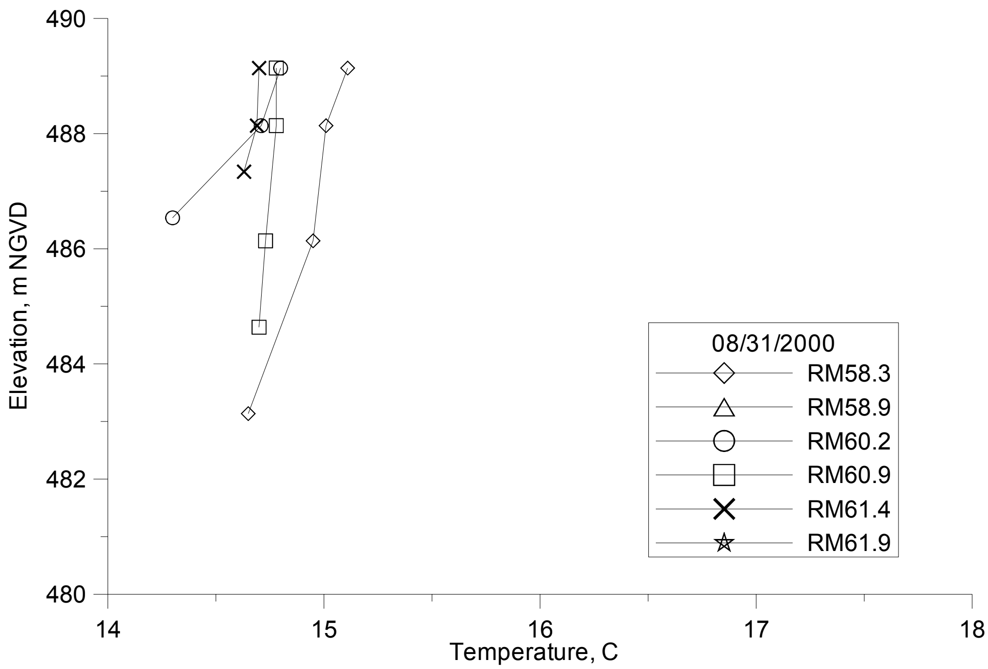


Figure 17. Nine Mile Dam Pool temperature profile, 2000

Model Forcing Data

The model forcing data consist of the system bathymetry developed into the model grid; the boundary condition flow, temperature and water quality; the tributary and discharger flow, temperature and water quality; the groundwater flow, temperature, and water quality; and the meteorological forcing data.

Model Geometry

Spokane River Bathymetry

The bathymetry for the system was developed separately for the 39.2 miles of the Spokane River between the Washington-Idaho state line and Long Lake and Long Lake itself as shown in Figure 18. Figure 19 shows the sites where river cross-sections were taken along the Spokane River upstream of Long Lake.

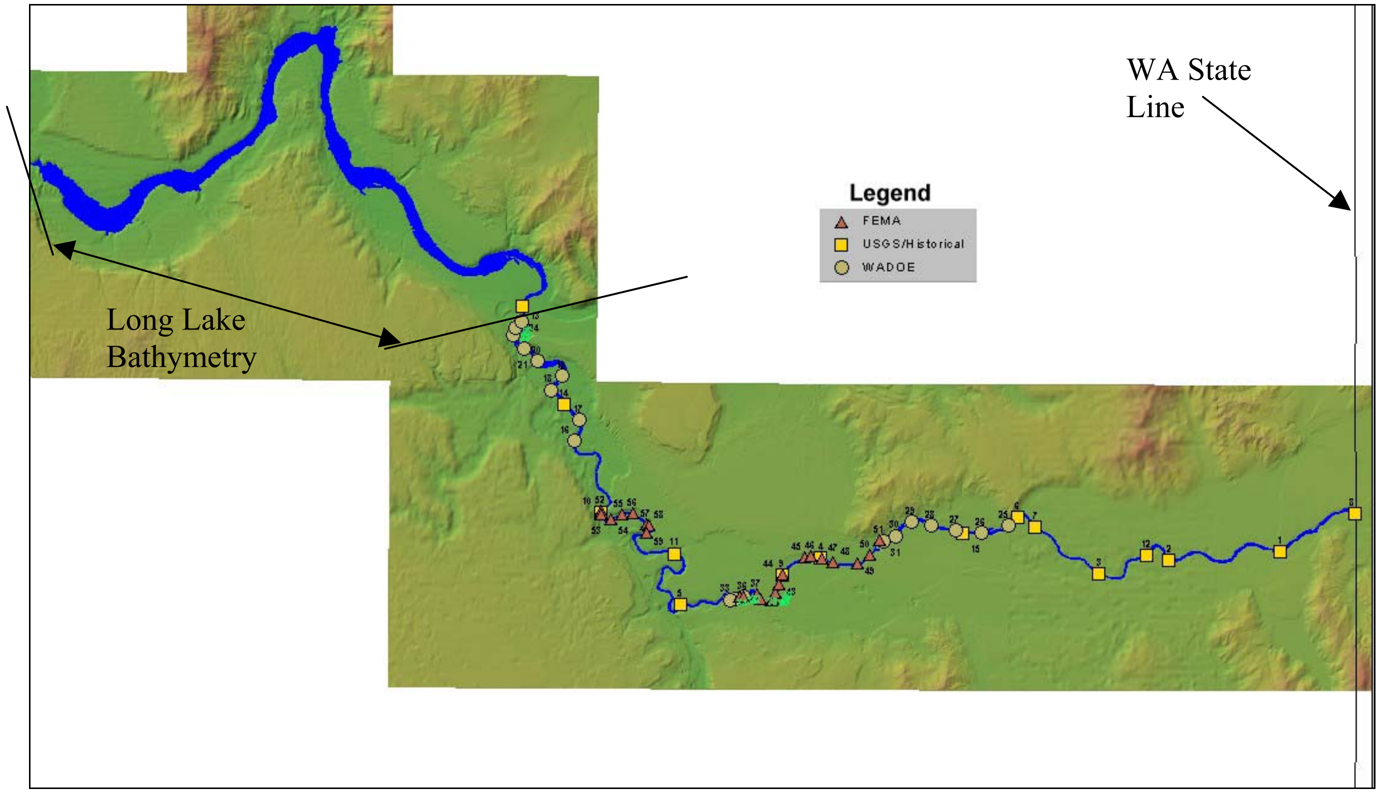


Figure 18. Model Domain

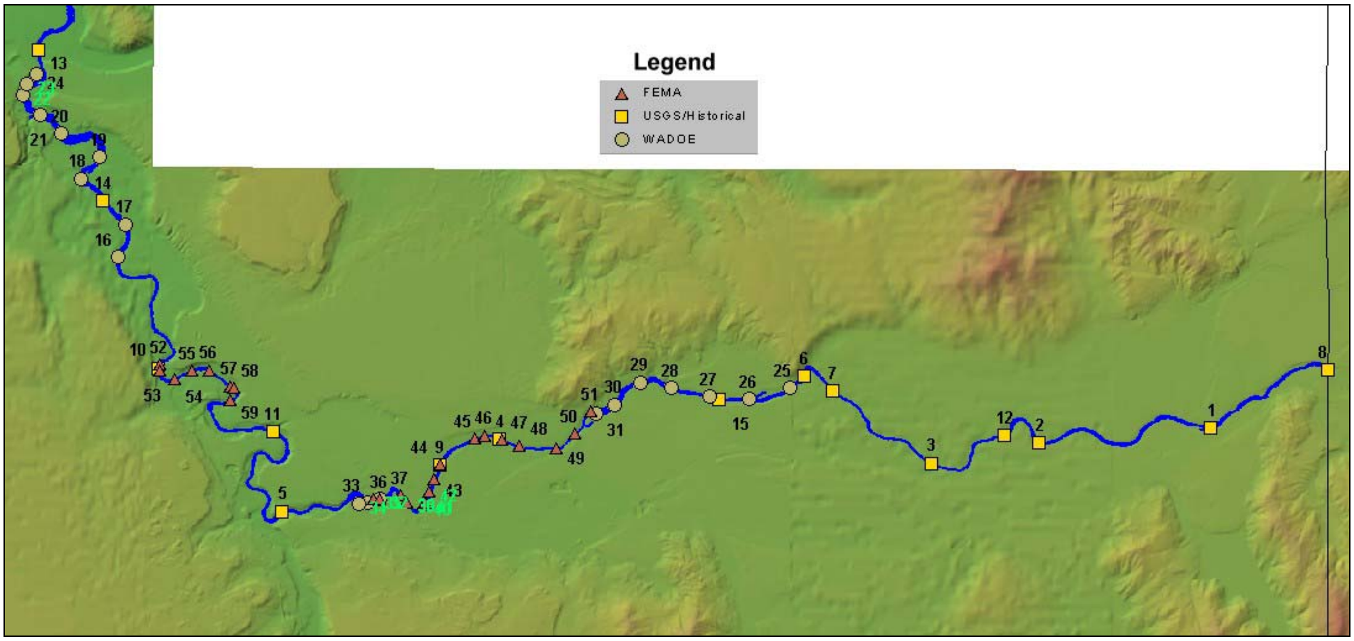


Figure 19. Spokane River between the state line and Long Lake

Two sources of data were used to develop the bathymetry for the Spokane River. Figure 20 shows the Digital Elevation Model (DEM) for the area with a resolution of 30 m in the horizontal direction and 1 m in vertical direction. A buffer area around the river of 400 m was identified and used to trim the DEM. The elevation information within this area was extracted from GIS to x, y and z coordinates (UTM). These data included elevations in the river itself, representing the water surface elevation.

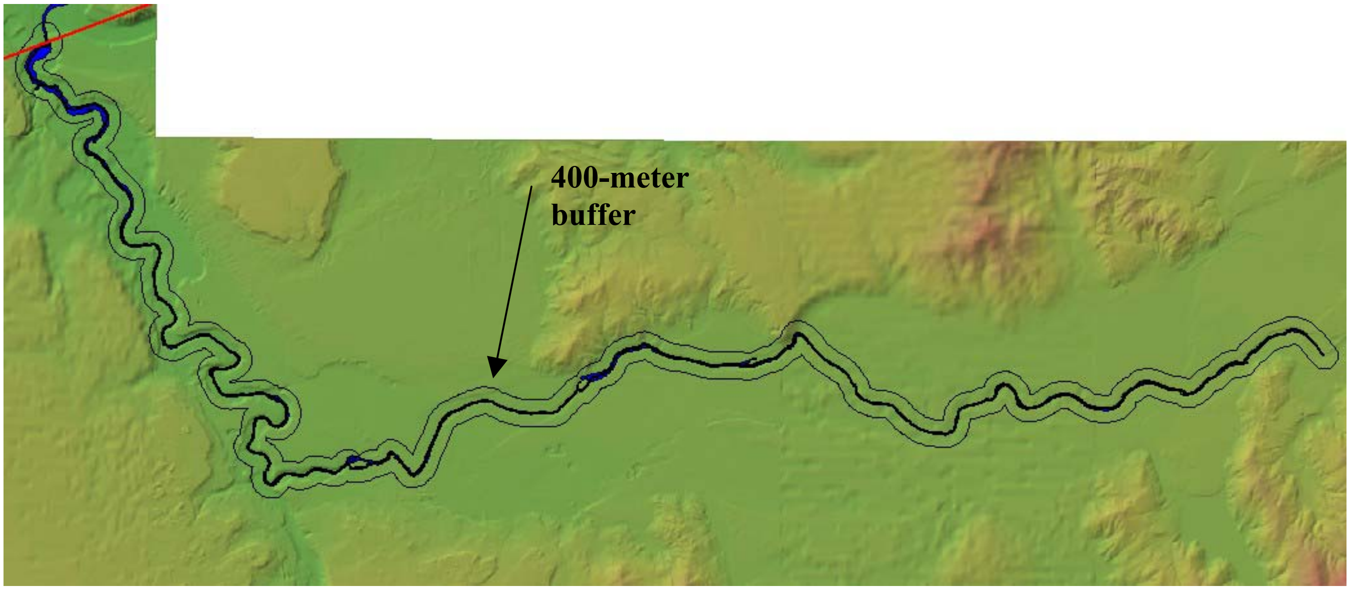


Figure 20. DEM information 400 m away from centerline of river.

River cross sections were identified and mapped in GIS as shown in Figure 19. Figure 21 to Figure 23 show the locations of the cross section data for several reaches of the Spokane River. Each cross section is marked with an number in the figures, which correspond to their listing in Table 7. Some of the cross sections were relatively recent and came from U.S. Geological Survey (USGS) with elevation reference information (Legend: USGS/Historical). Some of the cross sections had little or no elevation reference information. Reference elevations for these cross sections were identified by either using known elevation points or elevation contours near the cross section. The WA Dept of Ecology (Legend: WADOE) collected additional cross sections. A final set of cross sections was obtained from a FEMA flood study conducted in the 1970s, FEMA (1980) (Legend: FEMA). The river mile, a site description, and the left and right banks for each cross section were then identified. Figure 24 shows the location of cross section number 51 below the Upriver Dam. This cross section is below the spillway dam but the centerline of the river follows along the branch of the river where power is generated and the majority of the stream flow passes.

Table 7. Spokane River cross sections

ID	Site ID	Agency Source	Description	RM
1	12419500	USGS/Historical	Spokane River above Liberty Bridge, near Otis Orchards, WA (Harvard Rd)	93.8
2	12420500	USGS/Historical	Spokane River at Greenacres, WA (Barker Rd)	90.3
3	12420800	USGS/Historical	Spokane River at Sullivan Rd near Trentwood, WA, NAD27	87.6
4	12422000	USGS/Historical	Spokane River at Green St Bridge at Spokane, WA, NAD 27	78.1
5	12422500	USGS/Historical	Spokane River at Spokane, WA	72.9
6		USGS/Historical	Spokane River at Island Bridge, (Denny Ashlock Bridge on the Centennial Trail)	84.4
7	12421500	USGS/Historical	Spokane River at Trent Bridge	85.3
8		USGS/Historical	Spokane River at State Line Bridge	96.4
9		USGS/Historical	Spokane River at Mission Street	76.8
10		USGS/Historical	Spokane River at Riverside State Park	65.9
11		USGS/Historical	Spokane River at Fort Wright Bridge (T. J. Meenach Bridge)	69.8

Table 7. Spokane River cross sections				
ID	Site ID	Agency Source	Description	RM
12		USGS/Historical	Spokane River at Greenacres Waste	89.3
13		USGS/Historical	Spokane River below Nine Mile Dam	57.4
14		USGS/Historical	Spokane River Above Seven Mile Bridge	61.8
15		USGS/Historical	Upstream of Argonne Rd Bridge and IEPC discharge Pt	82.8
16	A	WADOE	DOE Nine Mile Reservoir Survey	63.1
17	B	WADOE	DOE Nine Mile Reservoir Survey	62.4
18	C	WADOE	DOE Nine Mile Reservoir Survey	61.2
19	D	WADOE	DOE Nine Mile Reservoir Survey	60.6
20	E	WADOE	DOE Nine Mile Reservoir Survey	59.5
21	F	WADOE	DOE Nine Mile Reservoir Survey	58.9
22	G	WADOE	DOE Nine Mile Reservoir Survey	58.4
23	H	WADOE	DOE Nine Mile Reservoir Survey	58.2
24	I	WADOE	DOE Nine Mile Reservoir Survey	58.0
25	J	WADOE	DOE Upriver Reservoir Survey	84.1
26	K	WADOE	DOE Upriver Reservoir Survey	83.3
27	L	WADOE	DOE Upriver Reservoir Survey	82.6
28	M	WADOE	DOE Upriver Reservoir Survey	81.8
29	N	WADOE	DOE Upriver Reservoir Survey	81.2
30	O	WADOE	DOE Upriver Reservoir Survey	80.6
31	P	WADOE	DOE Upriver Reservoir Survey	80.2
32	Q	WADOE	DOE Upper Falls Reservoir Survey	74.9
33	R	WADOE	DOE Upper Falls Reservoir Survey	74.7
34	S	WADOE	DOE Upper Falls Reservoir Survey	74.5
35	1604	FEMA		74.8
36	1605	FEMA	Downstream side of Division St Br.	74.9
37	1606	FEMA	Downstream side of RR Br.	75.4
38	1607	FEMA	Downstream side of Trent Rd Br.	75.6
39	1608	FEMA	Upstream side of Trent Rd Br.	75.6
40	1609	FEMA	Along downstream side of old "curved" Br.--Br. has been replaced	76.0
41	1610	FEMA	Downstream side of 2nd Trent Rd Bridge	76.1
42	1611	FEMA	Downstream side of 2nd RR Bridge	76.3
43	1612	FEMA		76.5
44	1613	FEMA	Downstream side of Mission St Bridge	76.8
45	1614	FEMA		77.6
46	1615	FEMA		77.8
47	1616	FEMA	Downstream side of Green St. Bridge	78.1
48	1700	FEMA		78.5
49	1800	FEMA		79.2
50	1900	FEMA		79.6
51	2000	FEMA	Downstream of Upriver Dam Spillway (side channel); may not be appropriate for model)	80.1
52	6620	FEMA	Downstream of Bowl and Pitcher Park Walk Br.	65.9
53	6629	FEMA		66.0
54	6664	FEMA		66.4
55	6695	FEMA		66.7
56	6726	FEMA	Downstream of Spokane WWTP	67.1
57	6764	FEMA	Upstream of Spokane WWTP	67.6
58	6775	FEMA		67.6
59	6813	FEMA		67.9

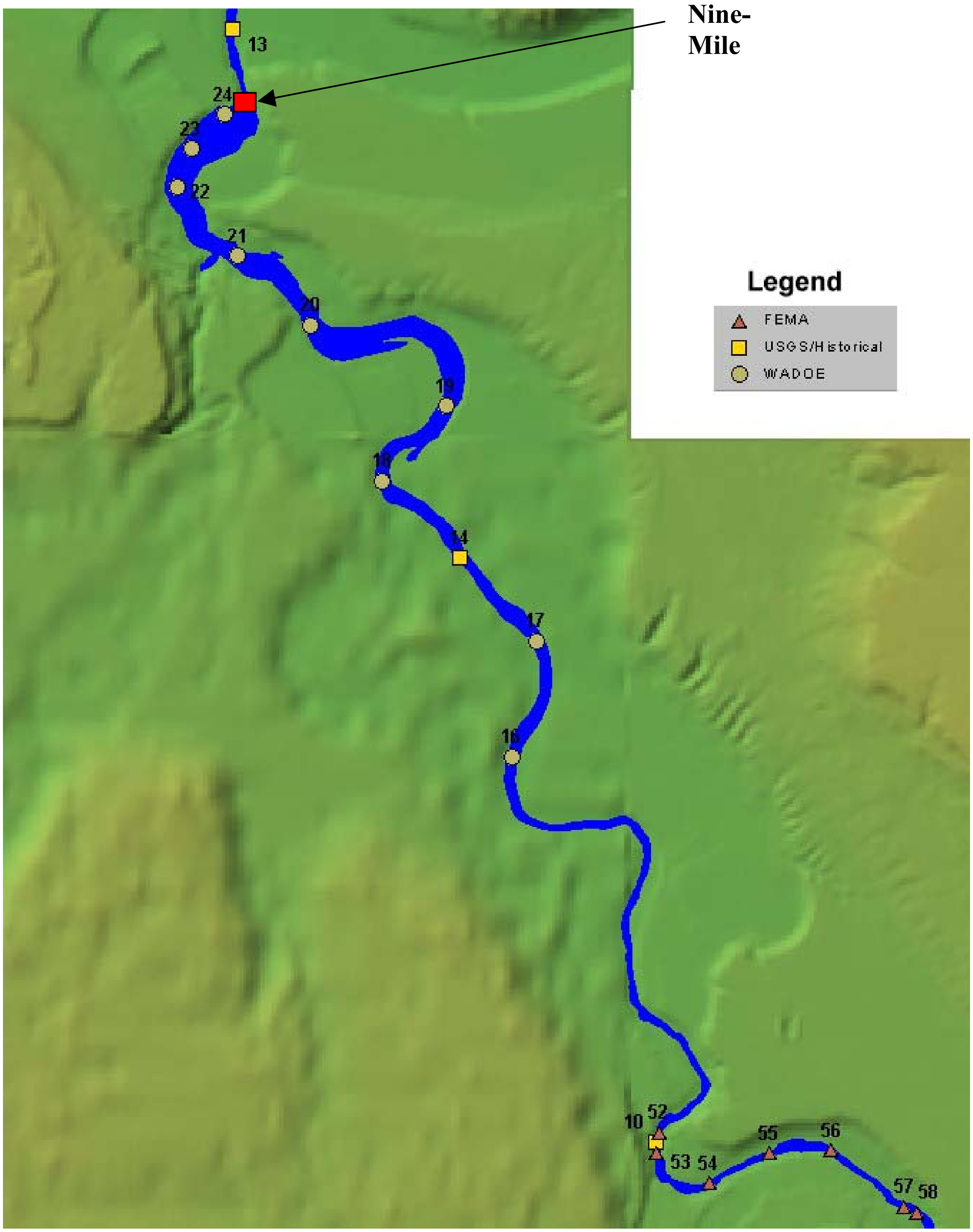


Figure 21. Spokane River cross sections above Nine Mile dam

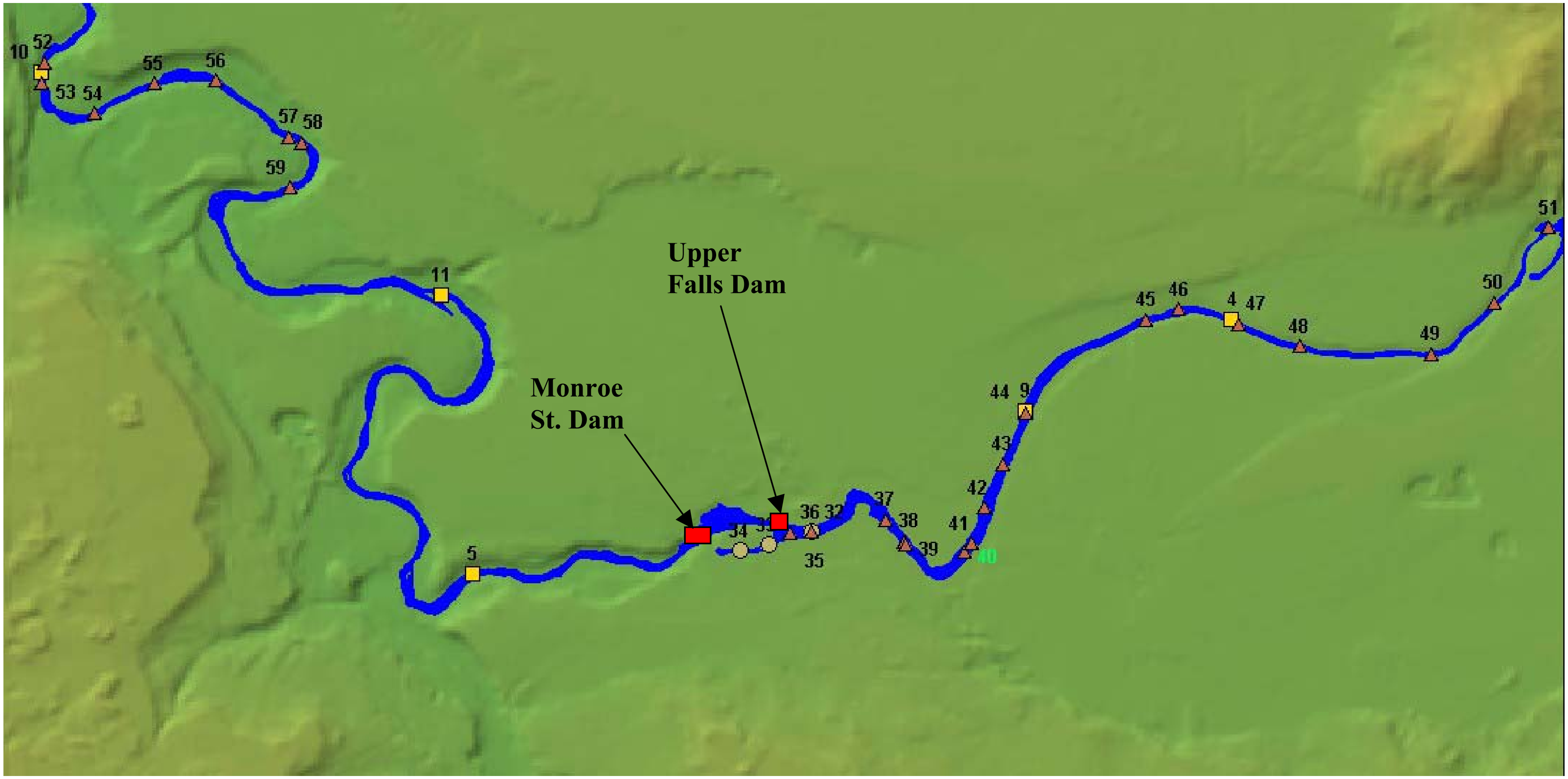


Figure 22. Spokane River cross sections above Upper Falls dam

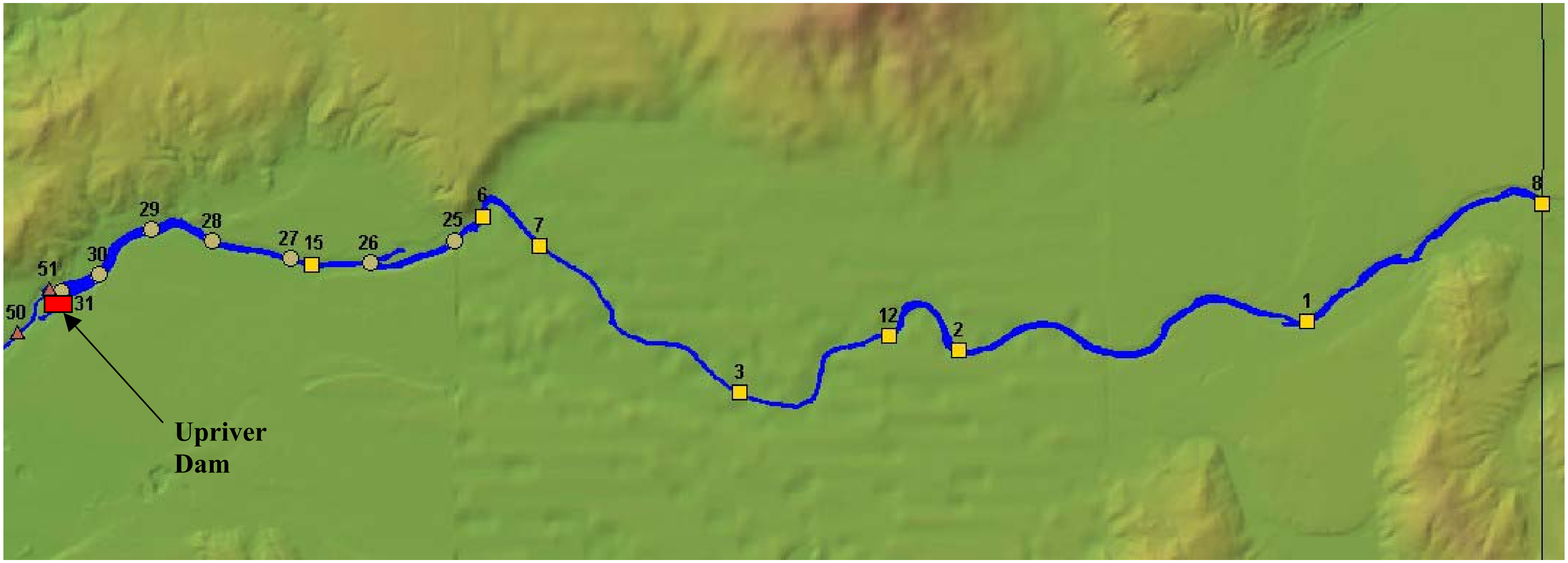


Figure 23. Spokane River cross-sections between Upriver dam and the state line

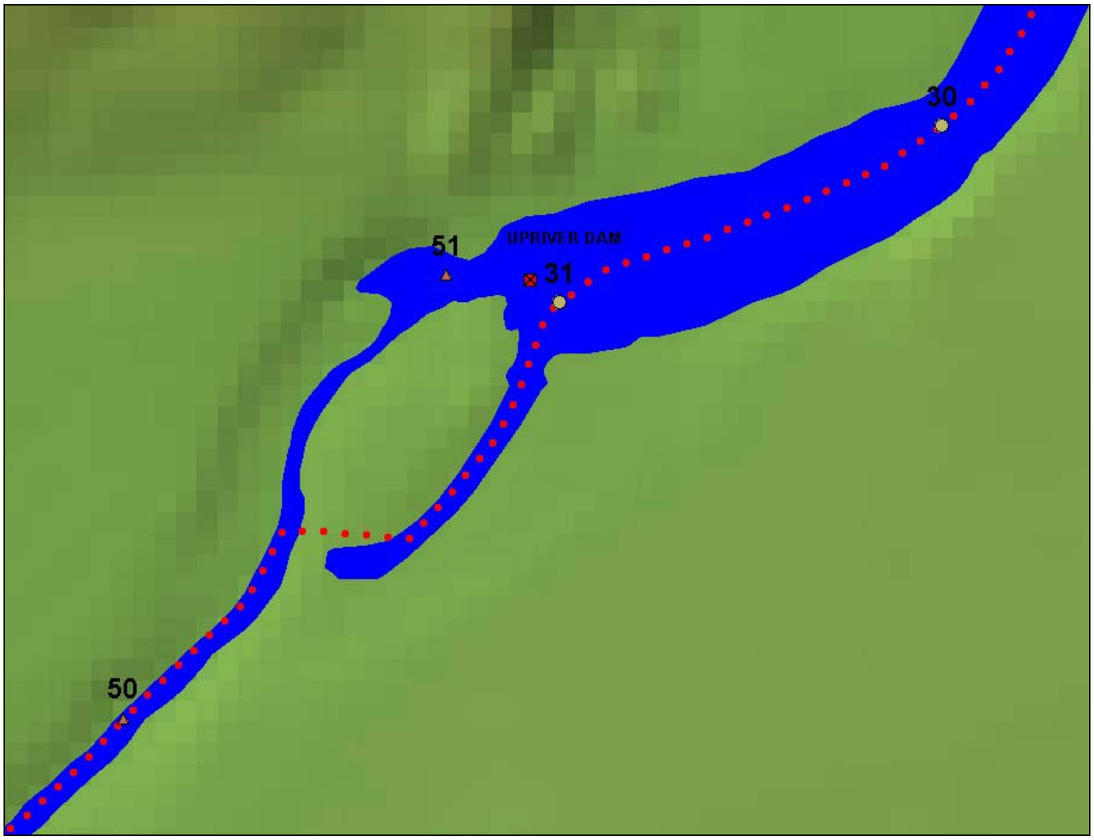


Figure 24. Cross-Section 51 - off main flow pathway

Long Lake Bathymetry

The Long Lake bathymetry was originally developed by the WA DOE and was based on bathymetric contour maps provided by AVISTA Corporation. Figure 26 shows an image of the reservoir contours used to develop the lake bathymetry. The volume-elevation data from Soltero (1992), also derived from the AVISTA Corporation bathymetry maps, was compared with the results of DOE work as shown in Figure 26. The figure shows there are good agreement between the Soltero data and the analysis conducted by DOE.

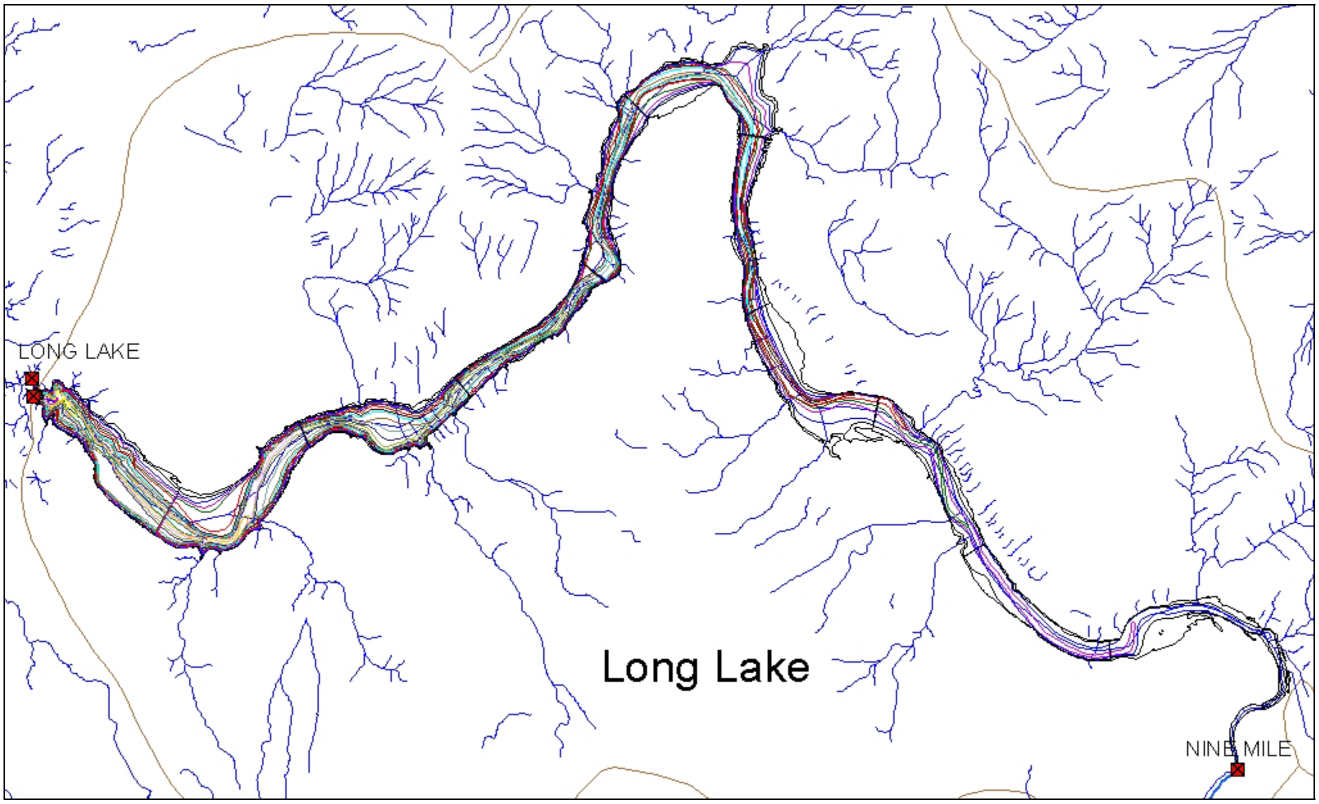


Figure 25. Long Lake bathymetric contours

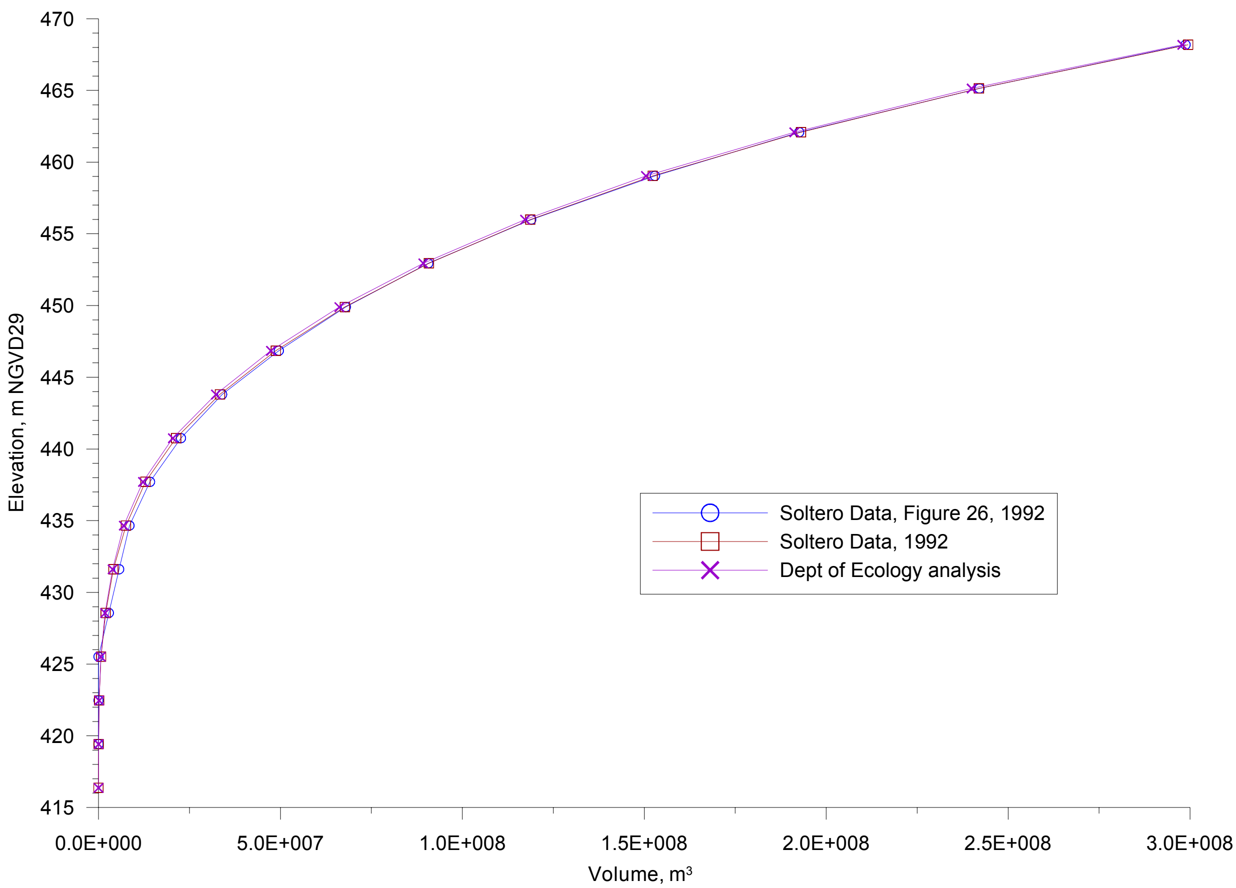


Figure 26. Volume-elevation data analysis for Long Lake

Grid Layout

The bathymetry for the Spokane River and Long Lake were then used to develop the model grid. Figure 27 shows the plan view of the grid layout for the Spokane River, upstream of Long Lake, assuming the breakup of the river into water-bodies and branches as outlined in Table 8.

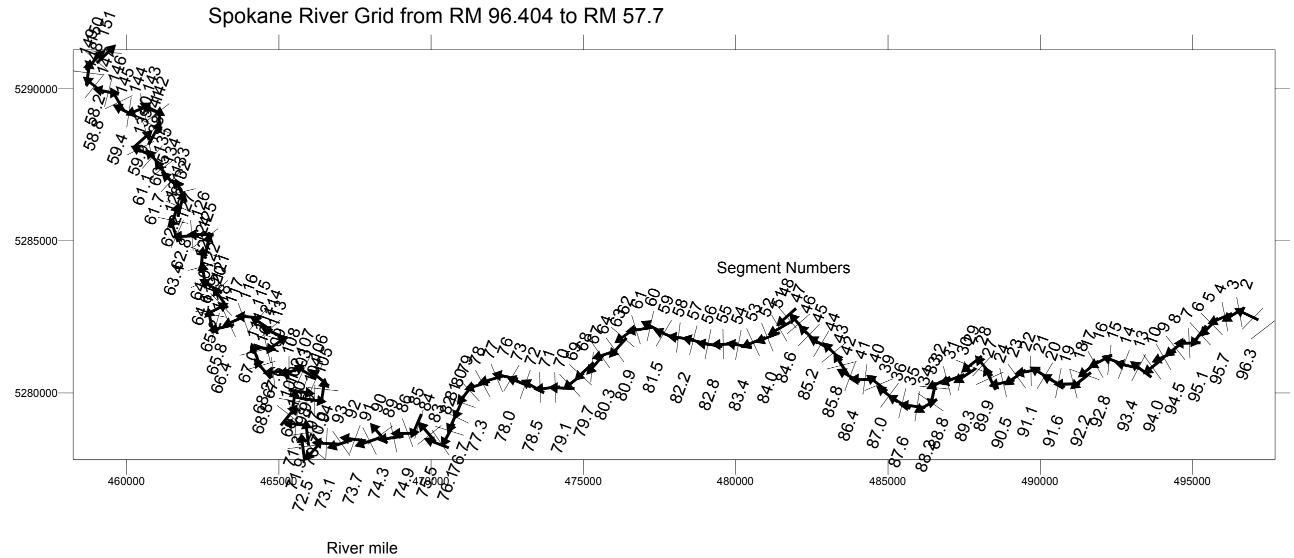


Figure 27. Plan view Spokane river grid. The arrows show the segment orientation.

The decision as to where the break the branches and water-bodies was based on (1) how groundwater inflow/recharge was computed for the Spokane River, (2) how the vertical slope changed from branch to branch, and (3) where there were pools or dams.

The vertical layout of the Spokane River, upstream of Long Lake, is shown in Figure 28. The figure also includes the locations of the branches, highest (red dots) and lowest (blue triangles) elevations recorded in a cross-section of the river, the water surface elevation from a GIS map (blue line), and a light blue line showing the elevations of the dam spillways or pools. Cross-sections were used to determine the cross-section of the model grid at segment centers by interpolation.

Table 8. Layout of Branches for the Spokane River and Long Lake

Comments	Start Branch (RM)	End Branch (RM)	Branch #	Distance m from upper boundary	Distance between in m	# of segments	DLX, m	Bottom Elev. start	Bottom Elev. end
Post Falls USGS gage to Stateline				0.00					
Stateline to Harvard Road Bridge	96.40	93.82	1	4154.52	4154.52	9	461.61	616	608.5
Harvard Road Bridge to Barker Road Bridge	93.82	90.34	2	9762.91	5608.39	12	467.37	608.5	600
Barker Road Bridge to RM 87.50	90.34	87.50	3	14333.51	4570.59	10	457.06	600	585
RM 87.50 to The Islands Foot Bridge	87.50	84.45	4	19249.74	4916.24	10	491.62	585	578
The Islands Foot Bridge to Upriver Dam	84.45	80.18	5	26107.61	6857.87	14	489.85	571	571
Upriver Dam to Green Street Bridge	80.18	78.10	6	29459.92	3352.30	7	478.90	560	560

Table 8. Layout of Branches for the Spokane River and Long Lake									
Comments	Start Branch (RM)	End Branch (RM)	Branch #	Distance m from upper boundary	Distance between in m	# of segments	DLX, m	Bottom Elev. start	Bottom Elev. end
Green Street Bridge to Upper Falls Dam	78.10	74.75	7	34856.11	5396.20	11	490.56	560	560
Upper Falls Dam to Spokane USGS gage	74.75	72.93	8	37781.81	2925.69	6	487.62	525	517.5
Spokane USGS gage to Seven Mile	72.93	63.20	9	53441.04	15659.24	32	489.35	517.5	485
Seven Mile to RM61.813	63.20	61.813	10	55673.23	2232.19	5	446.44	481	481
RM 61.813 to Nine Mile Dam	61.81	57.77	11	62179.89	6506.66	14	464.76	481	481
Nine Mile Dam to Long Lake Dam			12						

The complexity of the model in the vicinity of Monroe Street and Upper Falls dam has been simplified. The Monroe Street Dam is not explicitly modeled. Flow through Upper Falls dam is modeled using the CE-QUAL-W2 selective withdrawal algorithm to simulate the turbines and spillway gates. After passing through the dam, water is placed in the model river segment downstream of the Upper Falls dam, neglecting the Monroe Street dam. The grid between Upper Falls Dam and the lower section where Monroe Street Dam is located has significant vertical fall (see Table 8 and difference between Branch 7 and 8), which provided a natural point to break the bathymetry into separate branches. The vertical grid for the Spokane River has a vertical resolution of 0.5 m.

In the CE-QUAL-W2 model, the model user must specify the characteristics and connectivity of the model grid. The following parameters were used in the Spokane-Long-Lake model (see Cole and Wells, 2000, for detailed explanation of model grid characteristics):

IMP(# of segments) : 189
KMP(# of vertical layers): 47
NWB(# of water-bodies):6
NBR(# of branches):12

The branch layout was specified by these parameters for each branch (as specified in the w2_con.npt control file – see Cole and Wells, 2000).

The water-bodies included the following branches as shown in Table 9.

Table 9. Water body-Branch Layout (see Cole and Wells, 2000)

Water body	Branch Start	Branch End	JBDN
Jr 1 4 sloping branches above the pool of Upriver Dam	1	4	4
Jr 2 Pool of Upriver Dam	5	5	5
Jr 3 Pool of Upper Falls Dam	6	7	7
Jr 4 2 sloping branches above the Nine Mile Dam pool	8	9	9
Jr 5 Nine mile dam pool	10	11	11
Jr 6 Long Lake pool	12	12	12

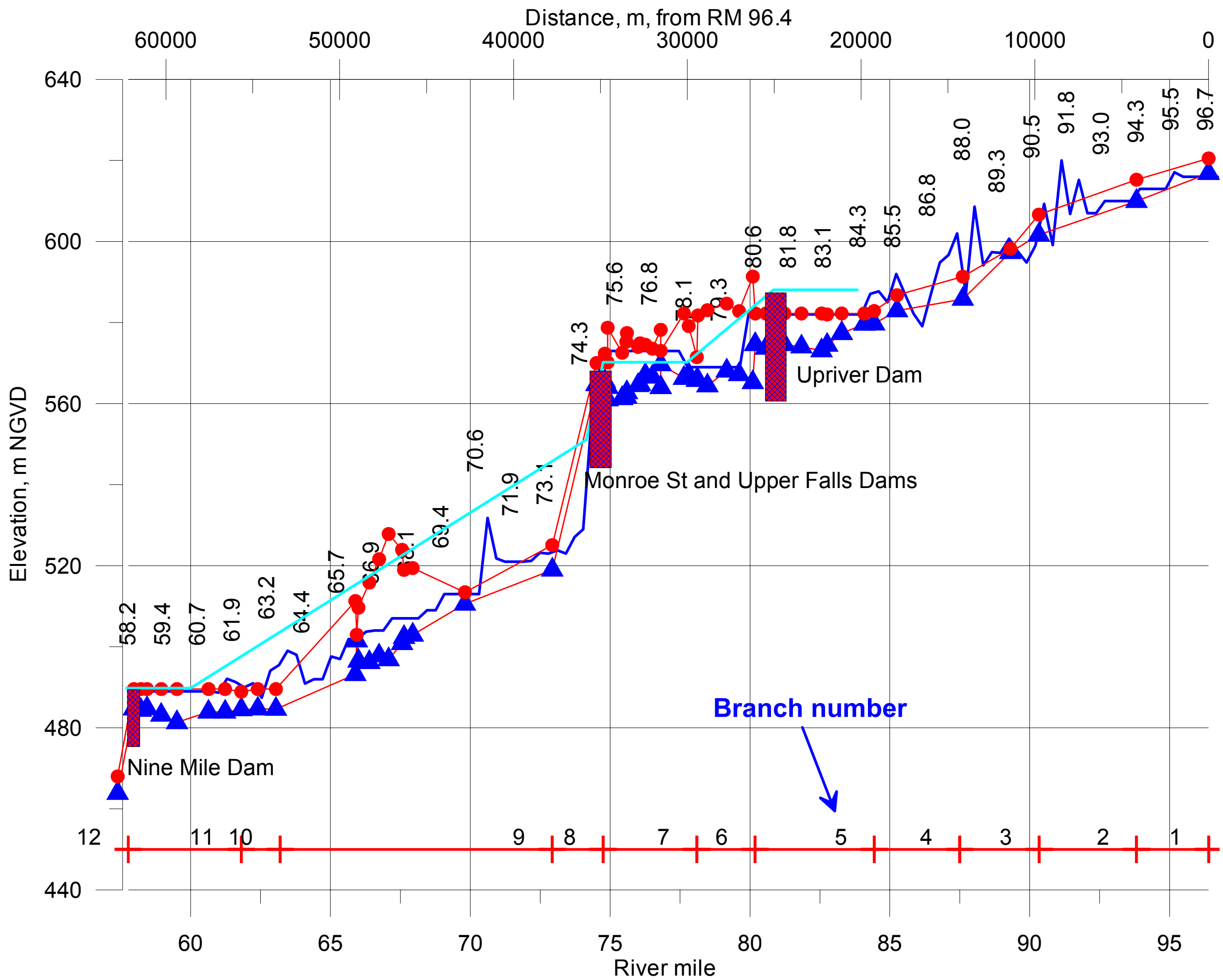


Figure 28. Vertical layout of Spokane River grid.

Figure 29 compares the volume-elevation data from Soltero (1992) with the SURFER contour program estimates and the W2 model grid for Long Lake. The figure shows there is close agreement between the model grid and data indicating the model grid is accurately representing the lake's volume as a function of elevation.

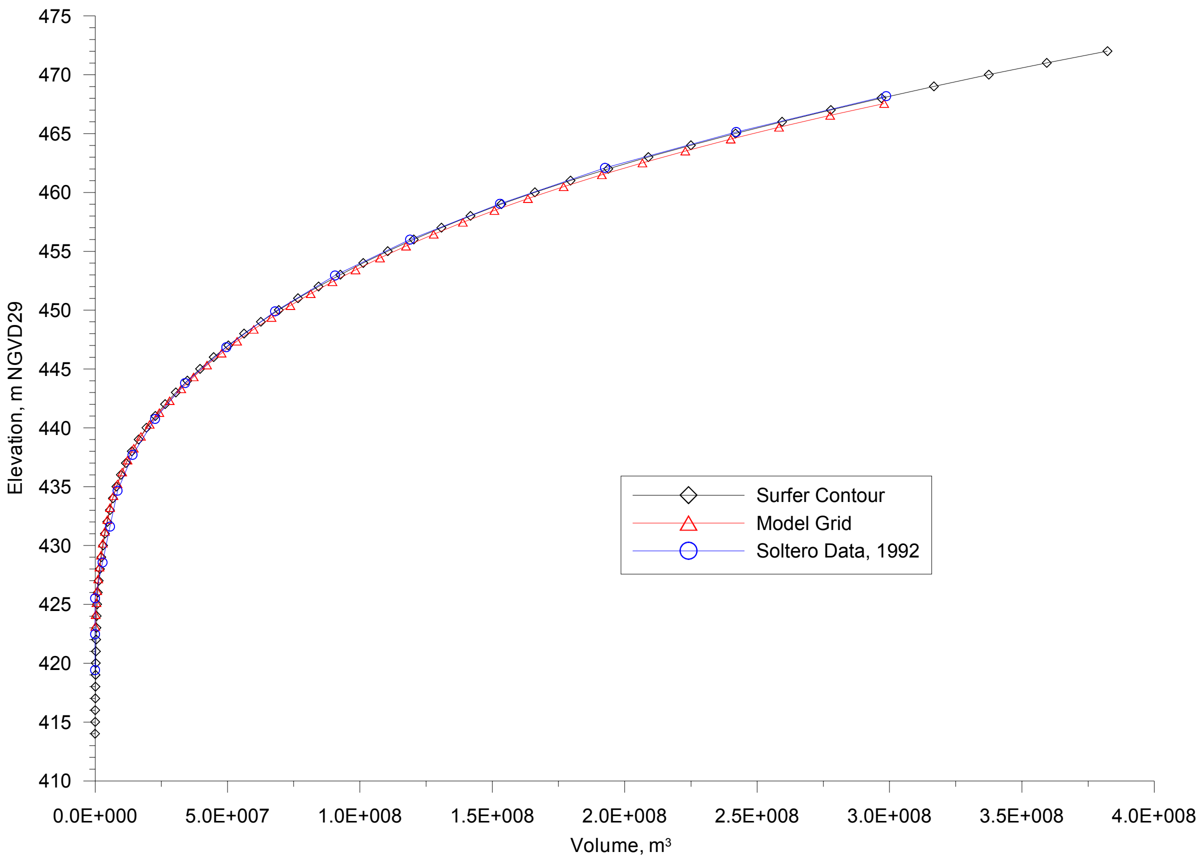


Figure 29. Long Lake volume-elevation comparison, data and model grid

The plan layout of the grid for the entire system is shown in Figure 30 from the Bathymetry editor. The longitudinal-vertical profile of the Spokane River and Long Lake grid can be found in Appendix F: Model Grid x-z plots.

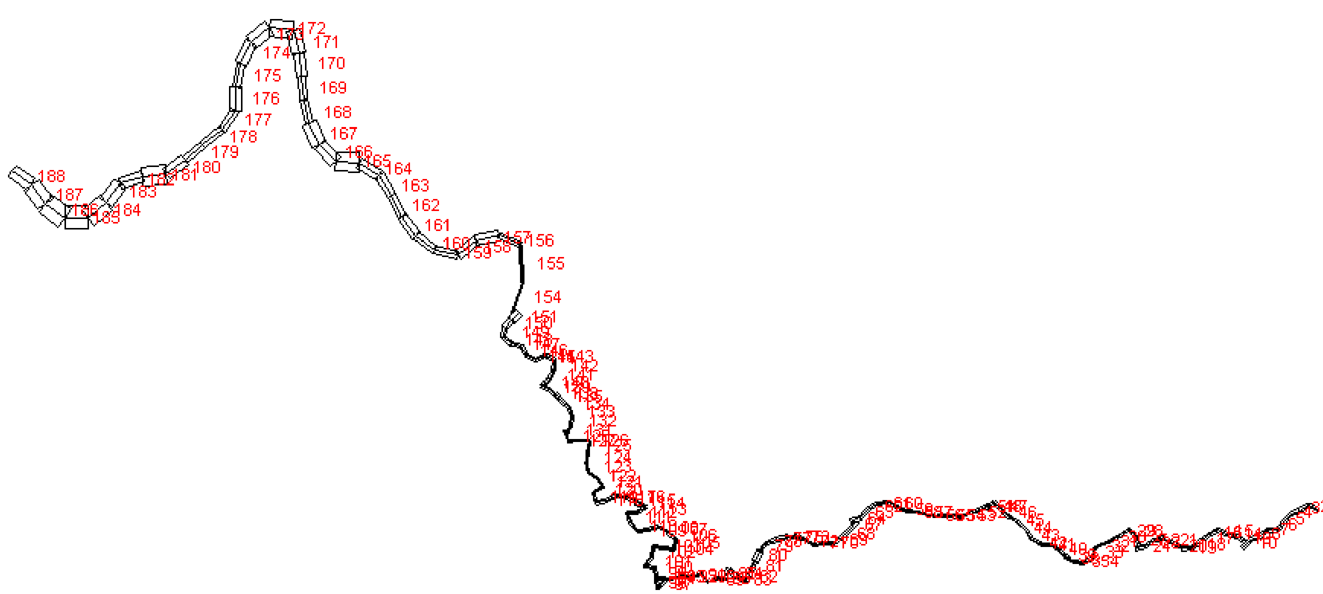


Figure 30. Plan view grid layout including Long Lake

Boundary Conditions

The upstream boundary condition for the model is the Spokane River at the WA-ID state line and the downstream boundary condition is the outflow from Long Lake. The upstream boundary condition was characterized by flow, water temperature, and water quality. The downstream boundary condition was characterized by flow rate. The model used internal interpolation to fill in the boundary conditions between the data.

Spokane River at state line

The upstream boundary condition on the Spokane River was set at the Washington-Idaho state line. The model time periods were from February 1, 1991 to January 31, 1992 and from January 1, 2000 to October 31, 2000. The boundary conditions consist of flow, water temperature and water quality characteristics during the modeling periods. Figure 31 shows the flow at the state line from 1991 to 1992 and 2000. The flows at the state line were developed by adjusting data obtained from the U.S. Geological Survey (USGS) gage station near Post Falls, ID (USGS: 12419000). The change in flow occurring between Post Falls and the state line were estimated by using flow data or estimates from Harvard Road (RM93.7), where data were available from 1/1/2000 through 12/6/2000. When data were not available, flow rates were estimated by applying a regression predicting flow at Harvard Road (RM 93.7) given data from Post Falls. Flow rates at Harvard Road were typically less than those at Post Falls due to losses to the aquifer. The difference in flow between Post Falls and Harvard Road was then used to estimate the flow at the state line, which lay 4.7 miles downstream of Post Falls. The total distance between Post Falls and Harvard Bridge is 7.7 miles, and the loss/gain to the aquifer occurring between Post Falls and the state line was estimated by multiplying the difference in flow between Post Falls and Harvard Road by the fraction f of river miles which lay between Post Falls and state line (f = 4.7 miles/7.7 miles). When data were not available, the regression used to estimate flow rates Q_{Harvard} at Harvard Road given flow rate $Q_{\text{Post Falls}}$ at Post Falls was

$$Q_{\text{Harvard}} = 0.00000199 Q^2{}_{\text{Post Falls}} + 0.9244 Q_{\text{Post Falls}} - 68.8$$

The gain/loss to the aquifer Q_{aquifer} (typically a loss) between Post Falls and State Line was estimated from

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

which was then used to estimate the flow at state line $Q_{\text{state line}}$ with

$$Q_{\text{state line}} = Q_{\text{Post Falls}} + Q_{\text{aquifer}}$$

When comparing flows 1991 had lower peak flows during the winter but higher overall flows than in 2000 when one large flow peak dominated the winter flow regime (Figure 31). Summer flows in 2000 appear to be slightly lower than in 1991.

Temperature data was next examined at the state line for both time periods. In both 1991 and 2000 there was very little data collected at the state line. The data consisted of periodic grab samples and some

Hydrolab data monitored over a short period in the summer of 2000. Figure 32 shows the stream temperature at the state line for 1991 and 2000. Both years show a similar warming and cooling trends over the course of the year with the peak stream temperature occurring in August.

Water quality files for 1991 and 2000 were developed from data collected at the State Line Bridge (RM 96.0), where possible constituent data was used for the upstream boundary condition. If data for a particular constituent was not available, constituent concentrations were estimated from other relevant data.

Organic matter in the upstream boundary condition, tributaries, and point sources was simulated using CBOD ultimate data and multiple CBOD compartments in CE-QUAL-W2. Each point source had a separate CBOD compartment and decay rate, and the upstream boundary condition and tributary BOD were grouped into a single CBOD compartment. The decay rates used for each compartment were obtained from the Washington Department of Ecology.

For the year 2000, data were available for the following constituents: alkalinity, chloride, conductivity, total dissolved solids, ammonia nitrogen, nitrite-nitrate nitrogen, phosphorus (soluble reactive phosphorus), fecal coliform, CBOD ultimate, and dissolved oxygen. Inorganic carbon concentration was calculated from pH, alkalinity and temperature data using equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981). Algae concentration was estimated using chlorophyll *a* data and assuming a ratio of 35 μg/l chlorophyll *a* to 1 mg/l algae.

Organic matter from the upstream boundary condition and tributaries was simulated using a single combined CBOD compartment and CBOD ultimate data. The constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero.

Concentrations of the inorganic suspended solid (ISS) were estimated using total suspended solids data (TSS), algae data, and the estimate of particulate organic matter (POM) giving

$$\text{ISS} = \text{TSS-POM} - \text{algae}$$

Particulate organic matter (POM) concentrations were estimated using dissolved organic carbon data (DOC), total organic carbon data (TOC), and algae data:

$$\text{POM} = \frac{\text{TOC - DOC}}{\delta_c} - \text{algae}$$

where δ_c was the stoichiometric equivalent between organic matter and carbon. It was assumed that δ_c=0.65.

In 1991 for the Idaho state line sampling site, data were available for conductivity, dissolved oxygen, pH, total suspended solids, ammonia nitrogen, nitrite-nitrate nitrogen, fecal coliform, and orthophosphate (soluble reactive phosphorus). Inorganic carbon concentrations were estimated using pH data and the average alkalinity concentration of the 2000 data. The equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981) were applied to calculate inorganic carbon. Chloride and total dissolved solid concentrations were assumed to be equal to that of the average 2000 concentration. Algae concentration was estimated by assuming the chlorophyll *a* concentration was equivalent to the average of the 2000 data, and then calculating the concentration by assuming a ratio of 35 µg/l chlorophyll *a* to 1 mg/l algae. CBOD ultimate concentration was estimated by averaging data collected in the year 2000.

Figure 33, Figure 34 and Figure 35 show the plots of constituent concentrations for both years.

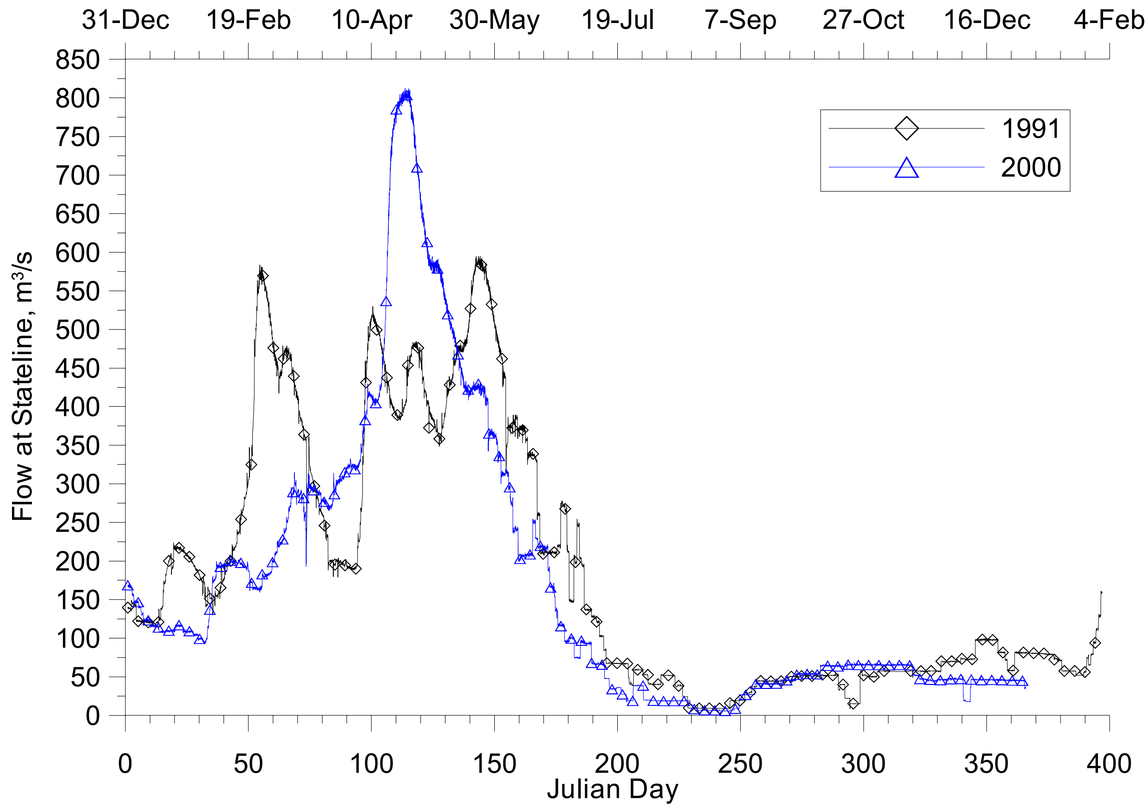


Figure 31. Spokane River flow at the state line, 1991-1992 and 2000

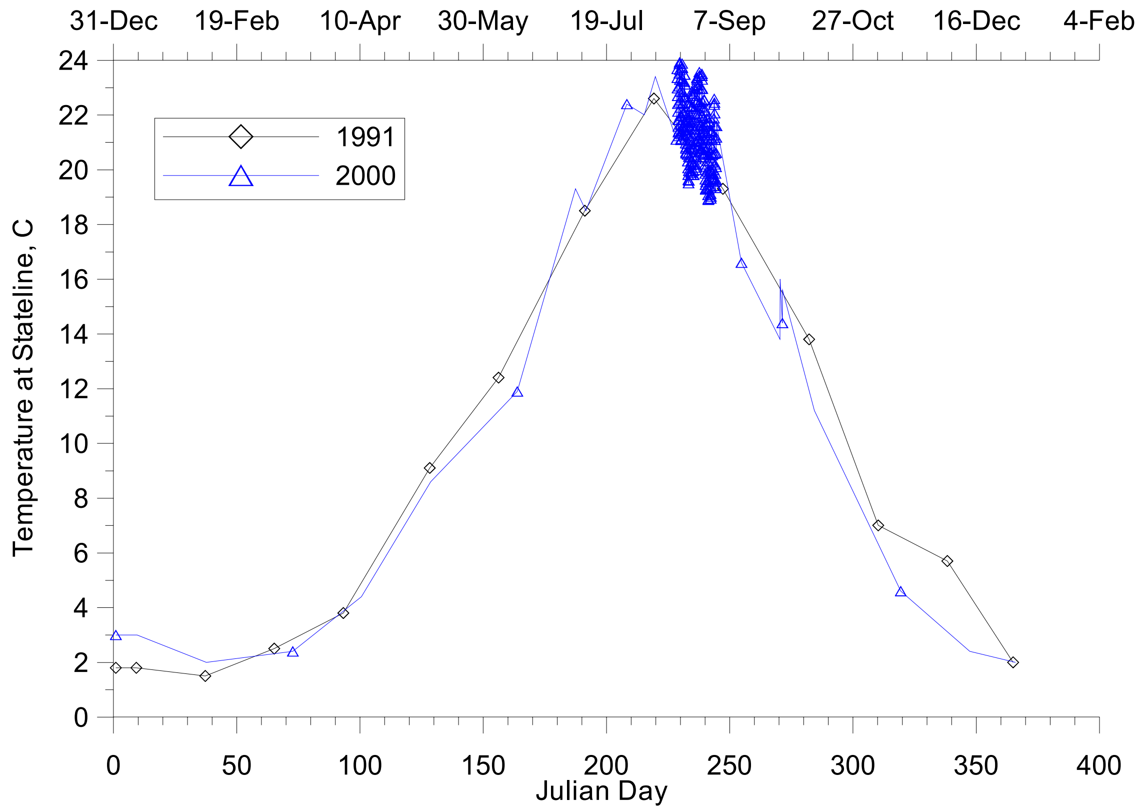


Figure 32. Spokane River temperature at the state line, 1991-1992 and 2000

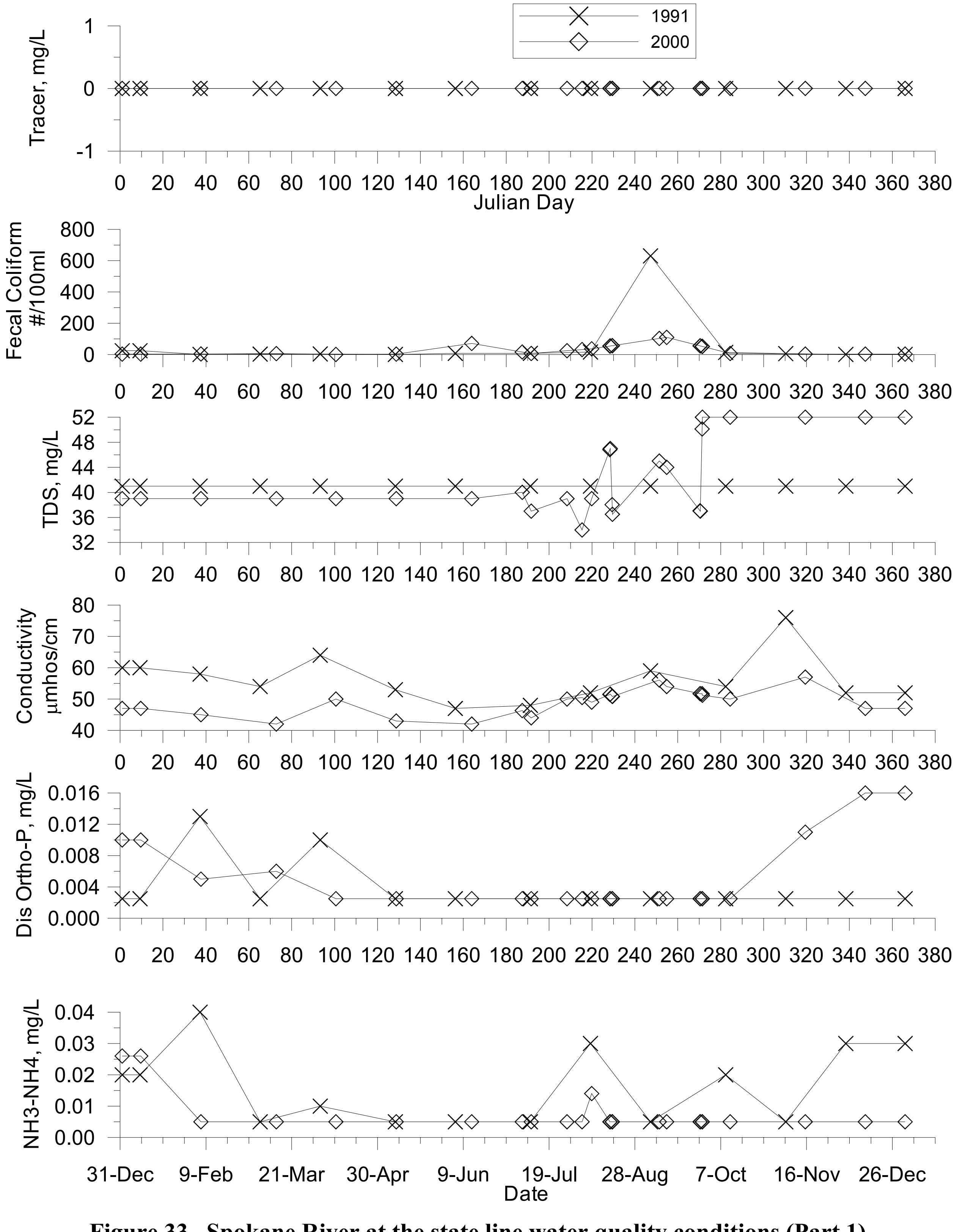


Figure 33. Spokane River at the state line water quality conditions (Part 1)

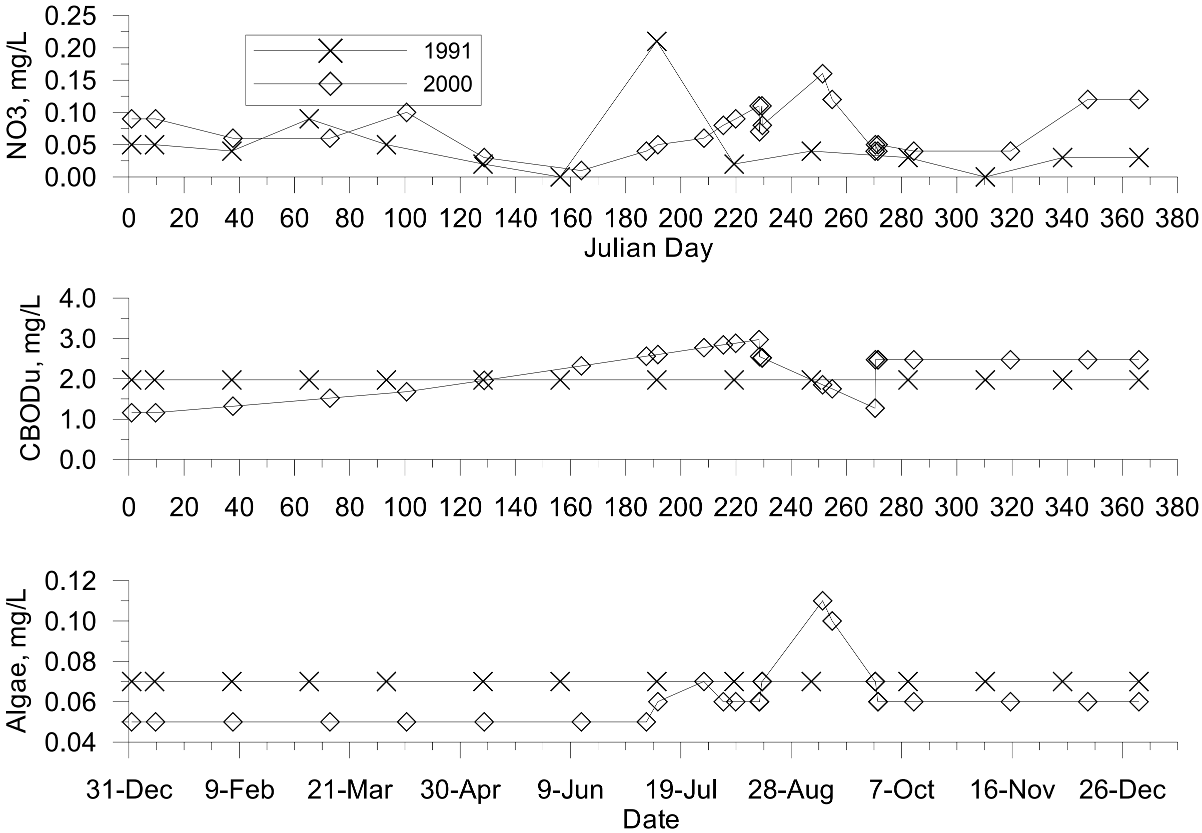


Figure 34. Spokane River at the state line water quality conditions (Part 2)

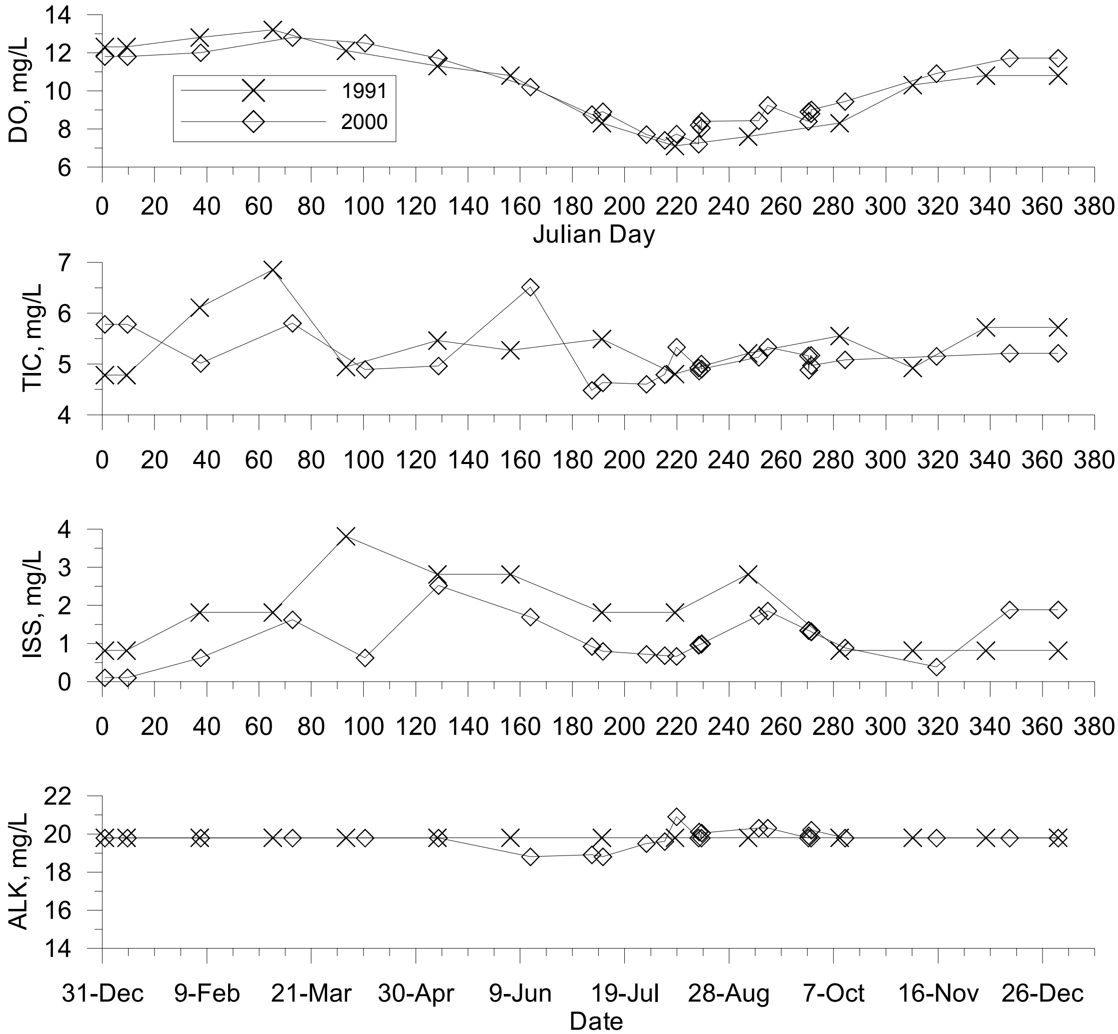


Figure 35. Spokane River at the state line water quality conditions (Part 3)

Long Lake outflow

The downstream boundary condition was set at the outflow from Long Lake. Flows, temperature and water quality characteristics were developed for the model. Figure 36 shows the outflows from Long Lake for 1991 to 1992 and 2000. In 1991 the outflows from Long Lake were larger than in 2000 with the exception of the peak flow in mid-April, 2000. During the summer, the flows were similar in 1991 and 2000.

Water quality of the Long Lake outflow was dependent upon the location of water withdrawn from reservoir using the CE-QUAL-W2 selective withdrawal algorithm. Turbine flow out of the dam was modeled as a point sink.

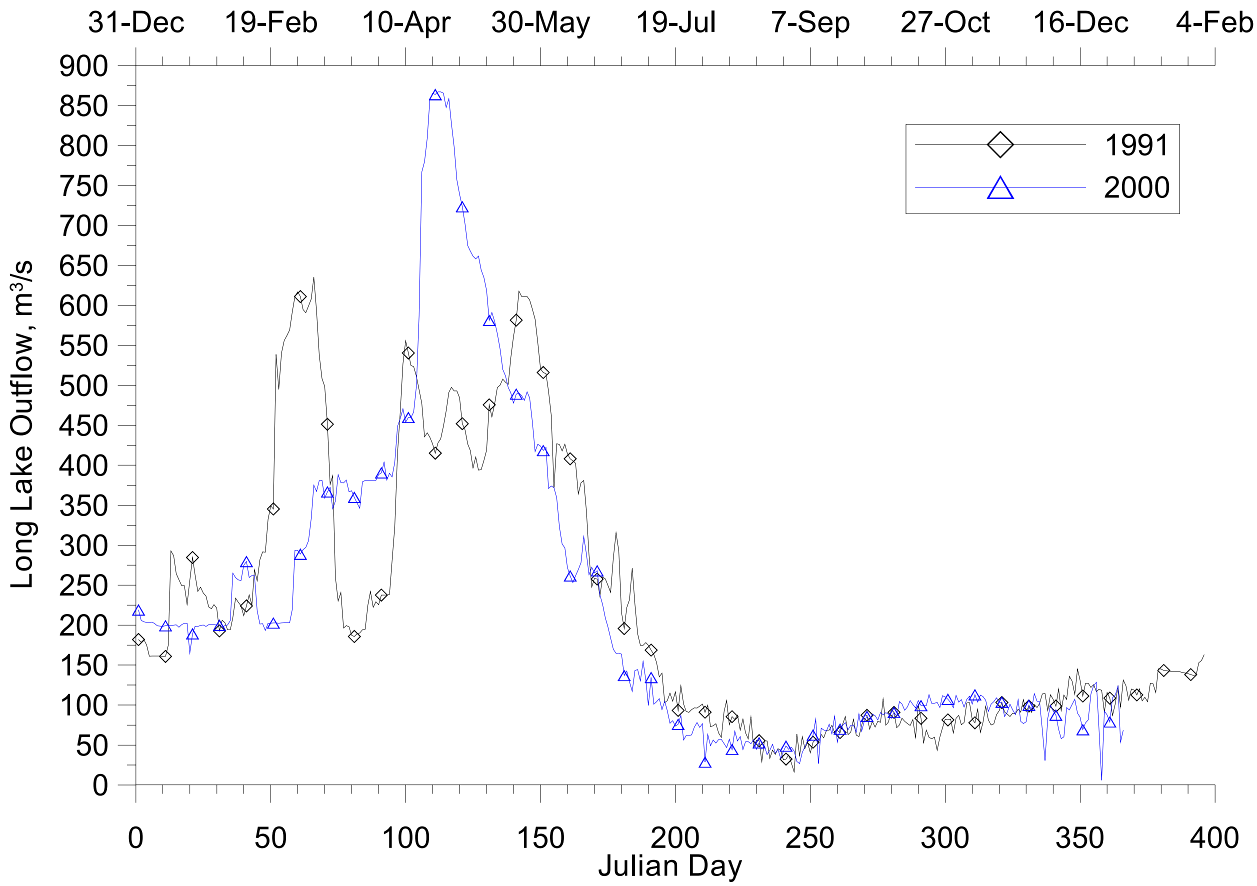


Figure 36. Long Lake Reservoir outflow, 1991-1992 and 2000

Tributaries

There are three main tributaries contributing flow to the Spokane River and Long Lake. They are Hangman Creek at RM 72.4, Little Spokane River at RM 56.4, and Coulee/Deep Creek basin on the Spokane River at RM 58.8. Each tributary was characterized by flow, water temperature, and water quality. The model used internal interpolation to fill in the boundary conditions between the data. In many cases there was not much data available to characterize water quality constituents. The result is that some water quality constituents remained constant over 1991 or 2000. This assumption should not have much influence on the water quality calibration due the small magnitude of these inflows.

Hangman Creek

The flows in Hangman Creek are similar between 1991 and 2000 as shown in Figure 37. Both winters experienced sharp peaks flows but Hangman Creek saw slightly higher peak flows in 1991. During both years the summer flow were very low, contributing little water to the Spokane River. Water temperatures in Hangman Creek are shown in Figure 38 for 1991 to 1992 and 2000. The creek shows a similar warming pattern during the year for both 1991 and 2000 but in 1991 there were several peak temperature achieved or the summer whereas in 2000 one predominant temperature peak occurred.

Water quality files for Hangman Creek were developed using data collected at the mouth of Hangman Creek. If data for a particular constituent were not available, constituent concentrations were estimated from other relevant data. As described in the state line boundary condition section, two separate methods were used to create the tributary water quality files.

For the year 2000, data were available for the following constituents: alkalinity, chloride, conductivity, total dissolved solids, ammonia nitrogen, nitrite-nitrate nitrogen, phosphorus (soluble reactive phosphorus), fecal coliform, CBOD ultimate, and dissolved oxygen. Inorganic carbon concentration was calculated from pH, alkalinity and temperature data using the method described above under Spokane River at state line. As was described in the state line boundary condition section, organic matter originating from Hangman Creek, the upstream boundary condition, and other tributaries was modeled using CBOD ultimate data and a single CBOD compartment. The remaining water quality constituents for the model were developed using the same procedure outlined under Spokane River at state line

In 1991 data at the mouth of Hangman Creek were available for conductivity, dissolved oxygen, pH, total suspended solids, ammonia nitrogen, nitrite-nitrate nitrogen, fecal coliform, and orthophosphate (soluble reactive phosphorus). Inorganic carbon concentration was calculated from pH, alkalinity and temperature data using the method described above under Spokane River at state line. Chloride and total dissolved solid concentrations were assumed to be equal to that of the average 2000 concentration. Algae concentration was estimated by assuming the chlorophyll *a* concentration was equivalent to the average of the 2000 data. CBOD ultimate concentration was estimated by averaging data collected in the year 2000.

Figure 39, Figure 40, and Figure 41 show the plots of the constituent concentrations for both years.

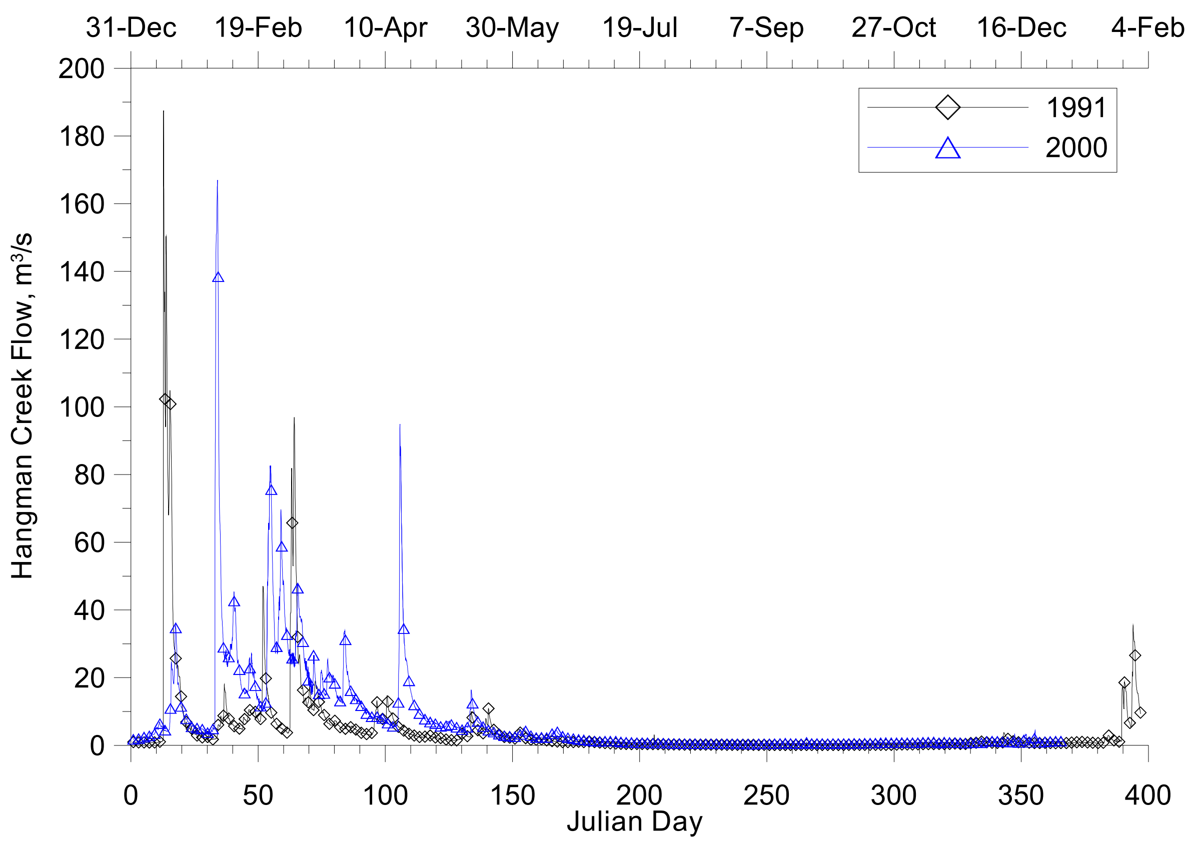


Figure 37. Hangman Creek flow, 1991-1992 and 2000

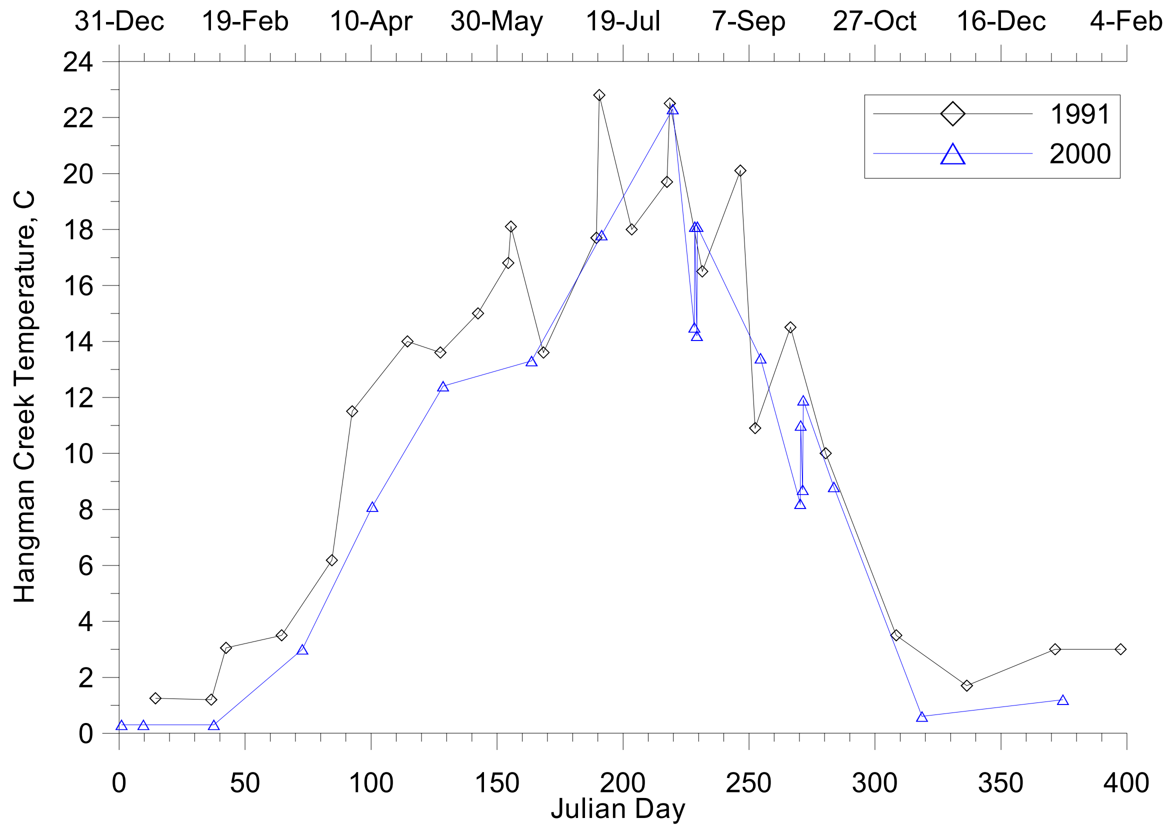


Figure 38. Hangman Creek water temperature, 1991-1992 and 2000

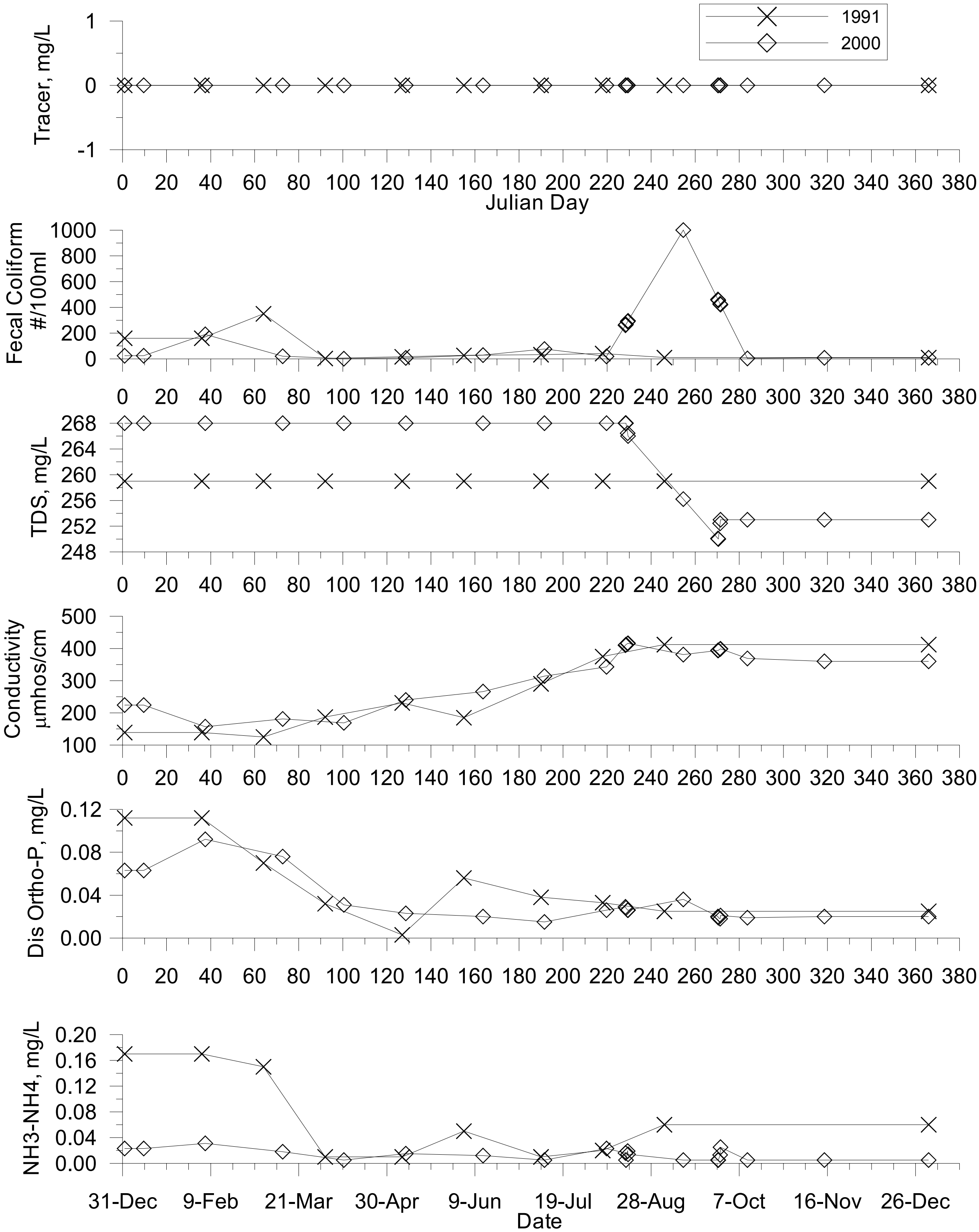


Figure 39. Hangman Creek water quality conditions (Part 1)

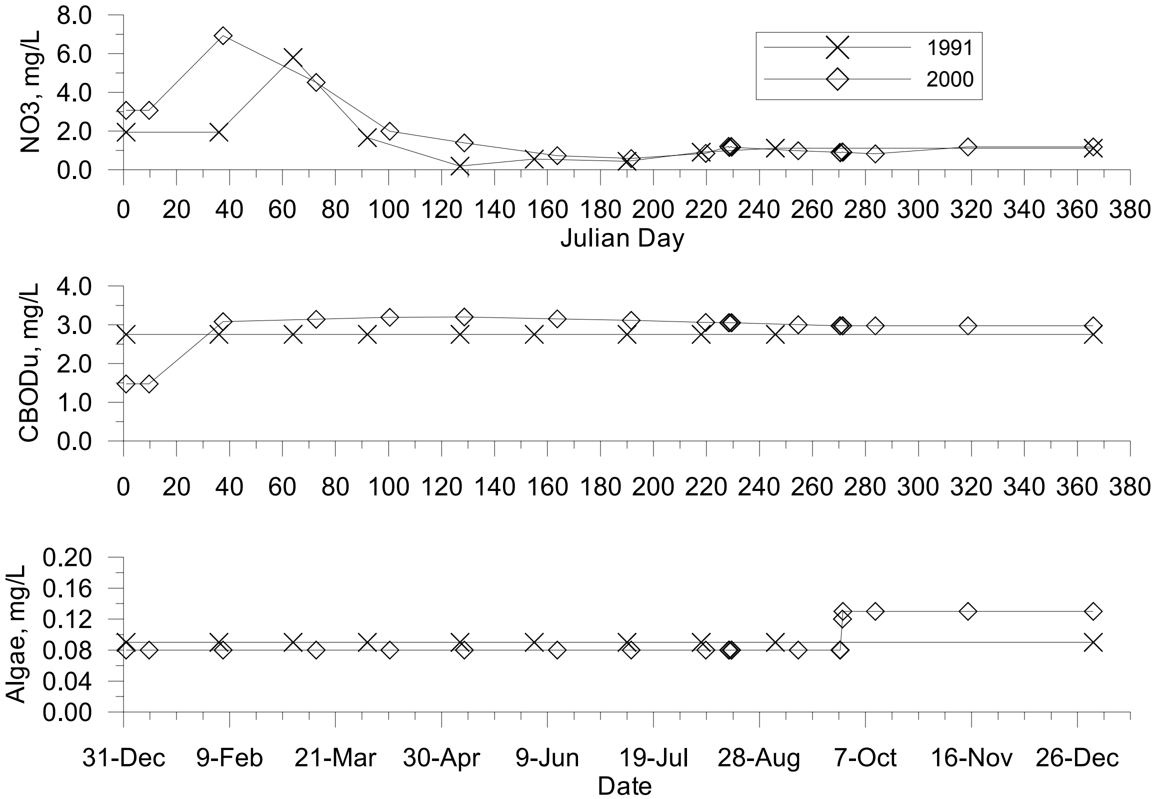


Figure 40. Hangman Creek water quality conditions (Part 2)

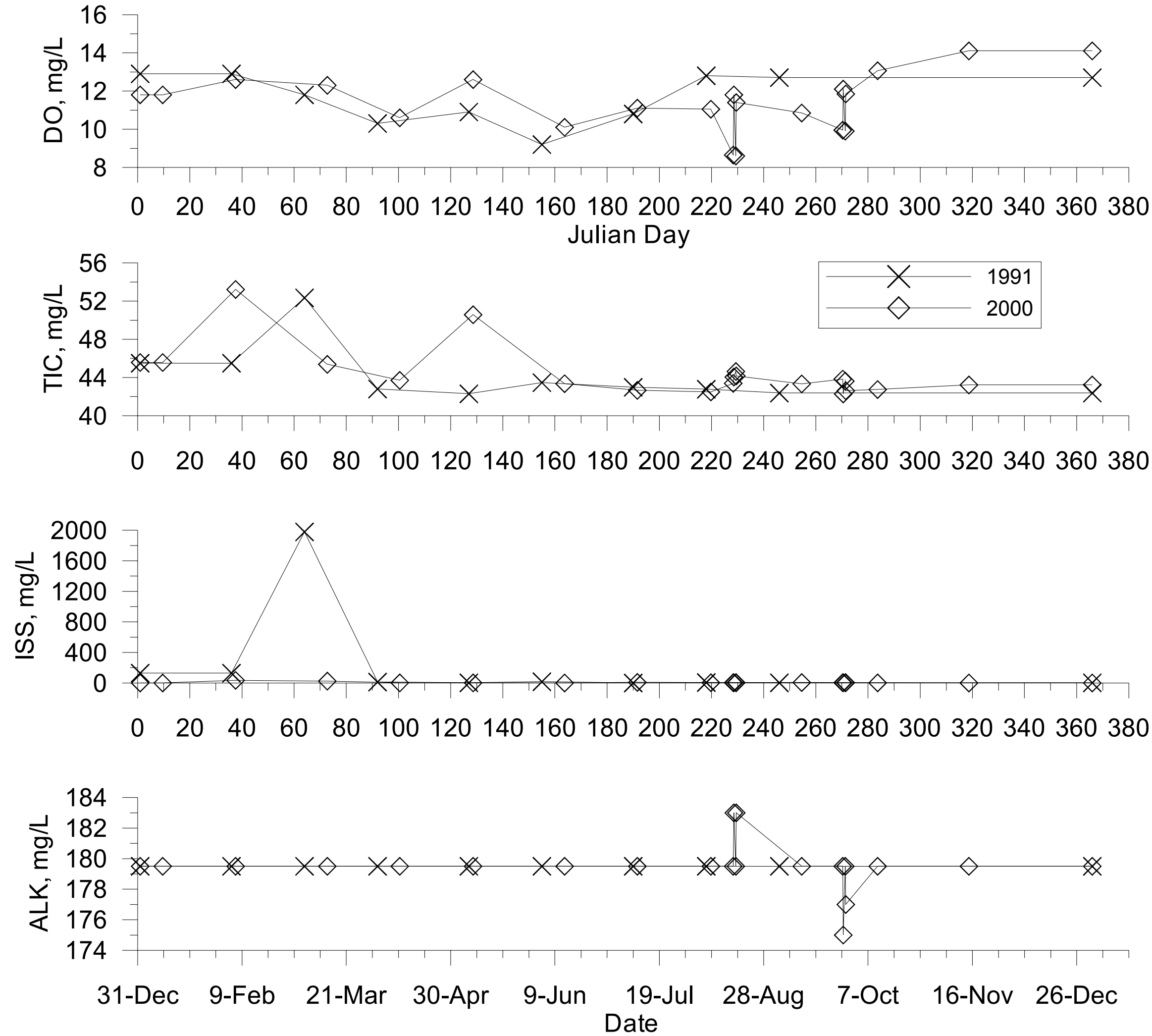


Figure 41. Hangman Creek water quality conditions (Part 3)

<u>Little Spokane River</u>

The Little Spokane River is located downstream of Nine Mile Dam and contributes flow directly to Long Lake. Approximately 7.7 miles upstream of the confluence with the lake the Little Spokane River flow is monitored at a USGS gage station at Dartford, WA (USGS: 12431000). As noted in Soltero et al. (1992), there is a considerable groundwater inflow between the gage station and the river's confluence with Long Lake. Groundwater modeling by Bolke and Vaccaro (1981) and Patmont et al. (1985, 1987) indicate that during the summer from June to October approximately 250 cfs should be added to the gage station flow to represent the flow entering Long Lake. During the winter from November to May, the flow added to gage station was calculated as follows based on Soltero et al. (1987):

Little Spokane River at mouth = (gage 12431000 x 1.09) + 252 cfs

The relationships above were used with the gage station flow to generate the Little Spokane River inflows to Long Lake. Figure 42 shows the estimated total flows from the Little Spokane river over 1991 and 2000. The figure indicates that the winter flows in 2000 had higher flows and much larger peak flows. Flows during the summer though were similar between the two years with 2000 have slightly higher flows coming into the summer. Water temperature measurements in the river show the same warming trend of the year between 1991 and 2000 as shown in Figure 43.

The method used to create water quality files representing the Little Spokane River inflows was identical to the one applied for the Spokane River at the state line (discussed above). Figure 44, Figure 45, and Figure 46 show the constituent concentrations for the Little Spokane in 1991 and 2000.

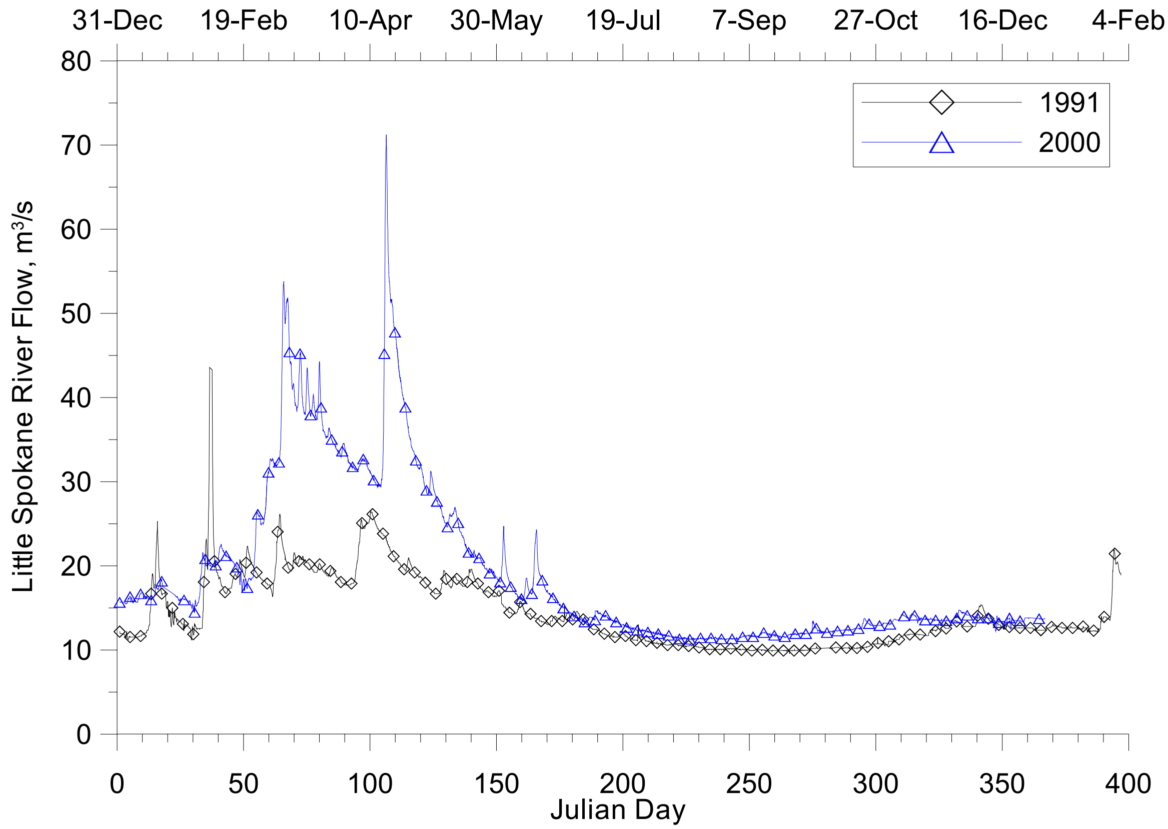


Figure 42. Little Spokane River flow, 1991-1992 and 2000

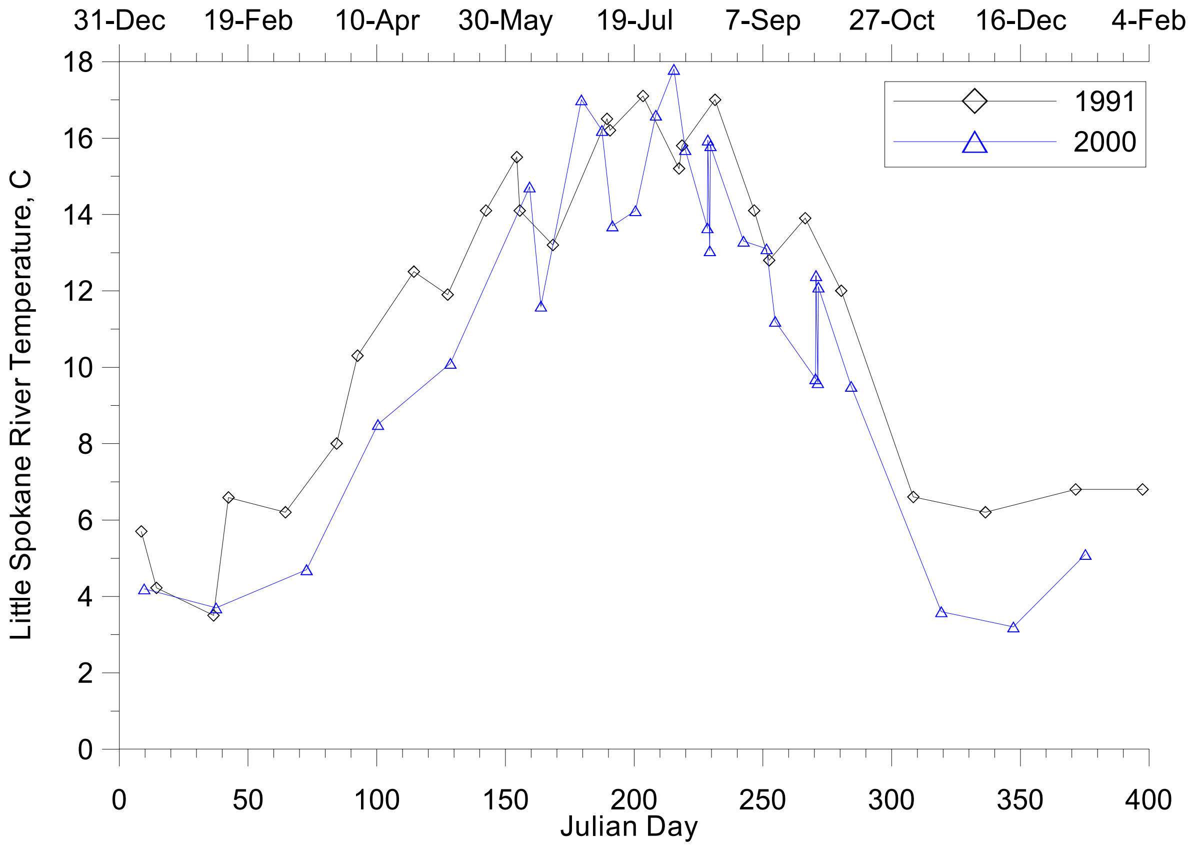


Figure 43. Little Spokane River temperature, 1991-1992 and 2000

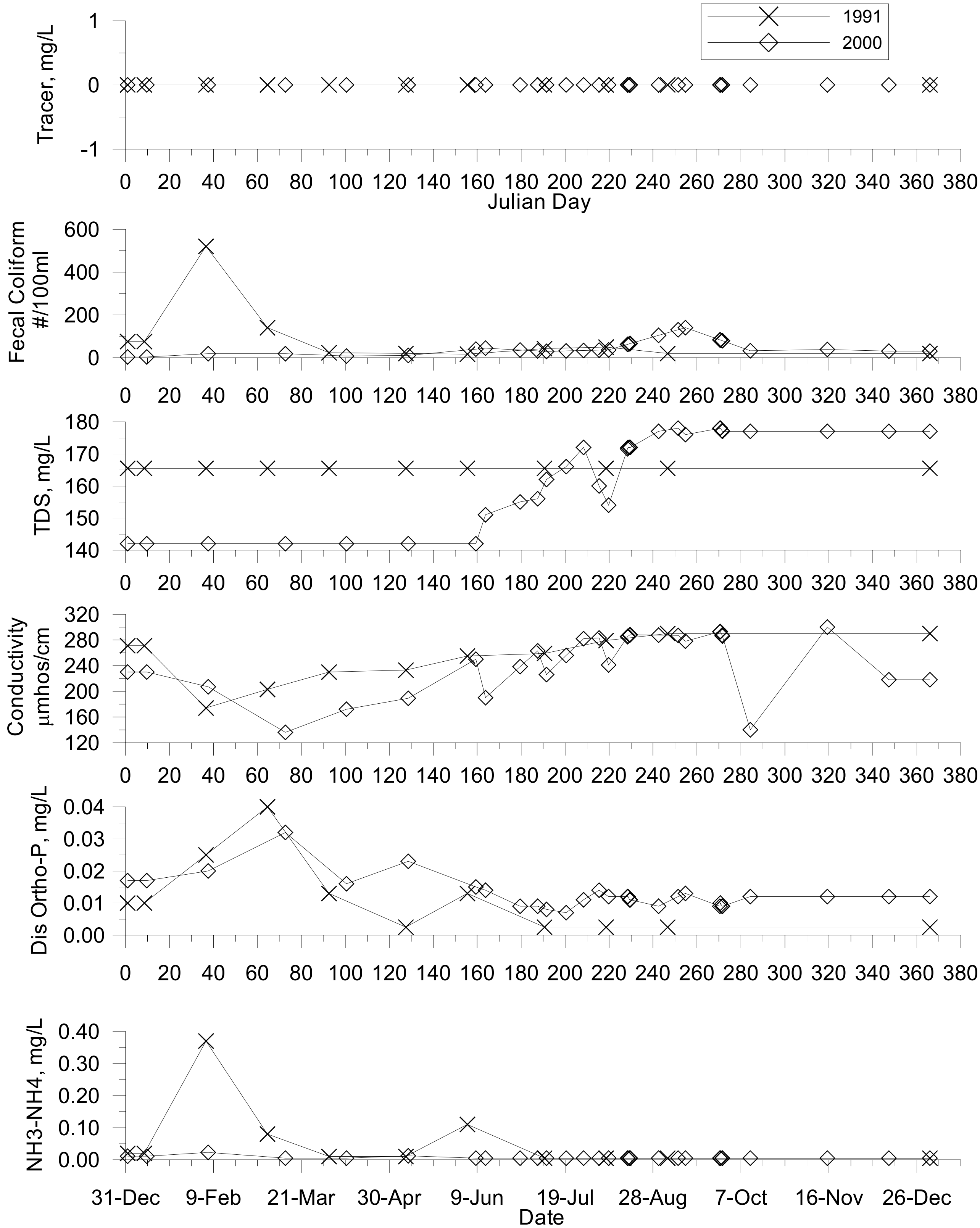


Figure 44. Little Spokane River water quality conditions (Part 1)

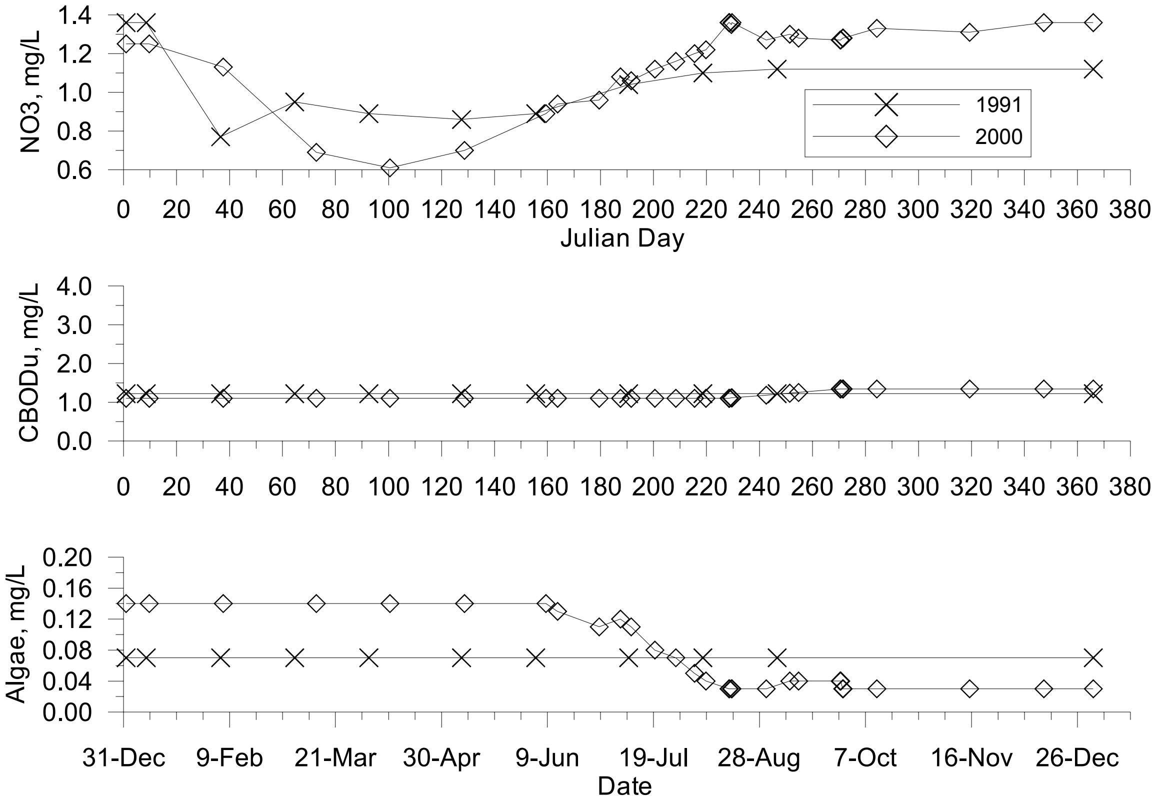


Figure 45. Little Spokane River water quality conditions (Part 2)

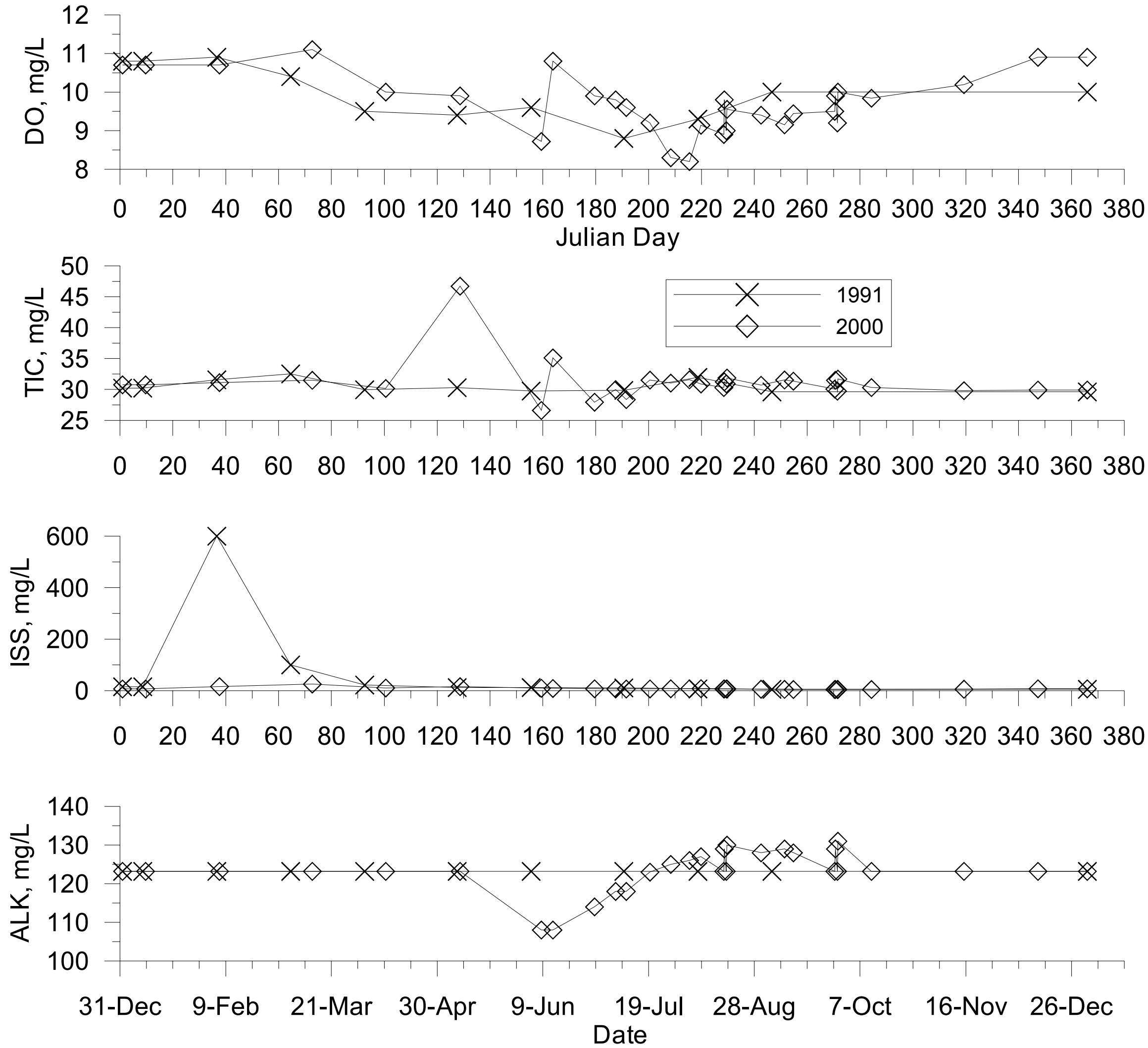


Figure 46. Little Spokane River water quality conditions (Part 3)

Coulee Creek

Adjacent to the Hangman Creek basin are the Coulee Creek and Deep Creek basins. Since there was no flow monitoring on either tributary, flow estimates were made by comparing basin areas with the Hangman Creek basin area and taking a fraction of the Hangman Creek flow using the following equation:

$$Coulee\,\&\,DeepCreekQ = \left(\frac{Coulee\,\&\,DeepCreek\_basin\_area}{HangmanCreek\_basin\_area} \right) HangmanCreekQ$$

The calculated flows for Coulee and Deep Creeks are plotted in Figure 47 for the 1991-1992 and 2000 time periods.

Deep Creek is intermittent and, although it has a larger drainage basin than Coulee Creek, most of the flow that reaches the Spokane River is from the Coulee Creek basin (email correspondence with Stan Miller, Spokane County). Coulee Creek enters Deep Creek just before Deep Creek's confluence with the Spokane River. In the lower reaches of Deep Creek, the river flows across alluvial gravel for a considerable distance loosing flow to groundwater. Additionally, it has been noted that the intermittent nature of Deep Creek may be the result of dewatering of the basalt interbeds by domestic wells and these interbeds feed springs which support the stream in its lower reaches (Stan Miller). Coulee Creek is believed to be a source of water to the Spokane River because water has been seen entering the Spokane River when Deep Creek was dry upstream, and Coulee Creek does not flow over the alluvial gravel for a very long distance. In general, it is also believed that a lot more water reaches the Spokane River in this stretch of river than is provided by the tributary inflow. As discussed later in this report, groundwater inflow and outflow files were developed for the majority of these stretches of the river to account for gains and losses of water.

Since there was no active monitoring taking place on Coulee and Deep Creeks, stream temperatures were unknown. Since the flows were much smaller than Hangman Creek and temperatures were monitored in the adjacent Hangman Creek basin, these temperature records were used for the Deep and Coulee Creek inflows.

Because no water quality data were available, the constituent concentrations of Coulee Creek were assumed to be equivalent to that of Hangman Creek. The method and data used to characterize Hangman Creek water quality were described above.

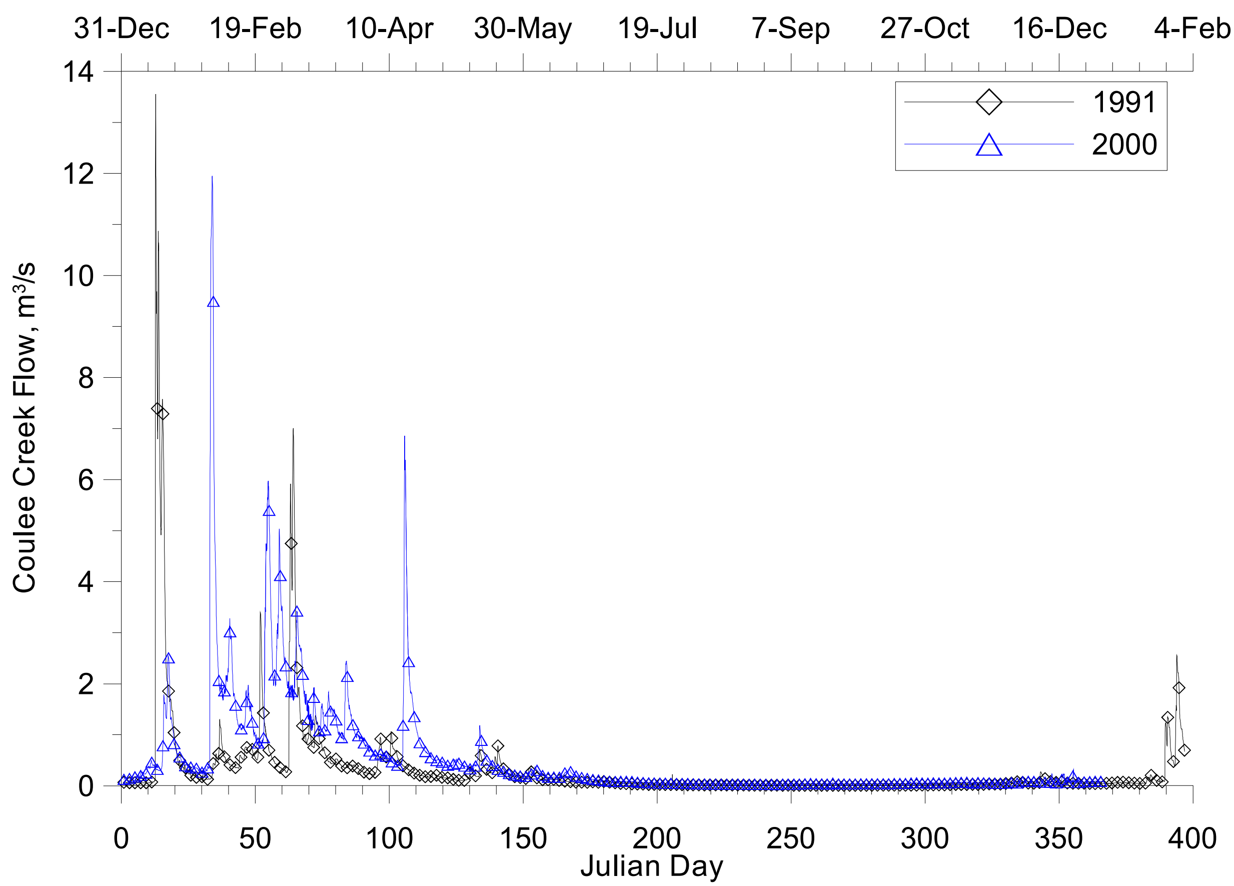


Figure 47. Coulee and Deep Creek flow, 1991-1992 and 2000

Reservoir Operations

Upriver Dam and Reservoir

Upriver Dam is located further upstream in the model area at river mile 80.2. The dam is operated as run-of-the-river facility so the water level at the pool behind it is maintained relatively constant at 1910.2 ft NGVD29 with a deviation of +/- 0.2 ft. Figure 48 shows a photo of the Upriver dam facility looking from the North bank of the Spokane River.

Figure 48. Upriver dam and spillway from North bank of the Spokane River

Figure 49 shows a plan view of the upriver dam facility showing where water is diverted through a powerhouse rather than over the spillway. Figure 50 shows a view of the spillway gate looking upstream towards the dam. Historical operations have been to have the first 8000 cfs of water pass through five turbines at the facility. Anything above that would pass over the spillway. As Figure 50 indicates, there are 8 vertical lift gates on the dam. Lifting them vertically opens the gates and each gate has a capacity of 6000 cfs when fully opened. Figure 51 shows a rating curve for flow passing through one gate. Although there are 8 gates only 4 of them are predominantly used. Using the rating curve from Figure 51 and the known gate operations flows over the spillway were plotted for 1991 and 2000 in Figure 52. Figure 53 shows the flow through the turbines at Upriver Dam for 1991 and 2000. Although the turbine operation is not considered a step function, either on or off, there were no data available for determining how much water was passing through the turbines over time. The flow through the turbines was determined by assuming that any river flow up to 8000 cfs passed through the turbines and any remaining flow passed over the spillway. The flow passing through the Upriver dam was determined by conducting a water balance and using a gage station downstream.

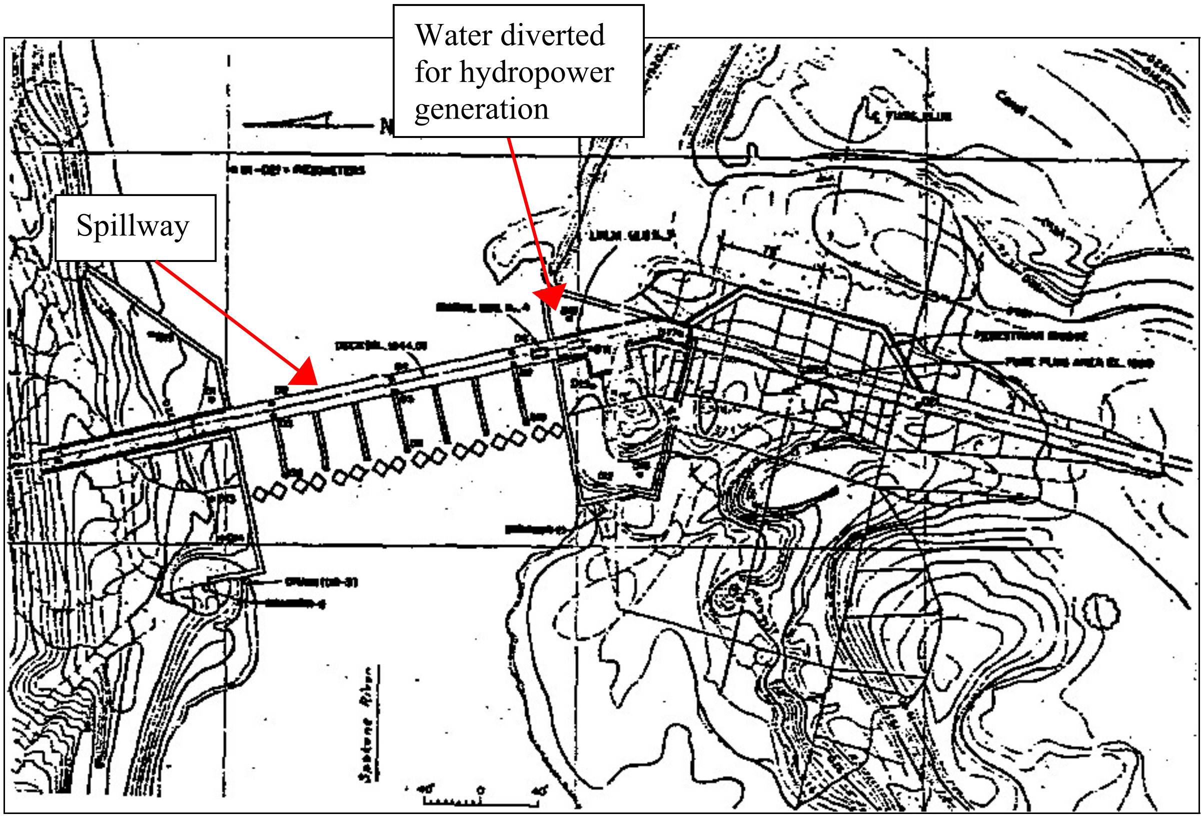


Figure 49. Upriver dam plan view of the Spokane River

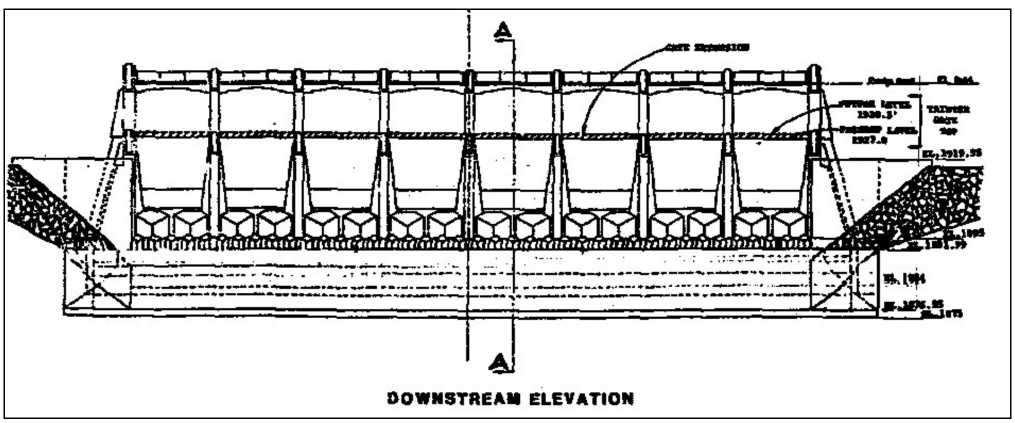


Figure 50. Spillway gates at Upriver Dam

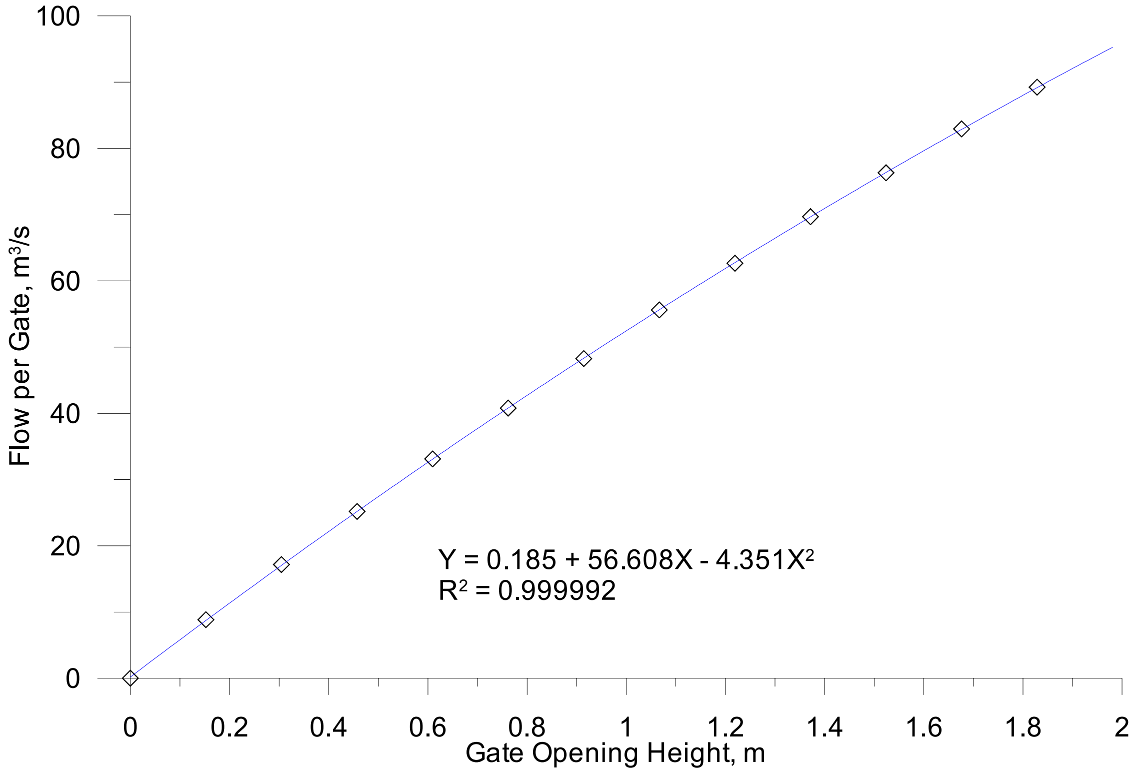


Figure 51. Upriver Dam Spillway Gate Rating Curve, flow per gate, m^3/s (there are 8 gates but 4 are predominately used)

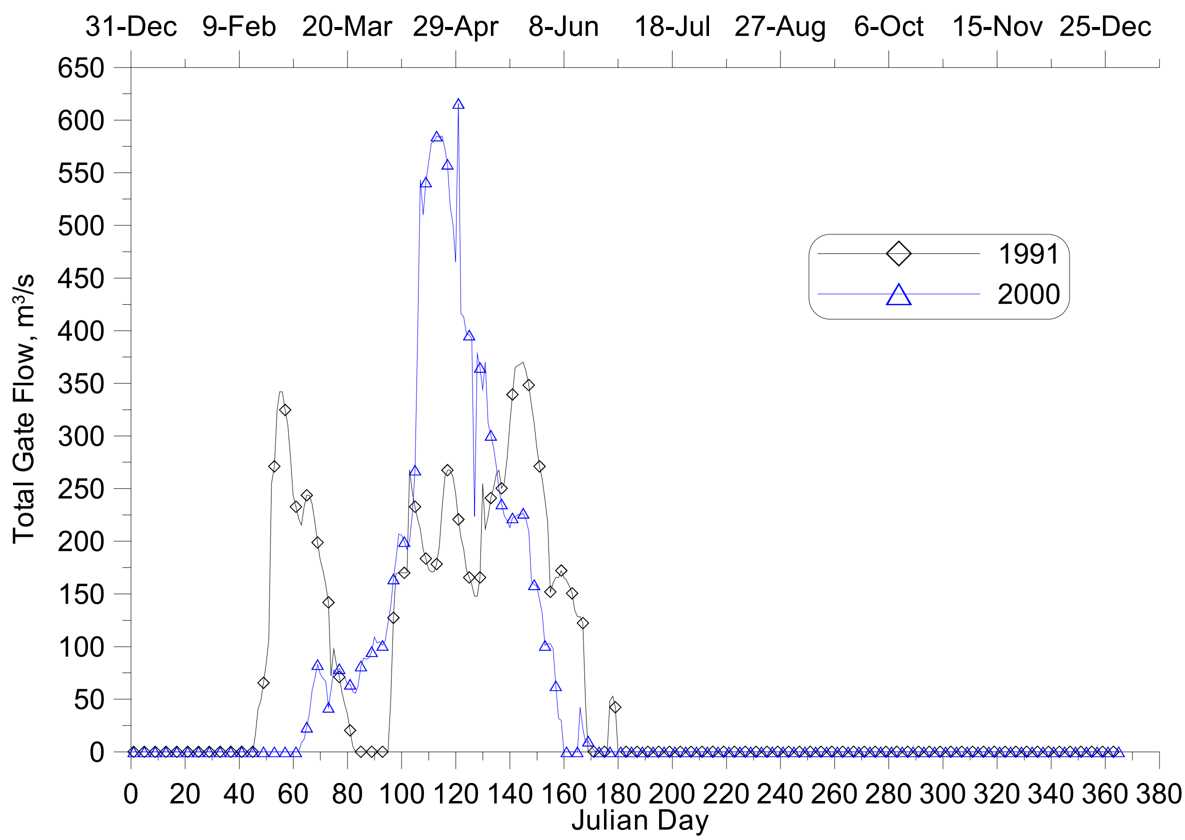


Figure 52. Upriver Dam total flow through all gates, 1991 to 1992 and 2000

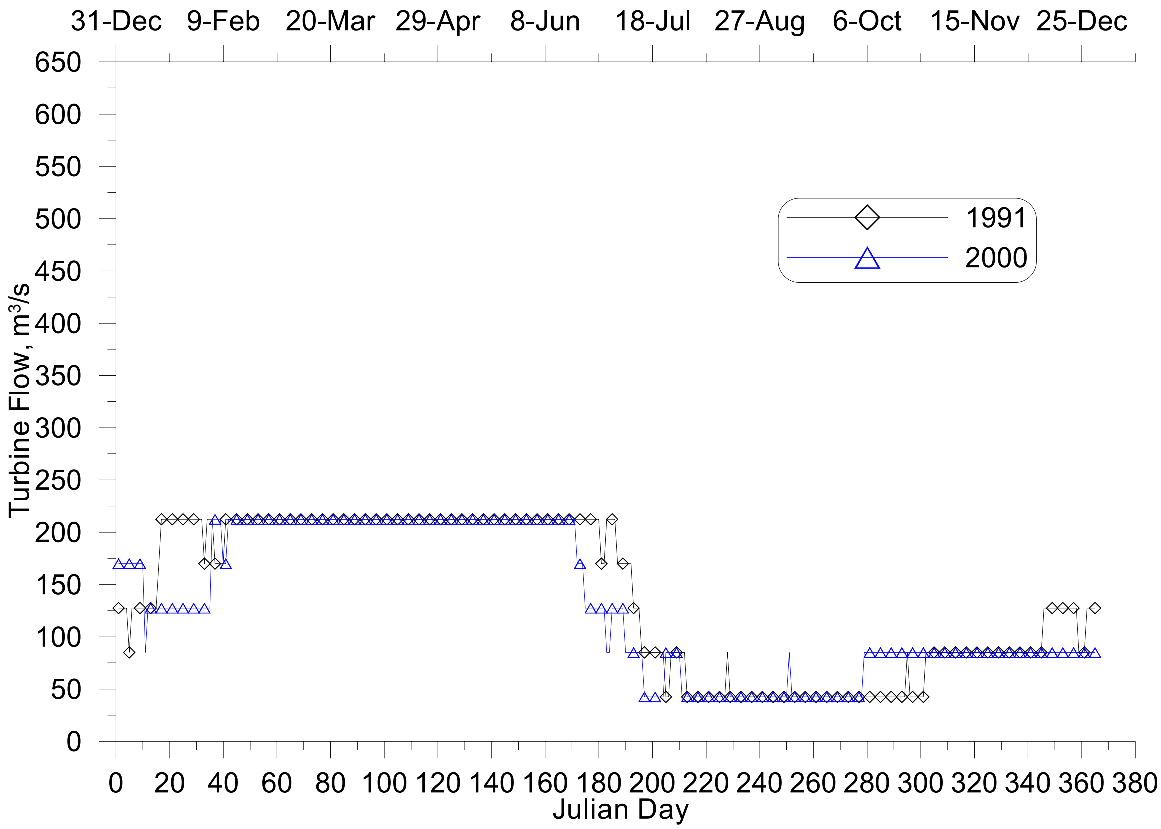


Figure 53. Upriver Dam flow through turbines, 1991 to 1992 and 2000

Upper Falls Dam and Reservoir

The Spokane Falls area is a highly managed stretch of the Spokane River that passes through downtown Spokane. Figure 54 shows an aerial photograph of the area, and Figure 55 shows a more detailed plan view with several features identified. Upper Falls Dam is located at approximately RM 74.8 but most of the river water is diverted down a side channel to the south, which leads to the Upper Falls Powerhouse. During the summer the Upper Falls Dam continuously releases 300 cfs down the north branch of the river. During the winter season when much higher flows are expected, the water cannot be passed through the powerhouse but is spilled at this dam facility. Flow through the Upper Falls powerhouse is then diverted back to the Spokane River to a pool area just below the Spokane Falls Rapids. The Spokane Falls Rapids consist of two branches as well. The furthest north branch is only used when there is very high water whereas the branch south is used to pass the 3000 cfs flow and winter flows regularly. The outflow from the turbines and the flow from the Spokane Rapids meet in a pool area just downstream. Just below the pool and at the top of the Spokane Falls sits the Monroe St Dam and powerhouse. This facility is designed to pass flow through it over a short distance, bypassing the Spokane Falls. The predominant flow through all of these facilities during the summer is through the Upper Falls powerhouse before rejoining the Spokane River.

Figure 56 shows the flow that passes through the turbines at Upper Falls Dam. The figure shows the flow pattern for both 1991 and 2000 were similar. The only exception was the flow through the turbines in 1991 was lower several times during the late summer and early fall indicating less flow was available. Figure 57 shows the flow over the spillway at Upper Falls Dam for 1991 and 2000. The availability of water to spill was similar each year except for the multiple flow peaks in 1991 were replaced by one much larger flow peak in 2000.

Figure 54. Upper Falls Dam and Monroe St. Dam in downtown Spokane, WA

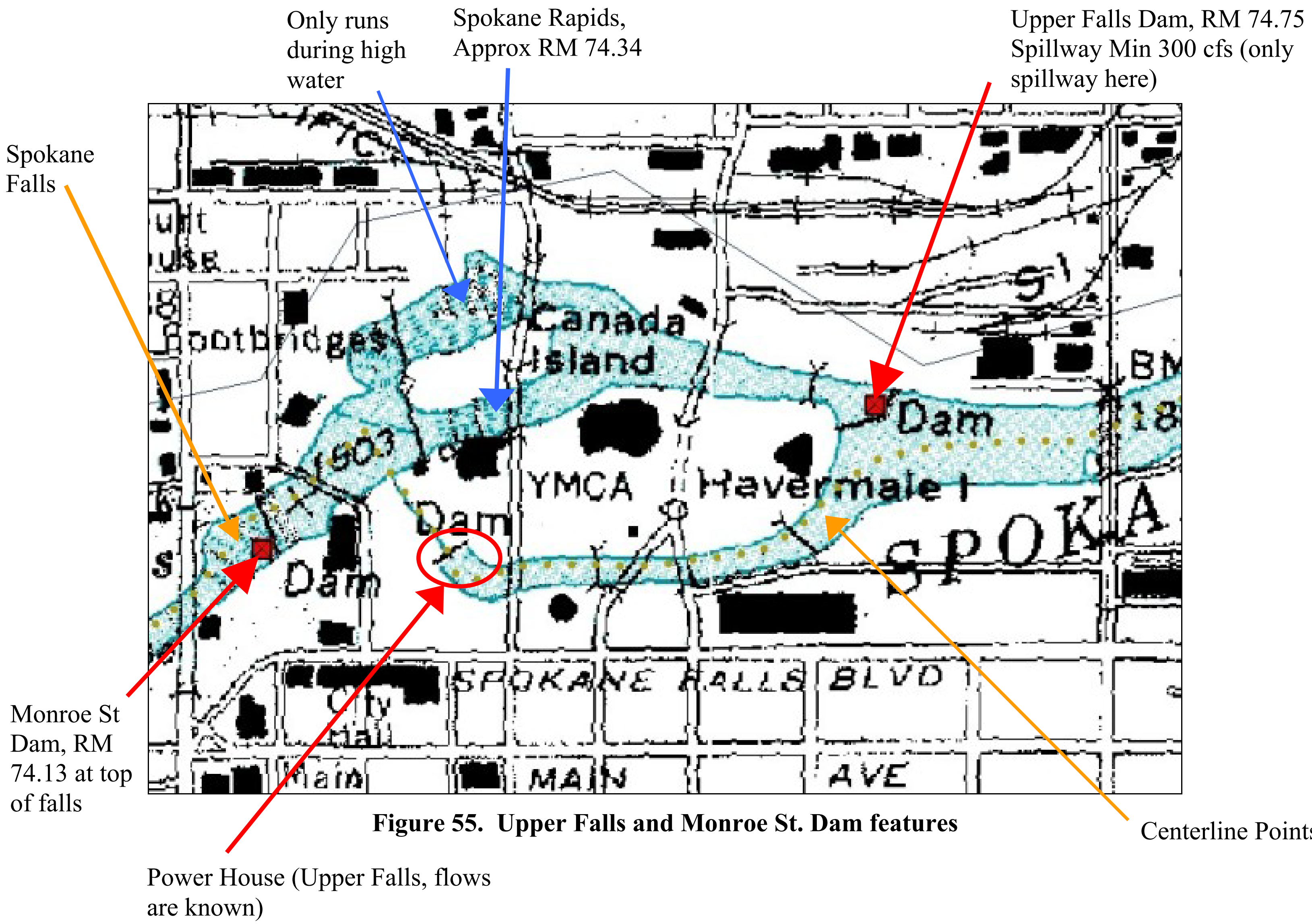


Figure 55. Upper Falls and Monroe St. Dam features

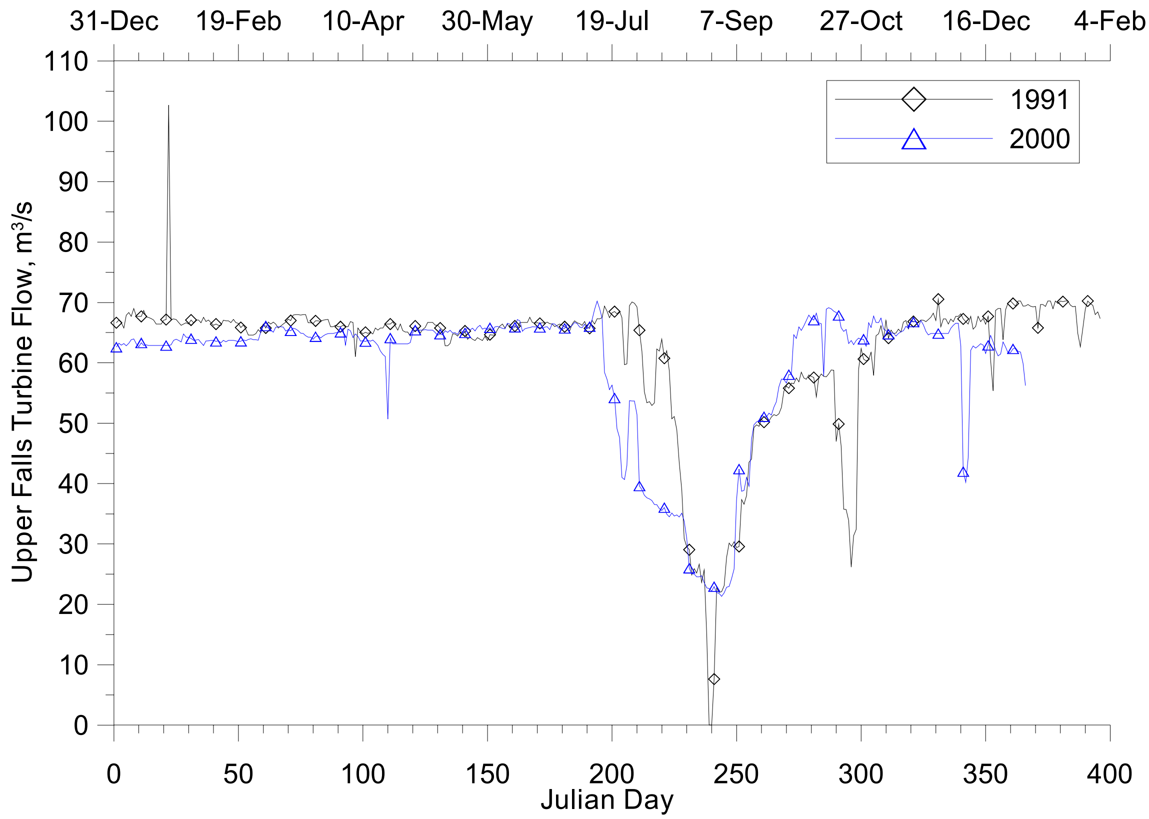


Figure 56. Upper Falls Dam flow through turbines, 1991 to 1992 and 2000.

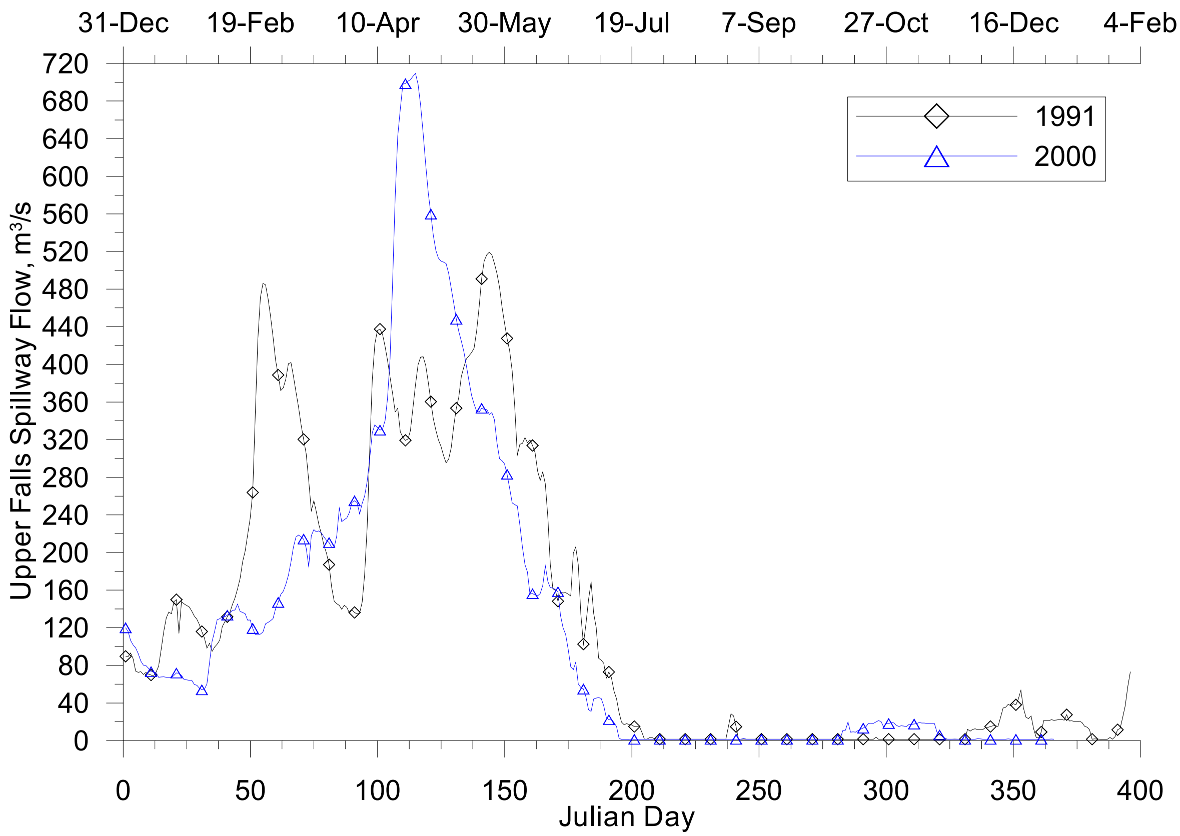
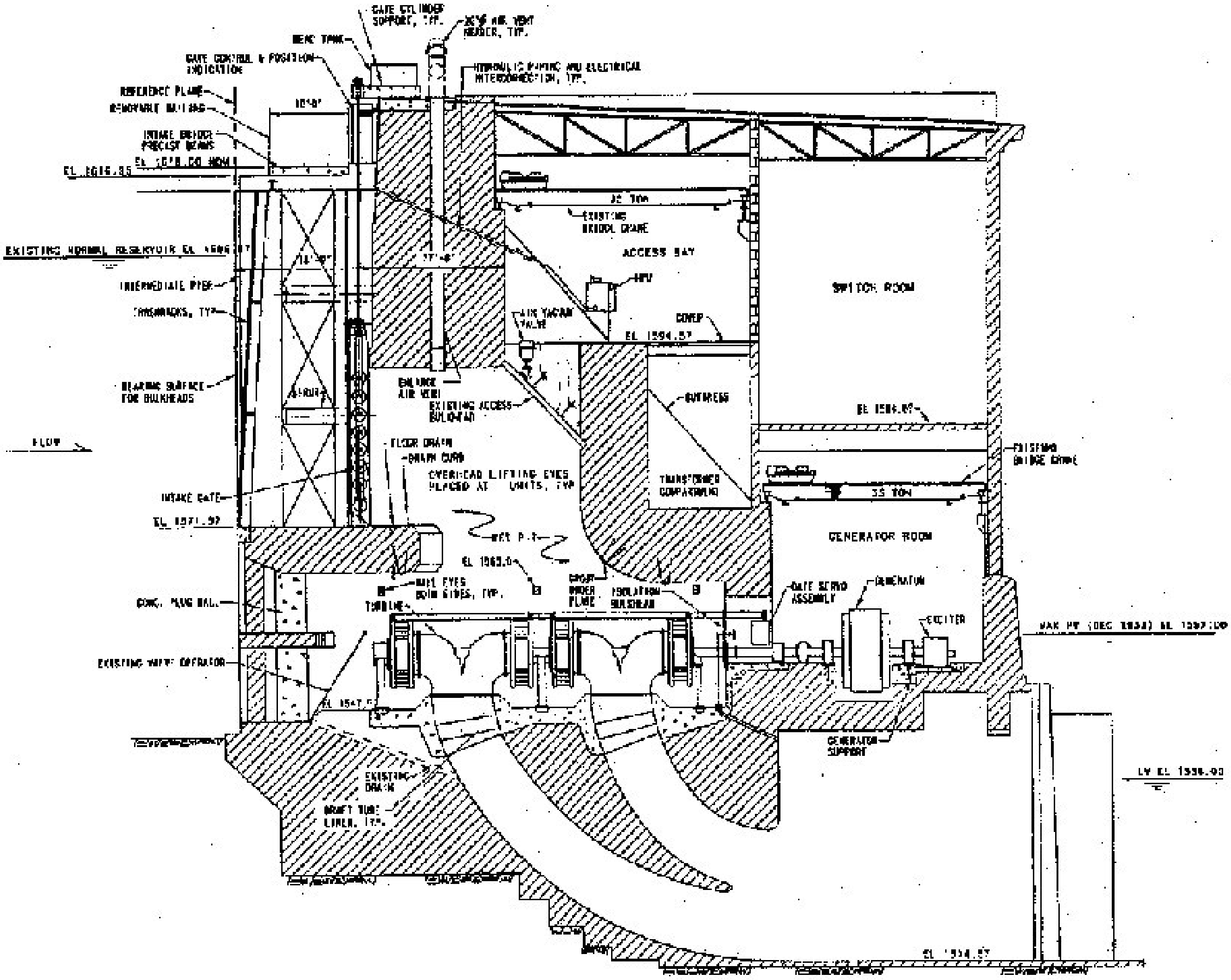


Figure 57. Upper Falls Dam flow over the spillway, 1991 to 1992 and 2000

Nine mile Dam and Reservoir

Nine Mile dam is located at RM 57.8 and consists of a spillway and a powerhouse with multiple turbines. Nine Mile Dam also serves as the headwaters to Long Lake Reservoir. Figure 58 shows a photo of the Nine Mile Powerhouse and spillway looking upstream from a bridge. Figure 59 shows the cross section of one of the turbines at the dam. Figure 60 shows the flow that passed through the turbines in 1991 and 2000. The figure indicates the turbines were able to handle higher flows in the spring of 2000 than in 1991. Also, later in the year the flows passing through the turbines were lower in 2000 in the summer and fall than in 1991. Figure 61 shows the spillway flows passed in 1991 and 2000. Similar to the Upper Falls Dam, the spillway flows show multiple peaks in 1991 but only one large peak in 2000.

Figure 58. Nine Mile Dam and spillway on the Spokane River



SECTION LOOKING WEST AT ℄ BAY #3 & #4

Figure 59. Cross section of Nine Mile Dam and a turbine

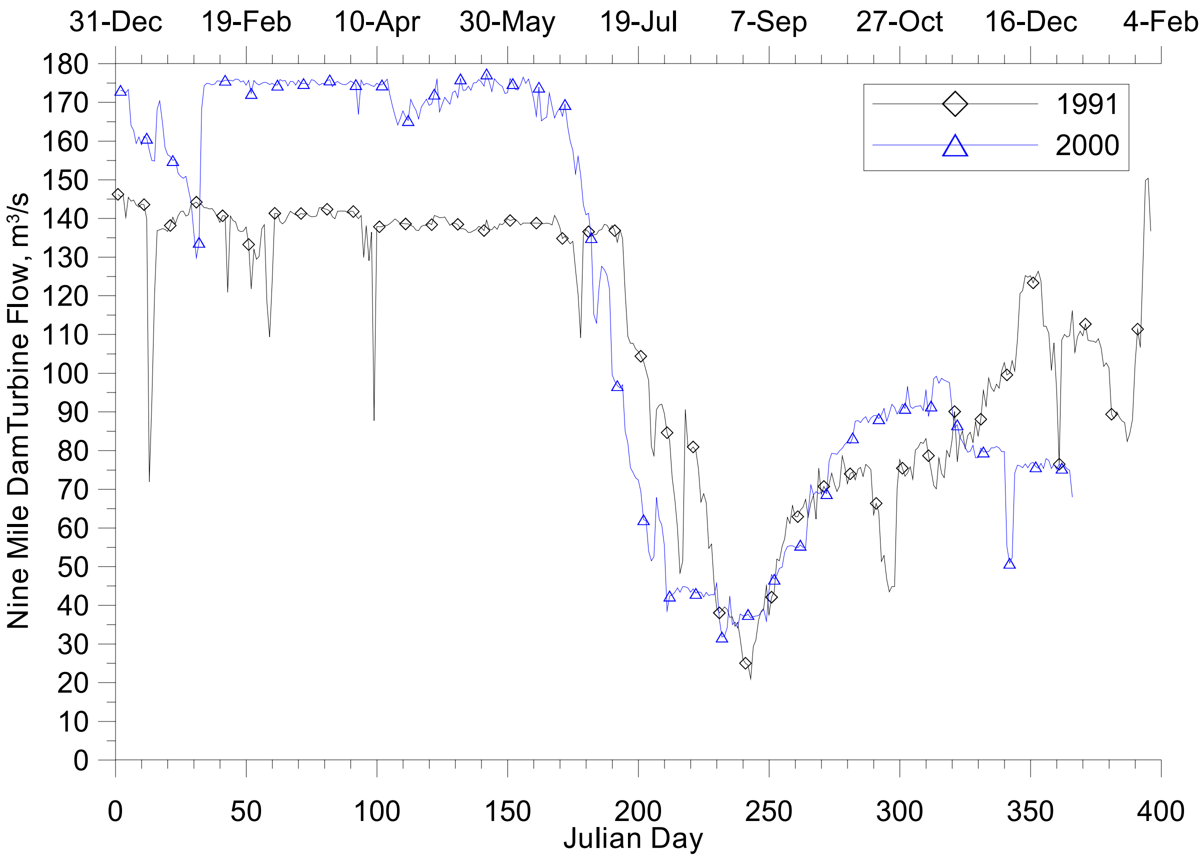


Figure 60. Nine Mile Dam flow through turbines, 1991 to 1992 and 2000

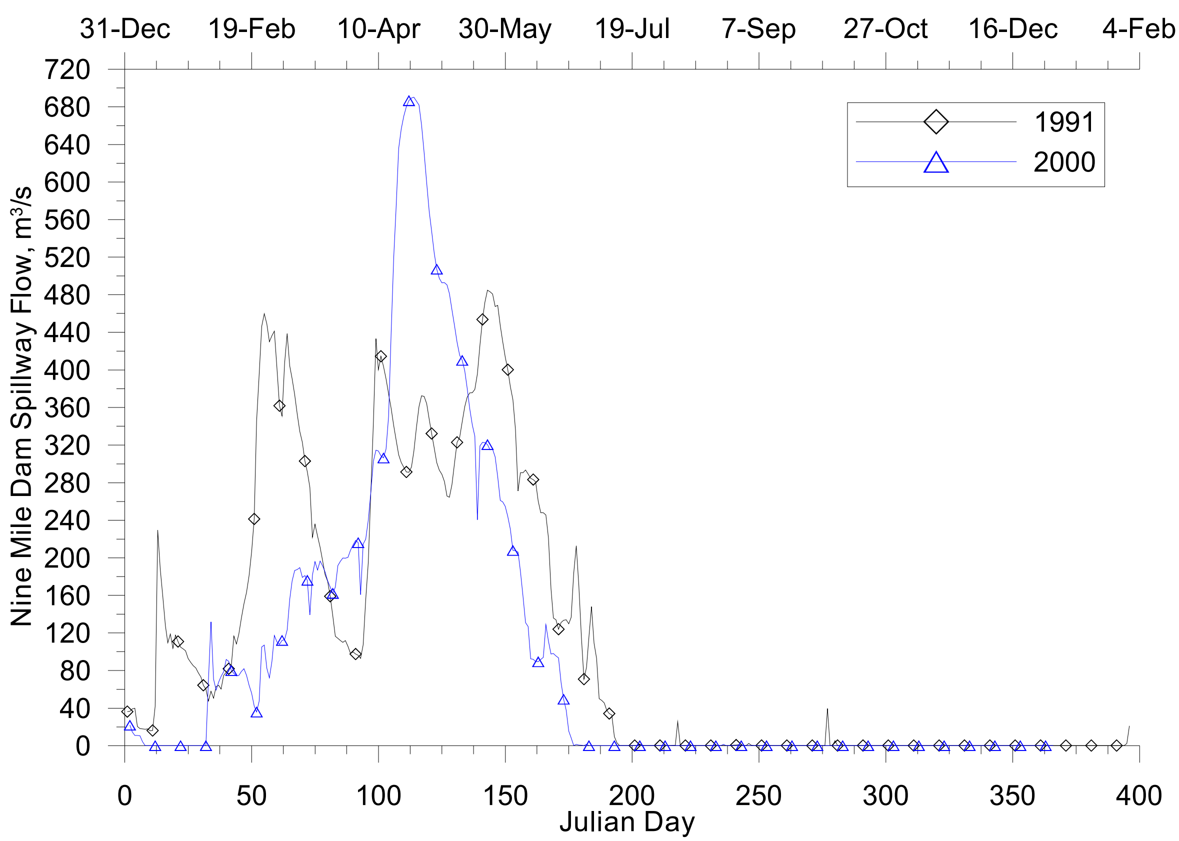


Figure 61. Nine Mile Dam flow over the spillway, 1991 to 1992 and 2000

Long Lake Dam and Reservoir

Long Lake Reservoir is located at the lower end of the modeled system. The dam facilities are located at approximately RM 32.5 and the lake backs up to one mile below Nine Mile Dam at RM 57.8. The Long Lake section of the model includes from Nine Mile Dam to Long Lake Dam, depending on water level the upper most segments of the model may act like a river or lake. The lake has a maximum depth of 170 ft at a full pool elevation of 1536 ft NGVD29. Figure 62 shows the Long Lake Dam, spillway and powerhouse generation facilities. There are 8 vertical lift gates on the dam. Aside from leakage these gates are closed to allow as much storage (normal pool is with gates closed) and power generation as possible. Table 10 lists some dam facility specifications. Figure 63 plots the turbine flow from Long Lake Reservoir for 1991 and 2000. There was no spillway flow data available for 1991 and 2000.

Figure 62. Long Lake Dam and Powerhouse

Table 10. Long Lake Dam and Reservoir Specifications

Specification	ft	m
Top of Dam Elevation	1537	468.48
Spillway Crest Elevation	1508	459.64
Spillway Gate Type	Vertical lift (8)	
Spillway Gate Height	29	8.84
Spillway Gate Width	25	7.62
Normal Full Pool Elevation	1536	468.18
Max Forebay Elevation	1536	468.18
Min Forebay Elevation	1512	460.86
Max Draw down	24	7.32

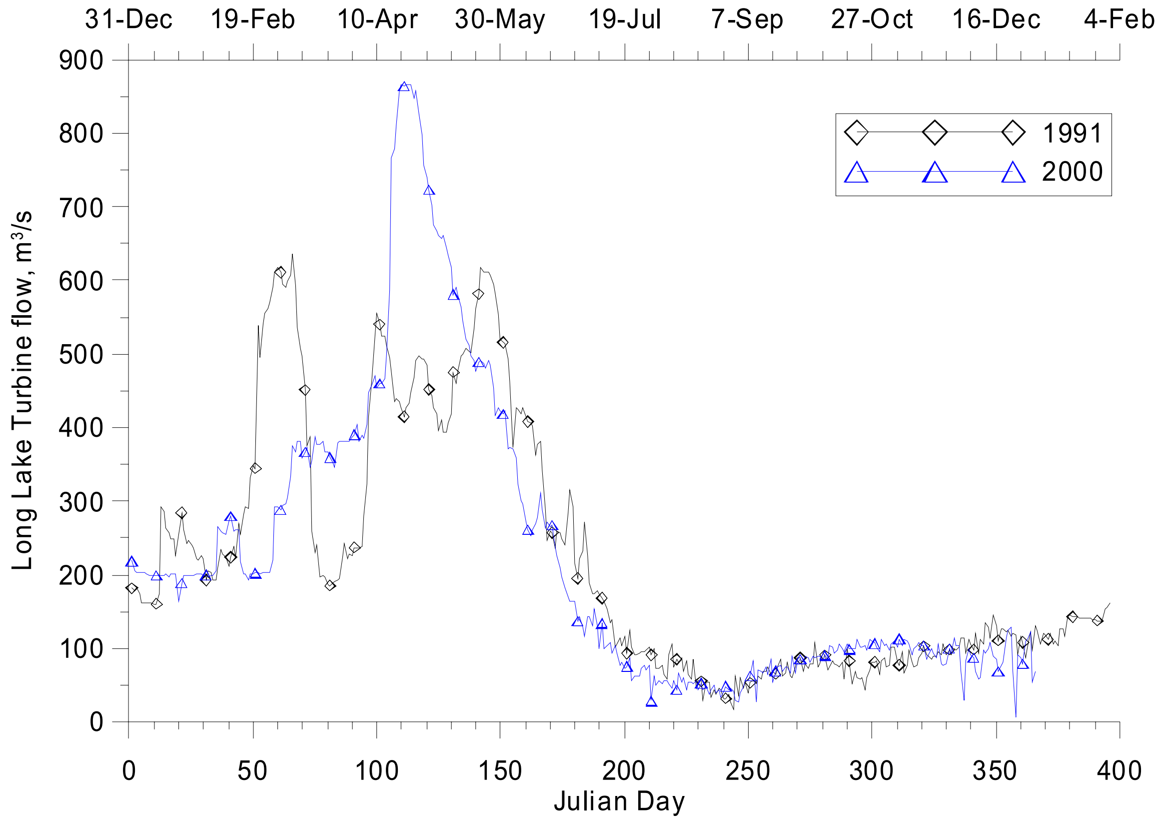


Figure 63. Long Lake Turbine flow, 1991 and 2000

Groundwater

The groundwater to the model was characterized for individual reaches of the rivers system using the model grid branches. The groundwater was characterized by flow, water temperature, and water quality. The model did not use internal interpolation to fill in the boundary conditions between the data.

Spokane River

Estimates for the 1991 river inflow/outflows were made by DOE staff. These techniques were based on review comments and suggestions from DOE staff familiar with the river/aquifer interactions and are discussed in more detail below.

Current and historical data suggest that there are specific inflow/outflow reaches in our study area can be grouped according to River Mile as shown in Table 11.

Table 11. Groundwater flow sections along the Spokane River

Spokane River inflow/outflow zones

RM	To	+ / -
100.7 – 93.7	Harvard Rd. gauge	Outflow
93.7 – 90.4	Barker Rd. gauge	Outflow
90.4 – 87.8	Sullivan Rd. Bridge	Transition
87.8 – 85.3	Trent Rd. Bridge	Inflow

85.3 – 84.2	Plantes Ferry Footbridge	Inflow
84.2 – 82.6	Argonne Rd. Bridge	No change
82.6 – 79.8	Upriver Dam	Outflow
79.8 – 78.0	Green St. Bridge	Inflow
78.0 – 76.7	Mission St.	Outflow
76.7 – 74.1	Post St. Powerhouse	Outflow
74.1 – 72.9	Monroe St. gauge	Inflow
72.9 – 62.0	Seven Mile Bridge	Inflow
62.0 – 58.1	Nine Mile Dam	?

USGS began collecting current data at the historical gauging sites near Harvard Rd and Barker Rd in 1999. In addition, some recent data have been collected at the Plantes Ferry Park Footbridge (historical gauge near Trent Rd). USGS has collected some data at the Green St. gauge (another historical gauging site). Although USGS measured flow at these stations in the past (pre 1970), there were some significant changes in the flow characteristics of the river between the Post Falls (RM 100.7) and Monroe St (RM 72.9) gauges from before and after the late 1960s. Because of the changes, none of the pre-1970 data upstream of the Green St. gauge were used to develop flow relationships. Historical data (1948-1952) from the Green St gauge was used though because the relationship between Green St. and Monroe St was assumed not to have changed.

The following is a summary of what information was used to establish the flow for each river reach:

Post Falls (RM 100.7) to Harvard Rd. (RM 96.0)

- Used gauge data collected in 1999 and 2000 at Harvard Rd. to establish a regression estimate (Harvard Rd vs. Post Falls).
- Flows <300 cfs were omitted from the regression based on a recommendation from Stan Miller, Spokane County, to not include the lowest flows. He suggested that the gauge-rating curve is probably not accurate at the lowest flows.
- The river stage is always higher than the measured groundwater level in monitoring wells in this reach (Gearhart and Buchanan, 2000)

Harvard Rd. (RM 96.0) to Barker Rd. (RM 90.4)

- (same as Post Falls to Harvard Rd. described above)

Barker Rd. (RM 90.4) to Sullivan Rd. (RM 87.8)

- The river reach between Barker Rd. and Sullivan Rd (RM 87.8) has been identified as a "transition zone" from river outflow to inflow conditions. The higher the flow the closer the upstream boundary of the inflow zone is to Barker Rd. Conversely, at low flows the upstream boundary of the inflow zone is closer to Sullivan Rd.
- At low river flow conditions it has been estimated that only about 28 cfs is lost between Bark Rd and Sullivan Rd (Gearhart and Buchanan, 2000)
- Stan Miller suggests that the reach is probably loosing water to about Flora Rd. (RM 89.1)

Barker Rd./Flora Rd. (RM 90.4 - 89.1) to the Plantes Ferry Park Footbridge (RM 84.0)

- Current and historical data show that this is an inflow reach.
- Used flow data collected at the footbridge provided by Stan Miller to establish a mean inflow of 318 cfs for this reach (std. dev 130 cfs).
- the mean inflow was used because there were only eight data points.

Plantes Ferry Foot Bridge (RM 84.0) to Argonne Rd. Bridge (RM 82.6)

- No change in river flow in this reach.

Argonne Rd. (RM 82.6) to Upriver Dam (RM 79.8)

- Used Upriver Dam flow data reported by Patmont et al. (1985) to establish a mean outflow for this reach of –256 cfs (std. dev 65 cfs).
- the mean outflow was used because there are only nine data points.

Upriver Dam (RM 79.8) to Green St. (RM 78.0)

- Historical data show that this is an inflow reach. Patmont et al. (1985) estimated the mean inflow for this reach to be 488 cfs (std. dev. 157 cfs).
- Used historical gauge data (1948-1952) to establish a regression estimate (Green St vs. Monroe St).

Green St. (RM 78.0) to Post St Powerhouse (RM 74.1)

- Well elevation data show that the river elevation is above the groundwater elevation in this reach.
- Historical data suggest that this is an outflow reach.
- Use turbine and spillway discharge estimates provided by AVISTA to provide estimated changes in river flow for this reach.

Post St. Powerhouse (RM 74.1) to Monroe St. (RM 72.9)

- Use AVISTA turbine and spillway discharge estimates and gauge data at Monroe St to determine flow balance.

Monroe St. (RM 72.9) to Seven Mile Br. (RM 62.0)

- Historical data show that this is an inflow reach.
- Used historical gauge data (1948-1952) to establish a regression estimate (Seven-Mile Br. vs. Monroe St).

Seven Mile Br. (RM 62.0) to Nine Mile Dam (RM 58.1)

- Used turbine and spillway discharge estimates provided by AVISTA to provide estimated changes in river flow for this reach.

Aquifer exchanges were modeled as distributed tributaries. CE-QUAL-W2 permits modeling of distributed tributaries on a branch-by-branch basis. The procedure to estimate flow for each model branch was summarized in Table 12.

Table 12. Aquifer exchange estimate for each model branch.

Branch #	Description	River Miles	Aquifer exchange flow estimate
1	Stateline to Harvard Road Bridge	96.40-93.82	Flow = Harvard Road Flow – State Line Flow • Used Harvard Road flow data for 2000 from Julian Day 1 to 231, and 246 to 341 • For times without data and when flow at Post Falls was less than 300 cfs, Harvard Road Flow estimated with Q =0.00000199*(Post Falls Q^2)+(0.924428071*Post Falls)-68.770025129 • The calculation estimating state line flow is described above in the section discussing boundary conditions
2	Harvard Road Bridge to Barker Road	93.82-90.34	Flow = Barker Road Flow-Harvard Road Flow – Liberty Lake Discharge • Used Barker flow data for 2000 from Julian 1 to 212, 226 to 232 and after 245 • For times without data and when flow at Post Falls was less than 300 cfs, Barker Road Flows estimated with Q =(0.000002598*(Post Falls Q^2))+(0.912746*Post Falls Q)-112.36
3-4	Barker Road Bridge to Islands Foot Bridge	90.34-84.45	Flow = 318 cfs
5	The Islands Foot Bridge to Upriver Dam	84.45-80.18	Flow = -256 cfs
6	Upriver Dam to Green Street Bridge	80.18-78.10	Flow = Green Street Flow – Upriver Dam Flow Green Street Flow estimated with Q=(1.0026*Spokane USGS gage Q)-27.65
7	Green Street Bridge to Upper Falls Dam	78.10-74.75	Flow = Upper Falls Flow – Green Street Flow
8	Upper Falls Dam to Spokane USGS gage	74.75-72.93	Flow= Spokane USGS Flow – Upper Falls Flow
9	Spokane USGS gage to Seven Mile Bridge	72.93-63.20	Flow = Seven Mile Bridge Flow – Spokane USGS gage Flow – Spokane WWTP Flow – Hangman Creek Flow • Seven Mile Bridge Flow estimated with Q=(0.9975684*Spokane USGS gage Q)+137.1542)
10-11	Seven Mile Bridge to Nine Mile Dam	63.20-57.77	Flow = Nine Mile Dam Flow – Seven Mile Bridge Flow

Spokane River groundwater quality

Groundwater constituent files for reaches between the Stateline and Nine Mile Dam were developed from 1999 well data compiled by the Washington Department of Ecology. Water quality data from three wells in the Sullivan Road area were chosen to characterize groundwater because this was a reach where groundwater generally flows into the river (Gearhart and Buchanan, 2000). Water quality data obtained from these wells included total alkalinity, total dissolved solids, soluble reactive phosphorus, nitrite-nitrate, pH, temperature, chloride and dissolved oxygen. These data were listed in Table 13.

Dissolved oxygen, temperature, pH, nitrate-nitrite and soluble reactive phosphorus data were plotted in Figure 64 through Figure 68. There did not appear to be any large seasonal trends in the data.

Table 13. Groundwater water quality collected in 1999 from wells in the Sullivan Road area.

Date	Total Alk. (mg/l)	Total Diss. Solids (mg/l)	Soluble Reactive Phosph. (mg/l)	Total Phos-phorus (mg/l)	Nitrite – Nitrate (mg/l)	pH	Temper-ature (C)	Chloride (mg/l)	D. O. (mg/l)
Well No. 5411R02 - Sullivan Rd., 200 ft North									
19-May-99	123	145			0.937	7.41	11.3	1.73	6.4
16-Jun-99	92.4	131	0.007	0.0038	0.733	7.47	12.2	1.47	7.9
13-Jul-99	116	154	0.005	0.0119	0.925	7.59	12.1	1.74	8
16-Aug-99	122	3	0.005	0.0181	0.988	7.72	12.1	1.45	7.1
13-Sep-99	125	156	0.006	0.0208	0.945	7.85	12.2	1.45	7.8
12-Oct-99	127	161			1	7.83	11.2	1.54	7.96
16-Nov-99	129	152			1.02	7.88	10.5	1.44	8.08
Average	119	129	0.0058	0.0137	0.94	7.68	11.66	1.55	7.61
Well No. 5411R03 - Sullivan Rd., 100 ft North									
19-May-99	125	147			0.932	7.28	11.1	1.63	5.9
16-Jun-99	99.5	127	0.007	0.015	0.749	7.9	11.8	1.45	7.4
13-Jul-99	122	156	0.006	0.0162	0.991	7.78	11.9	1.67	7.7
16-Aug-99	124	154	0.006	0.0187	1	7.74	11.8	1.44	7.1
13-Sep-99	128	156	0.007	0.0195	0.972	7.84	12.2	1.43	7.55
12-Oct-99	129	158			1.01	7.88	11.1	1.45	7.75
16-Nov-99	129	154			1.03	7.93	10.5	1.48	7.97
Average	122	150	0.0065	0.0174	0.95	7.76	11.49	1.51	7.34
Well No. 5411R04 - Sullivan Rd., 100 ft South									
19-May-99	105	126			0.821	7.82	10.6	1.37	9.4
16-Jun-99	103	136	0.007	0.0184	0.767	8.06	12.4	1.61	8
13-Jul-99	98.1	124	0.006	0.00679	0.868	7.84	12.4	1.47	8
16-Aug-99	114	144	0.007	0.0199	3.78	7.79	11.7	1.79	7
13-Sep-99	126	191	0.007	0.0263	1.01	7.82	12.2	1.54	6.77
12-Oct-99	126	156			0.984	7.86	11.5	1.5	7.36
16-Nov-99	124	155			0.96	7.92	11.4	1.46	7.1
Average	114	147	0.0068	0.0178	1.31	7.87	11.74	1.56	7.66

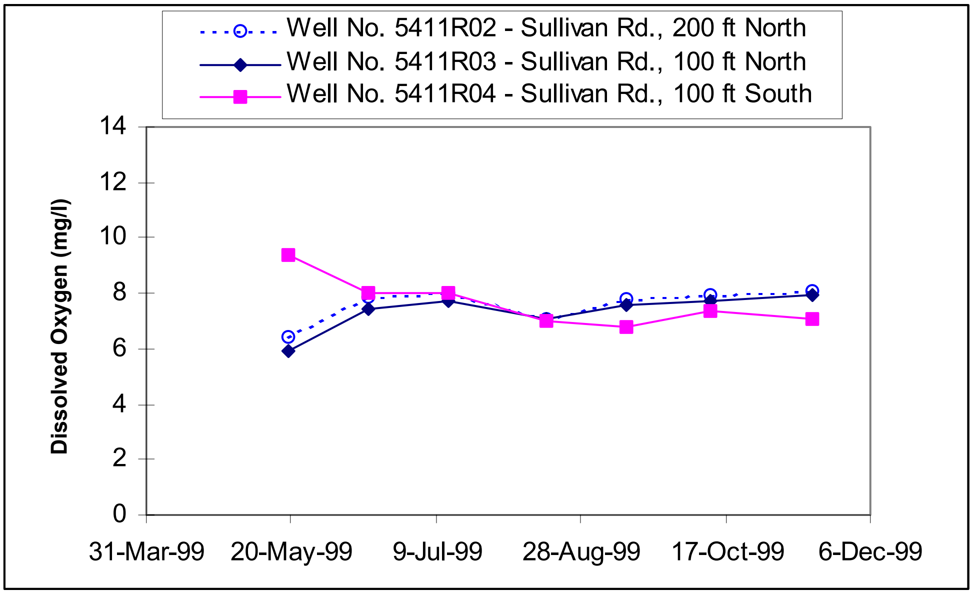


Figure 64. Groundwater dissolved oxygen data collected from wells in the Sullivan Road area.

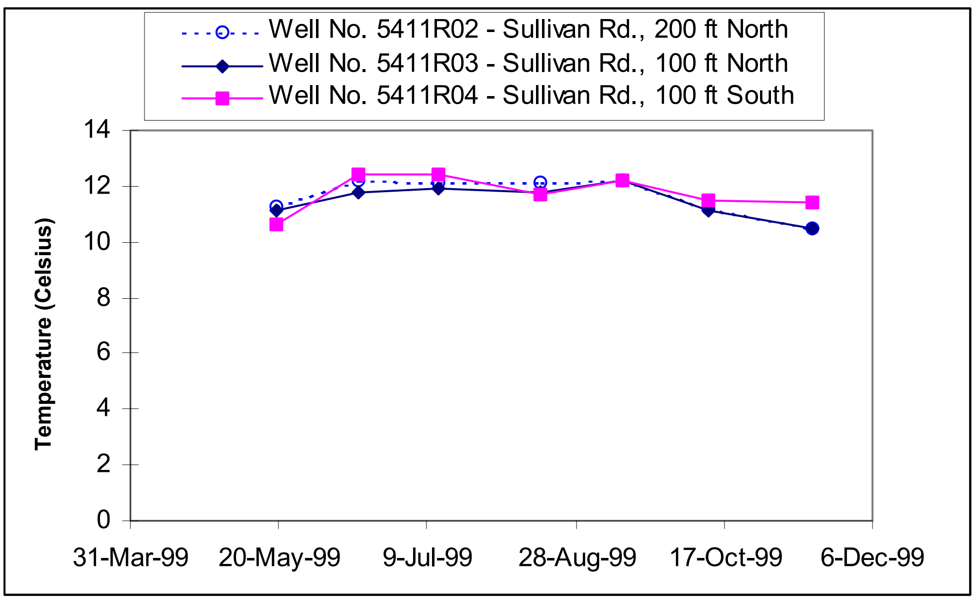


Figure 65. Temperature data collected from wells near the Spokane River in the Sullivan Road area.

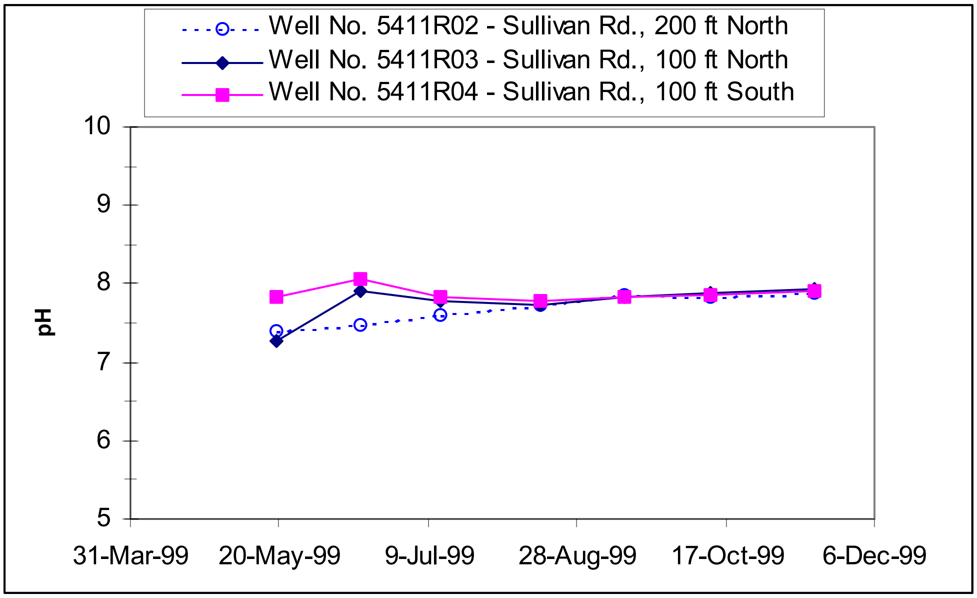


Figure 66. Groundwater pH data collected from wells in the Sullivan Road area.

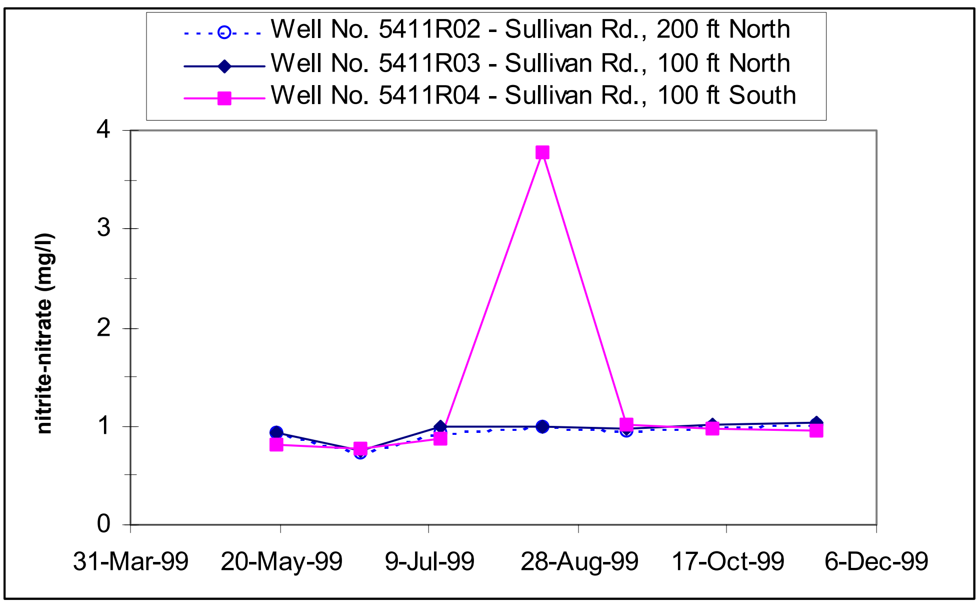


Figure 67. Groundwater nitrite-nitrate data collected from wells in the Sullivan Road area.

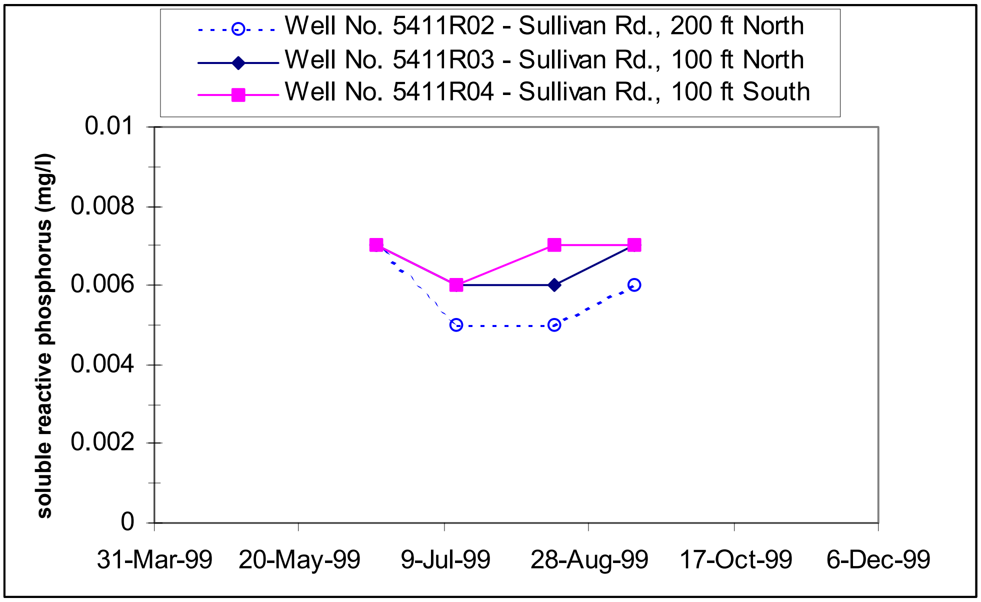


Figure 68. Groundwater soluble reactive phosphorus data collected from wells in the Sullivan Road area.

Groundwater inflows were modeled as distributed tributaries. The Sullivan Road well data were used to develop the temperature and water quality input files for model branches 1 through 11, which represent the river from the state line to Nine Mile Dam. The data from all three wells were averaged together over all sampling dates to develop model inputs for temperature, dissolved oxygen concentration, alkalinity, nitrite-nitrate, chloride, total dissolved solids and bioavailable phosphorus. The soluble reactive phosphorus data were used as the bioavailable phosphorus concentrations input to the model. Nitrification was assumed to be complete and ammonia-nitrogen concentrations were set to zero. Organic matter concentrations including labile and refractory dissolved organic matter, labile and refractory particulate organic matter were also assumed to be zero. Inorganic carbon concentration was calculated from pH, alkalinity and temperature data using the method described above under Spokane River at state line. Table 14 lists groundwater water quality concentrations used for branches 1 through 11 for the 1991 and 2000 simulations.

Table 14. Temperature and constituent concentrations used to characterize groundwater for model branches 1 through 11.

Parameter	Temp. (C)	Alk-alinity (mg/l)	TDS (mg/l)	PO4-P (mg/l)	Nitrate-Nitrite (mg/l)	D. O. (mg/l)	NH4-N (mg/l)	Chloride (mg/l)	Inorganic Carbon (mg/l)
Value	11.6	118	142	0.006	1.0	7.5	0.0	1.53	29.6

Long Lake

A distributed tributary was developed for Long Lake based on flows in the Little Spokane River basin. The ratio of the drainage area surrounding the lake was divided by the drainage area of the Little Spokane River basin and then multiplied by the estimated Little Spokane River flow. Figure 69 shows the estimated flow for the distributed tributary to Long Lake.

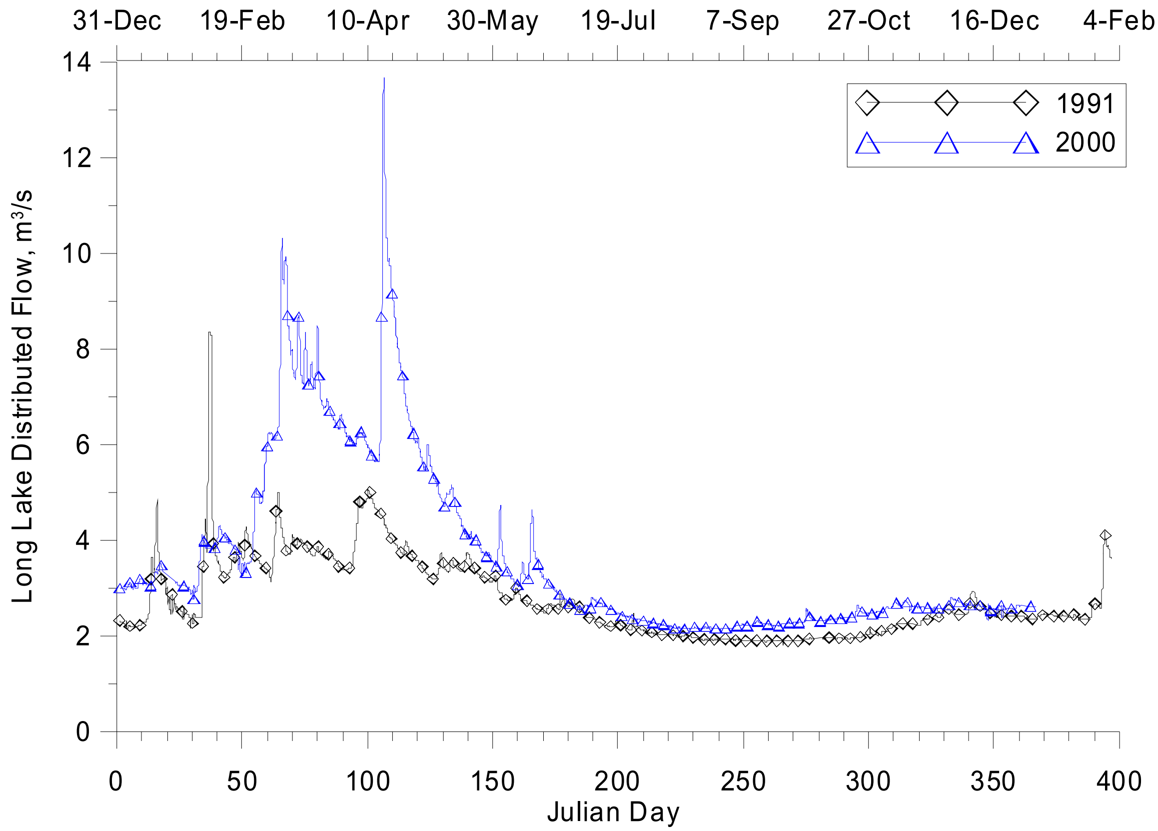


Figure 69. Long Lake distributed inflow, m^3/s, 1991 and 2000

Long Lake groundwater quality

The groundwater water quality flowing into Long Lake was characterized using well data described by Soltero et al. (1992). The groundwater quality and flow patterns about Long Lake are complex with areas where groundwater flows into the lake and other areas where reservoir water flows into the aquifer. Only data from wells where the gradient results in groundwater flow into Long Lake were used to characterize the groundwater quality. Well data means of temperature, soluble reactive phosphorus, nitrate, nitrite, dissolved oxygen, ammonia-N, conductivity and chloride were summarized in Table 15.

Table 15. Water quality means of wells located around Long Lake.

Well	Temperature (Celsius)	Soluble Reactive P (mg/l)	NO3-N (mg/l)	NO2-N (mg/l)	D. O. (mg/l)	NH-3-N (mg/l)	Chloride (mg/l)	Conduc-tivity (µmhos/cm)
SW-1	11.9	0.019	3.34	0.084	2.2	0.12	5.32	490
SW-2	12.0	0.007	0.75	0.004	7.1	0.03	2.84	449
SW-3	12.5	0.006	2.96	0.003	6.8	0.07	9.93	551
SCE-1	12.1	0.017	1.11	0.044	8.4	0.06	3.90	513
TY-1	12.5	0.006	2.23	0.003	5.9	0.02	5.67	467
TY-2	12.0	0.005	0.23	0.002	2.7	0.04	3.90	308
C-1	10.9	0.123	2.91	0.023	7.4	0.02	3.55	253
C-2	12.1	0.008	4.91	0.133	3.4	0.04	9.57	476
C-3	10.4	0.035	2.79	0.006	8.7	0.05	4.96	423
Average	11.82	0.025	2.36	0.030	5.84	0.05	5.51	393

The averages of these wells were used to characterize groundwater quality for the Long Lake reach of the model. Soluble reactive phosphorus was used as the bioavailable phosphorus required by the model. Alkalinity, inorganic carbon, and total dissolved solids were assumed to be the same as listed above for the other Spokane River model branches.

Table 16. Temperature and constituent concentrations used to characterize groundwater for Long Lake branch 12.

Parameter	Temp. (C)	Alk-alinity (mg/l)	TDS (mg/l)	PO4-P (mg/l)	Nitrate-Nitrite (mg/l)	D. O. (mg/l)	NH4-N (mg/l)	Chloride (mg/l)	Inorganic Carbon (mg/l)	Conduc-tivity (µmhos/cm)
Value	11.8	118	142	0.025	2.39	5.84	0.05	5.51	29.6	393

Point Dischargers

There are four significant point sources along the Spokane River that were included in the modeling effort. The sites are listed in Table 17 along with their river mile location. Figure 70 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 17. 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

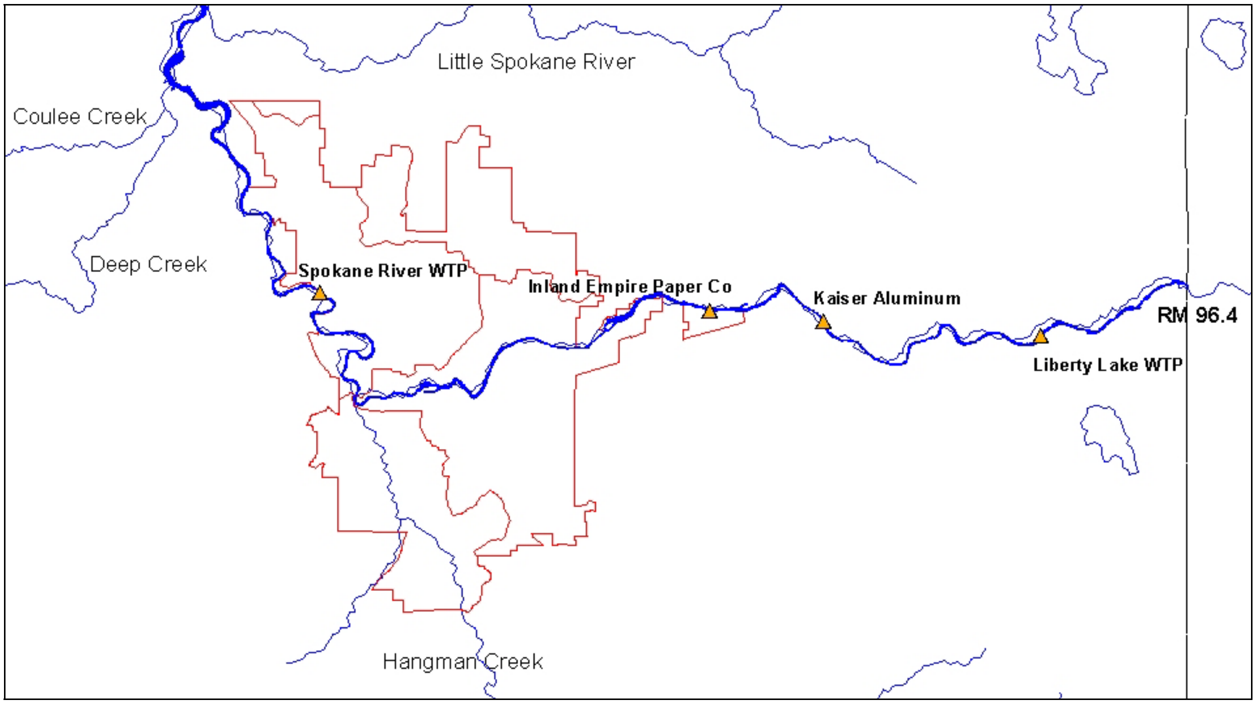


Figure 70. Point Discharges to the Spokane River

Kaiser Aluminum

Kaiser Aluminum flow data were recorded on a daily basis and temperature and water quality data were recorded on a monthly basis. Figure 71 shows the discharge flow for 1991 to 1992 and 2000. Figure 72 shows the discharge temperature for the same time periods. Figure 71 shows the discharge flow rate does not vary much over the course of the years or between 1991 and 2000. Overall discharge rates are slightly lower in 1991 over 2000. Discharge temperatures exhibit a similar warming trend over the course of the year between 1991 and 2000. Temperatures were lower in 2000 than in 1991, possibly due to larger flows in 2000.

For 2000, the Kaiser Aluminum point source water quality was characterized using dissolved oxygen, conductivity, chloride, ammonia nitrogen, nitrite-nitrate nitrogen, soluble reactive phosphorus, alkalinity, carbonaceous BOD ultimate ($CBOD_u$), and total and dissolved organic carbon data. No coliform data were available and concentrations were assumed to be zero.

A separate CBOD compartment and CBOD ultimate data were used in the model simulate organic matter originating from Kaiser Aluminum. Since organic matter was accounted for in the BOD compartment, LDOM, RDOM, LPOM, and RPOM concentrations were set to zero. The decay rate for the CBOD ultimate was obtained from the Washington Department of Ecology.

The inorganic carbon concentrations were estimated using alkalinity data and the method described above for the Spokane River at the state line. The pH was assumed to be 7.0. Inorganic suspended solids concentrations were estimated using the same procedure outlined for the Spokane River at the state line with the algae concentration as zero. Since no data were available, total dissolved solid (TDS) and fecal coliform concentrations were assumed to be zero.

Kaiser water quality data used to characterize the 1991 modeling year included soluble reactive phosphorus, carbonaceous BOD ultimate ($CBOD_u$), nitrite-nitrate nitrogen, ammonia nitrogen, and dissolved oxygen. The yearly average data from the year 2000 were used for alkalinity, chloride, and conductivity. Fecal coliform, inorganic suspended solids, and total dissolved solids were set to zero due to lack of data.

The 1991 and 2000 constituent concentrations of the Kaiser Aluminum point source were plotted in Figure 73, Figure 74, and Figure 75. Some constituents had few data points so an average of the available data was used.

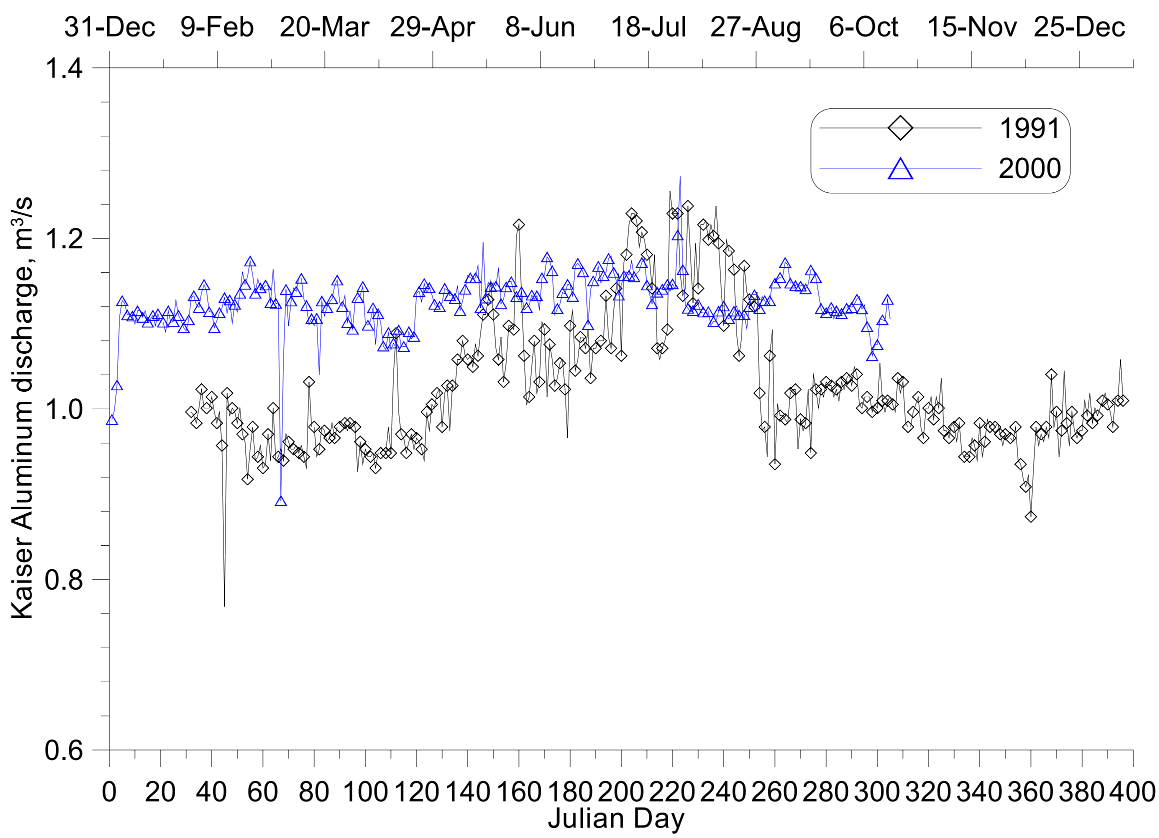


Figure 71. Kaiser Aluminum discharge flow, 1991-1992 and 2000

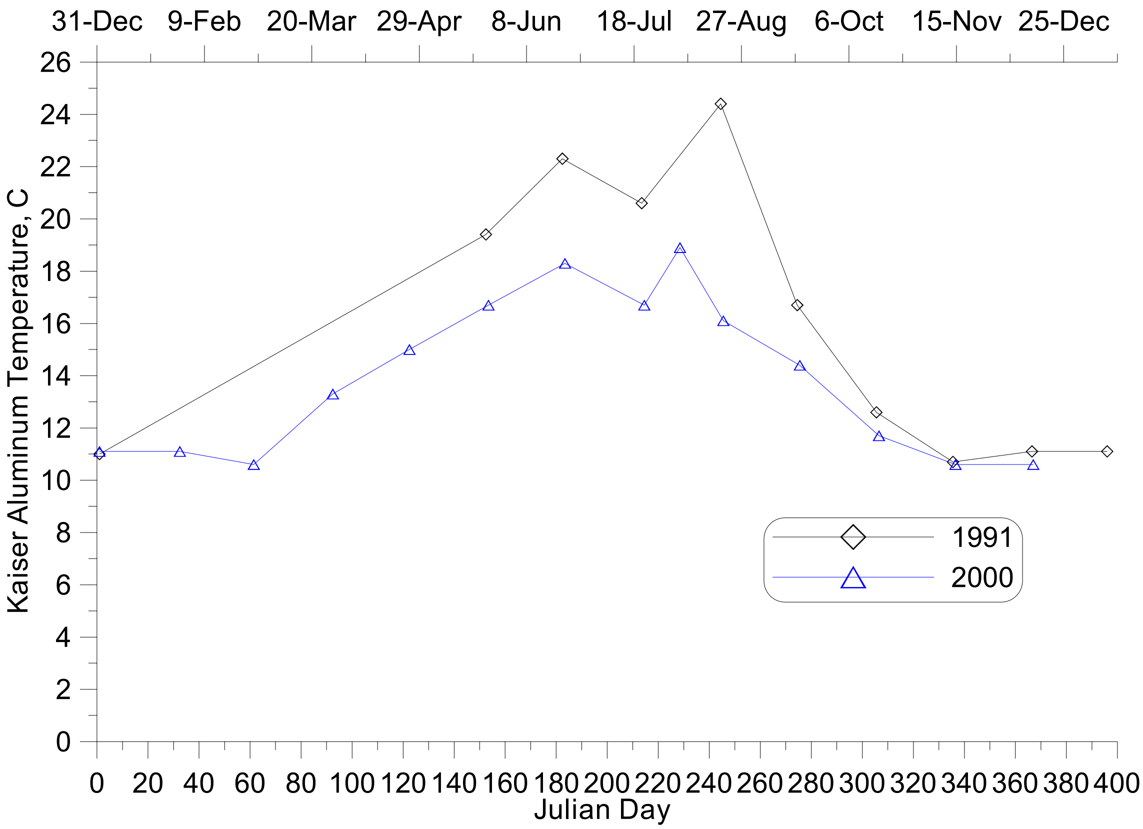


Figure 72. Kaiser Aluminum discharge temperature, 1991-1992 and 2000

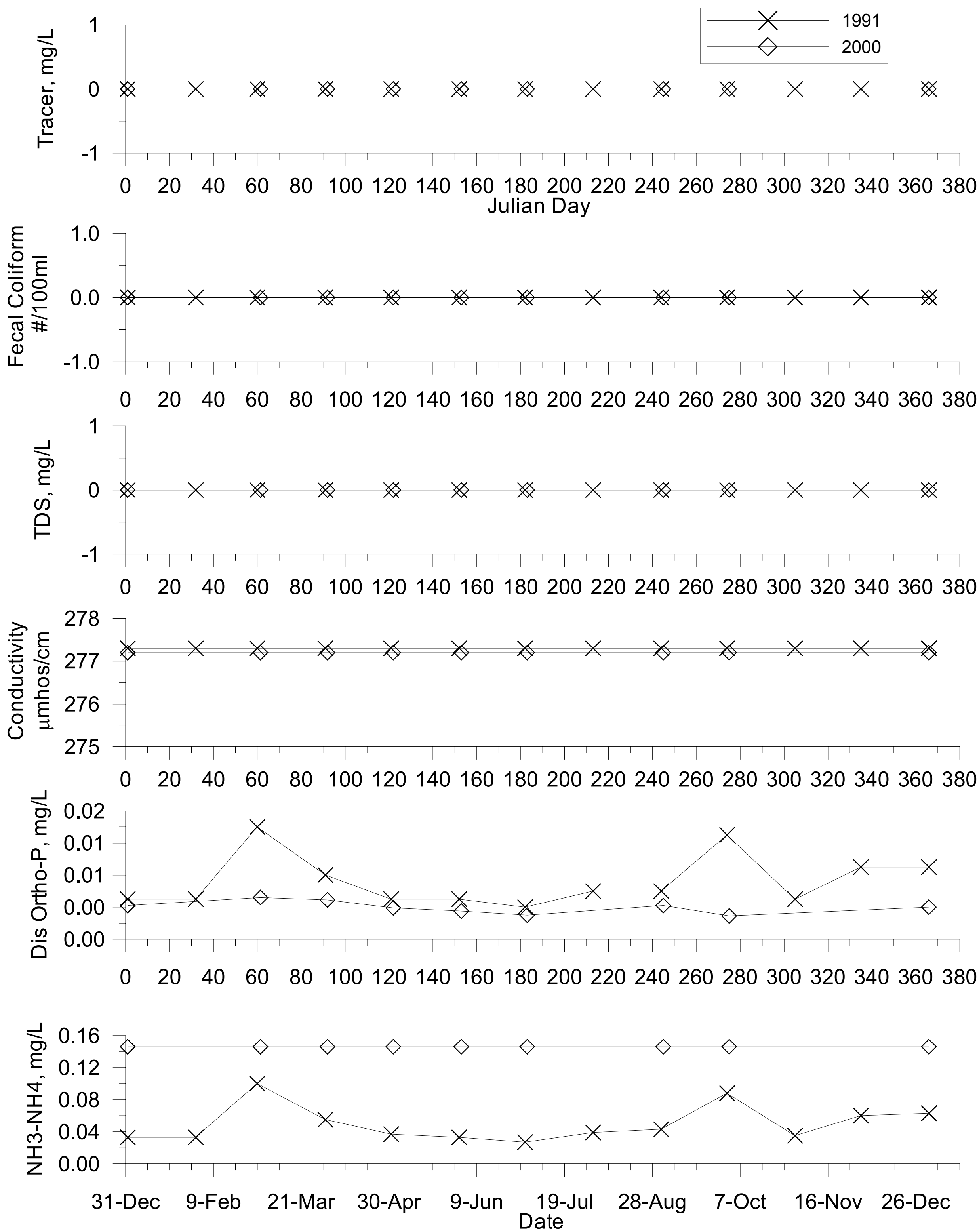


Figure 73. Kaiser Aluminum discharge water quality conditions (Part 1)

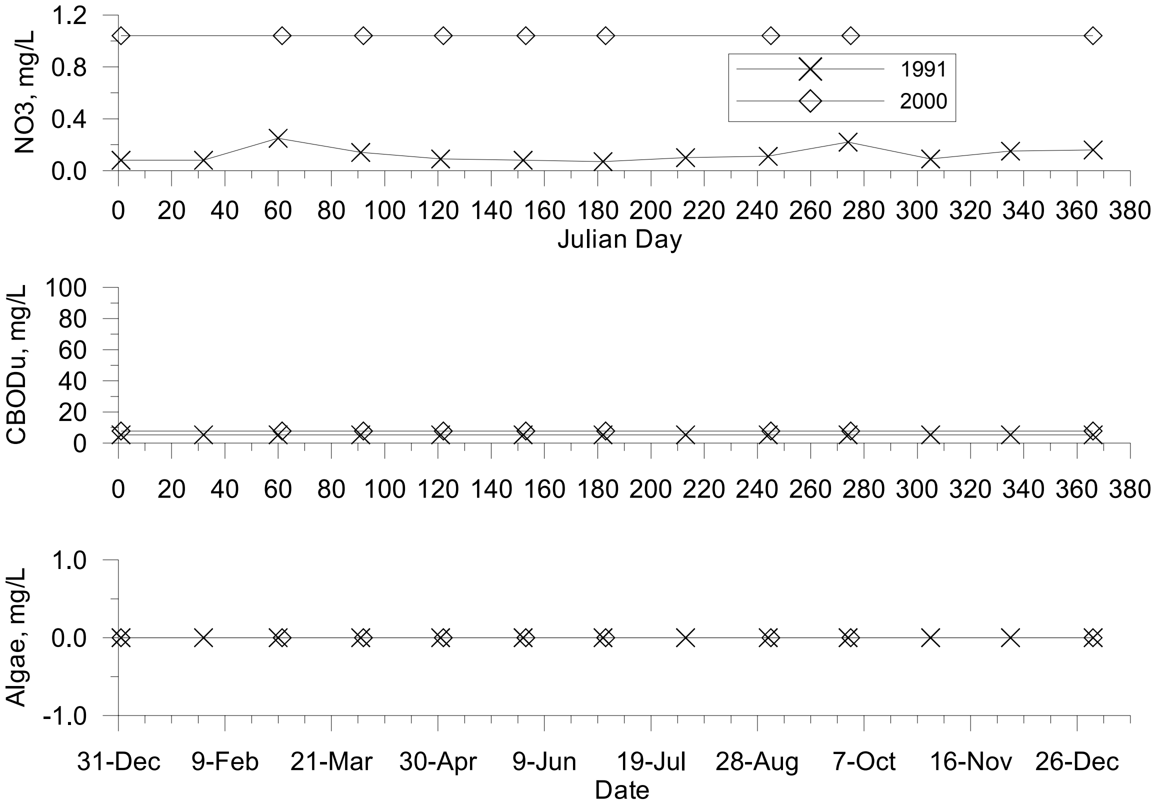


Figure 74. Kaiser Aluminum discharge water quality conditions (Part 2)

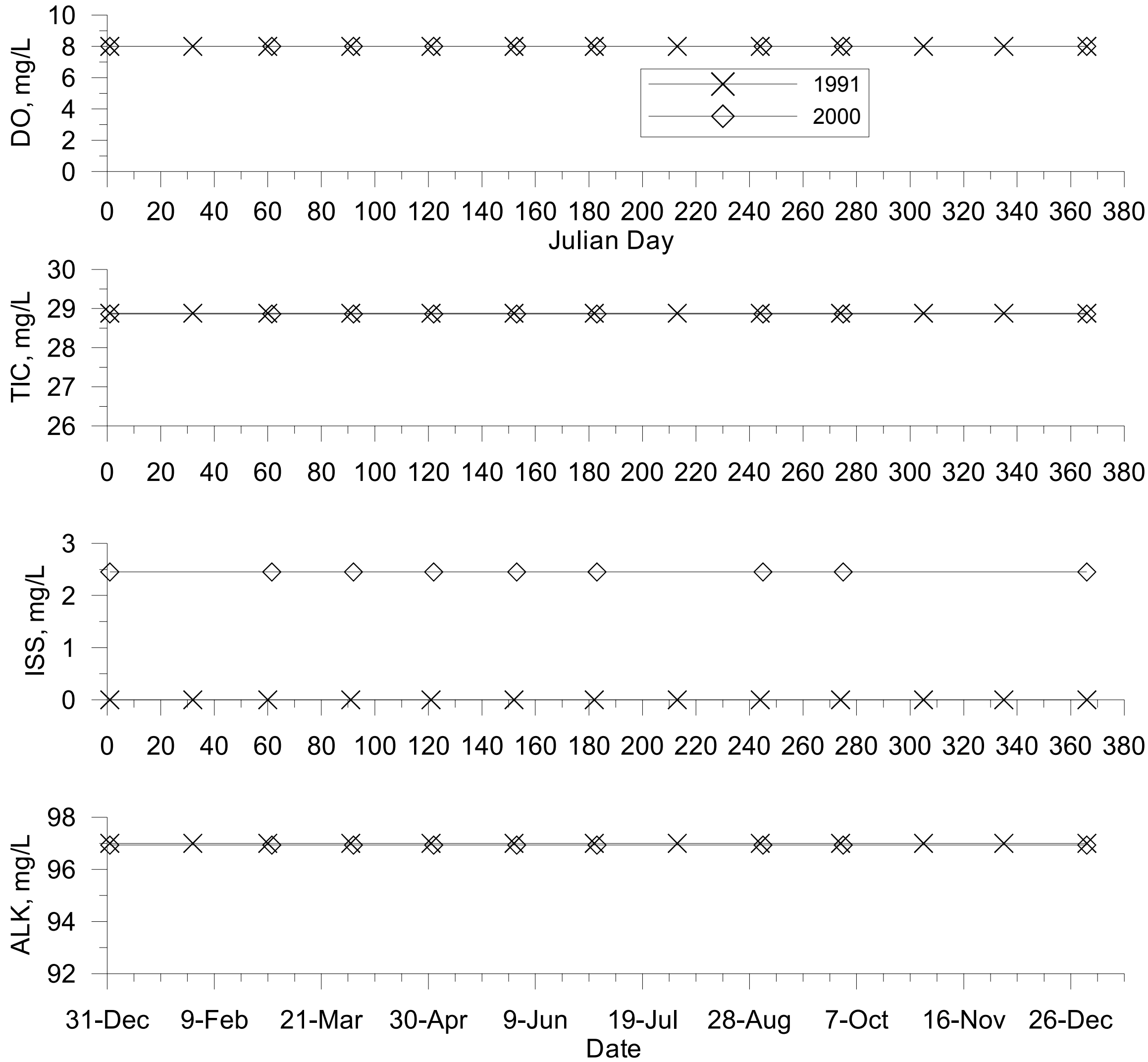


Figure 75. Kaiser Aluminum discharge water quality conditions (Part 3)

Liberty Lake Wastewater Treatment Plant

The Liberty Lake treatment plant discharge has low flows over the course of the year for 1991 and 2000 as shown in Figure 76. Figure 77 shows the discharge temperature over 1991 and 2000. The figure shows a similar warming pattern in 1991 and 2000 with temperatures gradually increasing and with the peak temperature reached at the end of July. Additionally the overall temperature in 1991 was lower than temperature in 2000.

The 2000 Liberty Lake water quality data were characterized from dissolved oxygen, ammonia nitrogen, conductivity, chloride, nitrite-nitrate nitrogen, alkalinity, soluble reactive phosphorus, dissolved and total organic carbon, carbonaceous BOD ultimate ($CBOD_u$), and total suspended solids data. Using the same approach described above in the Kaiser Aluminum section, organic matter from Liberty Lake was modeled using a CBOD compartment and decay rate. Inorganic suspended solids concentrations were estimated using the same procedure outlined for the Spokane River at the state line with the algae concentration as zero. Since no data were available, total dissolved solid (TDS) and fecal coliform concentrations were assumed to be zero.

Data available to create the 1991 Liberty wastewater treatment plant file included soluble reactive phosphorus, ultimate carbonaceous BOD, nitrite-nitrate nitrogen, ammonia nitrogen, and dissolved oxygen. Alkalinity, chloride, and conductivity concentrations were assumed to be equal to the average of the year 2000 data. Fecal coliform, inorganic suspended solids, and total dissolved solids were assumed to be zero because of lack of data. The inorganic carbon concentrations were estimated using method described for the Spokane River at the state line.

The concentrations of the Liberty Lake water quality constituents were plotted in Figure 78, Figure 79, and Figure 80. Some constituents had few data points so an average of the available data was used.

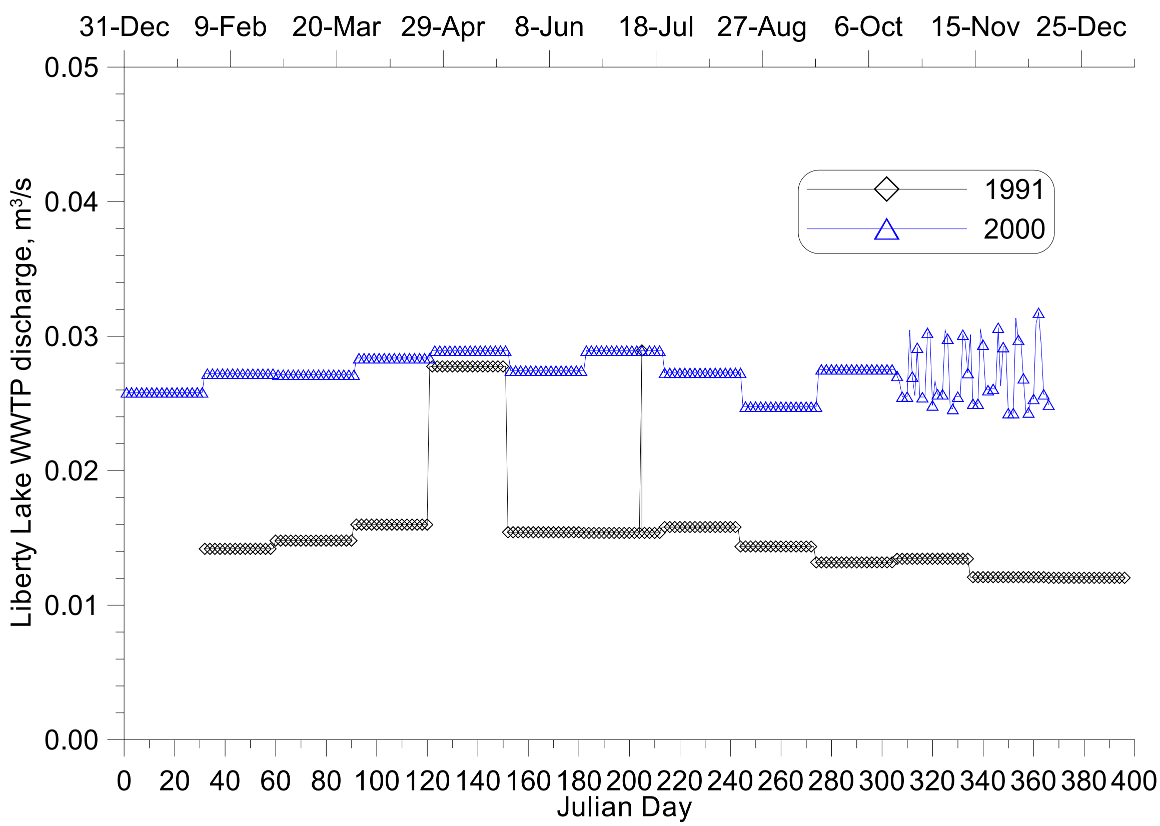


Figure 76. Liberty Lake WWTP discharge flow, 1991-1992 and 2000

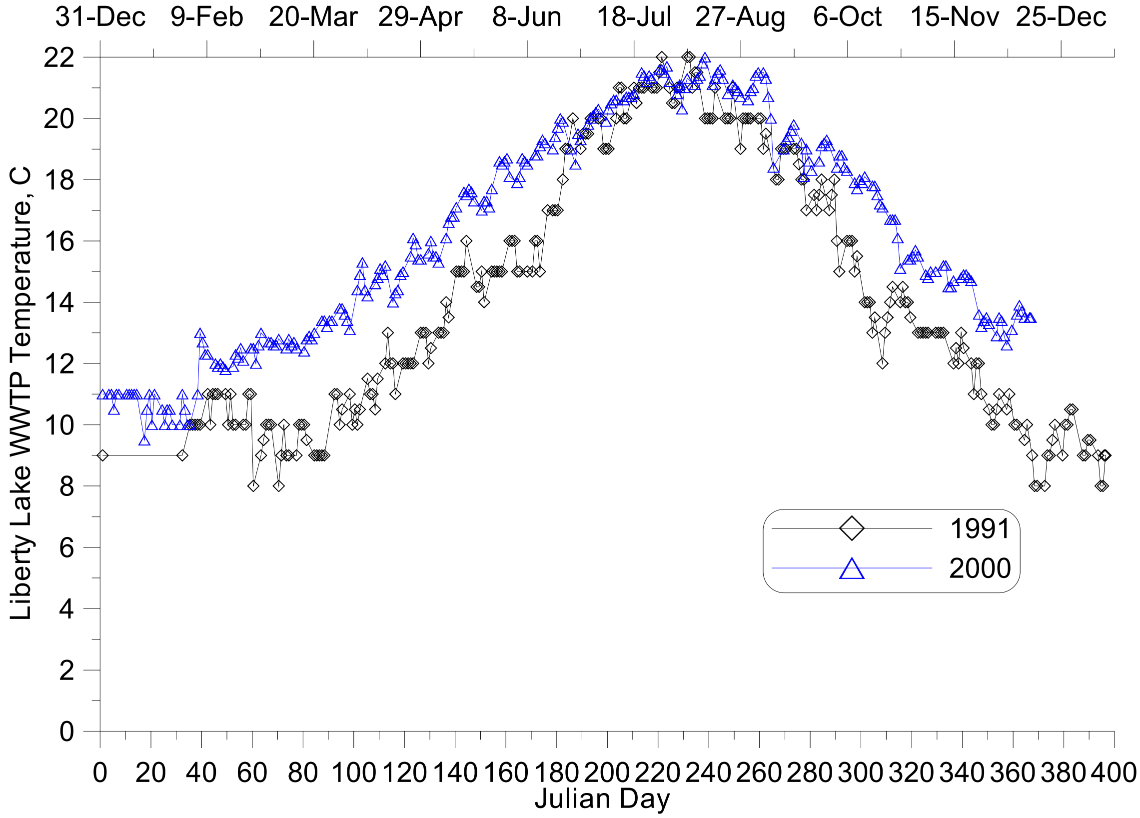


Figure 77. Liberty Lake WWTP discharge temperature, 1991-1992 and 2000

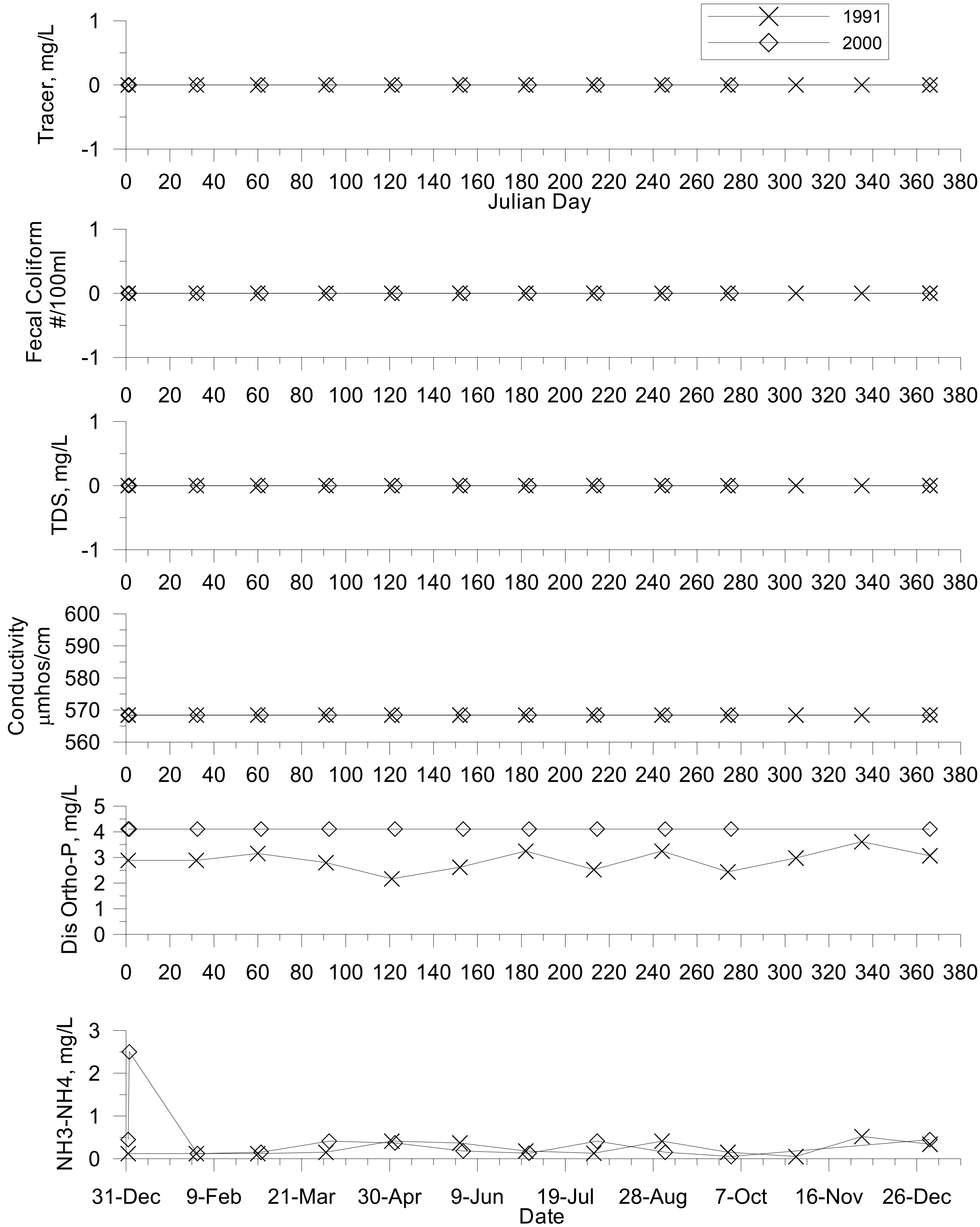


Figure 78. Liberty Lake WWTP discharge water quality conditions (Part 1)

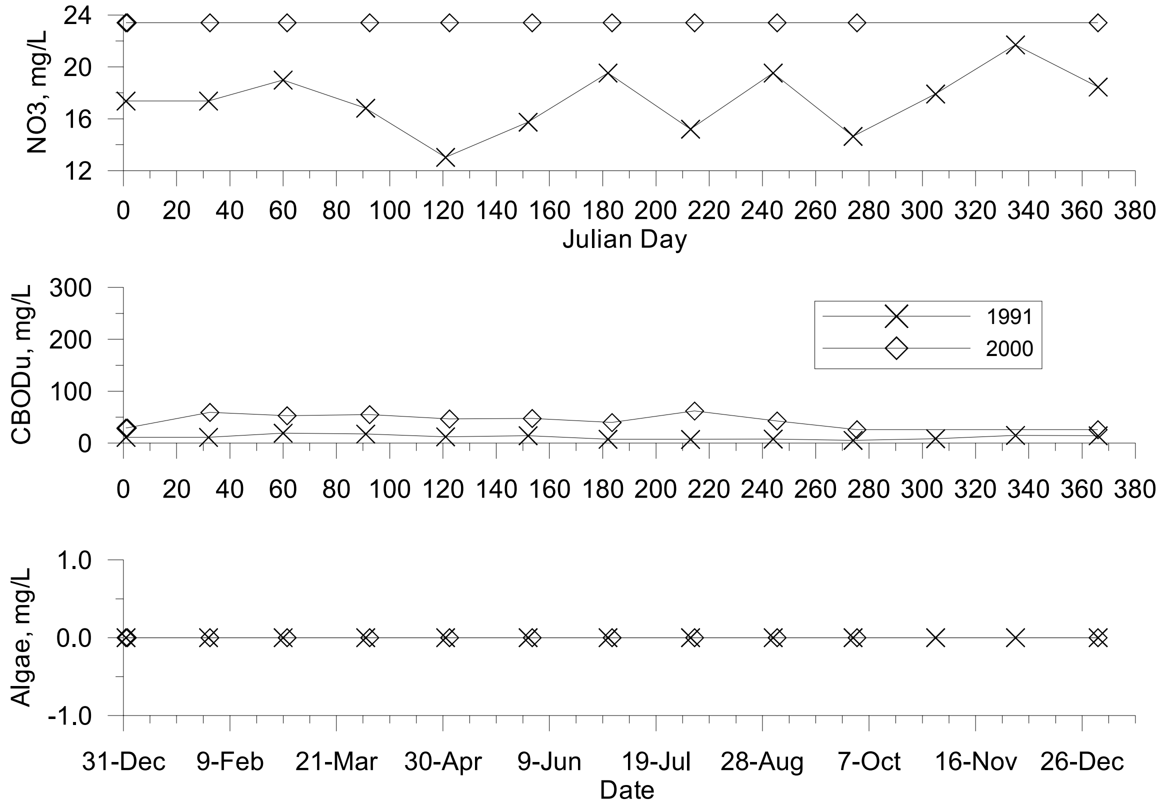


Figure 79. Liberty Lake WWTP discharge water quality conditions (Part 2)

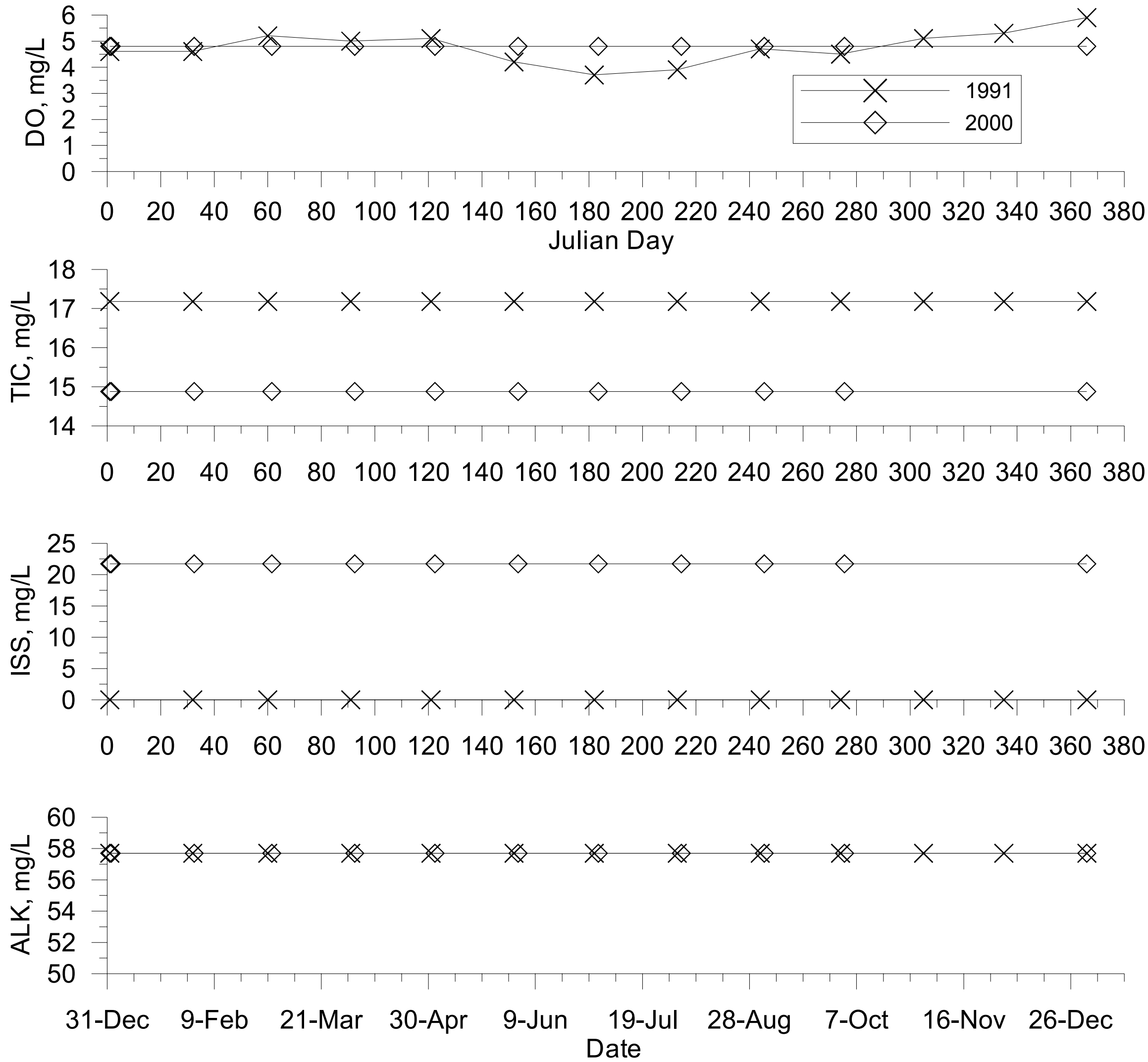


Figure 80. Liberty Lake WWTP discharge water quality conditions (Part 3)

Spokane Wastewater Treatment Plant

The City of Spokane wastewater treatment plant discharge was also incorporated into the model. Figure 81 shows the discharge flow for both 1991 and 2000 and reveals that both years had variable flow throughout the year. Flows in 2000 were consistently higher than in 1991 as might be expected with a growing city. Figure 82 shows the discharge temperature variations for 1991 and 2000. There were few temperature measurements recorded in 1991, but when compared to 2000, the discharge temperatures in 1991 were cooler overall than in 2000.

The 2000 water quality data were developed using dissolved oxygen, nitrite-nitrate nitrogen, pH, ammonia-nitrogen, fecal coliform, soluble reactive phosphorus, alkalinity, carbonaceous BOD ultimate ($CBOD_u$), conductivity and chloride data. Inorganic carbon concentrations were estimated using alkalinity and pH data and applying equations based on the carbonate-bicarbonate equilibrium reaction, which is described in Stumm and Morgan (1981). Water quality constituents for 2000 were developed using the method outlined for the Spokane River at the state line with algae concentration set to zero.

The 1991 constituent concentration input file for the Spokane wastewater treatment plant was developed using observed pH, soluble reactive phosphorus, nitrite-nitrate nitrogen, ammonia nitrogen, dissolved oxygen, and fecal coliform data. Alkalinity, chloride, and conductivity concentrations were assumed to be equal to the average of the year 2000 data. Because of lack of data, inorganic suspended solids and total dissolved solids data were assumed to be zero. Water quality constituents for 1991 were developed using the method outlined for the Kaiser Aluminum.

Using the same approach described above in the Kaiser Aluminum section, organic matter from the Spokane wastewater treatment plant was modeled using a CBOD compartment and decay rate.

The concentrations of the Spokane wastewater treatment plant constituents were plotted in Figure 83, Figure 84, and Figure 85. Some constituents had few data points so an average of the available data was used.

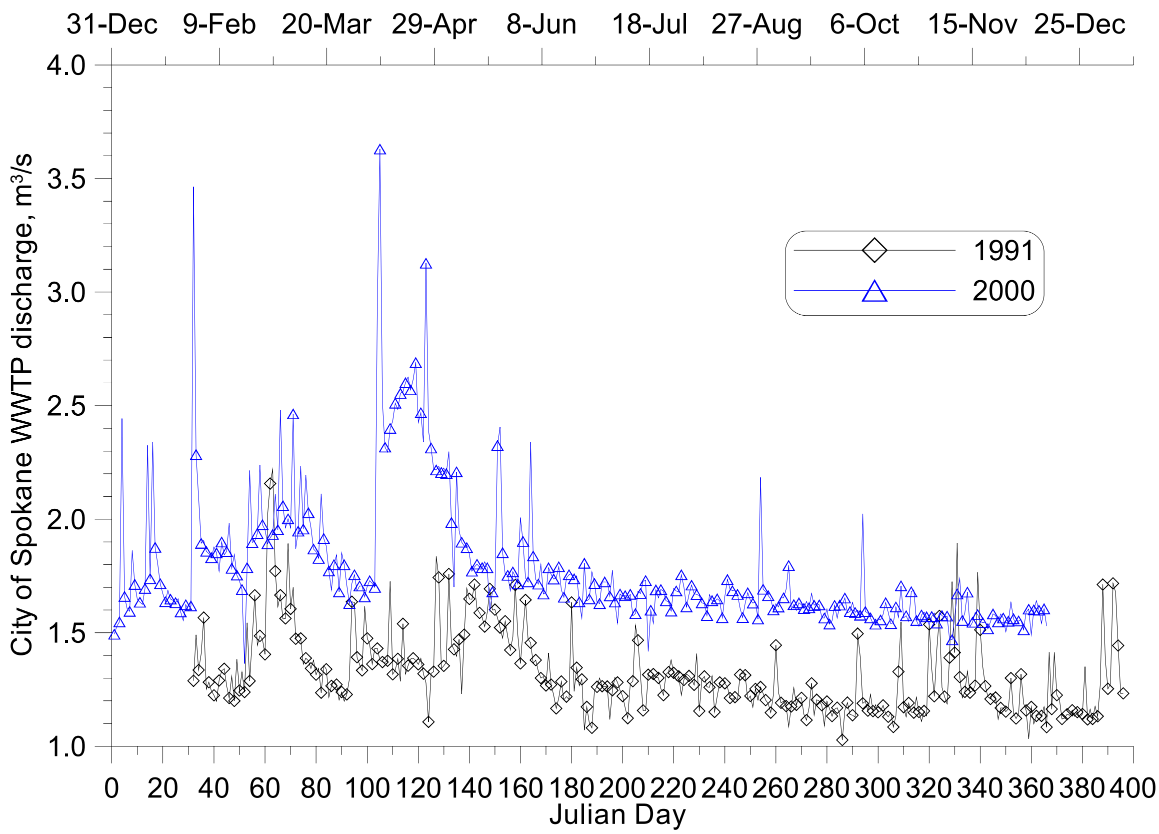


Figure 81. City of Spokane WWTP discharge flow, 1991-1992 and 2000

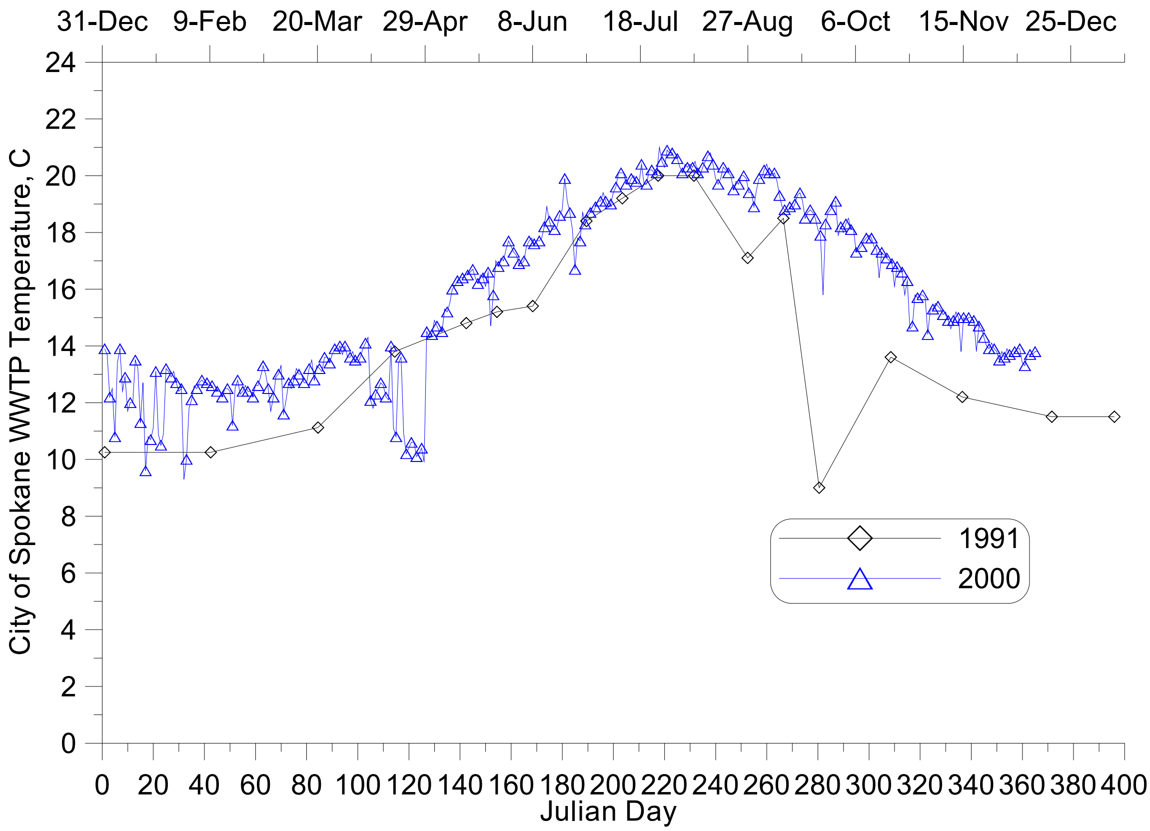


Figure 82. City of Spokane WWTP discharge temperature, 1991-1992 and 2000

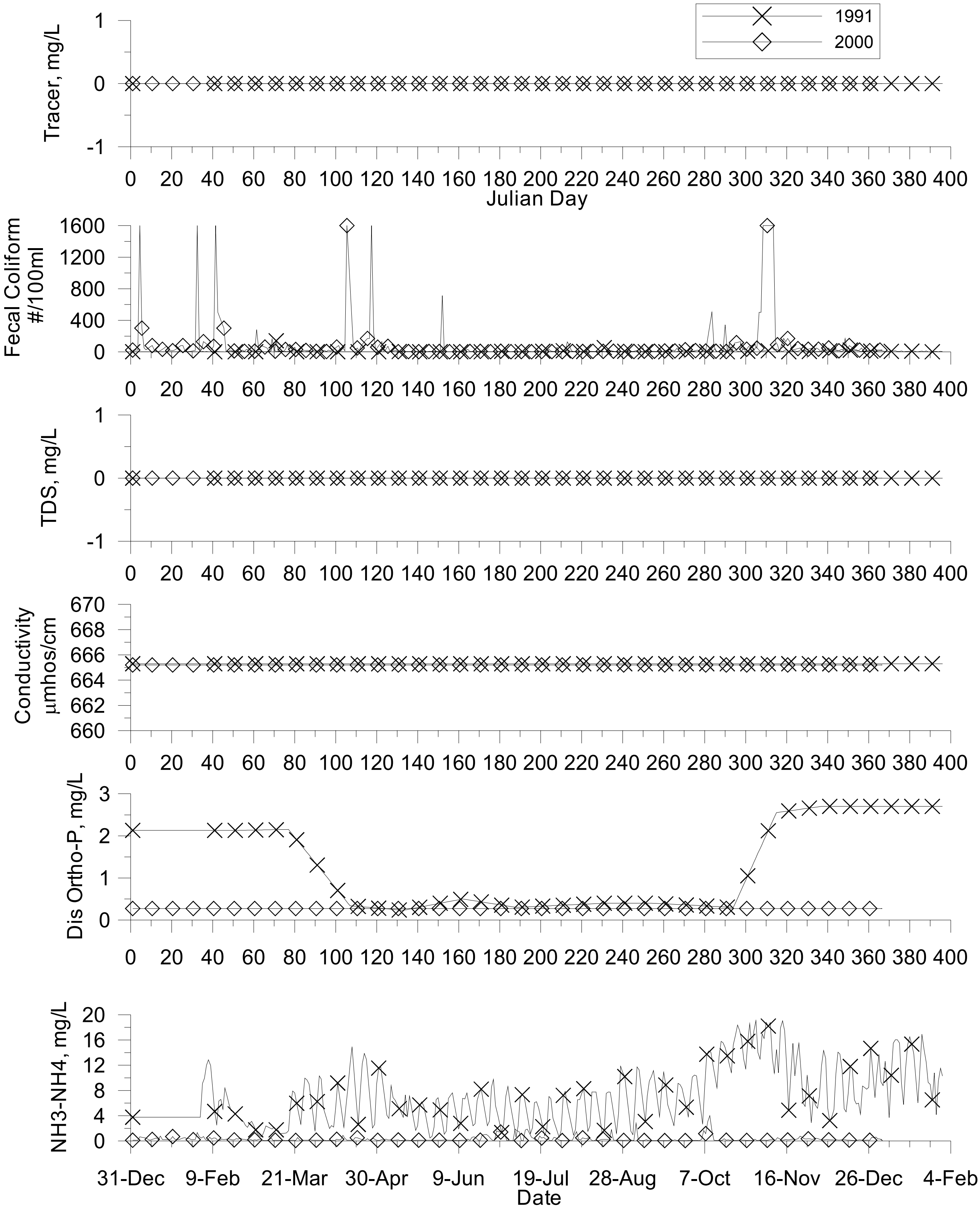


Figure 83. City of Spokane WWTP discharge water quality conditions (Part 1)

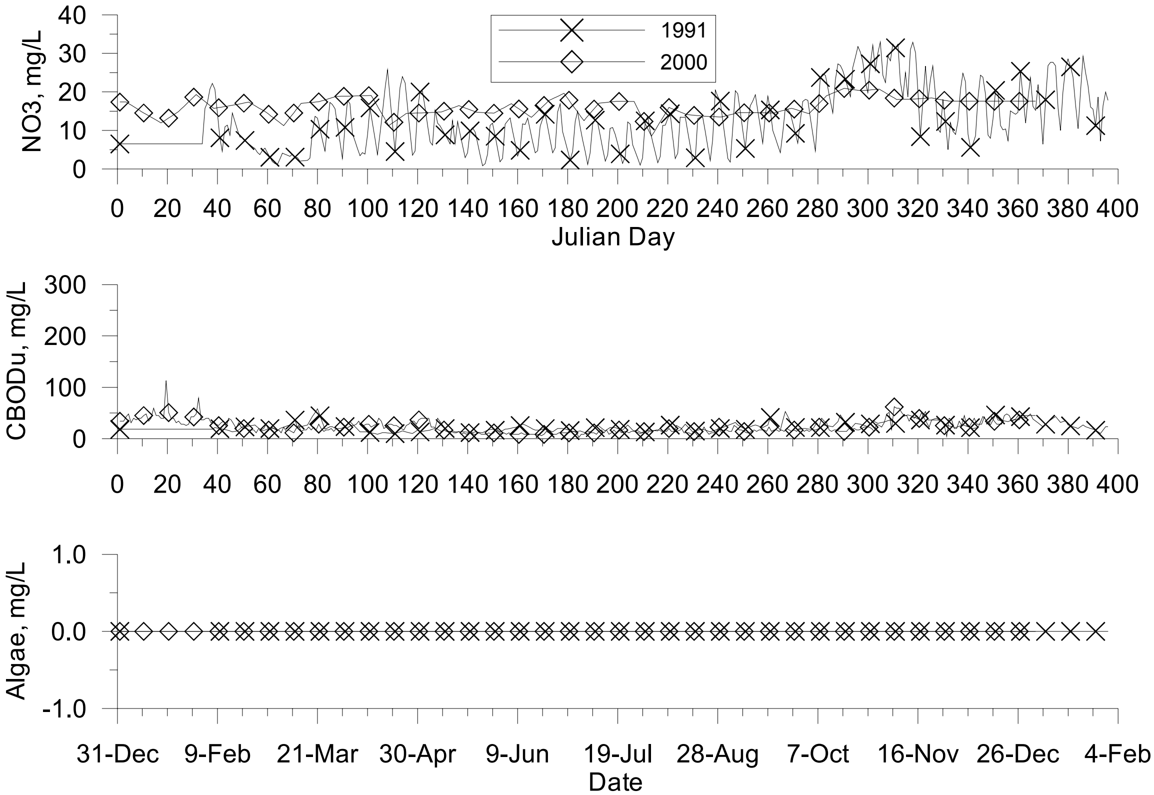


Figure 84. City of Spokane WWTP discharge water quality conditions (Part 2)

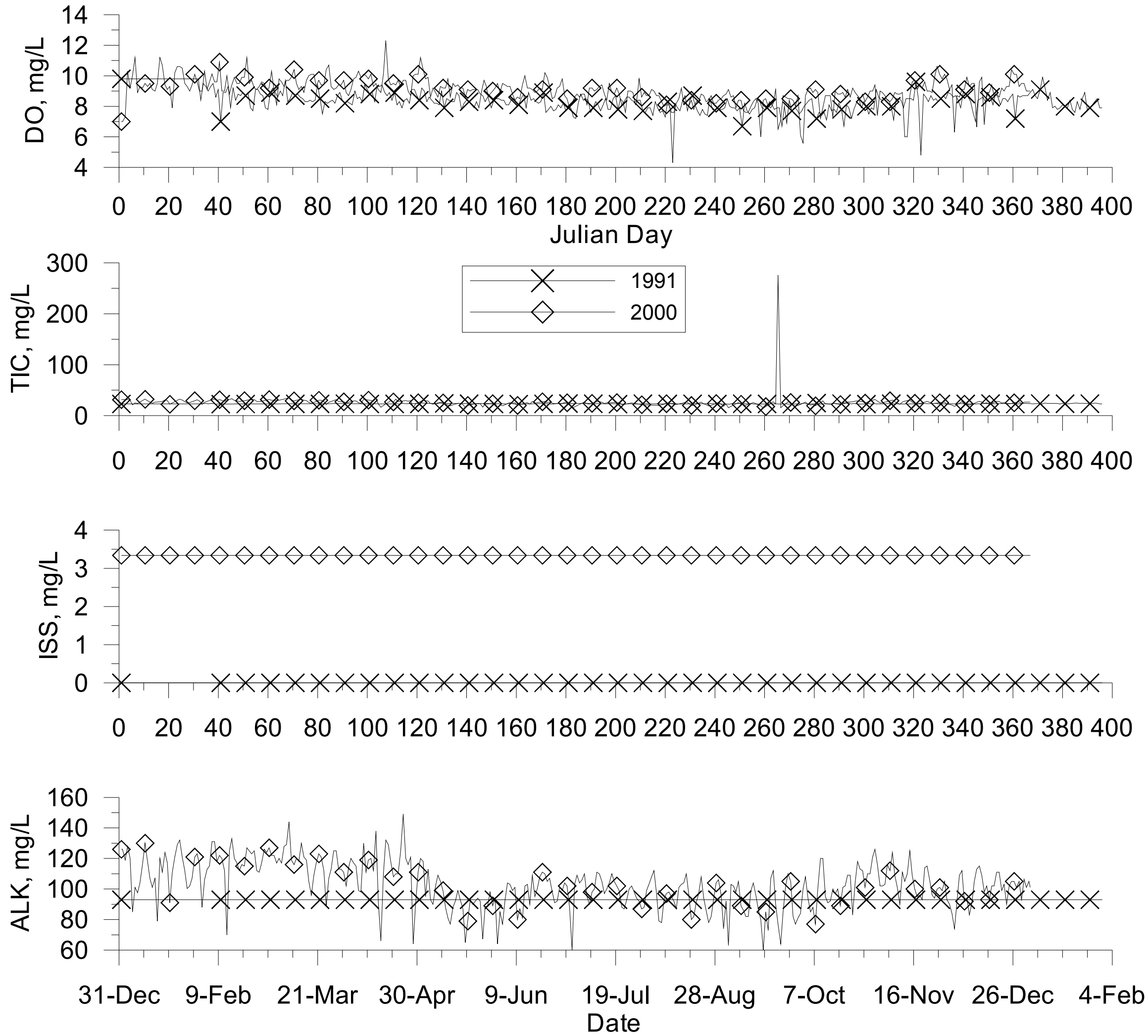


Figure 85. City of Spokane WWTP discharge water quality conditions (Part 3)

Inland Empire Paper Company

Inland Empire Paper Company discharges to the Spokane River upstream of Upriver Dam. Figure 86 shows the discharge flow for 1991 and 2000. Flows in 1991 and 2000 were similar over the course of the year and remained relatively constant. Figure 87 shows the discharge temperature for the same two years. Temperatures in both years were similar but in 2000 the temperatures appear to be slightly lower from April to December.

The 2000 water quality file corresponding to the Inland Empire point source was developed using conductivity, chloride, nitrite-nitrate nitrogen, ammonia nitrogen, soluble reactive phosphorus, total organic carbon, carbonaceous BOD ultimate ($CBOD_u$), dissolved organic carbon, alkalinity, and total suspended solids data. Dissolved oxygen concentration was set to the average of the 1991 data. Due to lack of data, fecal coliform and total dissolved solids data were set to zero. Water quality constituents for 2000 were developed using the method outlined for the Spokane River at the state line with algae concentration set to zero.

For the year 1991, the Inland Empire water quality file was characterized from soluble reactive phosphorus, nitrite-nitrate nitrogen, ammonia nitrogen, carbonaceous BOD ultimate and dissolved oxygen data. Alkalinity, chloride, and conductivity concentrations were set to the means of year 2000 concentrations. Algae concentrations were set to zero. Total dissolved solids, fecal coliform and inorganic suspend solids concentrations were set to zero due to lack of data. Water quality constituents for 1991 were developed using the method outlined for the Kaiser Aluminum.

Using the same approach described above in the Kaiser Aluminum section, organic matter from the Inland Empire was modeled using a CBOD compartment and decay rate.

The concentrations of the Inland Paper Company constituents were plotted in Figure 88, Figure 89, and Figure 90. Some constituents had few data points so an average of the available data was used.

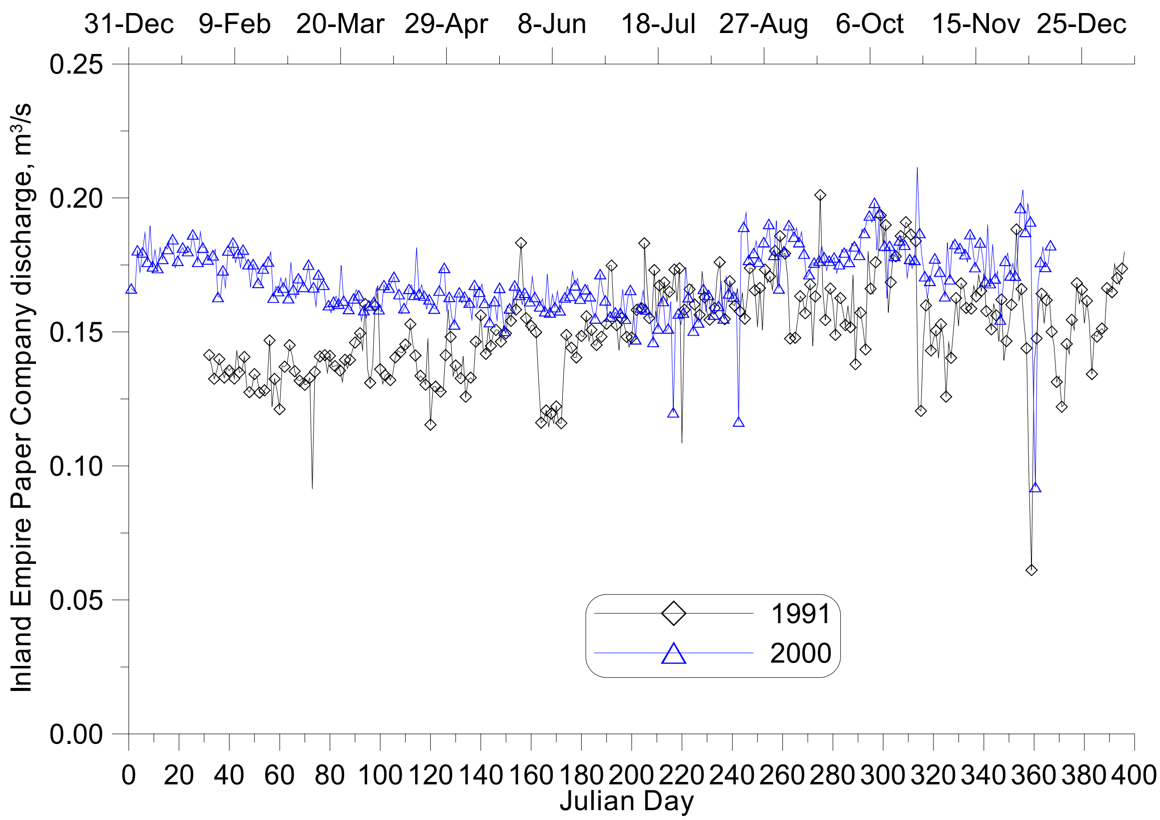


Figure 86. Inland Empire Paper Co. discharge flow, 1991-1992 and 2000

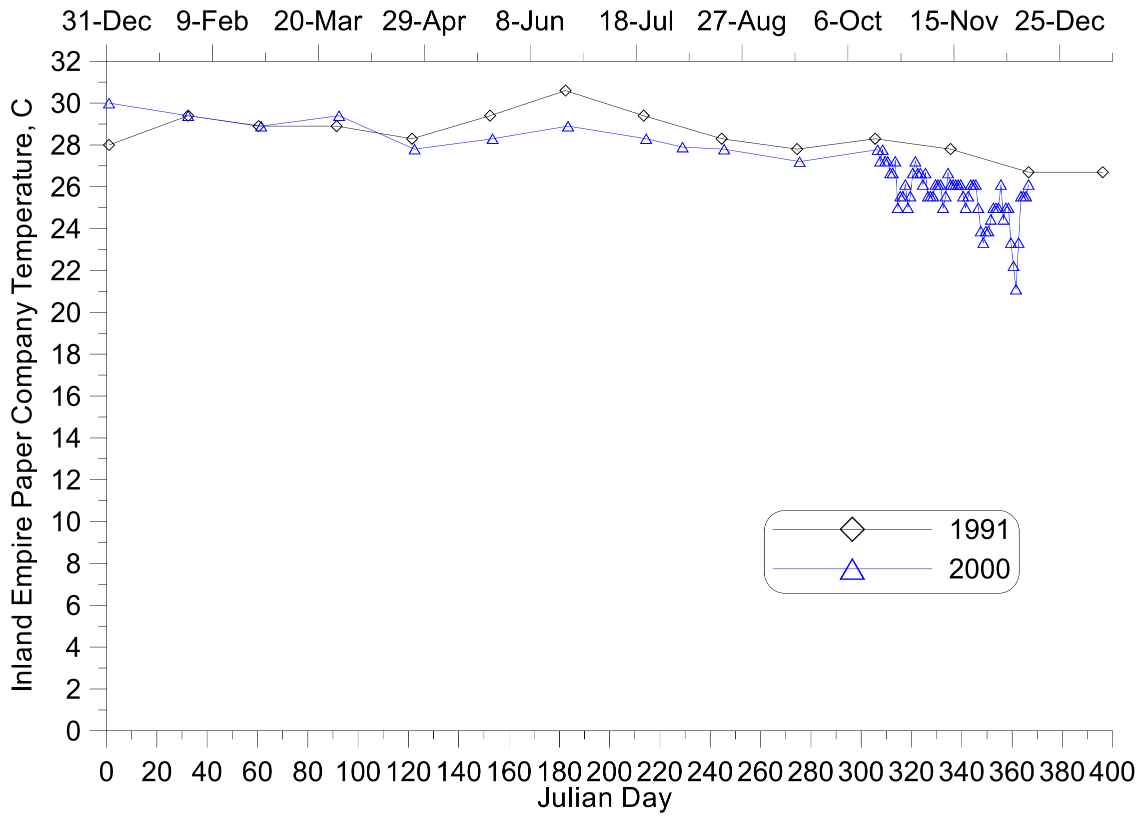


Figure 87. Inland Empire Paper Co. discharge temperature, 1991-1992 and 2000

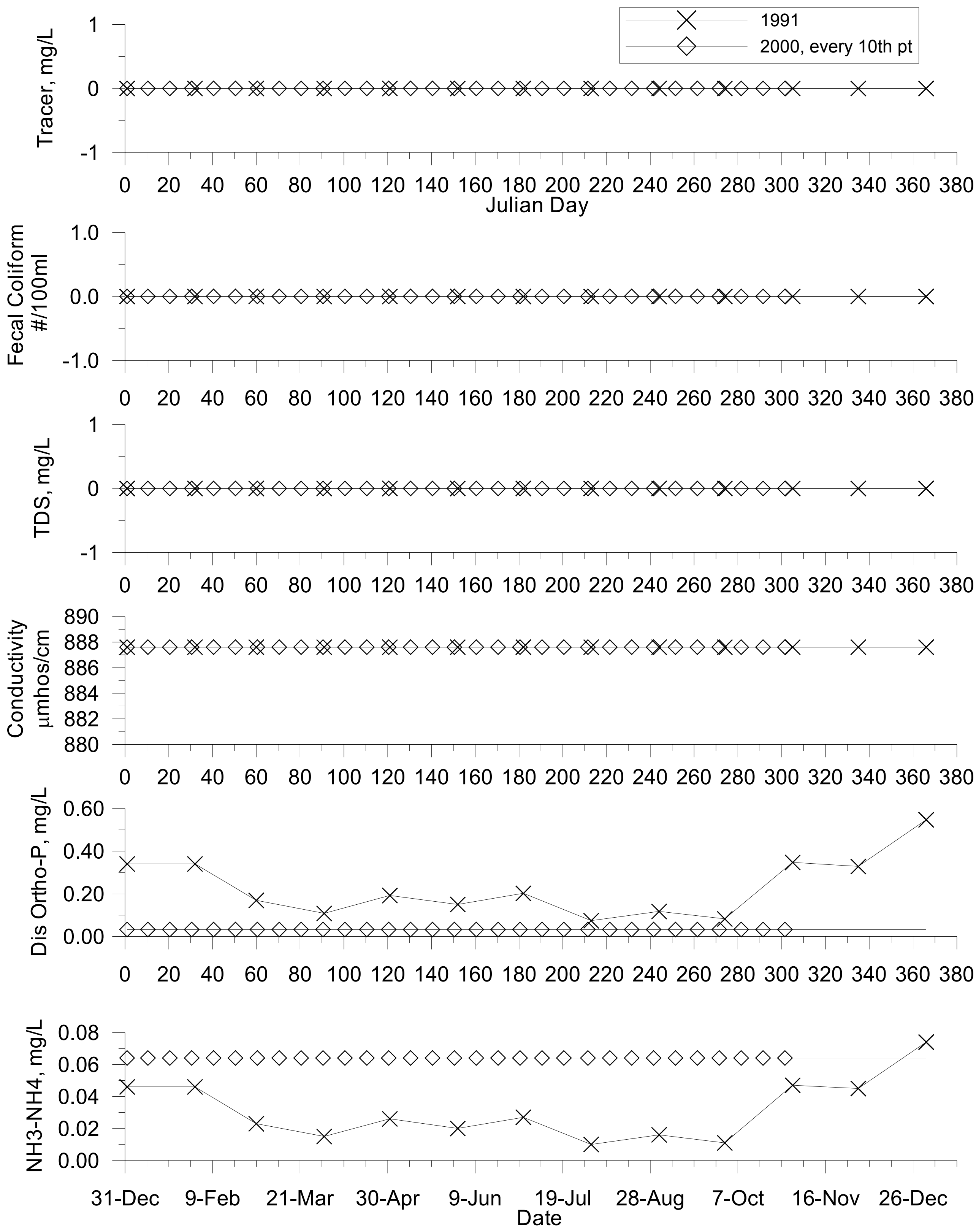


Figure 88. Inland Empire Paper Co. discharge water quality conditions (Part 1)

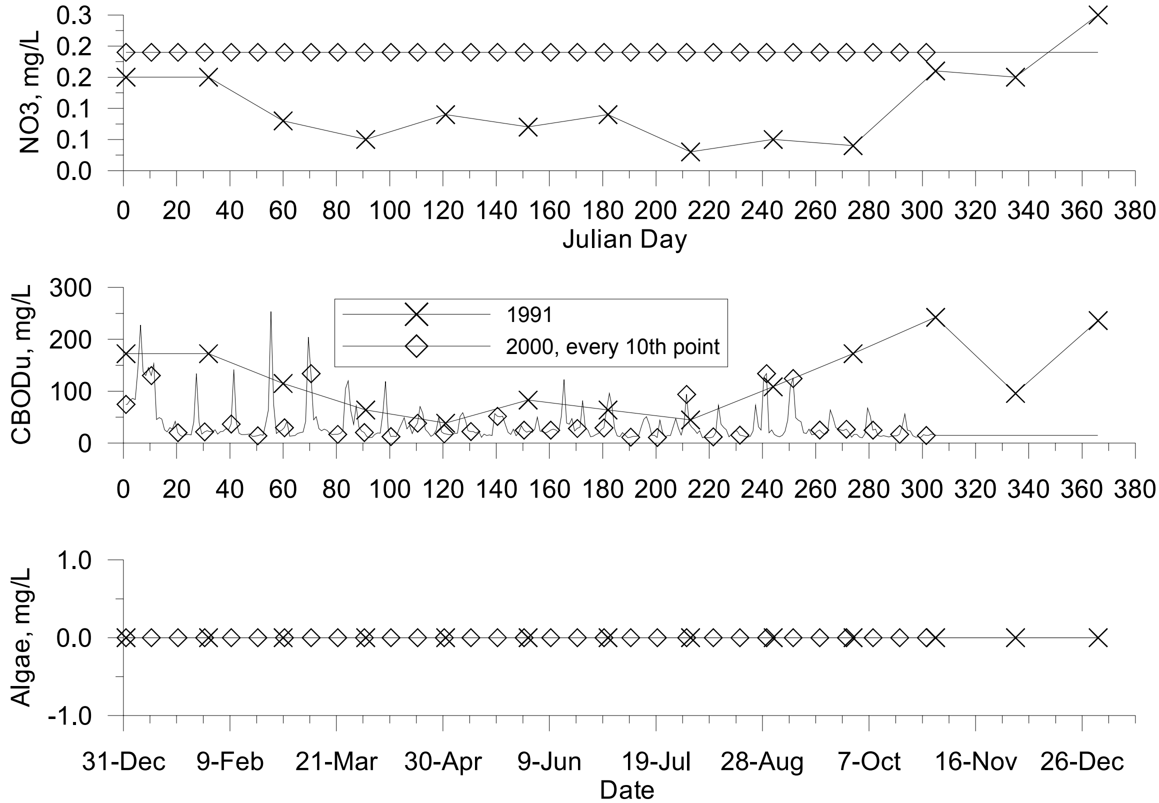


Figure 89. Inland Empire Paper Co. discharge water quality conditions (Part 2)

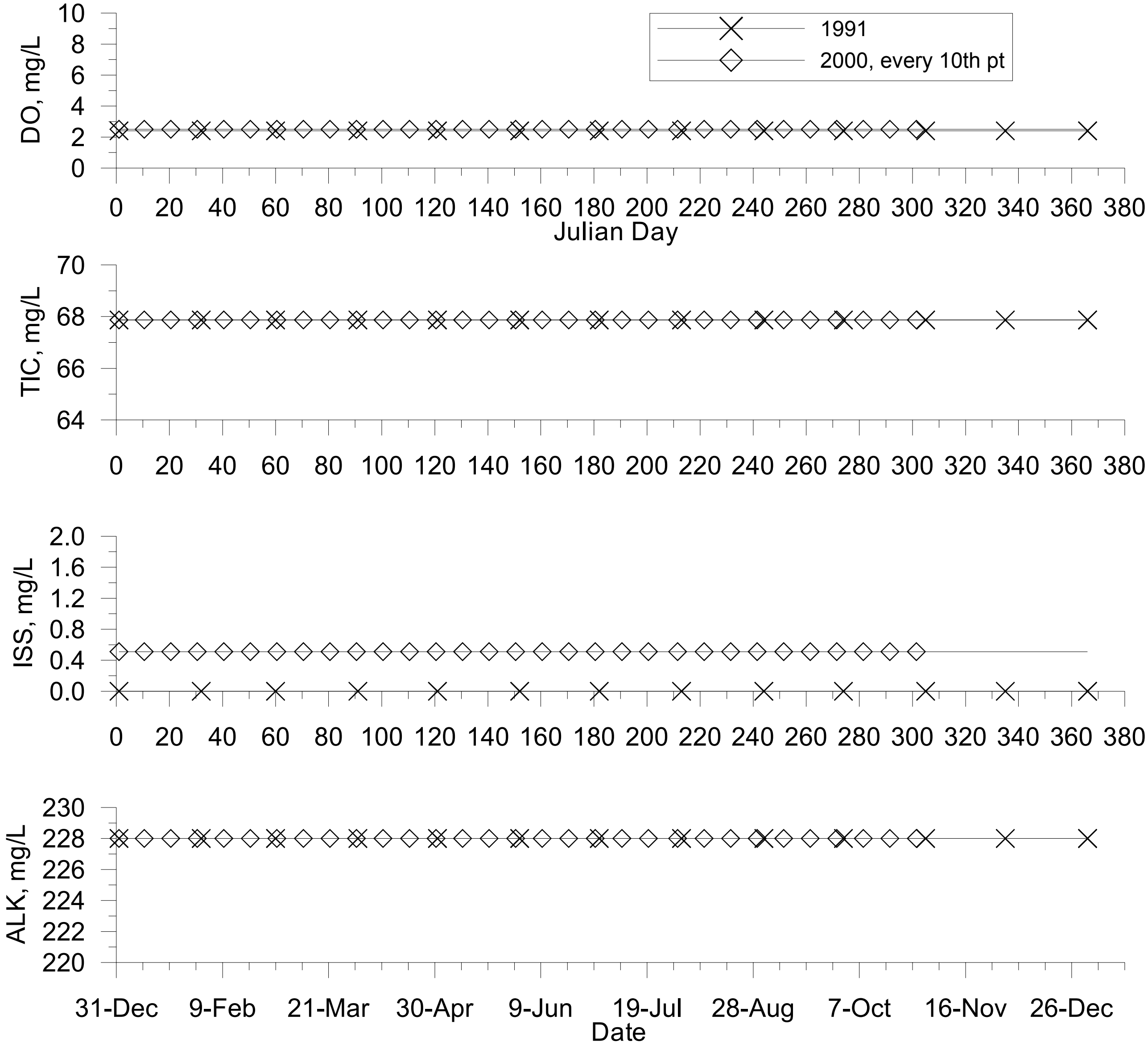


Figure 90. Inland Empire Paper Co. discharge water quality conditions (Part 3)

Meteorological Data

Meteorological data for the CE-QUAL-W2 model was taken predominantly from the Spokane International Airport (Figure 91). The airport site was located close to the river and offered the most complete set of meteorological data available. The model utilizes air and dew point temperature, wind speed and direction, and cloud cover or solar radiation. The airport did not have solar radiation data available, so solar radiation data from Odessa, WA was used. The cloud cover data collected at the airport is not very accurate because it is measured in only a few discrete increments. So solar radiation data at Odessa was used with the theoretical solar radiation for the location of the river to calculate daily values of cloud cover. The model used internal interpolation to fill in the meteorological information between input data. Meteorological conditions at Spokane Felts Field were also examined and utilized but were limited to 2000. Meteorological data from Coeur d'Alene was not used because it was too far away from the model domain, located 12 miles from the Idaho-Washington state line. In 1991, the model used meteorological data from the Spokane International Airport since this was the only data available. In 2000, the model used Spokane Felts Field meteorological data from the state line to Upper Falls Dam. Spokane International Airport meteorological data was then used below Upper Falls Dam down to Long Lake Dam.

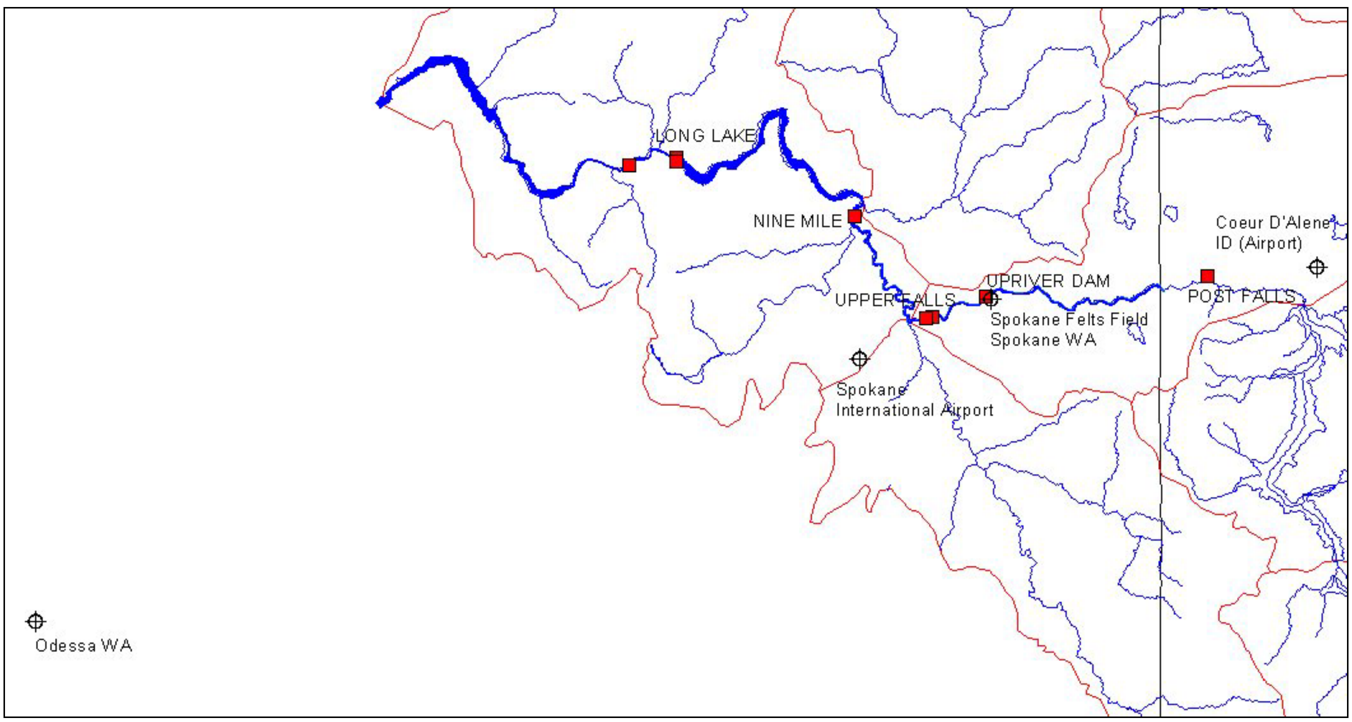


Figure 91. Meteorological stations near the Spokane River

<u>Spokane International Airport</u>

Air temperatures for 1991 to 1992 and for 2000 are shown in Figure 92. In 2000, the air temperatures were higher in July and August. Dew point temperatures for both years are shown in Figure 93. During 2000, dew point temperatures later in the year were slightly cooler than in 1991. Figure 94 shows wind speed and direction recorded at the airport for the calibration years. For both years the predominant wind directions were from 150 to 250 degrees from the North and from 0 to 70 degrees from the North. Figure 96 shows the cloud cover reported at the airport for 1991 and 2000. It should be noted that the National Weather Service (NWS) started recording cloud cover differently in 1996. Prior to 1996 the

NWS used a 0 to 10 scale for recording cloud density with 0 indicating no cloud cover and 10 indicating full cloud cover. After 1996, the scale was switched to 1 to 8. In order to compare the two sets of data, the cloud cover information from 2000 was converted to a scale of 0 to 10. This change can influence the model temperatures for both years.

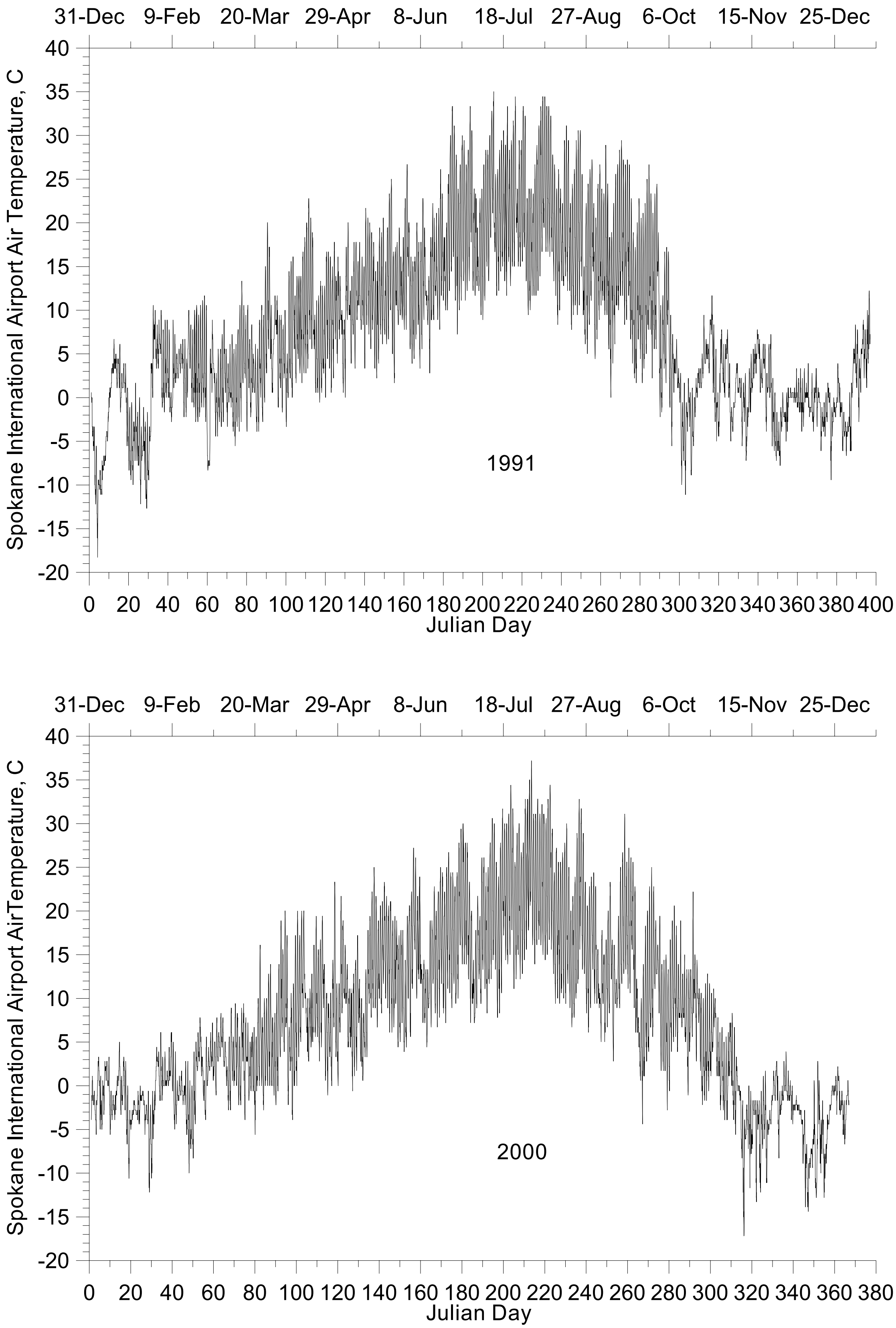


Figure 92. Air temperature (C) at the Spokane International Airport

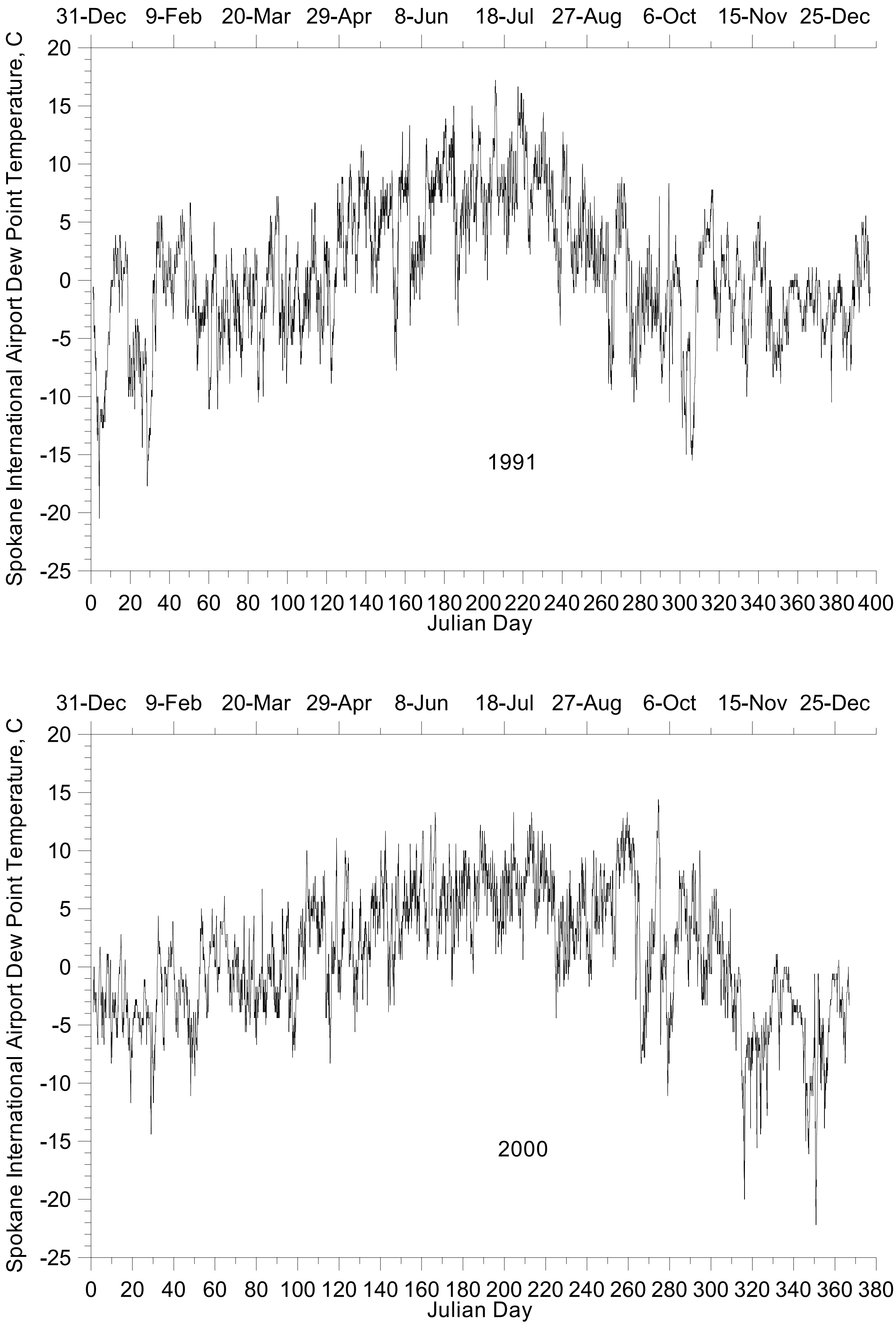
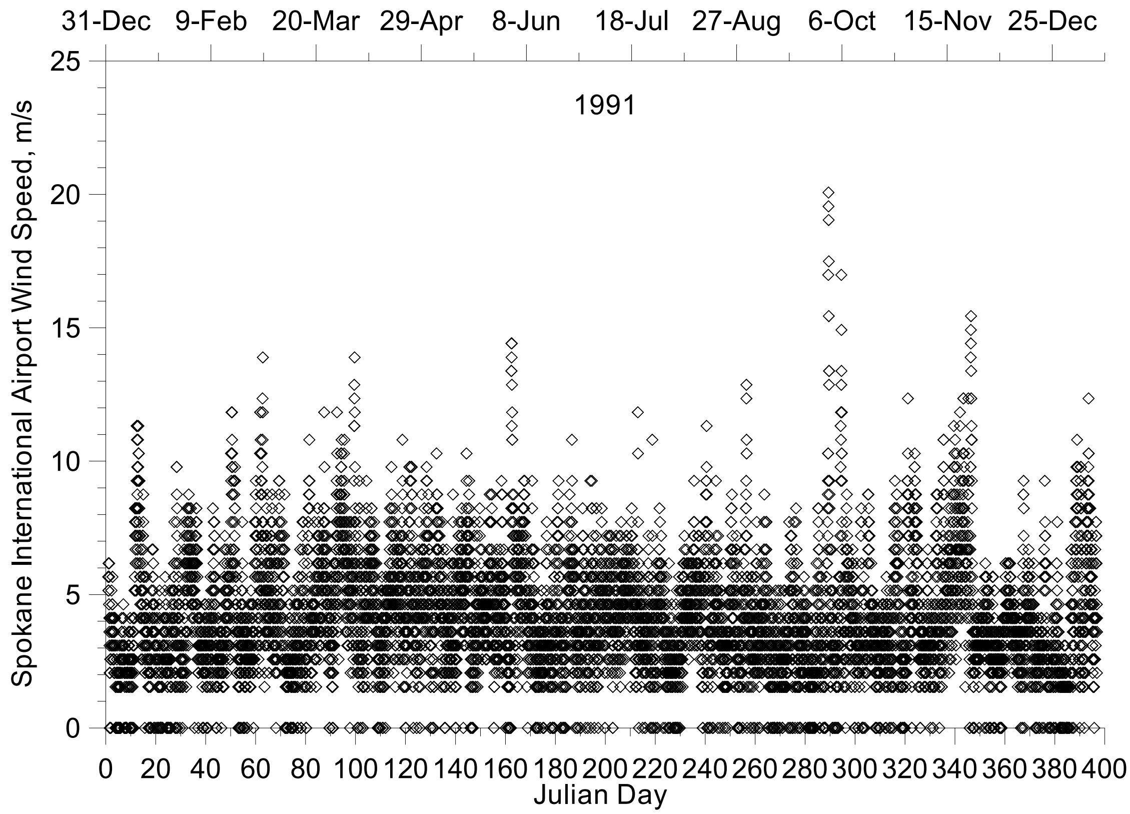


Figure 93. Dew point temperature (C) at the Spokane International Airport



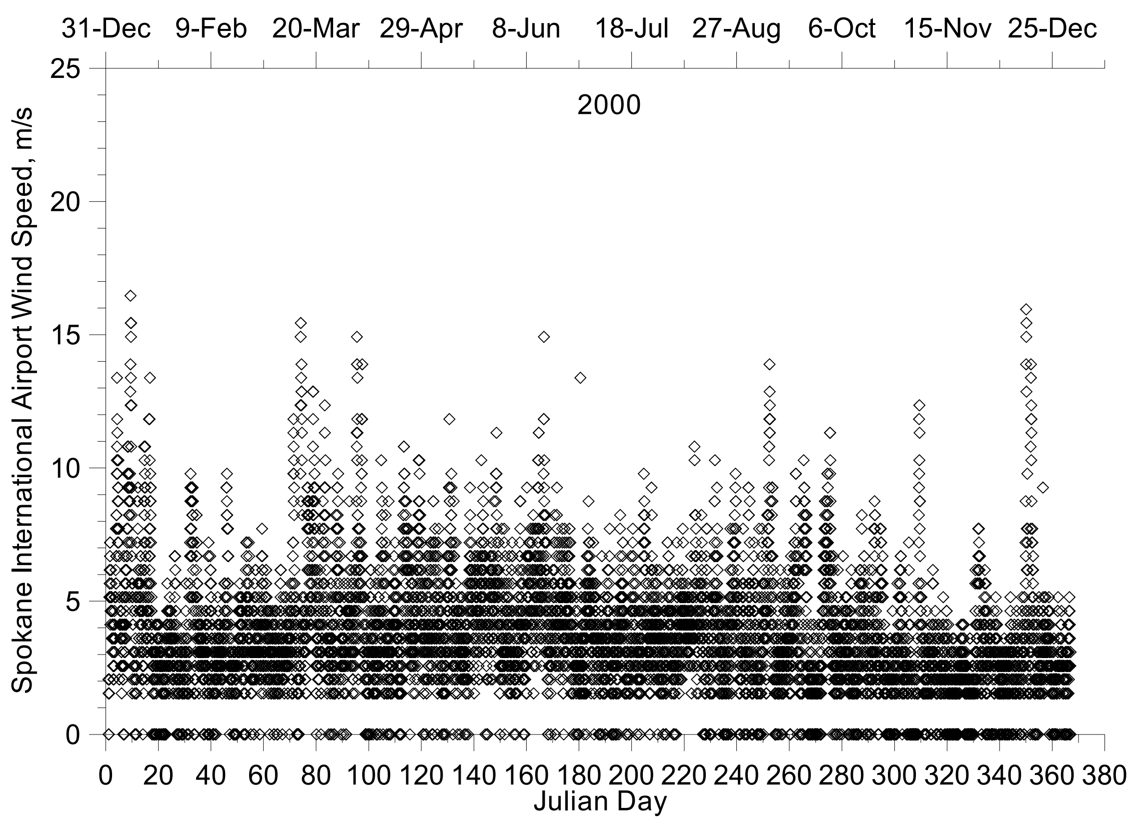
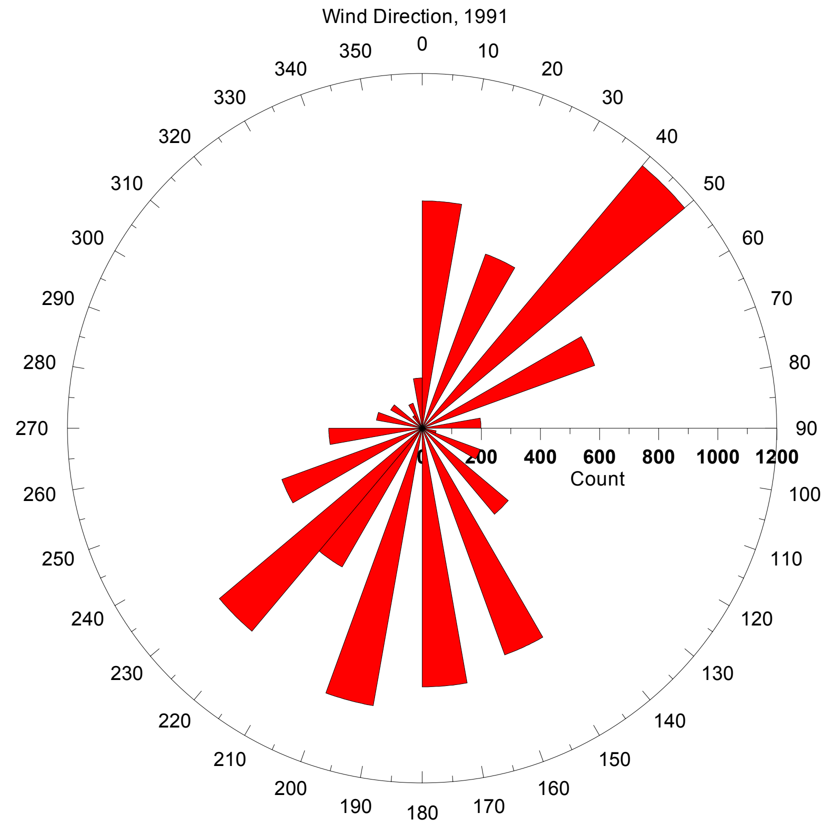


Figure 94. Wind Speed (m/s) at the Spokane International Airport



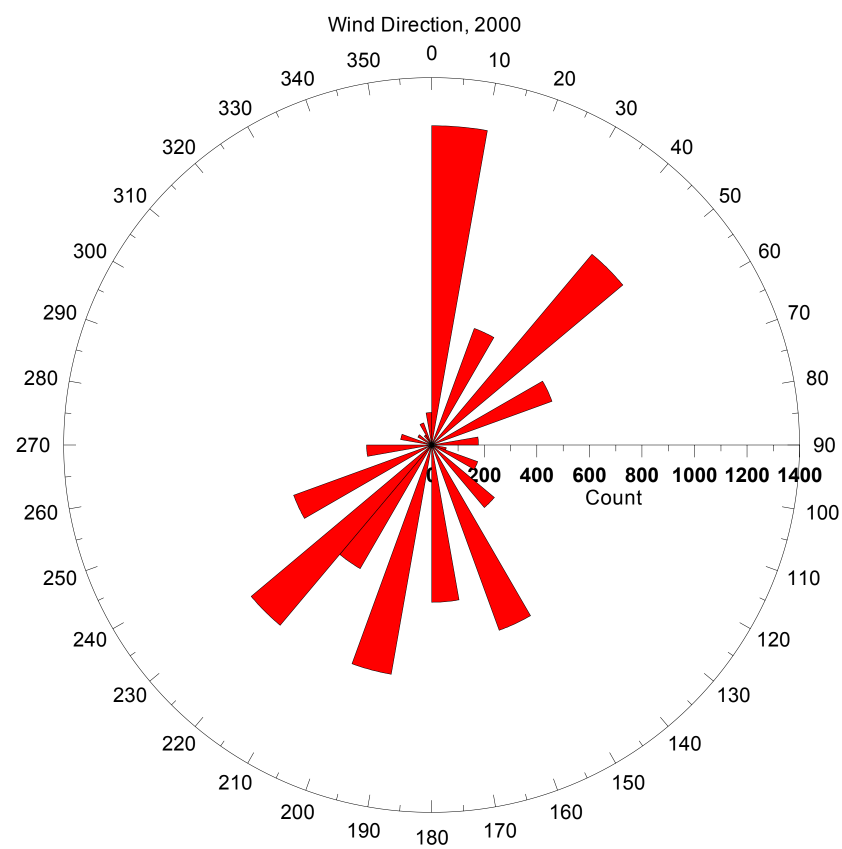


Figure 95. Wind direction, (degrees from North) at the Spokane International Airport, 1991 and 2000

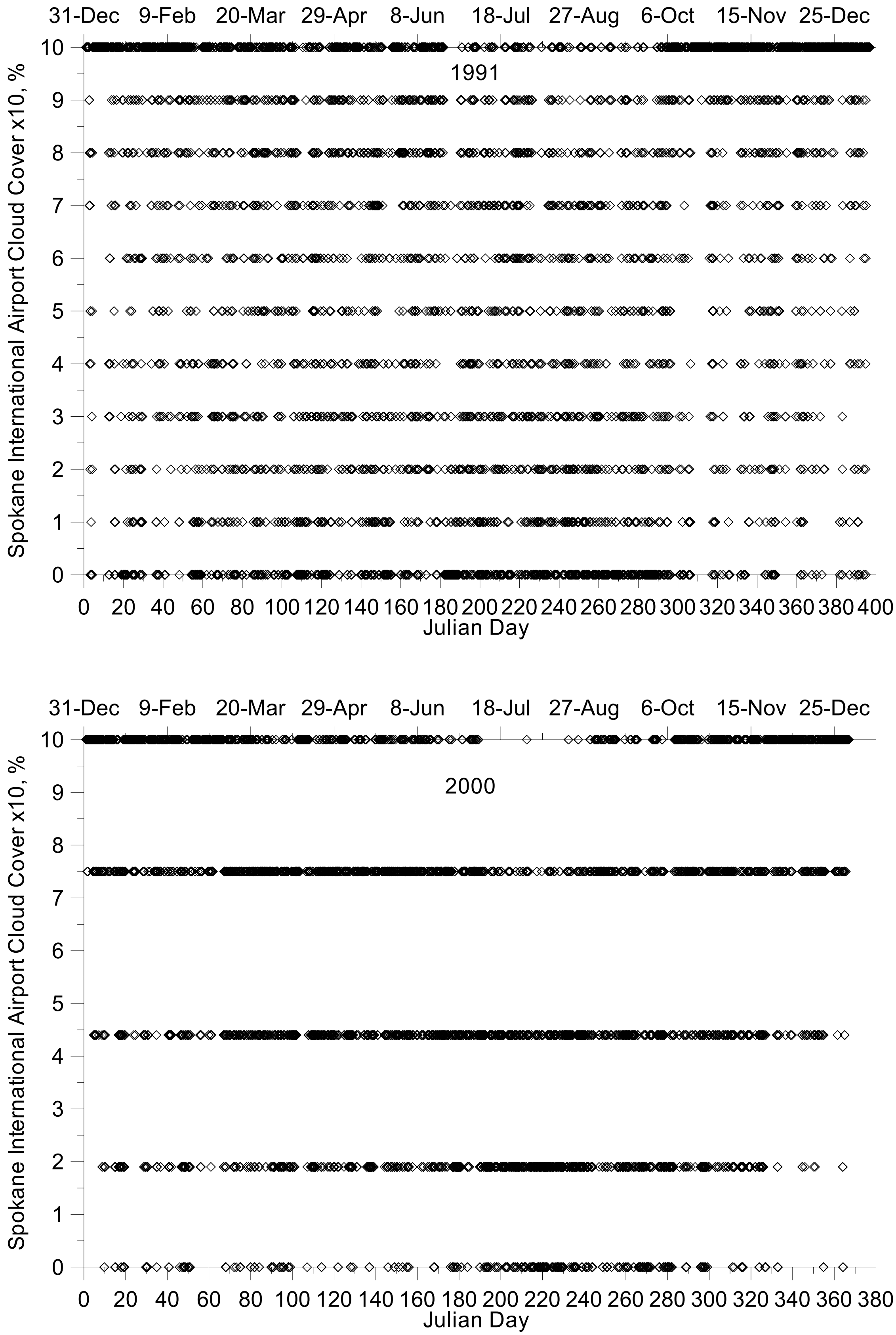


Figure 96. Cloud Cover (x10, %) at the Spokane International Airport

Spokane Felts Field

Meteorological data were not available at Felts Field for 1991 so only 2000 data are presented. Air temperatures for the year are shown in Figure 97 with the highest temperatures in July and August similar to temperatures shown for the Spokane International Airport. Dew point temperatures are shown in Figure 98. Figure 99 shows the wind speeds, which were lower than wind speeds at the Spokane International Airport. Figure 100 shows a rose diagram of the wind directions recorded where the predominant wind direction was 0 to 10 degrees from the North. Figure 101 shows the cloud cover reported for the year. Similar to the Spokane Airport, the cloud cover data recorded by the National Weather Service (NWS) were switched to 1 to 8 scale after 1996. In order to compare data from years prior to 1996 and for use in the model, the cloud cover information from 2000 was converted to a scale of 0 to 10.

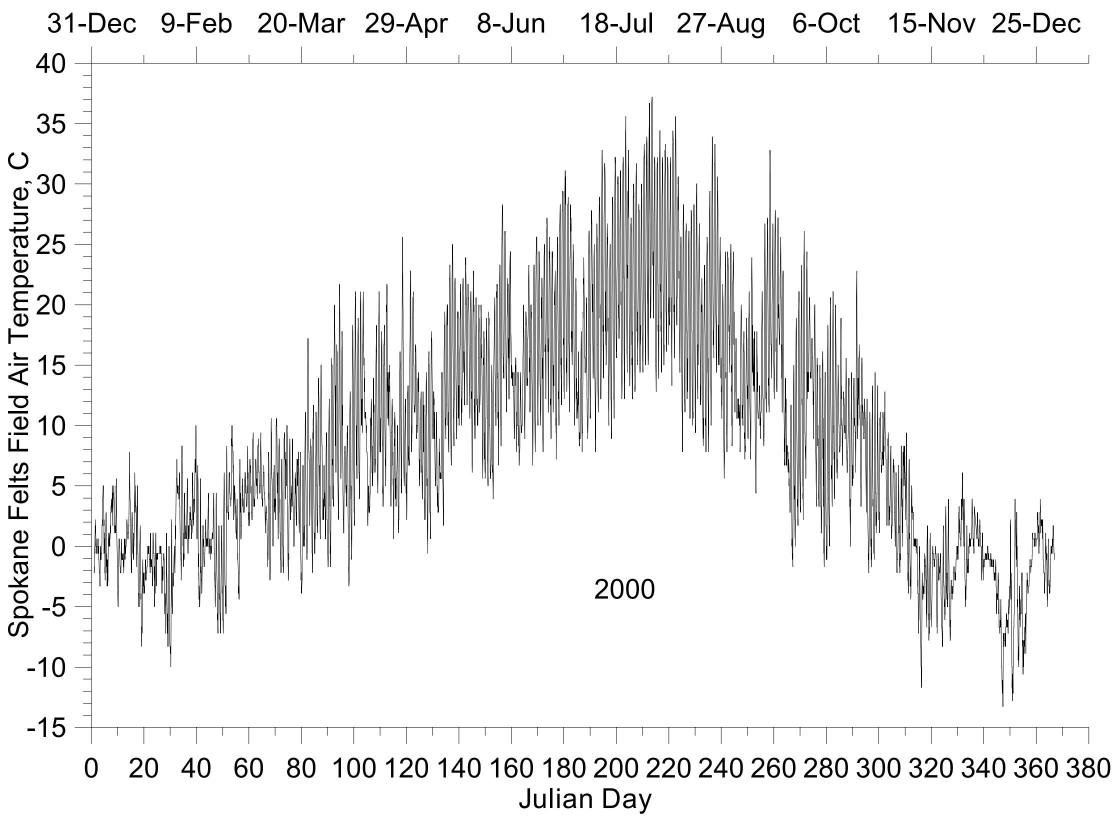


Figure 97. Air temperature (C) at Spokane Felts Field

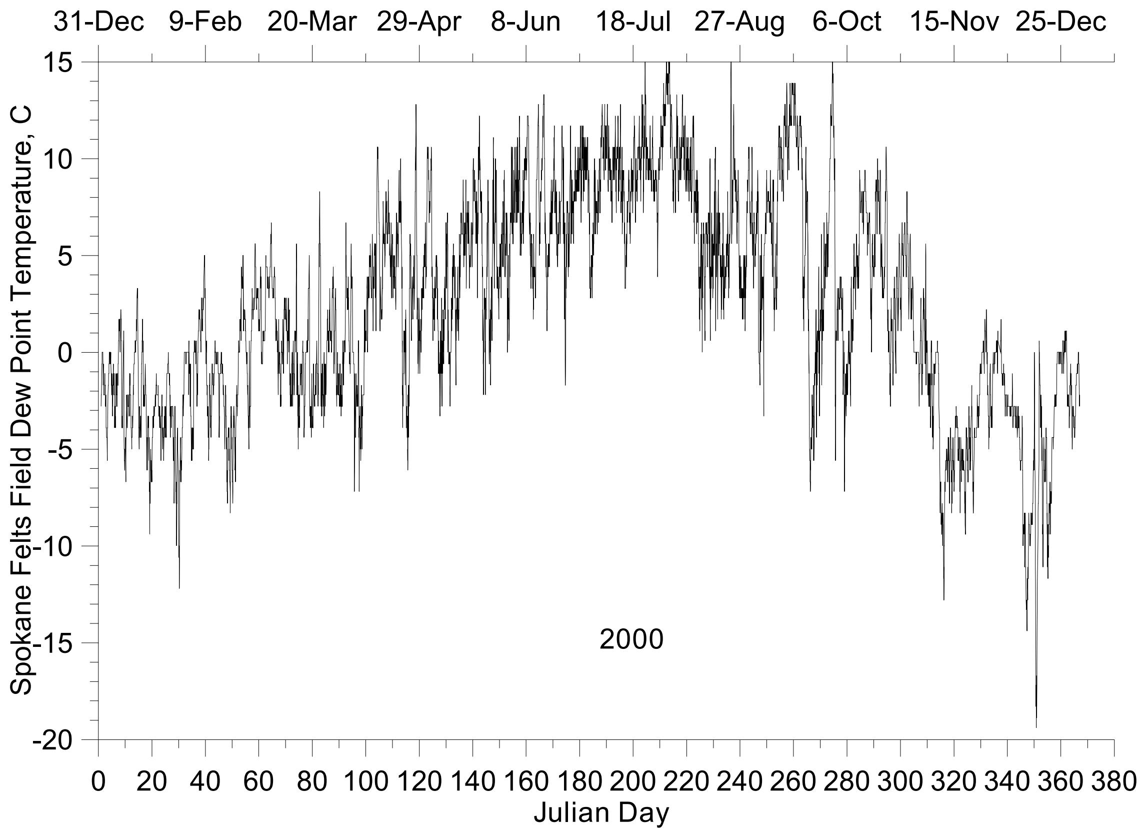


Figure 98. Dew point temperature (C) at Spokane Felts Field

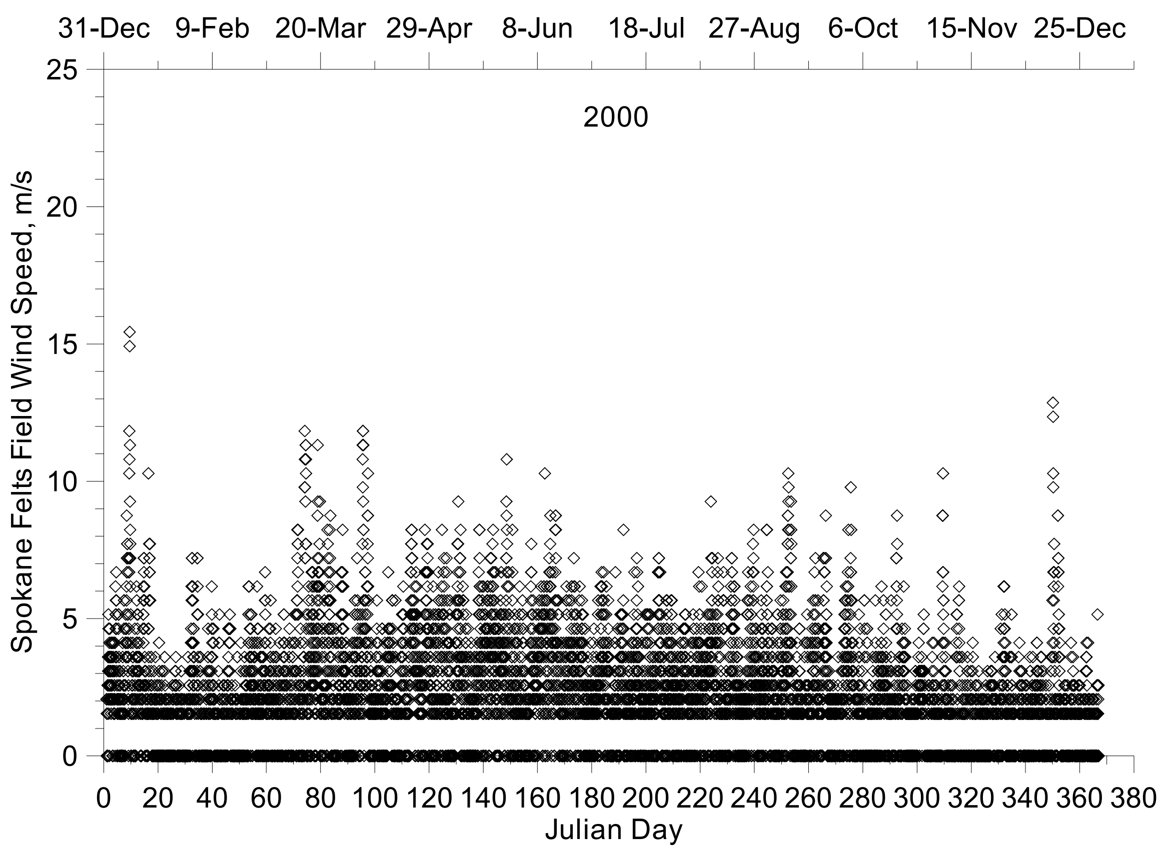


Figure 99. Wind speed (m/s) at Spokane Felts Field

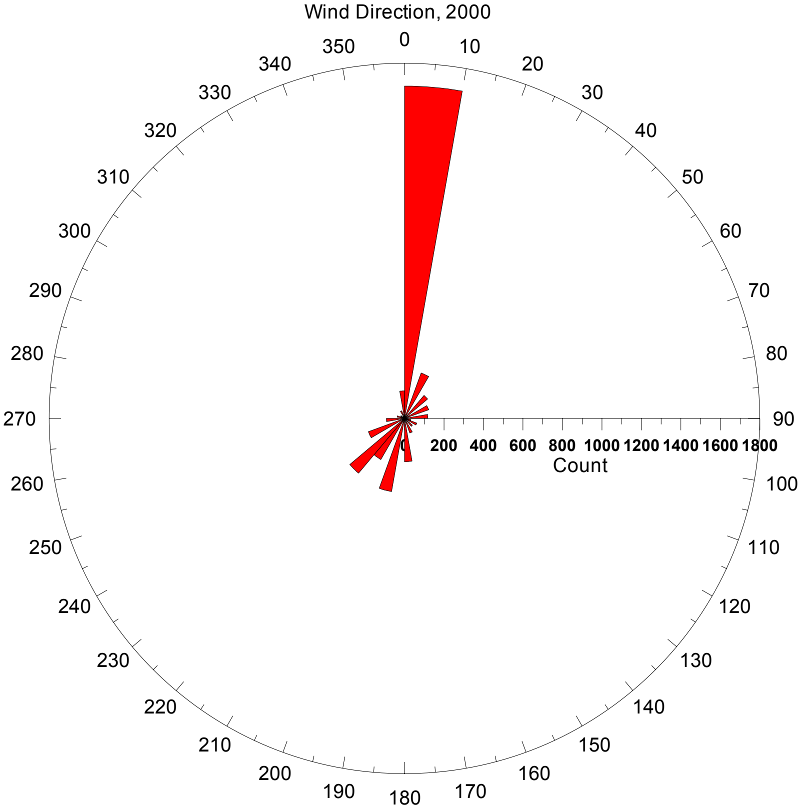


Figure 100. Wind direction, (degrees from North) at Spokane Felts Field

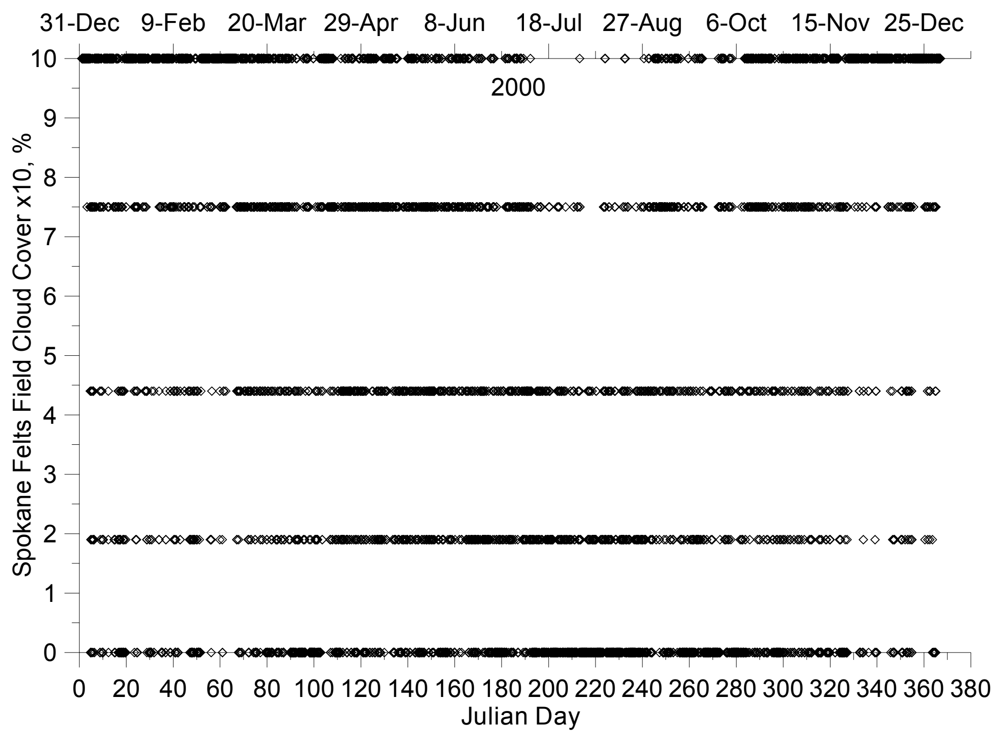


Figure 101. Cloud Cover (x10, %) at Spokane Felts Field

Odessa, WA

Since there were no solar radiation data available at the Spokane International Airport or at the Spokane Felts Field, data were used from a meteorological site in Odessa, WA (see Figure 91). The solar radiation data collected at Odessa in 1991 and 2000 are shown in Figure 102 and Figure 103, respectively. The solar radiation data were compared with the theoretical solar radiation for the latitude of the Spokane International Airport to calculate the cloud cover with the equation:

$$C = \sqrt{\frac{1}{0.0065}\left(1 - \frac{\varphi_{measured}}{\varphi_{theoretical\,clearsky}}\right)}$$

where C: cloud cover in tenths

$\varphi_{measured}$: measured short-wave solar radiation

$\varphi_{theoretical\ clear\ sky}$: computed from theoretical formulae with no cloud cover (from the CE-QUAL-W2 model)

Figure 104 and Figure 105 show daily cloud cover for 1991 and 2000, respectively.

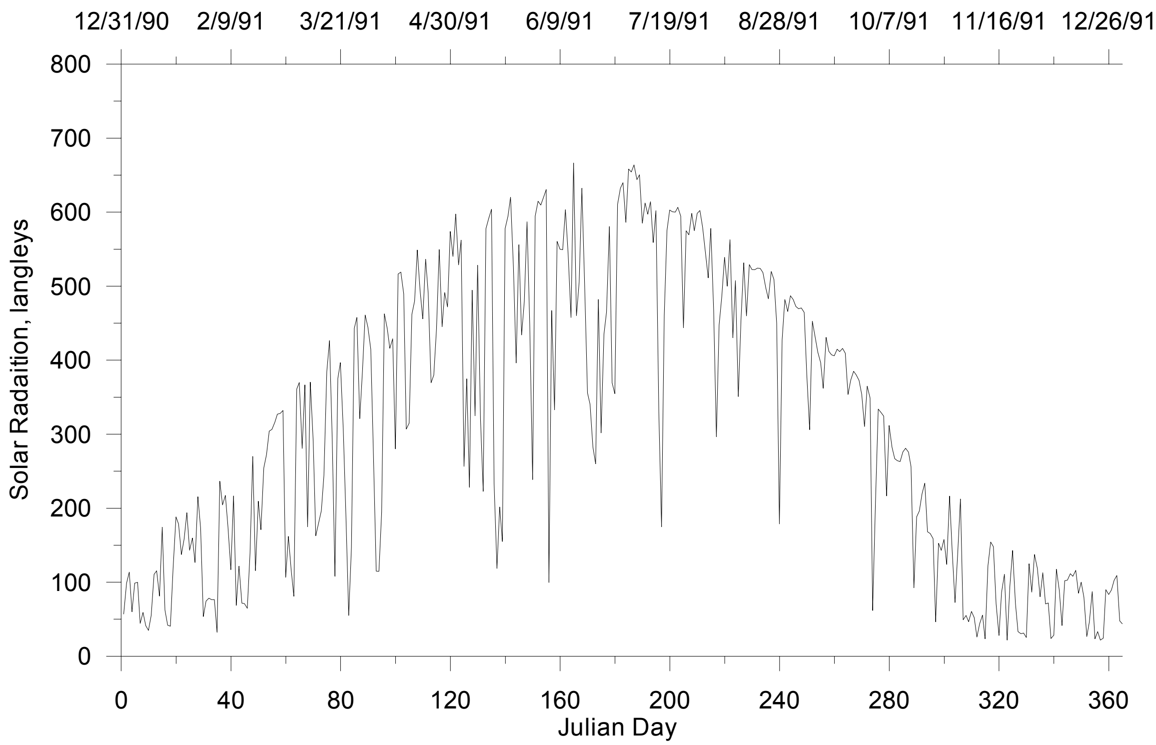


Figure 102. Solar radiation at Odessa, WA 1991

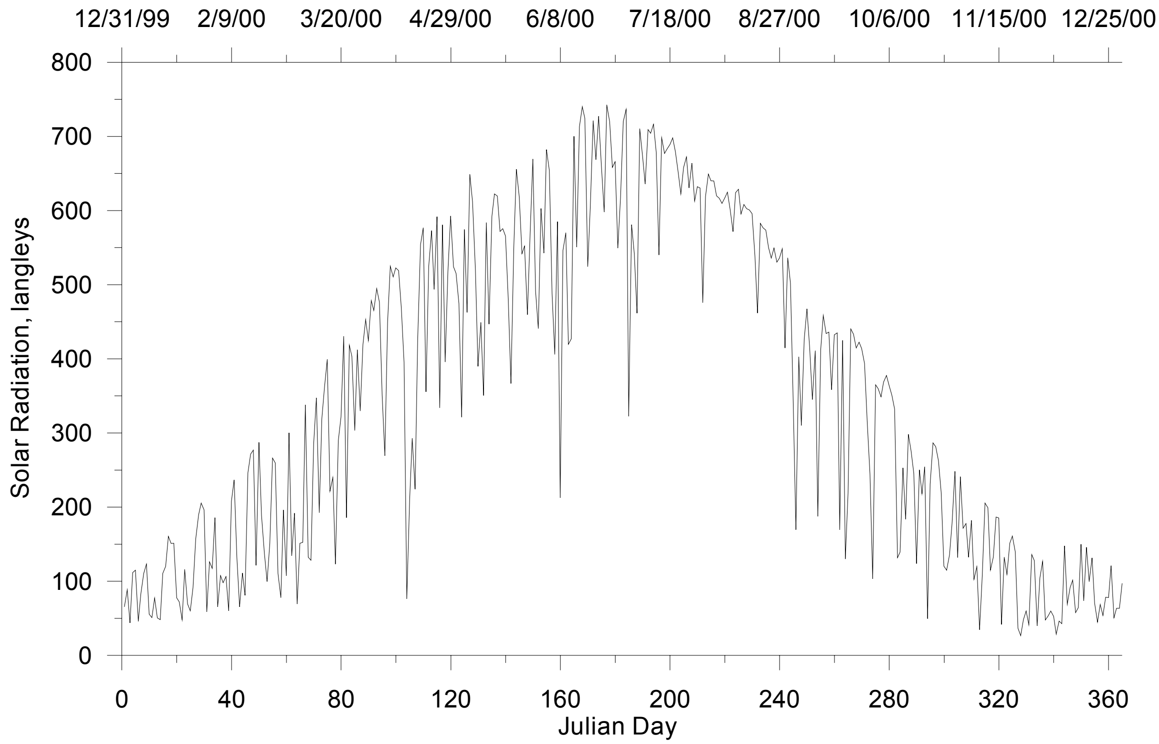


Figure 103. Solar radiation at Odessa, WA 2000

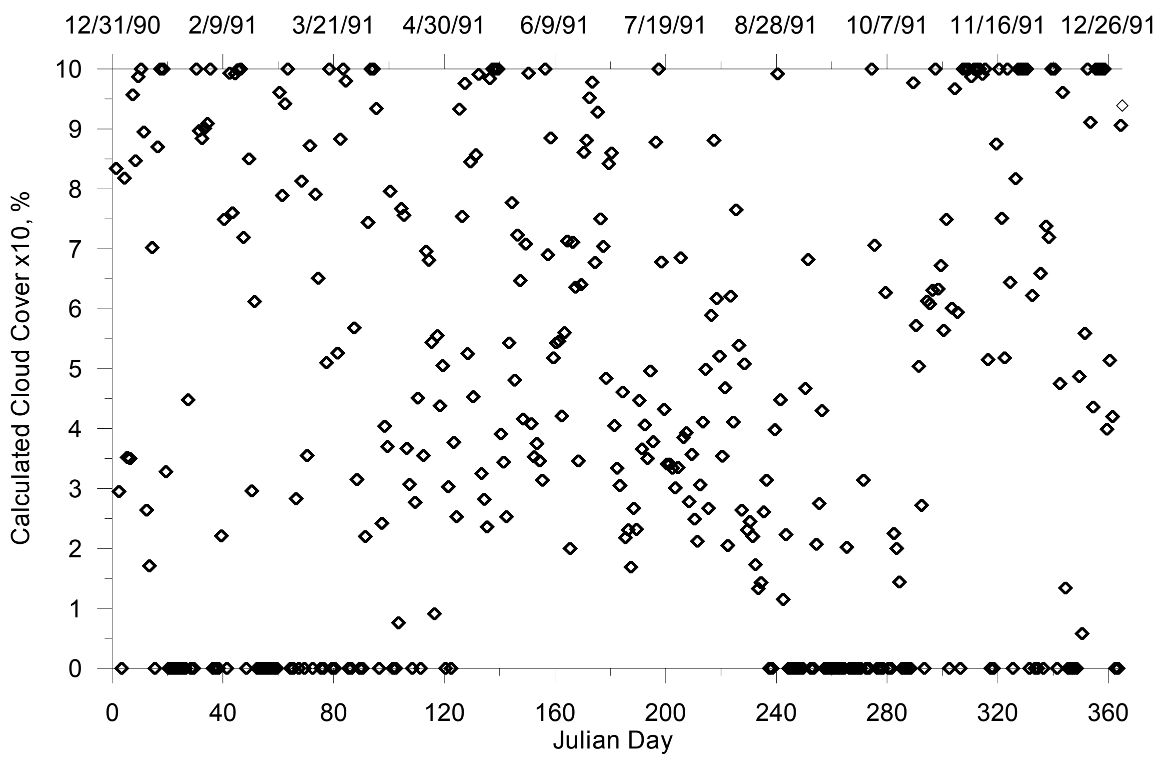


Figure 104. Cloud cover based on solar radiation data and theoretical values, 1991

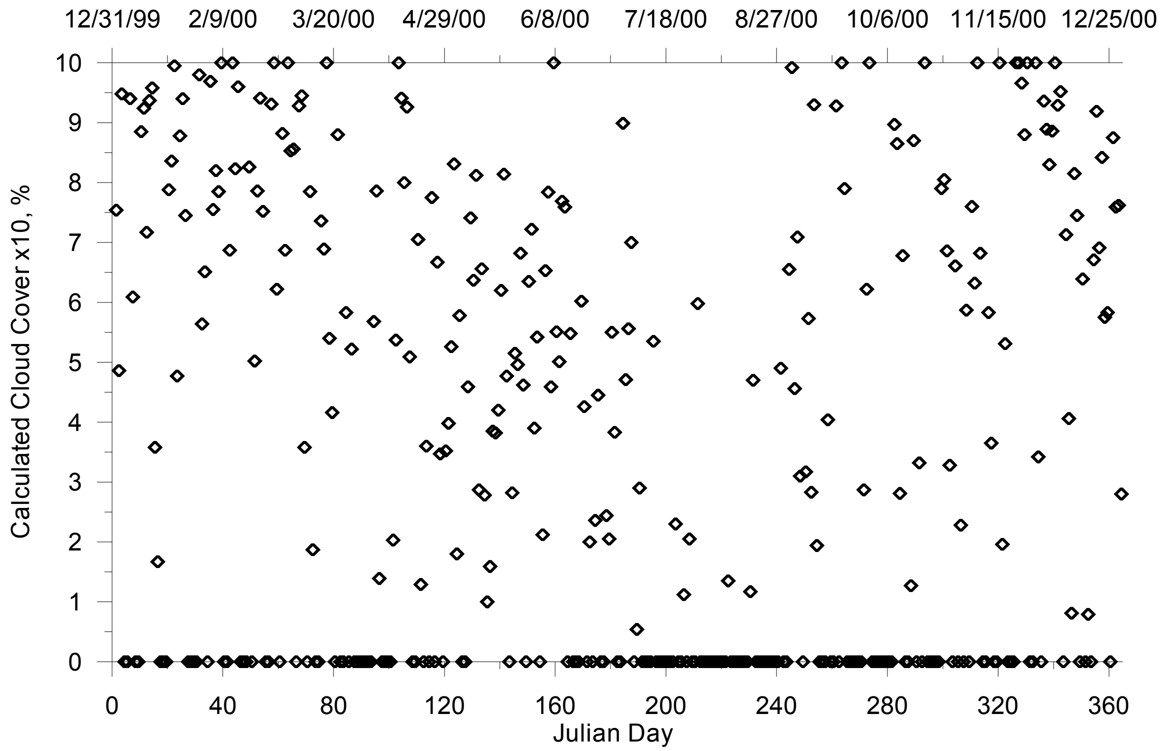


Figure 105. Cloud cover based on solar radiation data and theoretical values, 2000

Spokane Airport and Felts Field Comparison

Meteorological data from 2000 to 2002 at the Spokane International Airport were compared with data at Spokane Felt Field to determine variability between the two sites. The Spokane International Airport site is located 11 miles west of Spokane Felts Field. Figure 106 shows an air temperature correlation between the two sites. The coefficient of determination (R^2) for the correlation was 0.98, illustrating a close correlation between air temperatures at the two sites. Figure 107 shows a dew point temperature correlation for the two sites with a coefficient of determination of 0.92. The close correlation between the air temperature and dew point temperature at these two sites seems appropriate since the sites are not too far away and the topography does not change significantly between the two sites. Figure 108 attempts to correlate the wind speed at the two sites, and Figure 109 shows the correlation for wind direction. Based on these two figures there appears to be no correlation between the two sites for wind speed and direction. Figure 110 is a comparison of wind direction for both sites on the same rose diagram. The diagram shows that the predominant wind direction for both sites is in the range of 0 to 10 degrees from the North. One major difference is that the wind direction at the Spokane Airport is also common in other ranges, such as 150 to 250 degrees and 40 to 50 degrees from the North. The wind direction at Felts Field is primarily from the 0 to 10 degrees from the North. Figure 111 shows a correlation between cloud cover data from both sites and shows there is no correlation between the two sites.

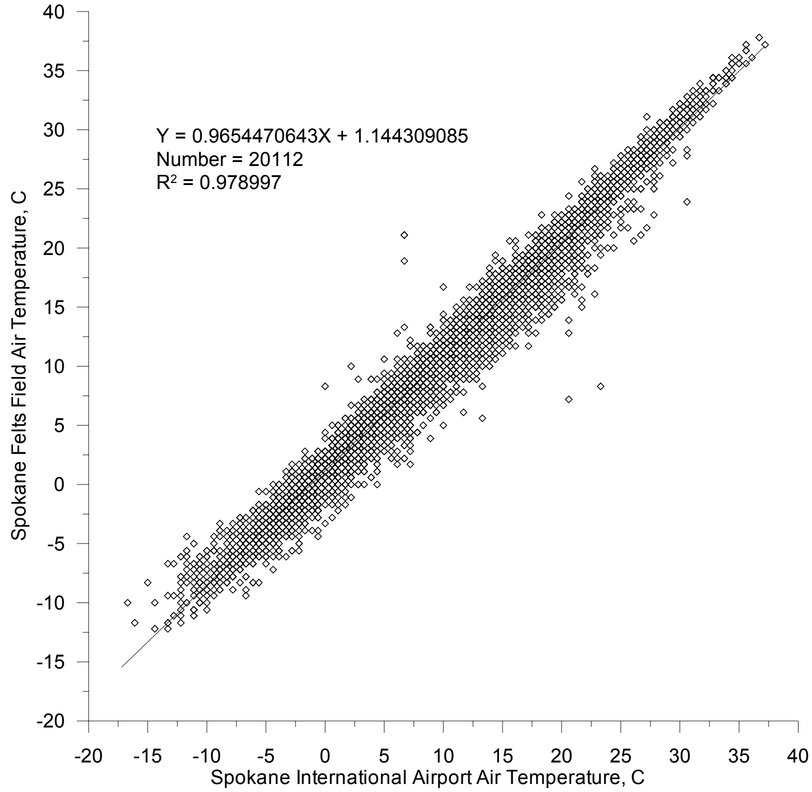


Figure 106. Air temperature correlation between Spokane Airport and Felts Field

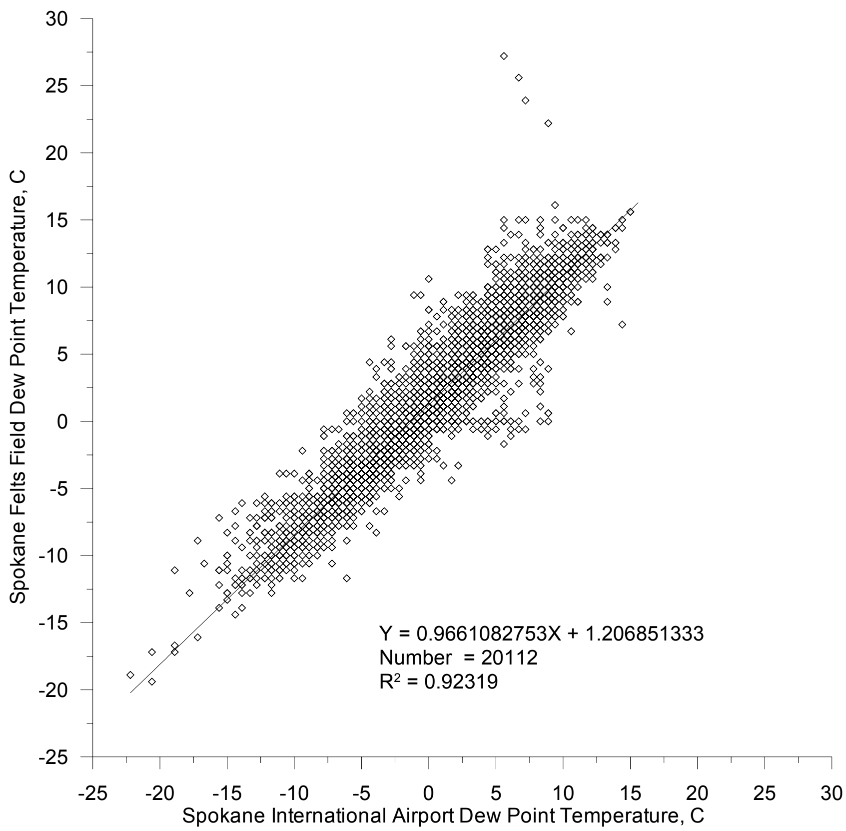


Figure 107. Dew point temperature correlation between Spokane Airport and Felts Field

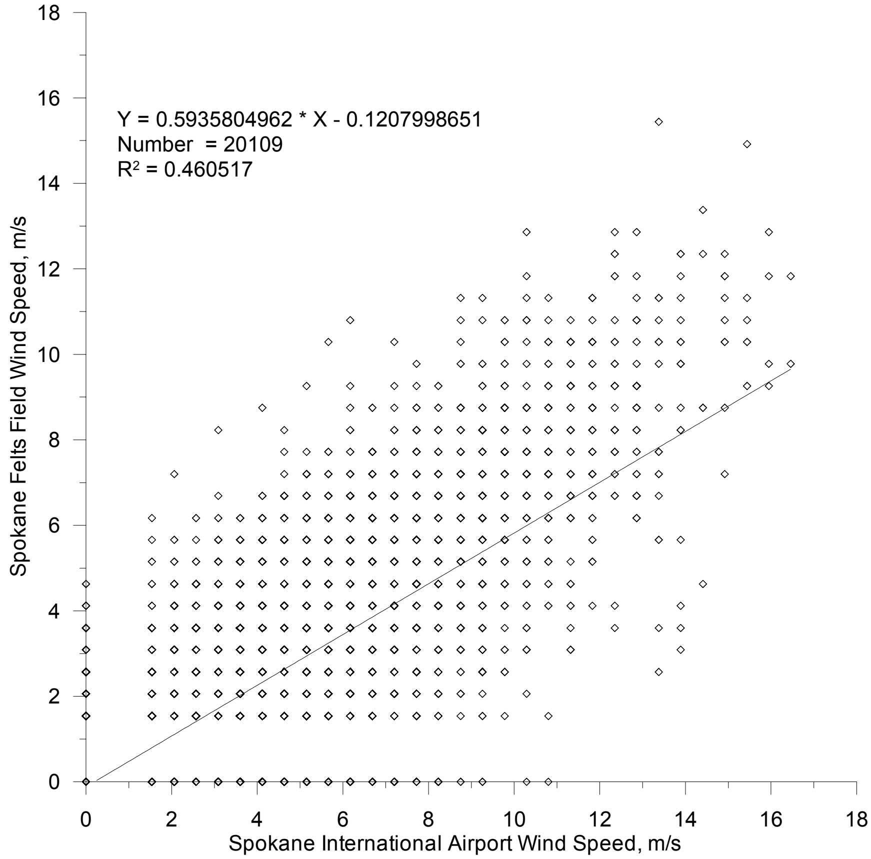


Figure 108. Wind speed correlation between Spokane Airport and Felts Field

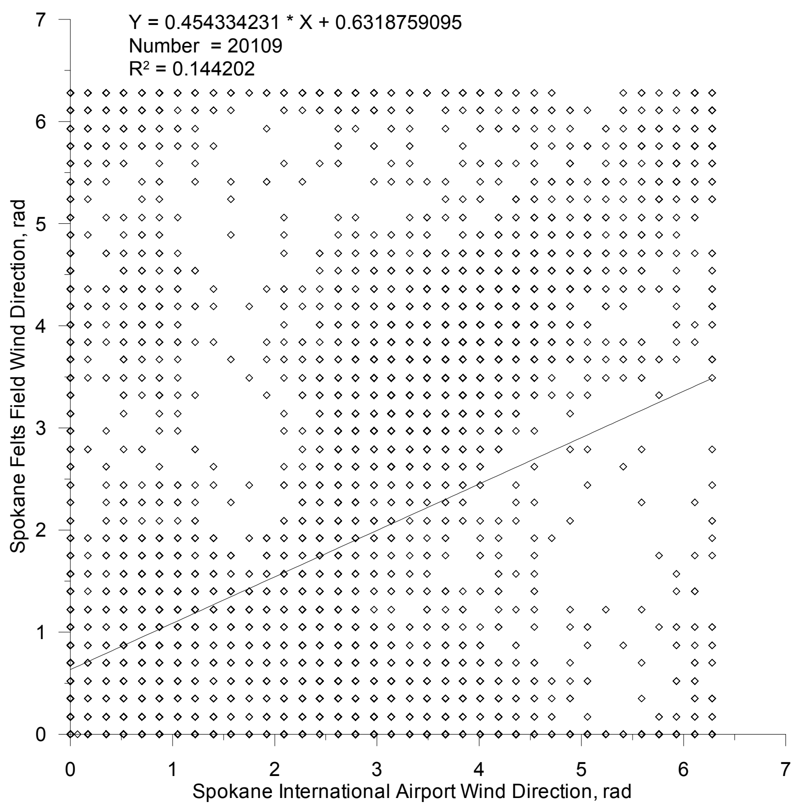


Figure 109. Wind direction correlation between Spokane Airport and Felts Field

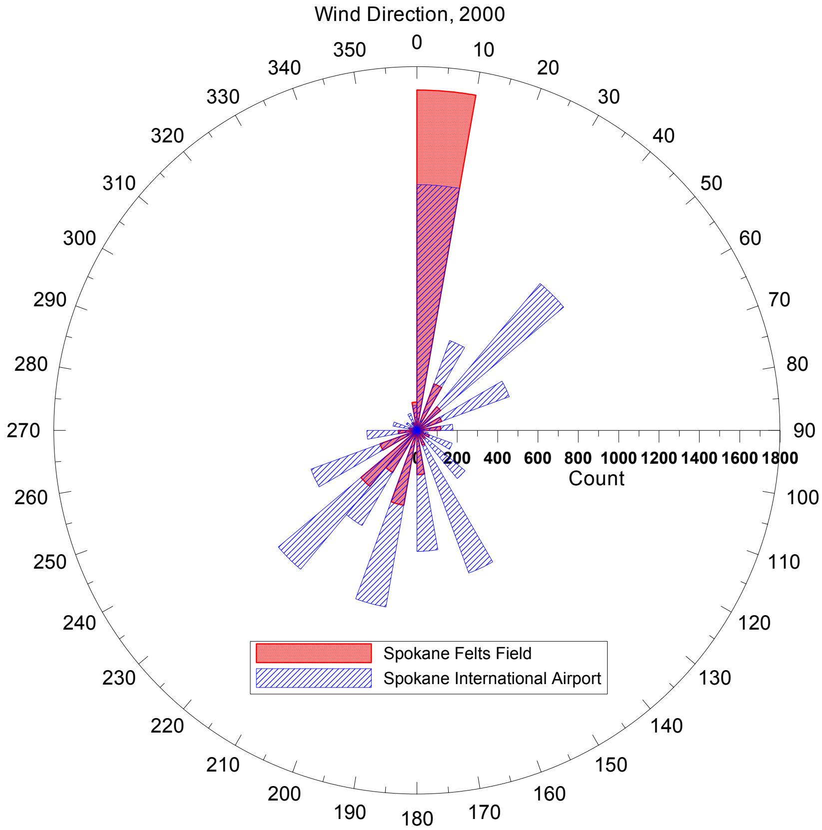


Figure 110. Wind direction comparison between Spokane Airport and Felts Field

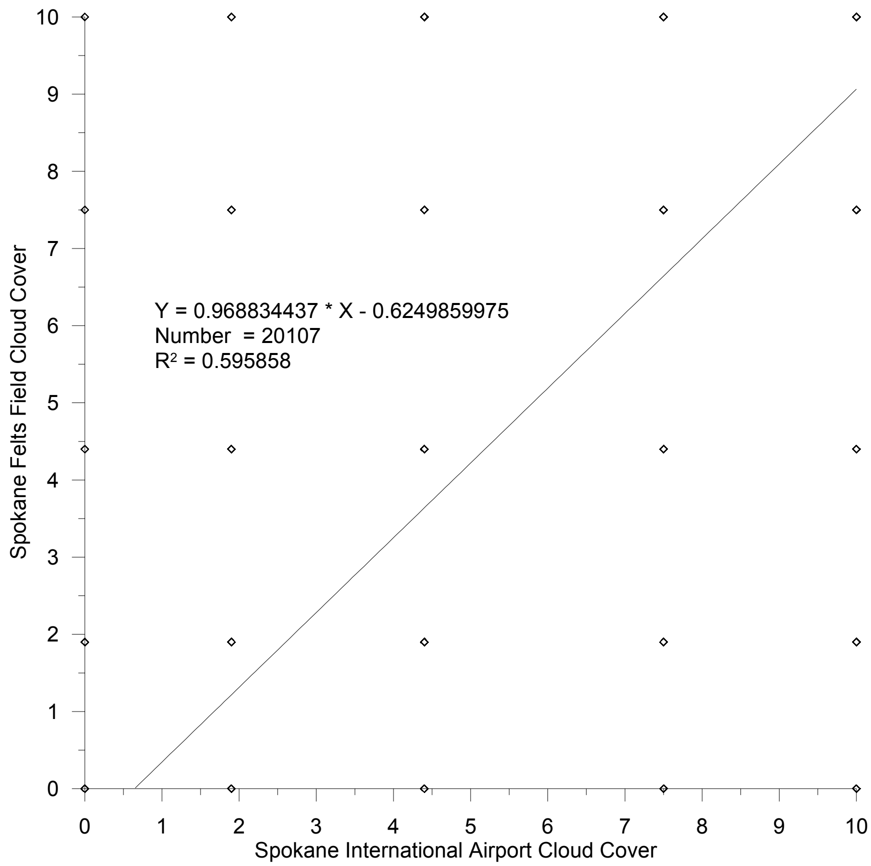


Figure 111. Cloud Cover data correlation between Spokane Airport and Felts Field

Periphyton Data

A periphyton algorithm was developed for the model to incorporate important nutrient and dissolved oxygen changes in the Spokane River. Although no periphyton data were collected in 2000, there were some data collected in 2001, which provided some guidance on how much periphyton biomass exists at various locations along the river.

Samples were collected at 8 sites on the Spokane River as listed in Table 18 in August and September 2001. Table 19 and Table 20 show the mean biomass and chlorophyll data from August 2001 for each site based on several samples collected. Table 21 and Table 22 show the mean biomass and chlorophyll data from September 2001 for each site based on several samples collected. Table 23 and Table 24 show the mean biomass and chlorophyll data for each site based on new growth over 28 days from incubated substrates at each site.

Table 18. Periphyton Data Sites

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

Table 19. August 2001 Site Mean Biomass from Natural Substrates

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

Table 20. August 2001 Site Mean Chlorophyll from Natural Substrates

RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	24.2	140	1.1	0.0	36.6	4.3	40.4	3.1	1.6
90.4	22.5	175	1.3	0.0	10.8	0.8	11.6	1.3	0.3
85.3	12.5	280	1.2	0.1	14.4	0.8	15.4	0.9	1.0
78.0	14.3	271	0.7	0.4	26.8	2.3	28.9	4.5	1.4

Table 20. August 2001 Site Mean Chlorophyll from Natural Substrates									
RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
72.7	15.7	270	0.7	0.3	44.0	3.0	47.0	5.2	4.9
67.6	15.2	210	0.9	0.4	43.4	2.0	45.9	4.7	1.8
64.6	16.0	329	0.6	0.3	77.9	-0.1	80.6	1.6	4.9
58.1	18.1	326	0.8	0.0	80.0	4.8	85.7	2.1	5.5

Table 21. September 2001 Sites Mean Biomass from Natural Substrates					
RM	Depth (m)	ODW (g/m2)	AFODW (g/m2)	Autotrophic Index (Mono Chl a)	Autotrophic Index (Tri Chl a)
96.0	1.39	172.10	9.46	236.79	211.01
90.4	1.78	21.61	5.08	413.41	382.36
85.3	0.97	36.75	5.01	436.66	404.29
78.0	0.78	67.81	8.59	312.56	288.26
72.7	0.62	75.91	8.15	347.10	303.12
67.6	0.79	26.88	8.80	320.92	292.22
64.6	0.72	47.65	19.89	192.81	185.45
58.1	0.68	557.08	12.21	306.63	278.79

Table 22. September 2001 Site Mean Chlorophyll from Natural Substrates									
RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	20.5	135	1.5	0.0	44.2	7.4	50.0	5.4	1.9
90.4	17.5	90	1.8	0.0	11.6	1.0	12.6	1.7	0.6
85.3	10.7	240	1.0	0.1	12.6	1.2	13.6	1.8	0.6
78.0	11.5	230	0.8	0.5	30.3	2.3	32.4	5.3	1.0
72.7	13.4	250	0.6	0.2	27.9	5.4	32.0	3.7	2.0
67.6	14.0	220	0.8	0.3	29.4	2.9	32.0	3.0	1.8
64.6	13.9	240	0.7	0.1	103.3	1.7	107.7	6.4	4.4
58.1	15.1	268	0.7	0.1	43.9	3.3	47.3	3.1	2.6

Table 23. September 2001 Sites Mean Biomass, New Growth Over 28 days on Incubated Substrates					
RM	Depth (m)	ODW (g/m2)	AFODW (g/m2)	Autotrophic Index (Mono Chl a)	Autotrophic Index (Tri Chl a)
96.0	1.39	96.87	15.42	176.35	153.27
90.4	1.65	21.18	2.96	362.73	284.44
85.3	0.97	34.29	4.60	327.87	301.46
78.0	0.77	40.79	9.08	276.48	256.77
72.7	0.62	19.94	5.86	291.91	266.61

Table 23. September 2001 Sites Mean Biomass, New Growth Over 28 days on Incubated Substrates					
67.6	0.79	22.90	5.05	351.24	308.10
64.6	0.71	29.81	10.43	180.35	172.28
58.1	0.61	68.20	7.31	200.76	185.50

Table 24. September 2001 Site Mean Chlorophyll, New Growth Over 28 days on Incubated Substrates

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

Summary

This report summarizes boundary conditions for the CE-QUAL-W2 Version 3.1 model of the Spokane River from the Idaho-Washington state-line to the outlet to Long Lake. Since the CE-QUAL-W2 model allows the user to separate the river basin into separate branches (collections of model longitudinal segments or computational cells) and water bodies (collections of branches with similar kinetic coefficients, turbulence closure, and meteorological forcing). The W2 model was composed of both riverine and reservoir sections, such as

- The Spokane River
- Nine Mile Dam pool
- Upriver Dam pool
- Upper Falls Dam pool
- Long Lake

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

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

In addition, this report includes a review of water quality data collected from 1991 to 1992 and from 2000. Also, in order to account for distributed flow into and out of the Spokane River, a groundwater algorithm was developed for predicting the dynamic groundwater flows for various reaches in the model.

Comparisons were also made of meteorological data in the Long Lake Spokane River area at the Spokane International Airport, Spokane Felts Field, and at Odessa, Washington.

A companion report, entitled: "Spokane River Model: Model Calibration" considers the following:

- Calibration of the Long Lake – Spokane River system model
- Sensitivity analysis of the reservoir-river model

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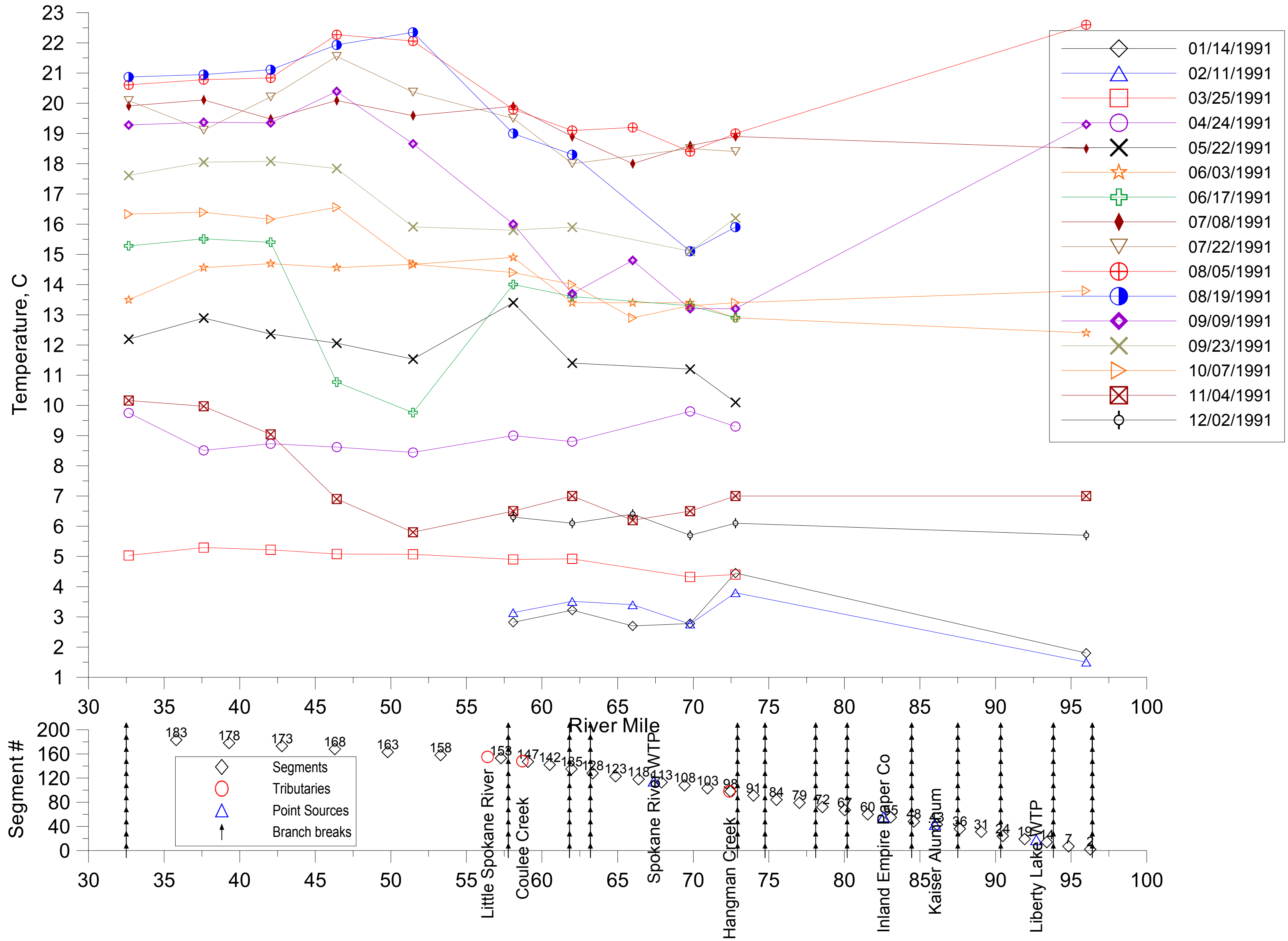
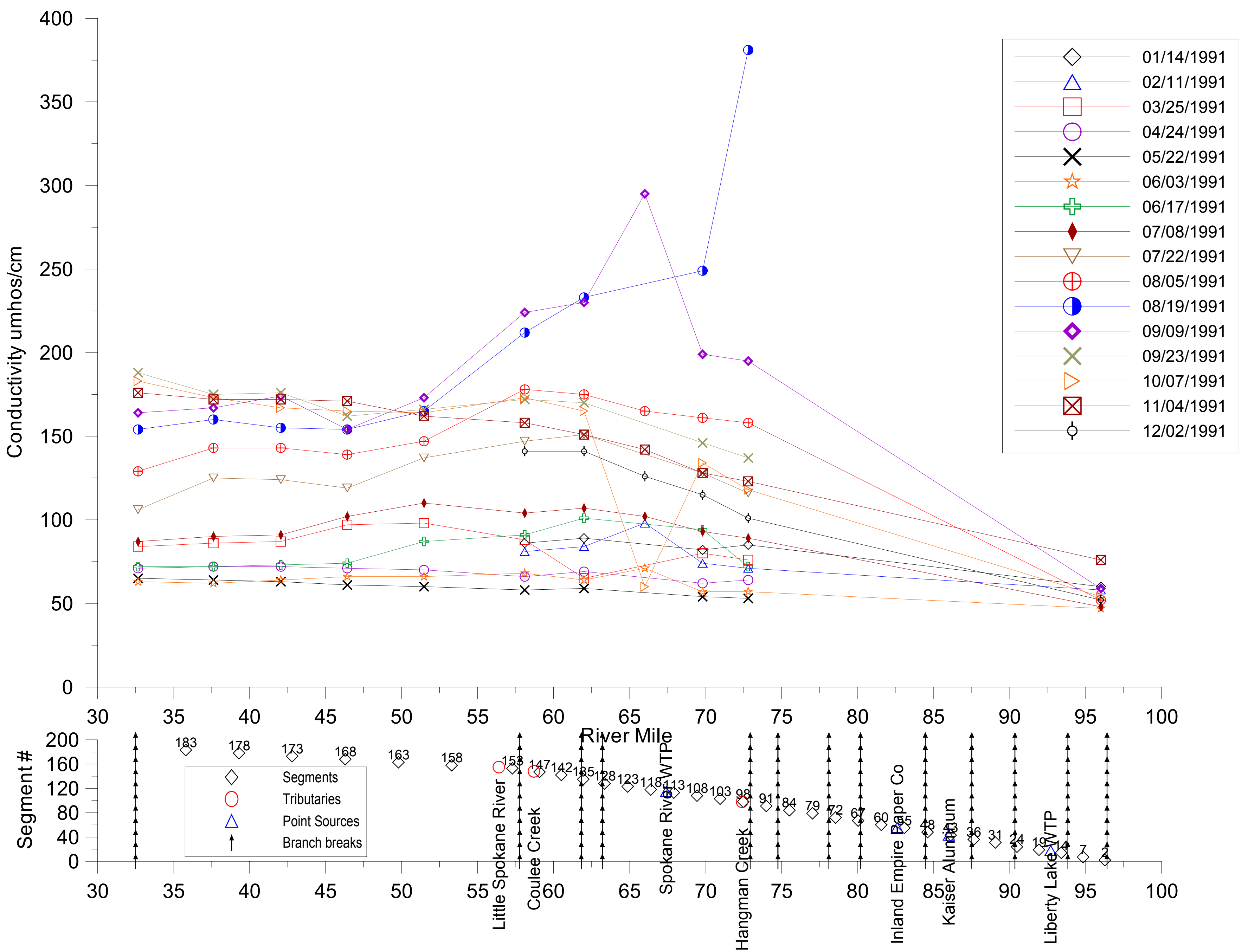
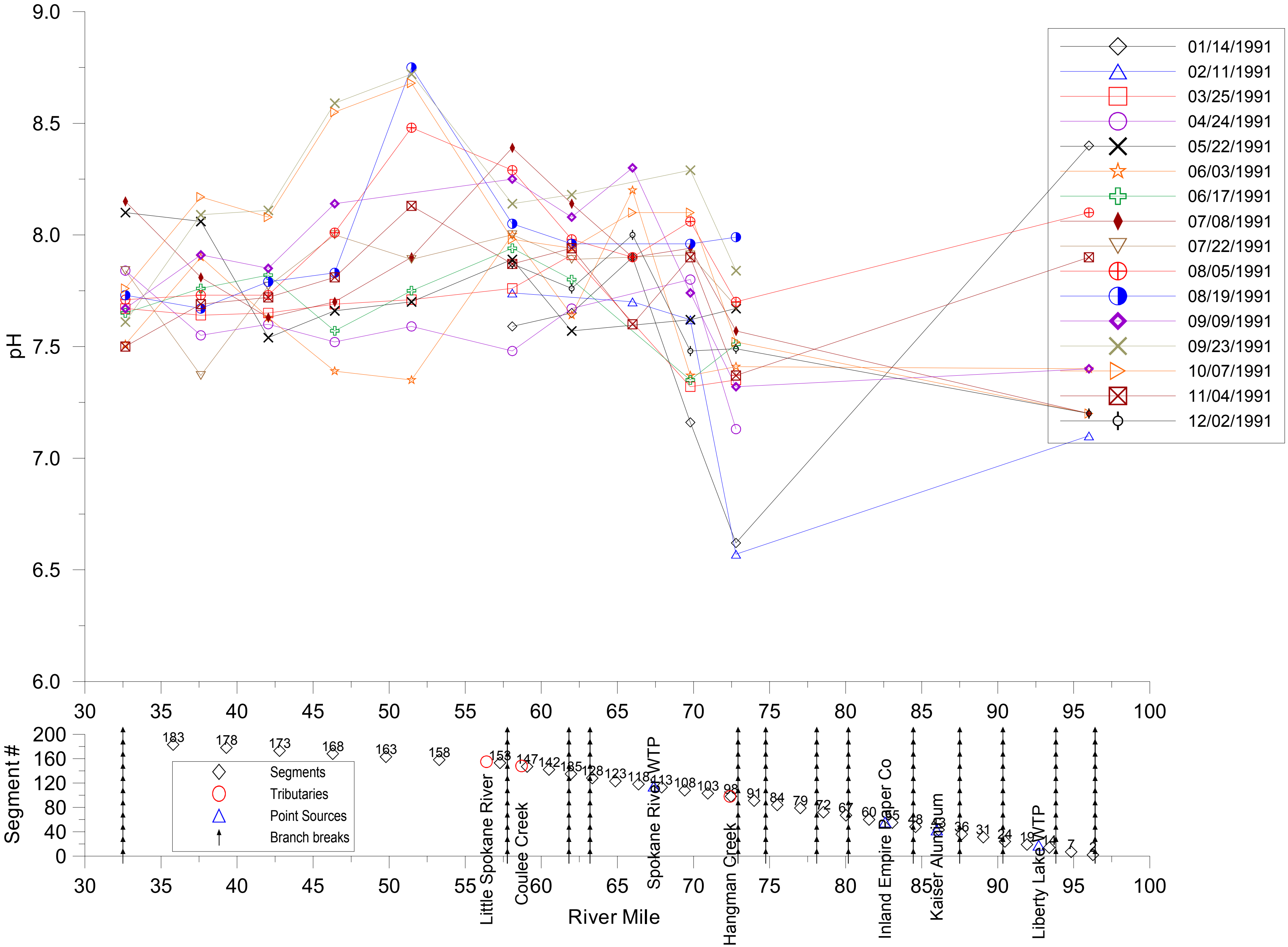
Appendix A: 1991 Longitudinal Profiles





Conductivity umhos/cm
400
350
300
250
200
150
100
50
0
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
River Mile
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



pH
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
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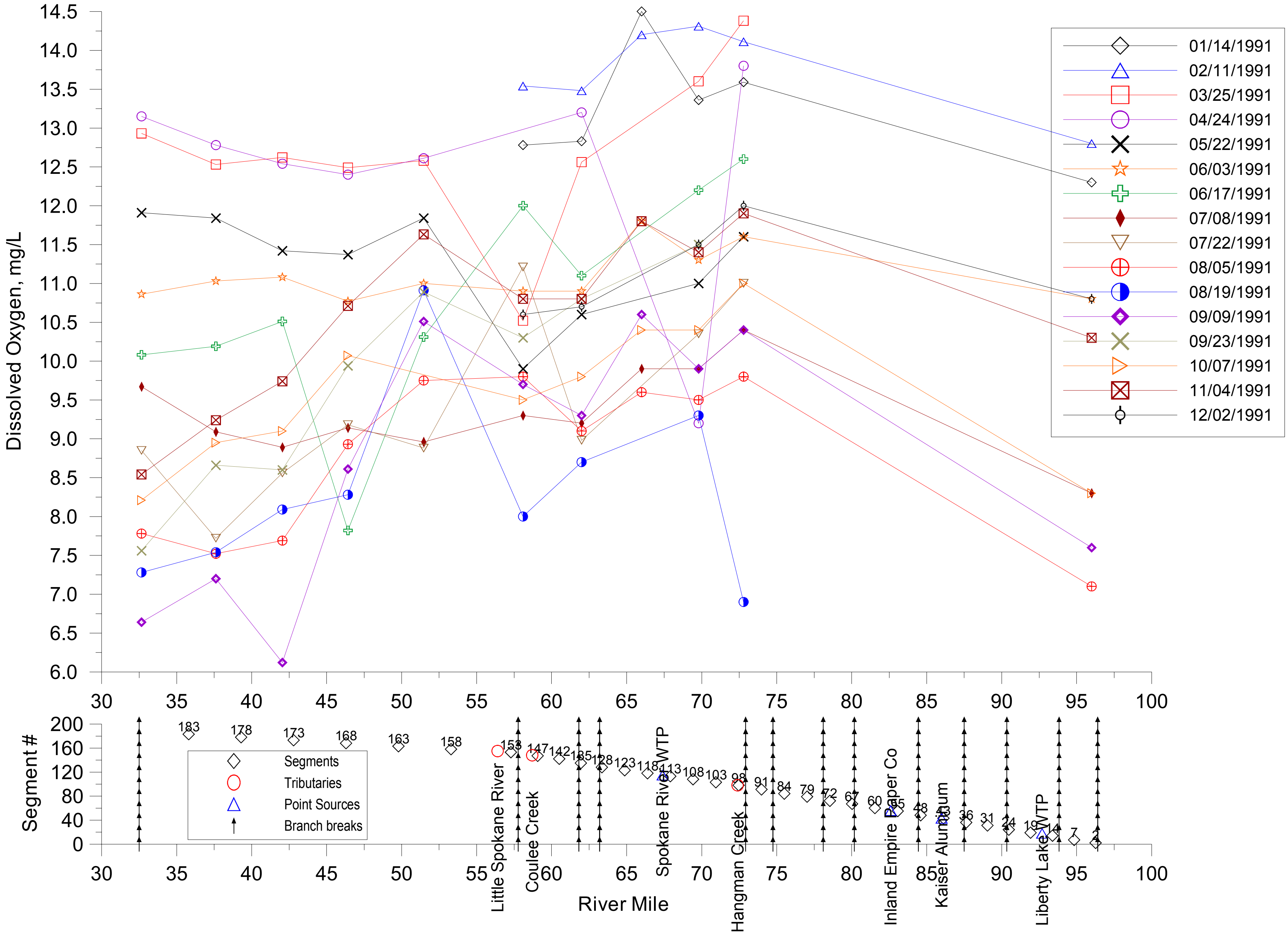
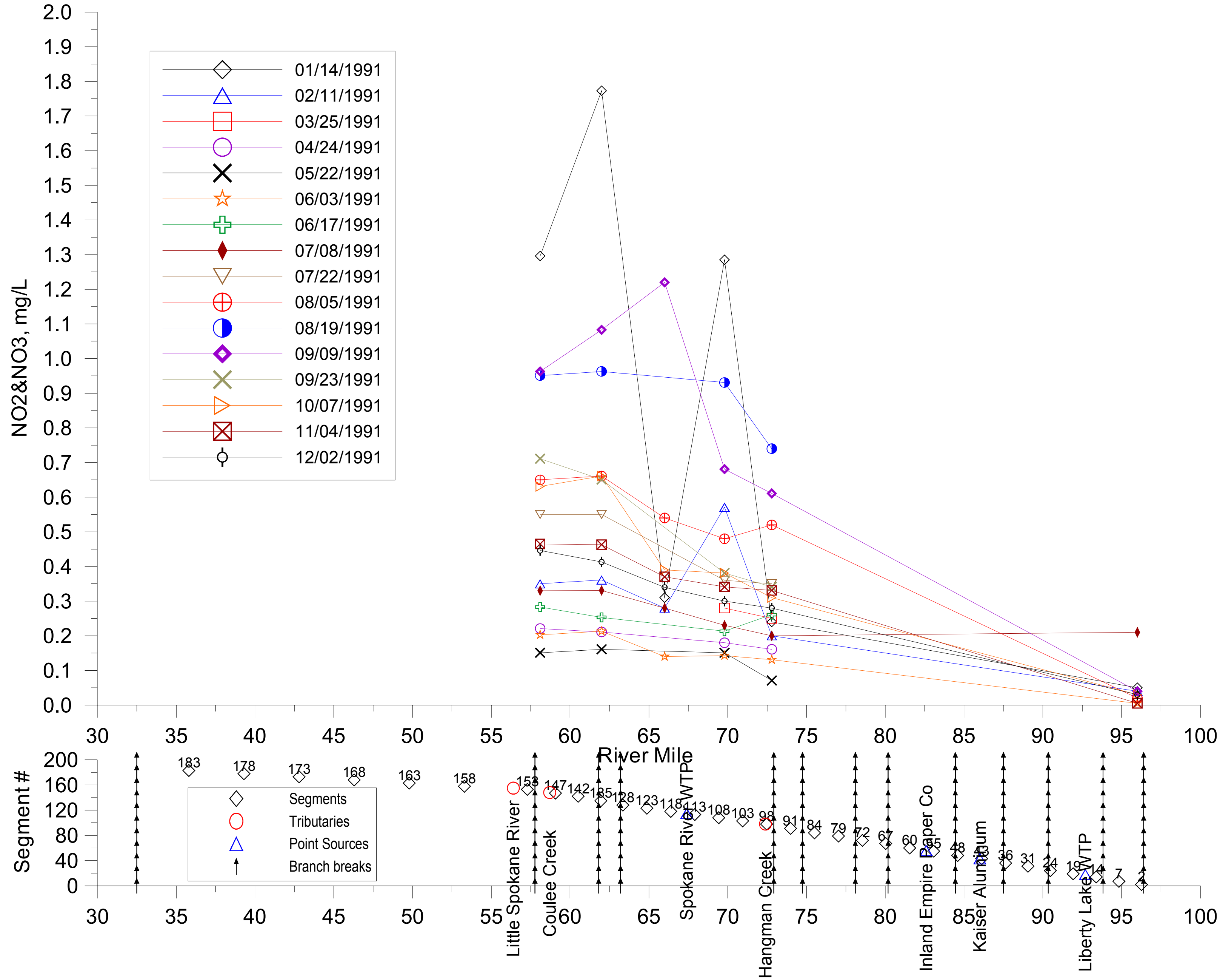
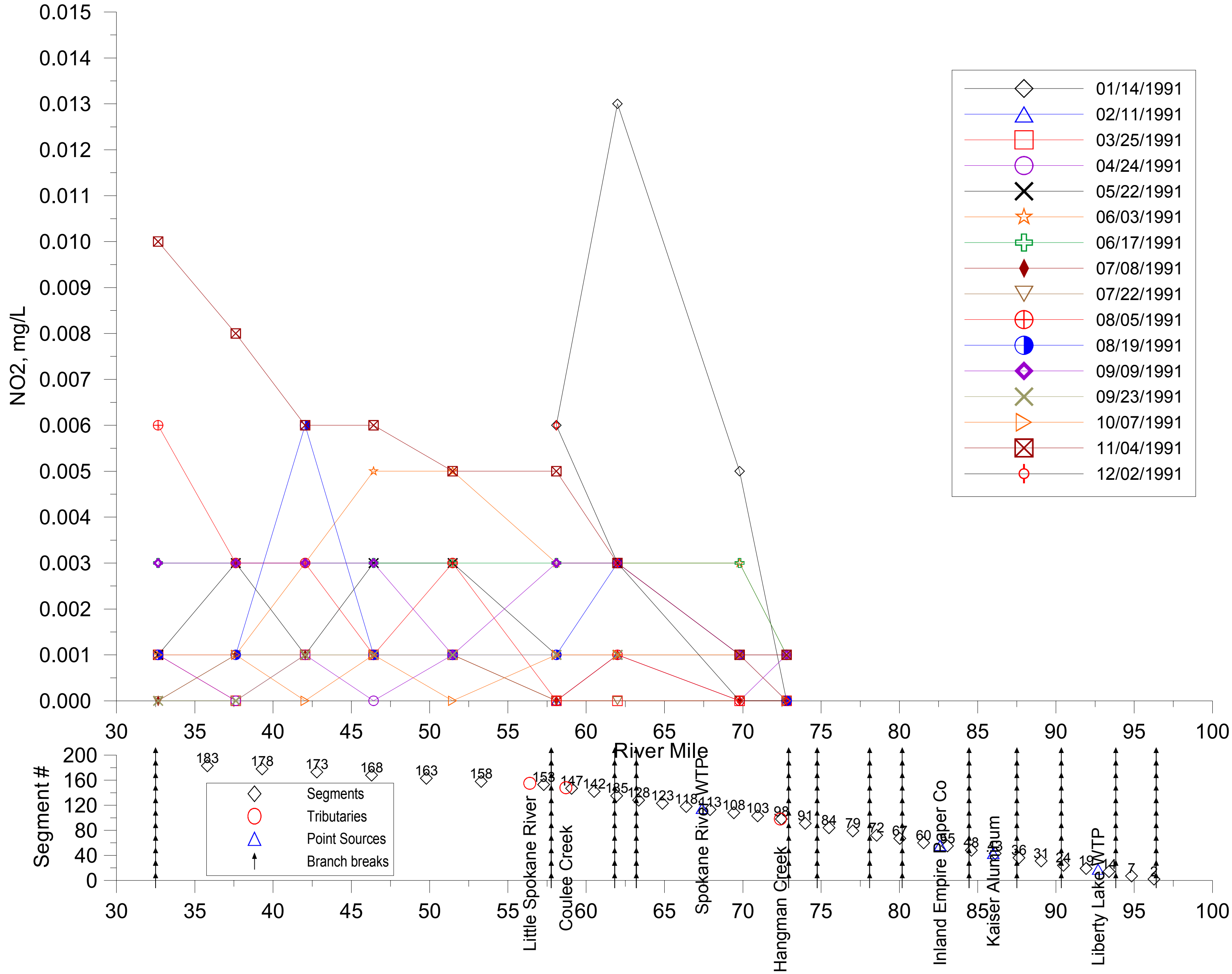
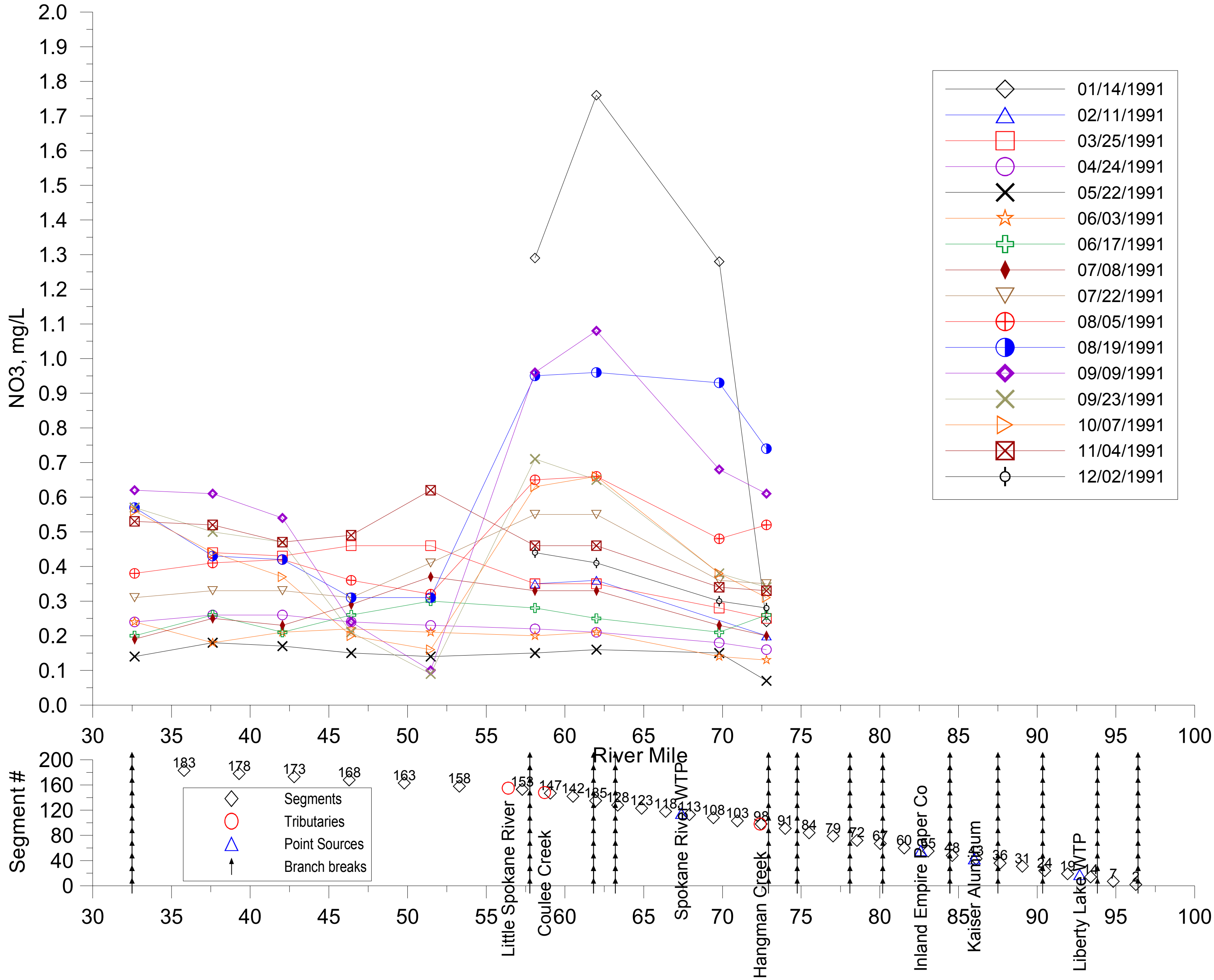
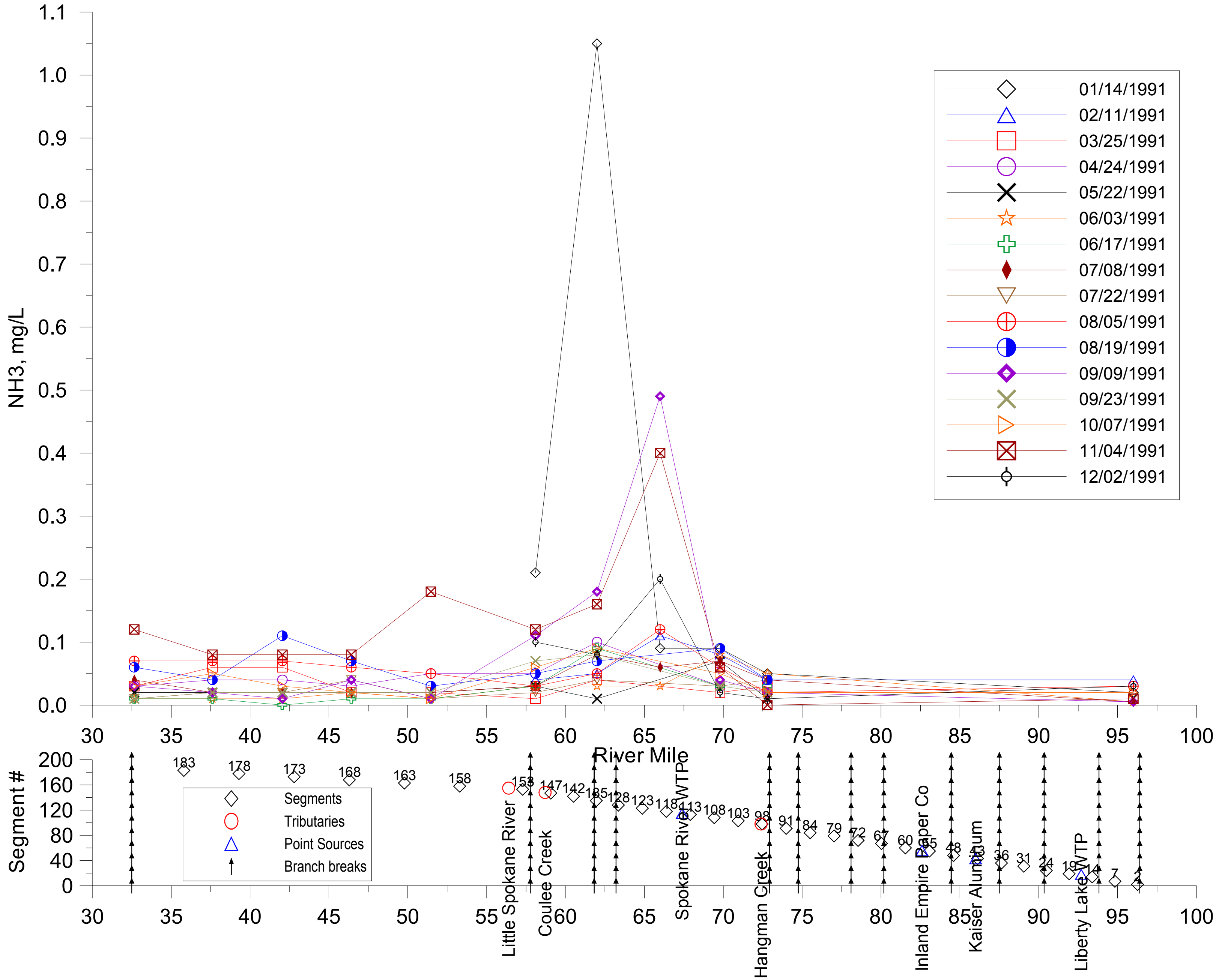
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

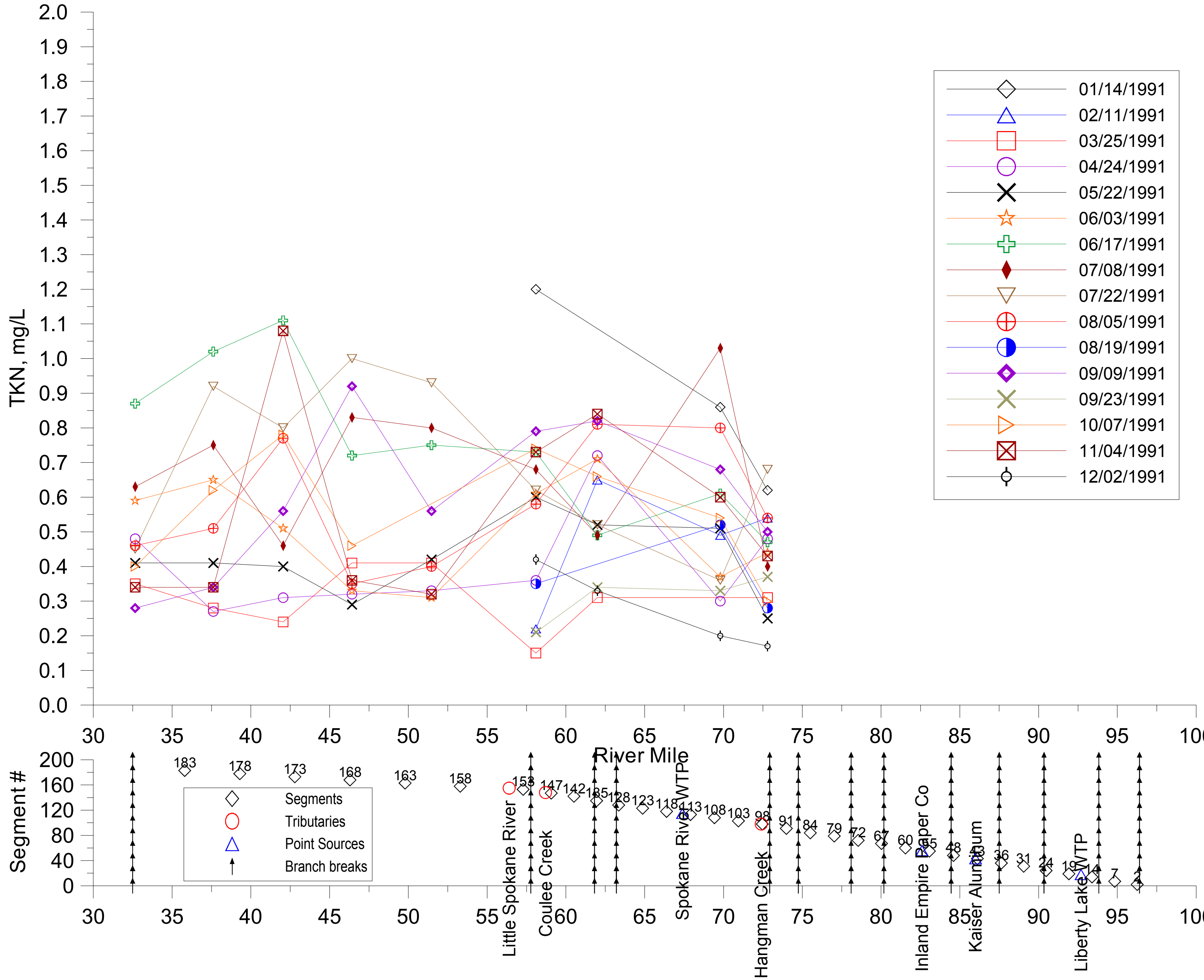

Dissolved Oxygen, mg/L
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100


NO2&NO3, mg/L
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
River Mile
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP


NO2, mg/L
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP


NO3, mg/L
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP


NH3, mg/L
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
River Mile
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segment #
200
160
120
80
40
0
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



TKN, mg/L
River Mile
Segment #
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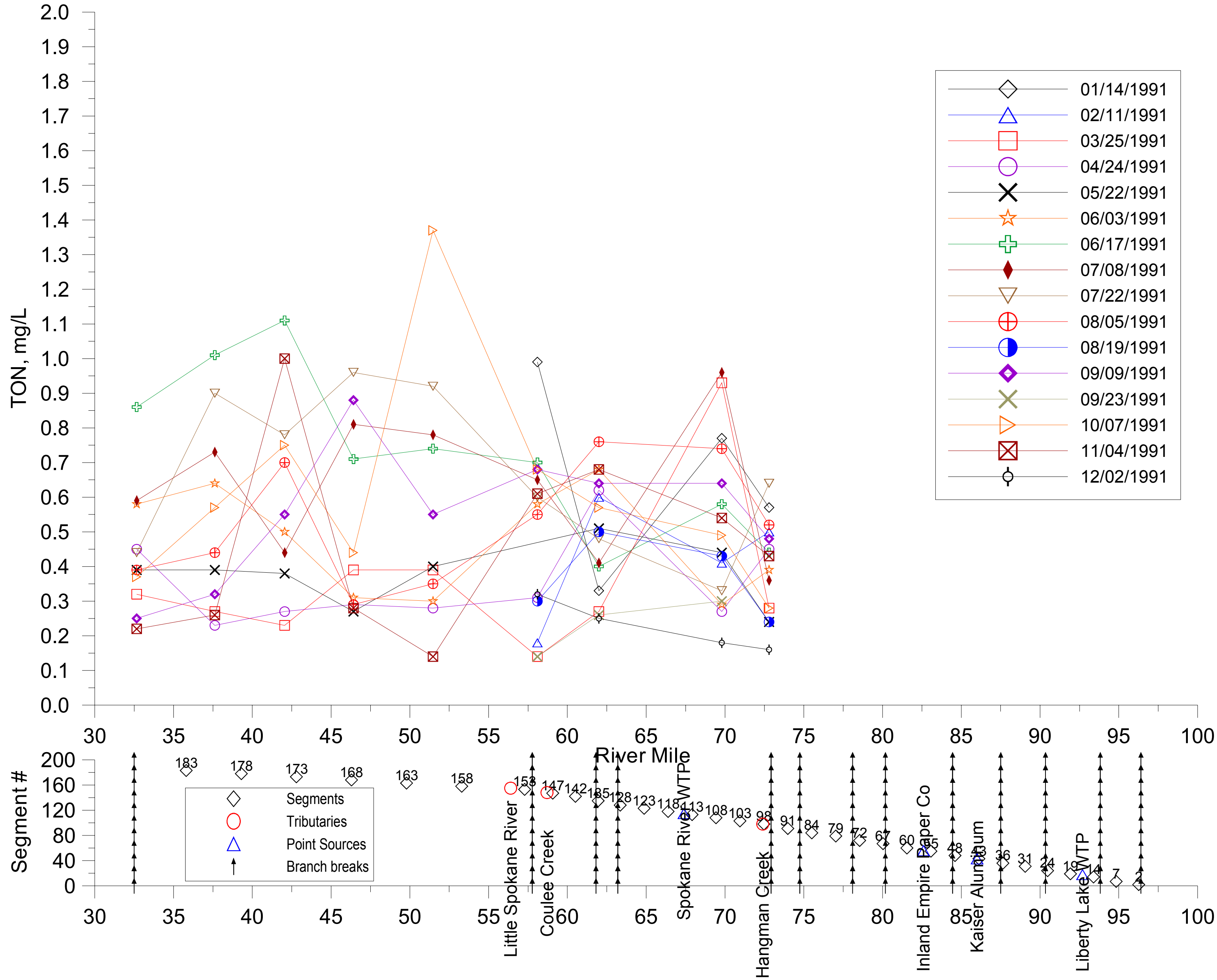
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP


TON, mg/L
River Mile
Segment #
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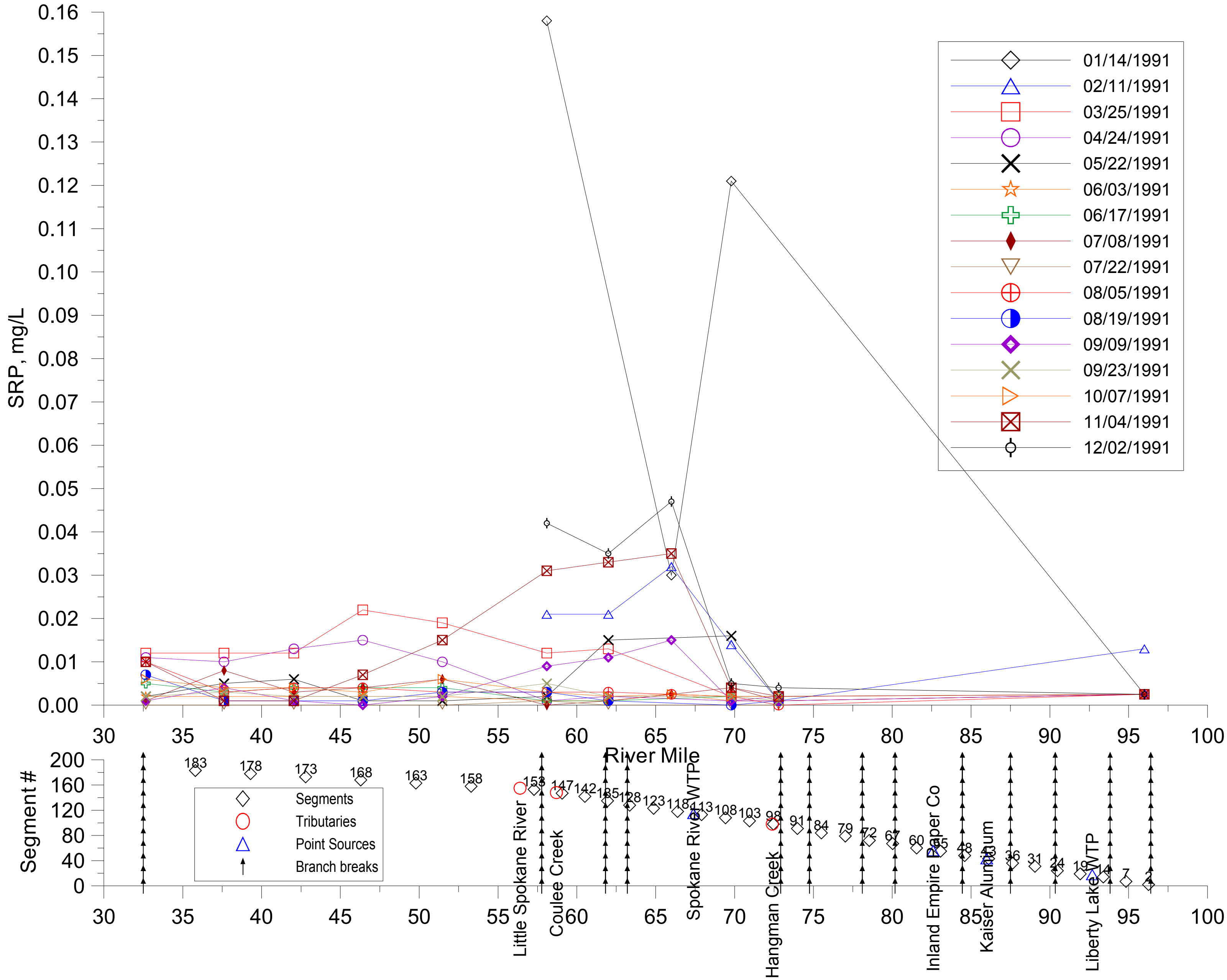
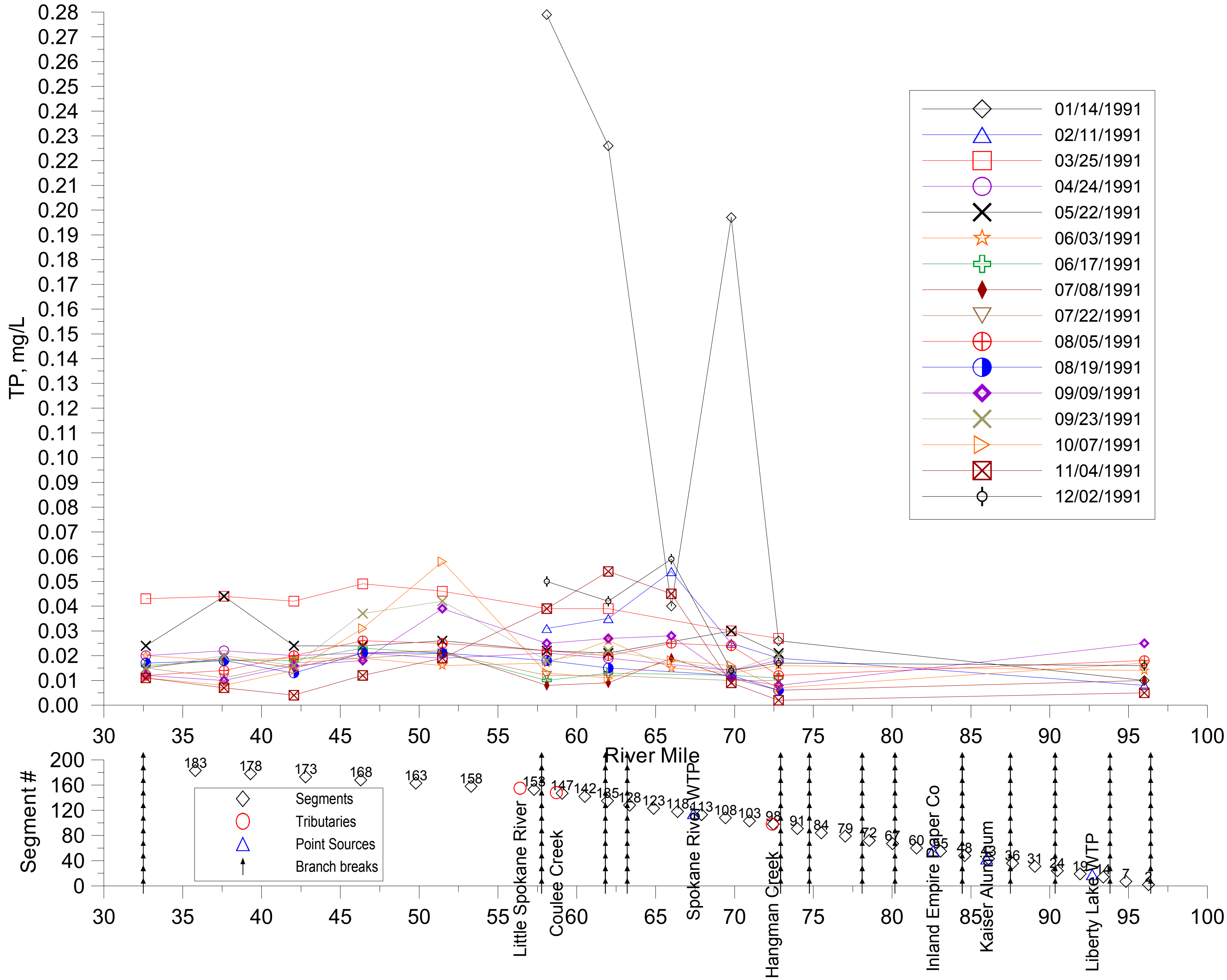
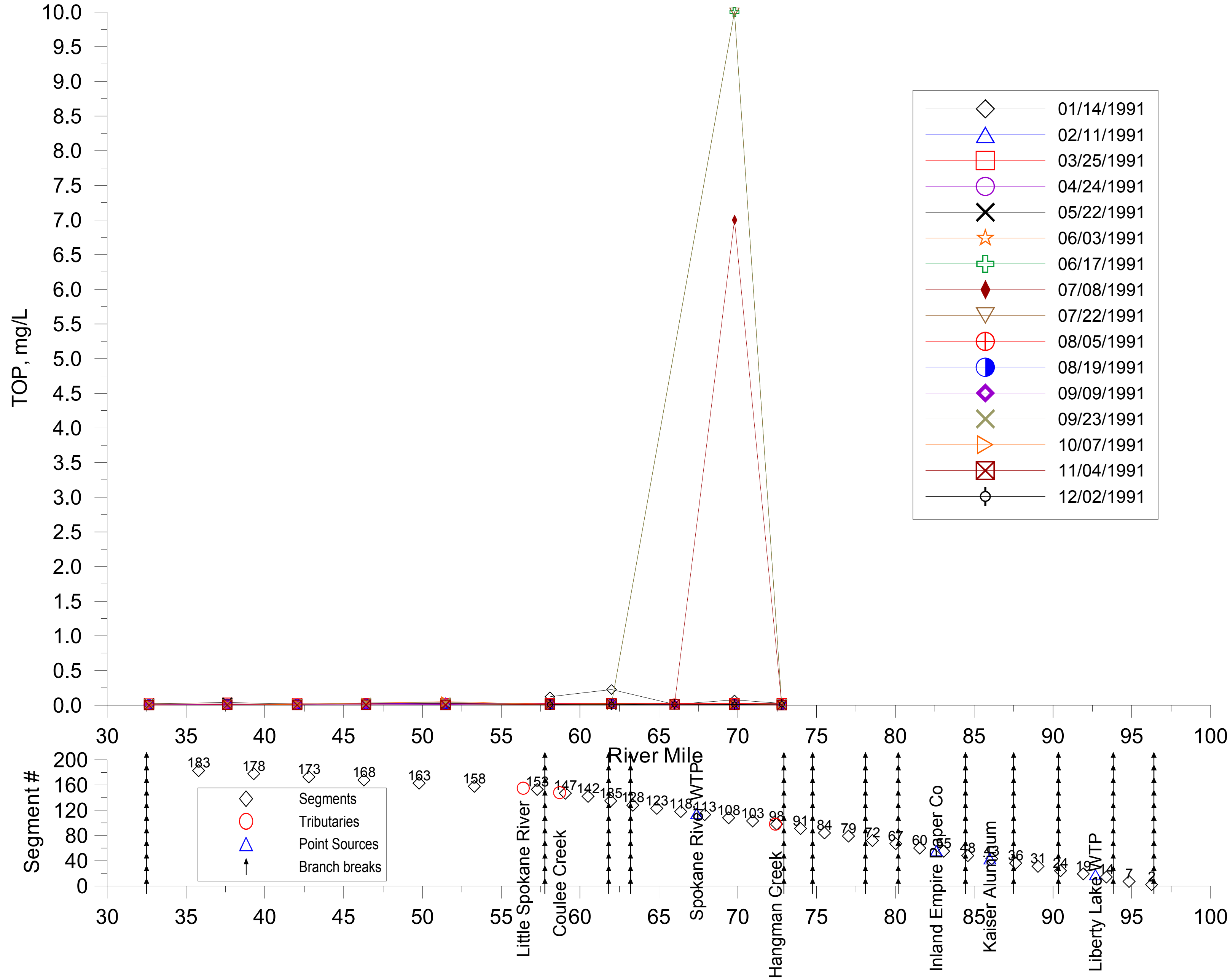
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

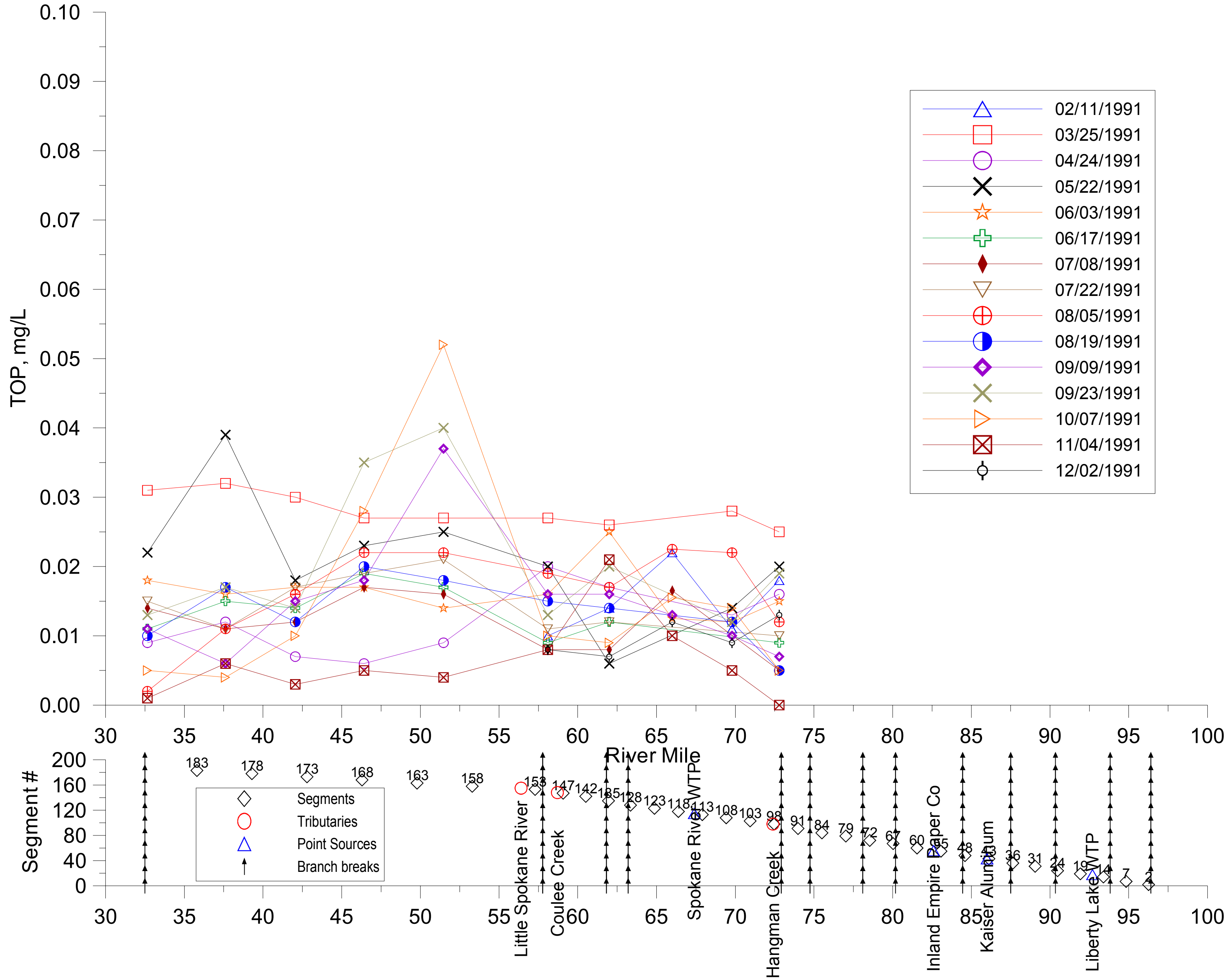

SRP, mg/L
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



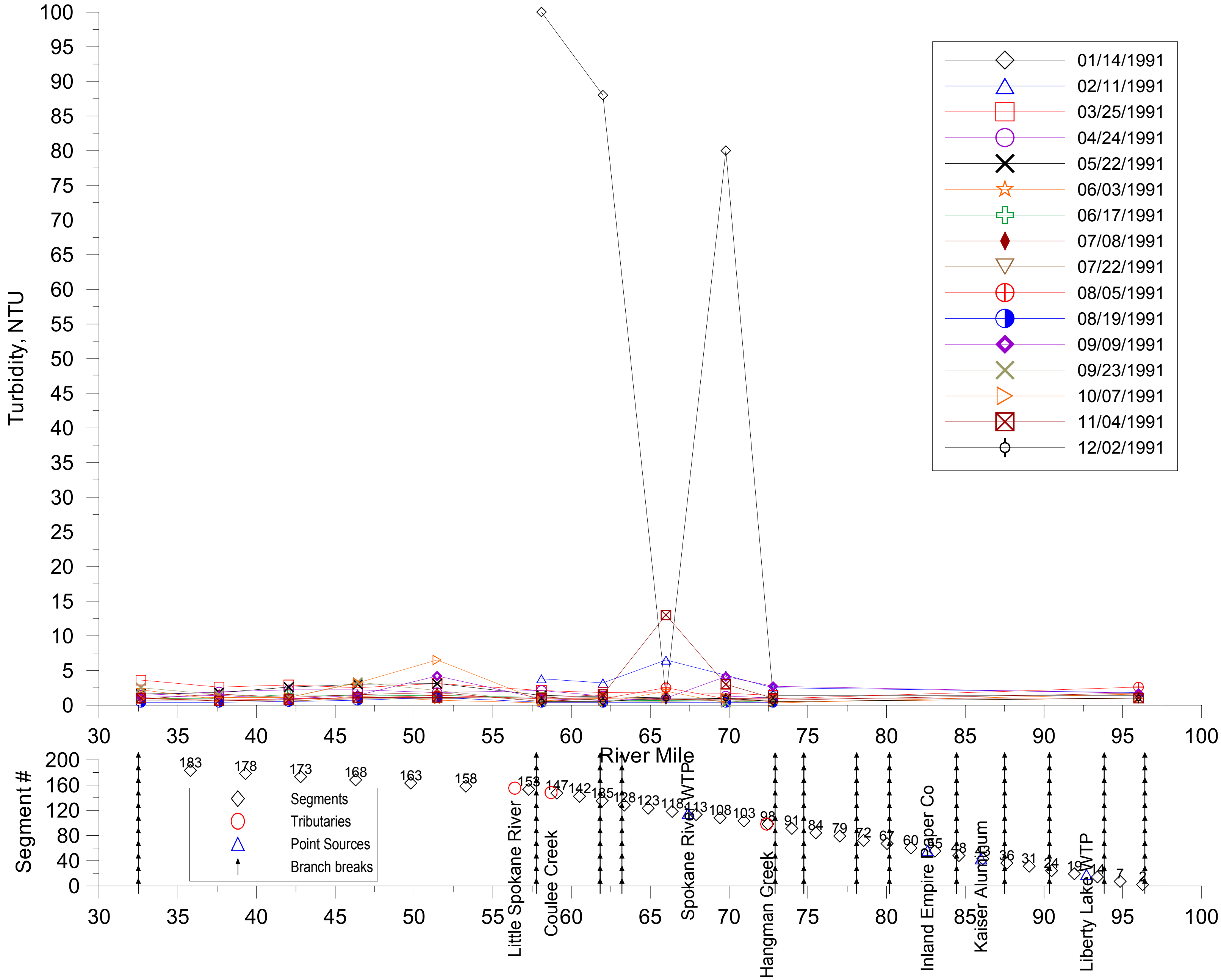
TP, mg/L
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



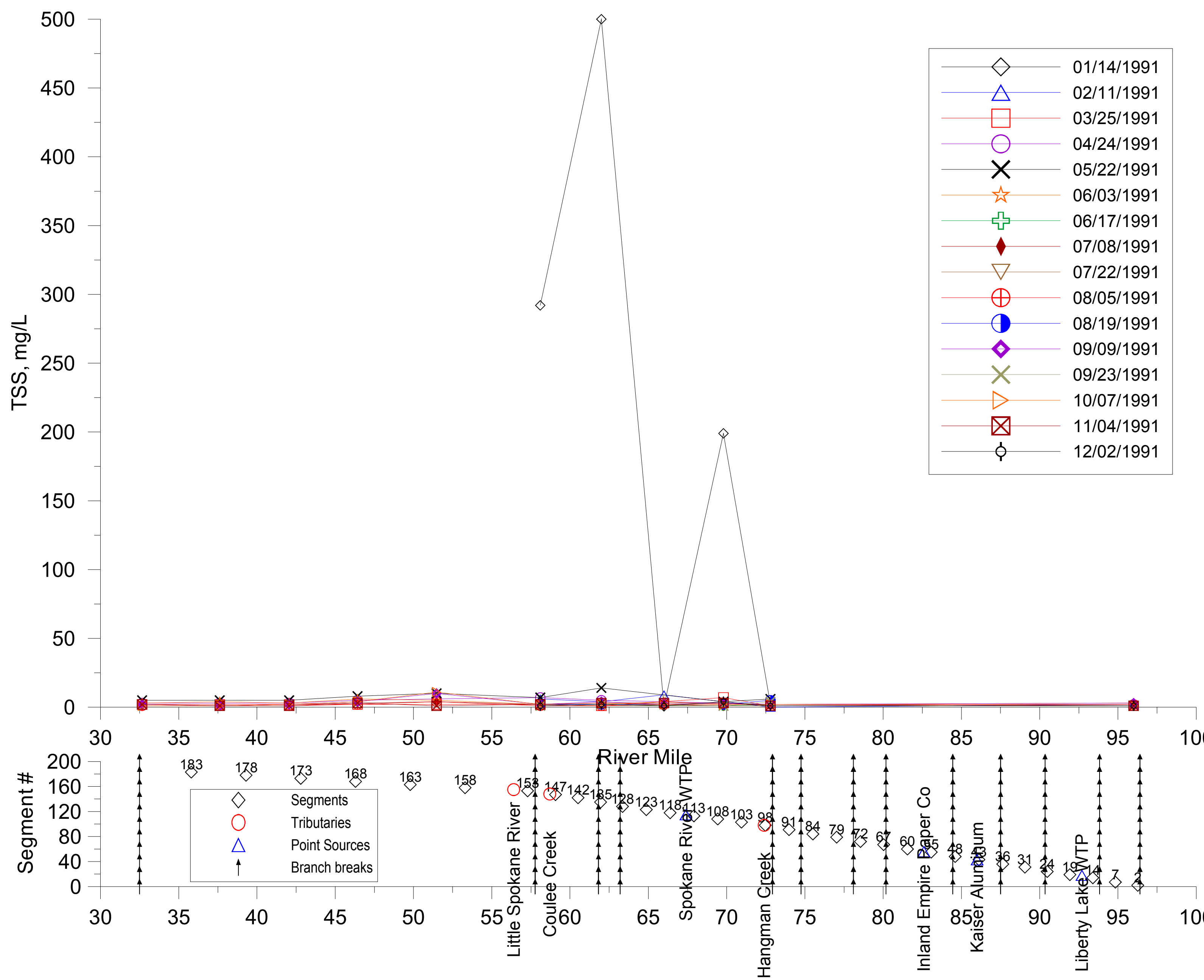
TOP, mg/L
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



TOP, mg/L
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
River Mile
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



Turbidity, NTU
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP


TSS, mg/L
River Mile
Segment #
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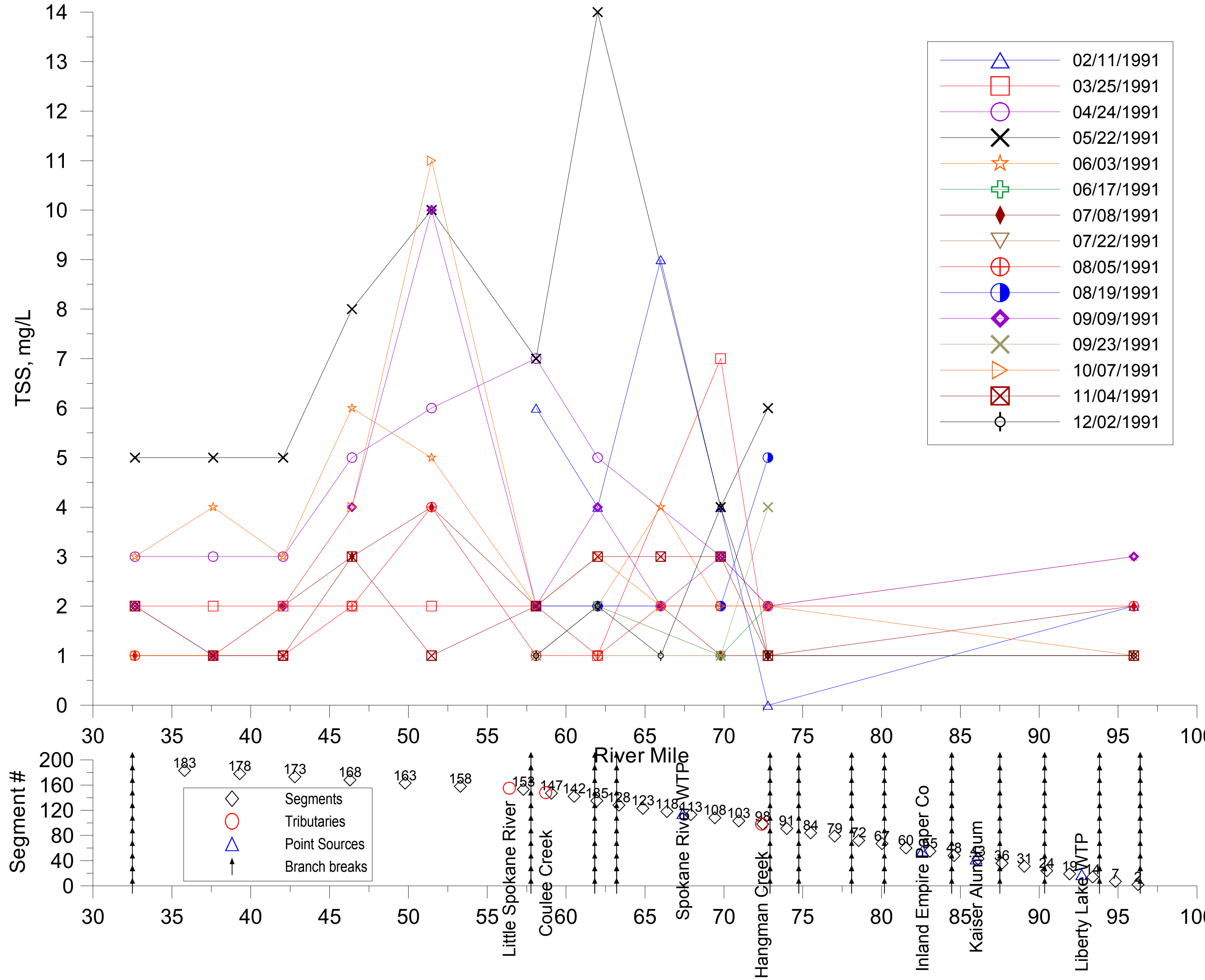
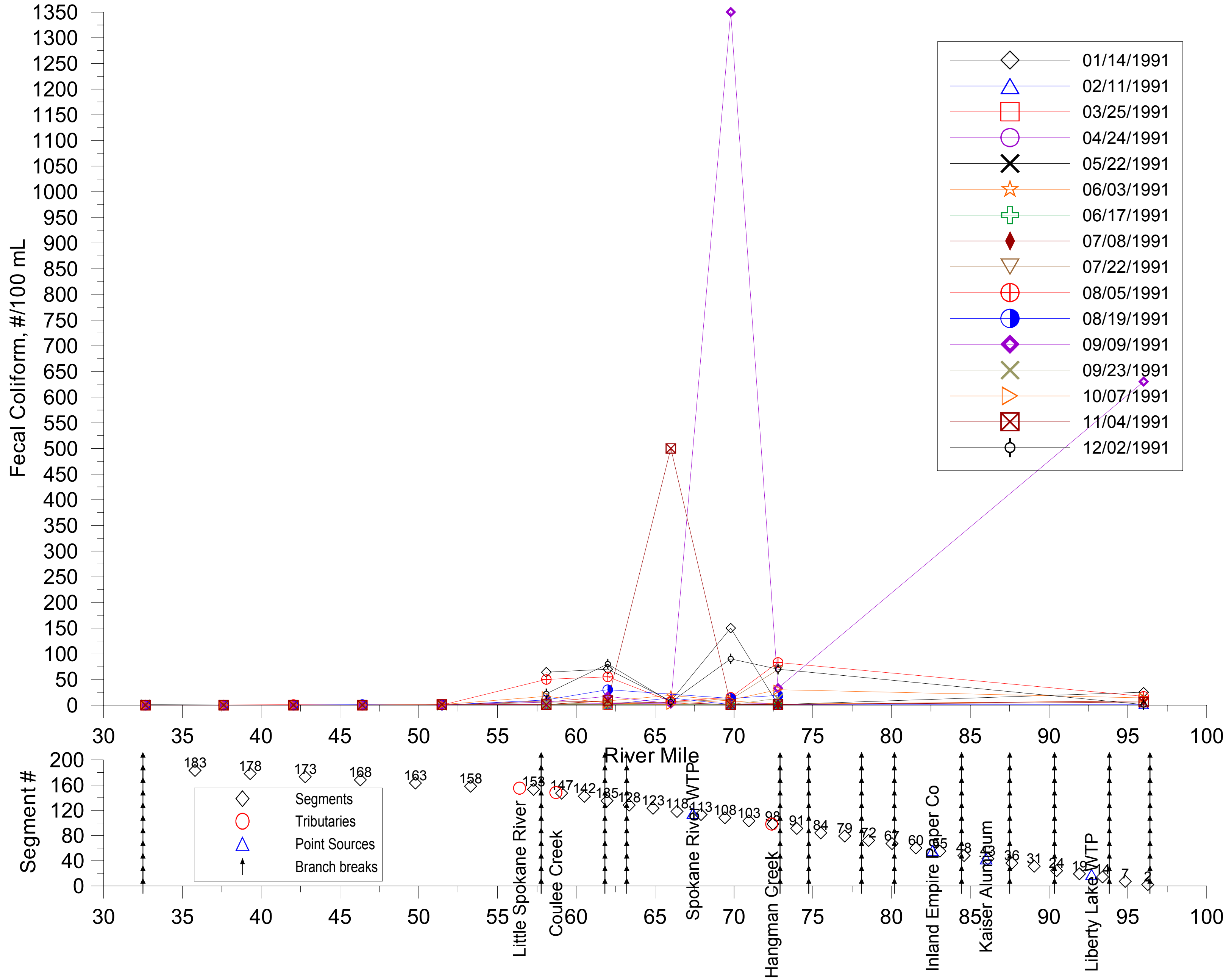
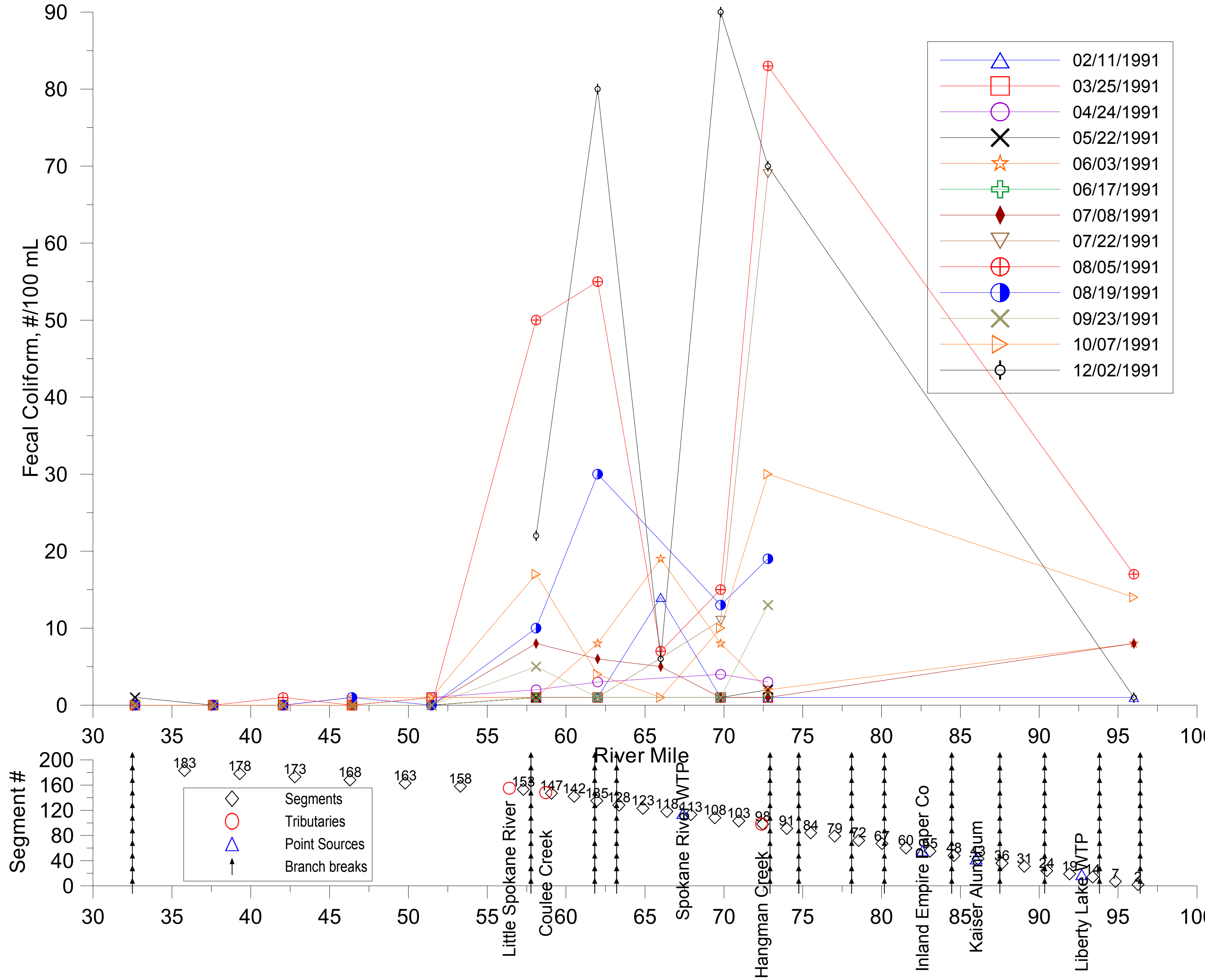
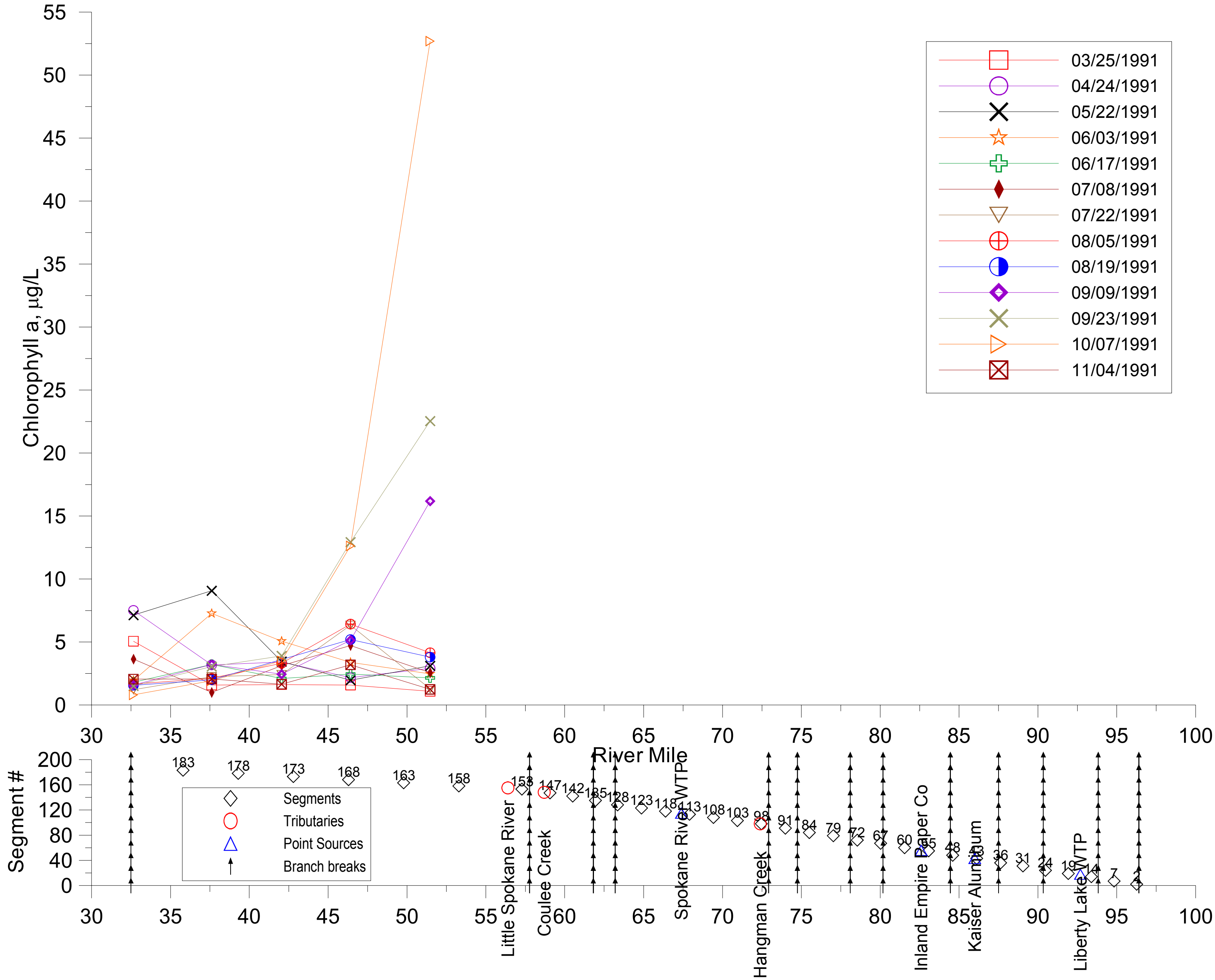
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

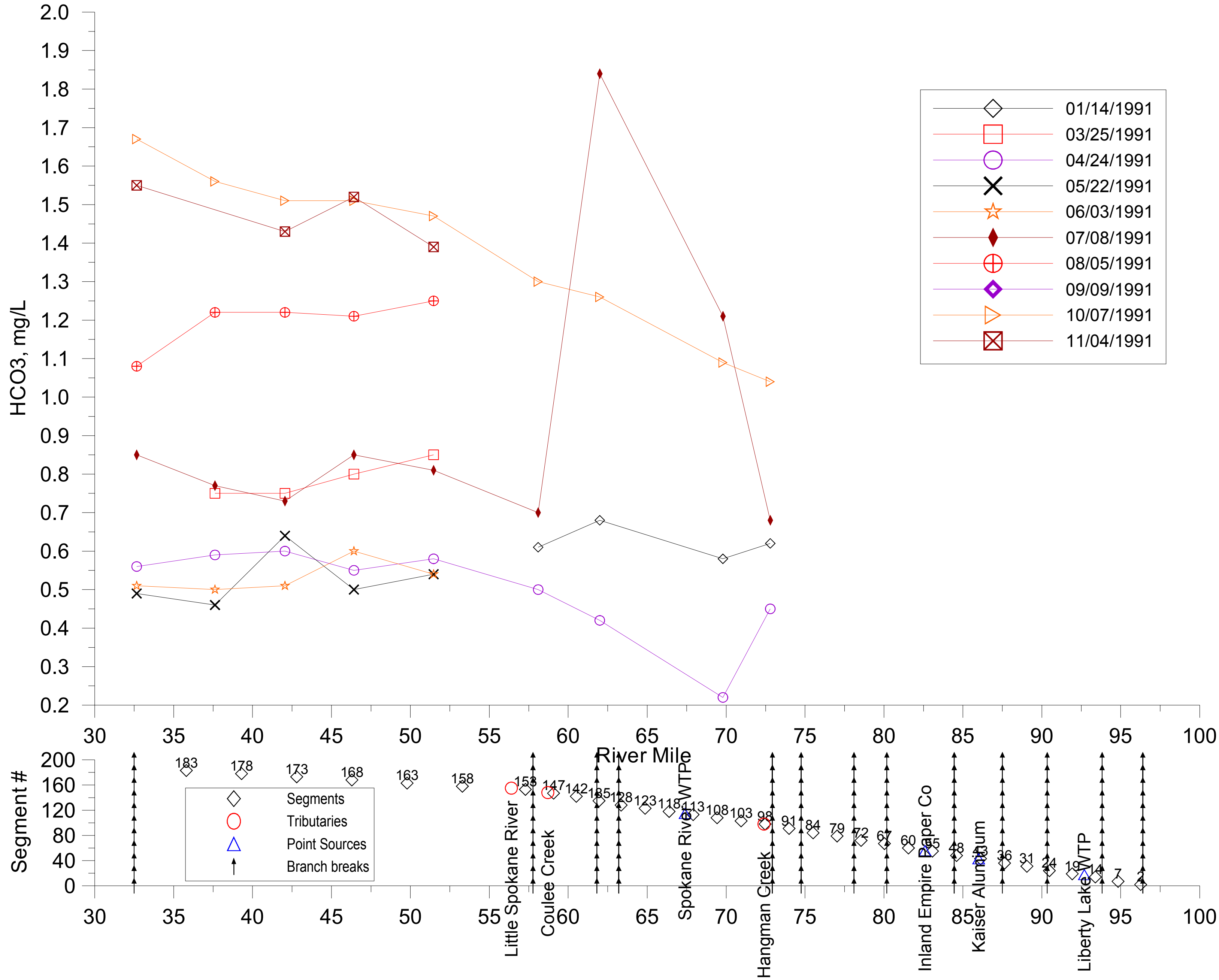

TSS, mg/L
River Mile
Segment #
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP


Fecal Coliform, #/100 mL
River Mile
Segment #
01/14/1991
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
12/02/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

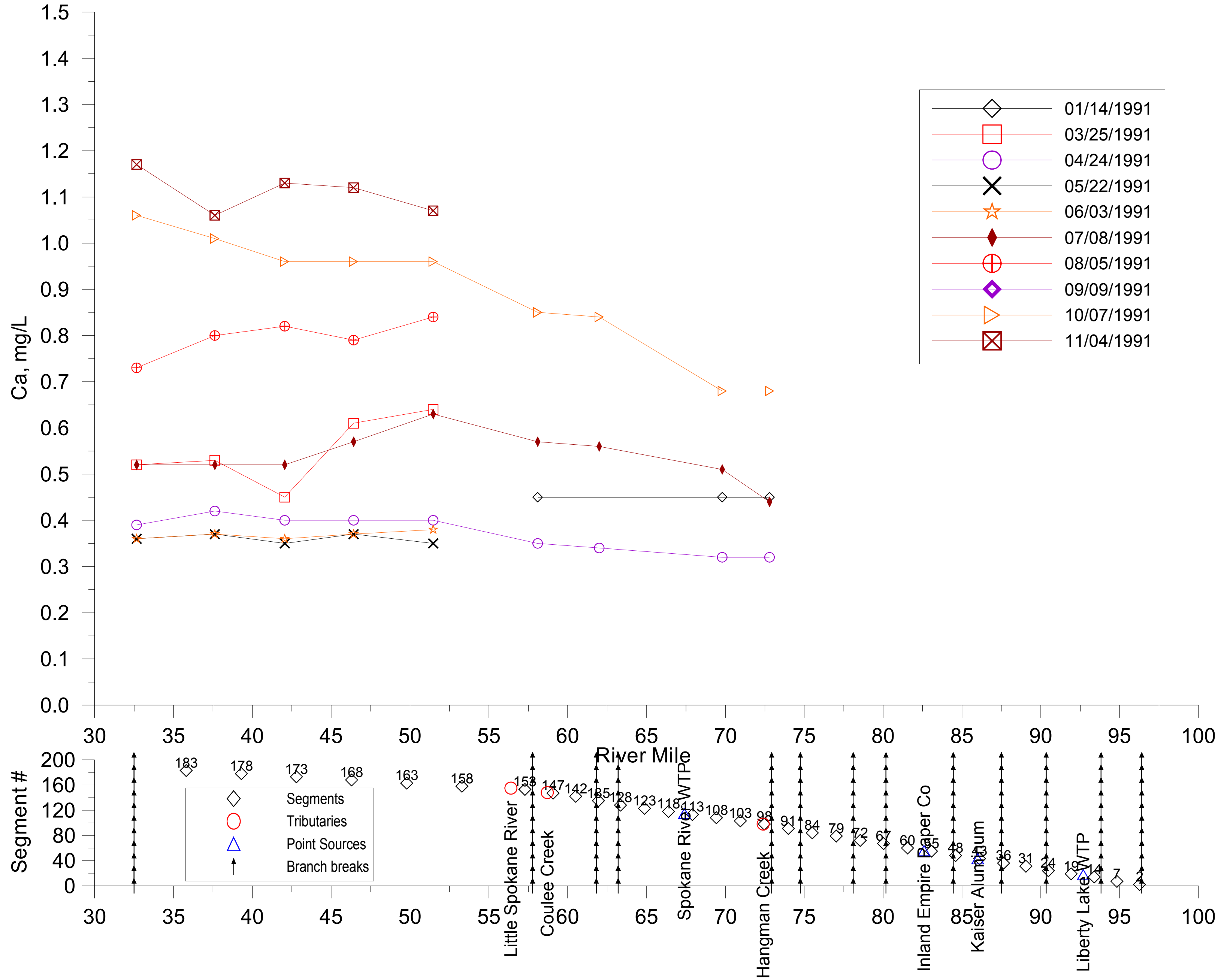


Fecal Coliform, #/100 mL
River Mile
02/11/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/23/1991
10/07/1991
12/02/1991
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

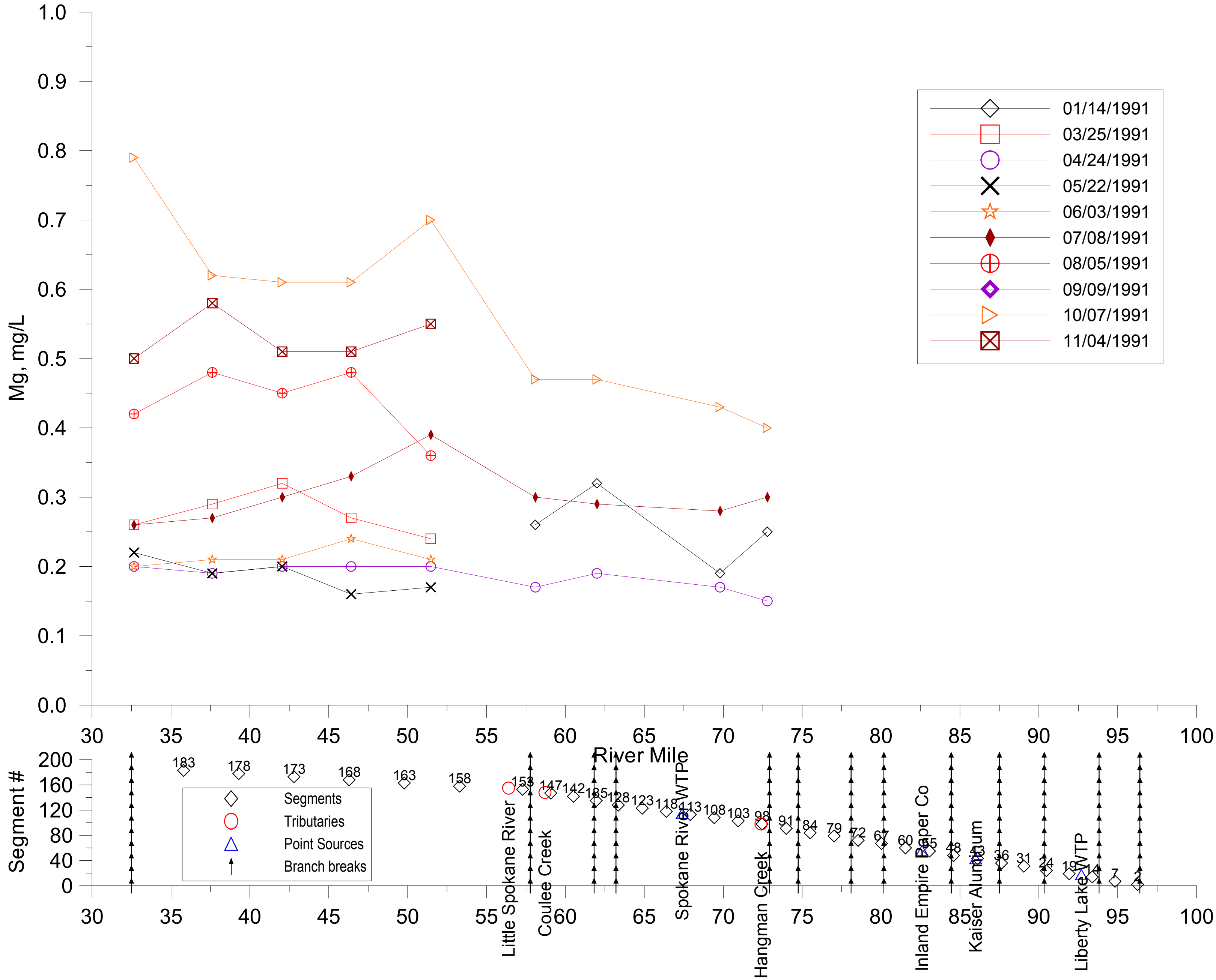

Chlorophyll a, µg/L
River Mile
Segment #
03/25/1991
04/24/1991
05/22/1991
06/03/1991
06/17/1991
07/08/1991
07/22/1991
08/05/1991
08/19/1991
09/09/1991
09/23/1991
10/07/1991
11/04/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



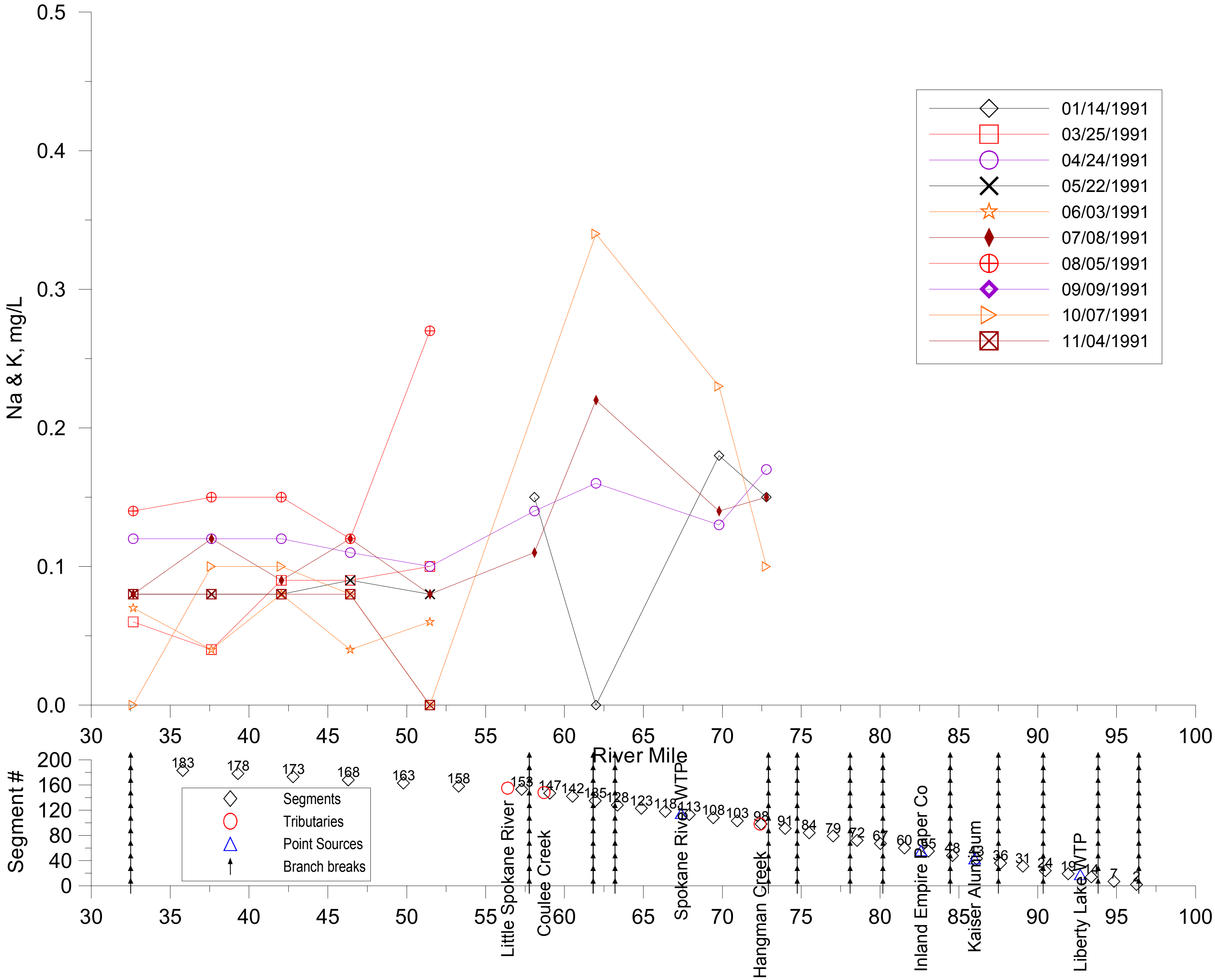
HCO3, mg/L
River Mile
Segment #
01/14/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
07/08/1991
08/05/1991
09/09/1991
10/07/1991
11/04/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



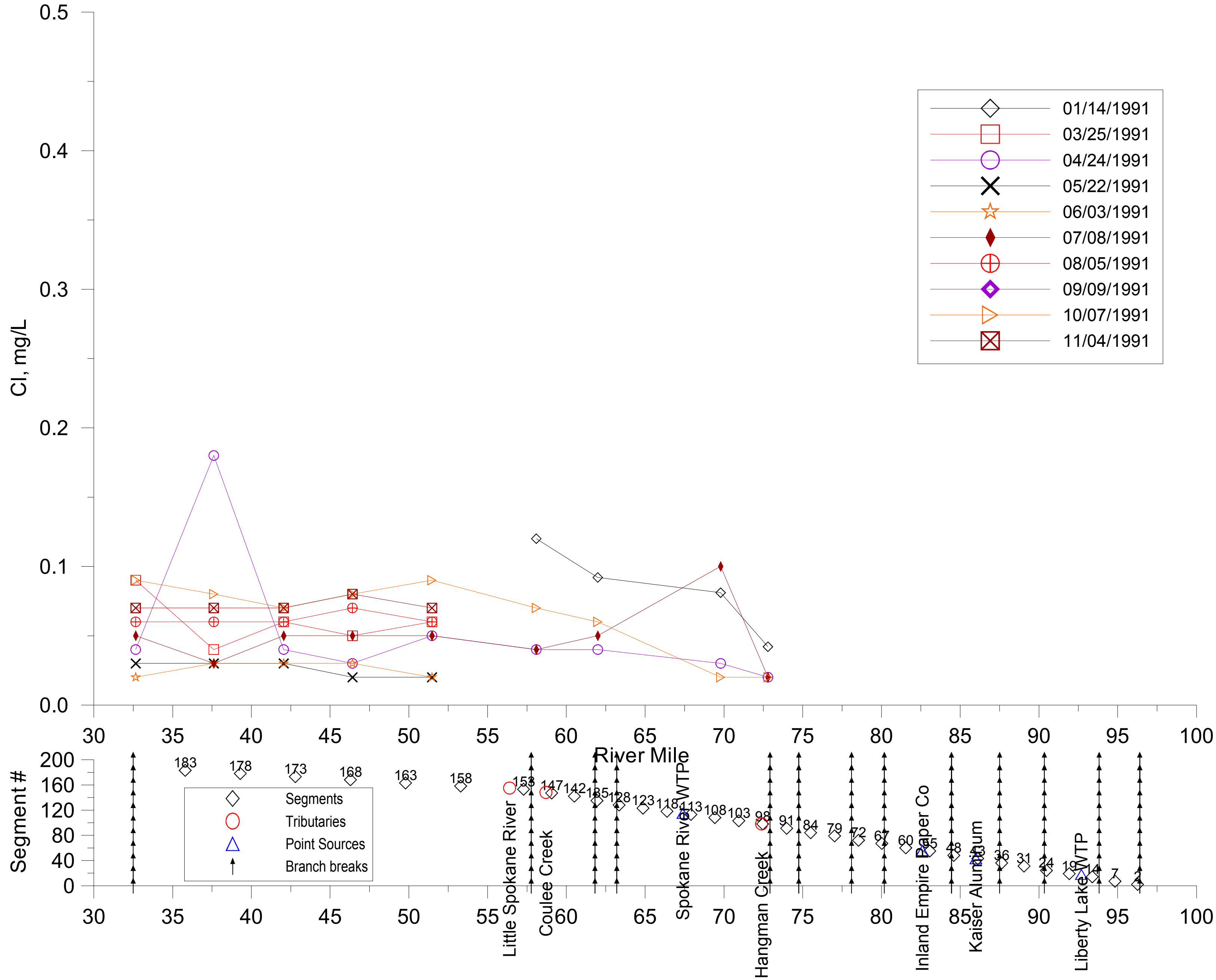
Ca, mg/L
River Mile
Segment #
01/14/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
07/08/1991
08/05/1991
09/09/1991
10/07/1991
11/04/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

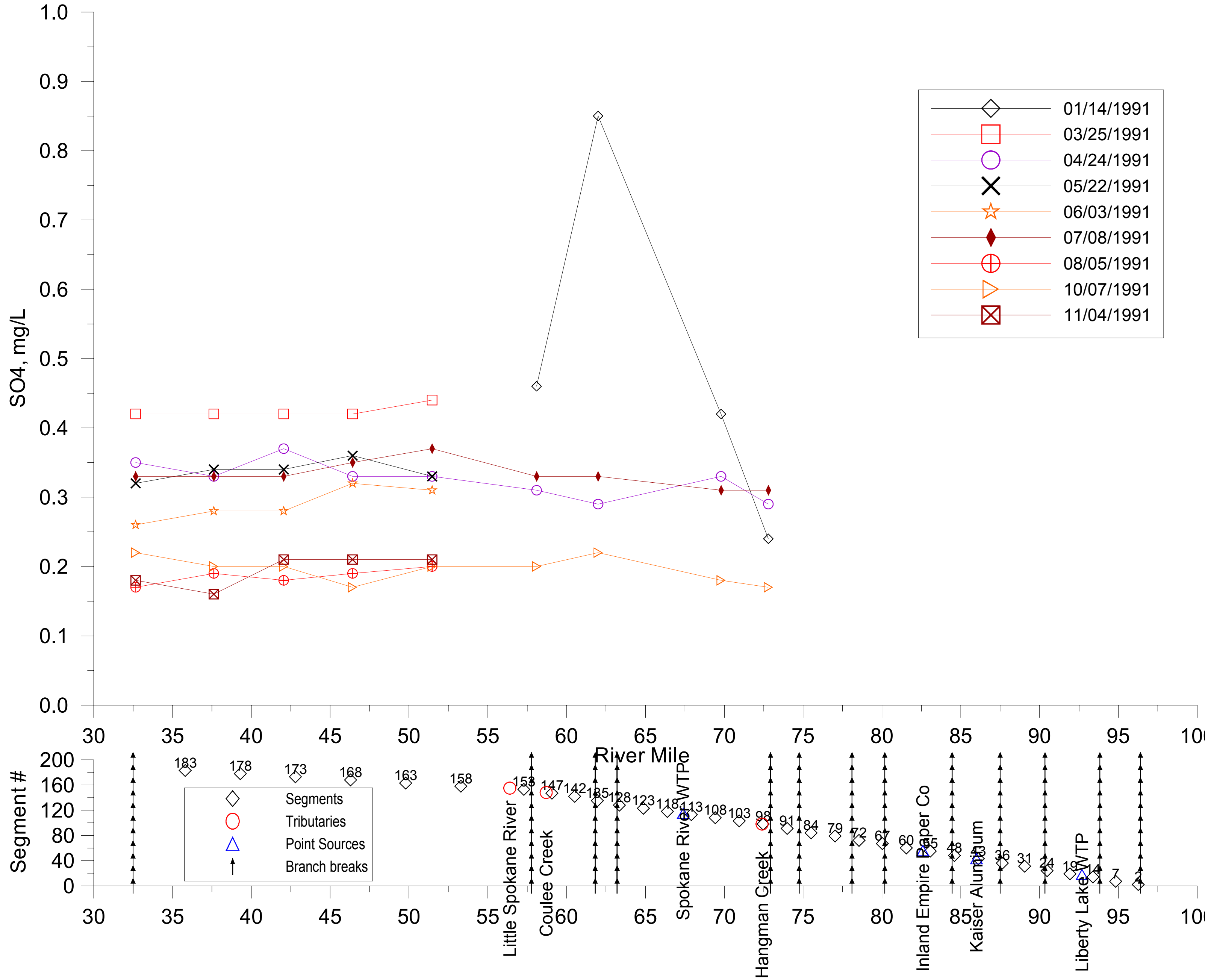


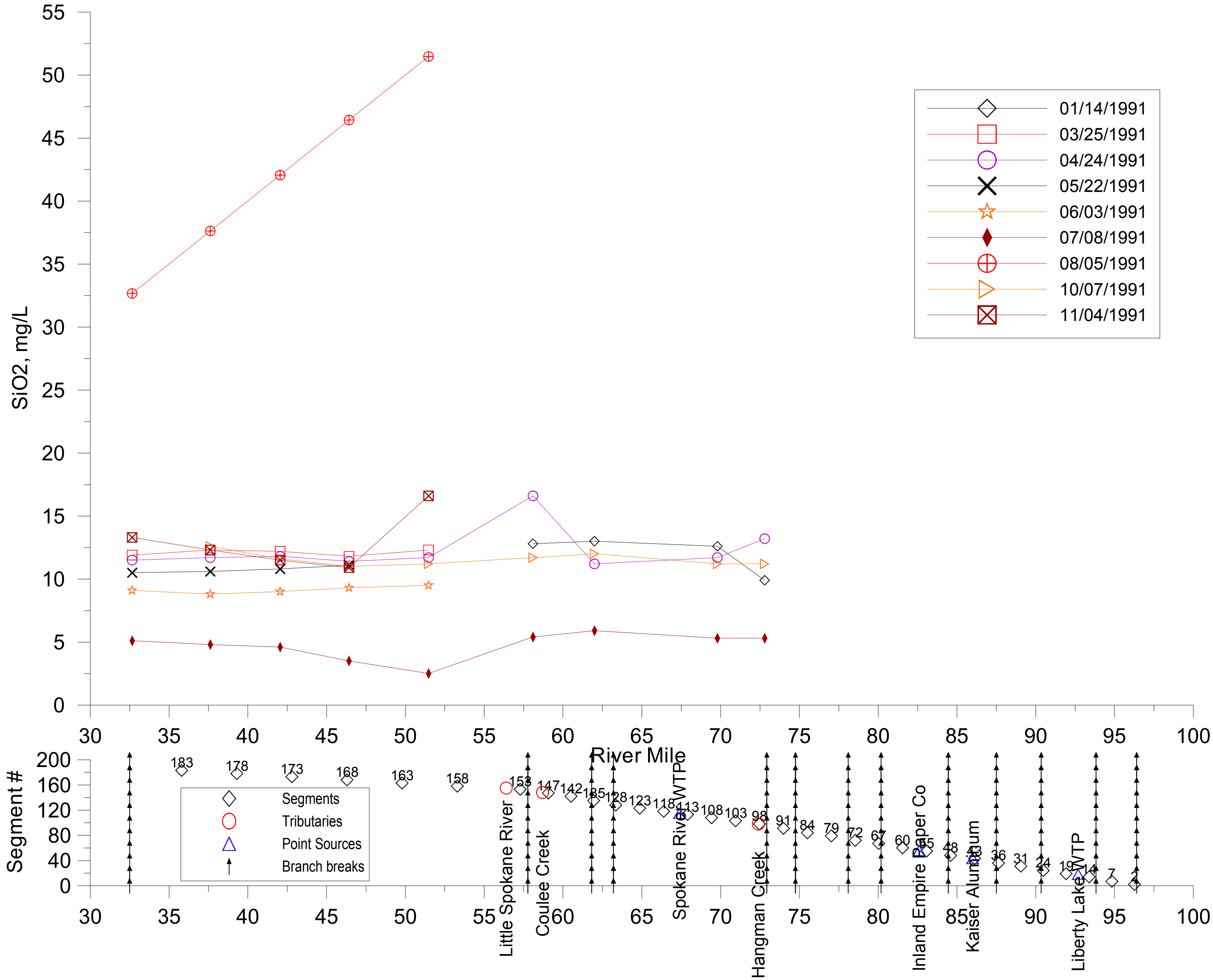
Mg, mg/L
River Mile
Segment #
01/14/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
07/08/1991
08/05/1991
09/09/1991
10/07/1991
11/04/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



0.5
0.4
0.3
0.2
0.1
0.0
Na & K, mg/L
01/14/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
07/08/1991
08/05/1991
09/09/1991
10/07/1991
11/04/1991
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
River Mile
Segment #
200
160
120
80
40
0
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

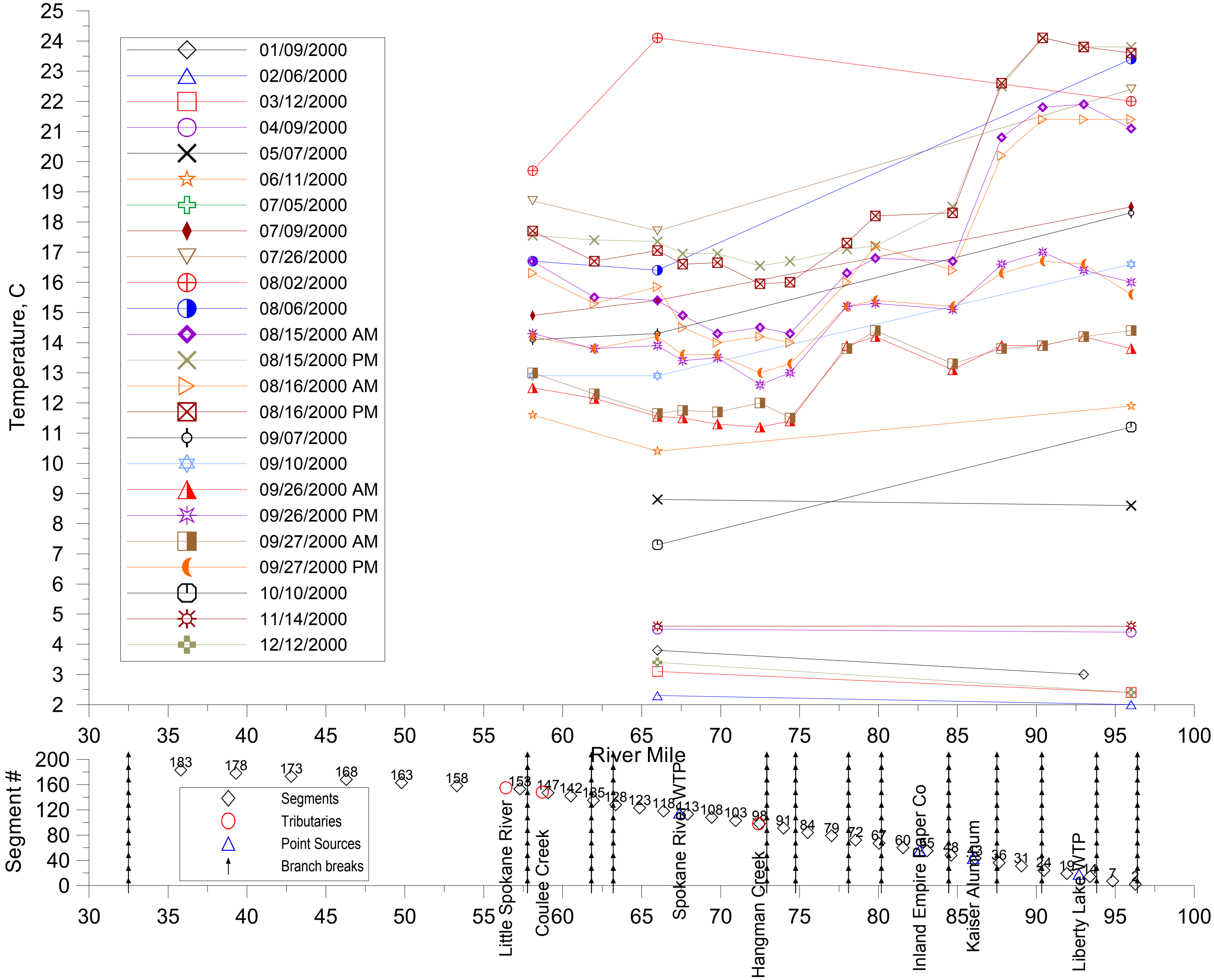

Cl, mg/L
River Mile
01/14/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
07/08/1991
08/05/1991
09/09/1991
10/07/1991
11/04/1991
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

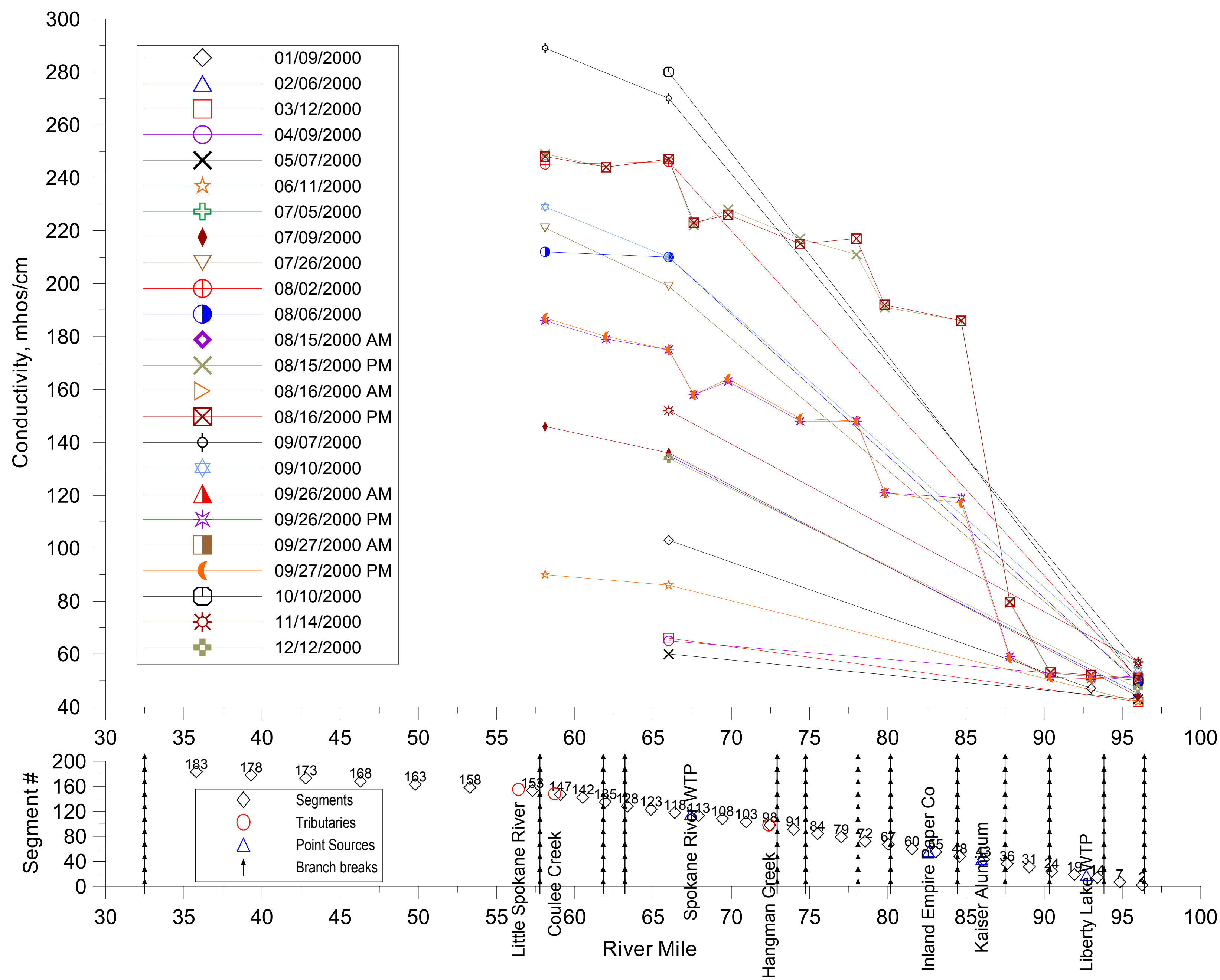

SO4, mg/L
River Mile
Segment #
01/14/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
07/08/1991
08/05/1991
10/07/1991
11/04/1991
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

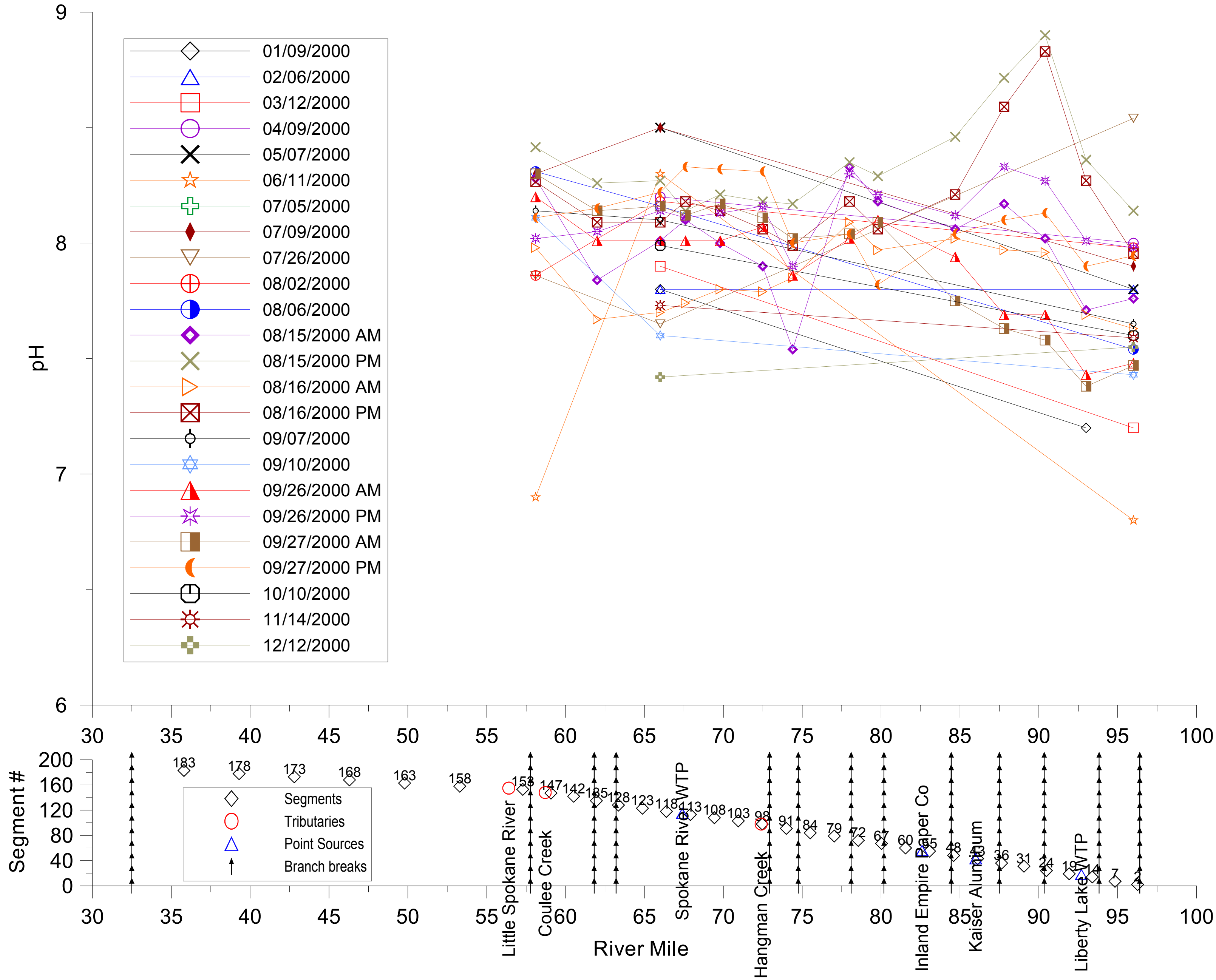


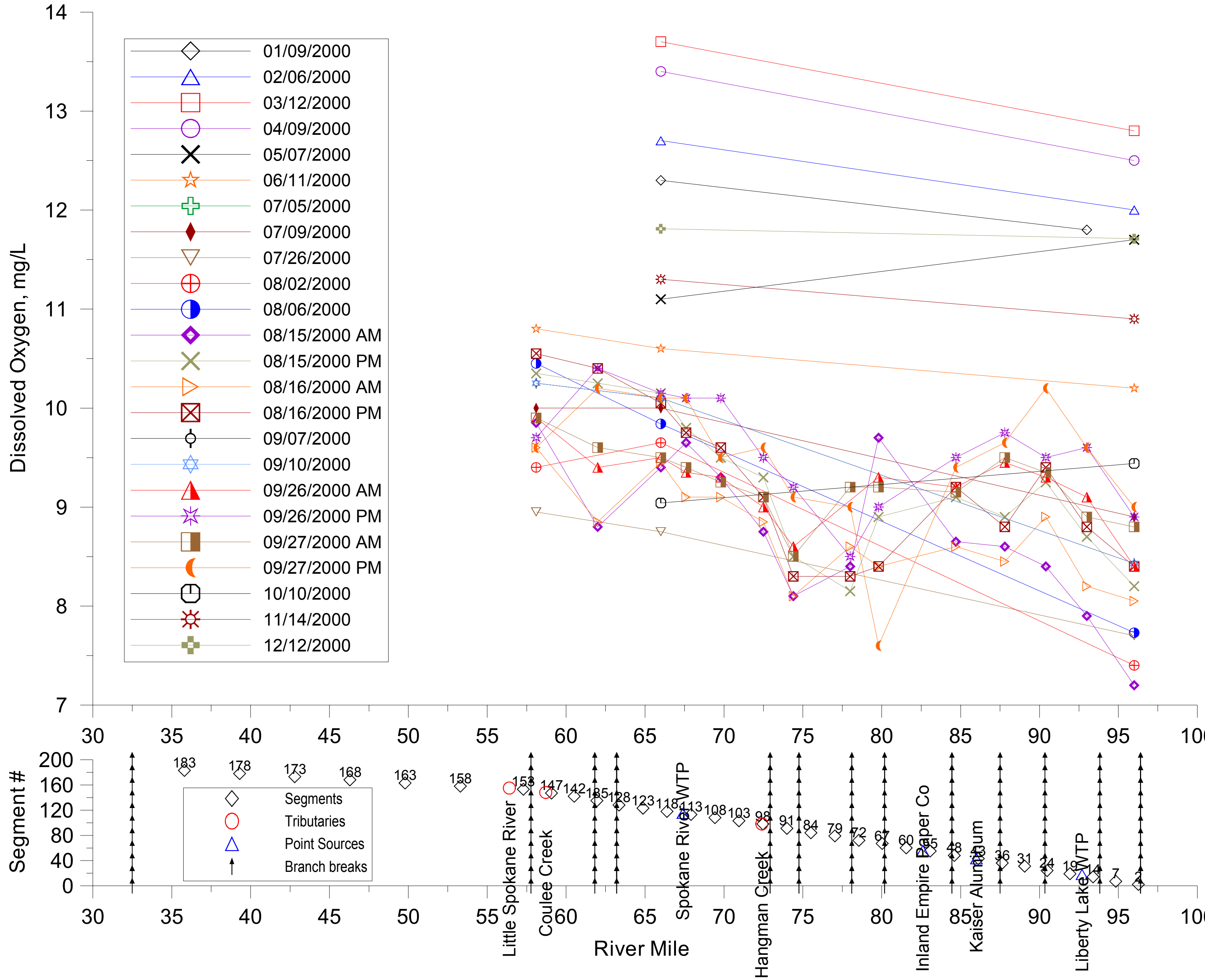
SiO2, mg/L
River Mile
01/14/1991
03/25/1991
04/24/1991
05/22/1991
06/03/1991
07/08/1991
08/05/1991
10/07/1991
11/04/1991
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

Appendix B: 2000 Longitudinal Profiles

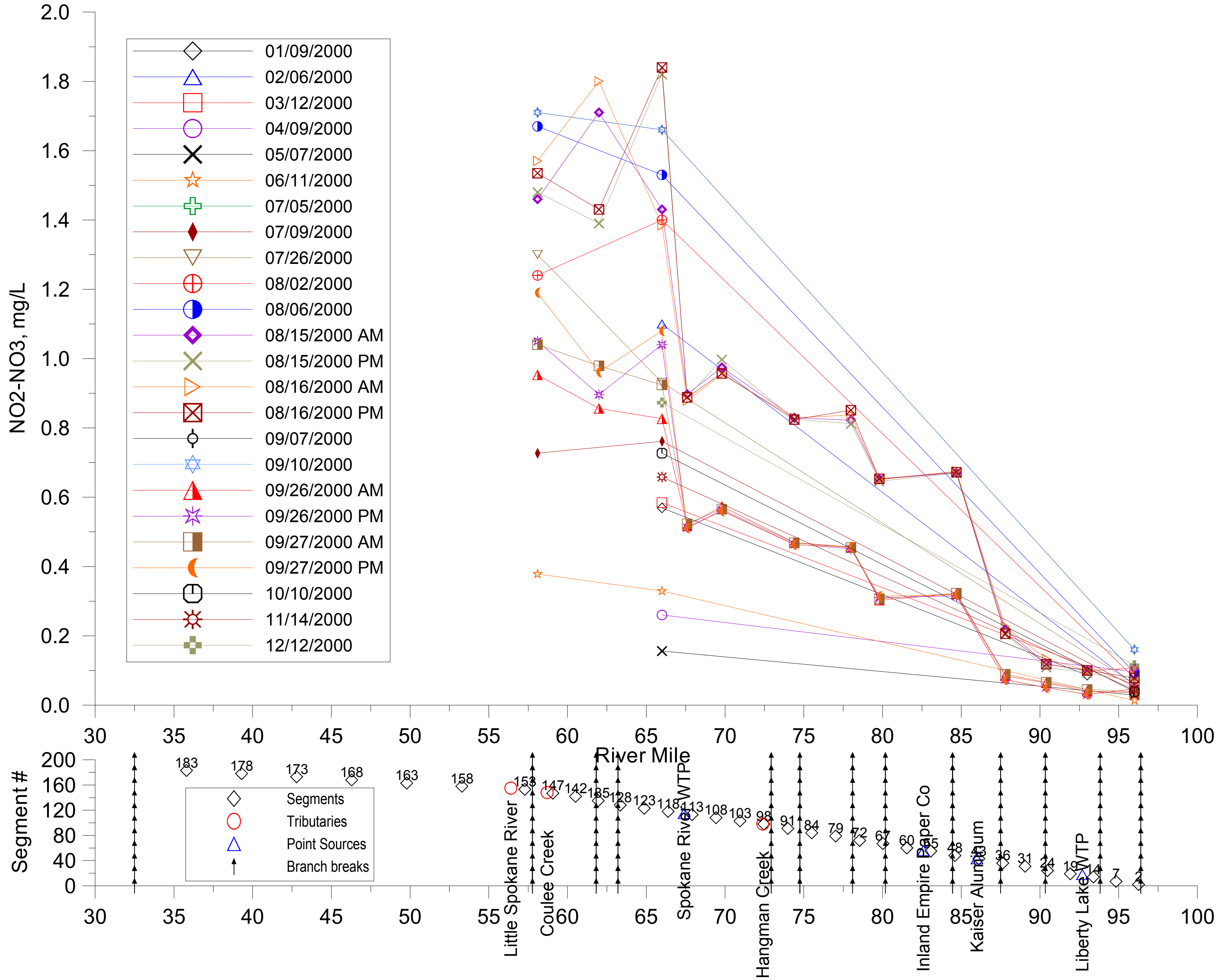


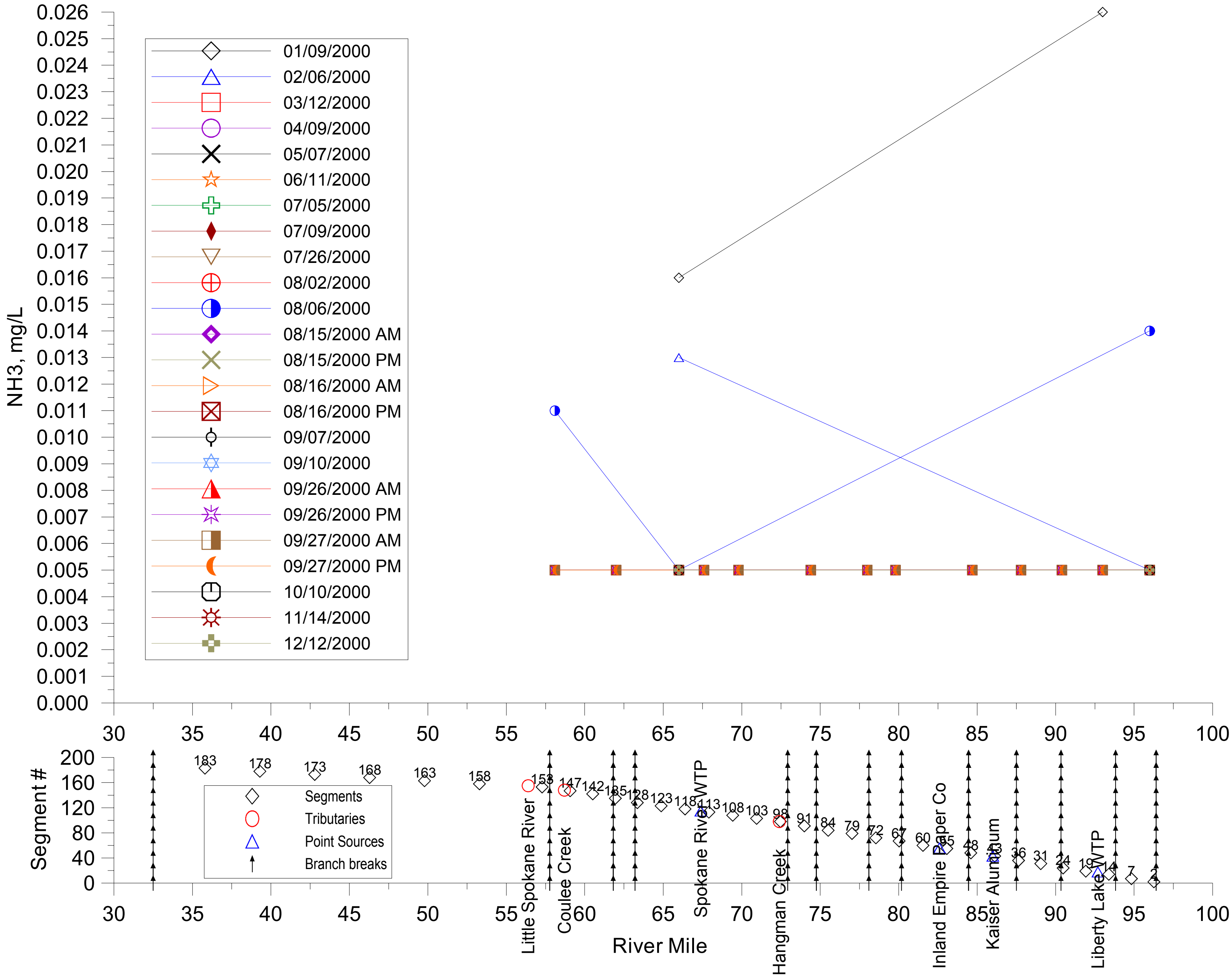

Conductivity, mhos/cm
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile


pH
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile

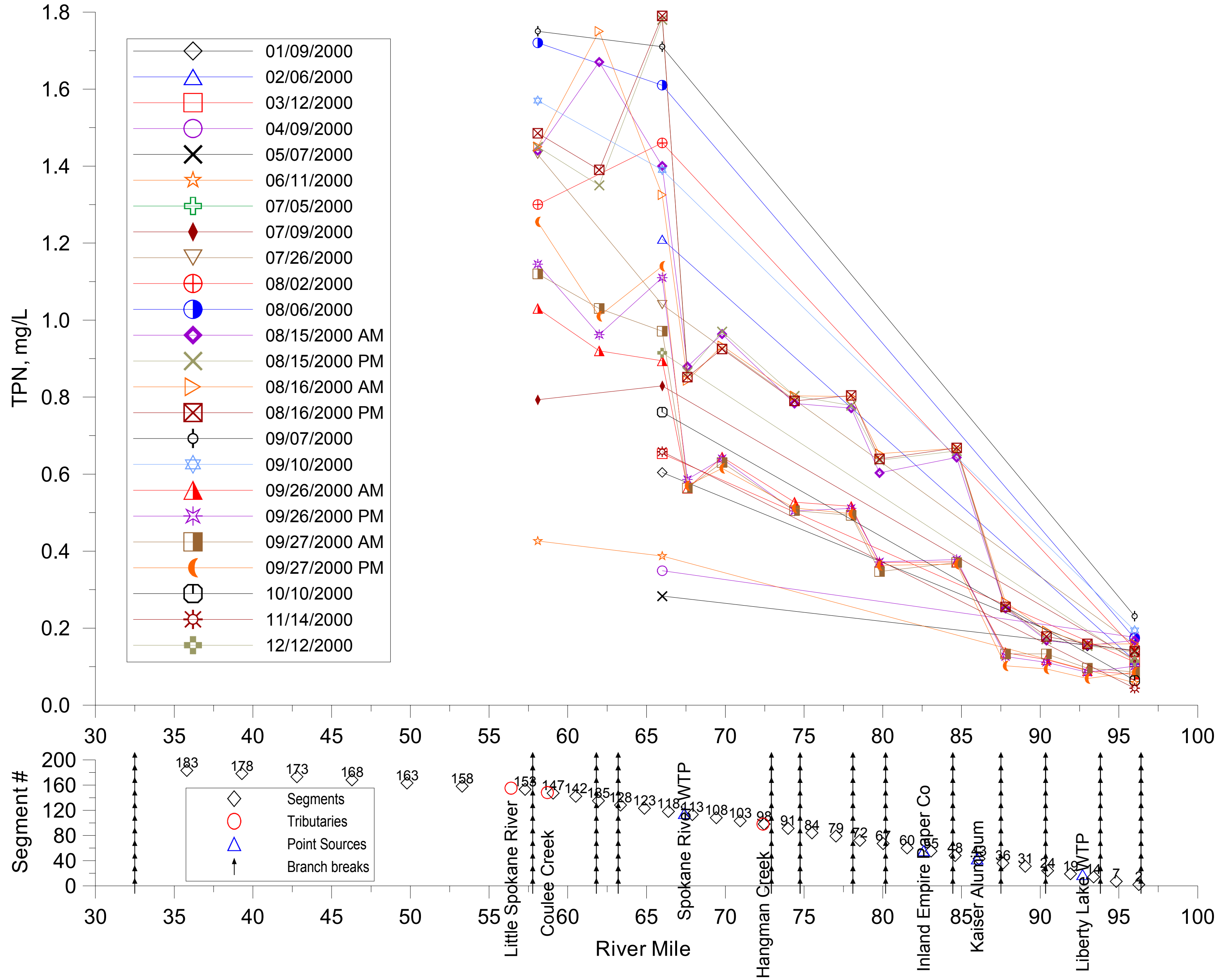


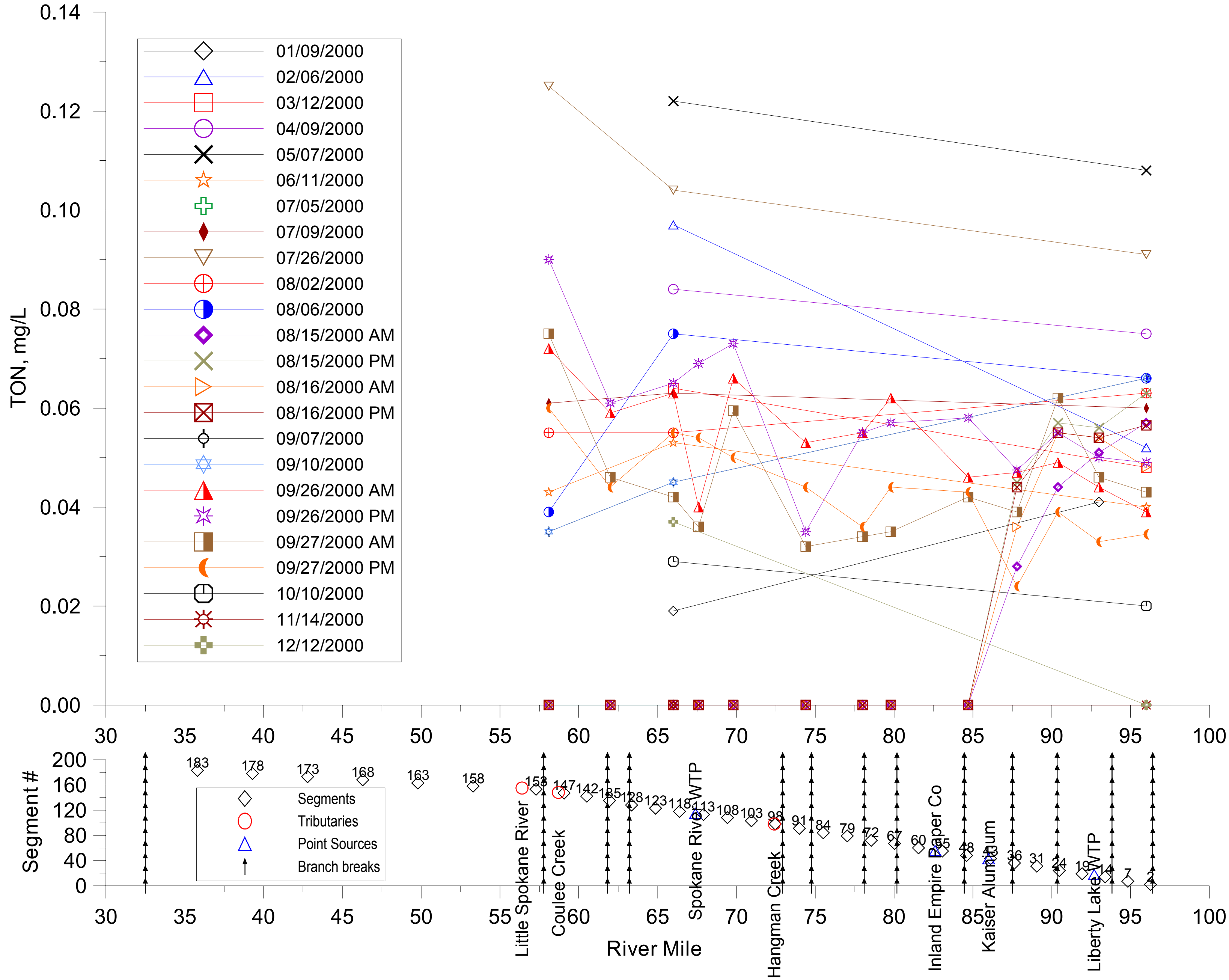
Dissolved Oxygen, mg/L
14
13
12
11
10
9
8
7
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Segment #
200
160
120
80
40
0
183 178 173 168 163 158 153 147 142 135 128 123 118 113 108 103 98 91 84 79 72 67 60 55 48 43 36 31 24 19 14 7 2
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile


NO2-NO3, mg/L
River Mile
Segment #
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

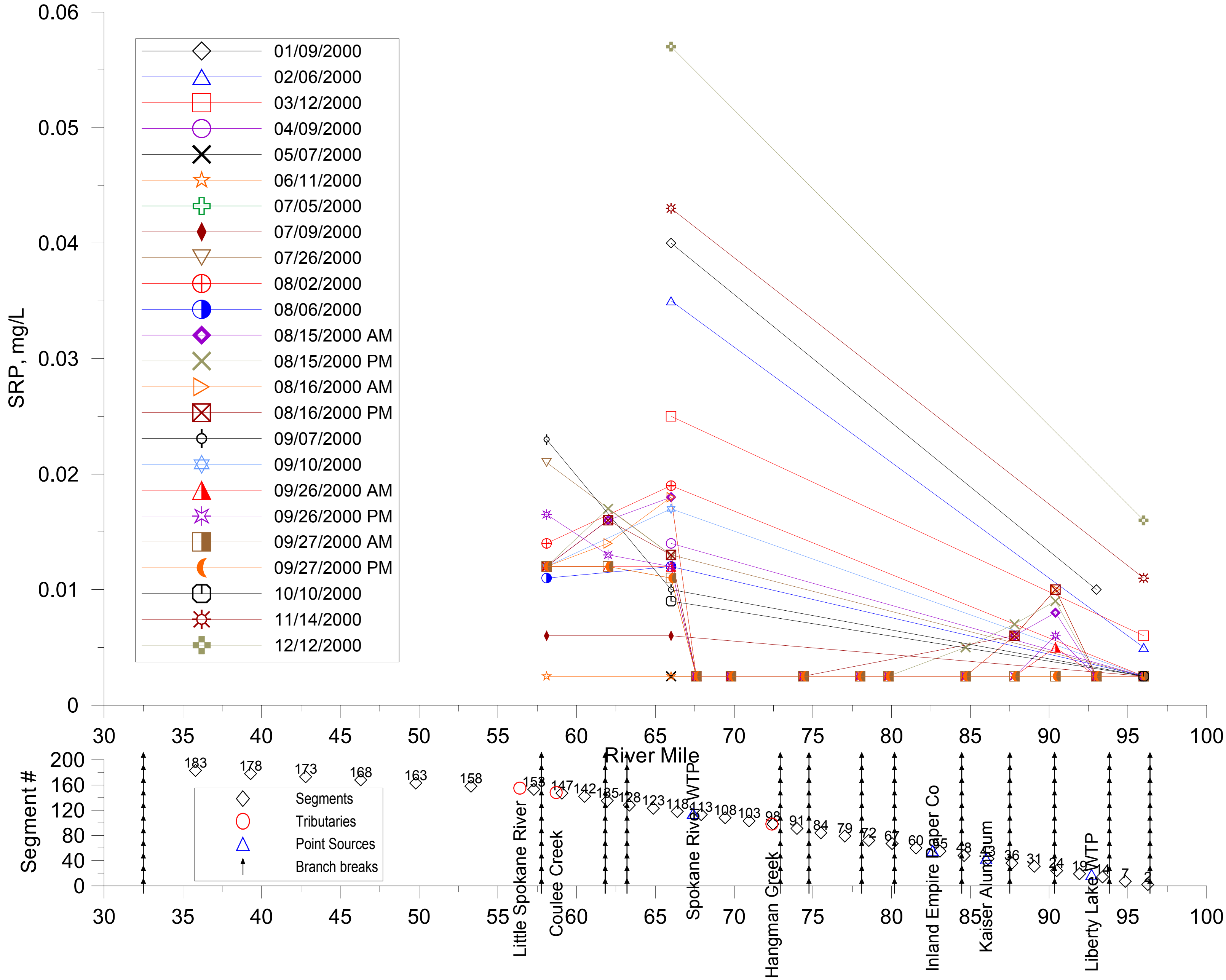


NH3, mg/L
0.026
0.025
0.024
0.023
0.022
0.021
0.020
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile

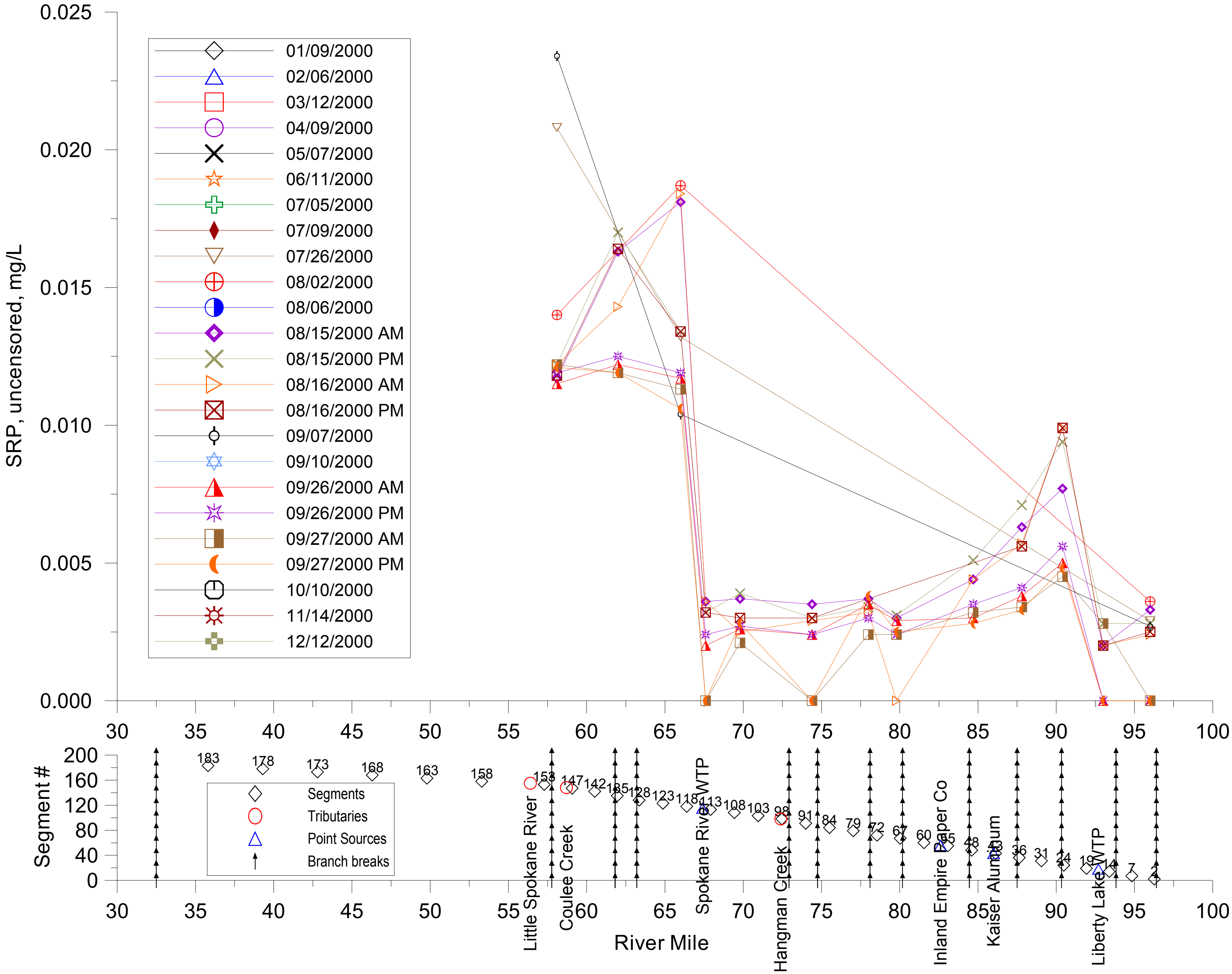

TPN, mg/L
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



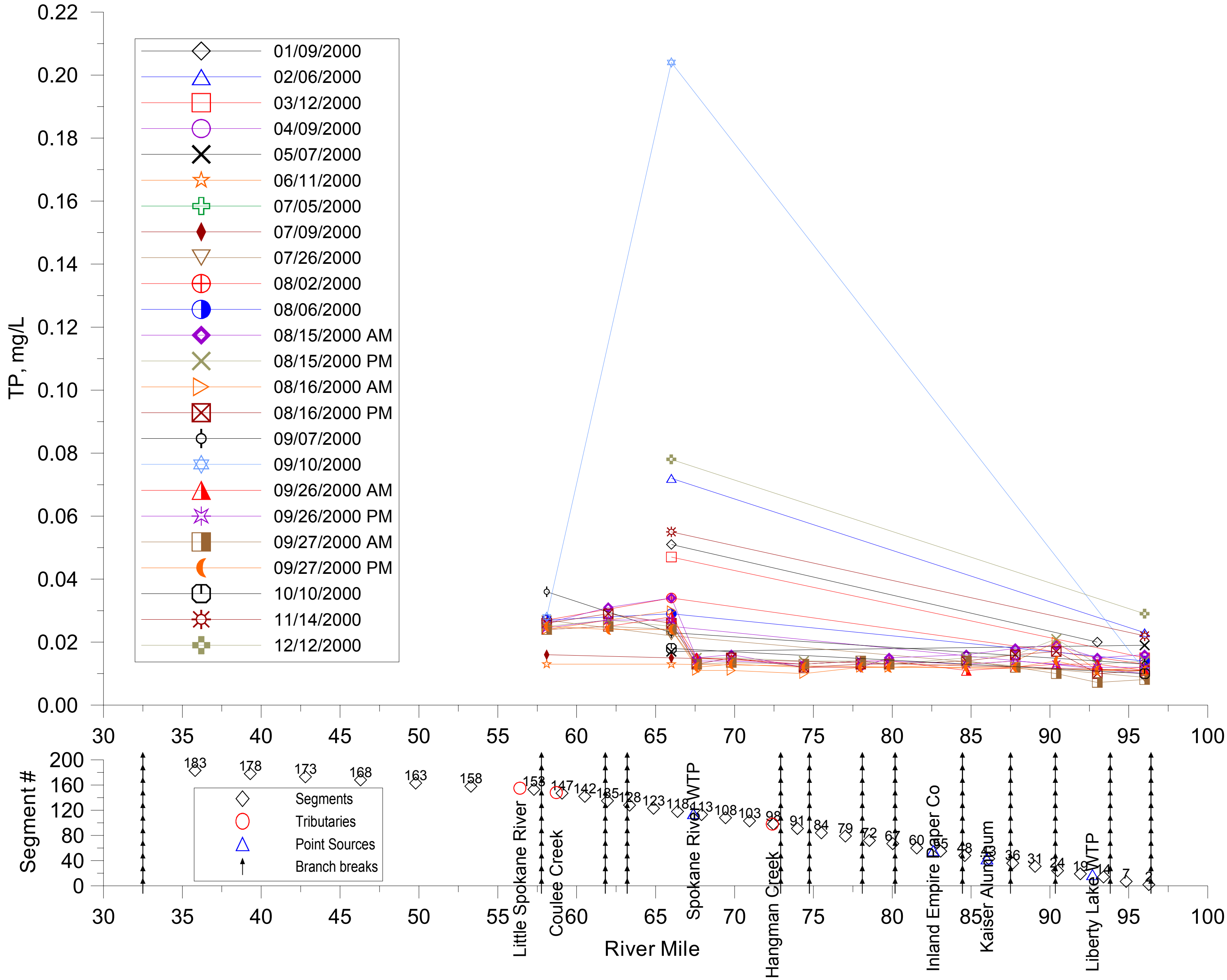
TON, mg/L
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Segment #
200
160
120
80
40
0
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



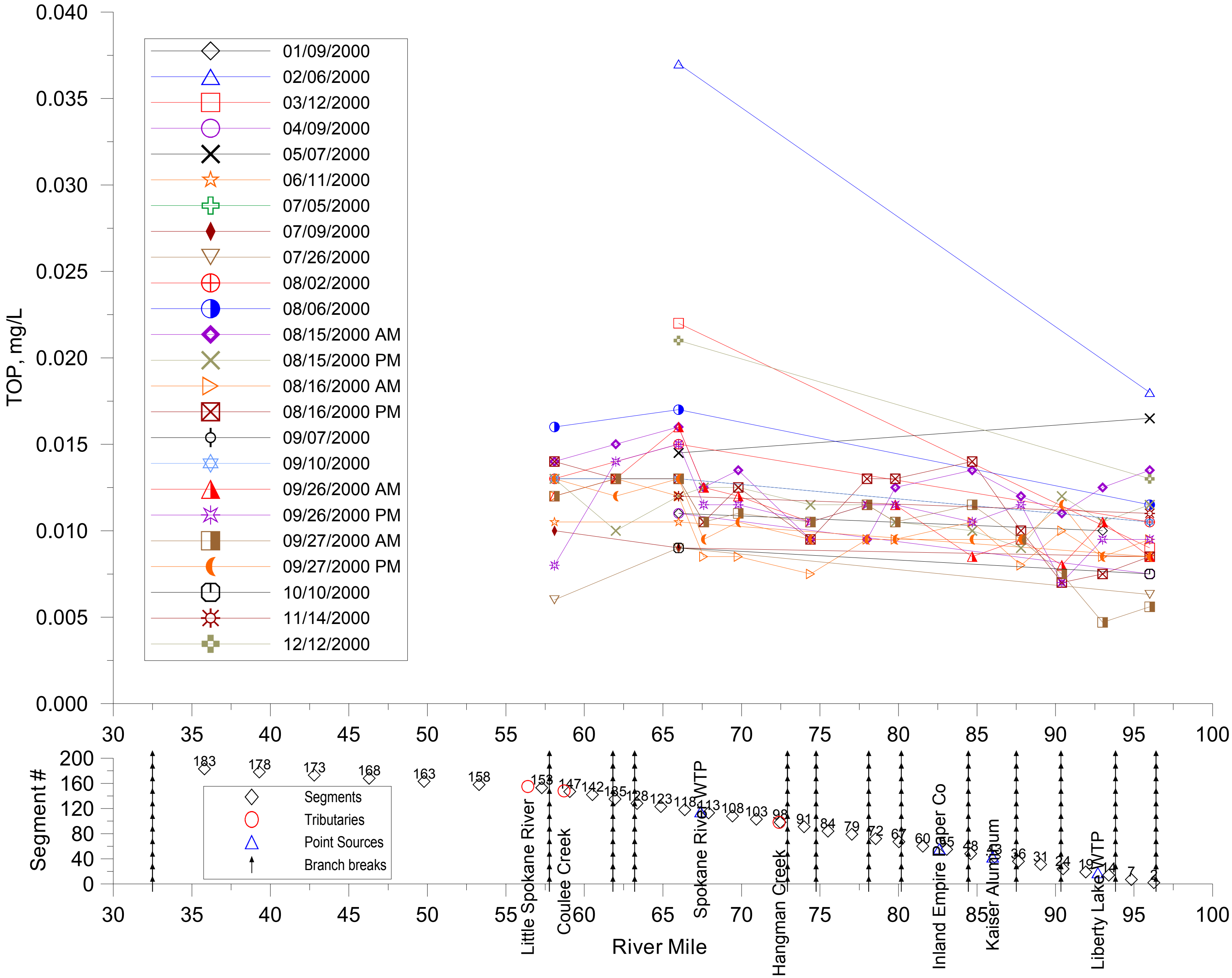
SRP, mg/L
River Mile
Segment #
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



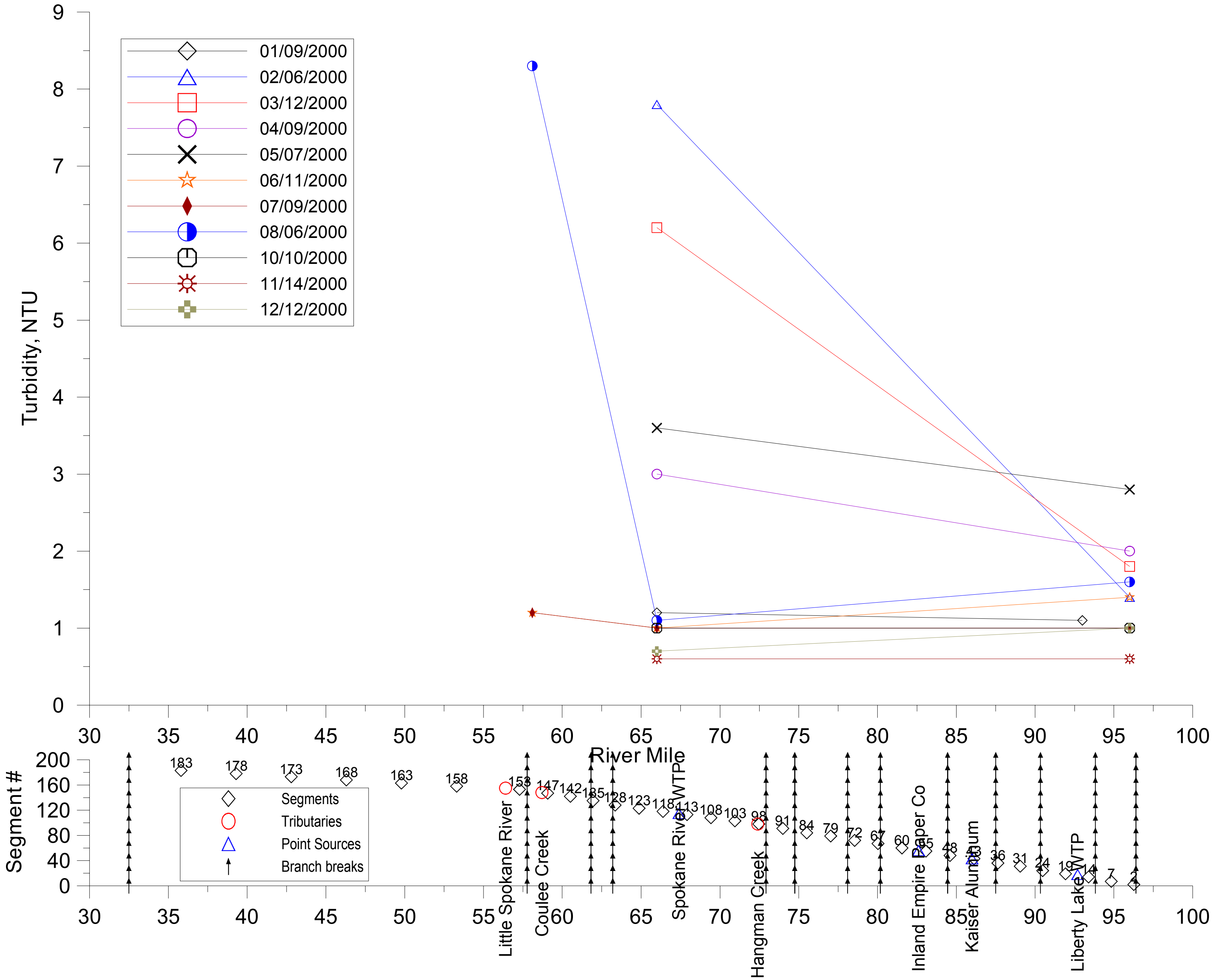
SRP, uncensored, mg/L
0.025
0.020
0.015
0.010
0.005
0.000
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



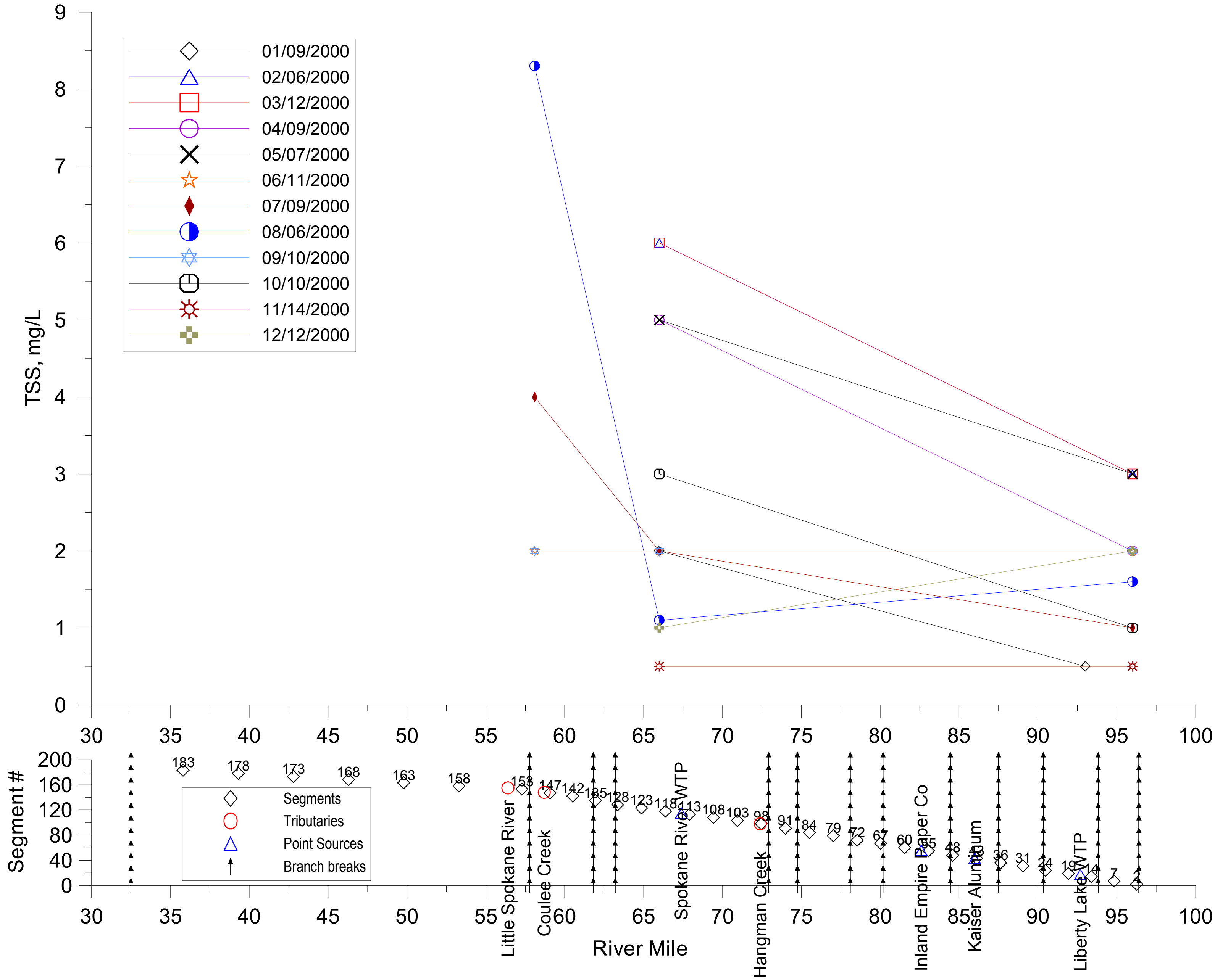
TP, mg/L
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Segment #
0
40
80
120
160
200
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



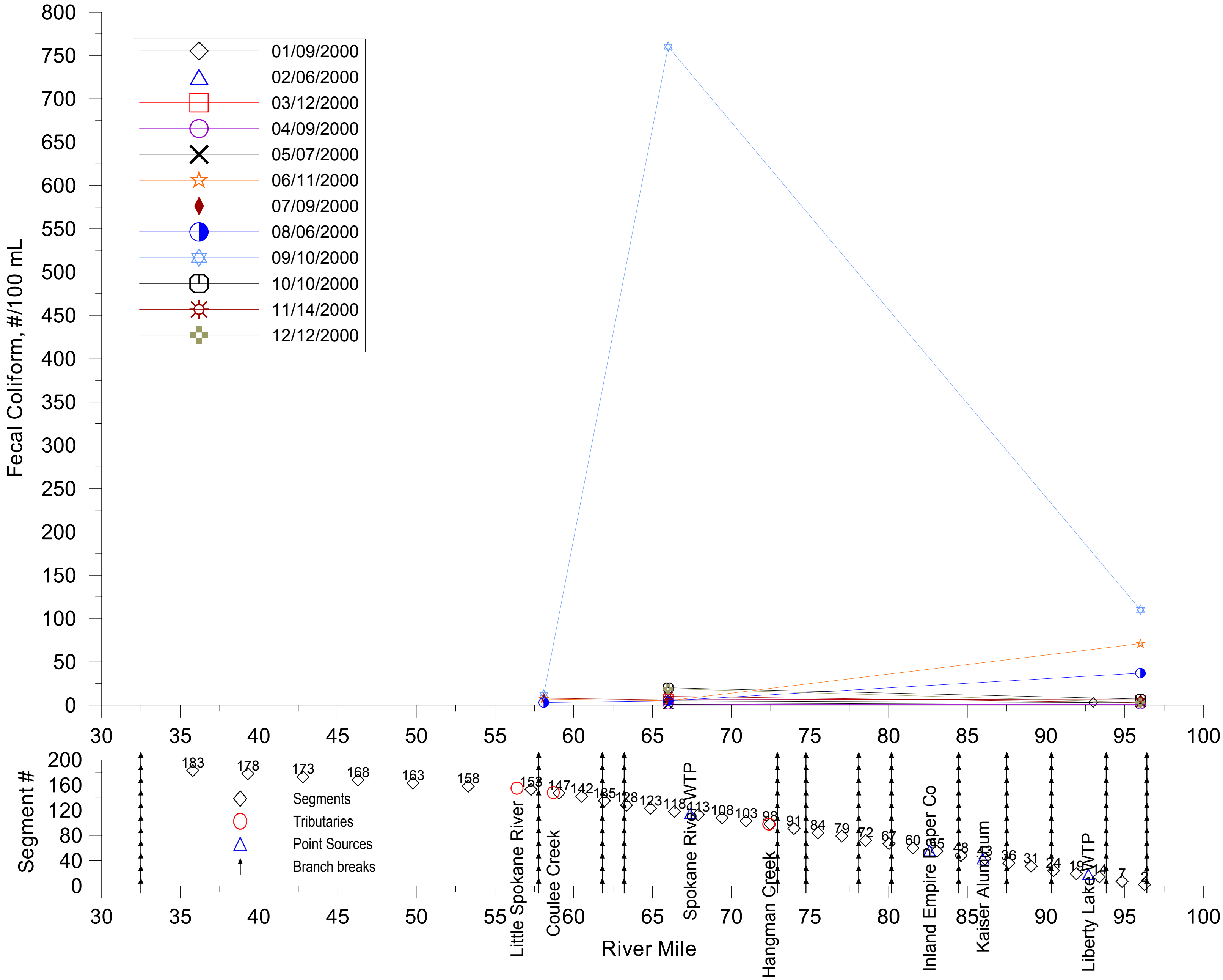
TOP, mg/L
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000 AM
08/15/2000 PM
08/16/2000 AM
08/16/2000 PM
09/07/2000
09/10/2000
09/26/2000 AM
09/26/2000 PM
09/27/2000 AM
09/27/2000 PM
10/10/2000
11/14/2000
12/12/2000
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Segment #
200
160
120
80
40
0
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



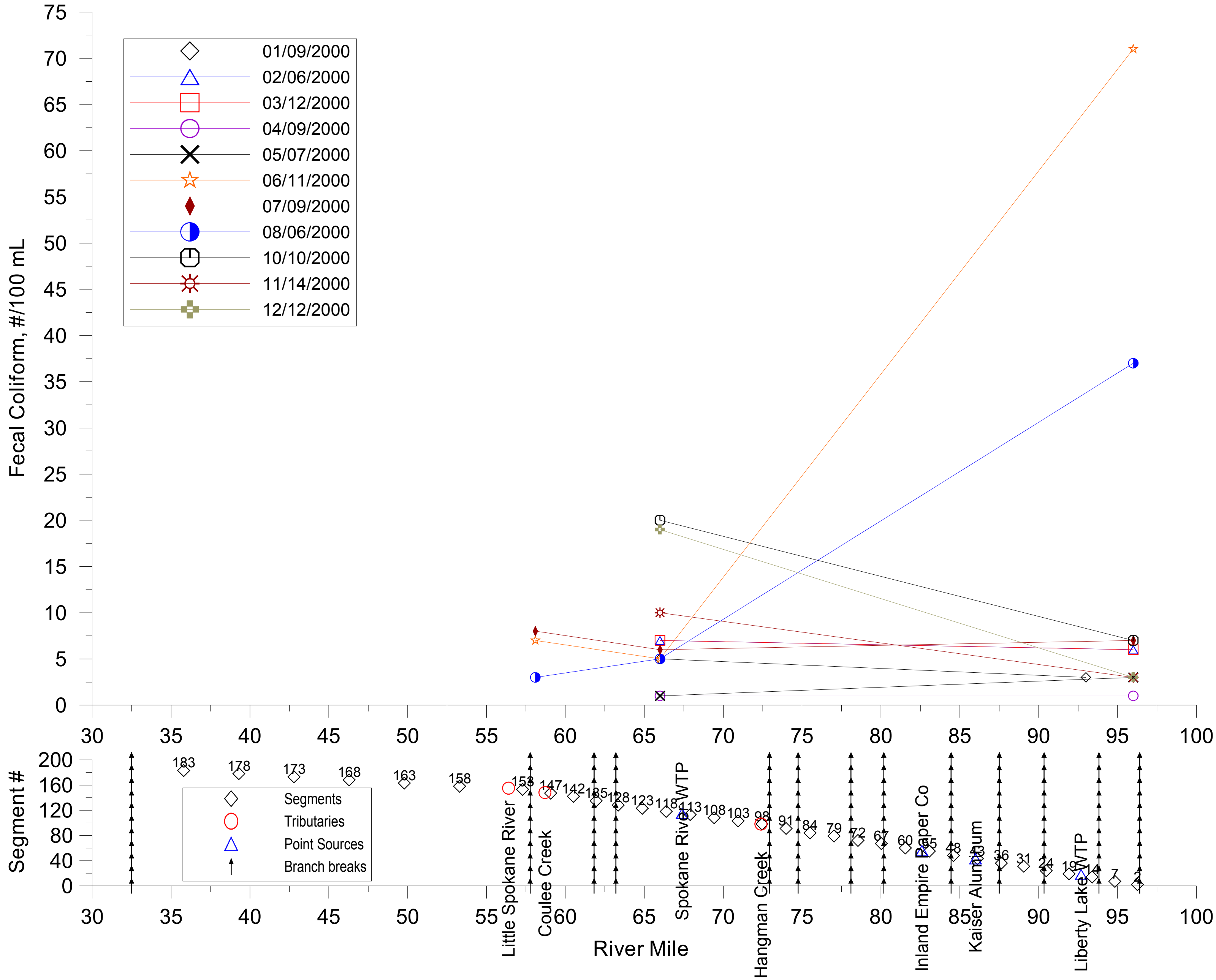
Turbidity, NTU
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/09/2000
08/06/2000
10/10/2000
11/14/2000
12/12/2000
River Mile
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

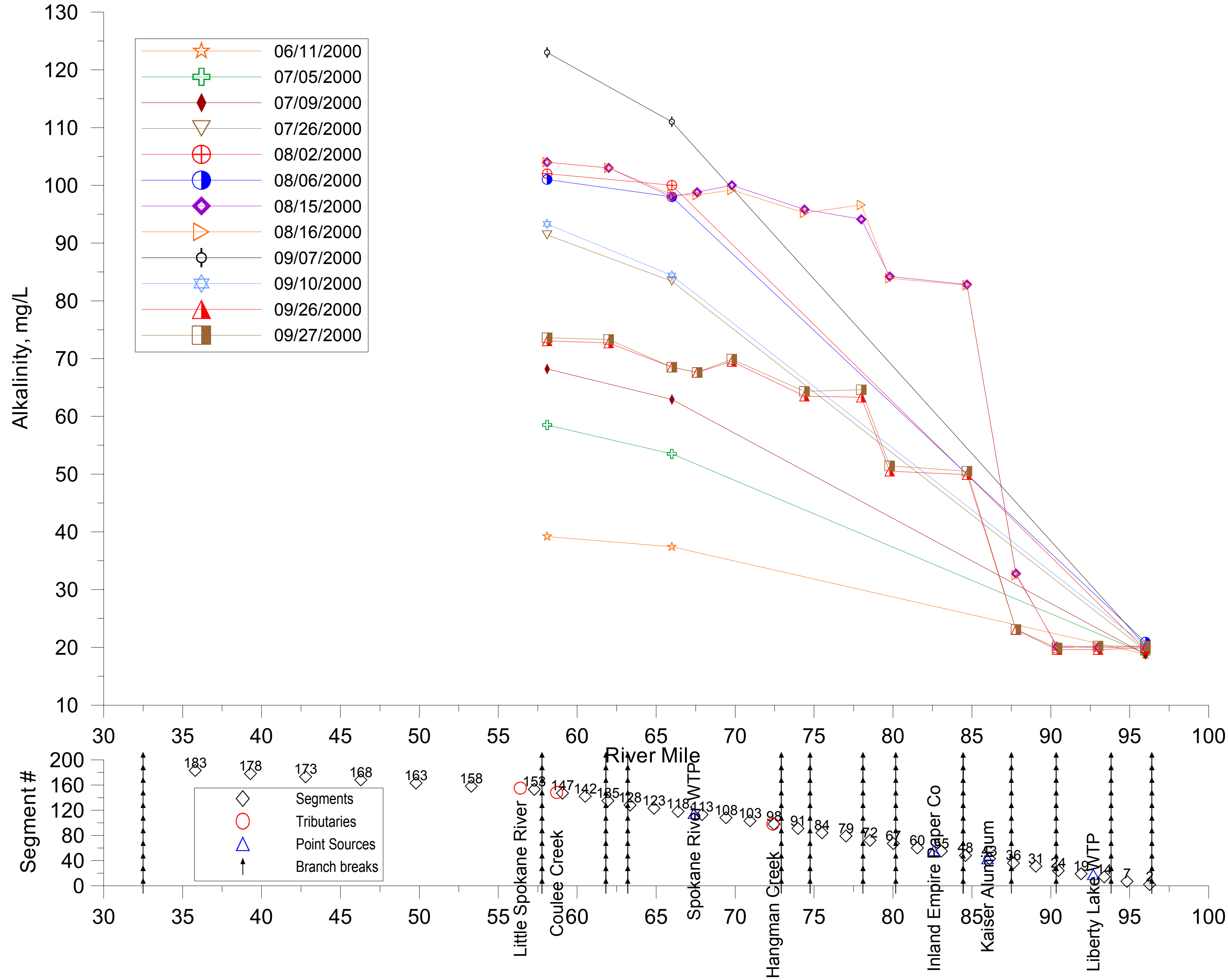


TSS, mg/L
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/09/2000
08/06/2000
09/10/2000
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile

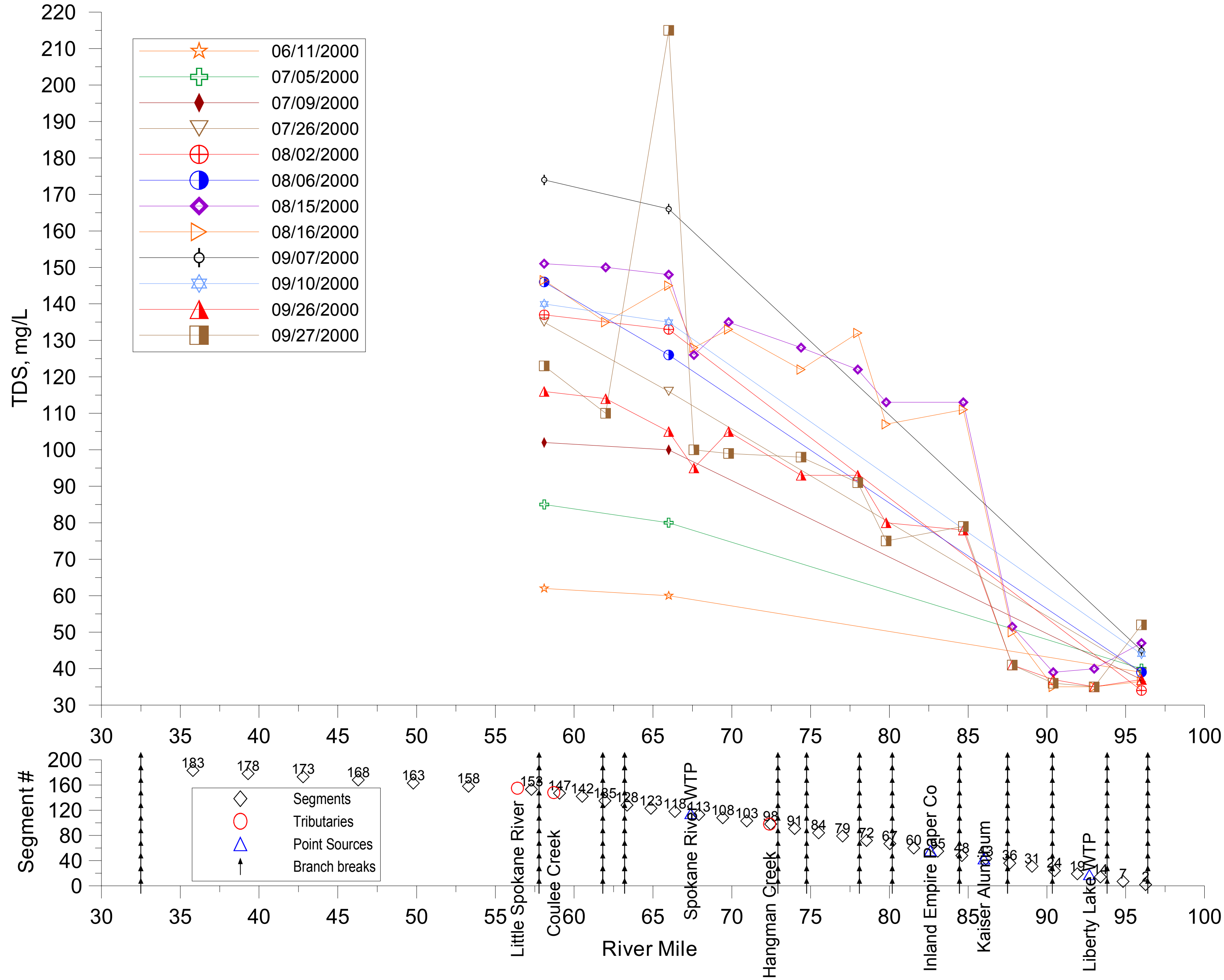


Fecal Coliform, #/100 mL
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/09/2000
08/06/2000
09/10/2000
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile

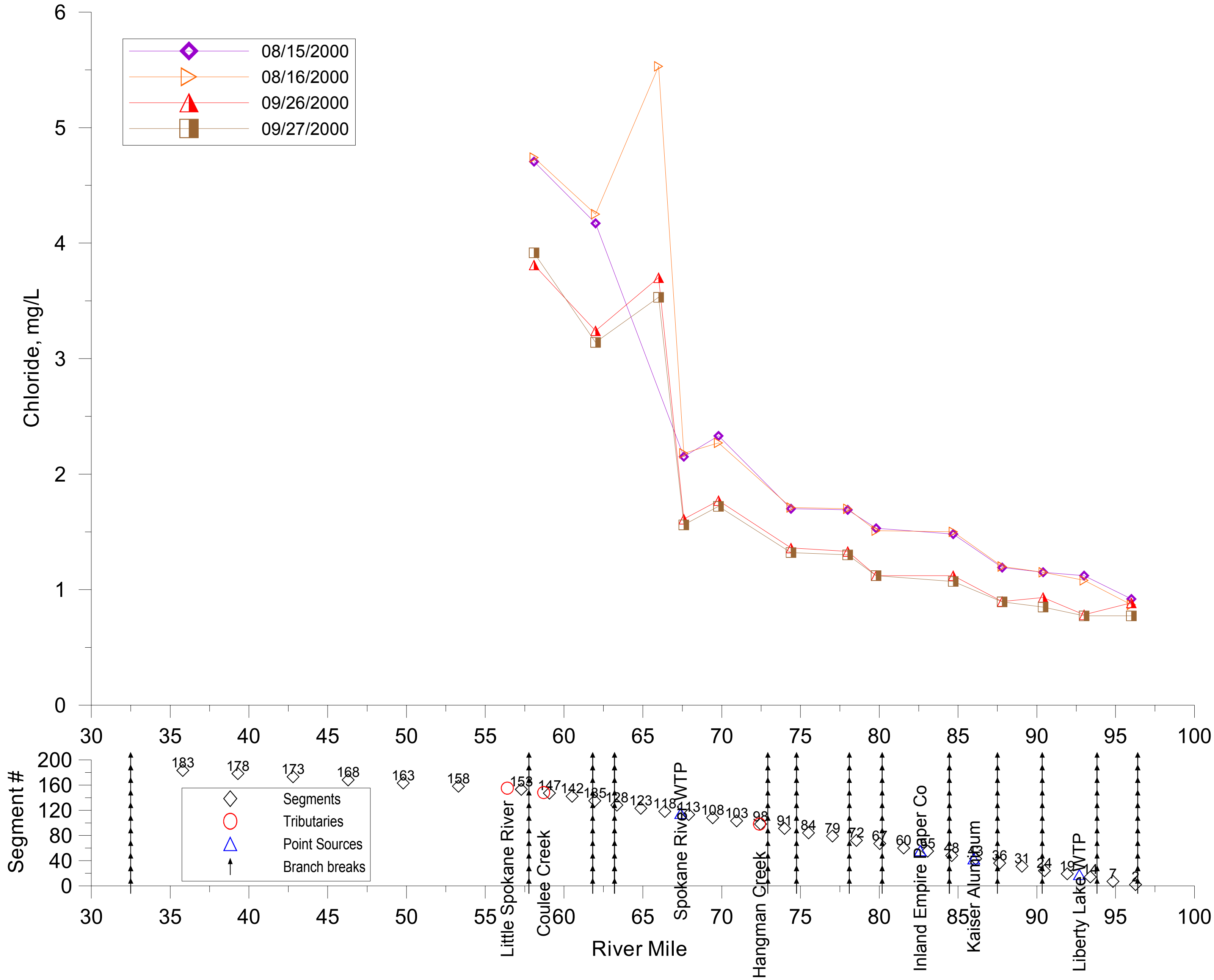

Fecal Coliform, #/100 mL
01/09/2000
02/06/2000
03/12/2000
04/09/2000
05/07/2000
06/11/2000
07/09/2000
08/06/2000
10/10/2000
11/14/2000
12/12/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



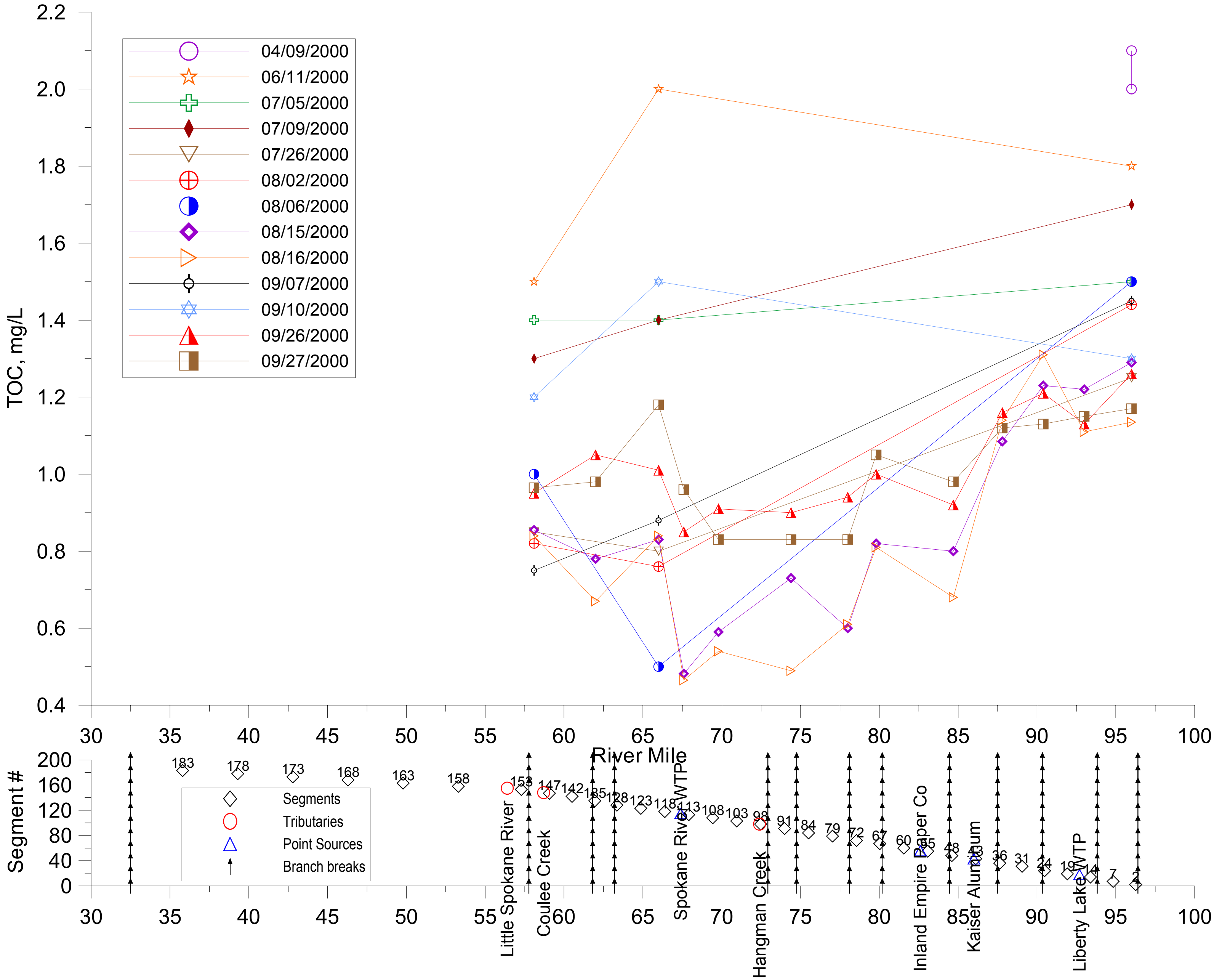
Alkalinity, mg/L
River Mile
Segment #
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000
08/16/2000
09/07/2000
09/10/2000
09/26/2000
09/27/2000
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



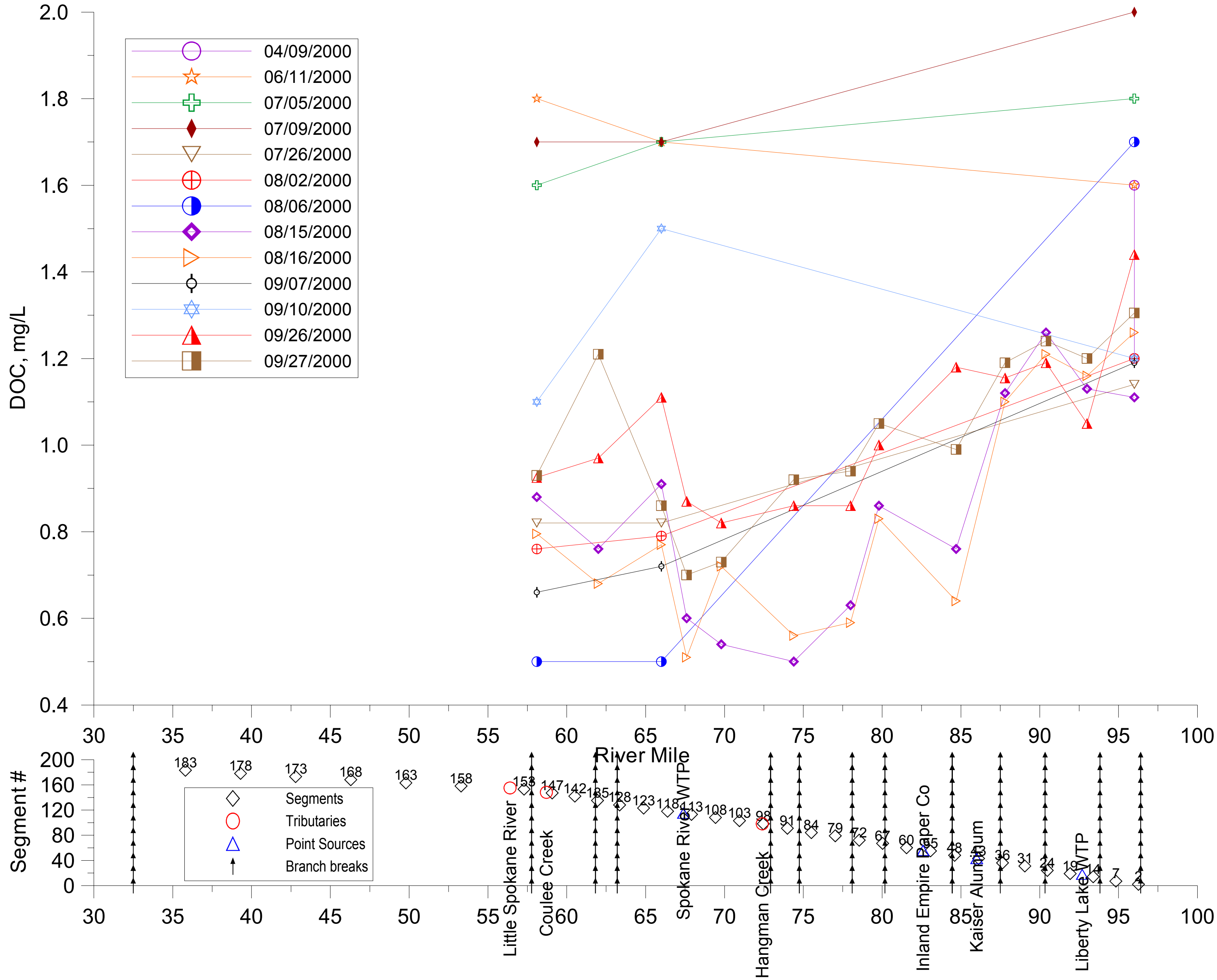
TDS, mg/L
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000
08/16/2000
09/07/2000
09/10/2000
09/26/2000
09/27/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



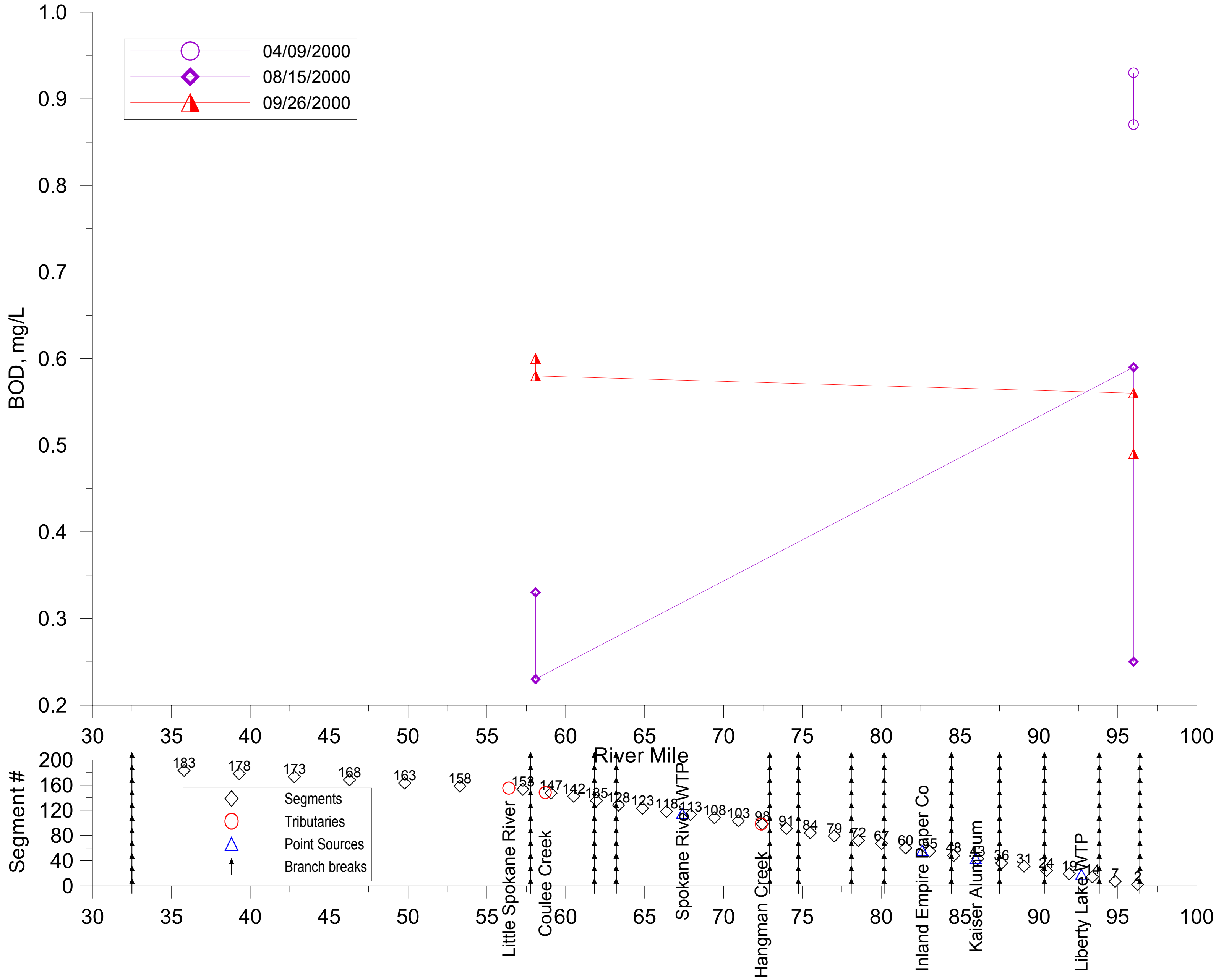
Chloride, mg/L
08/15/2000
08/16/2000
09/26/2000
09/27/2000
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP
River Mile



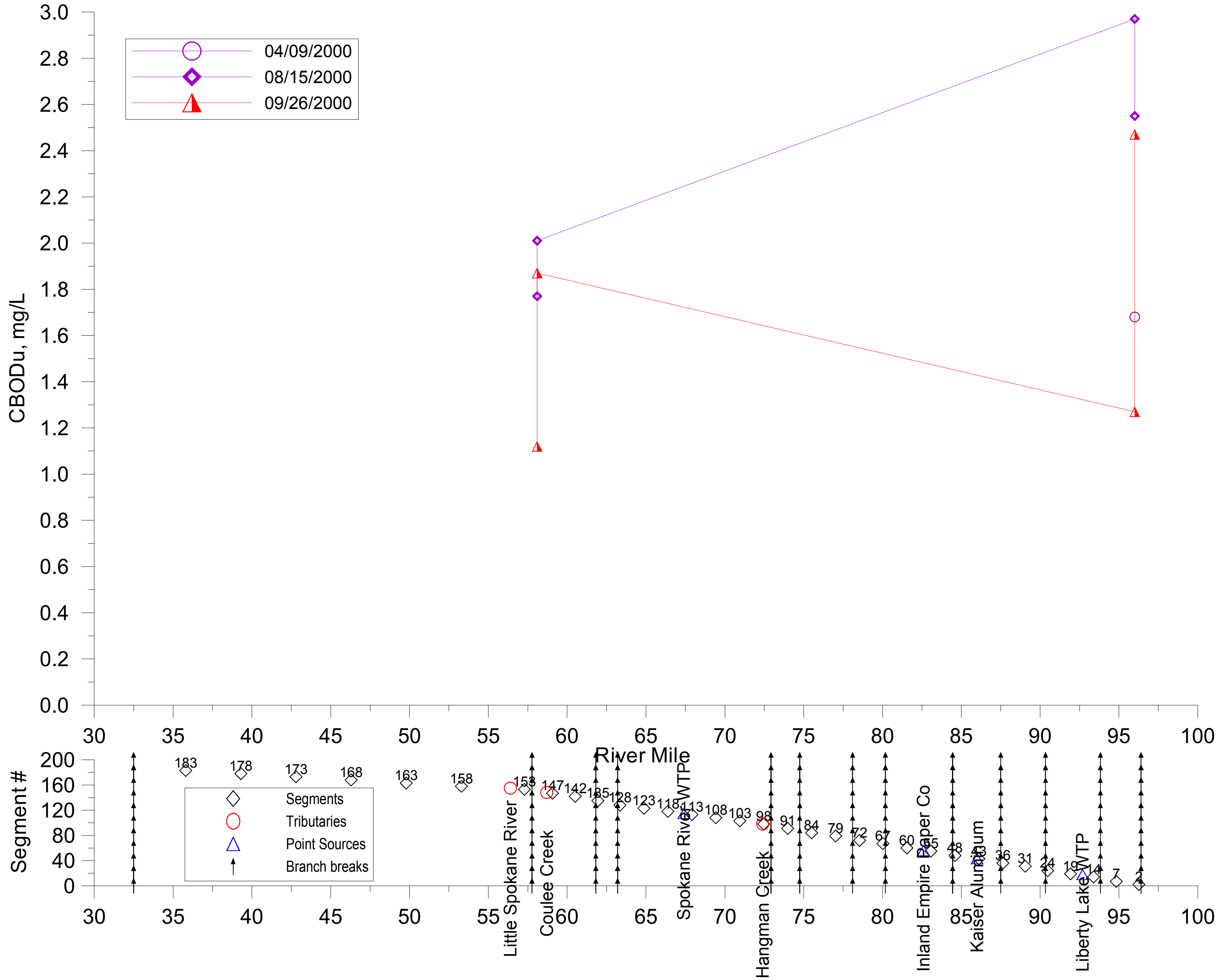
TOC, mg/L
River Mile
Segment #
04/09/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000
08/16/2000
09/07/2000
09/10/2000
09/26/2000
09/27/2000
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



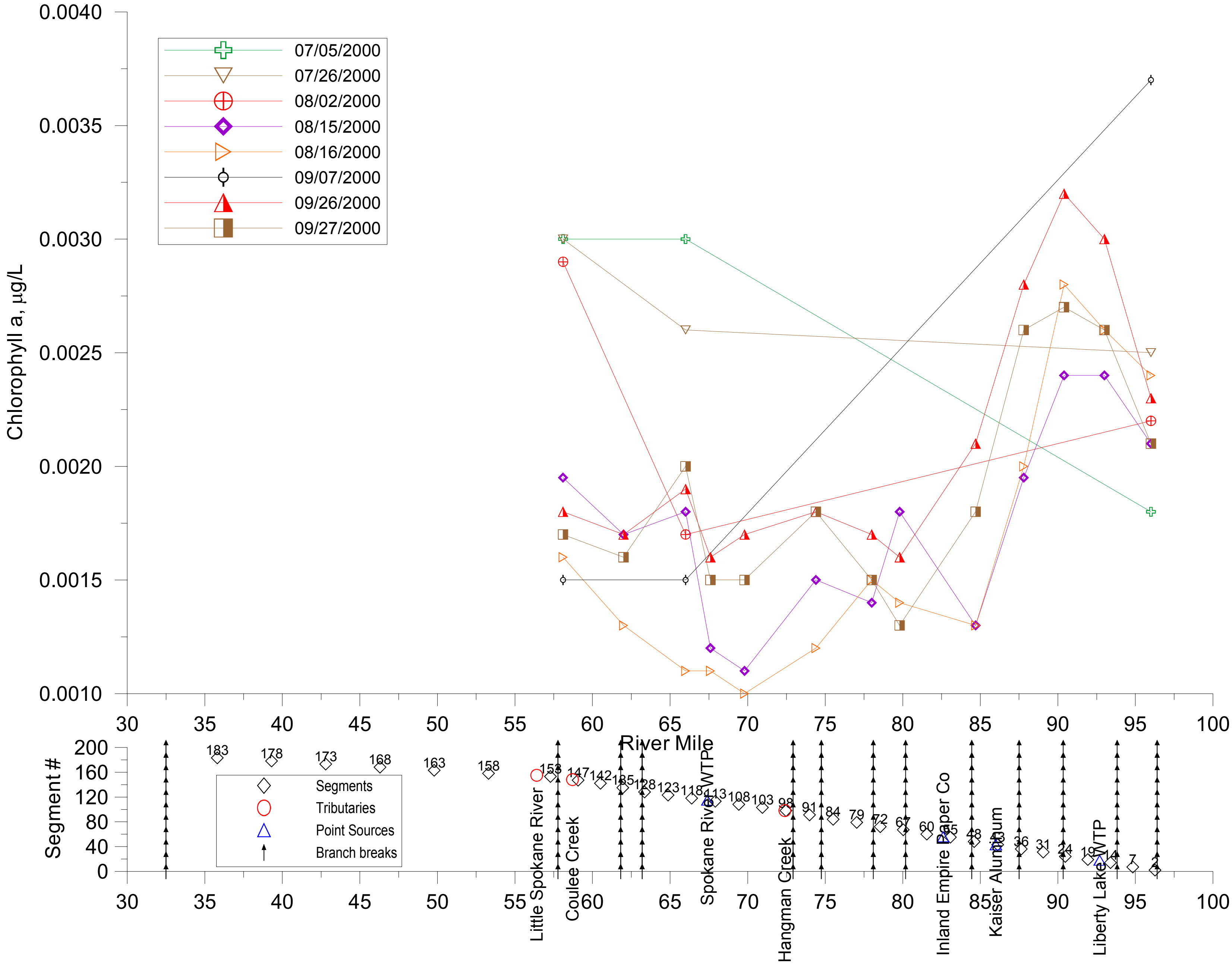
DOC, mg/L
River Mile
Segment #
04/09/2000
06/11/2000
07/05/2000
07/09/2000
07/26/2000
08/02/2000
08/06/2000
08/15/2000
08/16/2000
09/07/2000
09/10/2000
09/26/2000
09/27/2000
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP



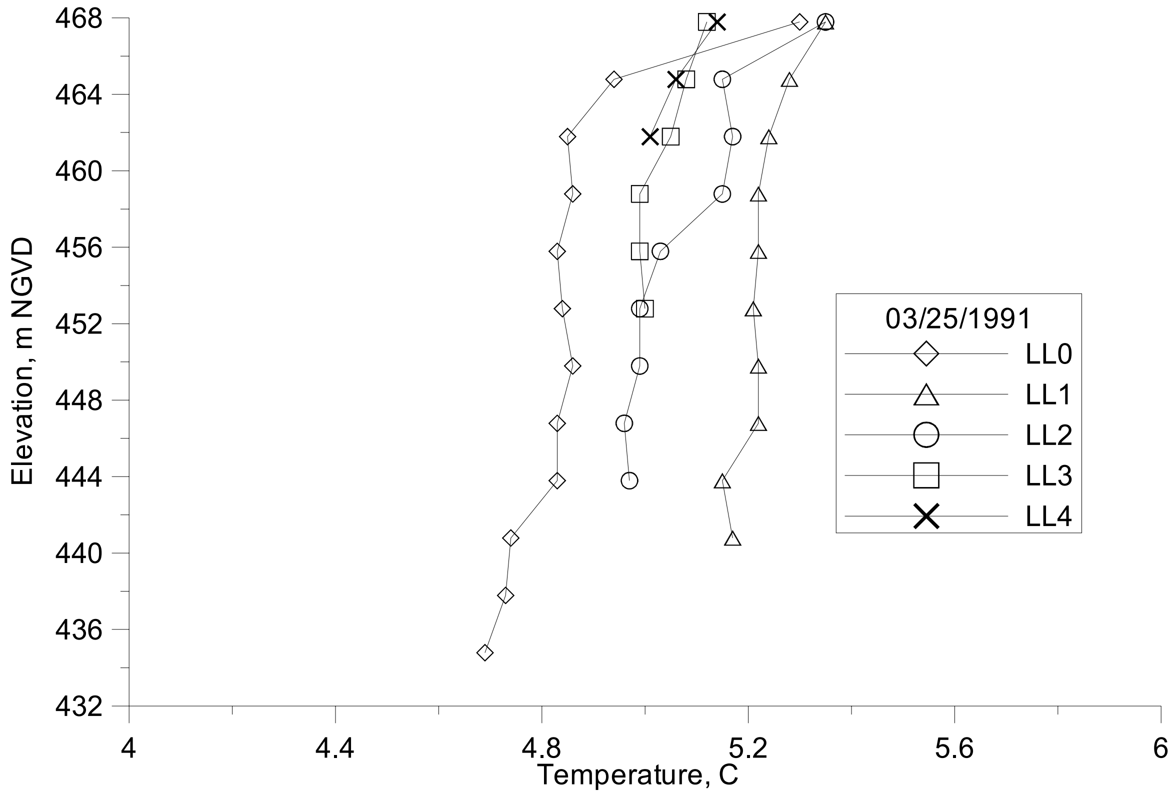
BOD, mg/L
04/09/2000
08/15/2000
09/26/2000
River Mile
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

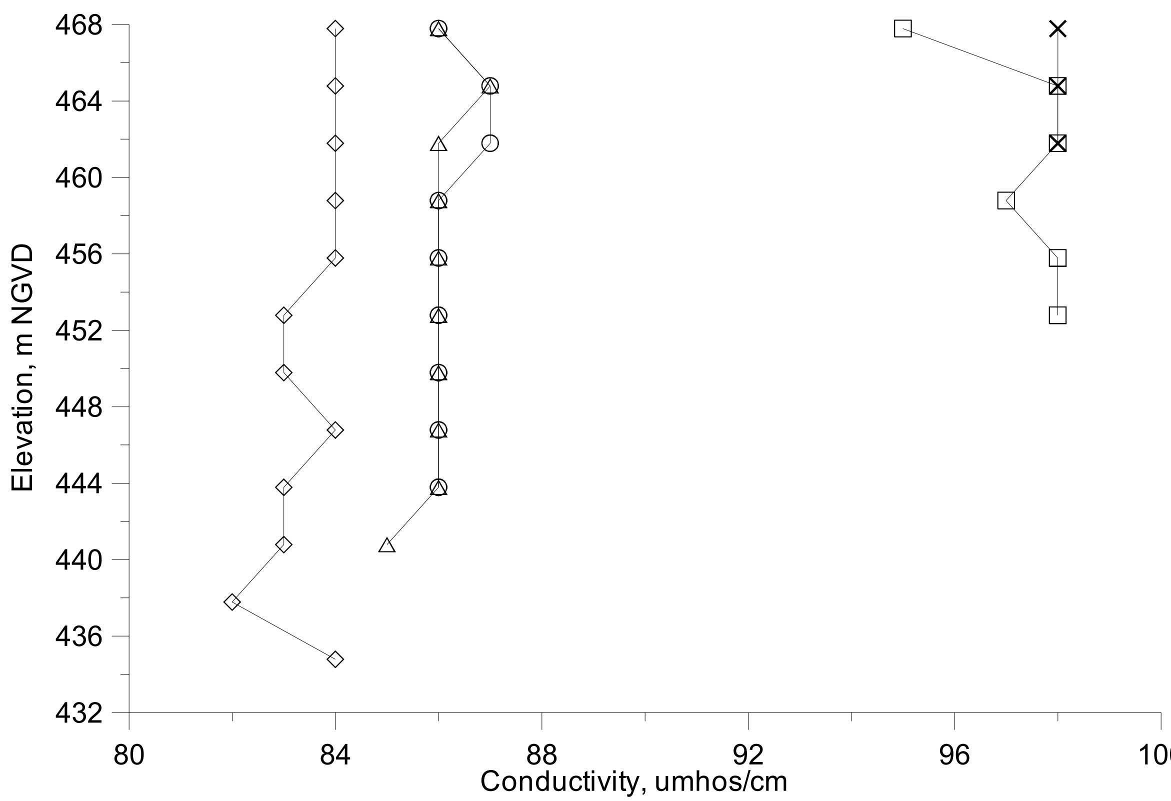


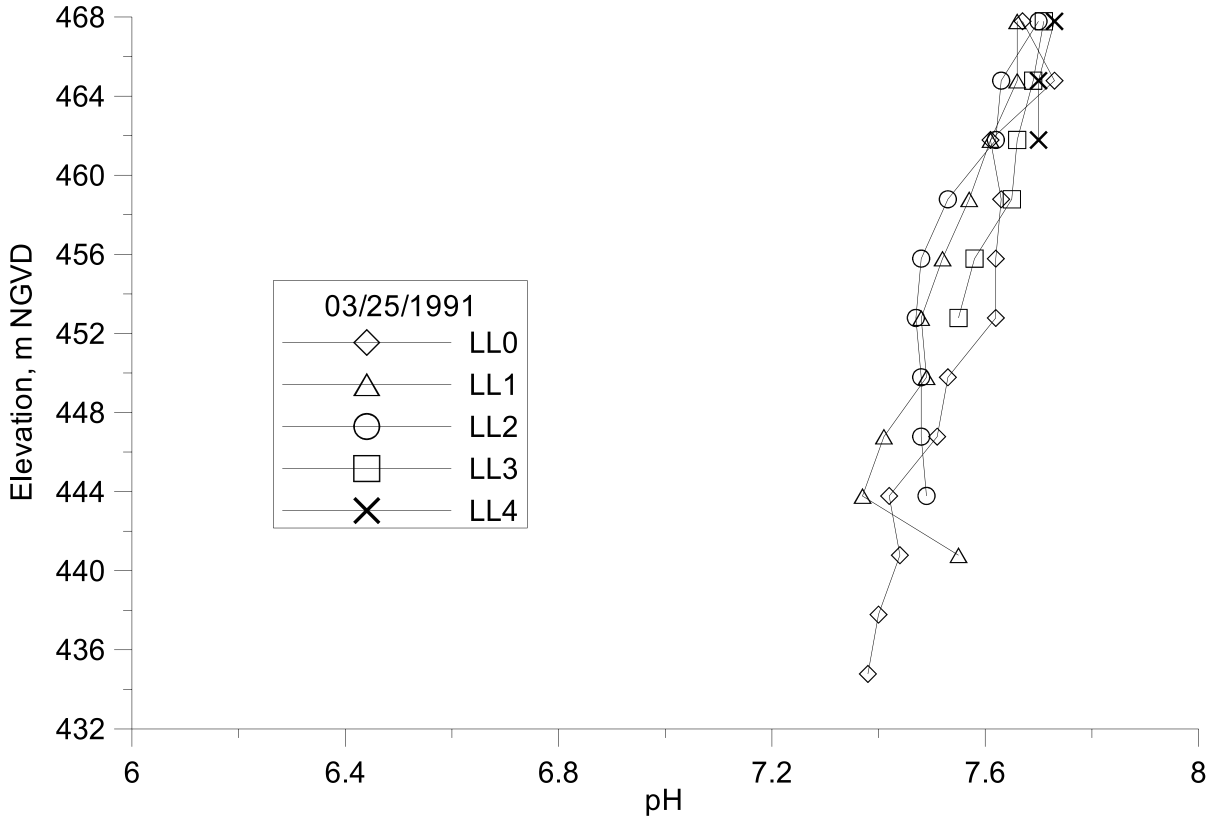
04/09/2000
08/15/2000
09/26/2000
CBODu, mg/L
River Mile
Segment #
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

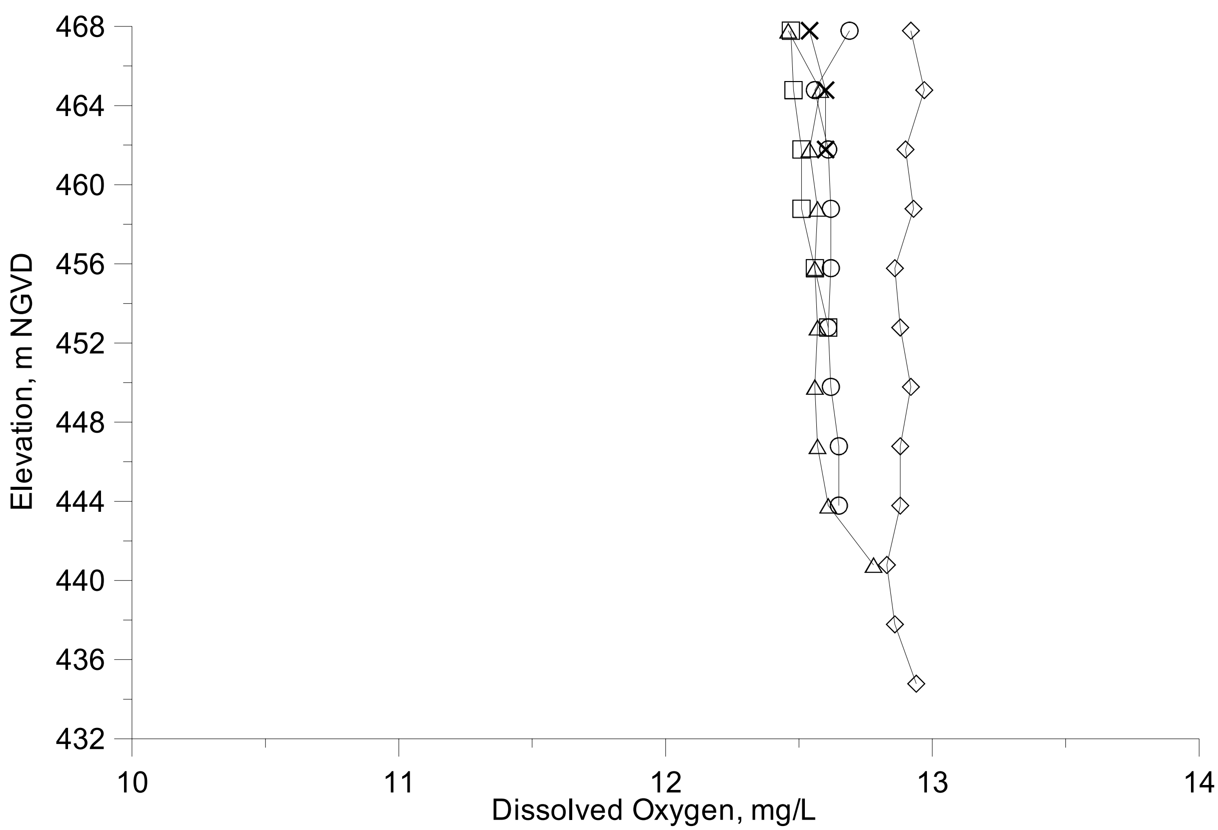

0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
Chlorophyll a, µg/L
07/05/2000
07/26/2000
08/02/2000
08/15/2000
08/16/2000
09/07/2000
09/26/2000
09/27/2000
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
River Mile
Segment #
200
160
120
80
40
0
Segments
Tributaries
Point Sources
Branch breaks
Little Spokane River
Coulee Creek
Spokane River WTP
Hangman Creek
Inland Empire Paper Co
Kaiser Aluminum
Liberty Lake WTP

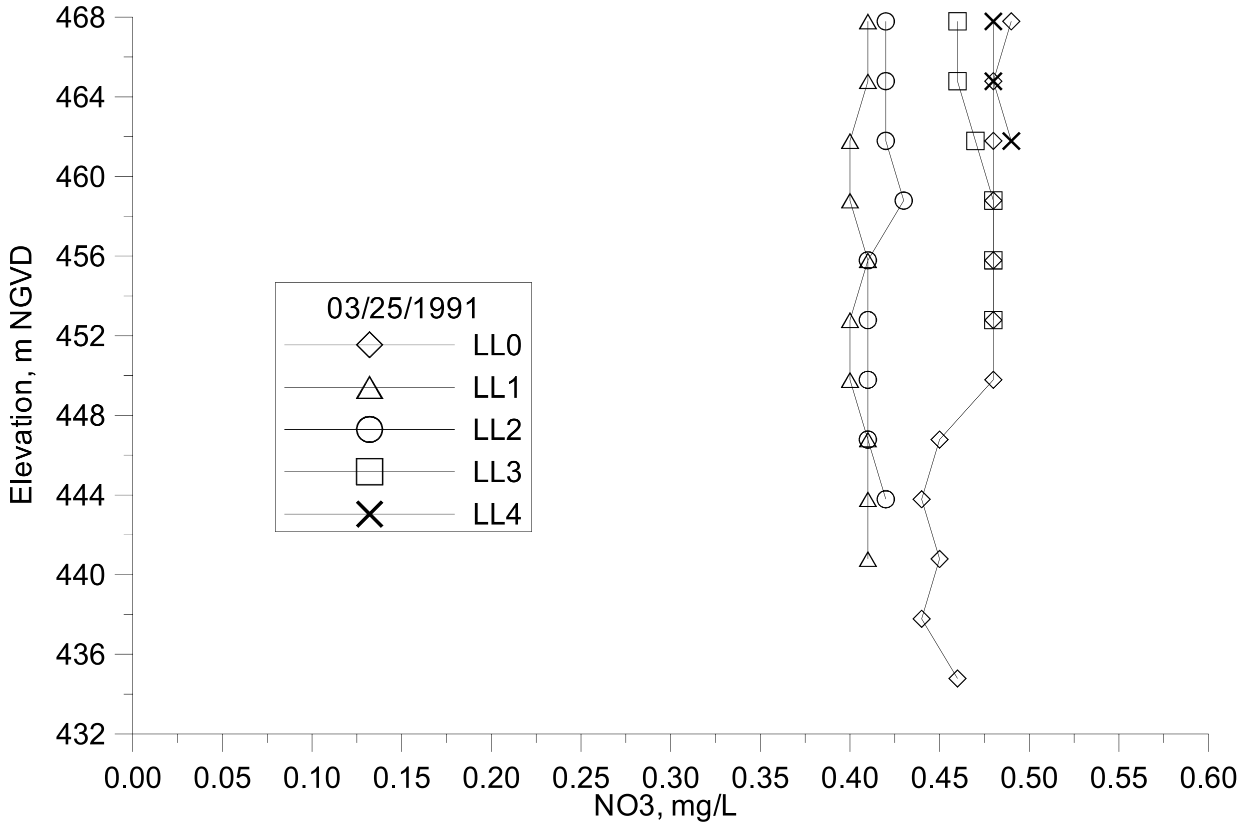
Appendix C: 1991 Long Lake Vertical Profiles

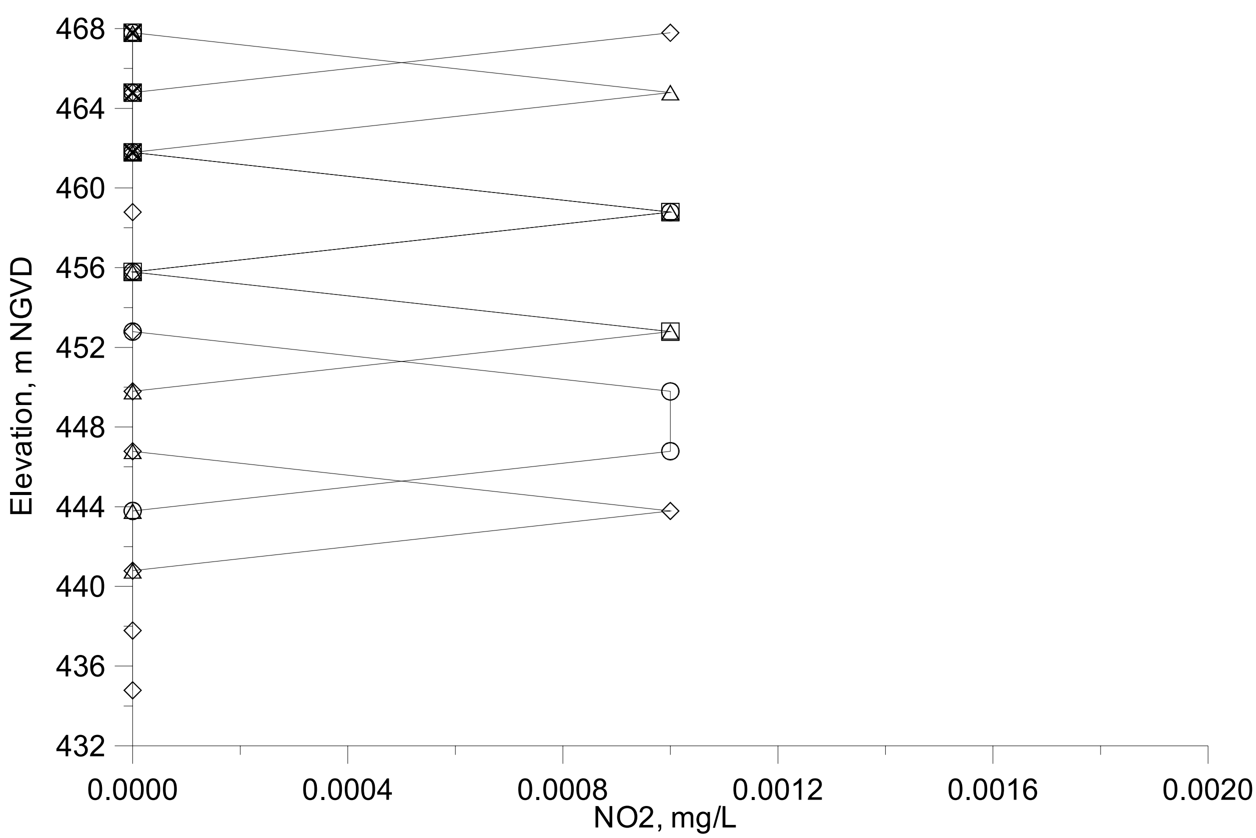


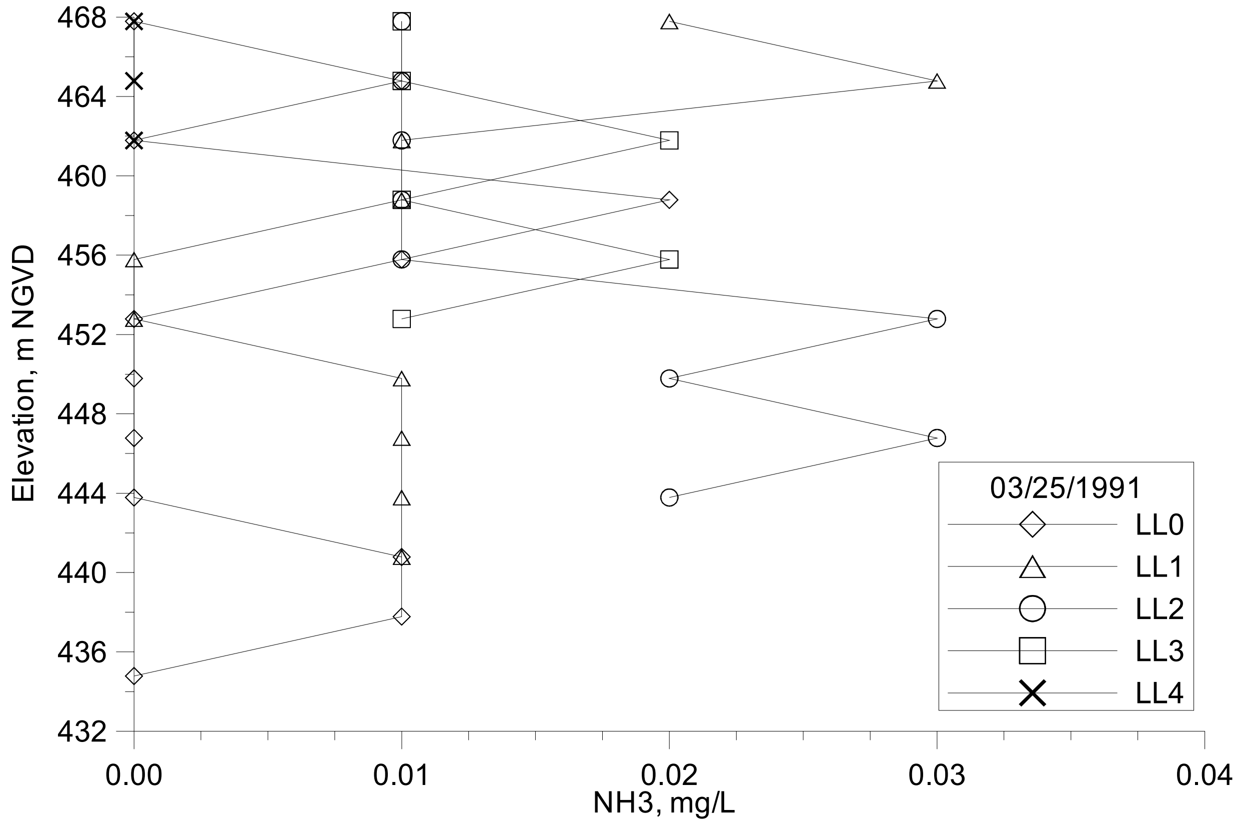


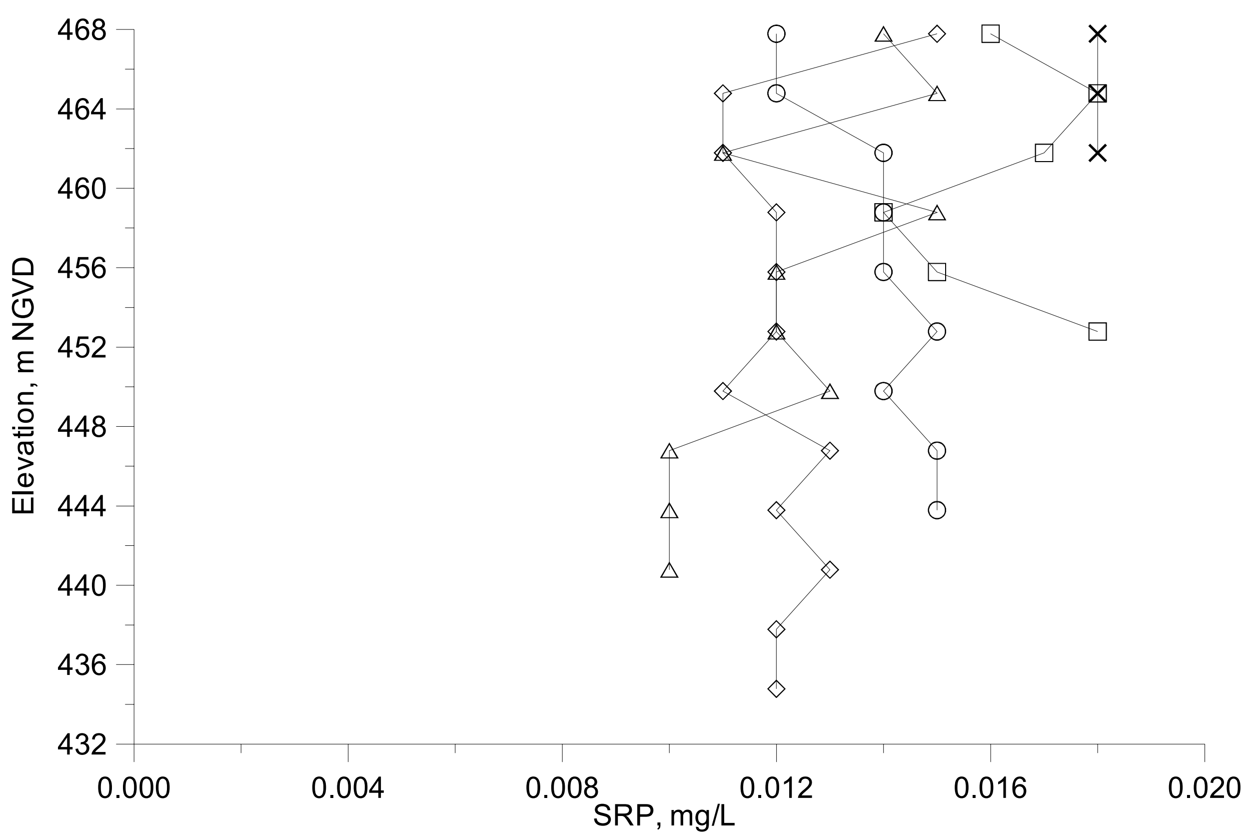

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
6
6.4
6.8
7.2
7.6
8
pH
03/25/1991
LL0
LL1
LL2
LL3
LL4

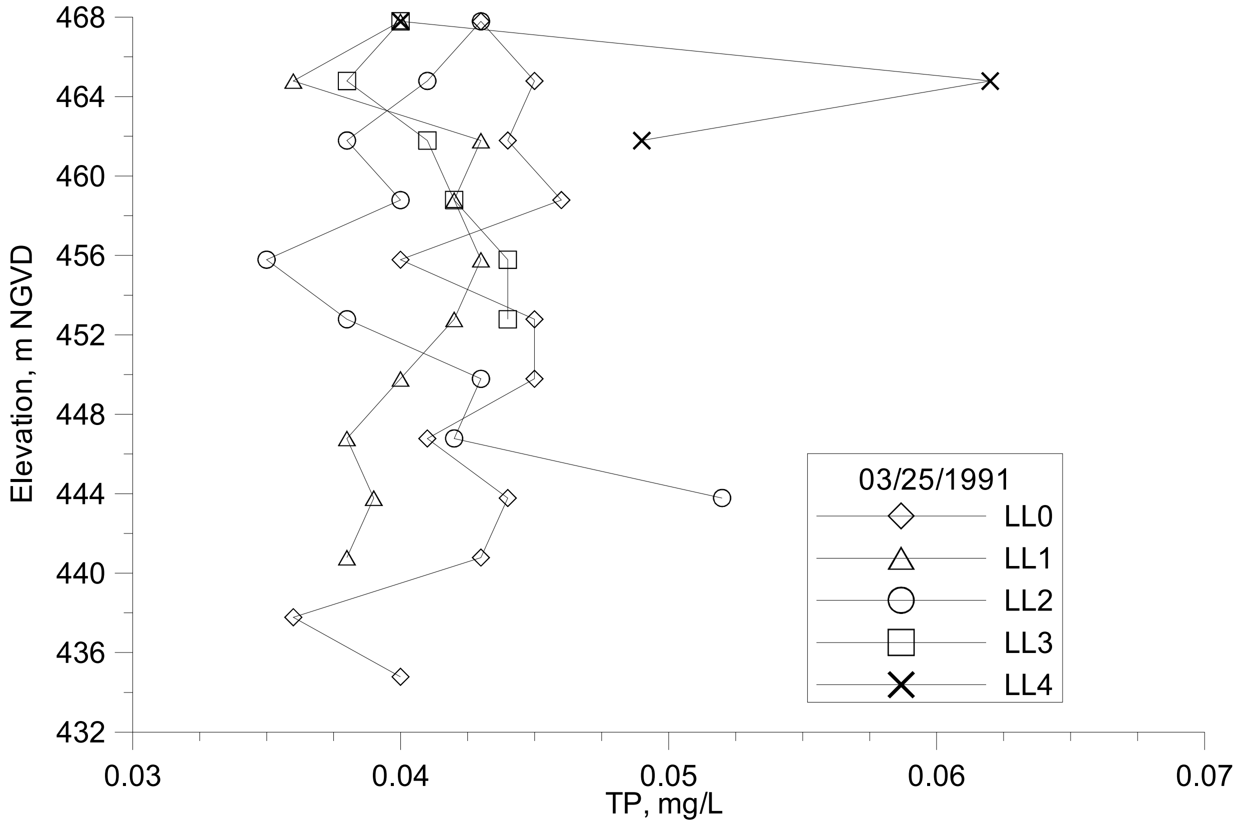

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
10
11
12
13
14
Dissolved Oxygen, mg/L


03/25/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NO3, mg/L
468
464
460
456
452
448
444
440
436
432
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60

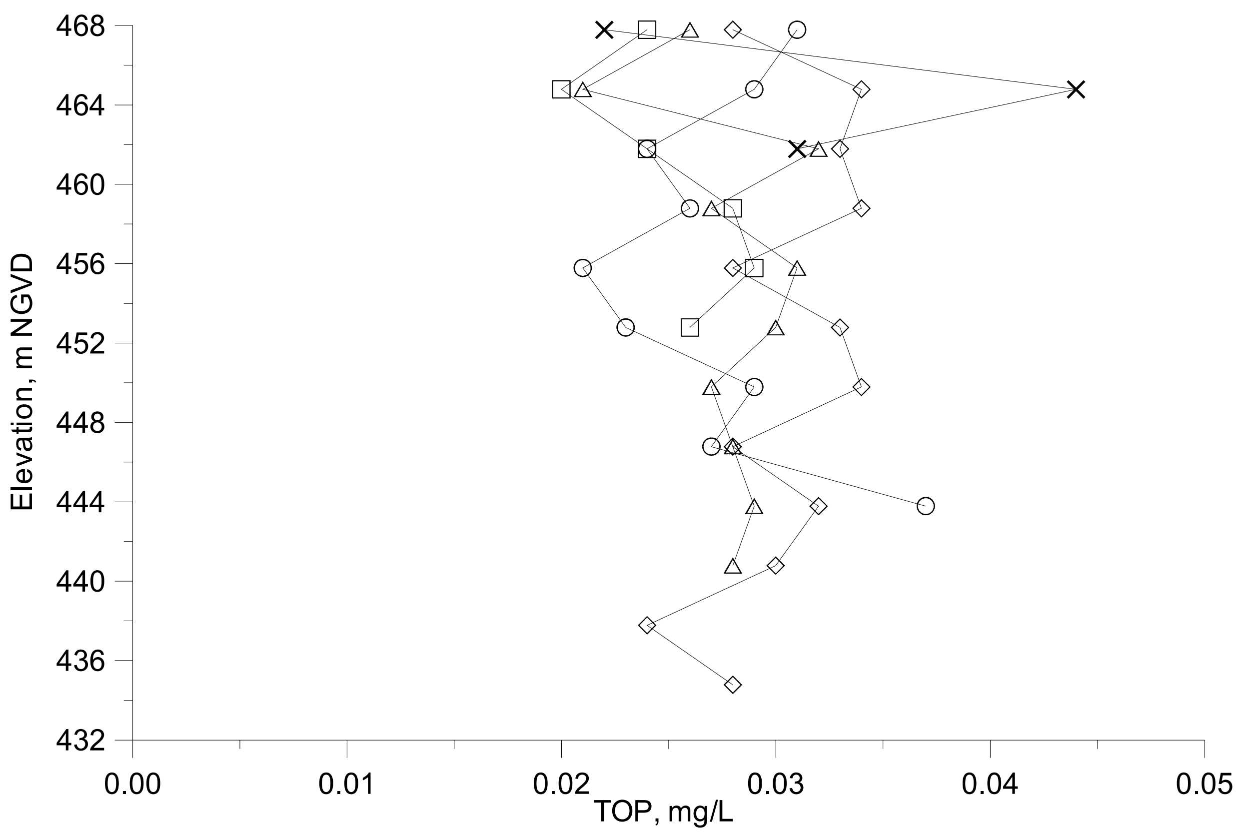

Elevation, m NGVD
NO2, mg/L
468
464
460
456
452
448
444
440
436
432
0.0000
0.0004
0.0008
0.0012
0.0016
0.0020


03/25/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NH3, mg/L
468
464
460
456
452
448
444
440
436
432
0.00
0.01
0.02
0.03
0.04

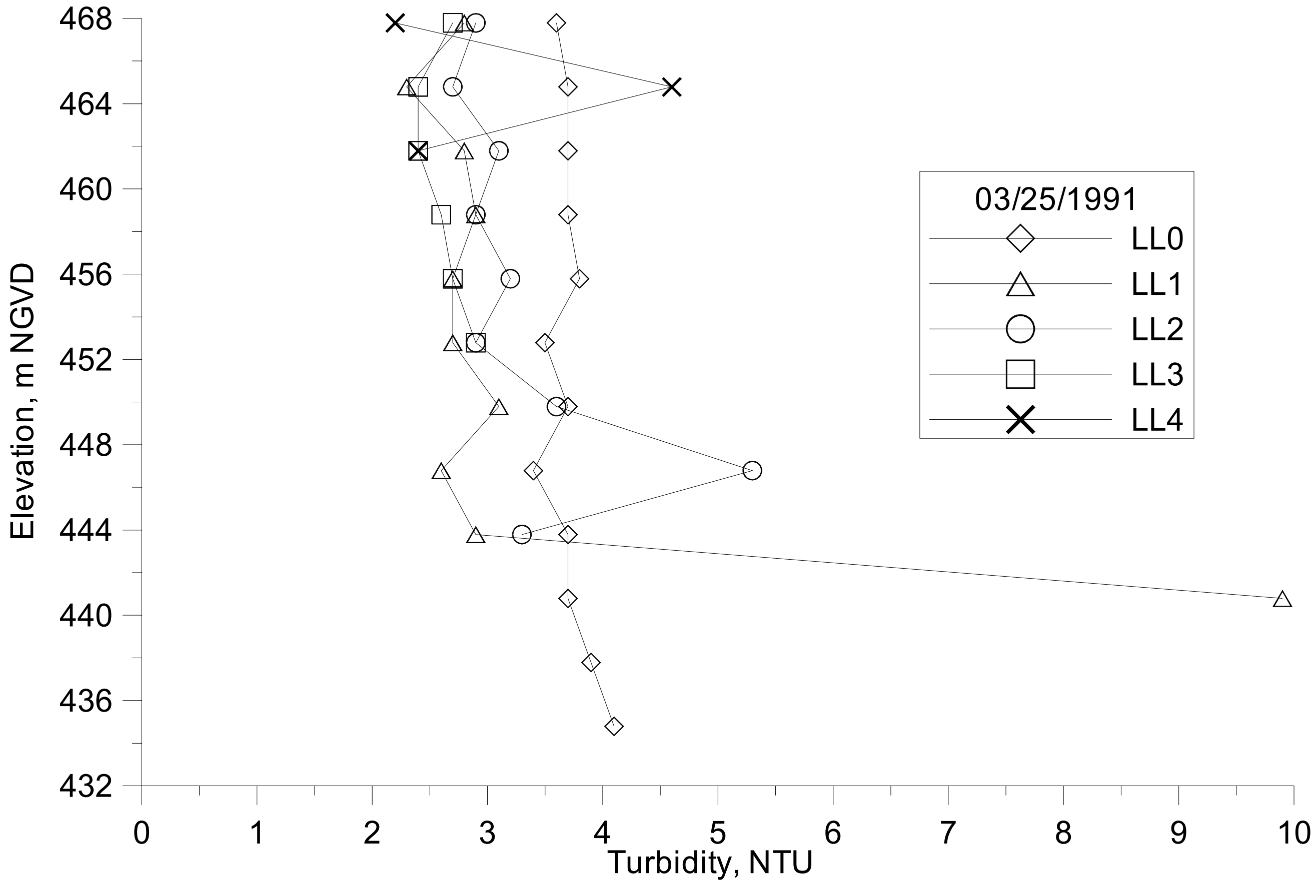

Elevation, m NGVD
SRP, mg/L
468
464
460
456
452
448
444
440
436
432
0.000
0.004
0.008
0.012
0.016
0.020



468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.03
0.04
0.05
0.06
0.07
TP, mg/L
03/25/1991
LL0
LL1
LL2
LL3
LL4



468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
0.05
TOP, mg/L



03/25/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Turbidity, NTU
468
464
460
456
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448
444
440
436
432
0
1
2
3
4
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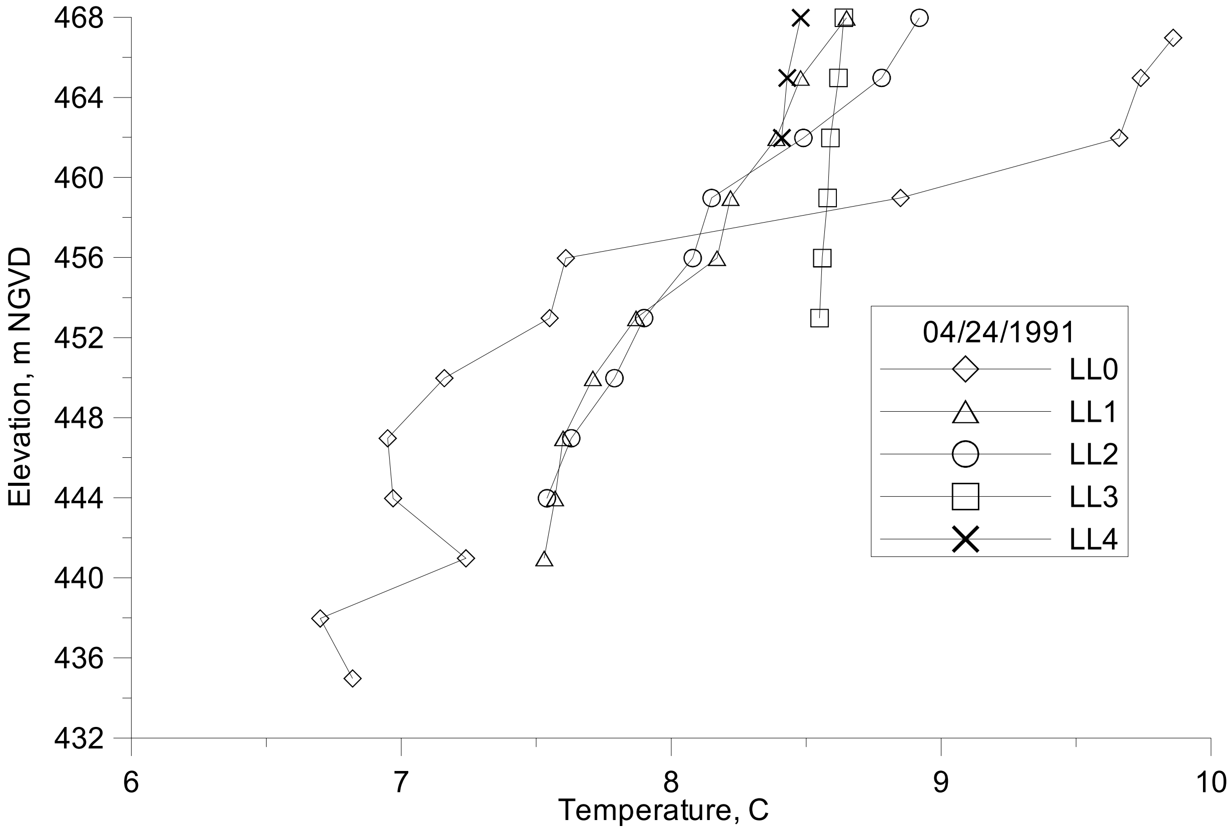
6
7
8
9
10


04/24/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Temperature, C
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464
460
456
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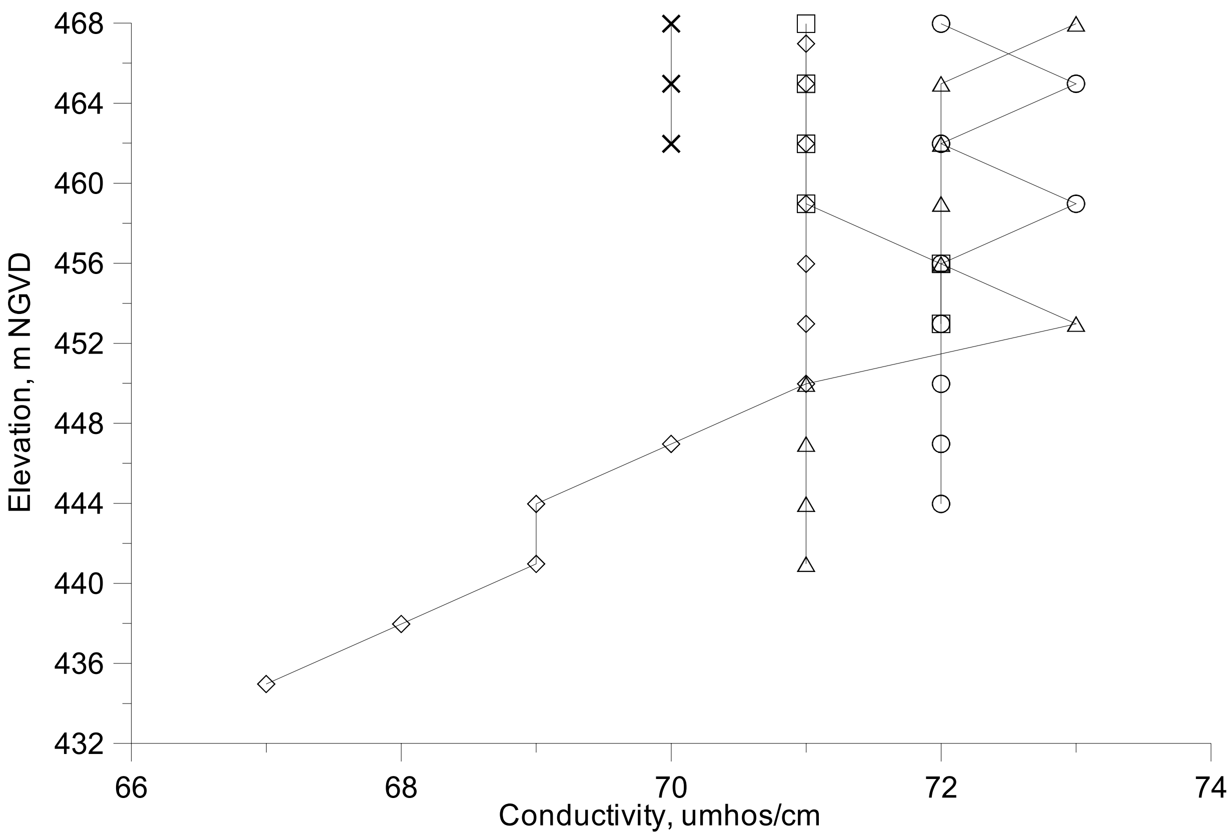
444
440
436
432
6
7
8
9
10


Elevation, m NGVD
Conductivity, umhos/cm
468
464
460
456
452
448
444
440
436
432
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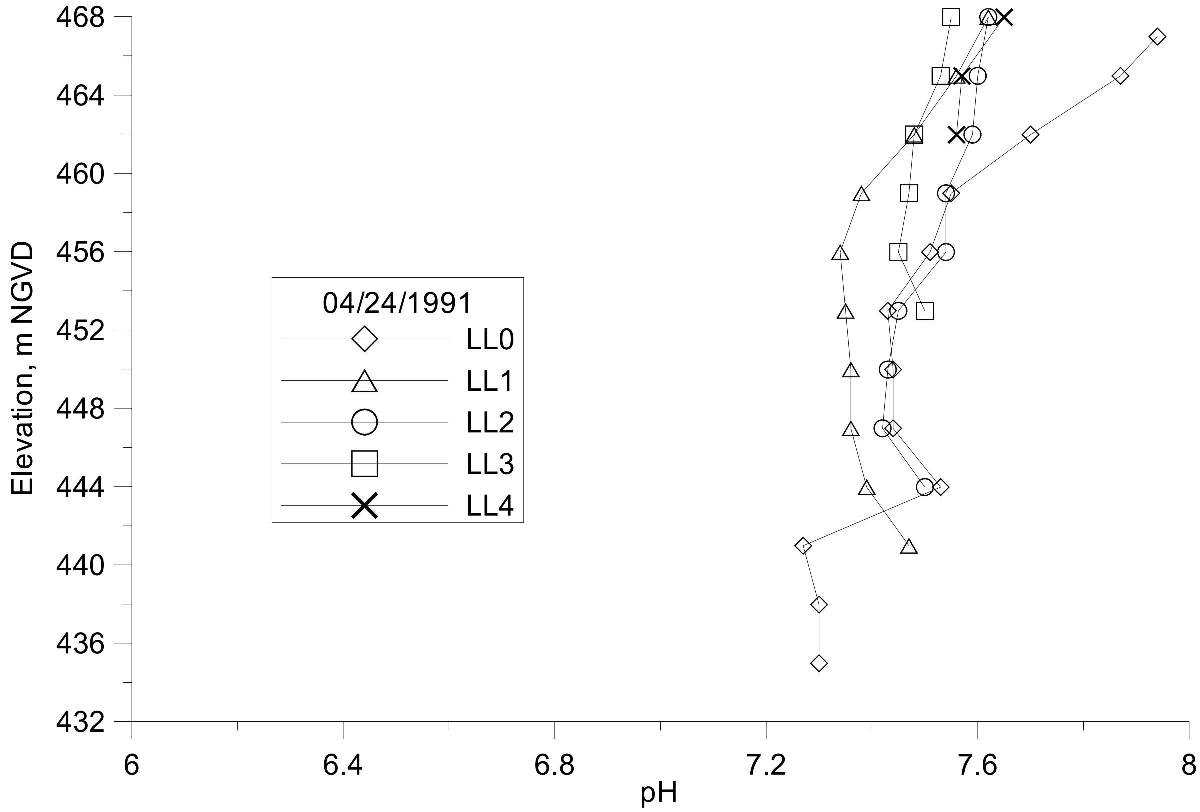
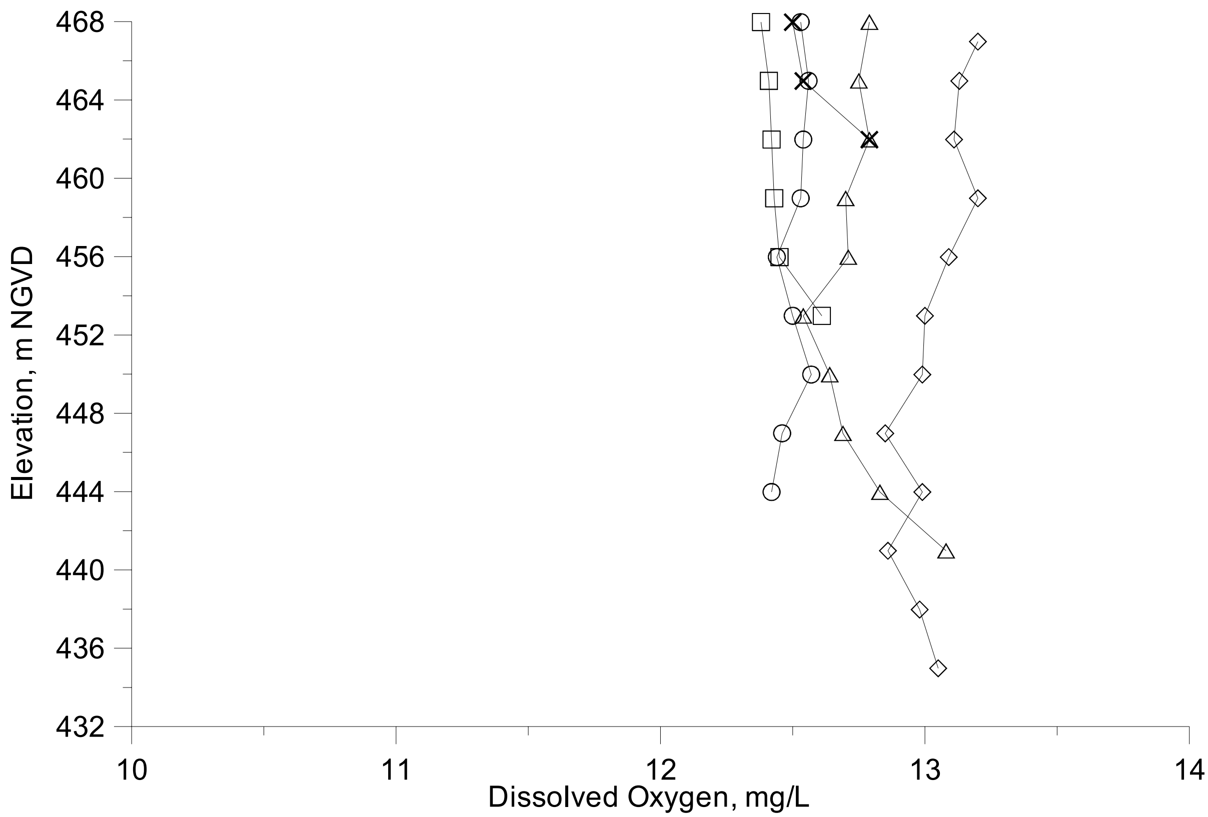
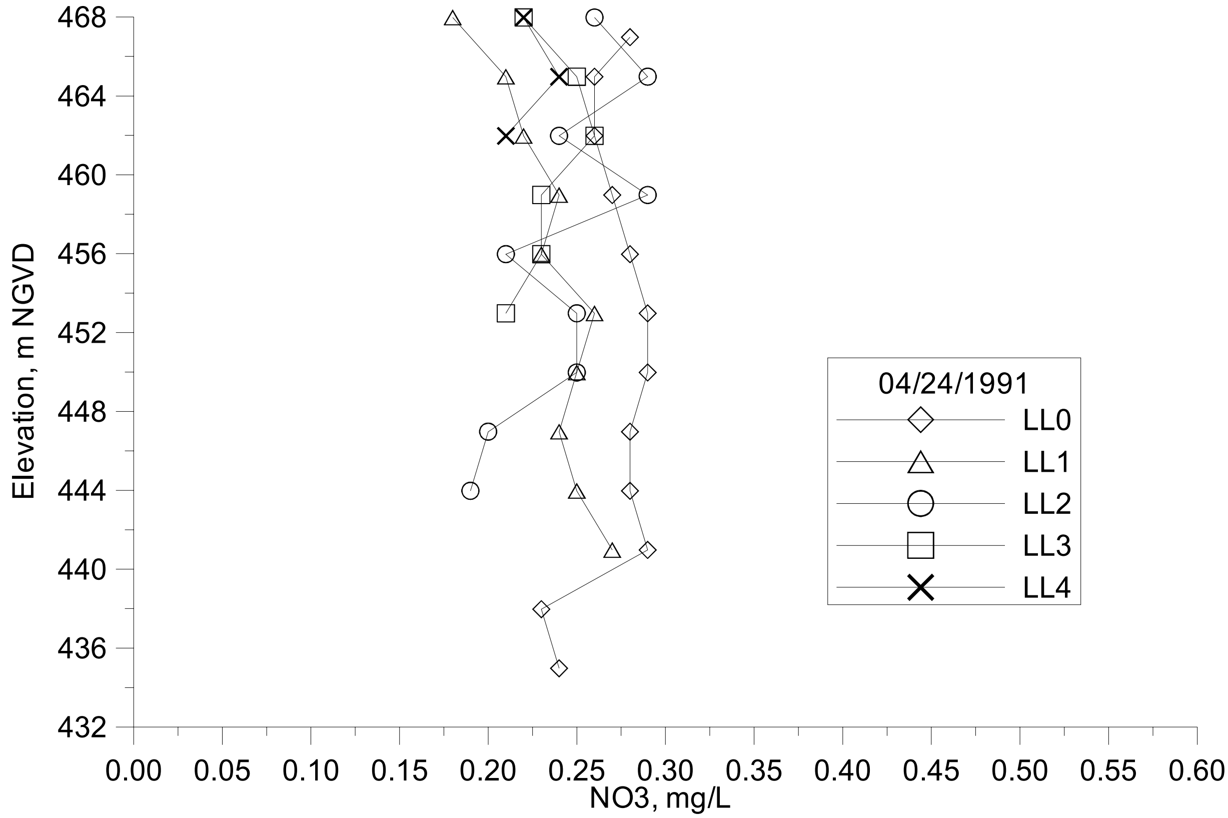
68
70
72
74



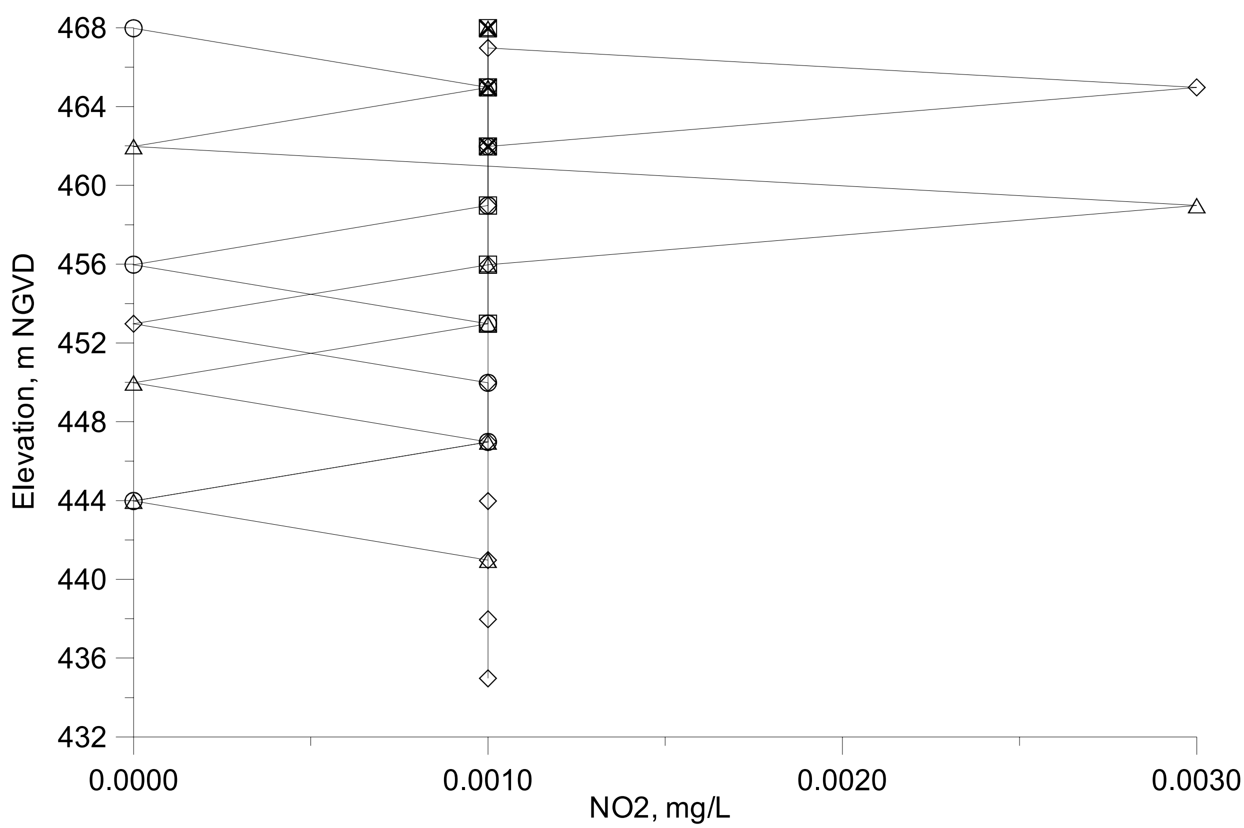
Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
6
6.4
6.8
7.2
7.6
8
pH
04/24/1991
LL0
LL1
LL2
LL3
LL4



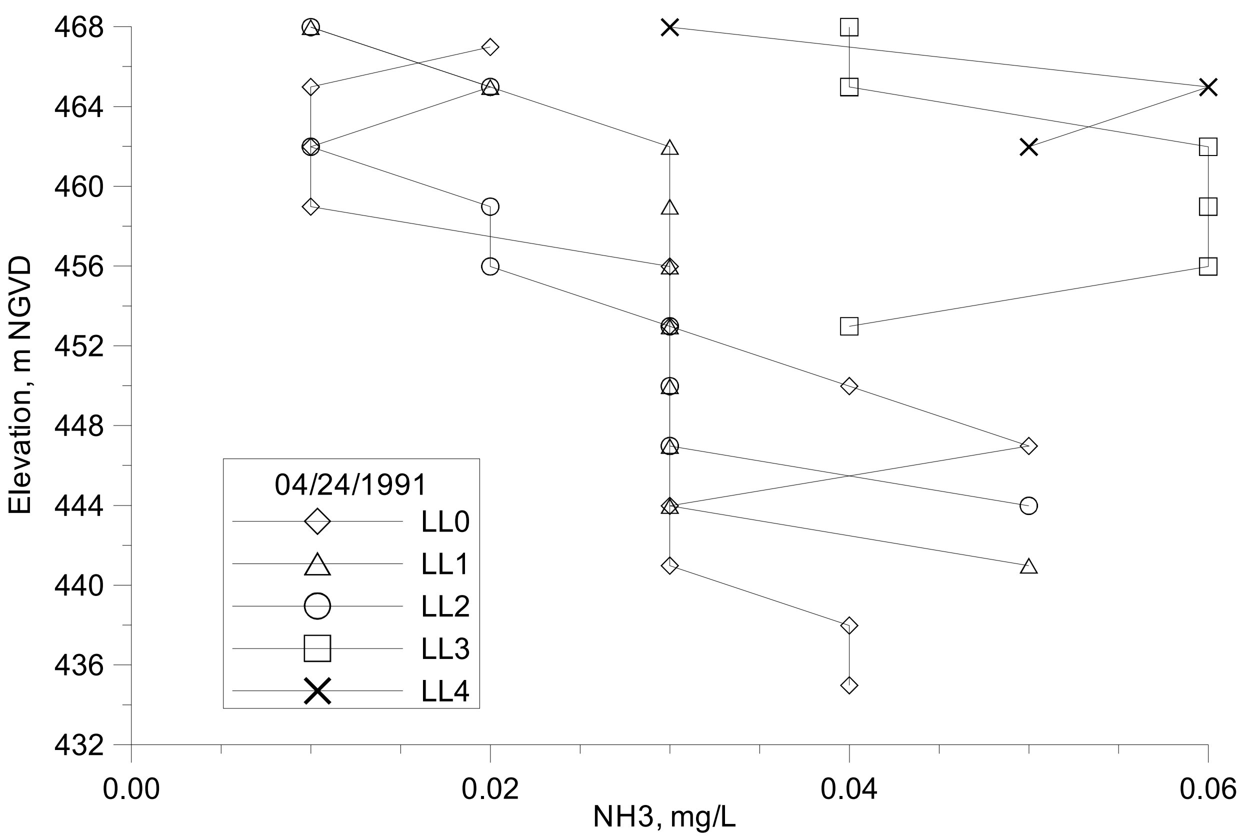
Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
10
11
12
13
14
Dissolved Oxygen, mg/L



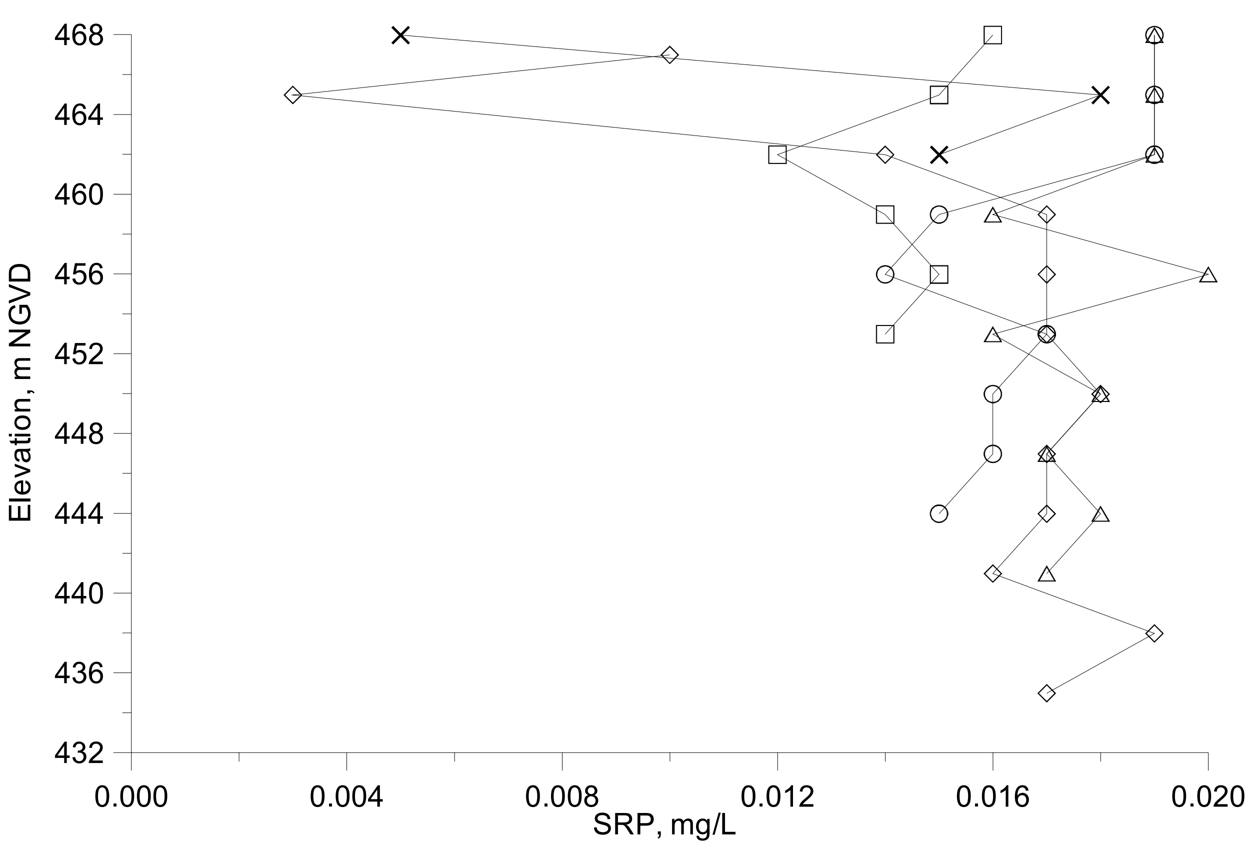
Elevation, m NGVD
NO3, mg/L
04/24/1991
LL0
LL1
LL2
LL3
LL4



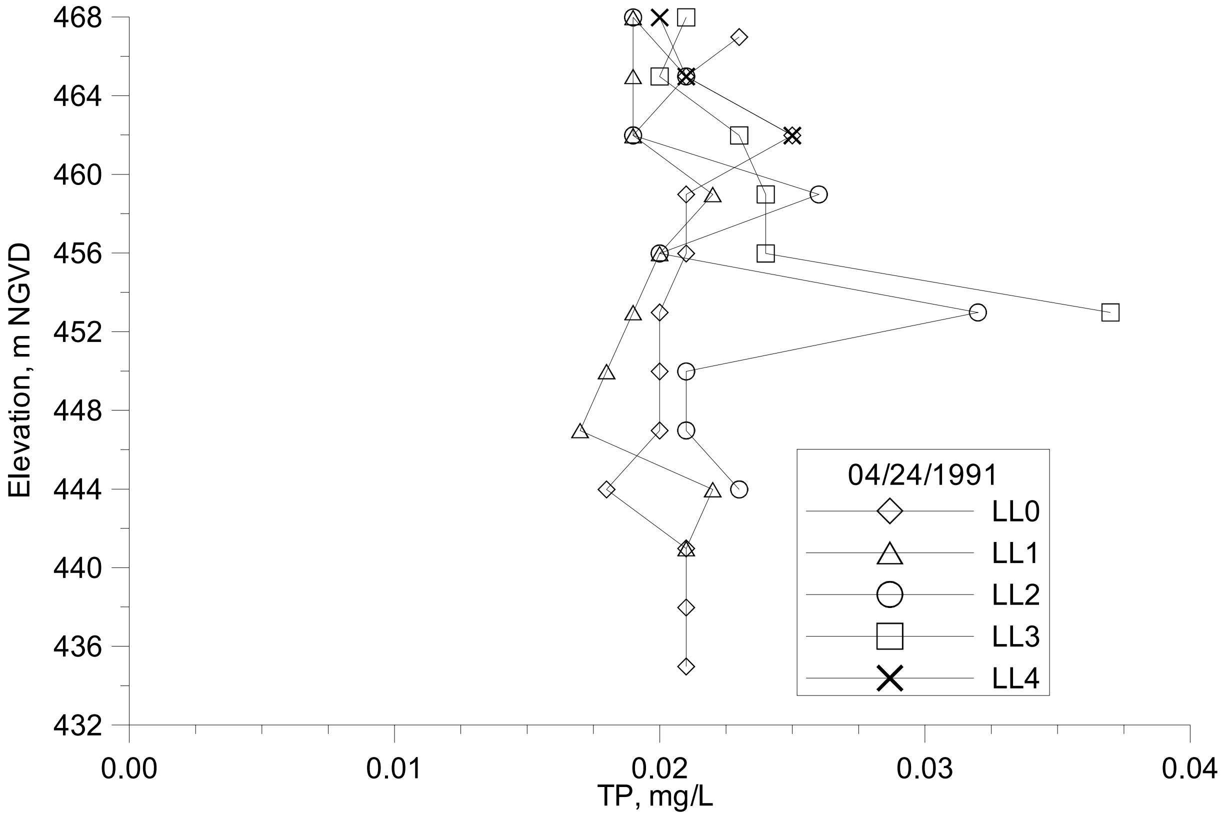
Elevation, m NGVD
NO2, mg/L

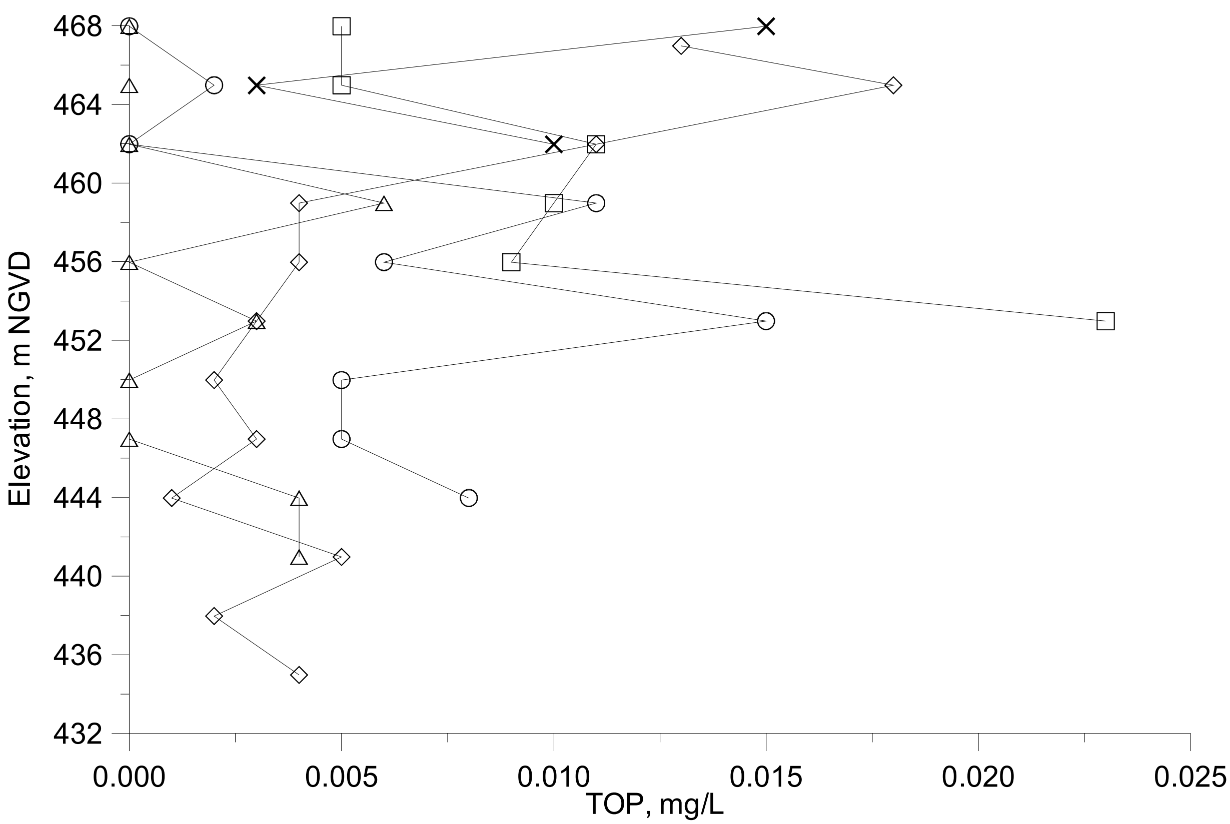


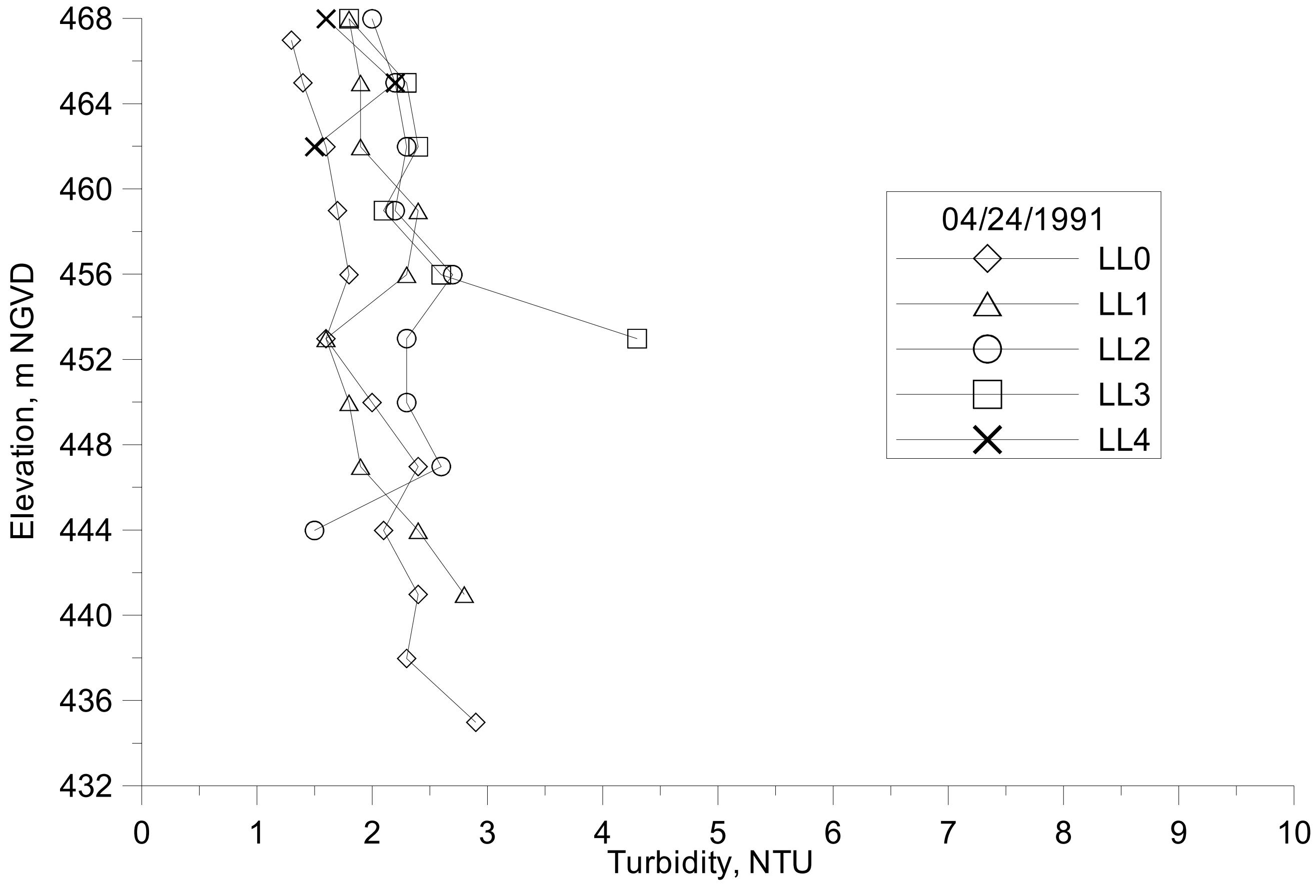
04/24/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NH3, mg/L



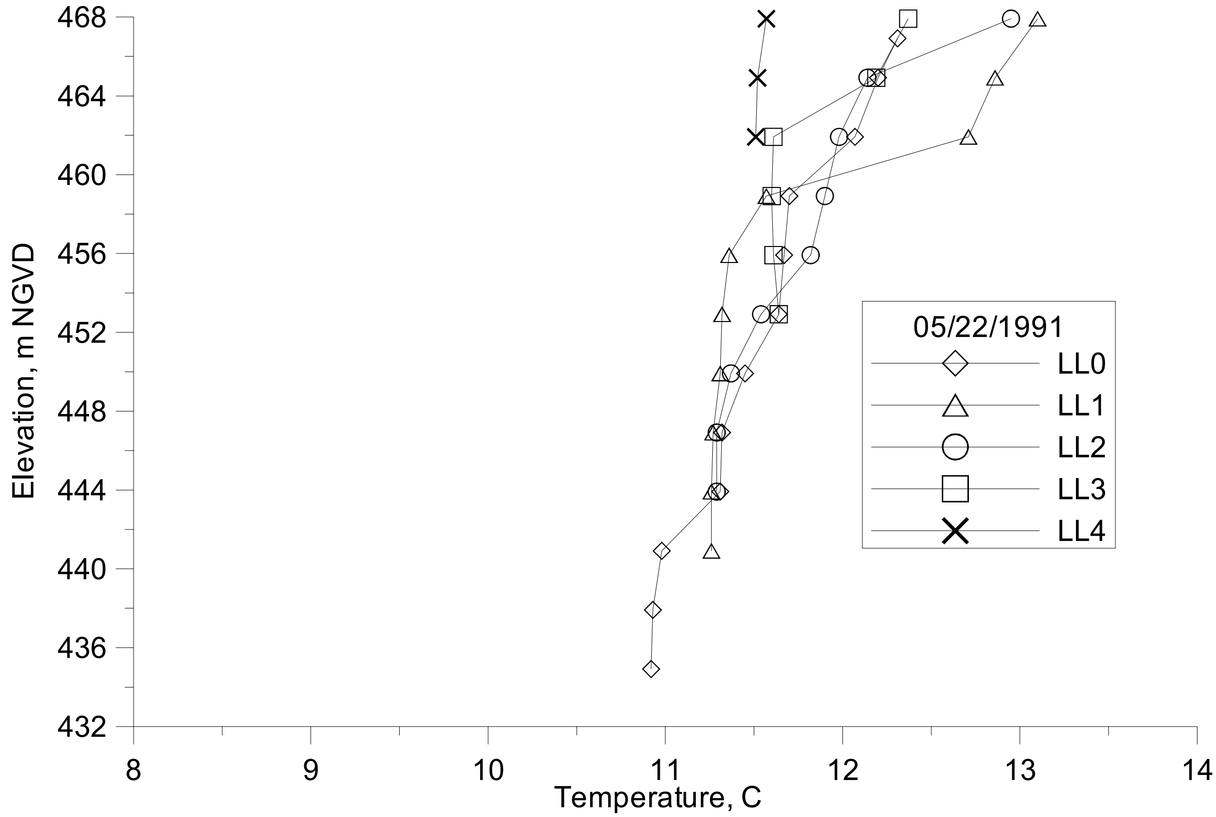
Elevation, m NGVD
SRP, mg/L


Elevation, m NGVD
TP, mg/L
04/24/1991
LL0
LL1
LL2
LL3
LL4

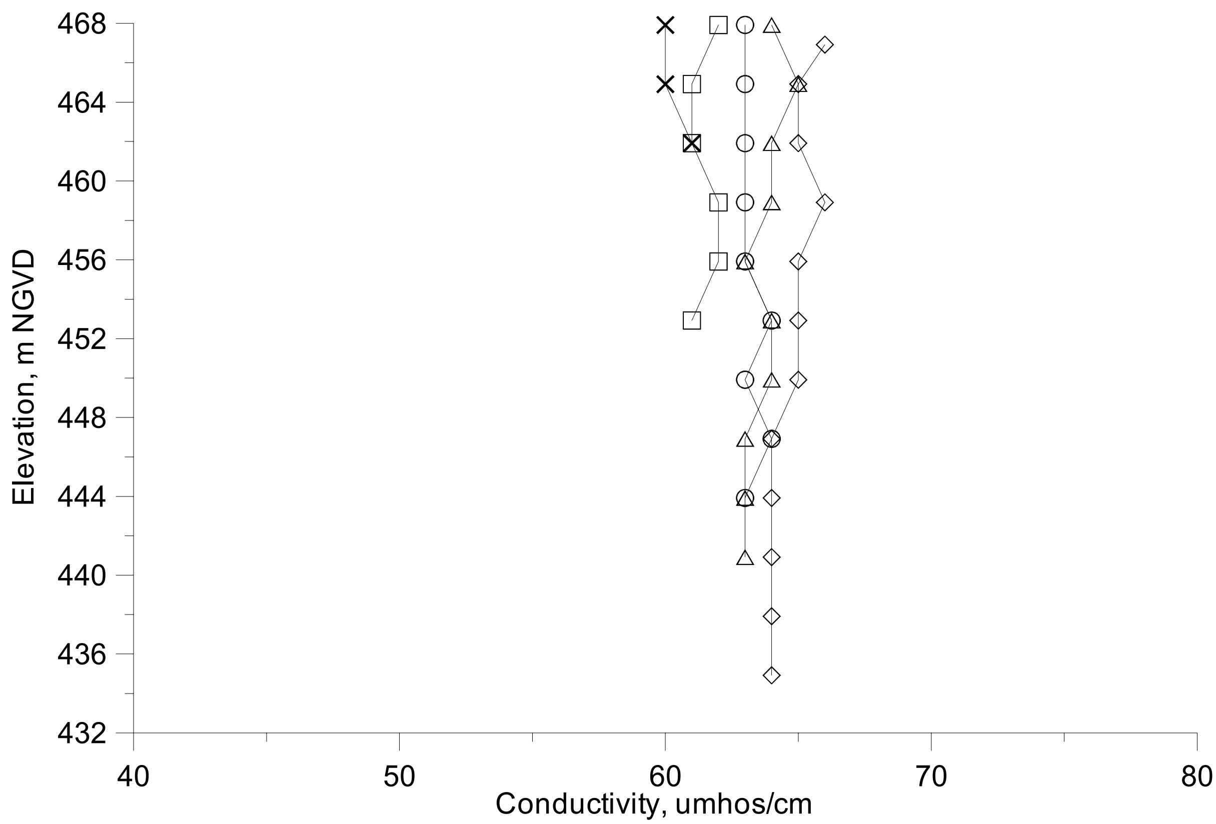

Elevation, m NGVD
TOP, mg/L



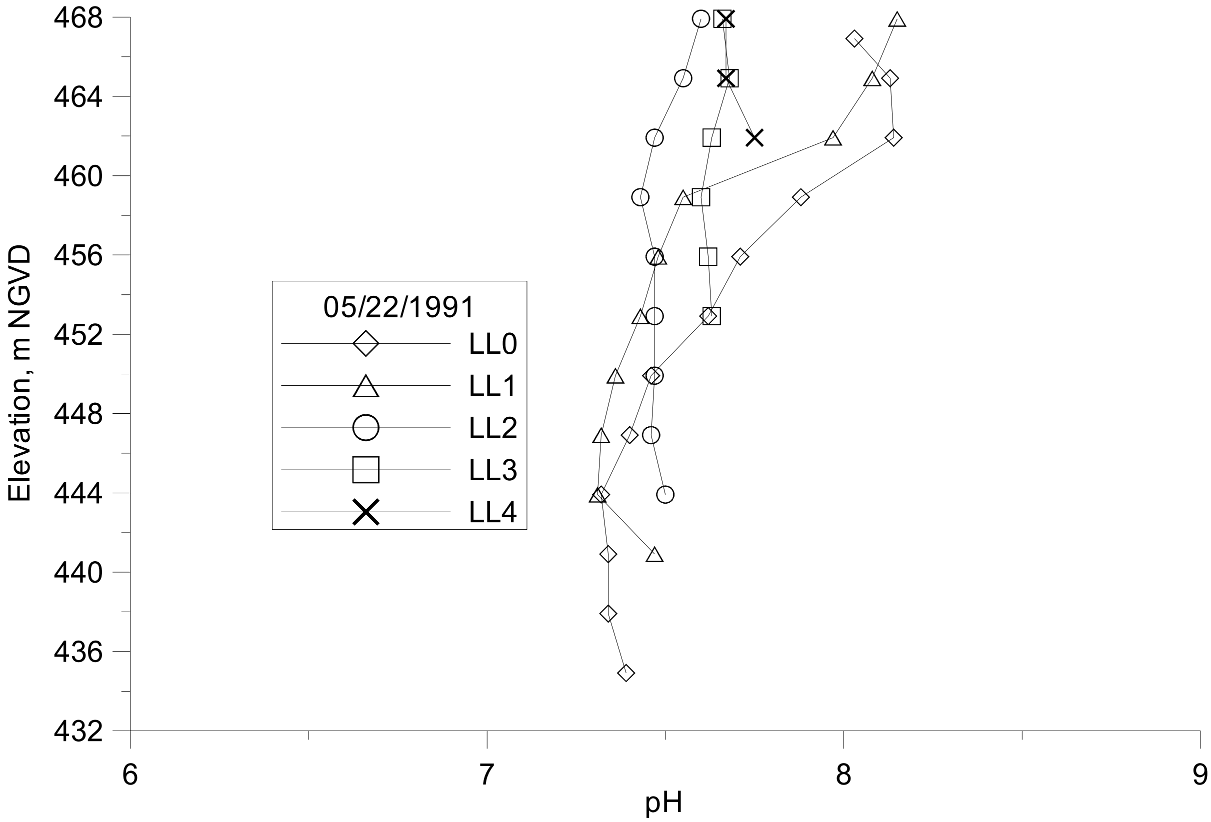
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
5
6
7
8
9
10
Turbidity, NTU
04/24/1991
LL0
LL1
LL2
LL3
LL4



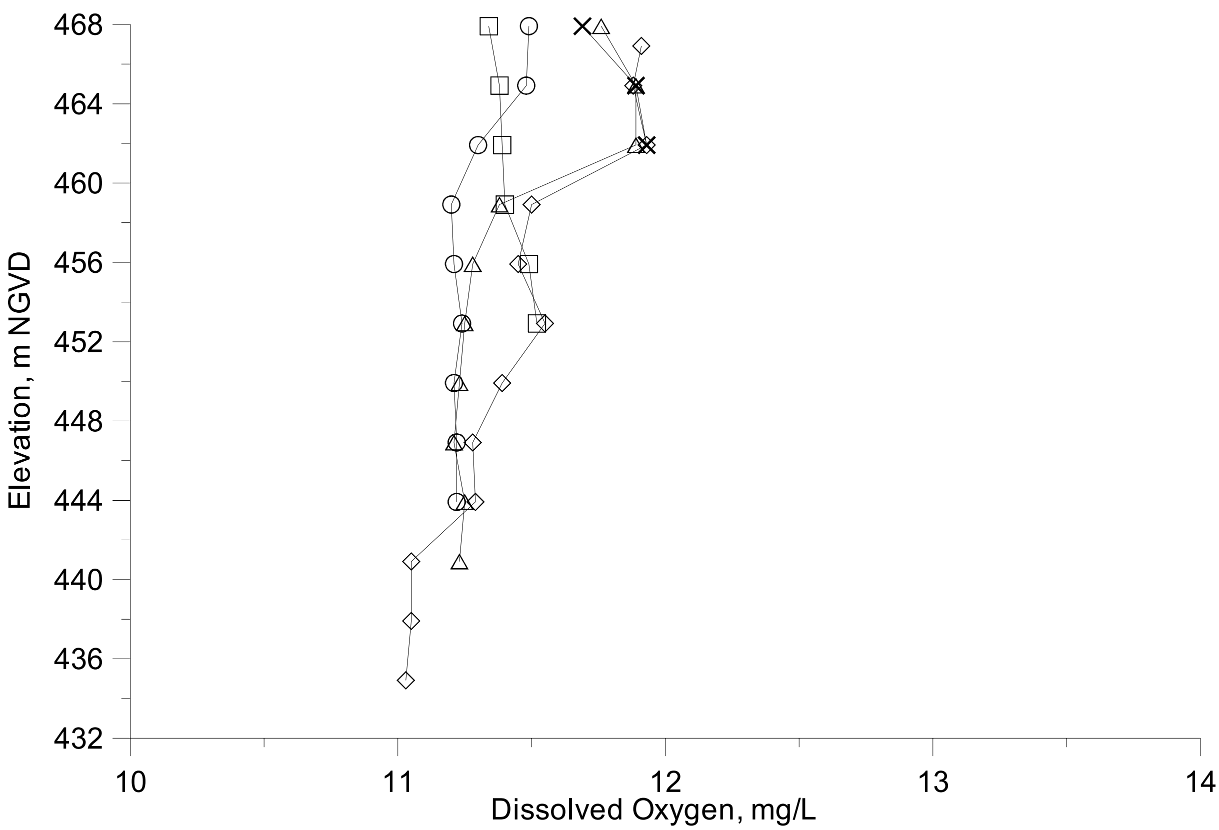
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
8
9
10
11
12
13
14
Temperature, C
05/22/1991
LL0
LL1
LL2
LL3
LL4



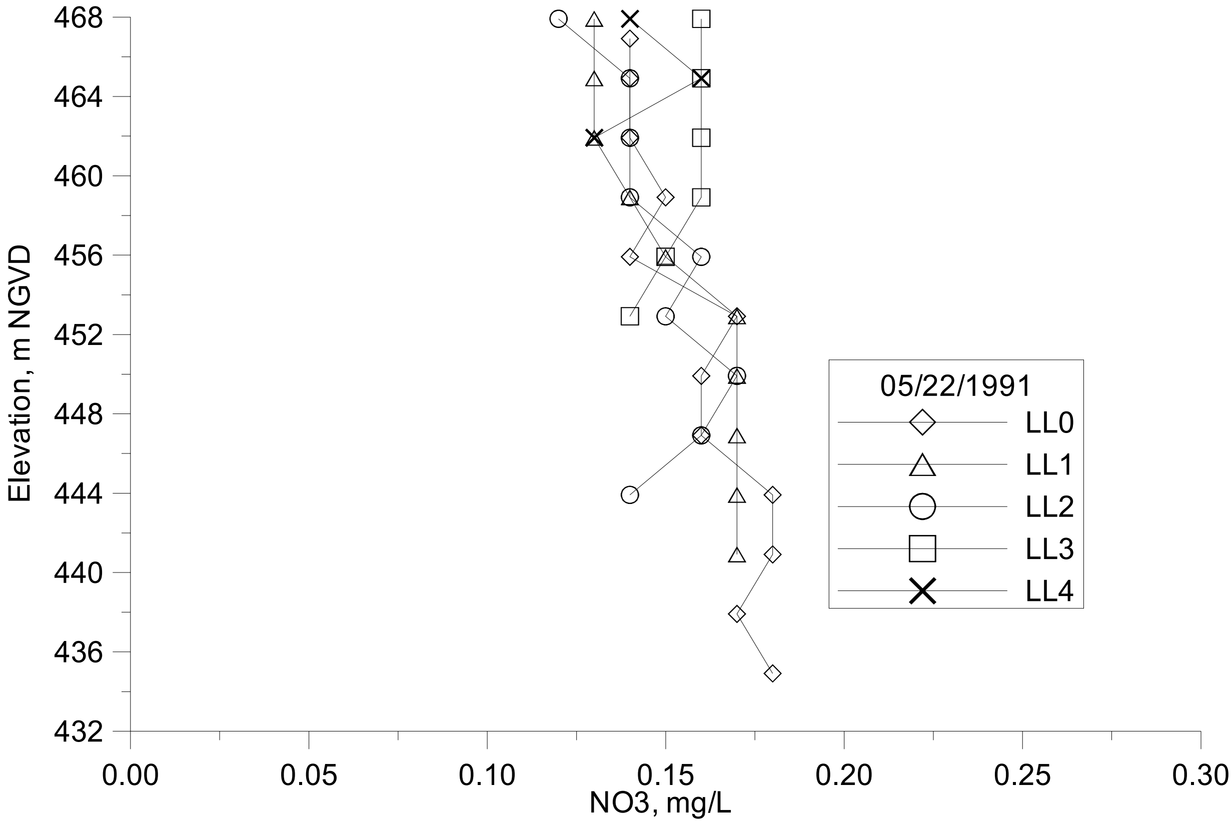
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
40
50
60
70
80
Conductivity, umhos/cm



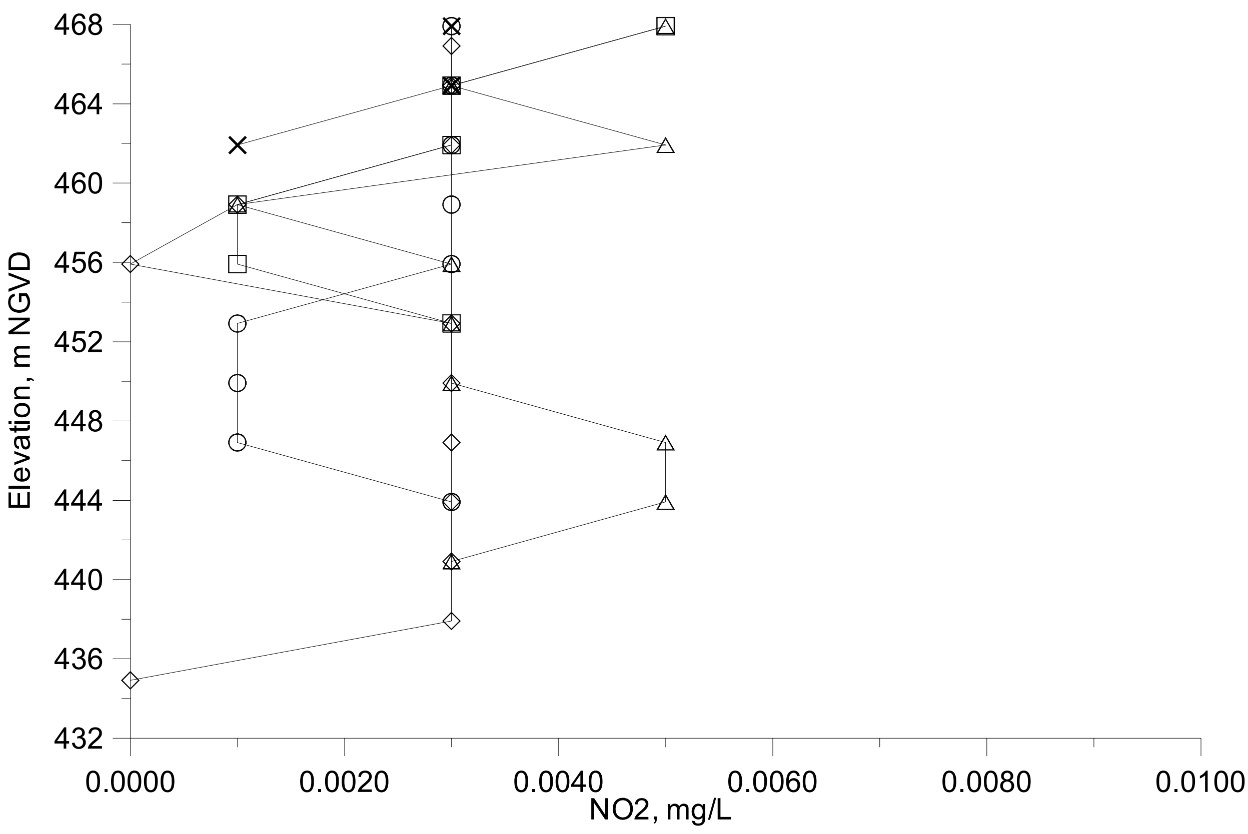
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
05/22/1991
LL0
LL1
LL2
LL3
LL4
6
7
8
9
pH



468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
10
11
12
13
14
Dissolved Oxygen, mg/L



468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.05
0.10
0.15
0.20
0.25
0.30
NO3, mg/L
05/22/1991
LL0
LL1
LL2
LL3
LL4



468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.0000
0.0020
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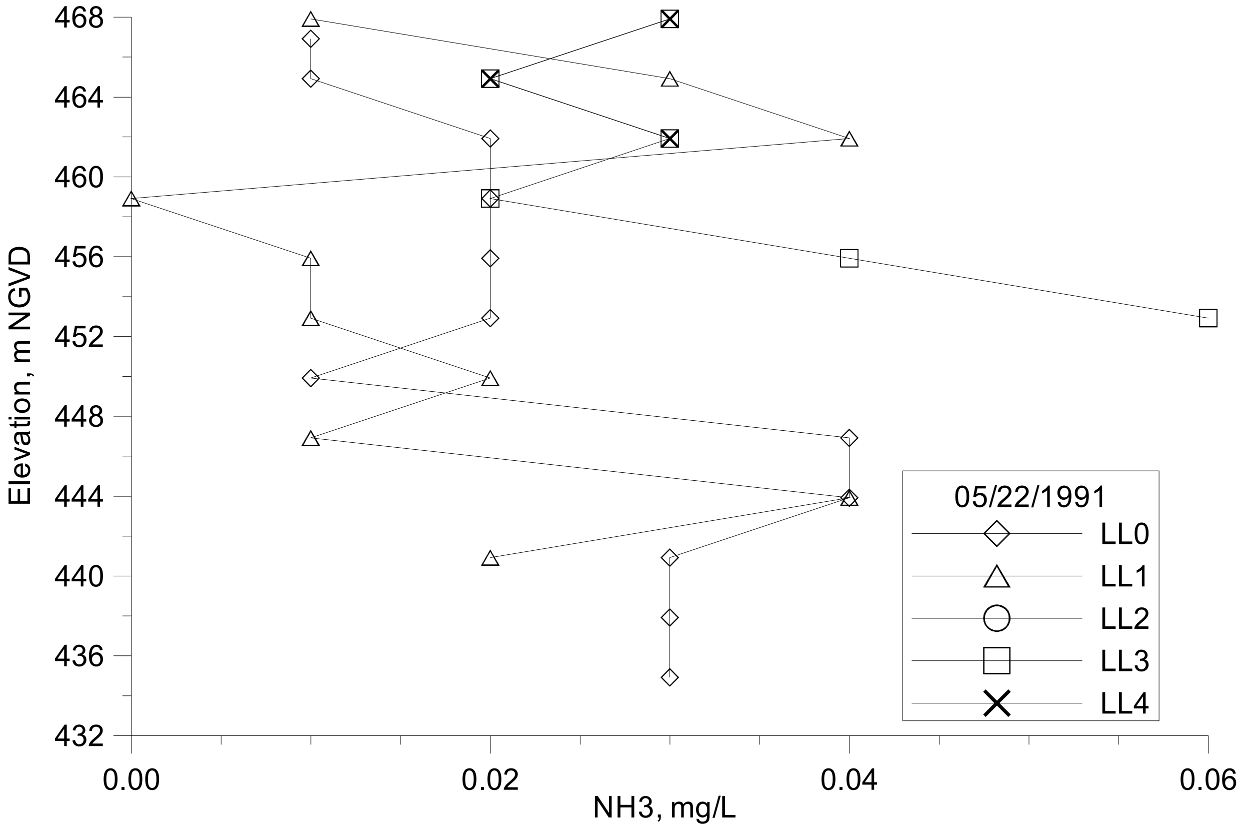
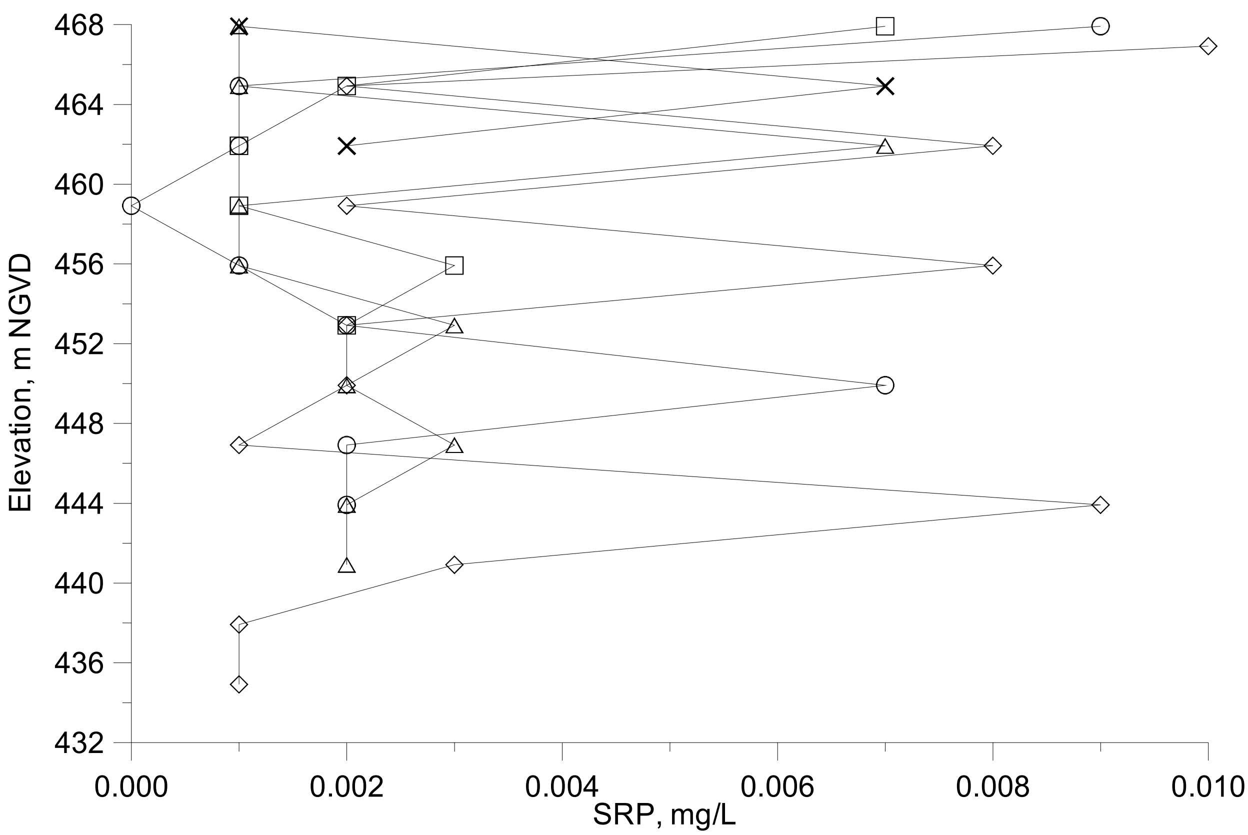
0.0060
0.0080
0.0100
NO2, mg/L


Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
0.00
0.02
0.04
0.06
NH3, mg/L
05/22/1991
LL0
LL1
LL2
LL3
LL4


Elevation, m NGVD
468
464
460
456
452
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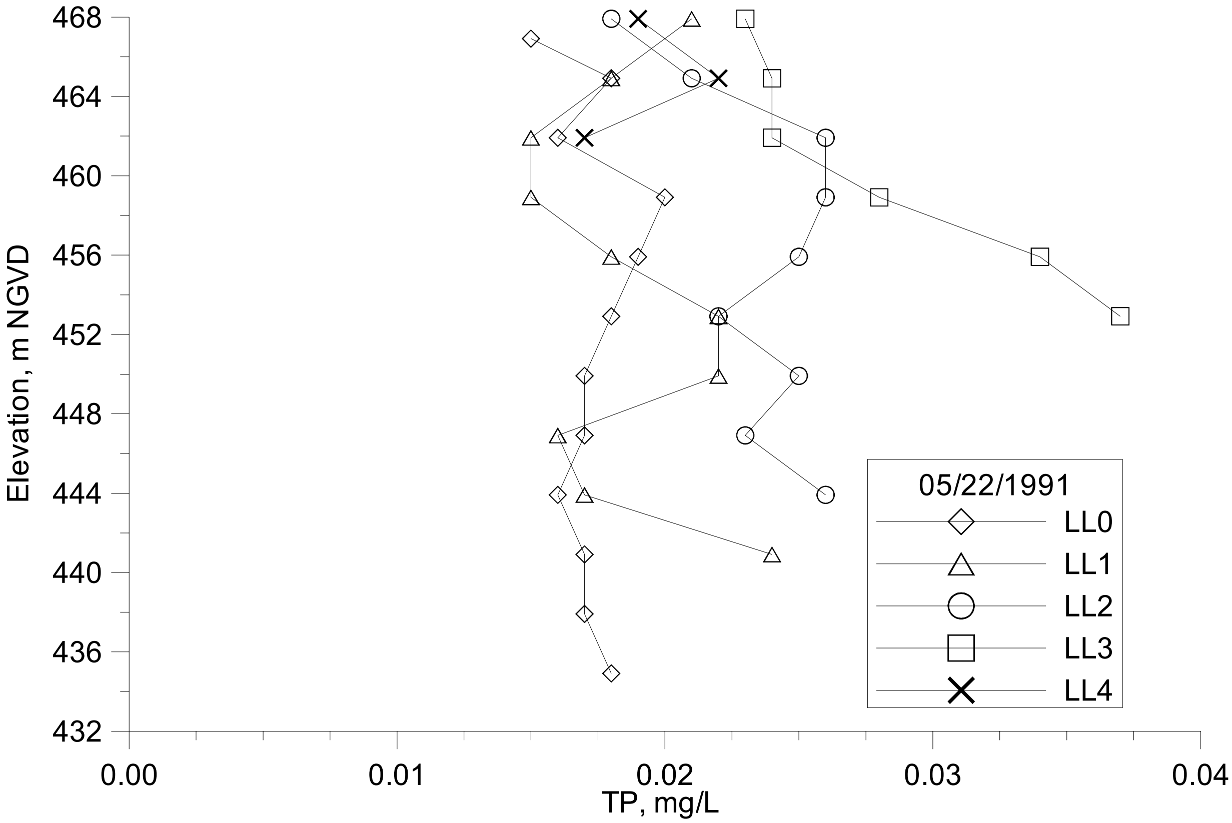
444
440
436
432
0.000
0.002
0.004
0.006
0.008
0.010
SRP, mg/L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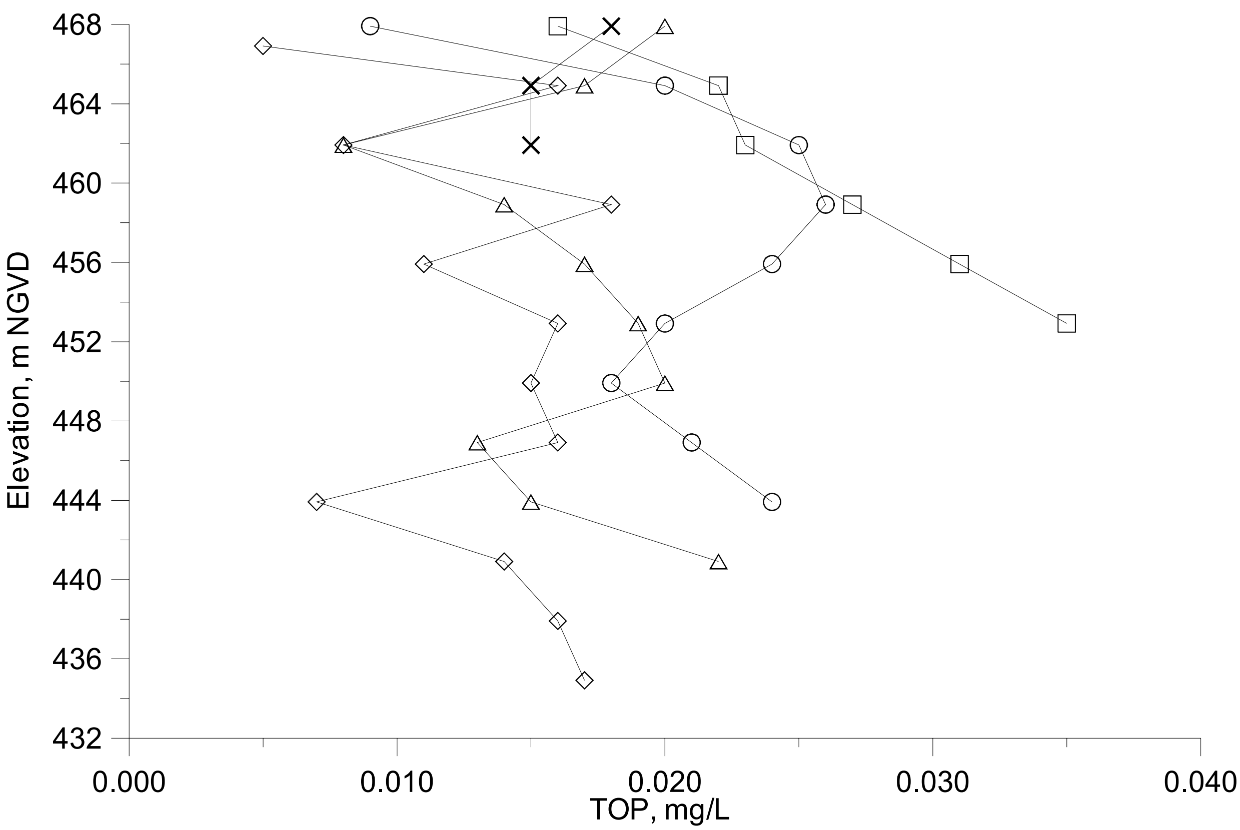
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
TP, mg/L
05/22/1991
LL0
LL1
LL2
LL3
LL4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464
460
456
452
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444
440
436
432
Elevation, m NGVD
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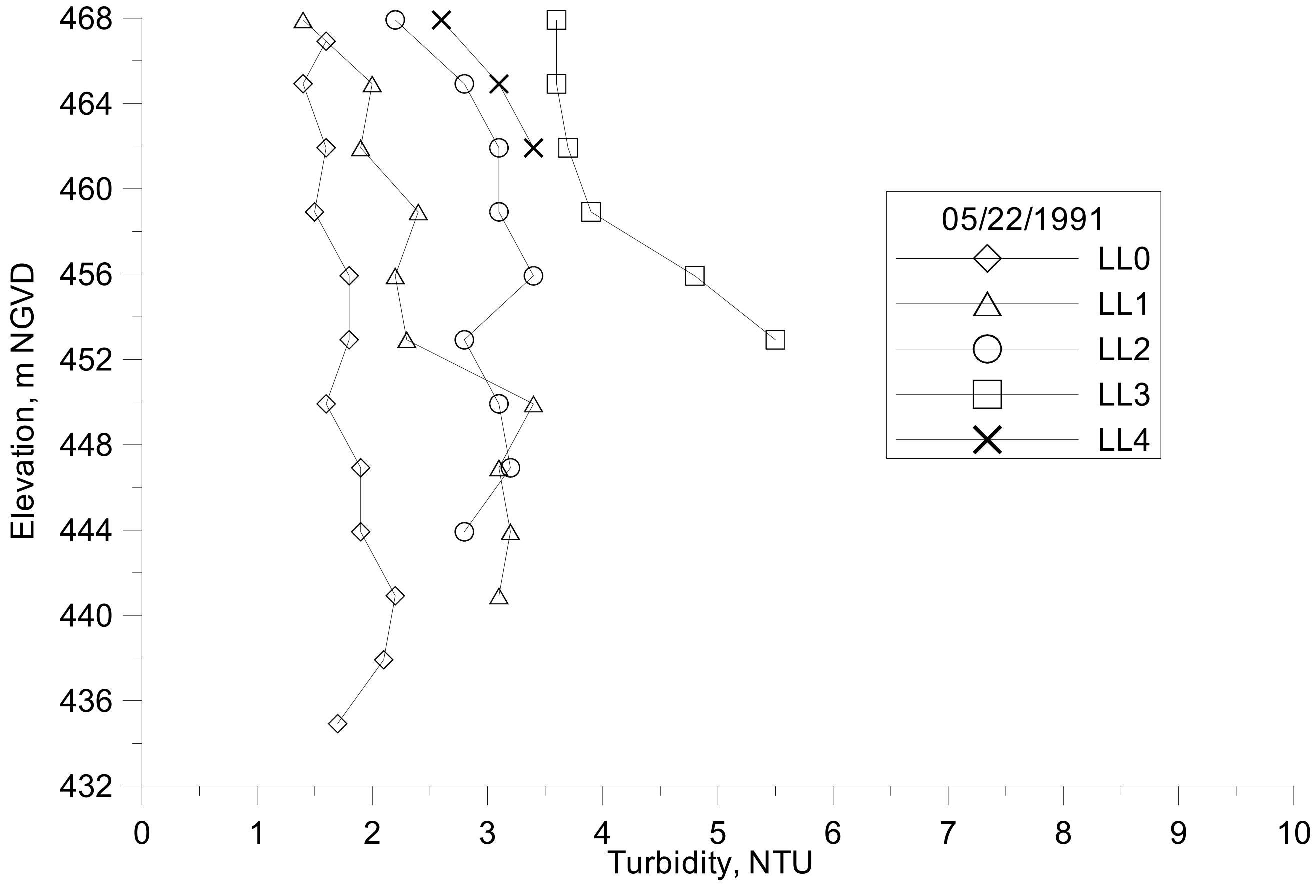
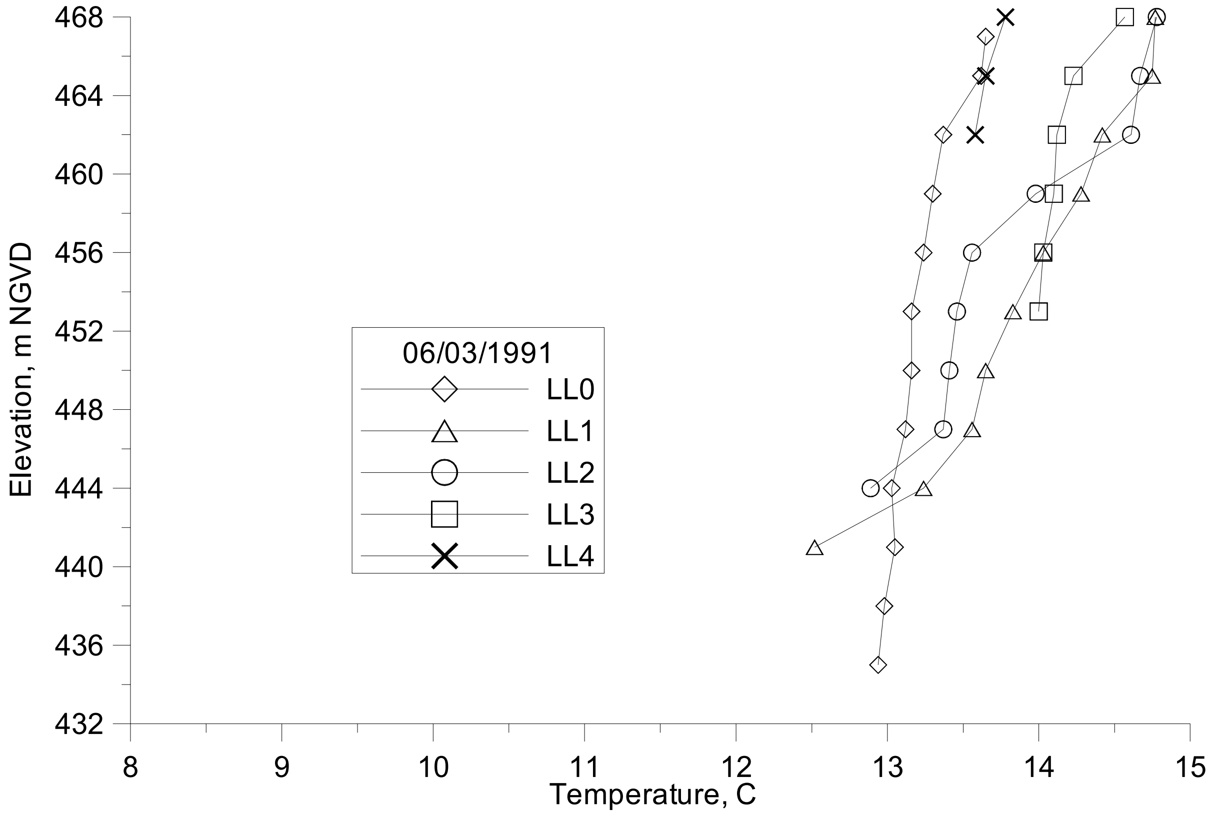
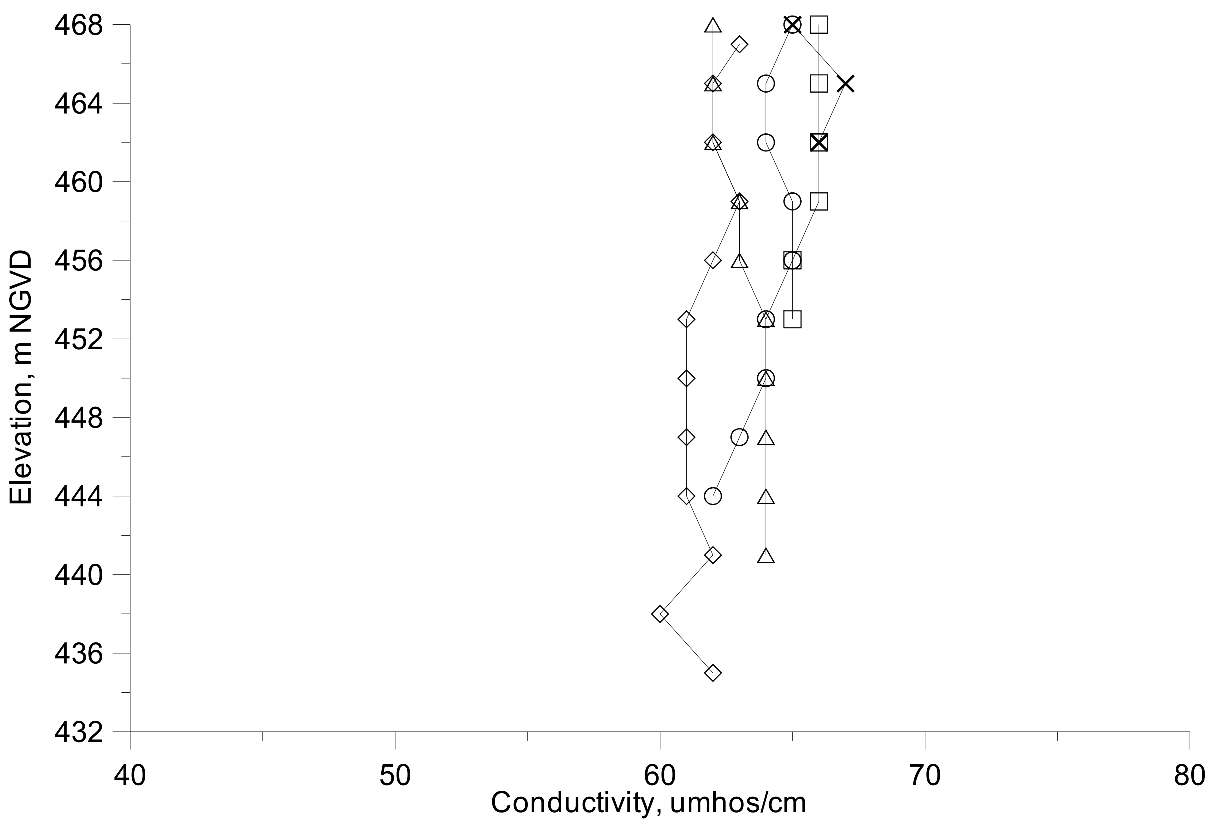
0.010
0.020
0.030
0.040
TOP, mg/L



468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
5
6
7
8
9
10
Turbidity, NTU
05/22/1991
LL0
LL1
LL2
LL3
LL4


468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
8
9
10
11
12
13
14
15
Temperature, C
06/03/1991
LL0
LL1
LL2
LL3
LL4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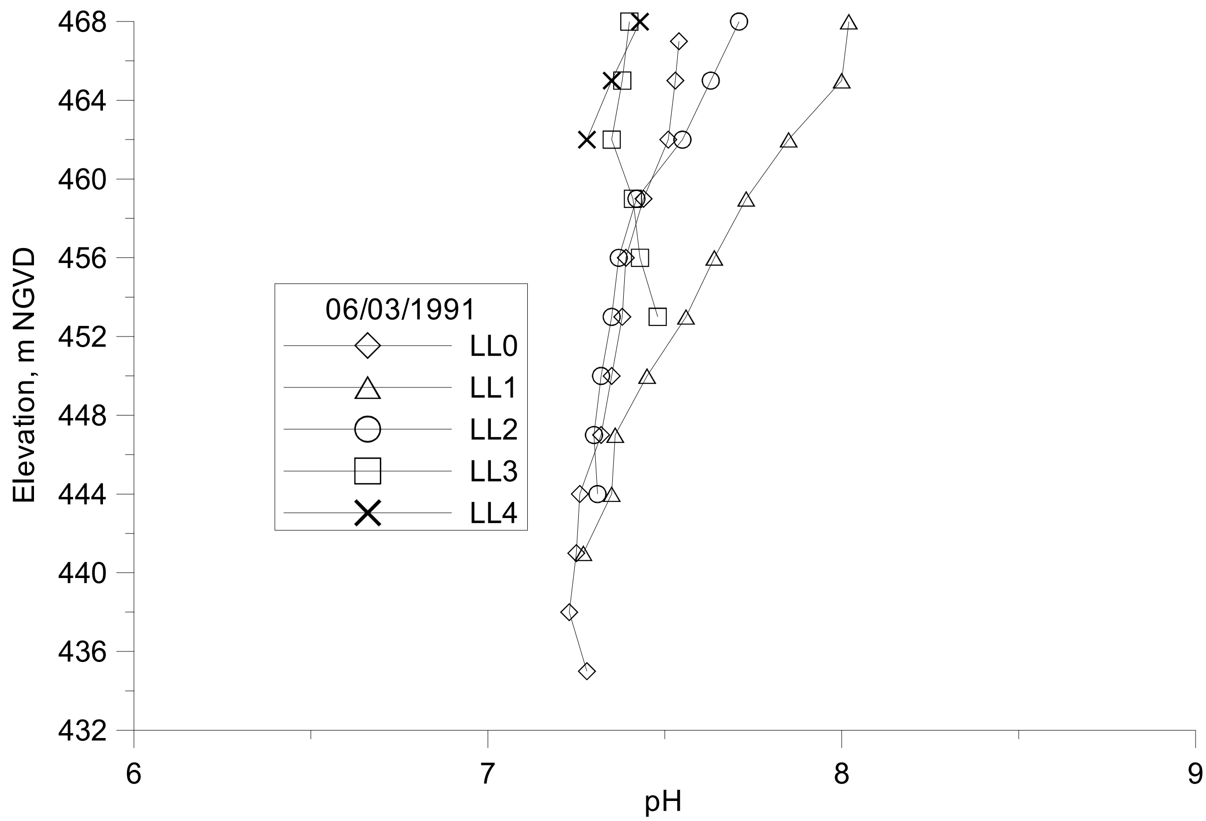
448
444
440
436
432
Elevation, m NGVD
40
50
60
70
80
Conductivity, umhos/cm


468
464
460
456
452
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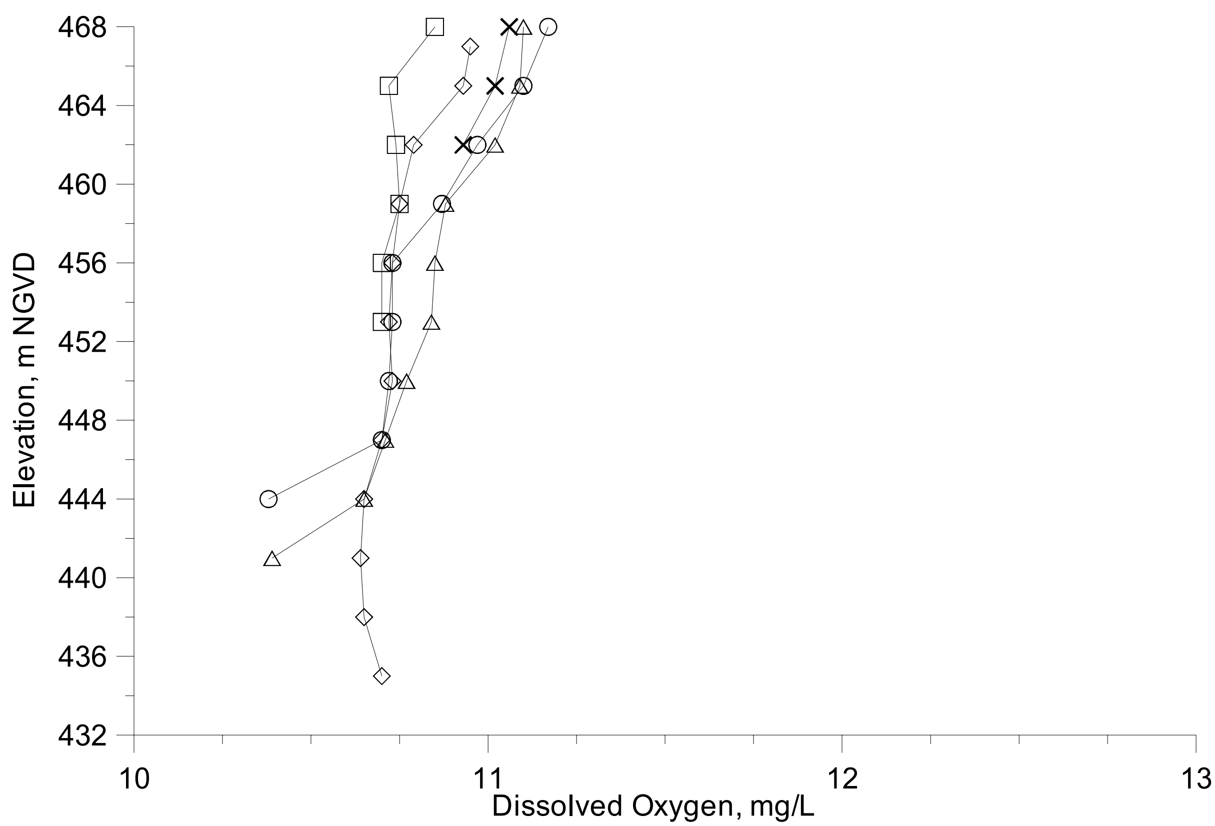
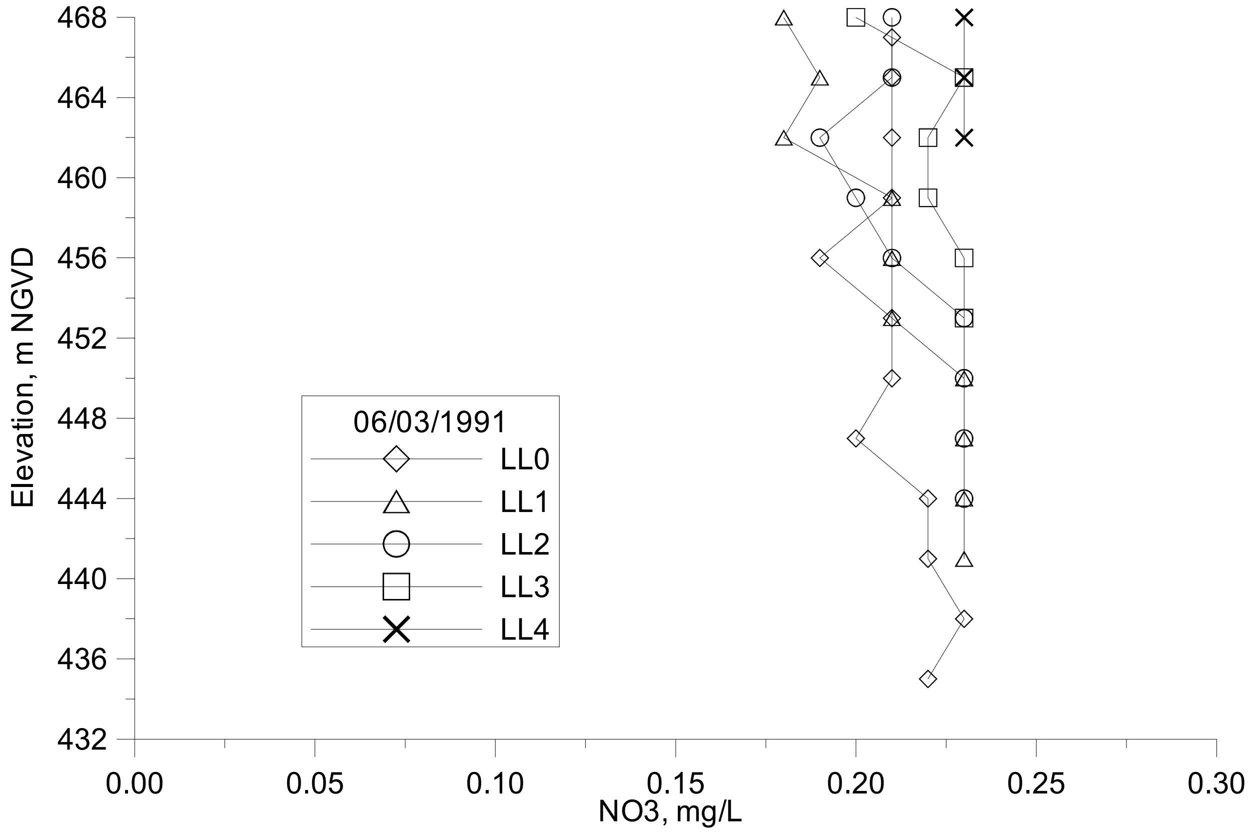
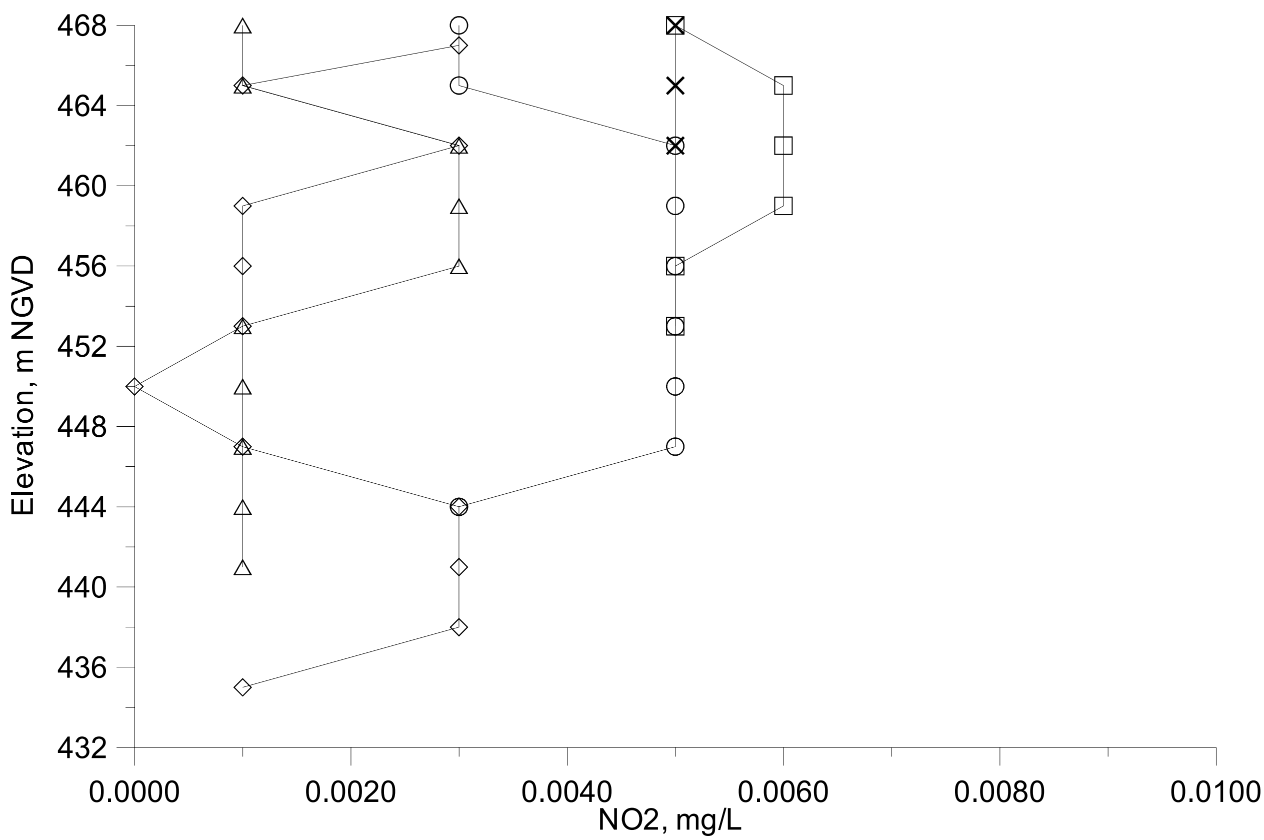
436
432
Elevation, m NGVD
06/03/1991
LL0
LL1
LL2
LL3
LL4
6
7
8
9
pH


468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
10
11
12
13
Dissolved Oxygen, mg/L


06/03/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NO3, mg/L
468
464
460
456
452
448
444
440
436
432
0.00
0.05
0.10
0.15
0.20
0.25
0.30


Elevation, m NGVD
NO2, mg/L
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464
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452
448
444
440
436
432
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0.0060
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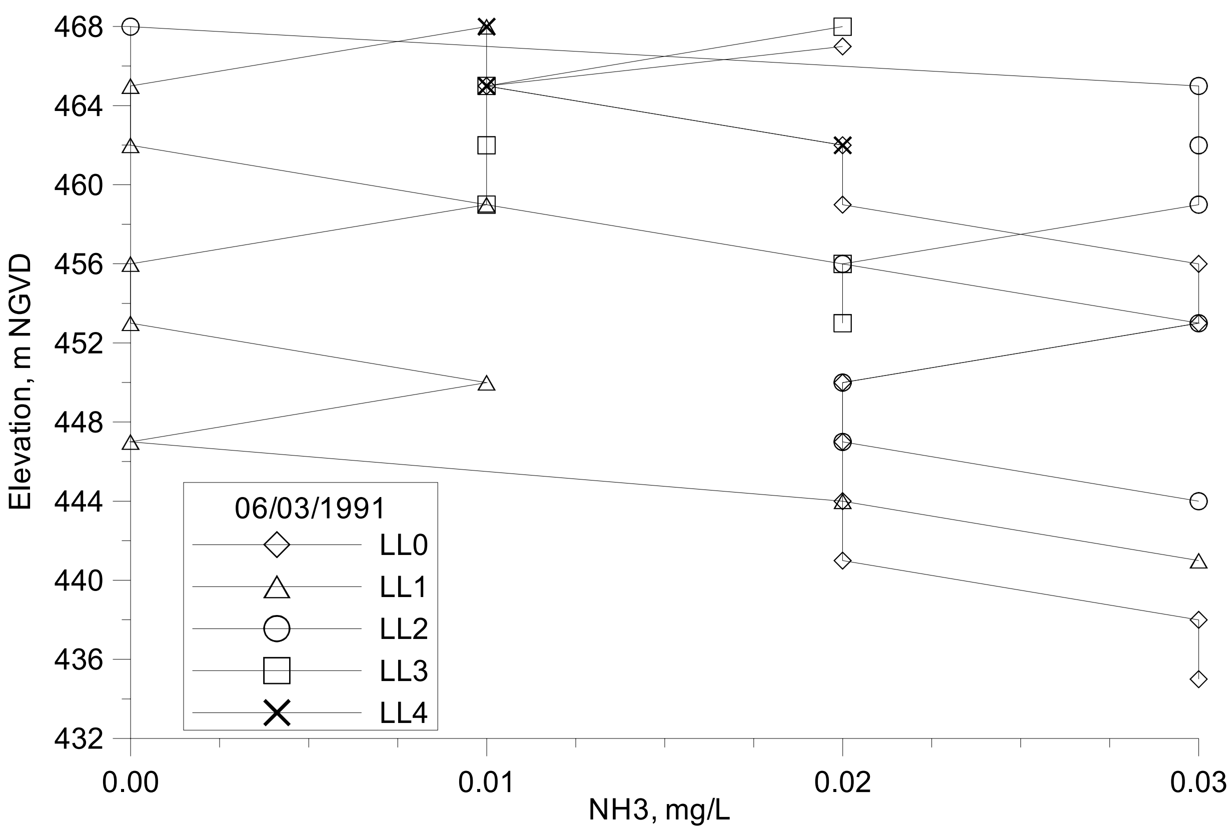
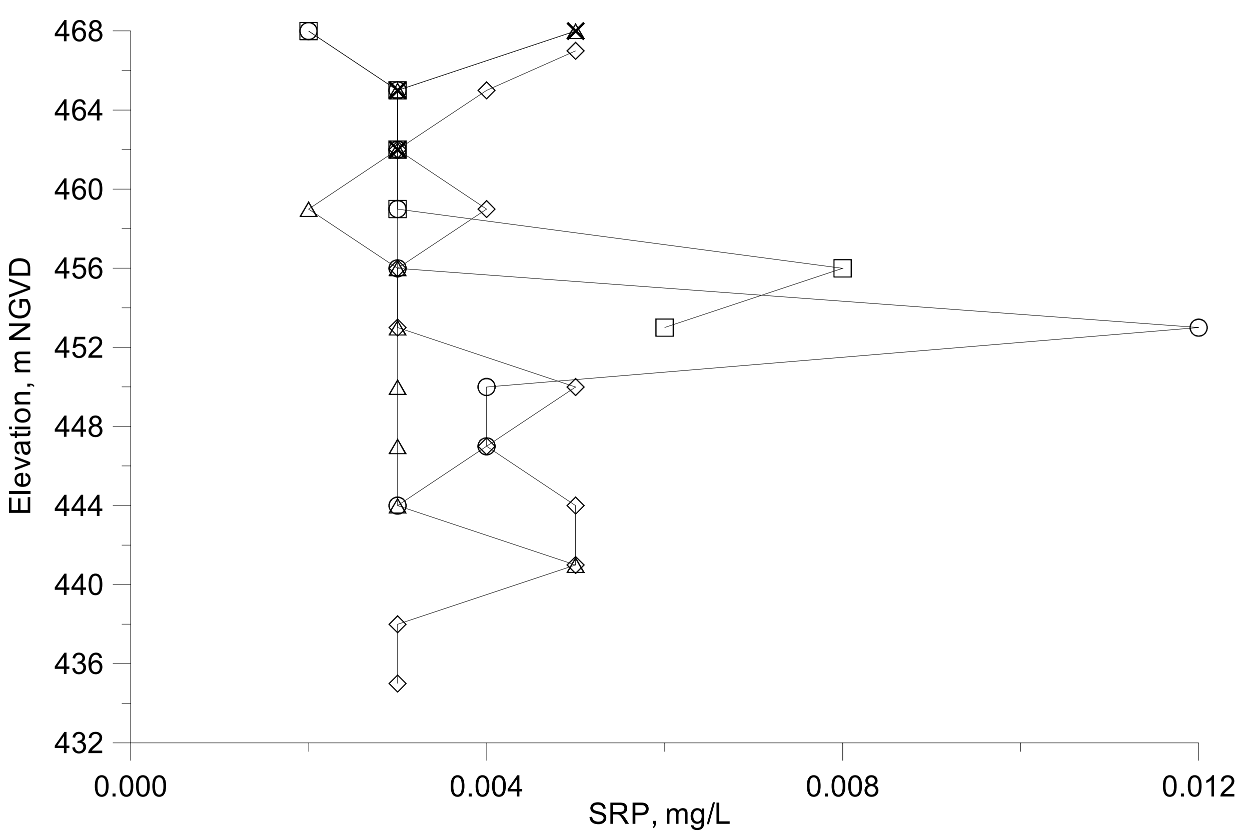
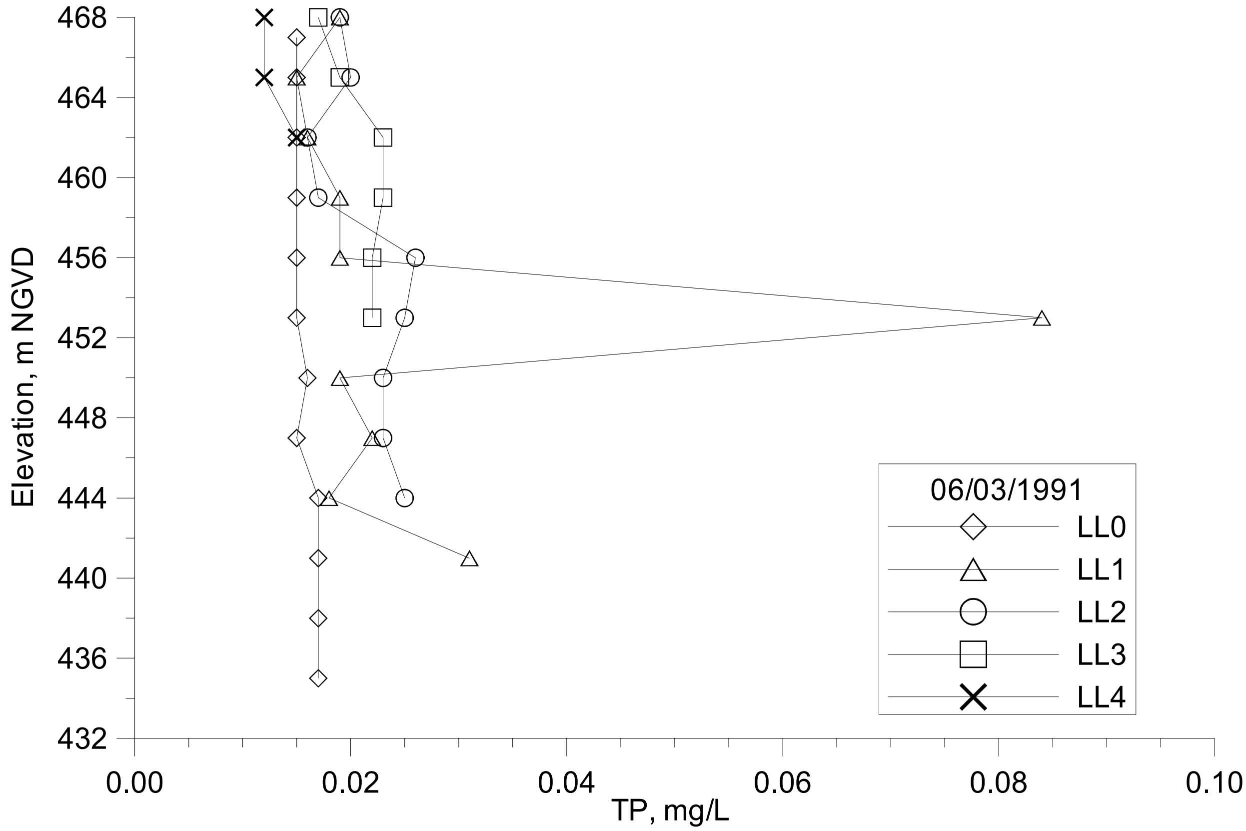
0.0100



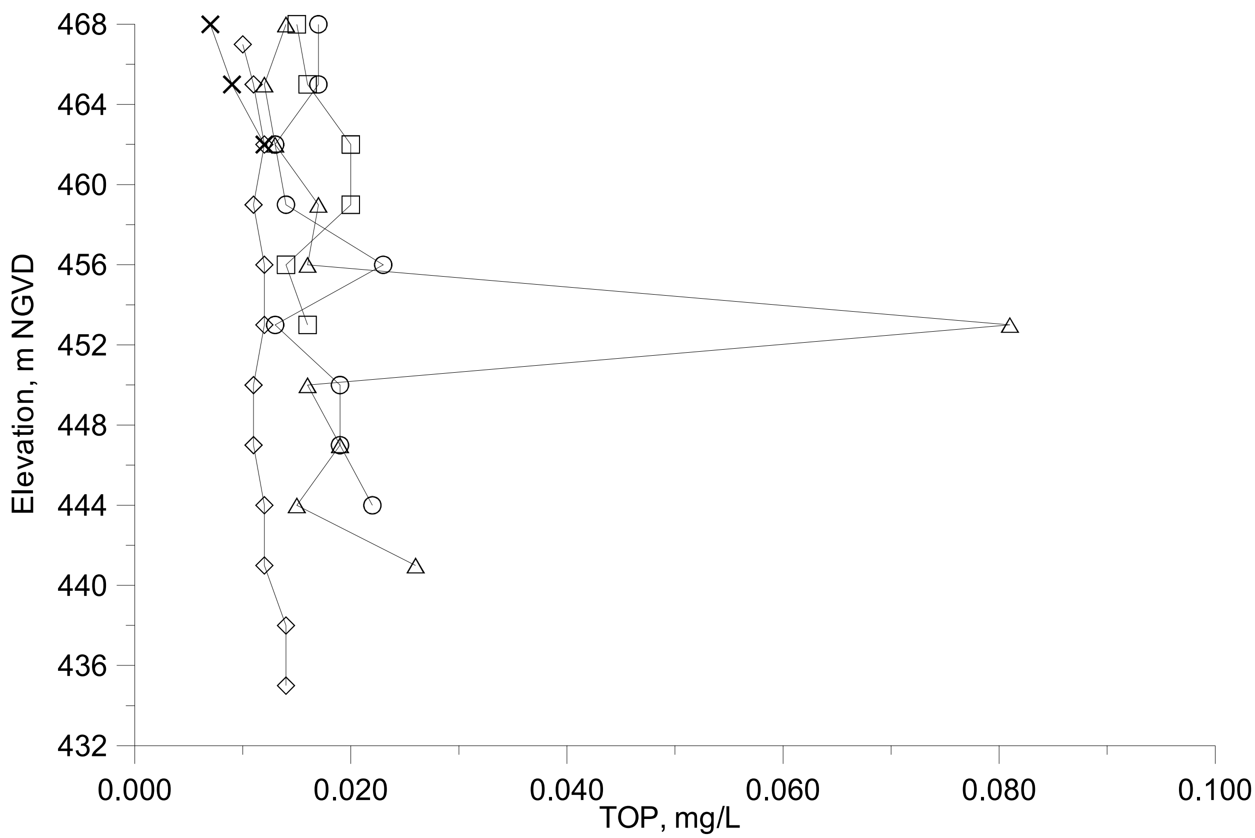
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
06/03/1991
LL0
LL1
LL2
LL3
LL4
0.00
0.01
0.02
0.03
NH3, mg/L



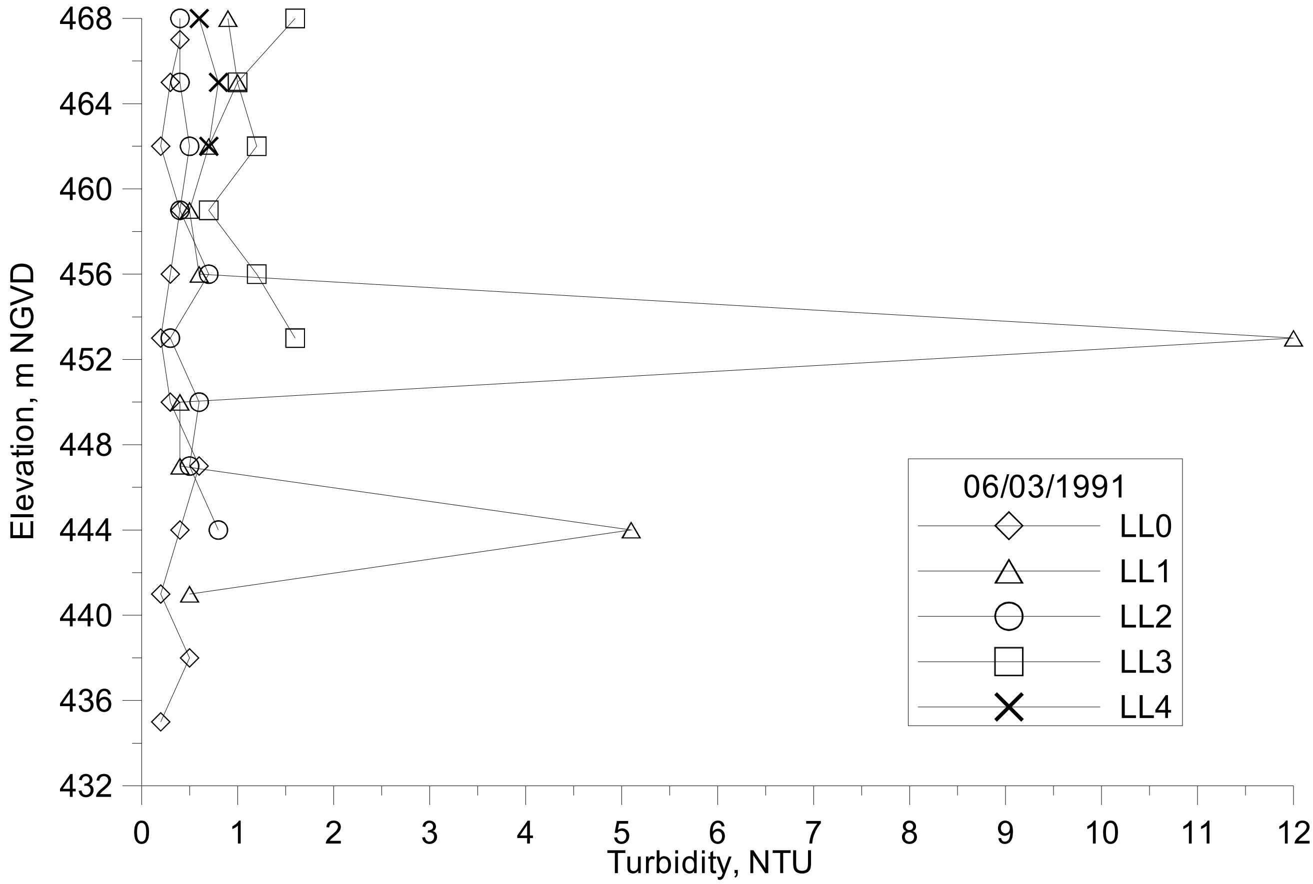
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.004
0.008
0.012
SRP, mg/L



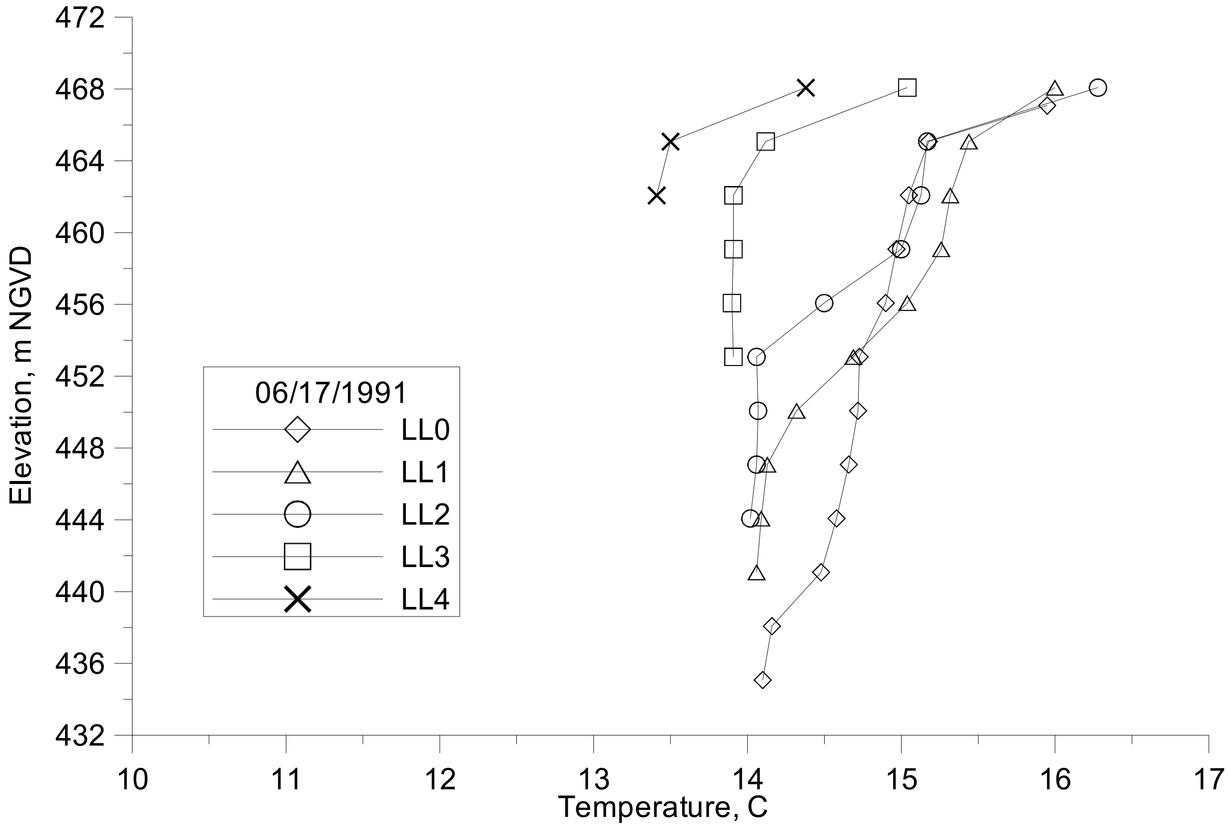
Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
0.00
0.02
0.04
0.06
0.08
0.10
TP, mg/L
06/03/1991
LL0
LL1
LL2
LL3
LL4



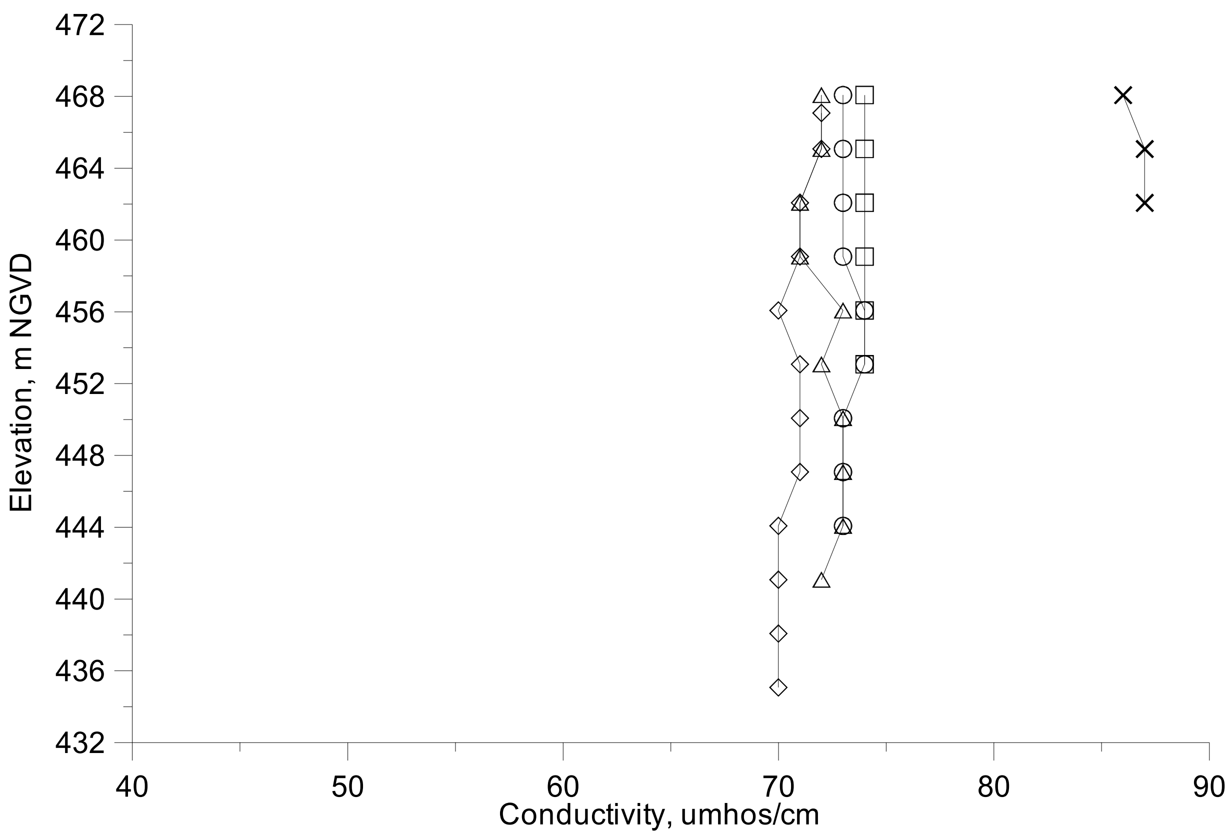
Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
0.000
0.020
0.040
0.060
0.080
0.100
TOP, mg/L



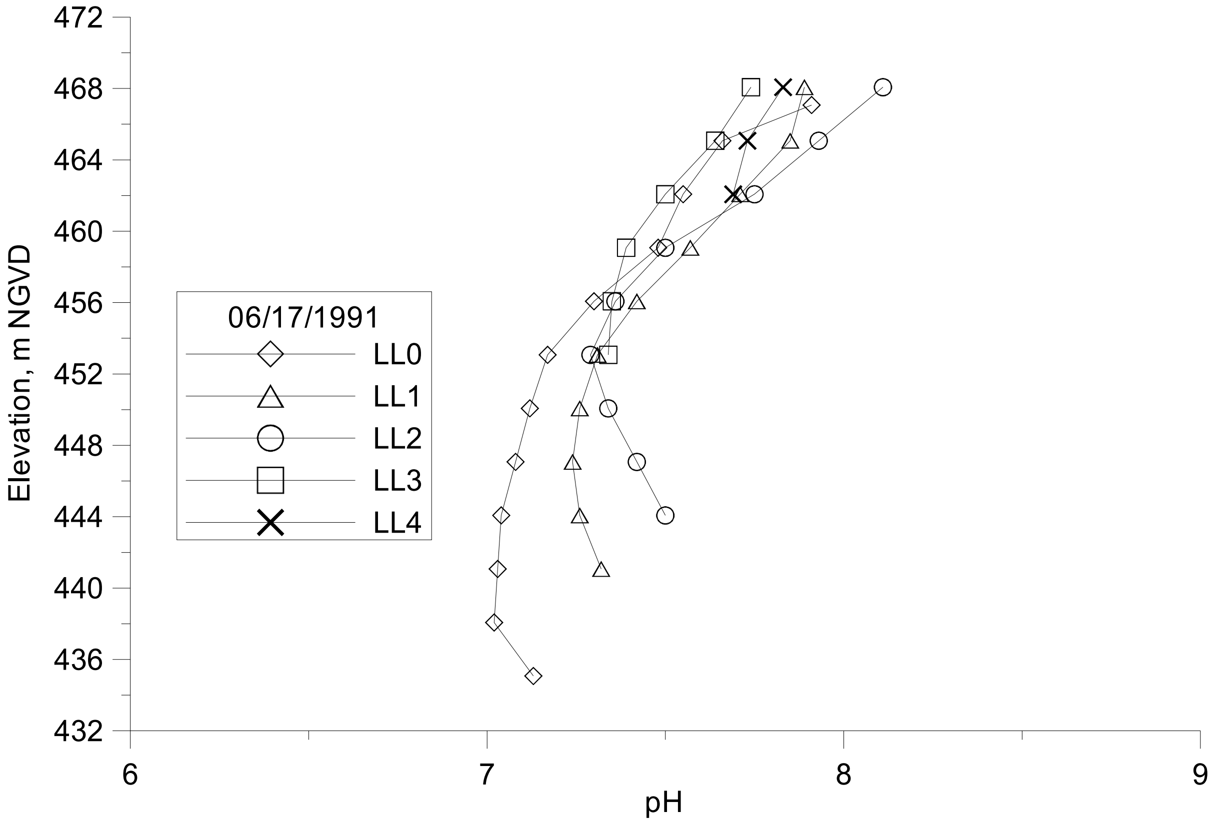
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
5
6
7
8
9
10
11
12
Turbidity, NTU
06/03/1991
LL0
LL1
LL2
LL3
LL4



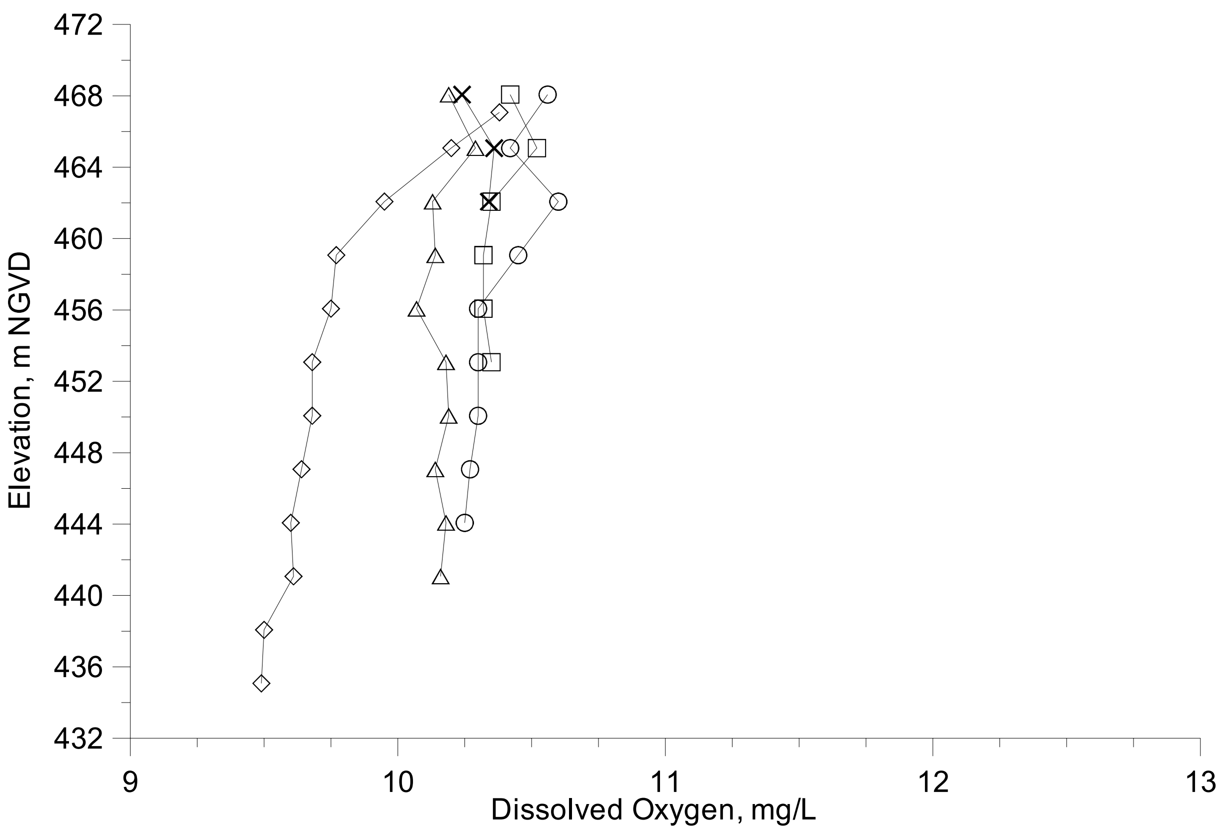
06/17/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Temperature, C



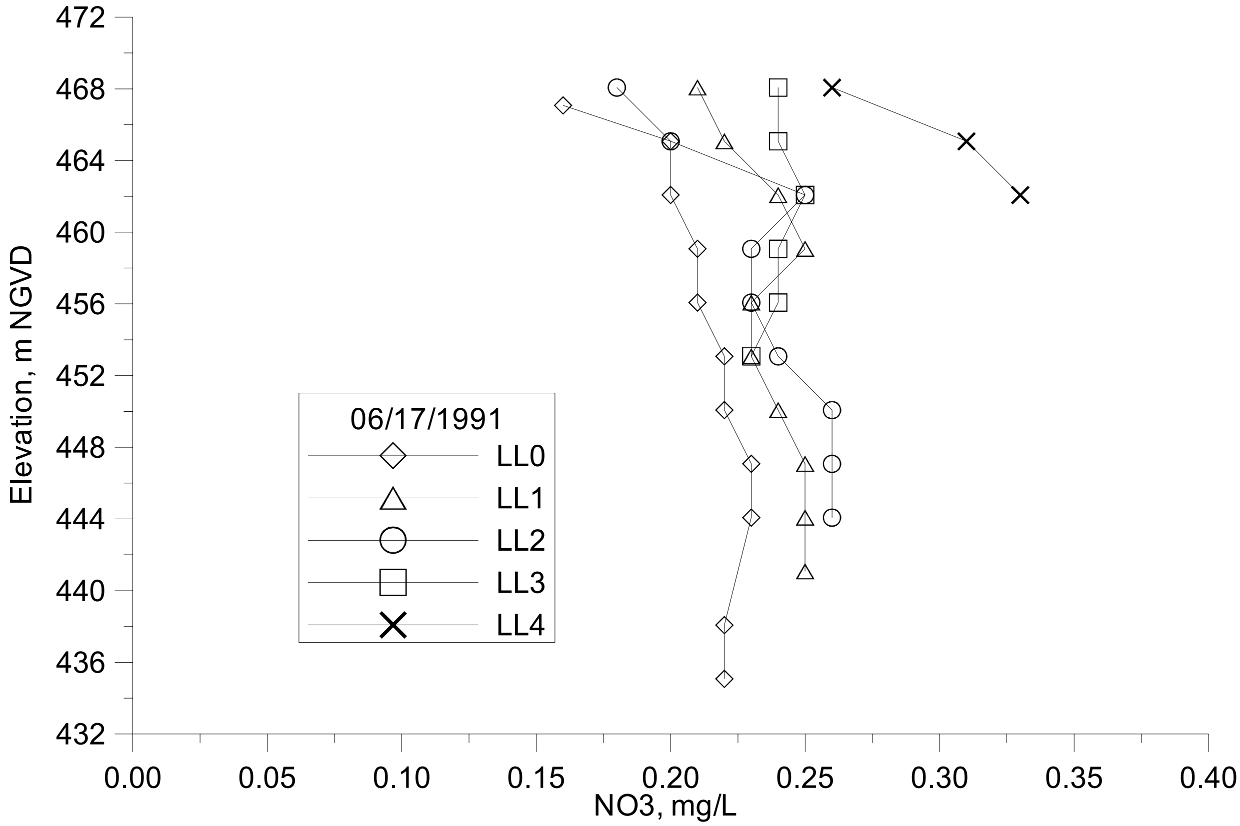
Elevation, m NGVD
Conductivity, umhos/cm

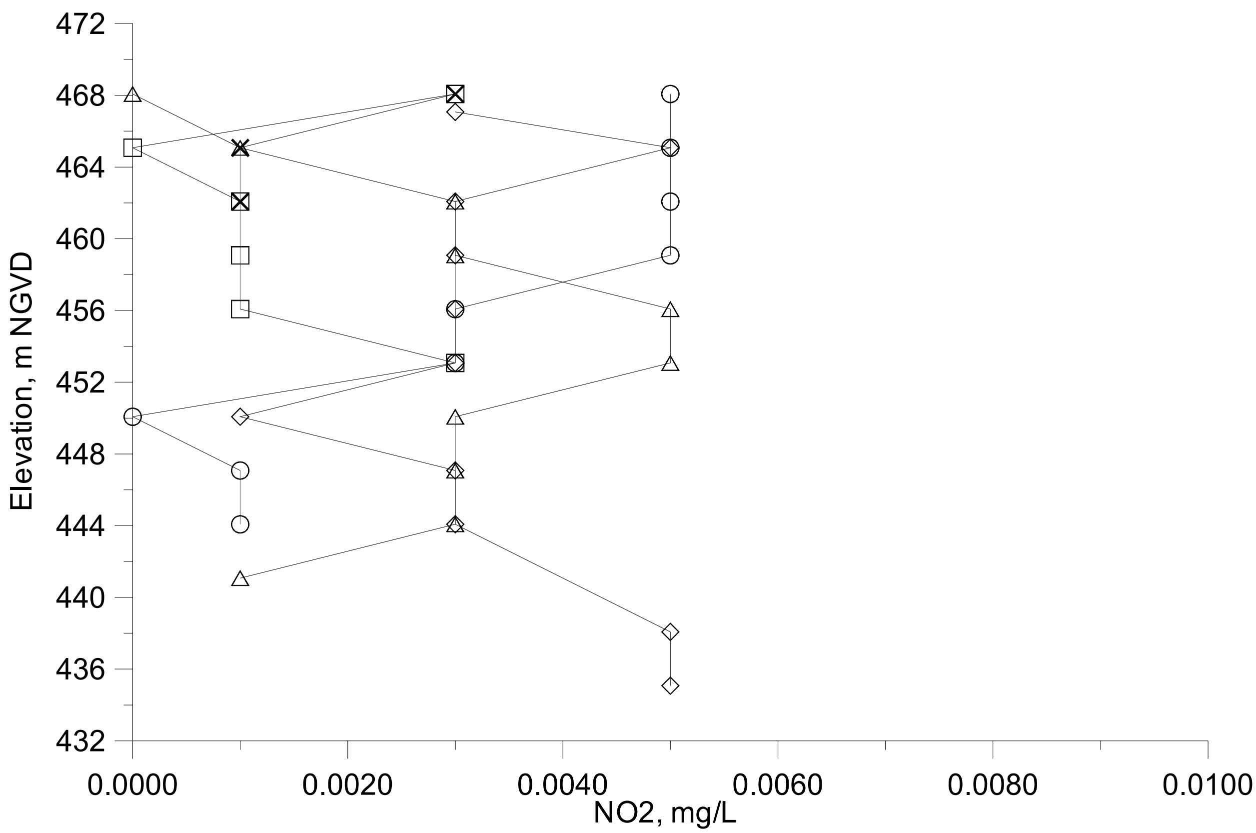


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
06/17/1991
LL0
LL1
LL2
LL3
LL4
6
7
8
9
pH



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
9
10
11
12
13
Dissolved Oxygen, mg/L


06/17/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NO3, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40


Elevation, m NGVD
NO2, mg/L
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452
448
444
440
436
432
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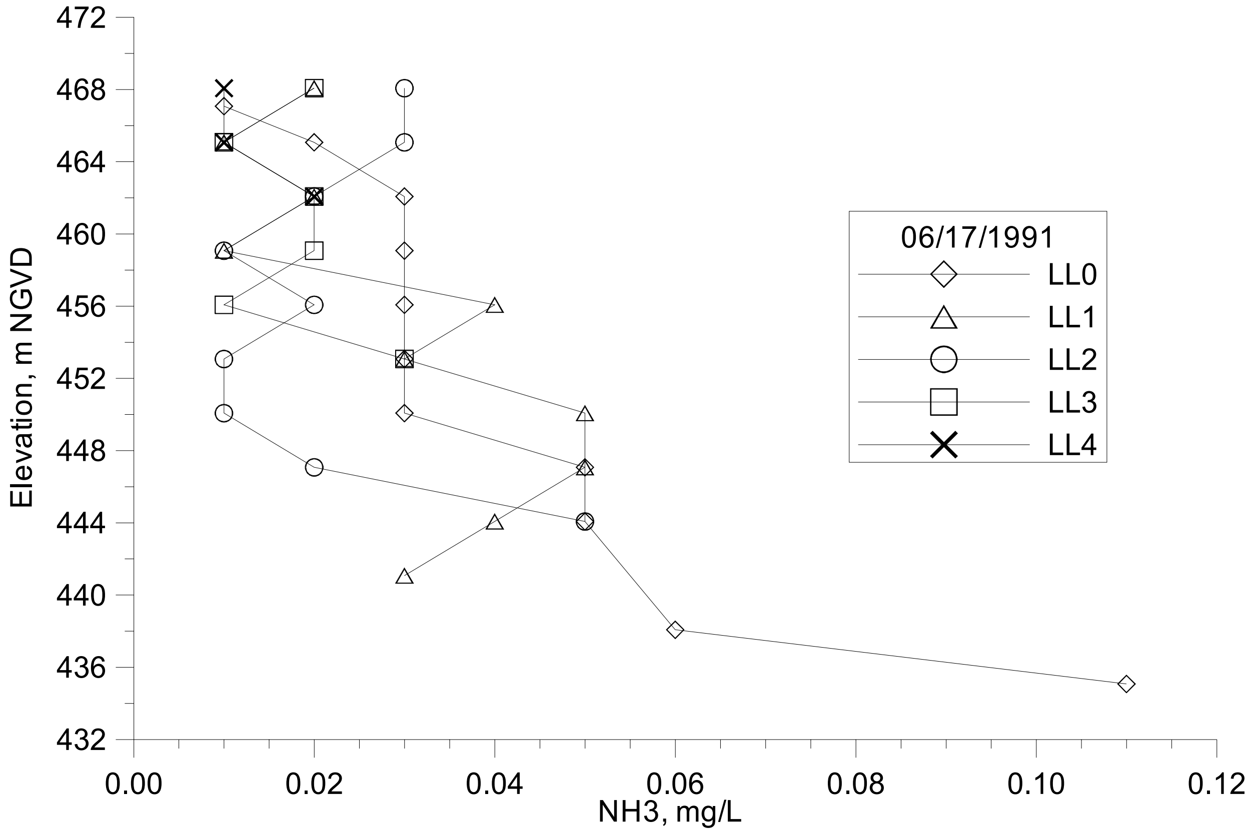
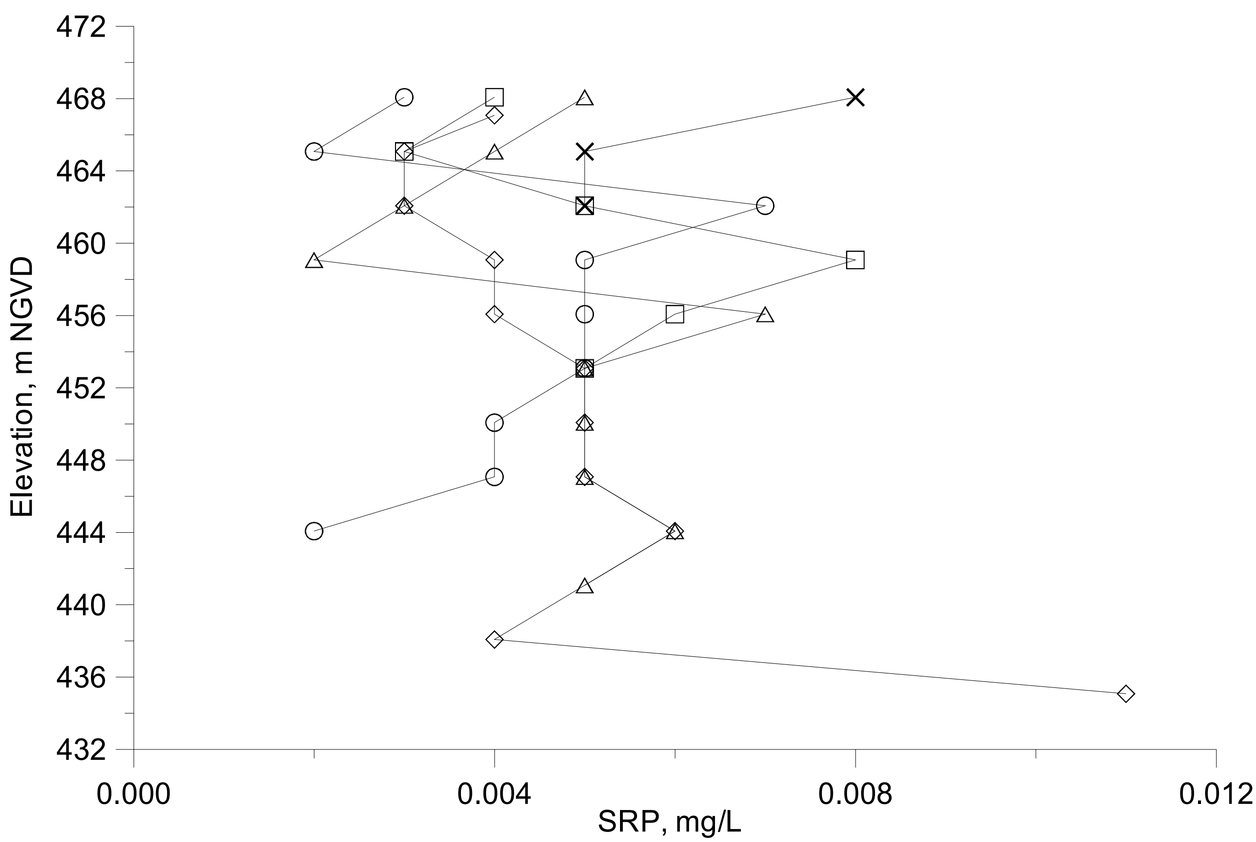
0.0040
0.0060
0.0080
0.0100


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.02
0.04
0.06
0.08
0.10
0.12
NH3, mg/L
06/17/1991
LL0
LL1
LL2
LL3
LL4


472
468
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460
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452
448
444
440
436
432
Elevation, m NGVD
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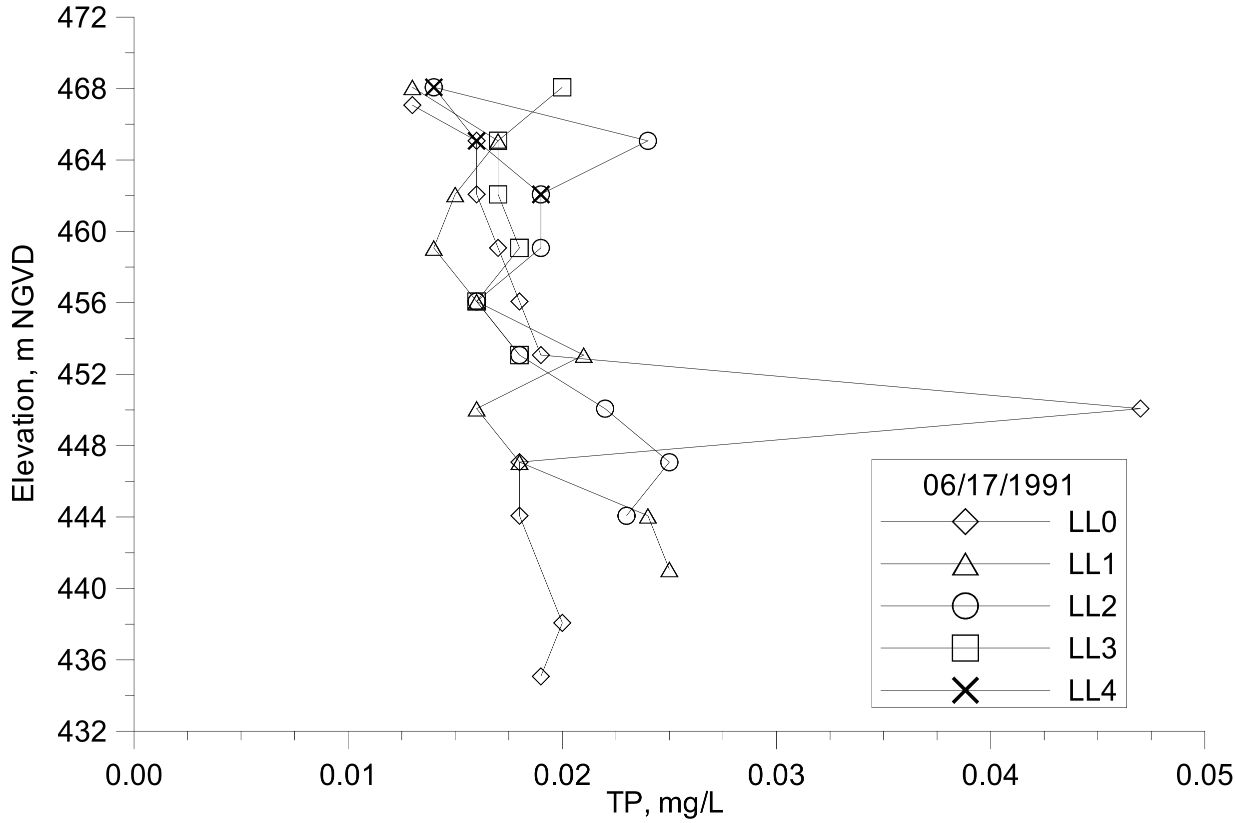
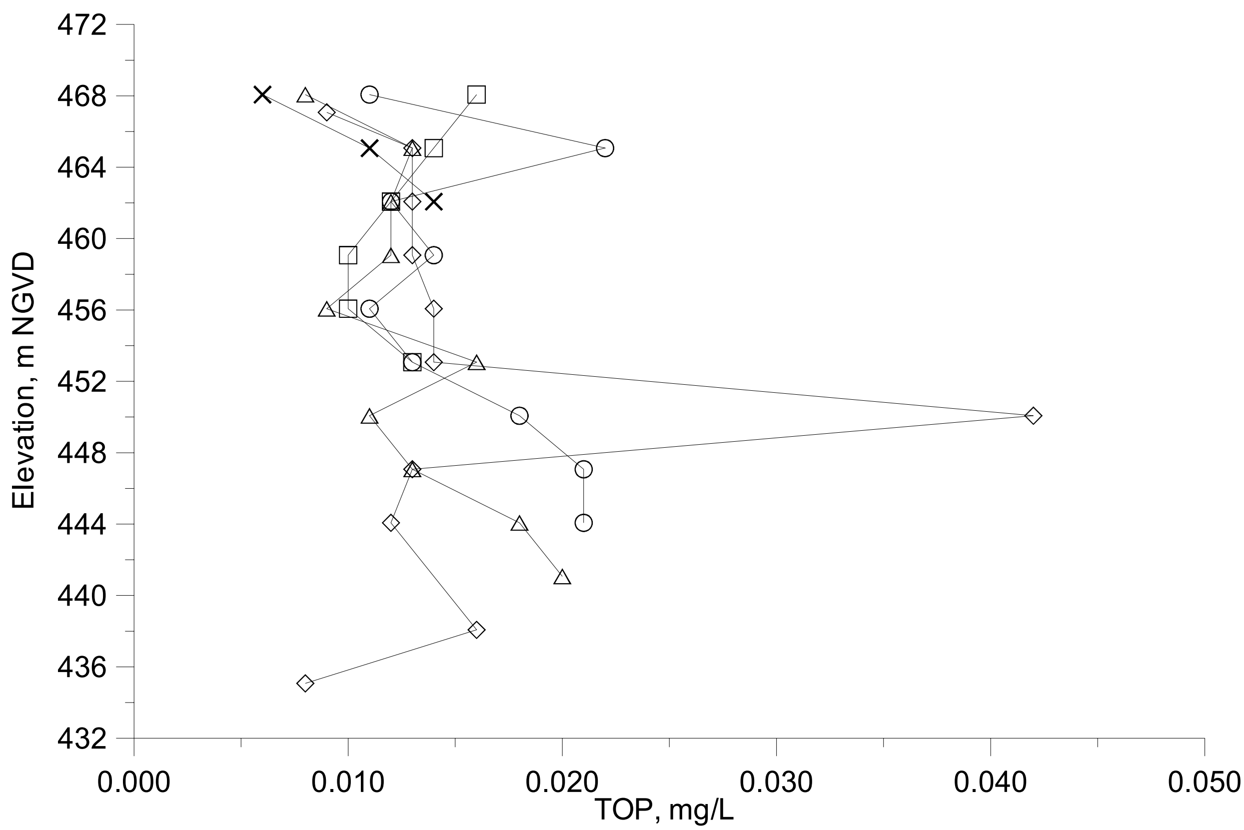
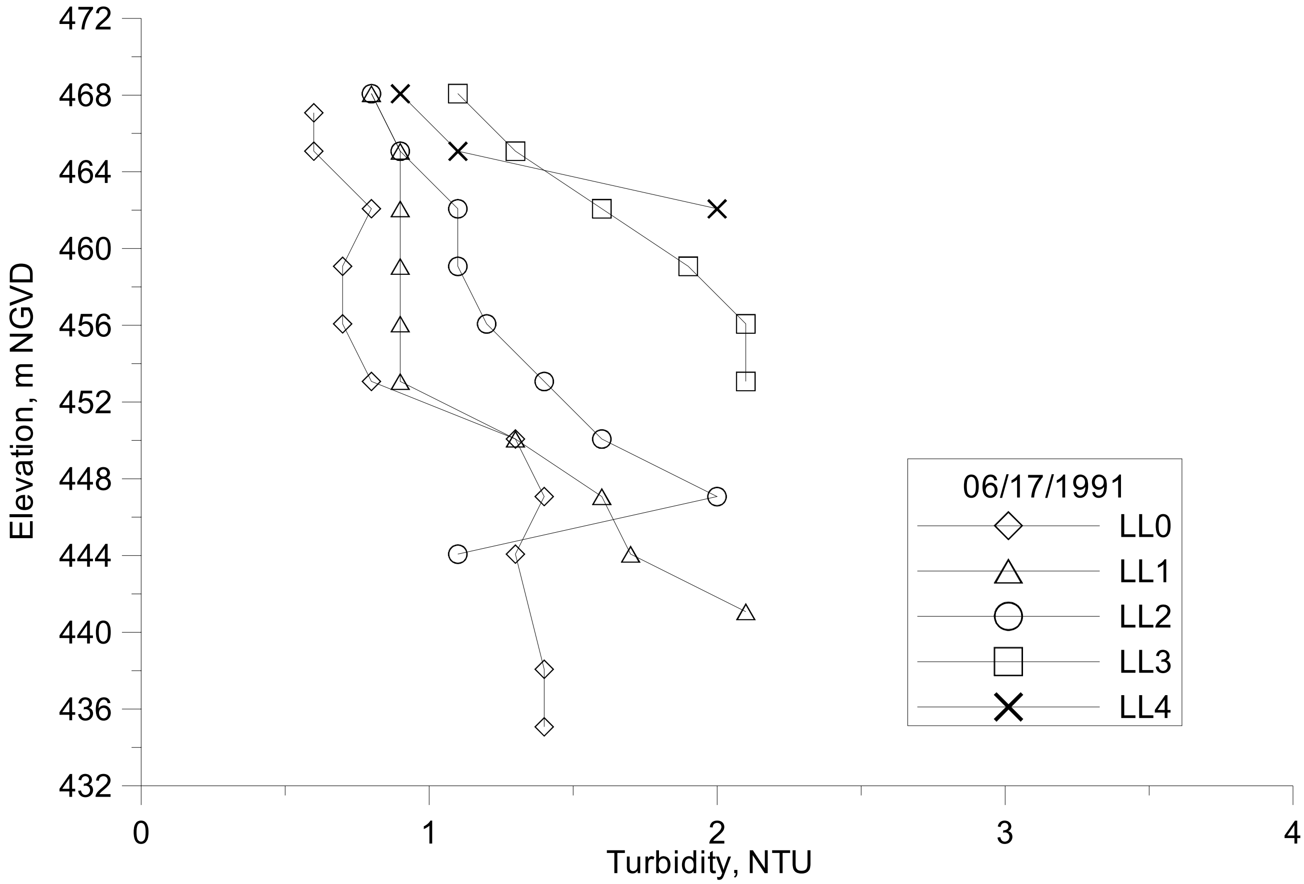
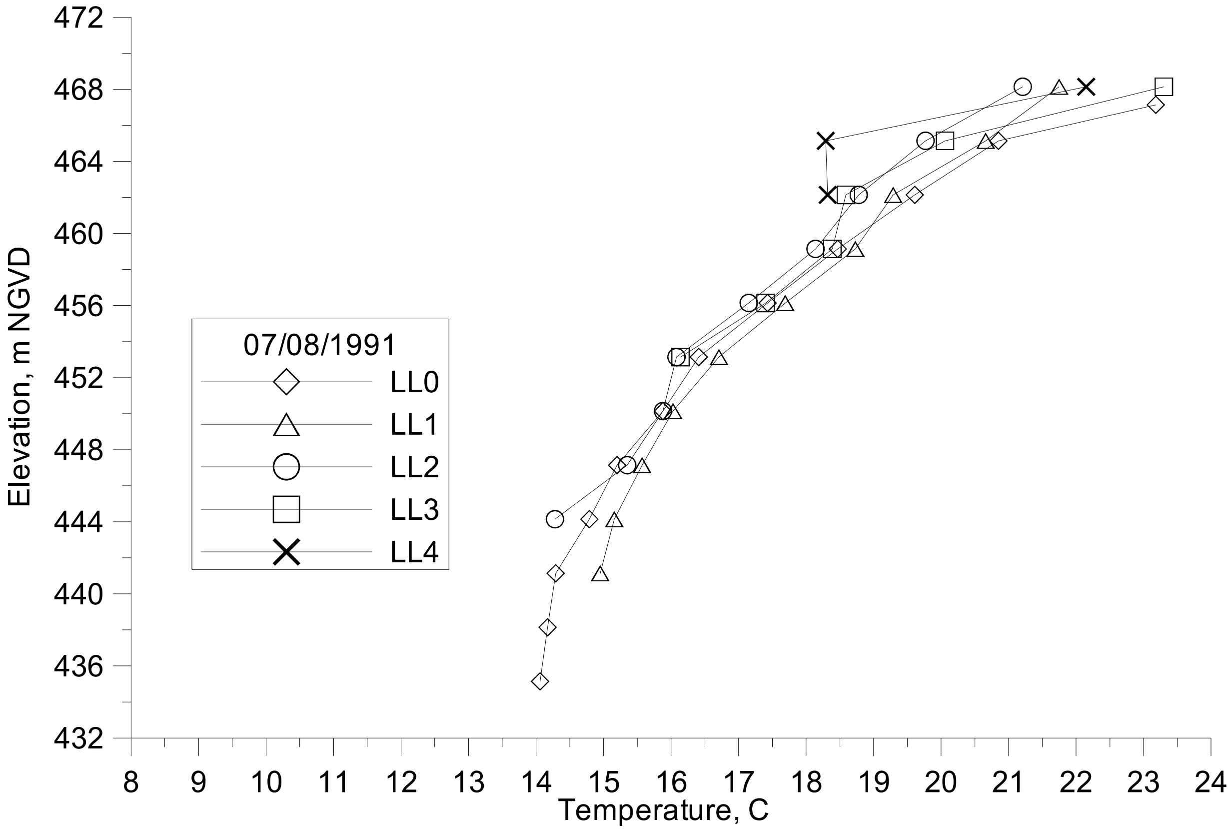
0.004
0.008
0.012
SRP, mg/L


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
0.05
TP, mg/L
06/17/1991
LL0
LL1
LL2
LL3
LL4


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.010
0.020
0.030
0.040
0.050
TOP, mg/L



Elevation, m NGVD
472
468
464
460
456
452
448
444
440
436
432
0
1
2
3
4
Turbidity, NTU
06/17/1991
LL0
LL1
LL2
LL3
LL4



Elevation, m NGVD
Temperature, C
07/08/1991
LL0
LL1
LL2
LL3
LL4
472
468
464
460
456
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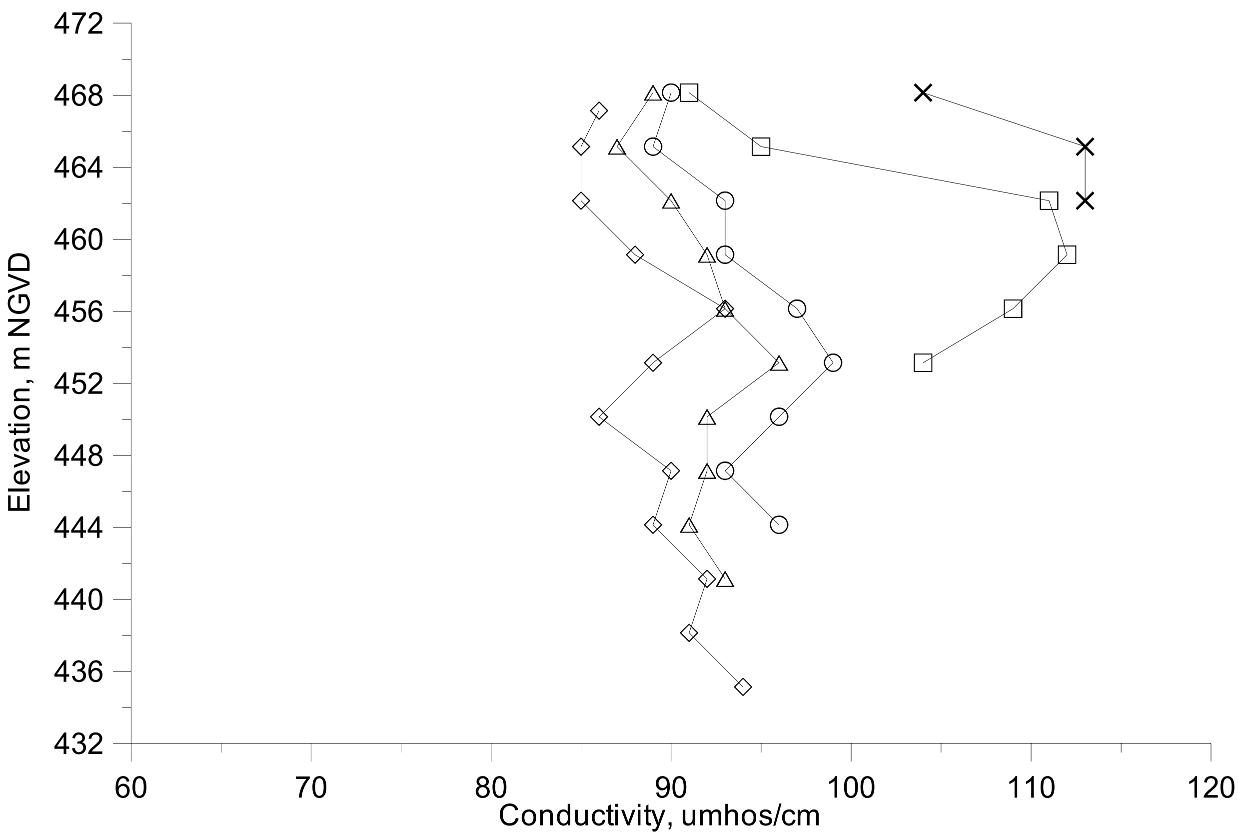
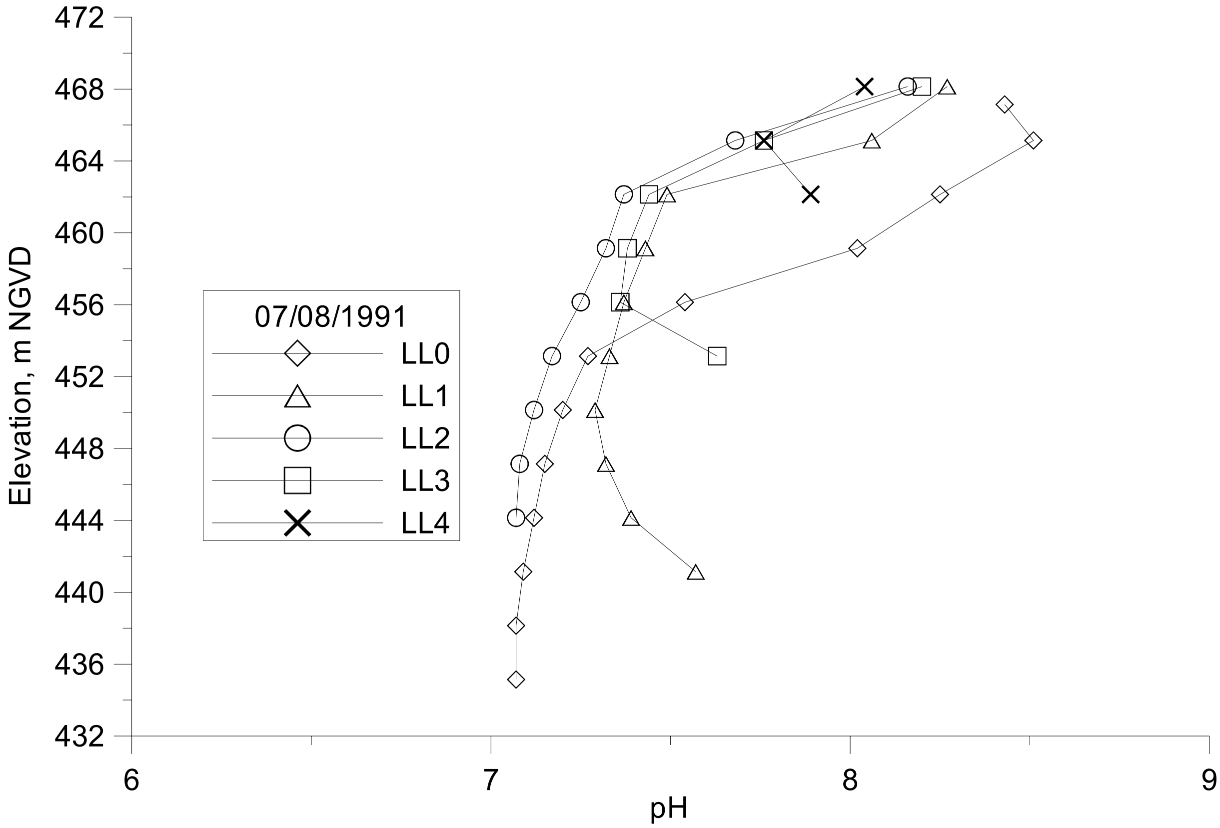
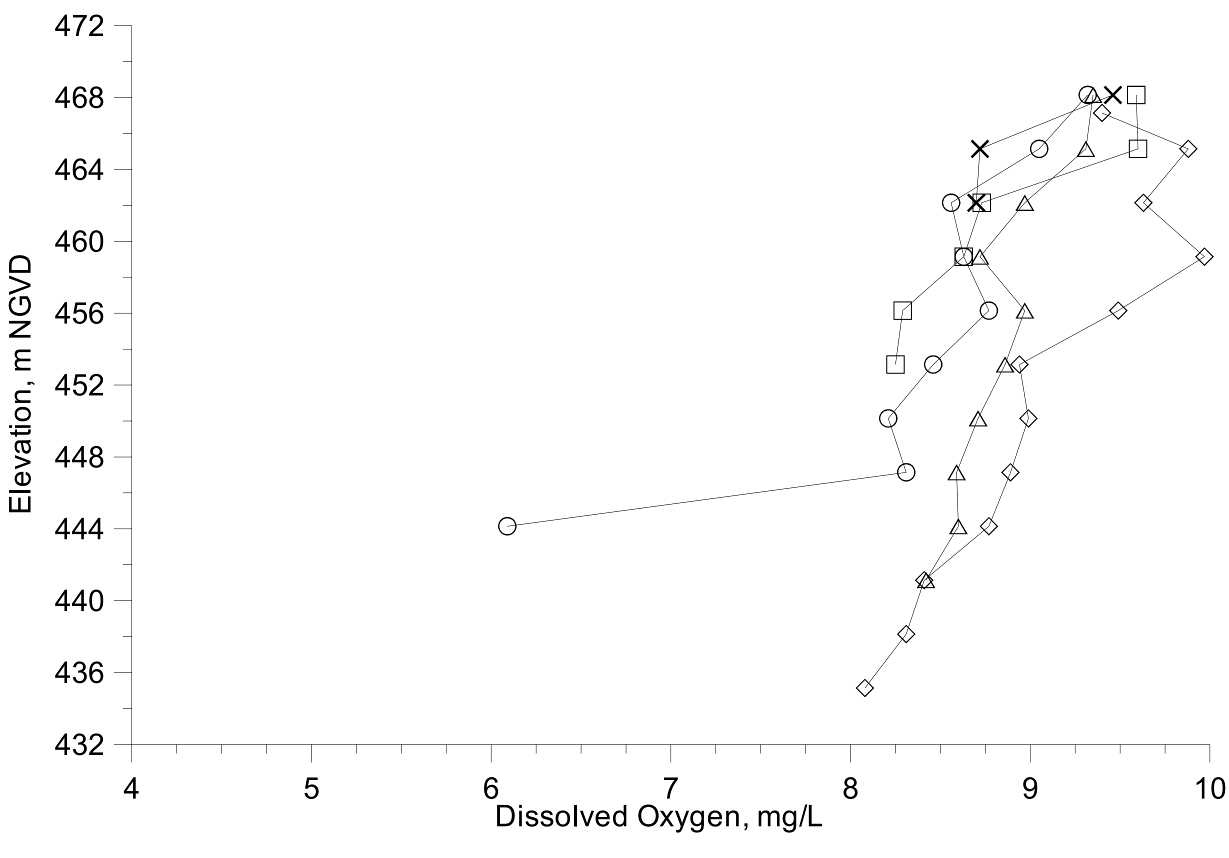


Elevation, m NGVD
Conductivity, umhos/cm
472
468
464
460
456
452
448
444
440
436
432
60 70 80 90 100 110 120



Elevation, m NGVD
472
468
464
460
456
452
448
444
440
436
432
6
7
8
9
pH
07/08/1991
LL0
LL1
LL2
LL3
LL4



Elevation, m NGVD
472
468
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448
444
440
436
432
4
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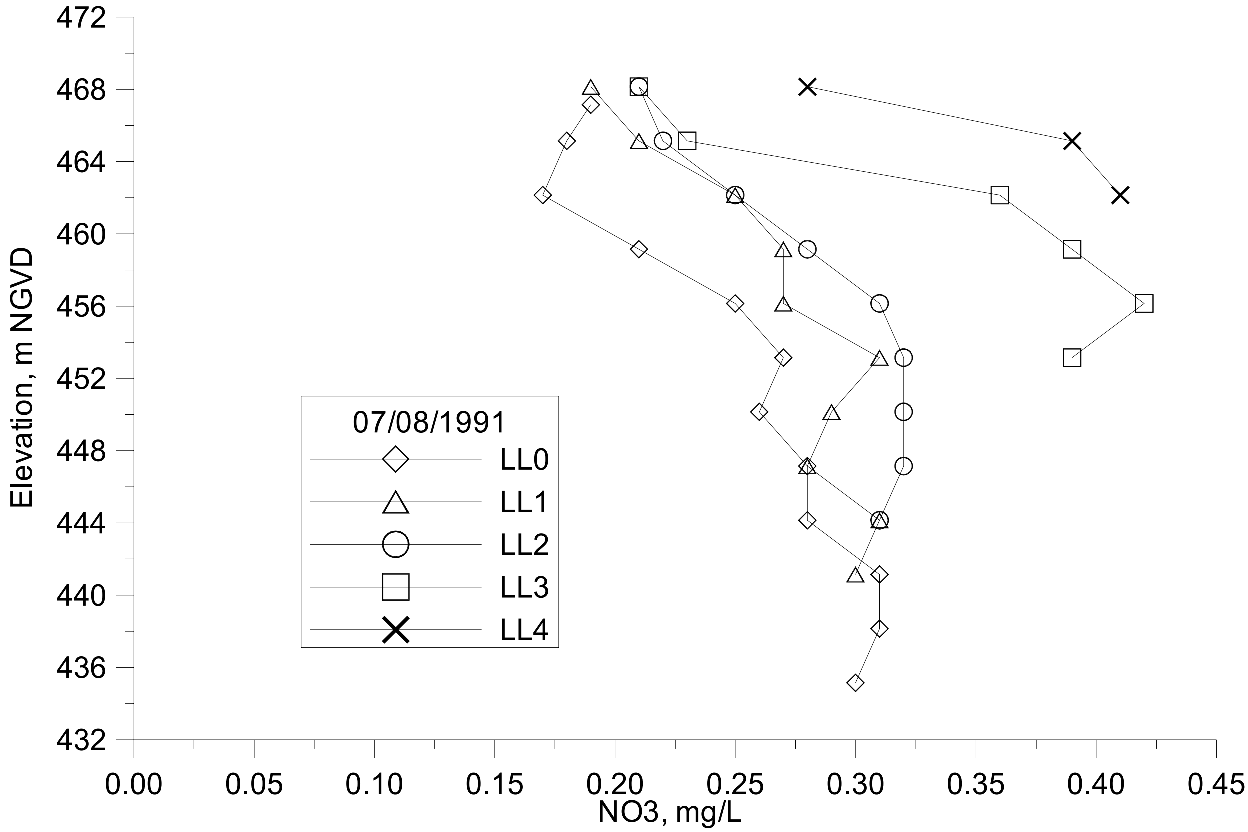
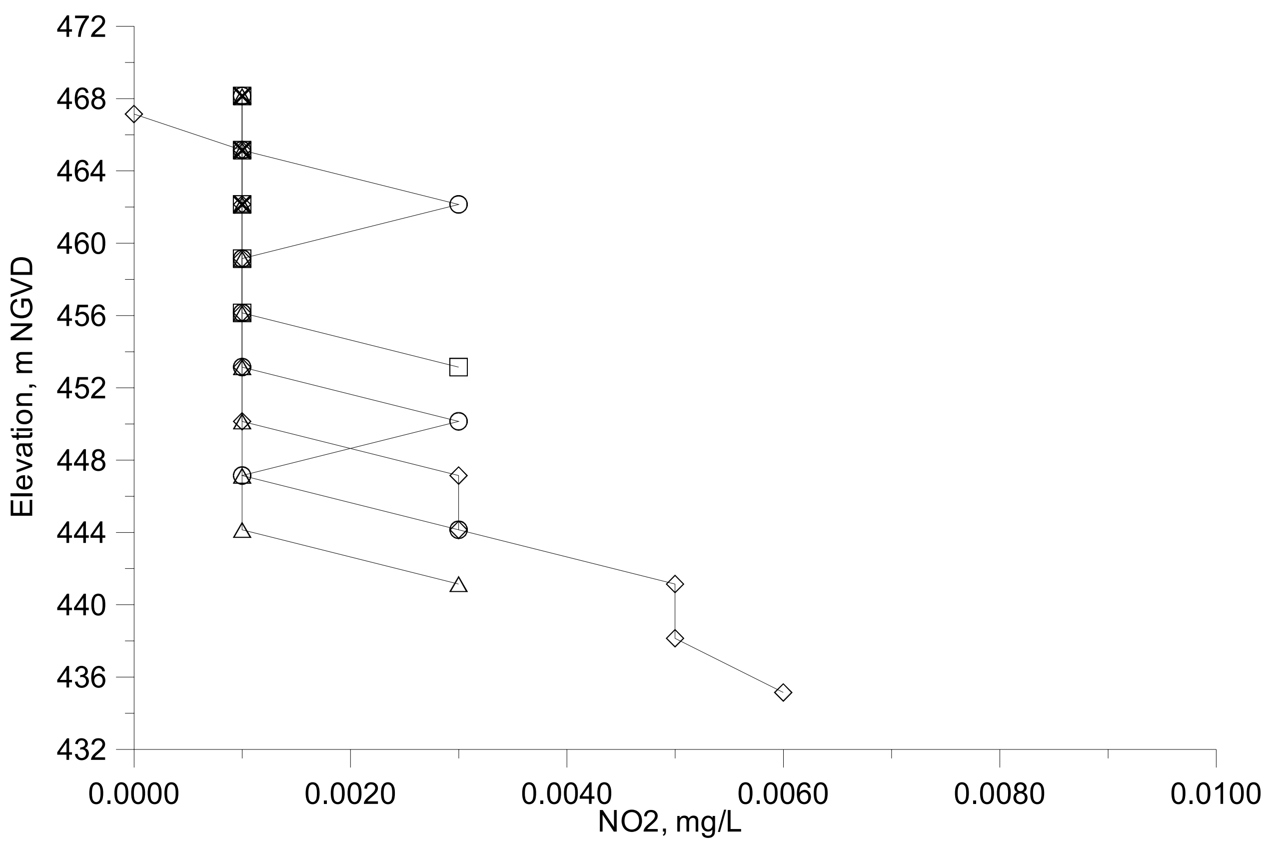
6
7
8
9
10
Dissolved Oxygen, mg/L



07/08/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NO3, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45



Elevation, m NGVD
NO2, mg/L
472
468
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452
448
444
440
436
432
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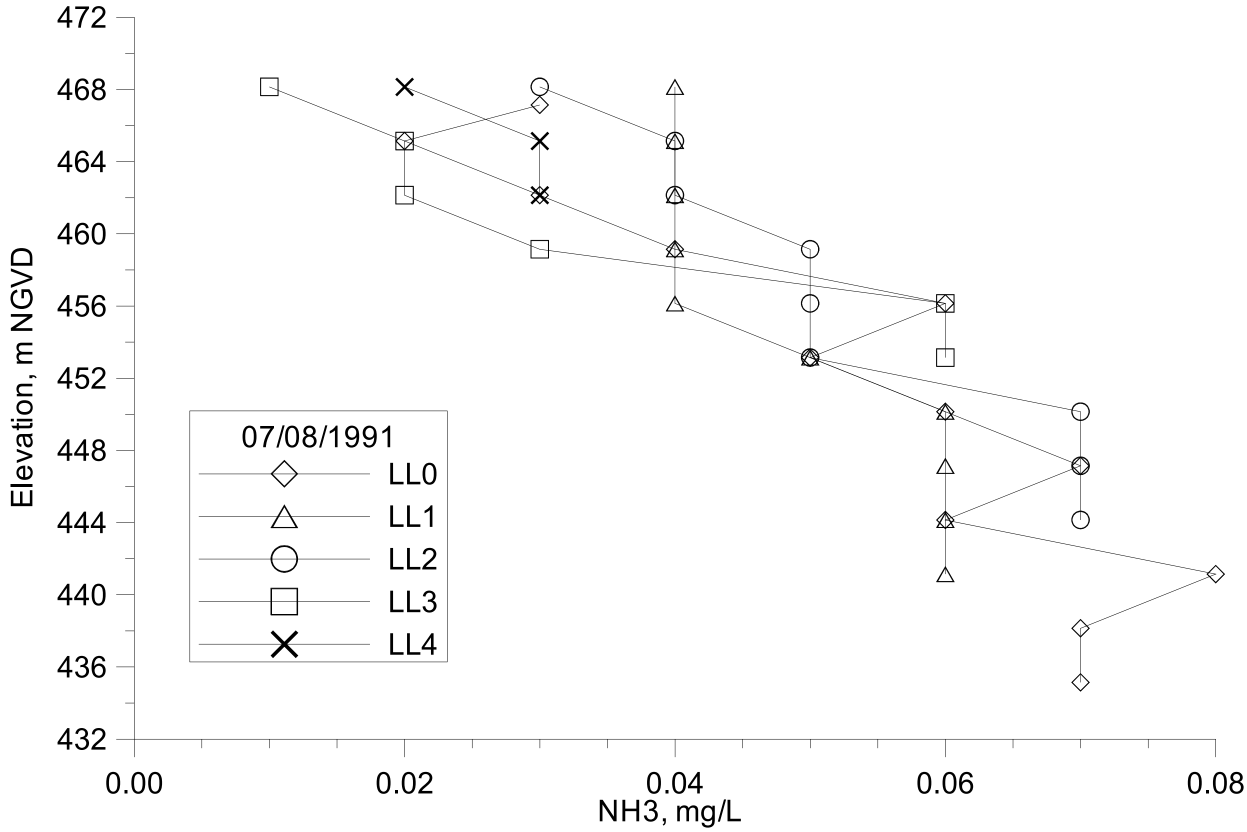
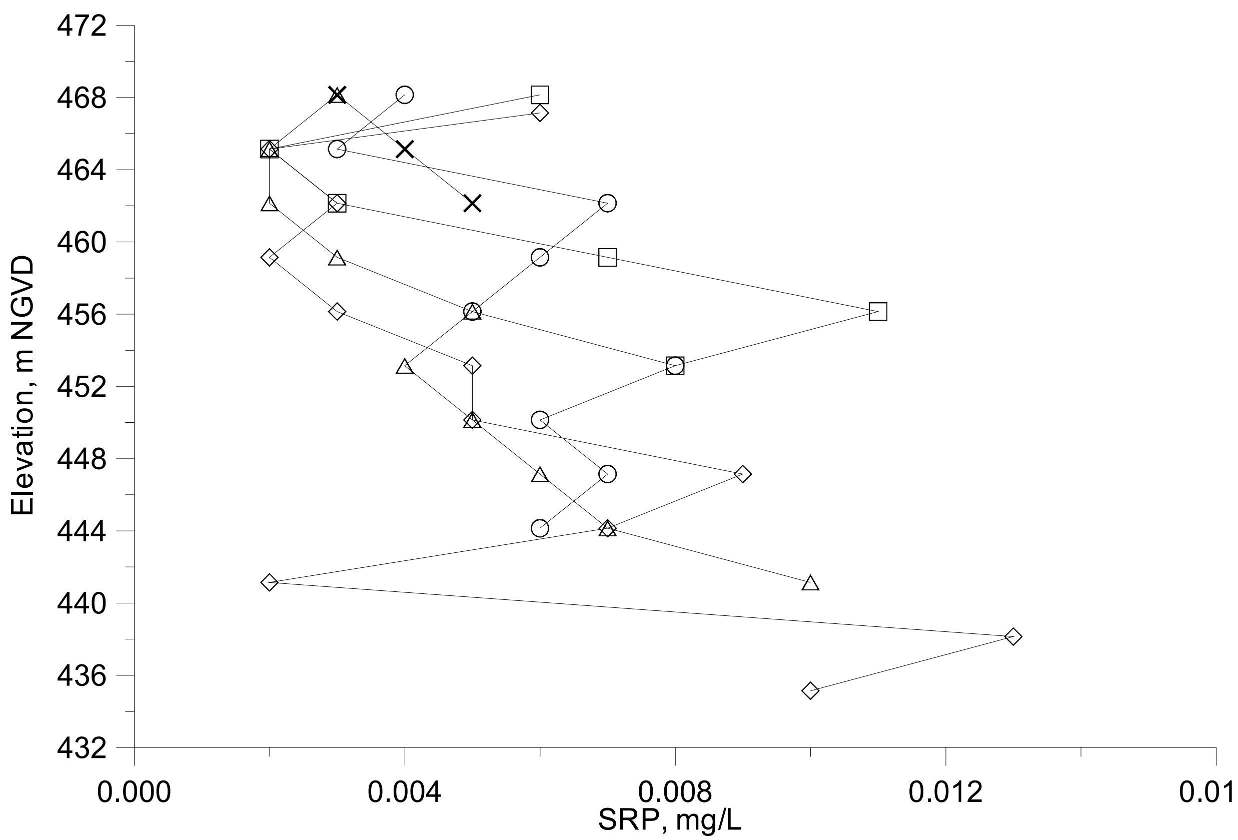
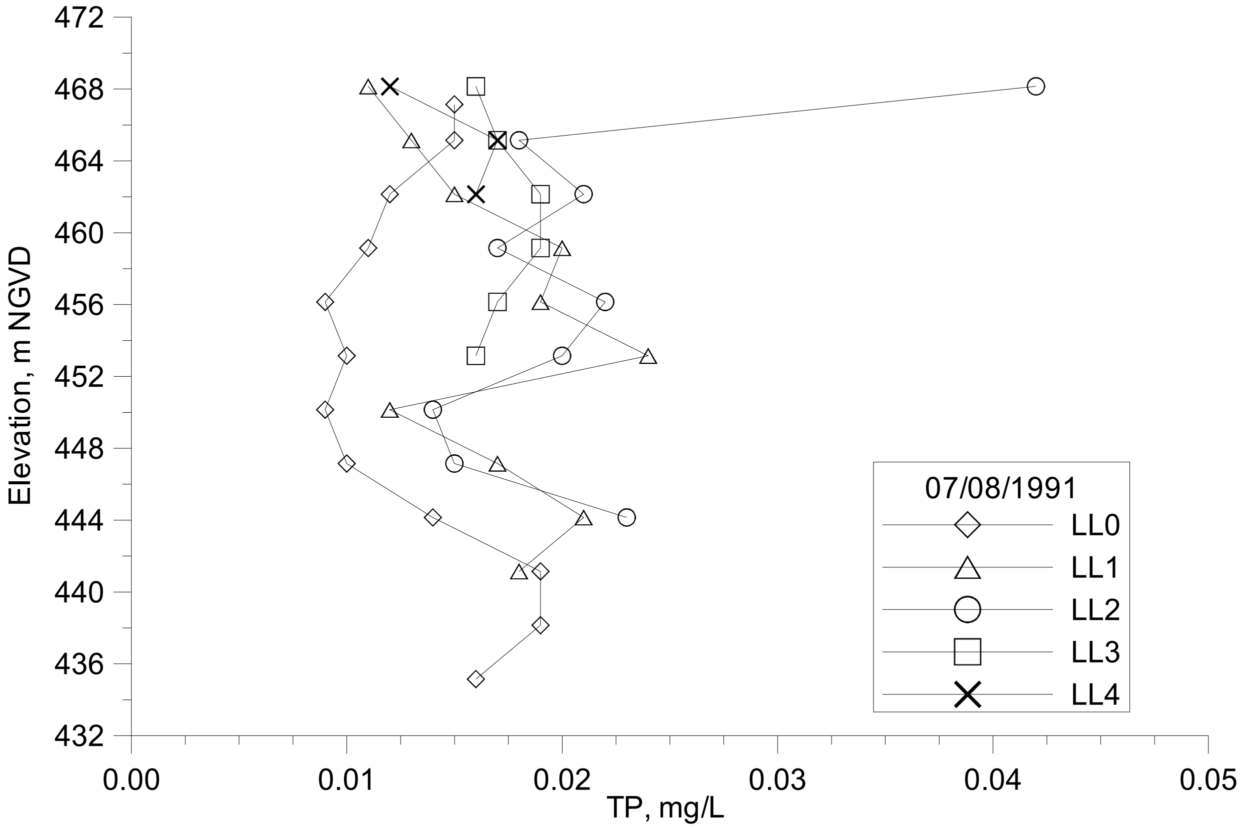
0.0060
0.0080
0.0100



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.02
0.04
0.06
0.08
NH3, mg/L
07/08/1991
LL0
LL1
LL2
LL3
LL4



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.004
0.008
0.012
0.016
SRP, mg/L


472
468
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460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
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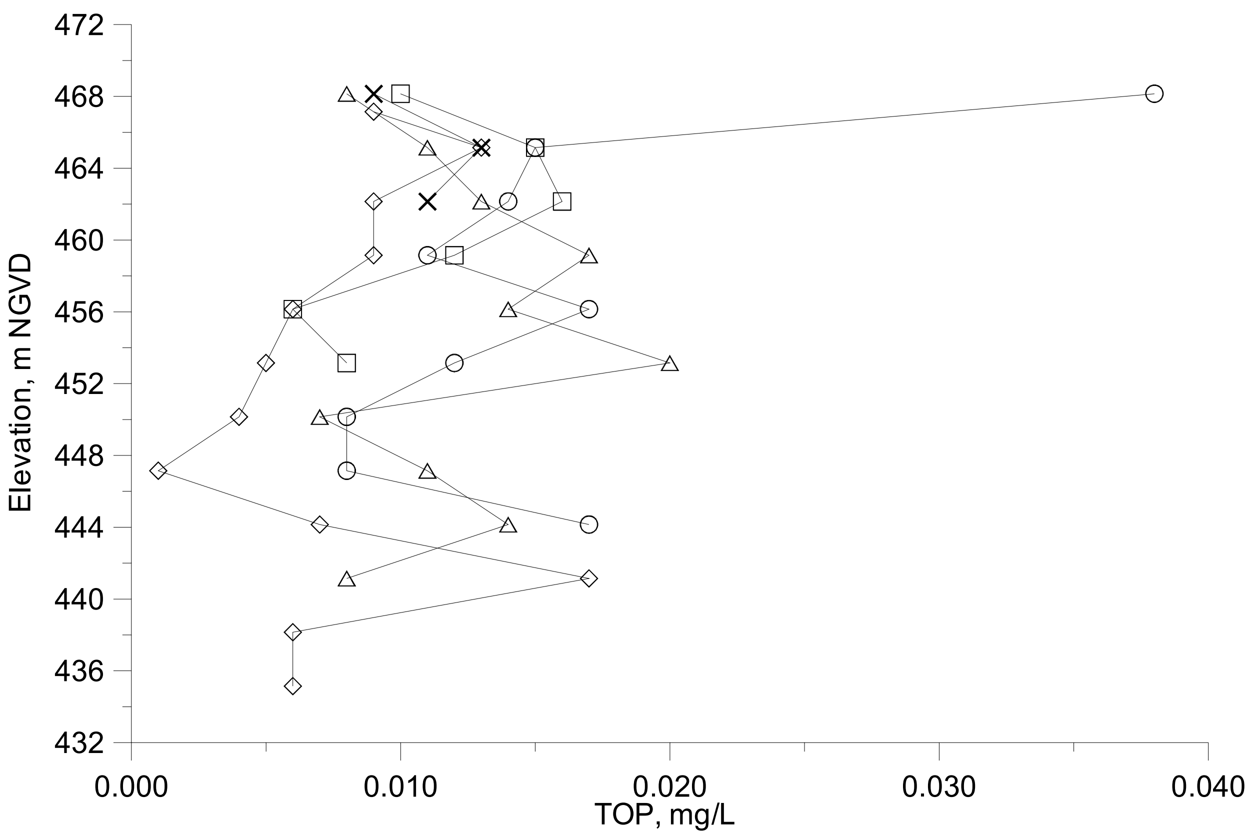
0.02
0.03
0.04
0.05
TP, mg/L
07/08/1991
LL0
LL1
LL2
LL3
LL4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468
464
460
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440
436
432
Elevation, m NGVD
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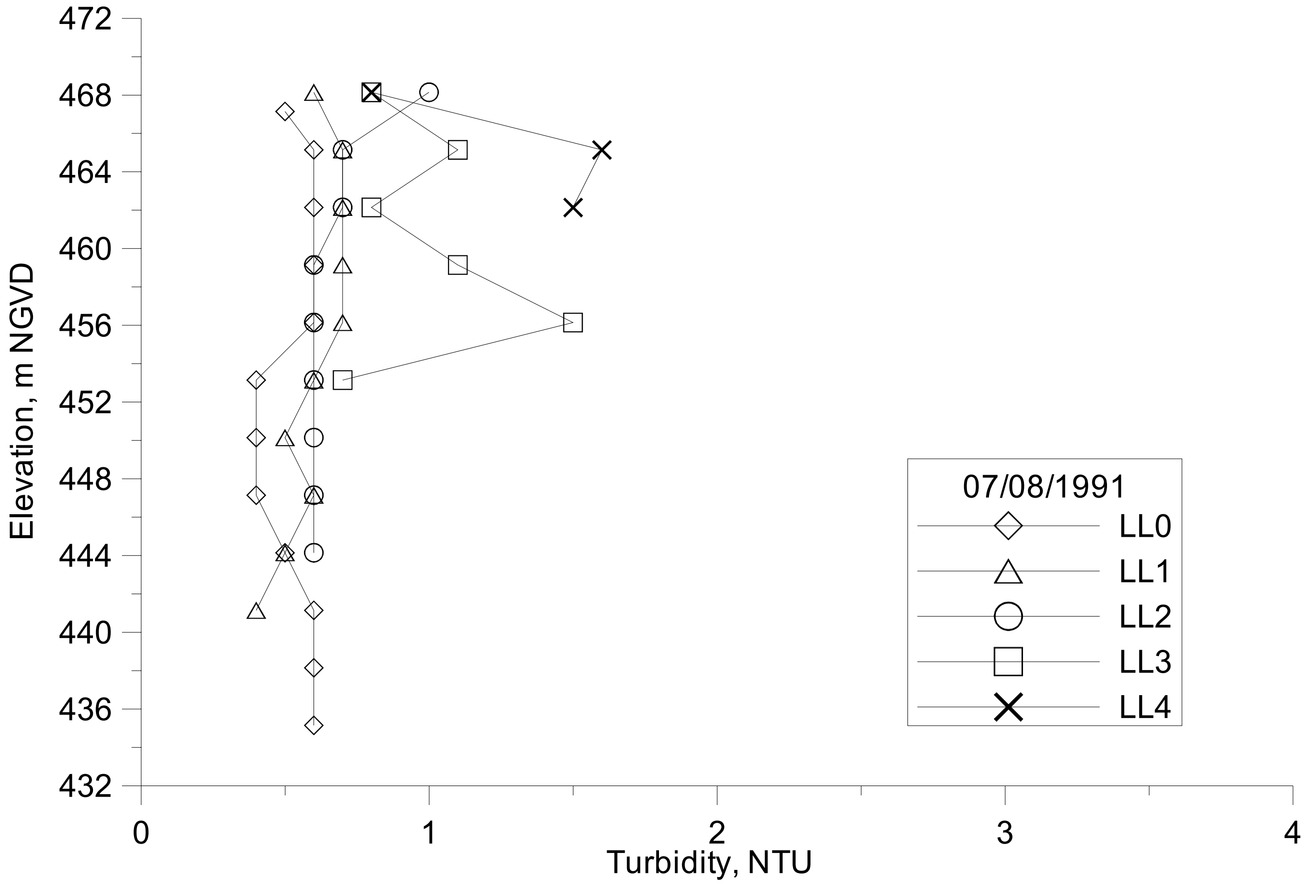
0.020
0.030
0.040
TOP, mg/L



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
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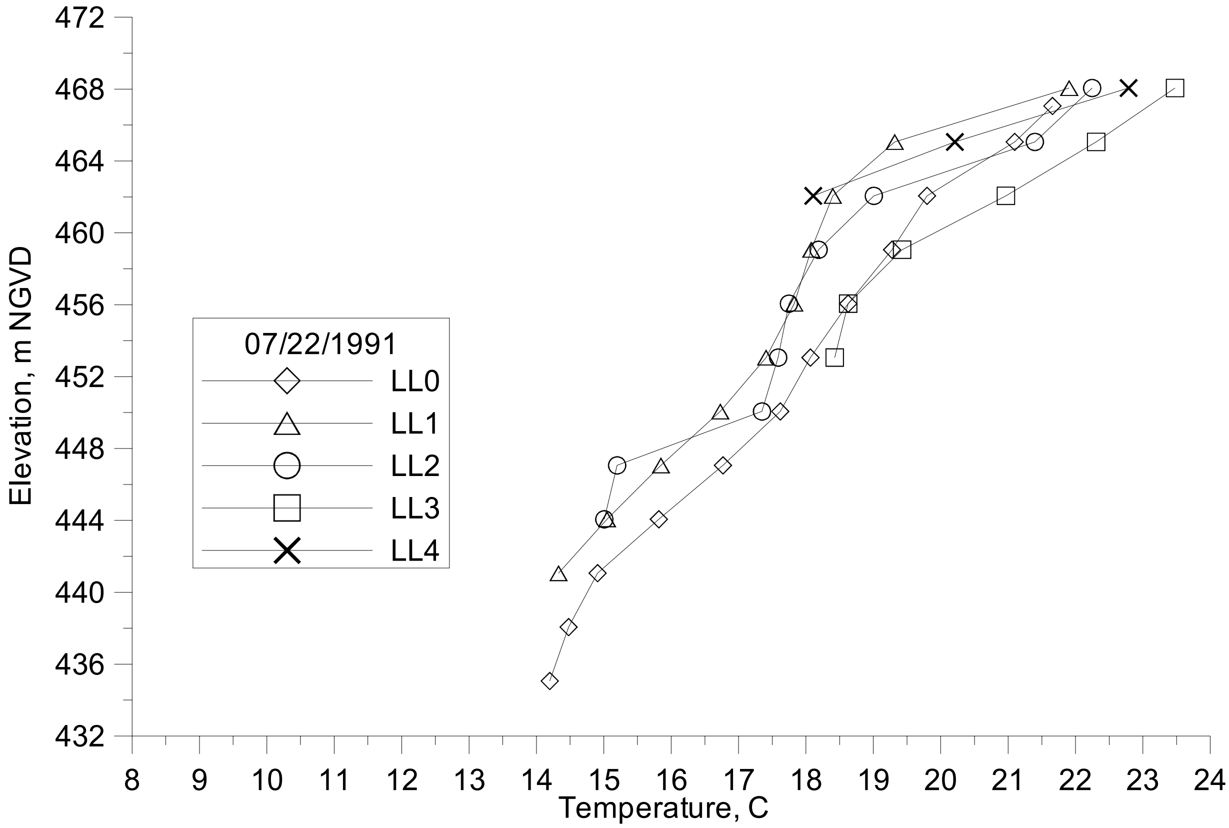
2
3
4
Turbidity, NTU
07/08/1991
LL0
LL1
LL2
LL3
LL4



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468
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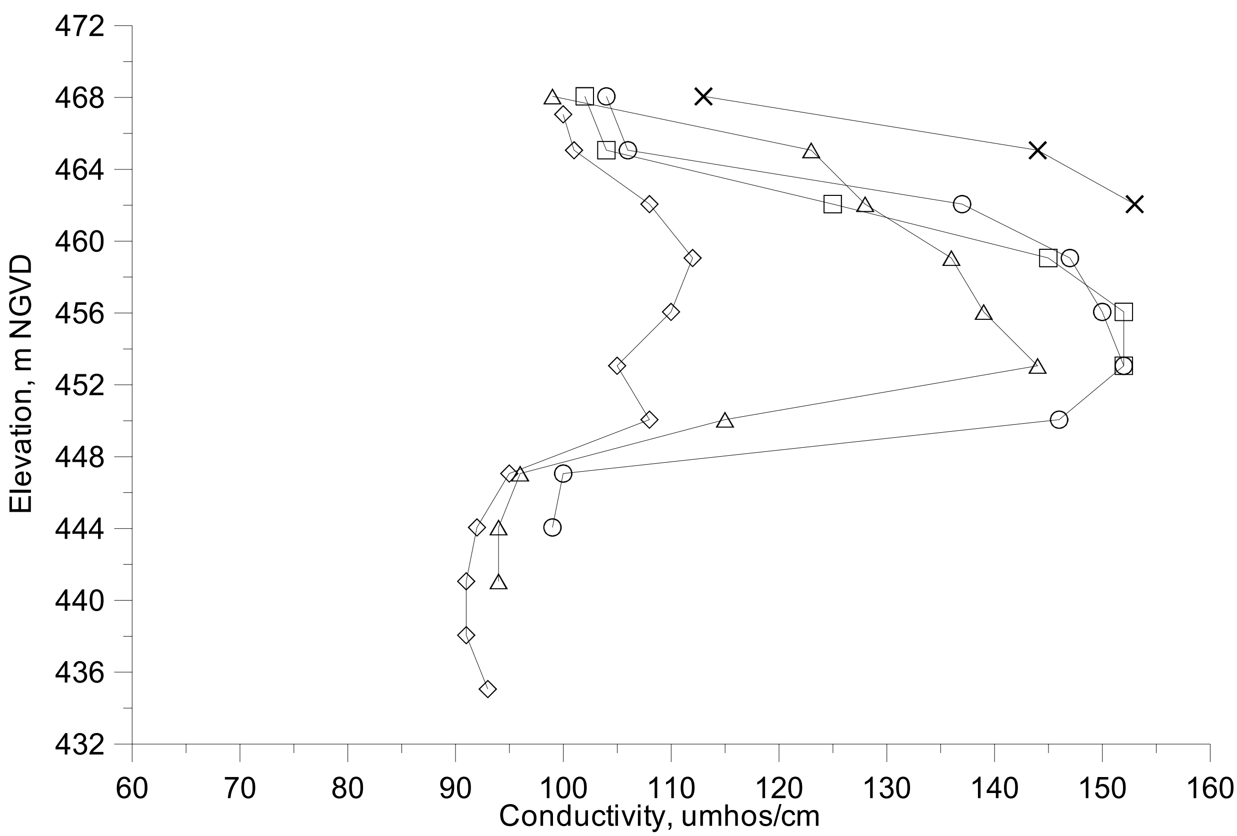
460
456
452
448
444
440
436
432
Elevation, m NGVD
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Temperature, C
07/22/1991
LL0
LL1
LL2
LL3
LL4



472
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464
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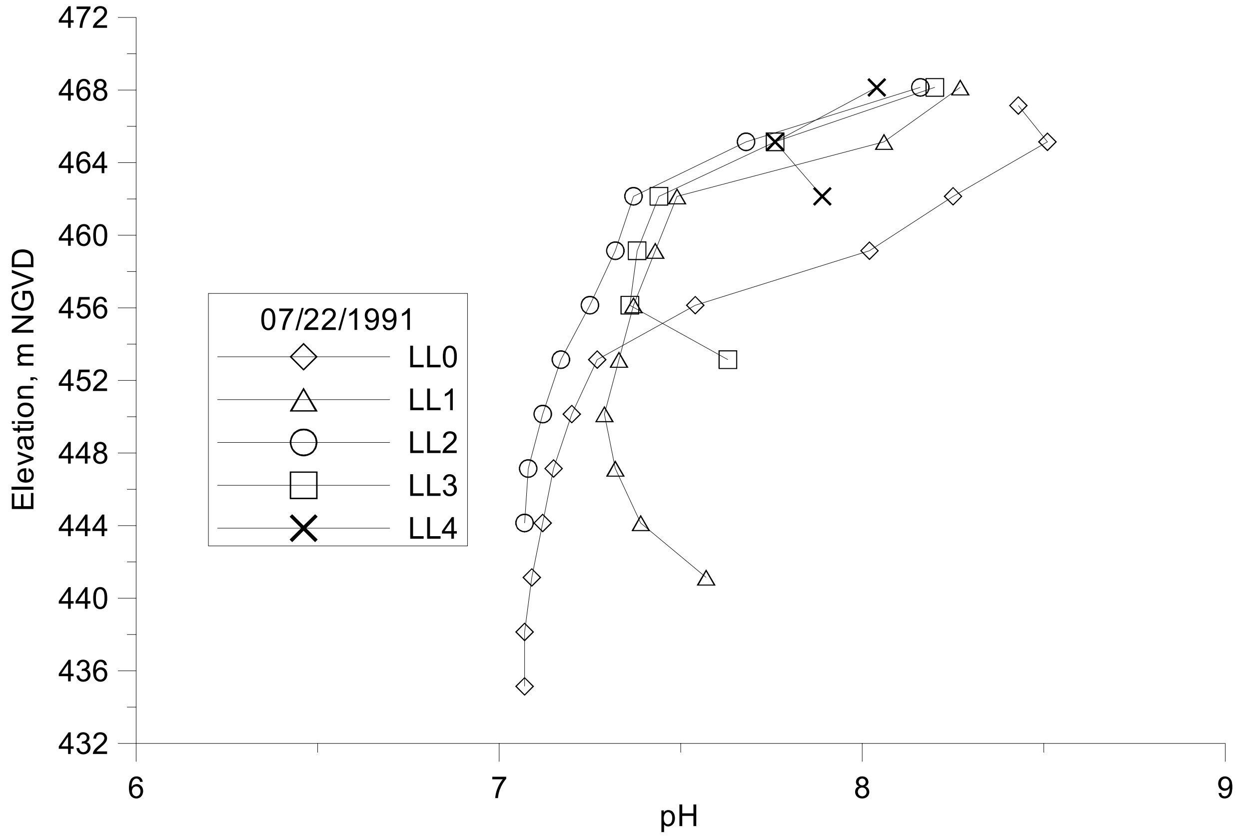
452
448
444
440
436
432
Elevation, m NGVD
60 70 80 90 100 110 120 130 140 150 160
Conductivity, umhos/cm


07/22/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
pH
472
468
464
460
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452
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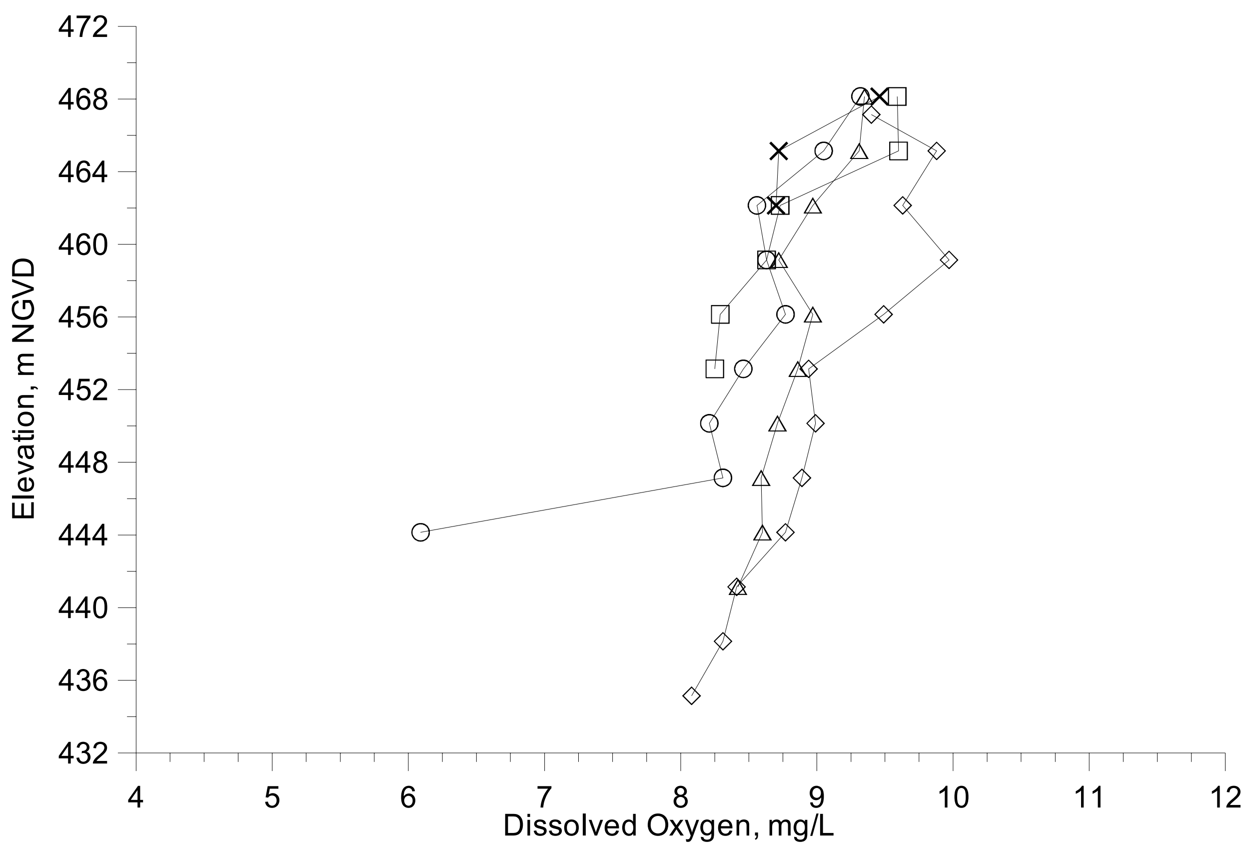
432
6
7
8
9


Elevation, m NGVD
Dissolved Oxygen, mg/L
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468
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460
456
452
448
444
440
436
432
4
5
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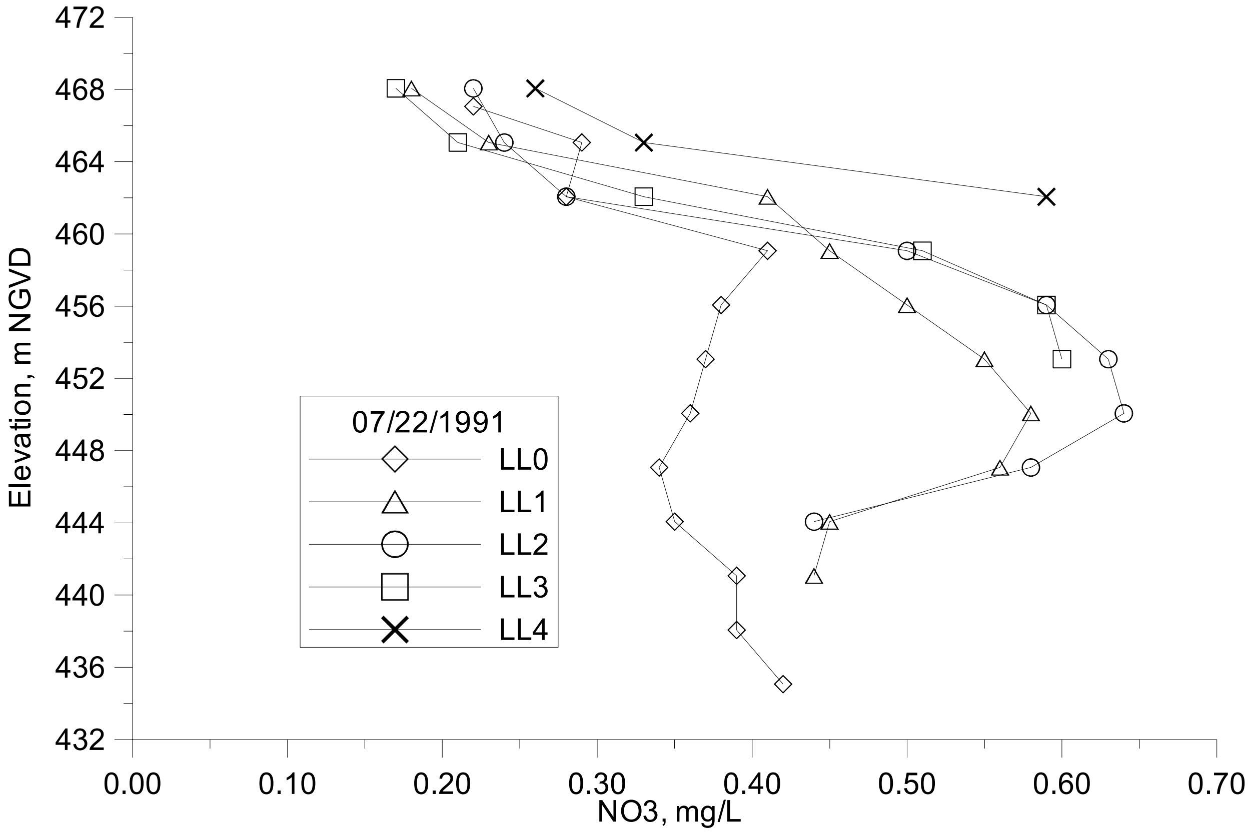
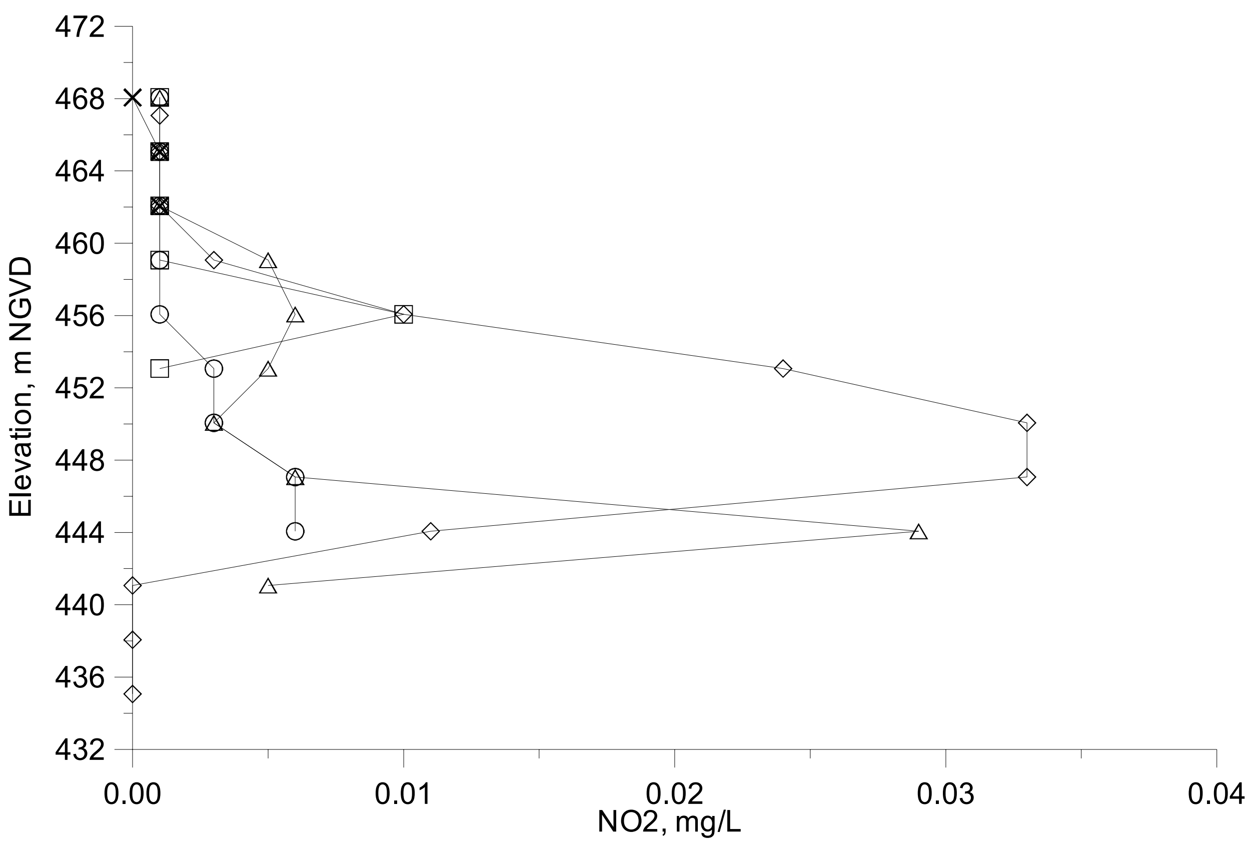
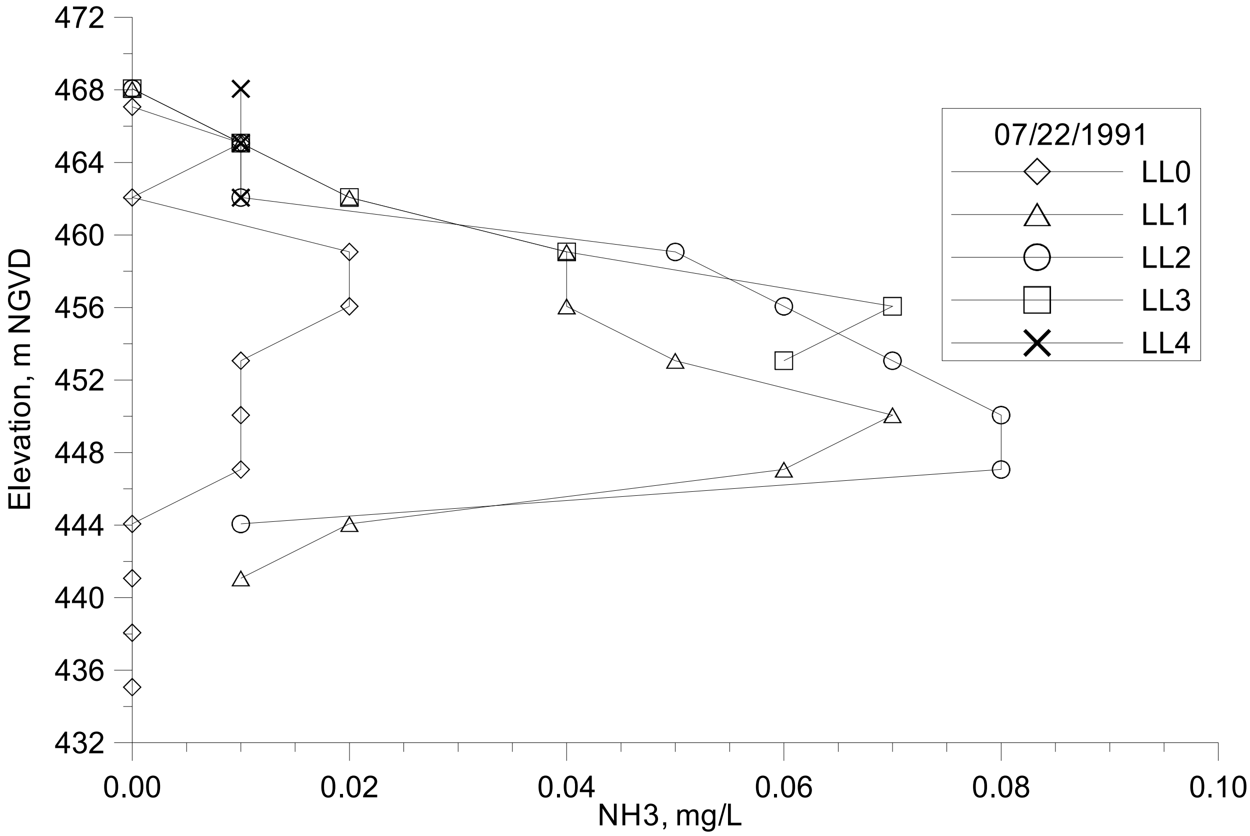
8
9
10
11
12



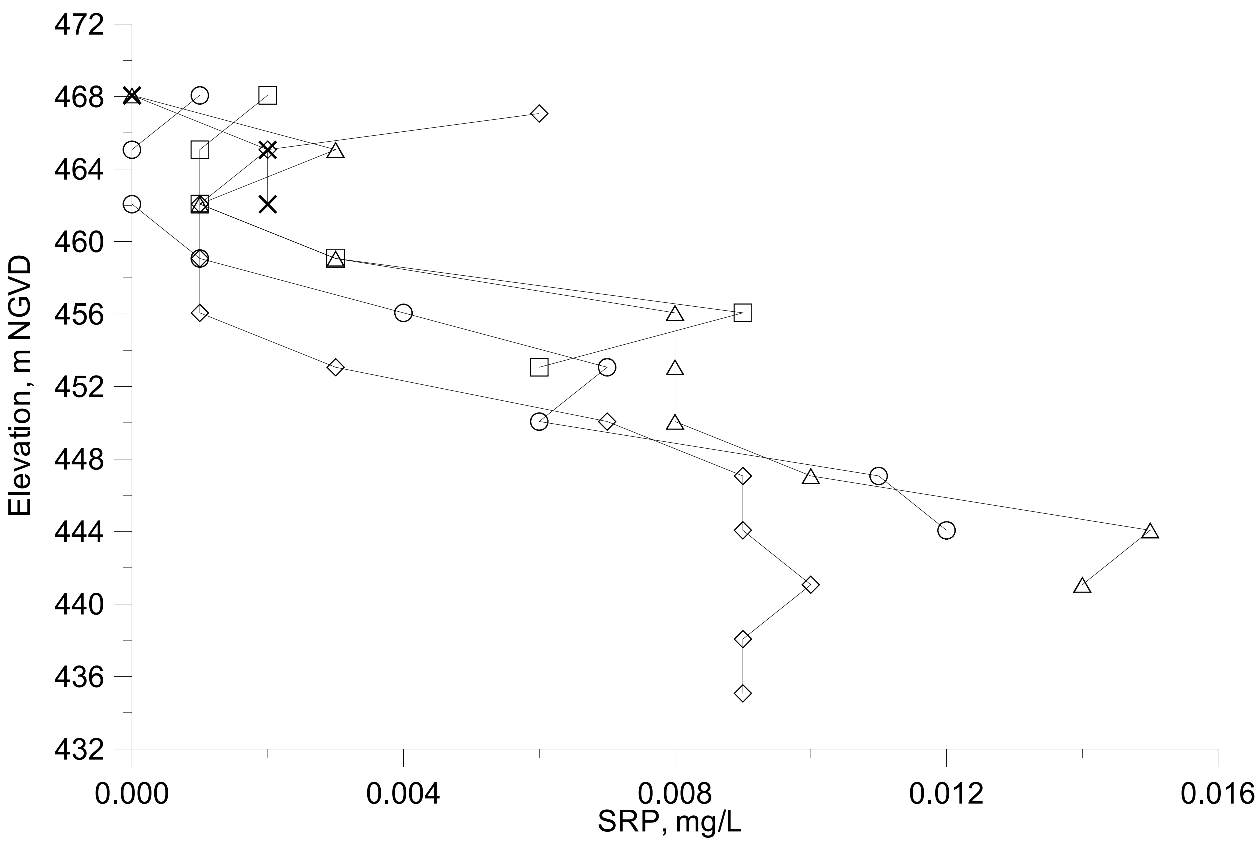
Elevation, m NGVD
NO3, mg/L
07/22/1991
LL0
LL1
LL2
LL3
LL4



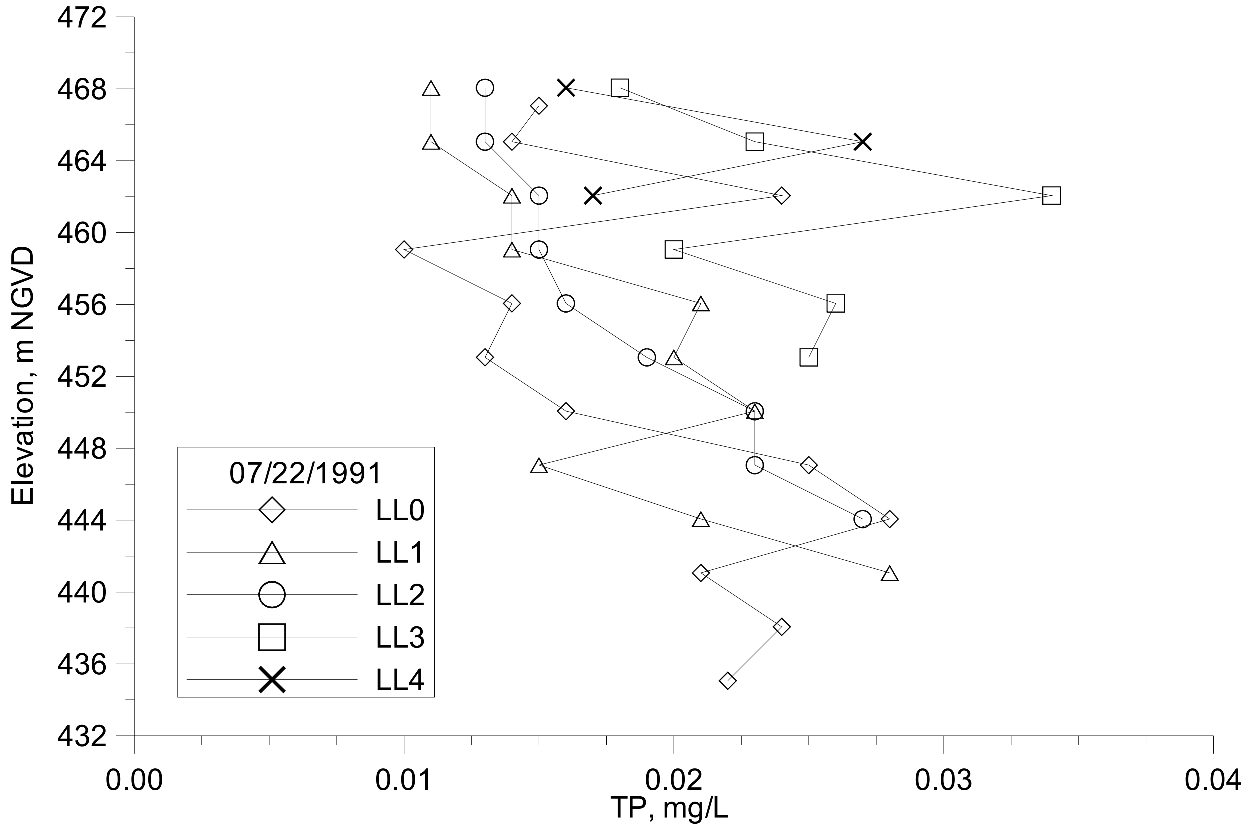
Elevation, m NGVD
NO2, mg/L



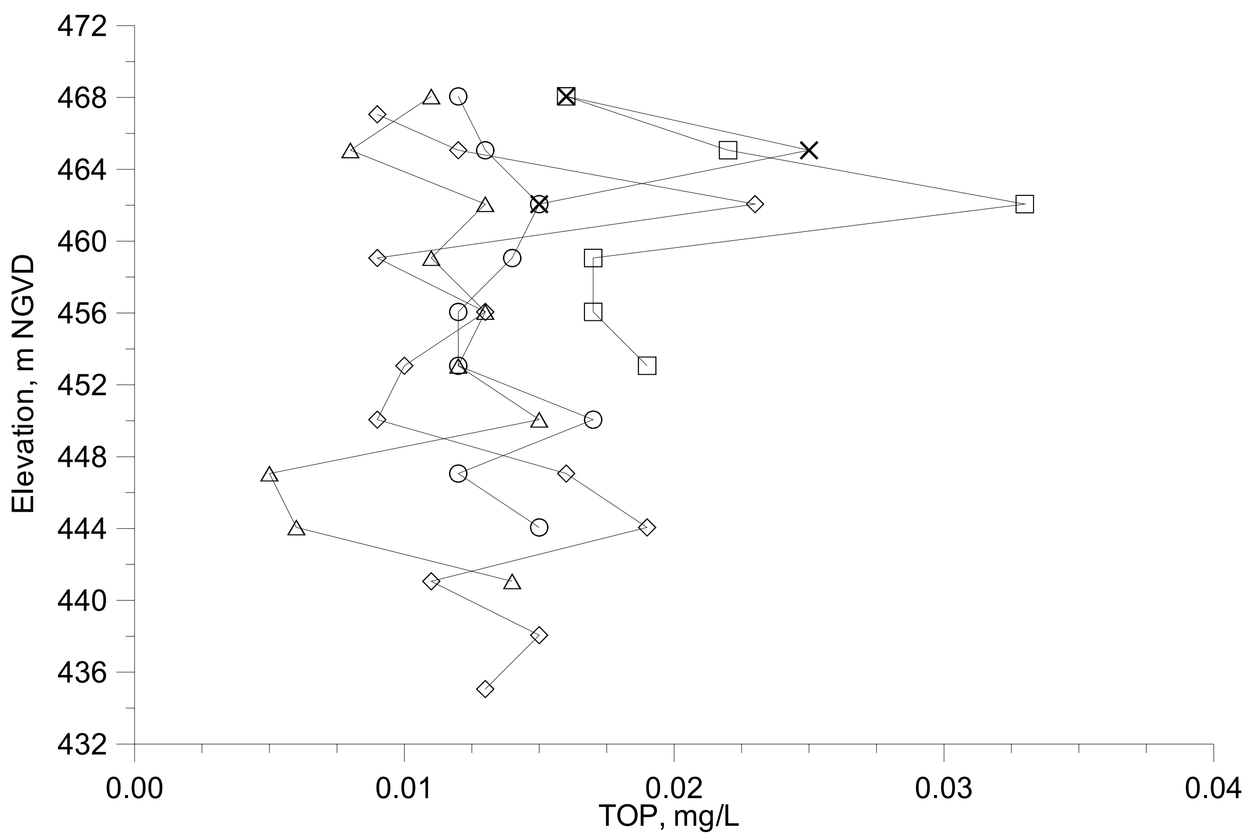
Elevation, m NGVD
472
468
464
460
456
452
448
444
440
436
432
0.00
0.02
0.04
0.06
0.08
0.10
NH3, mg/L
07/22/1991
LL0
LL1
LL2
LL3
LL4



Elevation, m NGVD
472
468
464
460
456
452
448
444
440
436
432
0.000
0.004
0.008
0.012
0.016
SRP, mg/L



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
07/22/1991
LL0
LL1
LL2
LL3
LL4
0.00
0.01
0.02
0.03
0.04
TP, mg/L



472
468
464
460
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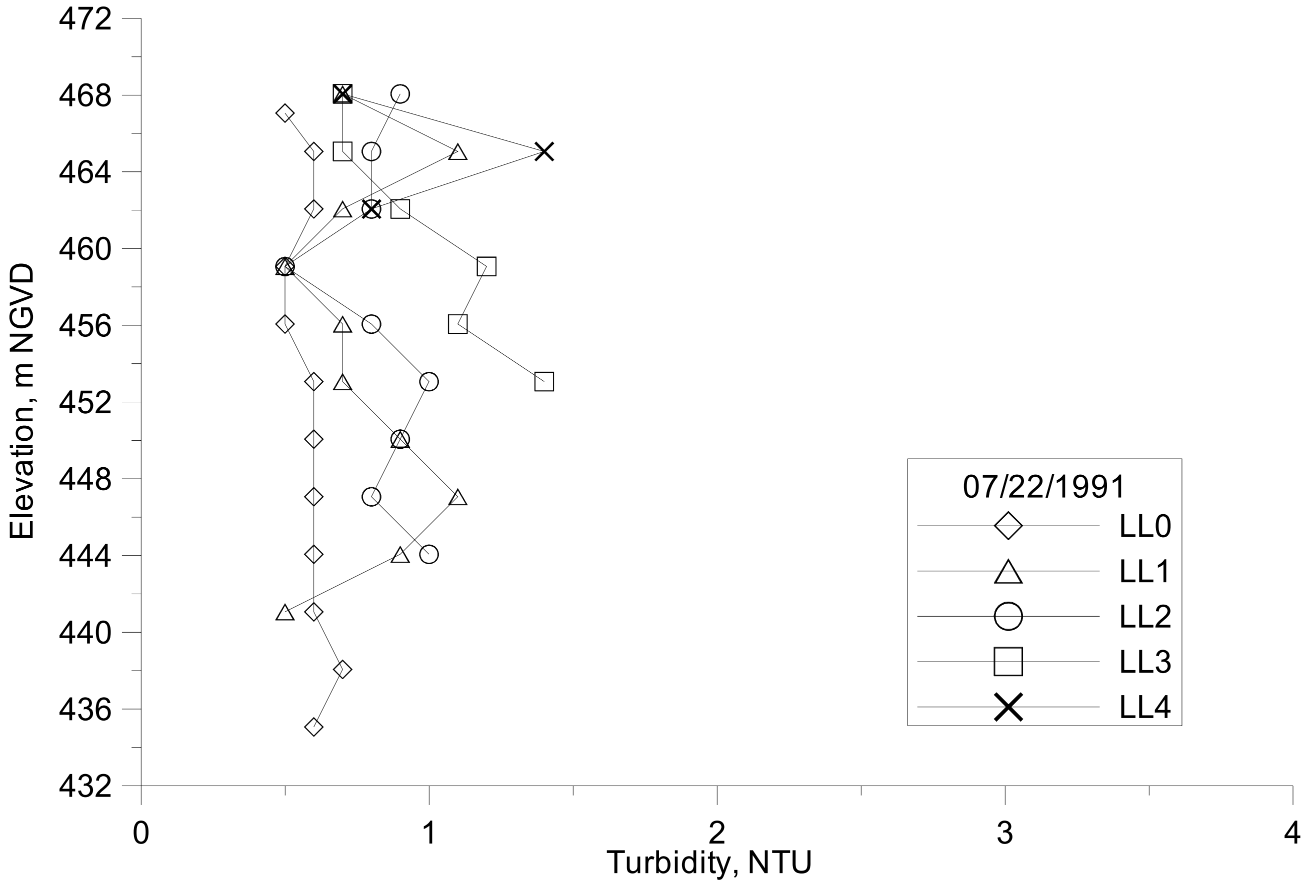
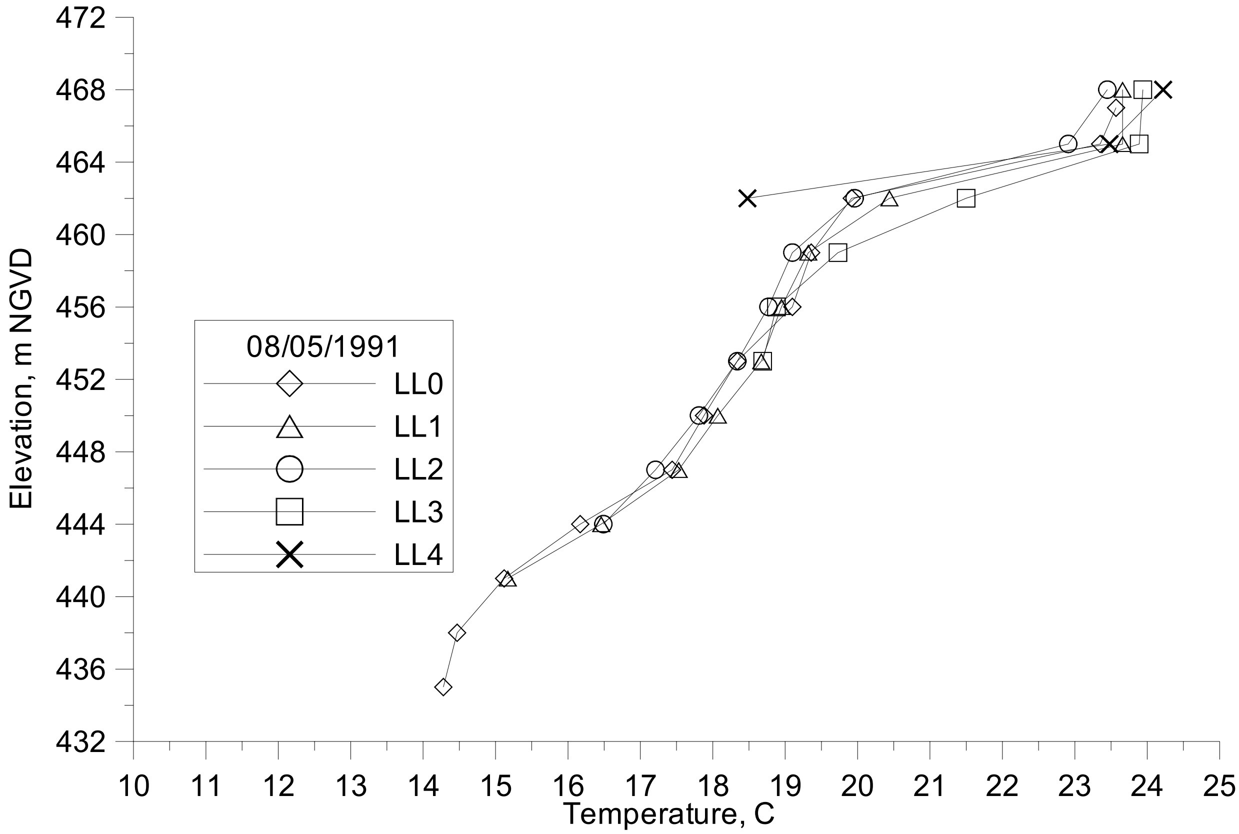
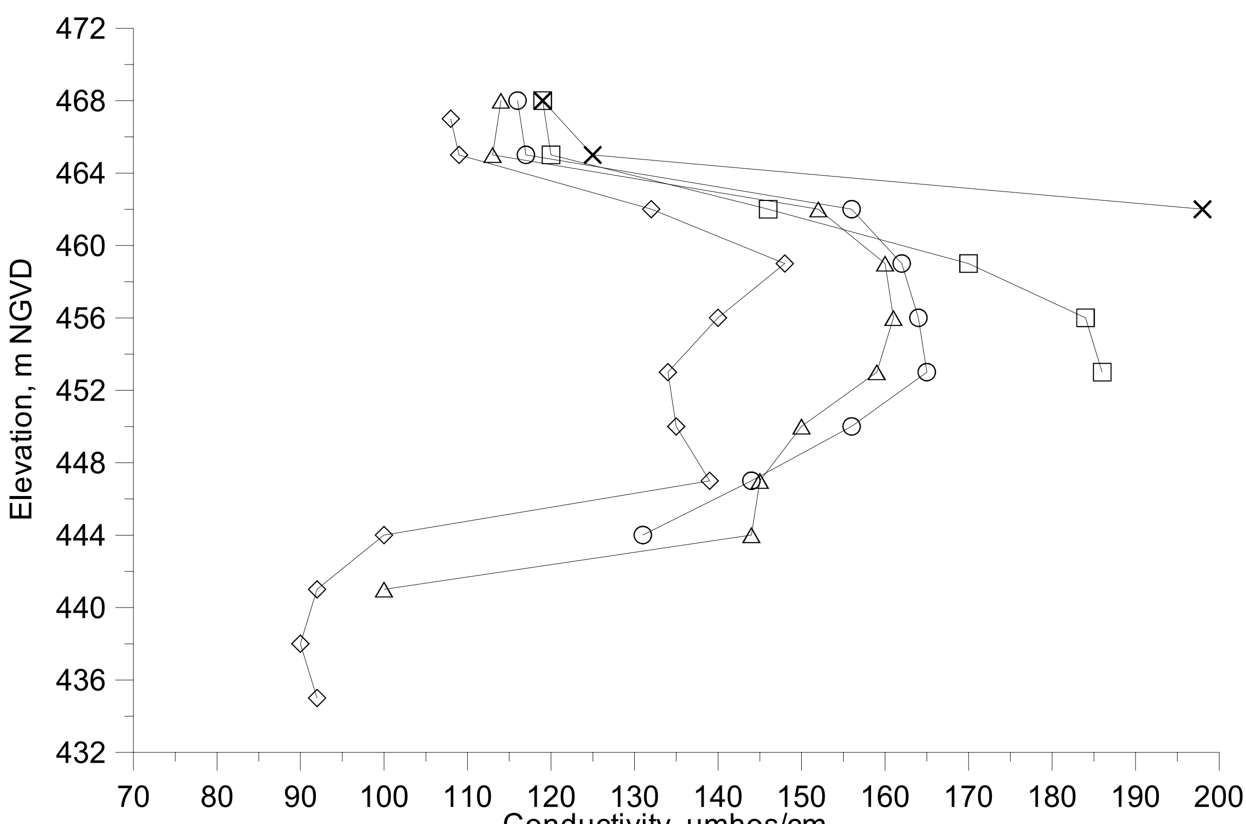
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
TOP, mg/L



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
Turbidity, NTU
07/22/1991
LL0
LL1
LL2
LL3
LL4



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Temperature, C
08/05/1991
LL0
LL1
LL2
LL3
LL4



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
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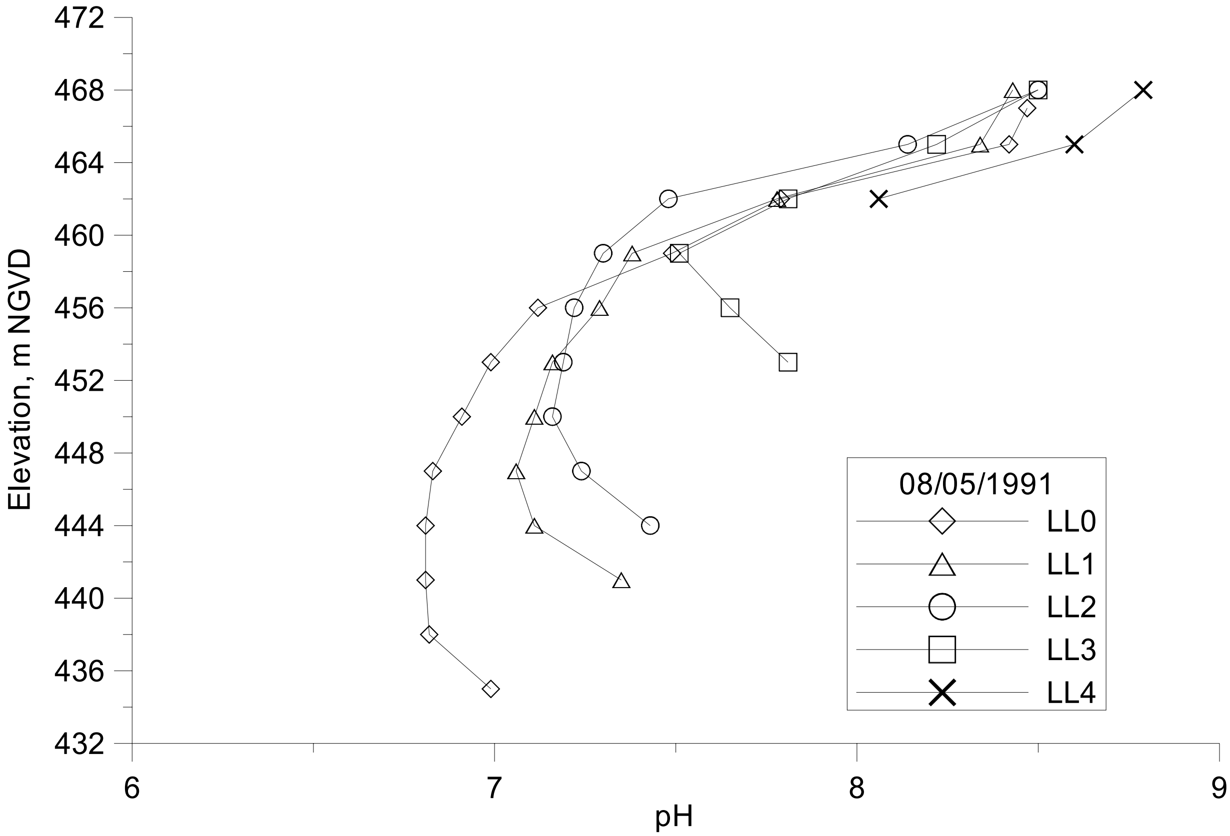
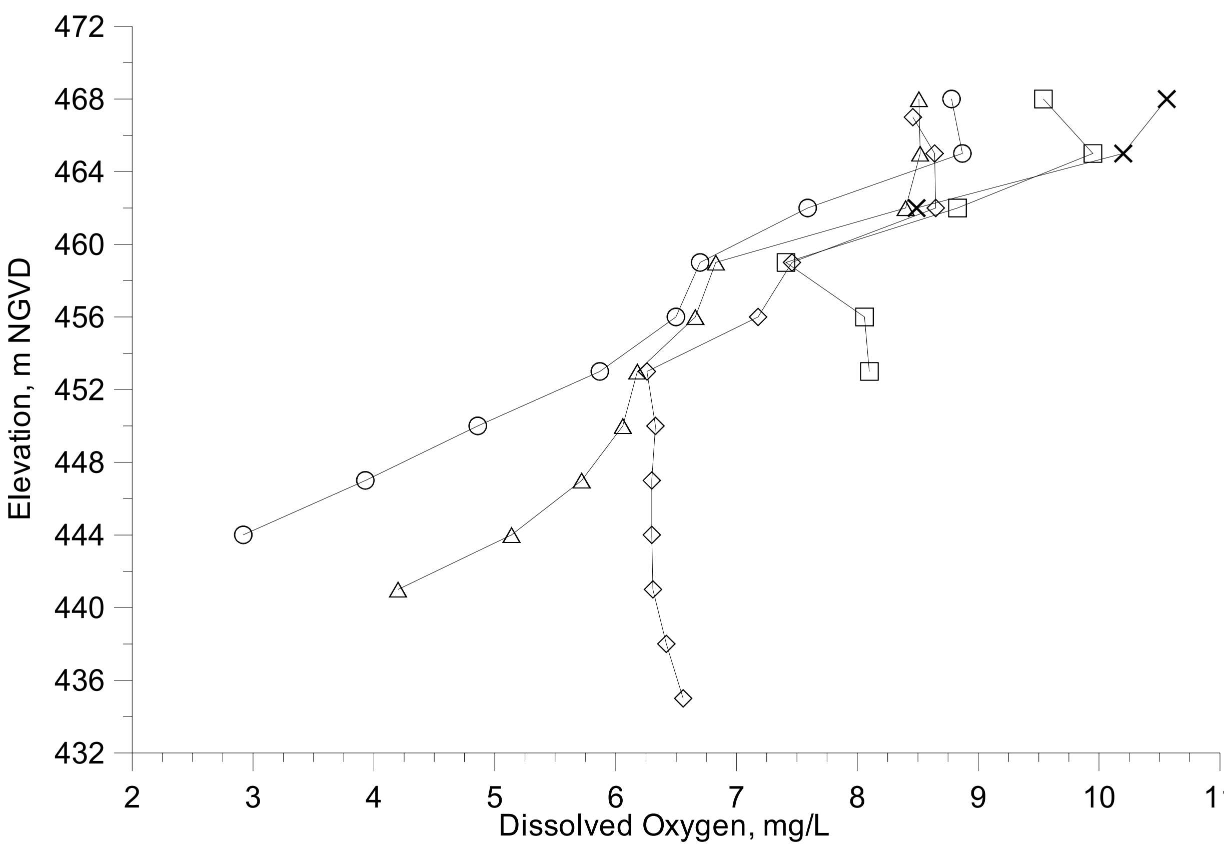
80
90
100
110
120
130
140
150
160
170
180
190
200
Conductivity, umhos/cm


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
6
7
8
9
pH
08/05/1991
LL0
LL1
LL2
LL3
LL4


472
468
464
460
456
452
448
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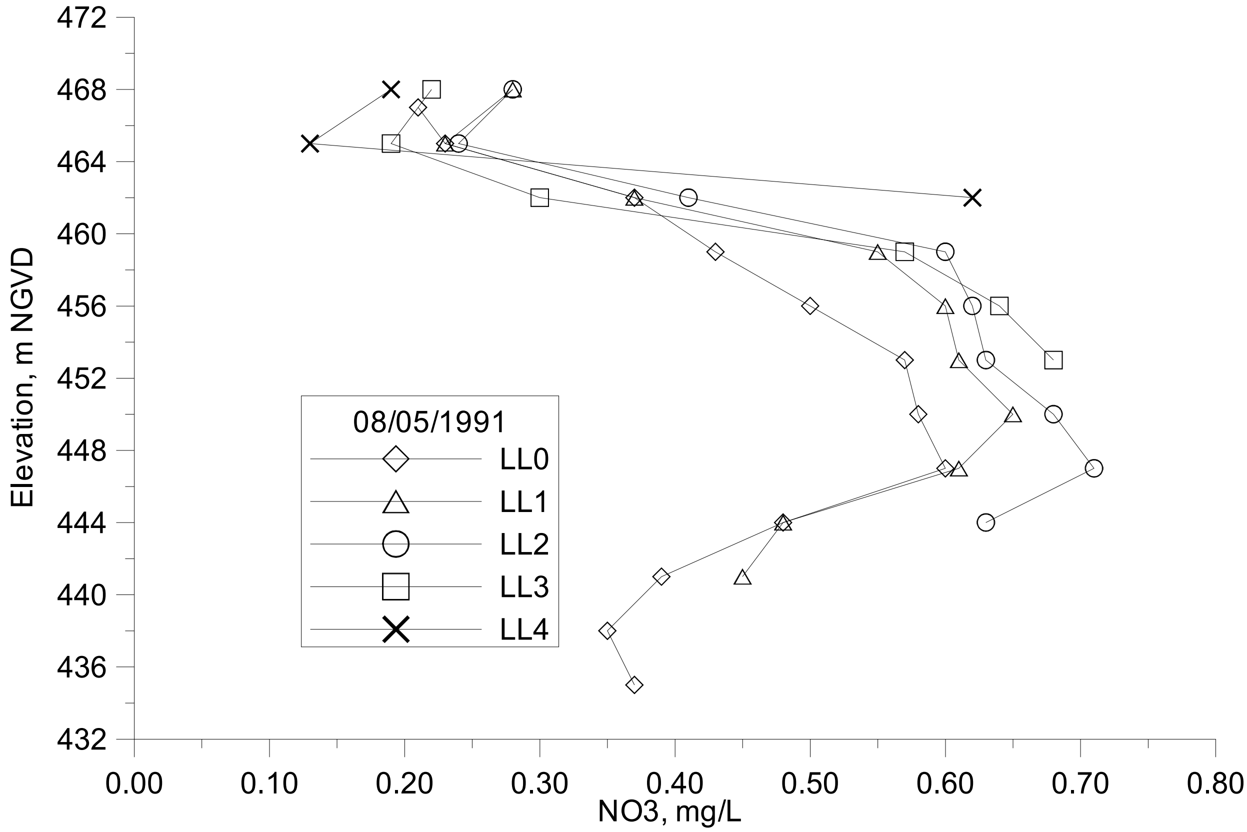
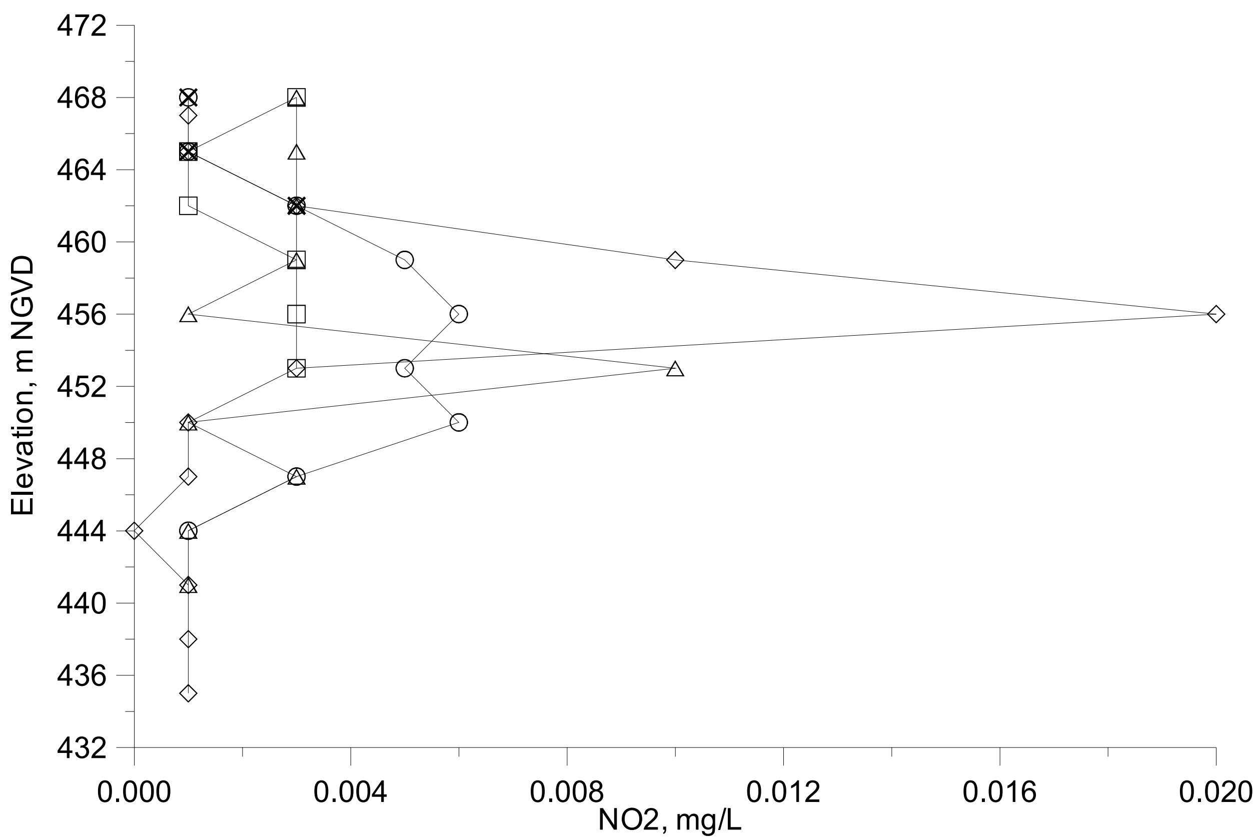
440
436
432
Elevation, m NGVD
2
3
4
5
6
7
8
9
10
11
Dissolved Oxygen, mg/L



08/05/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NO3, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80



Elevation, m NGVD
NO2, mg/L
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468
464
460
456
452
448
444
440
436
432
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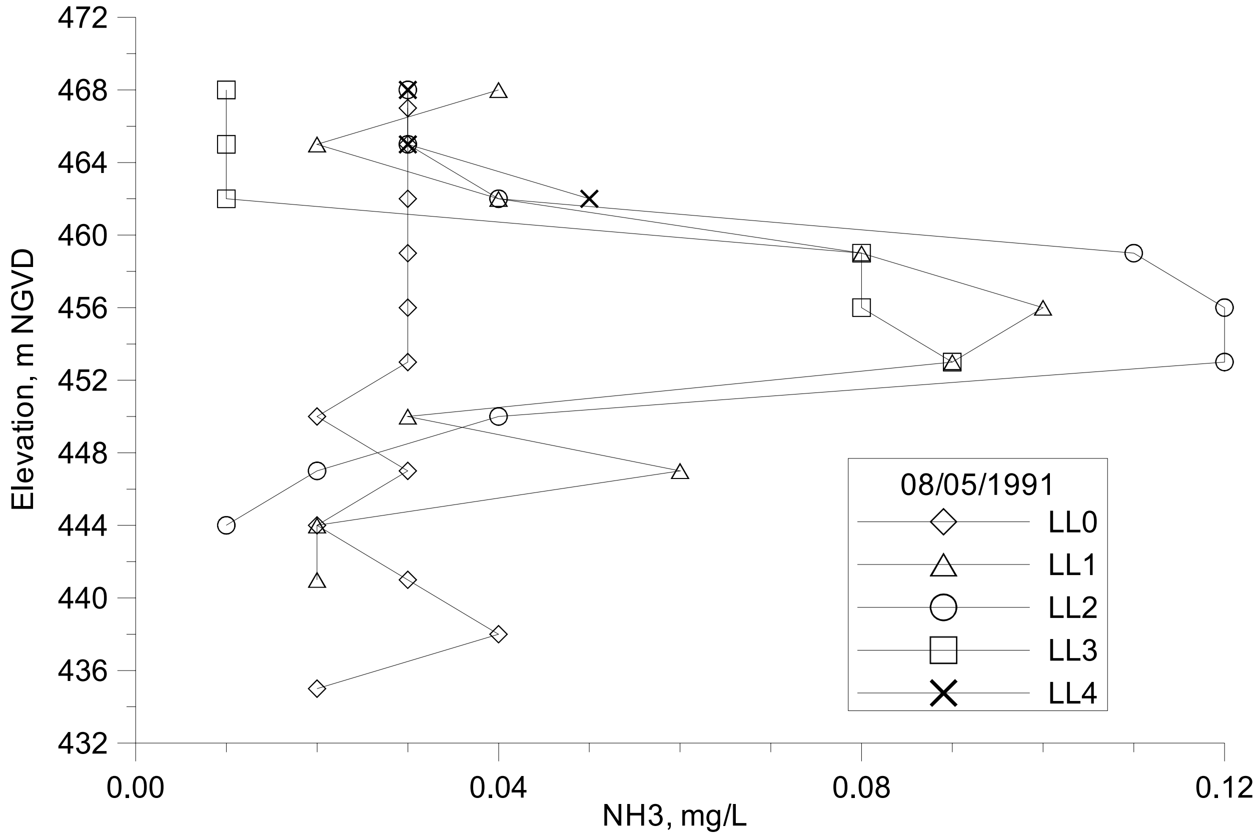
0.004
0.008
0.012
0.016
0.020


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
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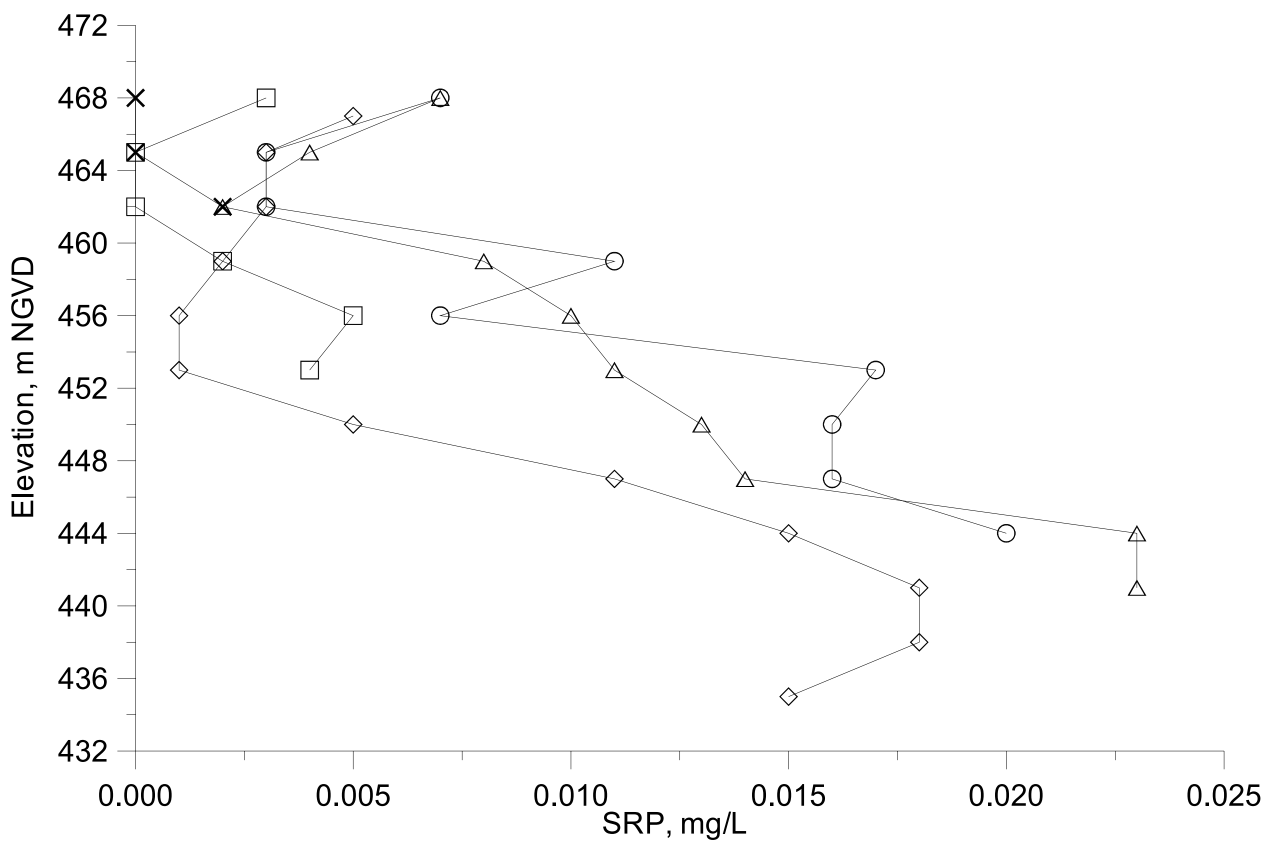
0.08
0.12
NH3, mg/L
08/05/1991
LL0
LL1
LL2
LL3
LL4


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
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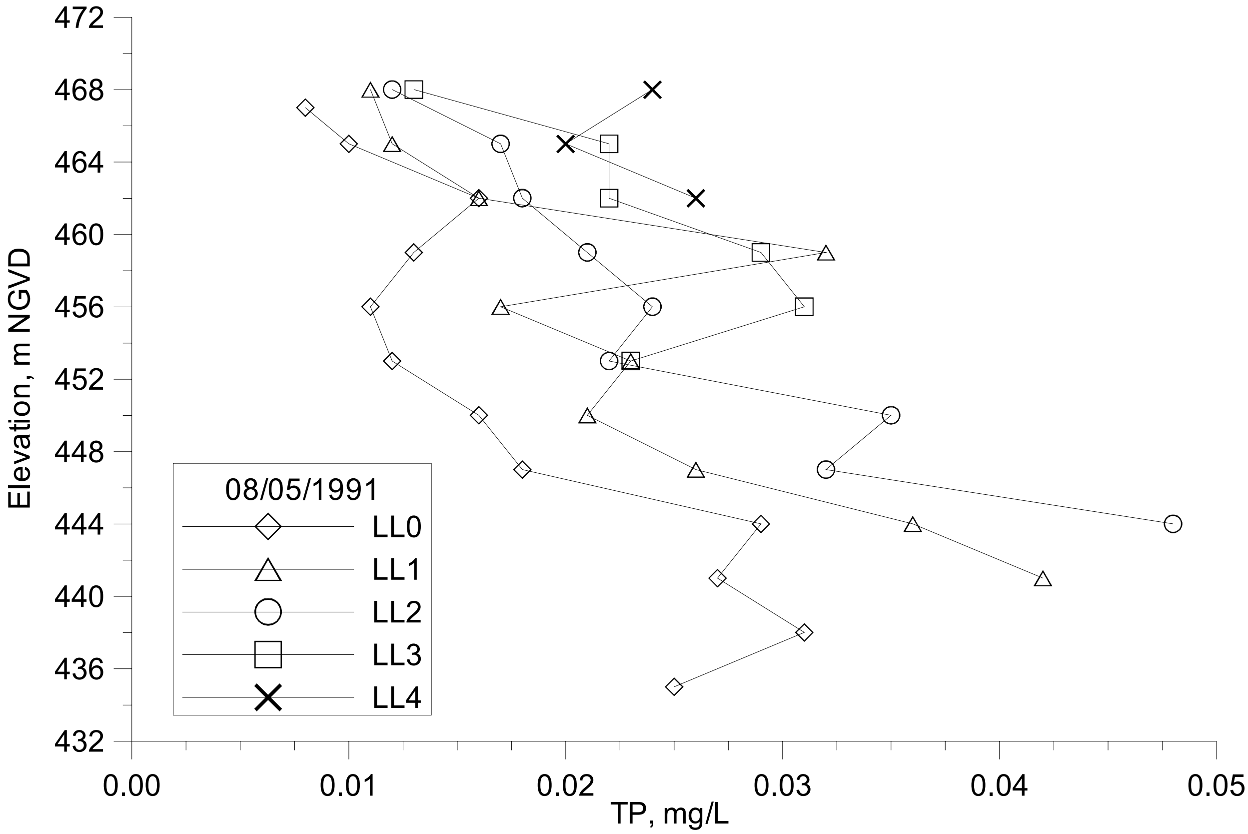
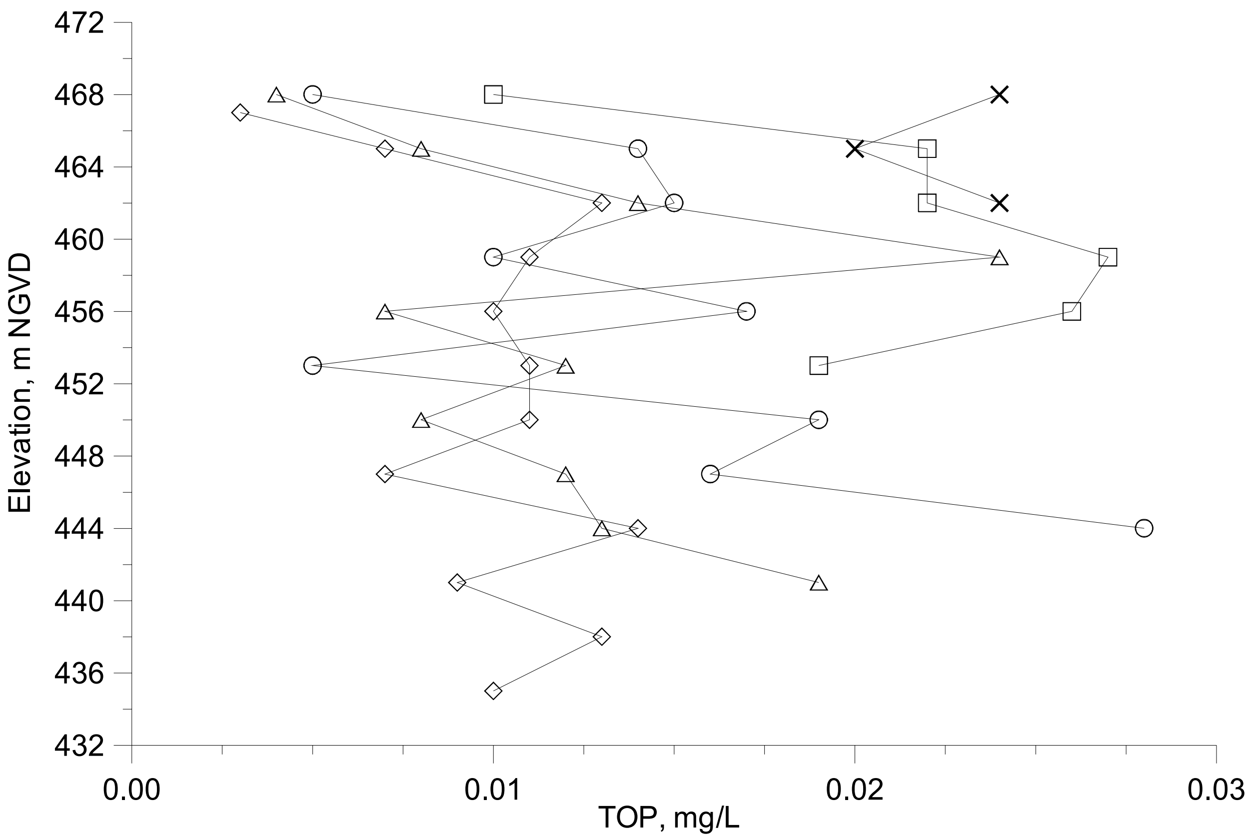
0.010
0.015
0.020
0.025
SRP, mg/L


08/05/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
TP, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.01
0.02
0.03
0.04
0.05


Elevation, m NGVD
TOP, mg/L
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468
464
460
456
452
448
444
440
436
432
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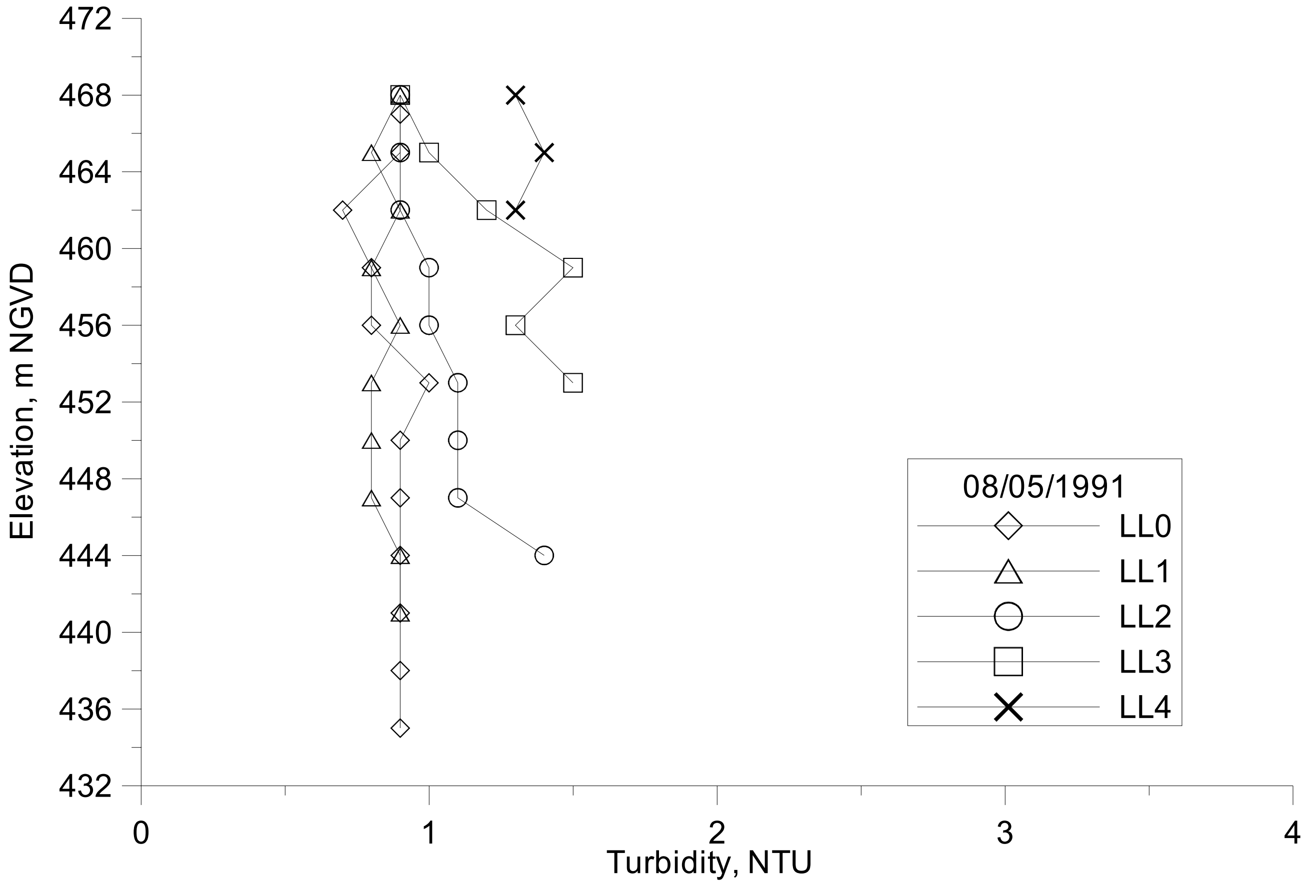
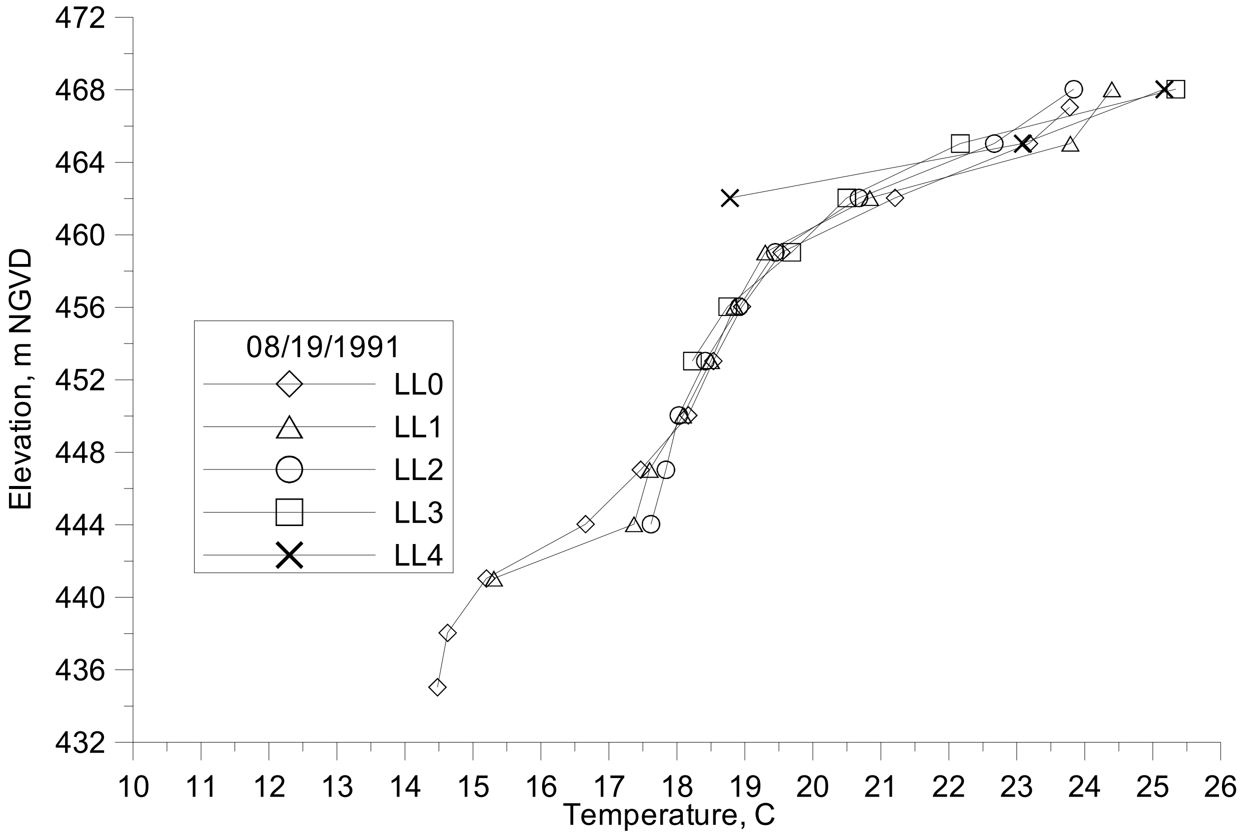
0.02
0.03


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
Turbidity, NTU
08/05/1991
LL0
LL1
LL2
LL3
LL4


08/19/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Temperature, C
472
468
464
460
456
452
448
444
440
436
432
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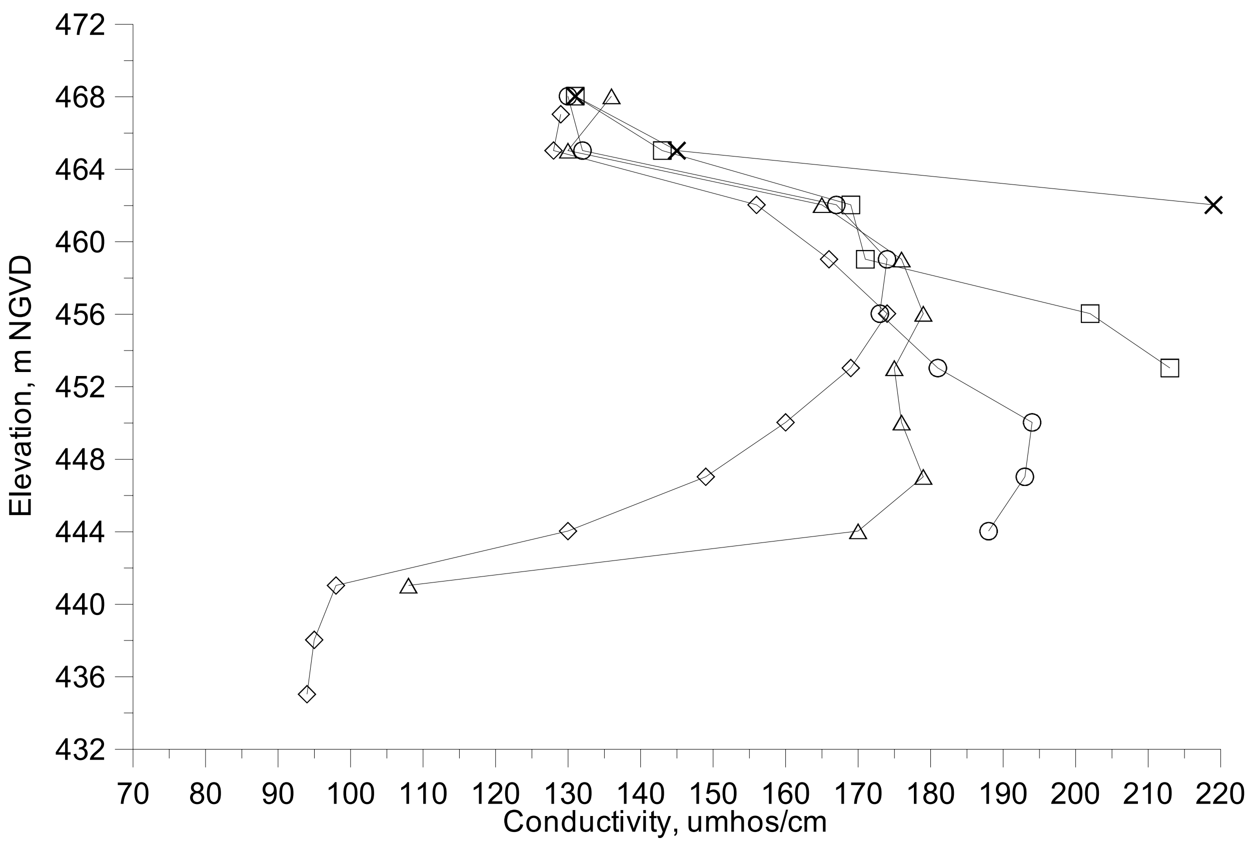
25
26


Elevation, m NGVD
Conductivity, umhos/cm
472
468
464
460
456
452
448
444
440
436
432
70
80
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180
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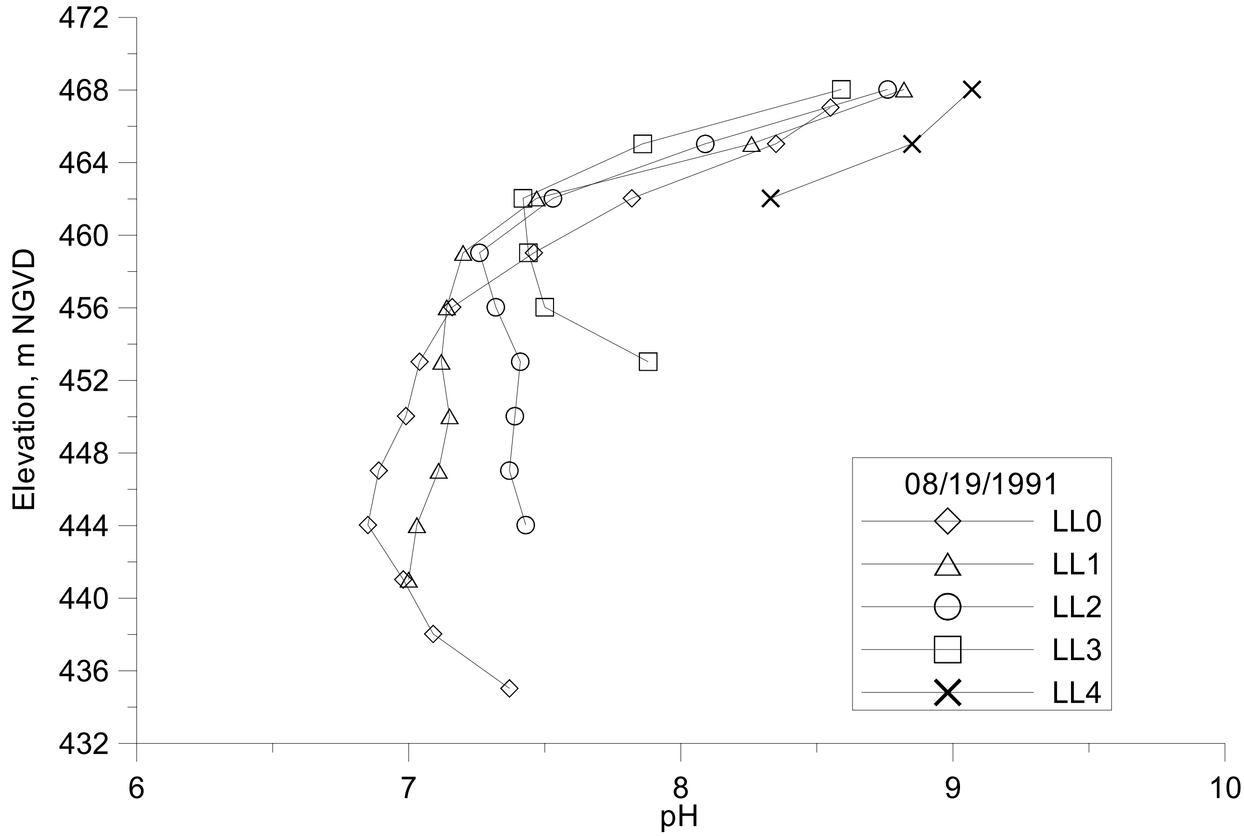
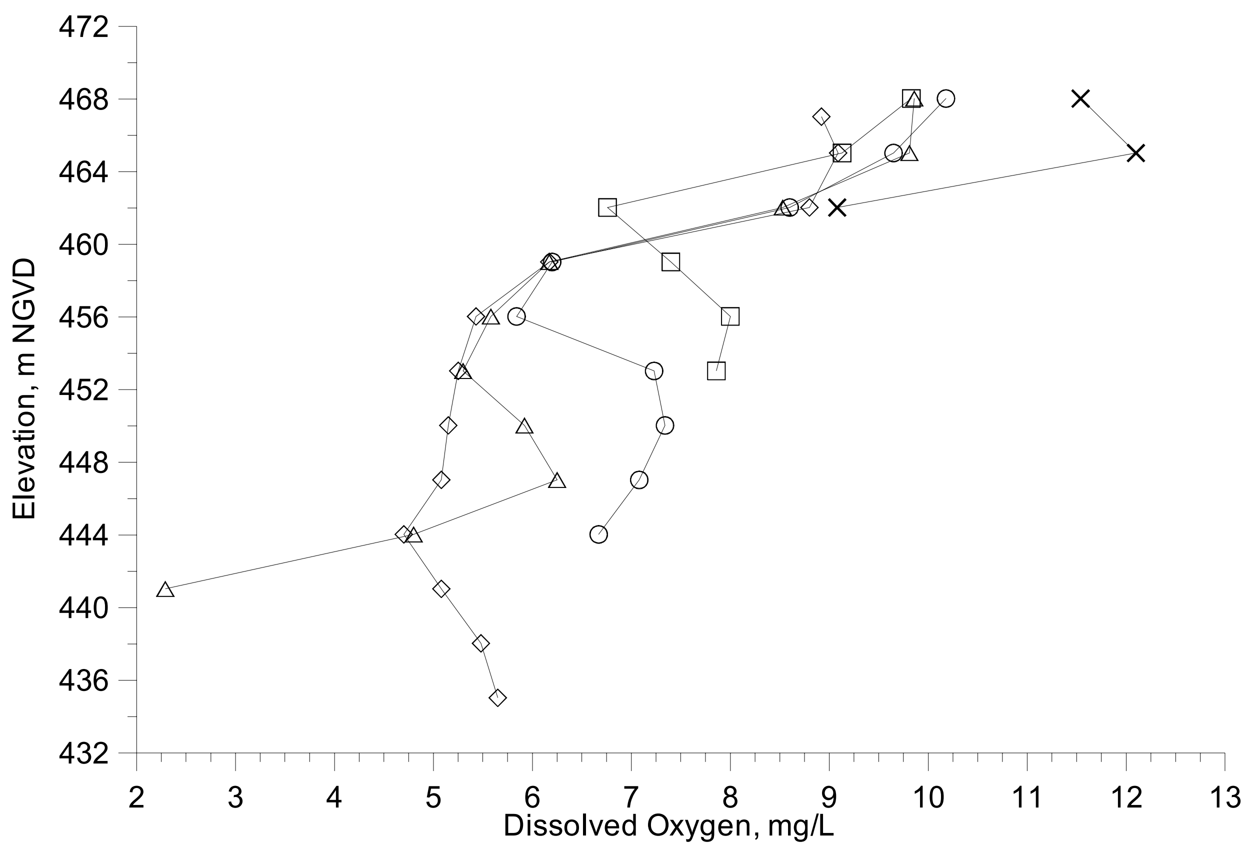
200
210
220



08/19/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
pH
432
436
440
444
448
452
456
460
464
468
472
6
7
8
9
10



Elevation, m NGVD
Dissolved Oxygen, mg/L
432
436
440
444
448
452
456
460
464
468
472
2
3
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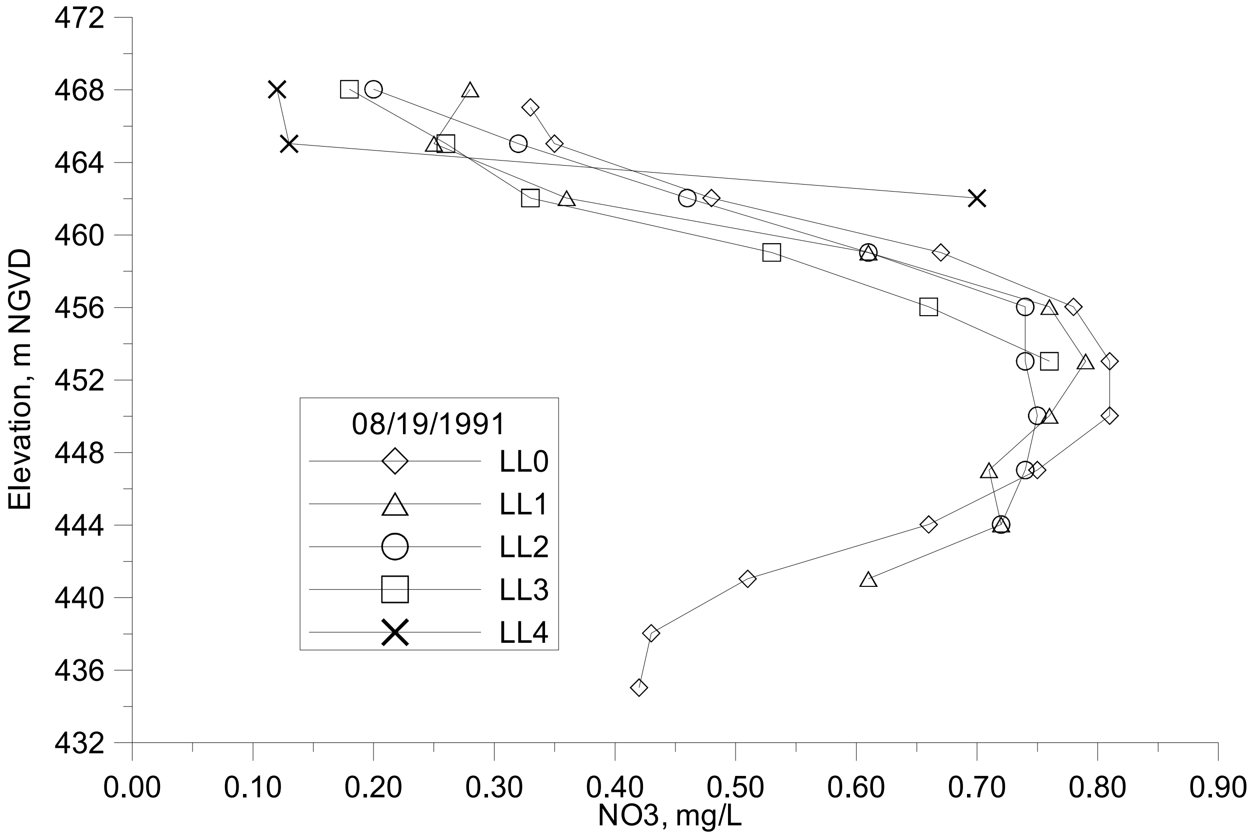
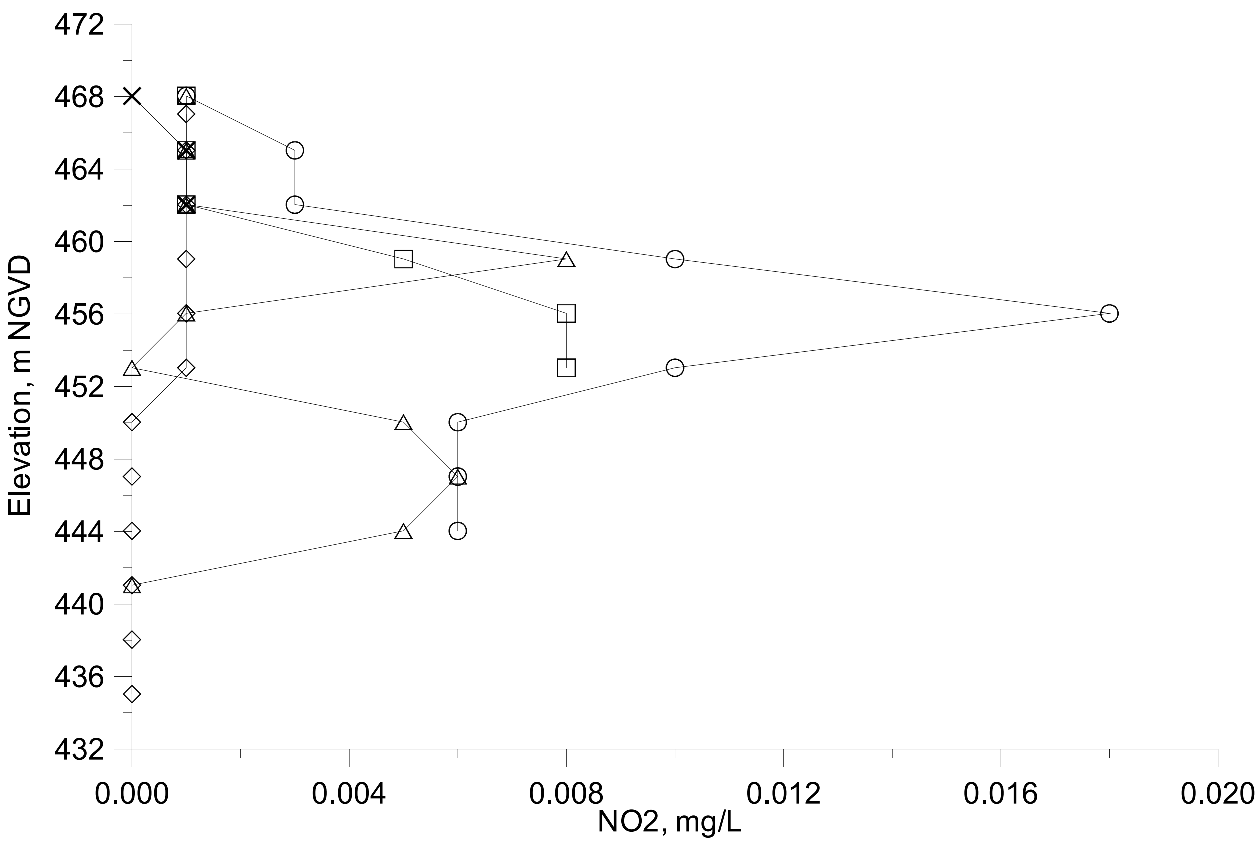
9
10
11
12
13



472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
NO3, mg/L
08/19/1991
LL0
LL1
LL2
LL3
LL4



472
468
464
460
456
452
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440
436
432
Elevation, m NGVD
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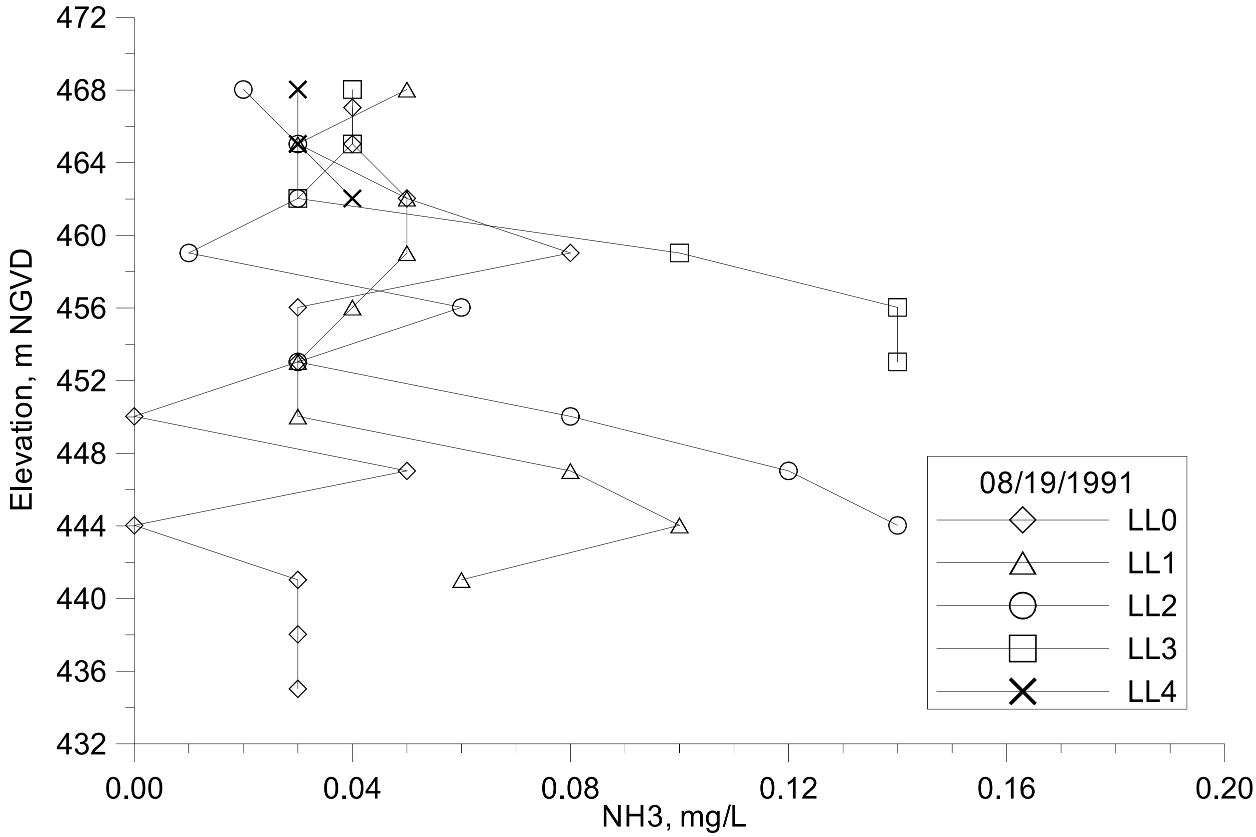
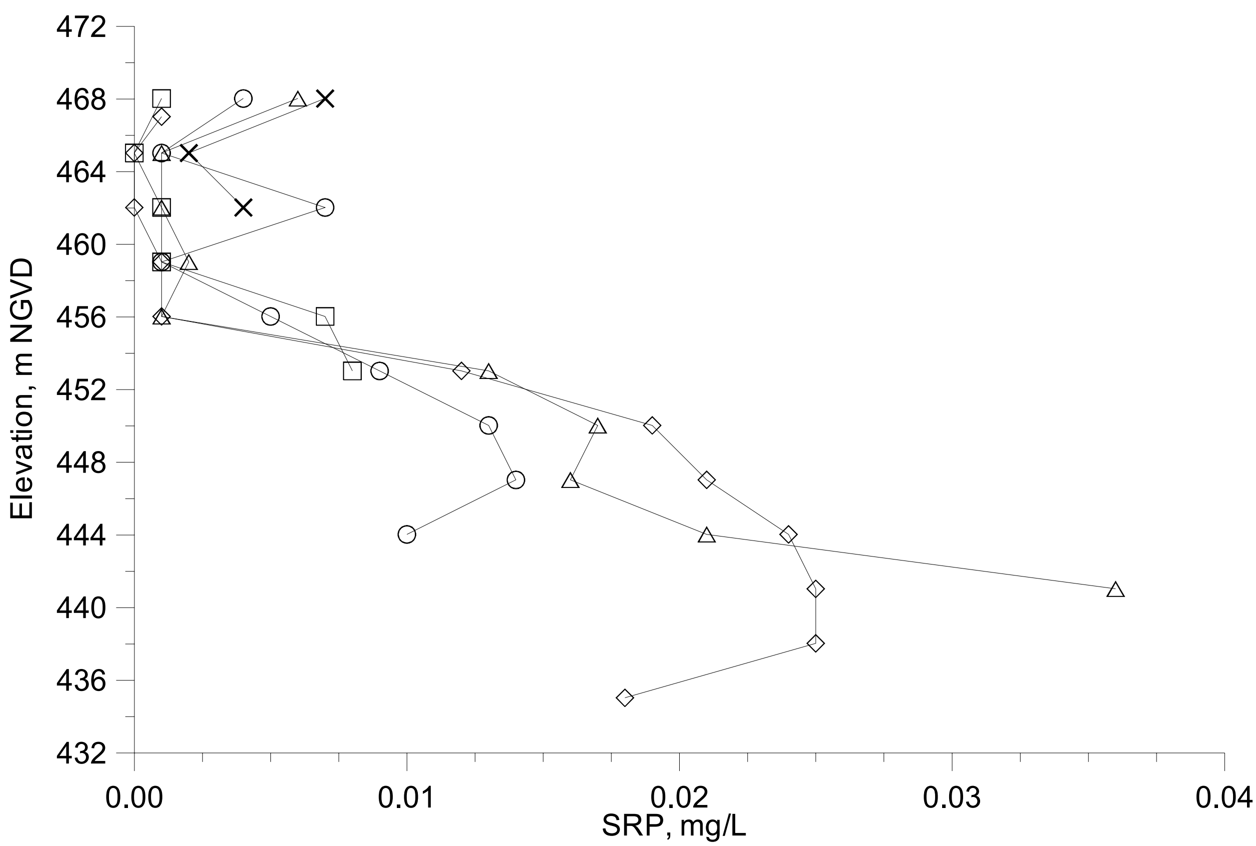
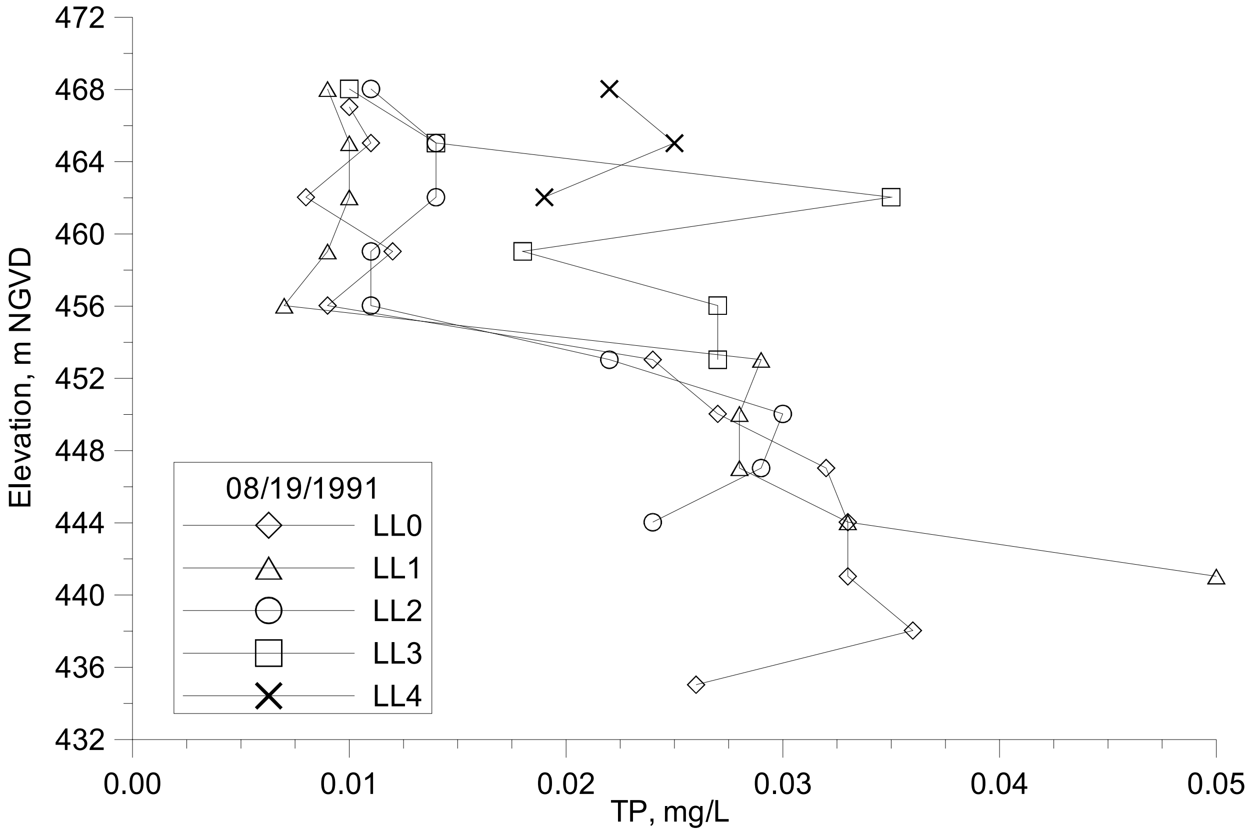
0.008
0.012
0.016
0.020
NO2, mg/L



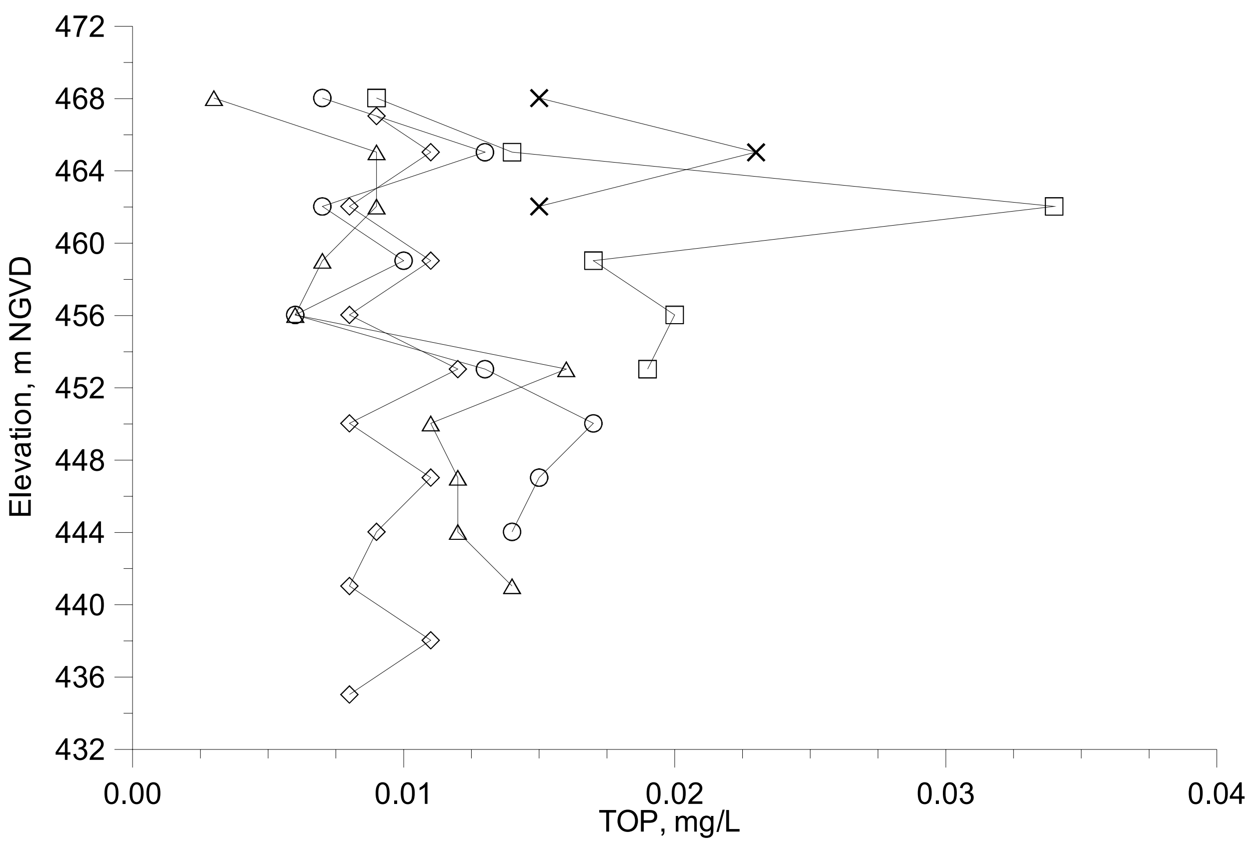
08/19/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NH3, mg/L



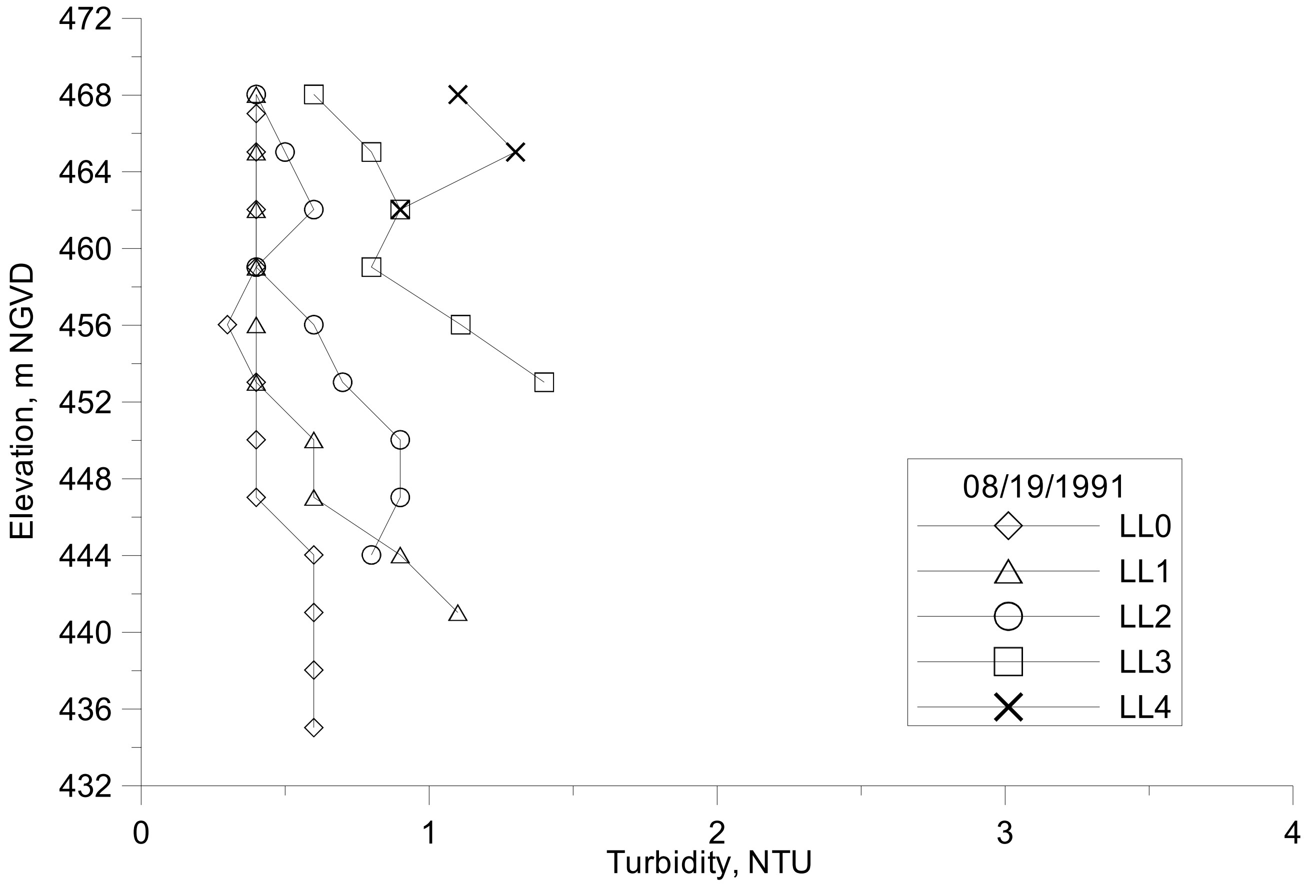
Elevation, m NGVD
SRP, mg/L

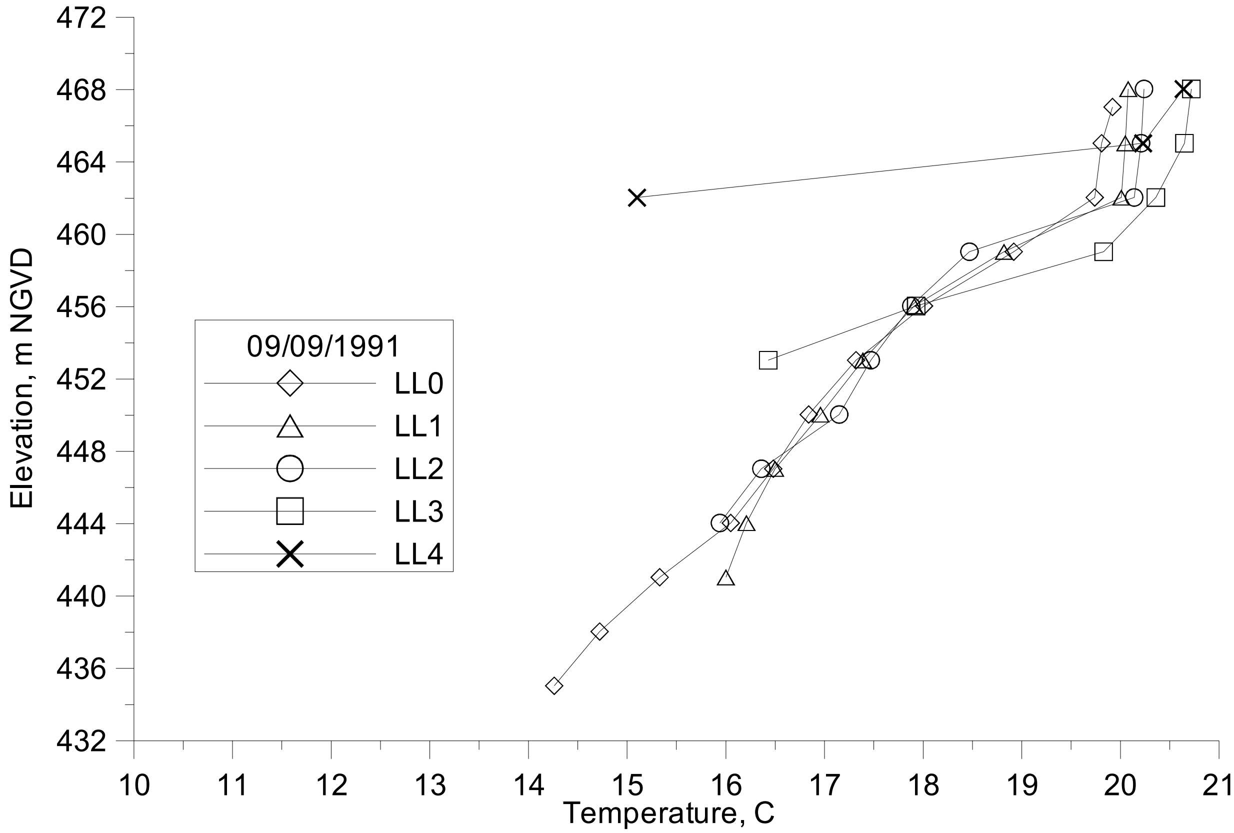


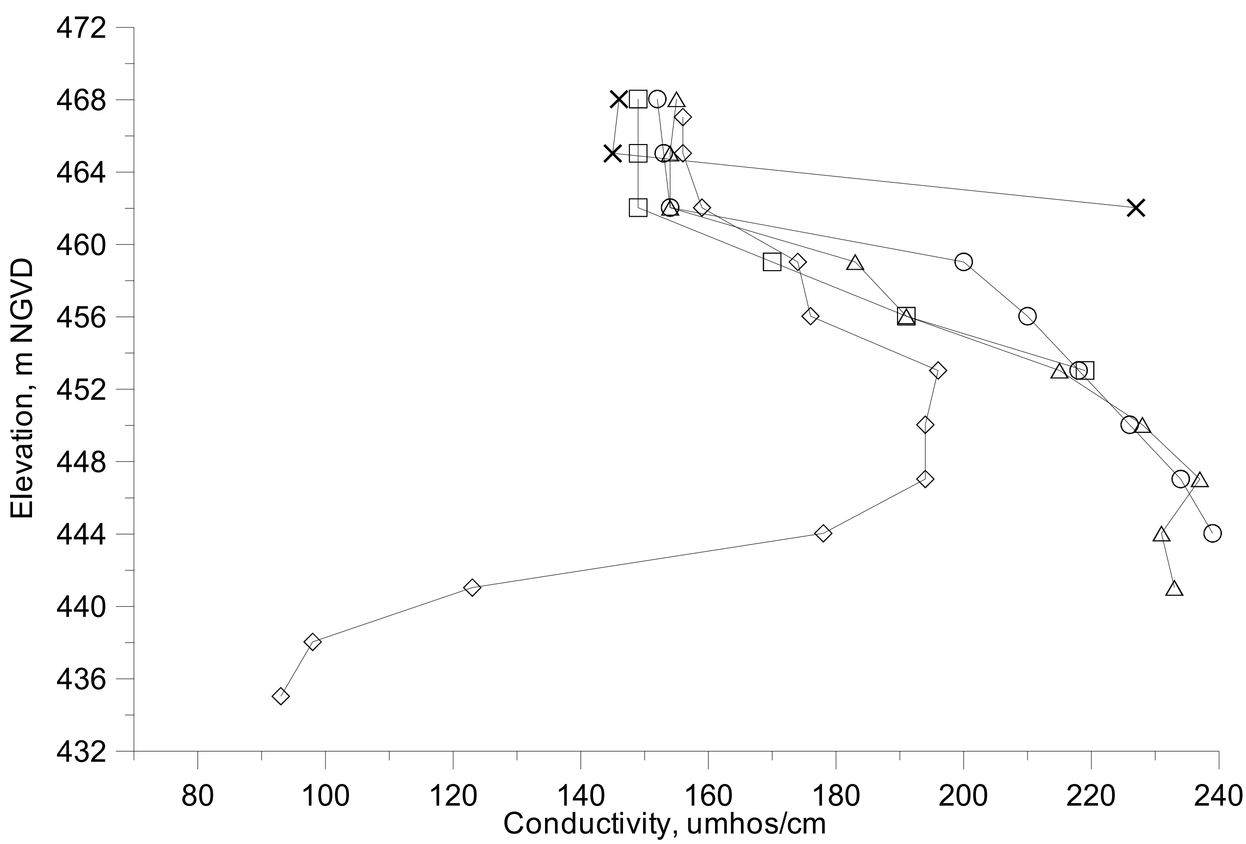
Elevation, m NGVD
472
468
464
460
456
452
448
444
440
436
432
08/19/1991
LL0
LL1
LL2
LL3
LL4
0.00
0.01
0.02
0.03
0.04
0.05
TP, mg/L

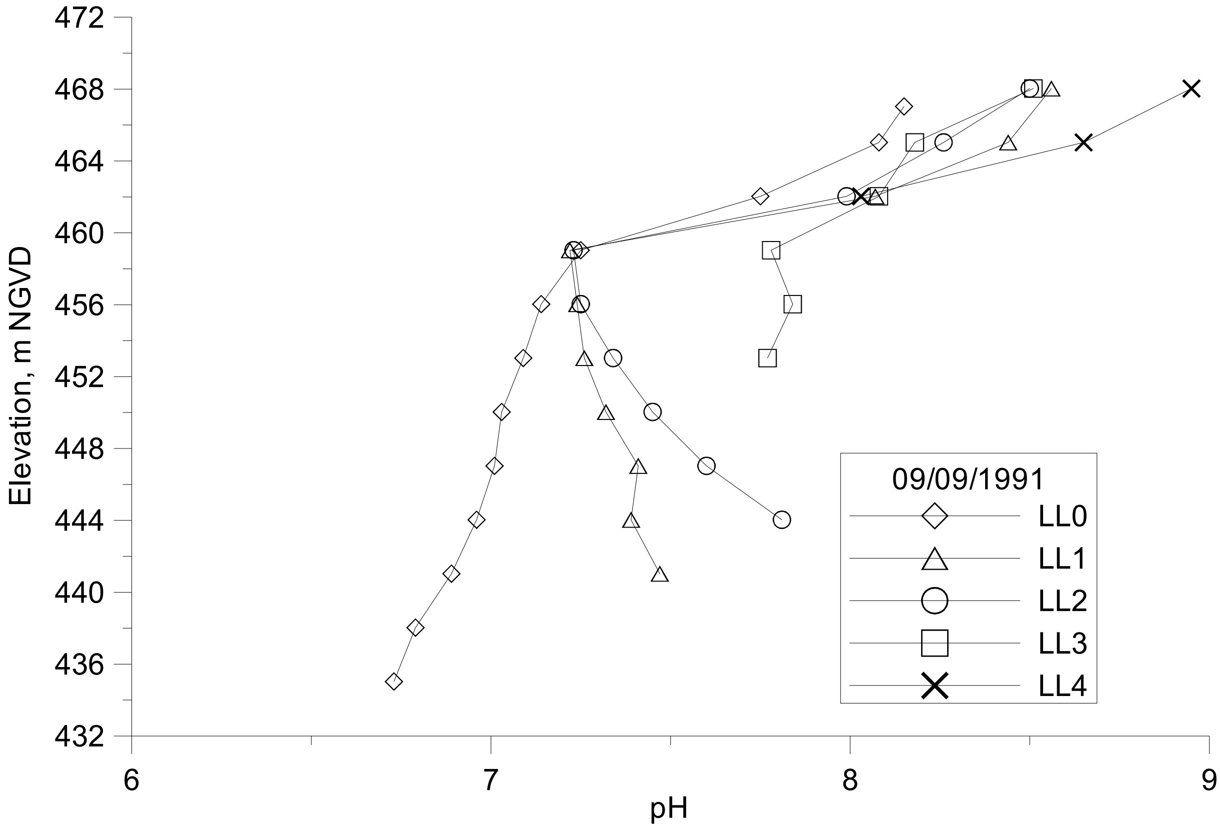


Elevation, m NGVD
472
468
464
460
456
452
448
444
440
436
432
0.00
0.01
0.02
0.03
0.04
TOP, mg/L

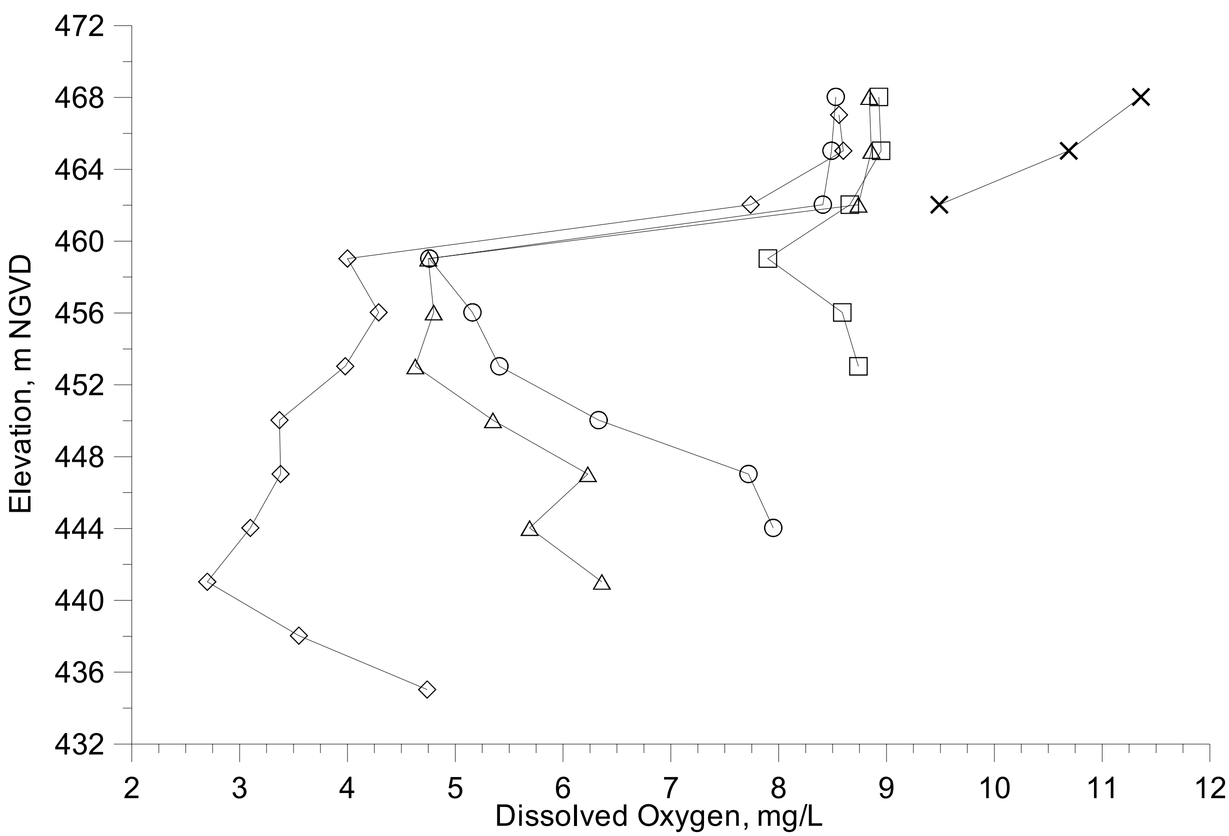

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
Turbidity, NTU
08/19/1991
LL0
LL1
LL2
LL3
LL4


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
09/09/1991
LL0
LL1
LL2
LL3
LL4
10
11
12
13
14
15
16
17
18
19
20
21
Temperature, C

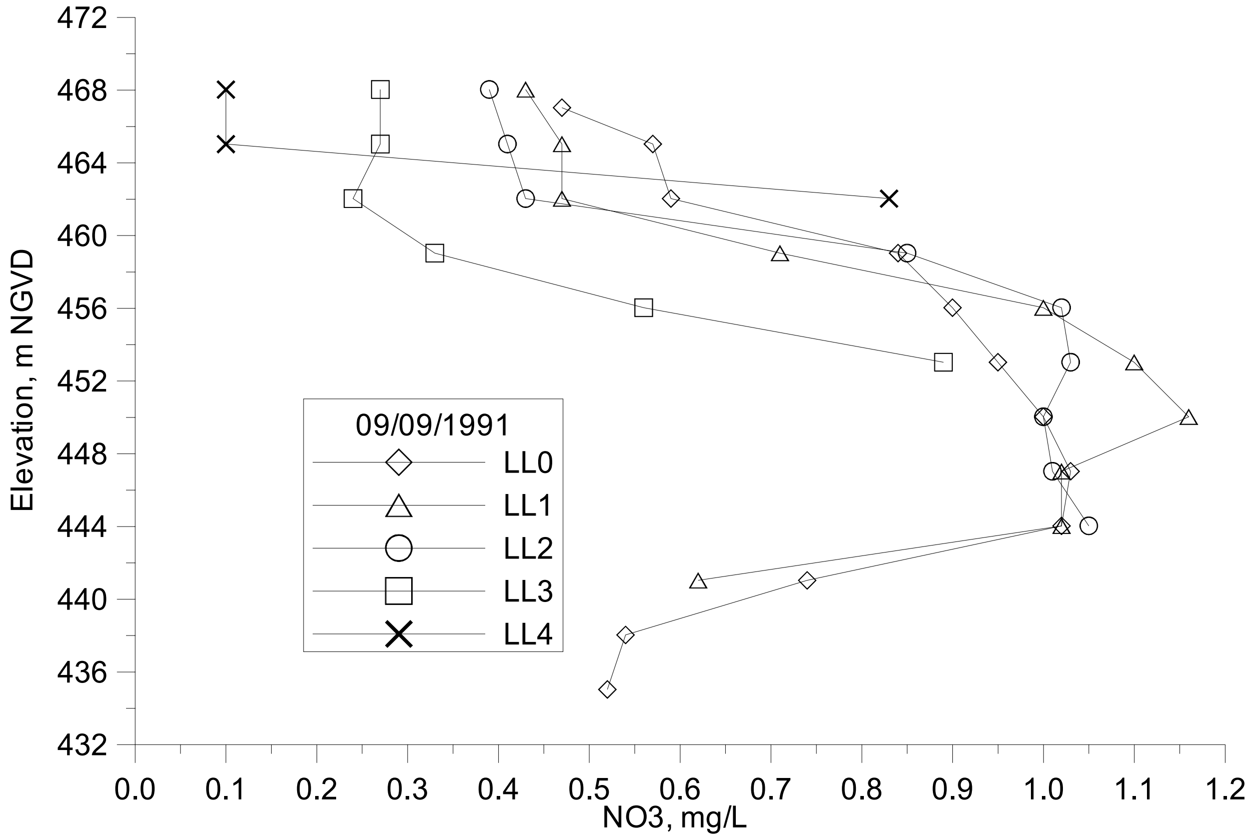

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
80
100
120
140
160
180
200
220
240
Conductivity, umhos/cm

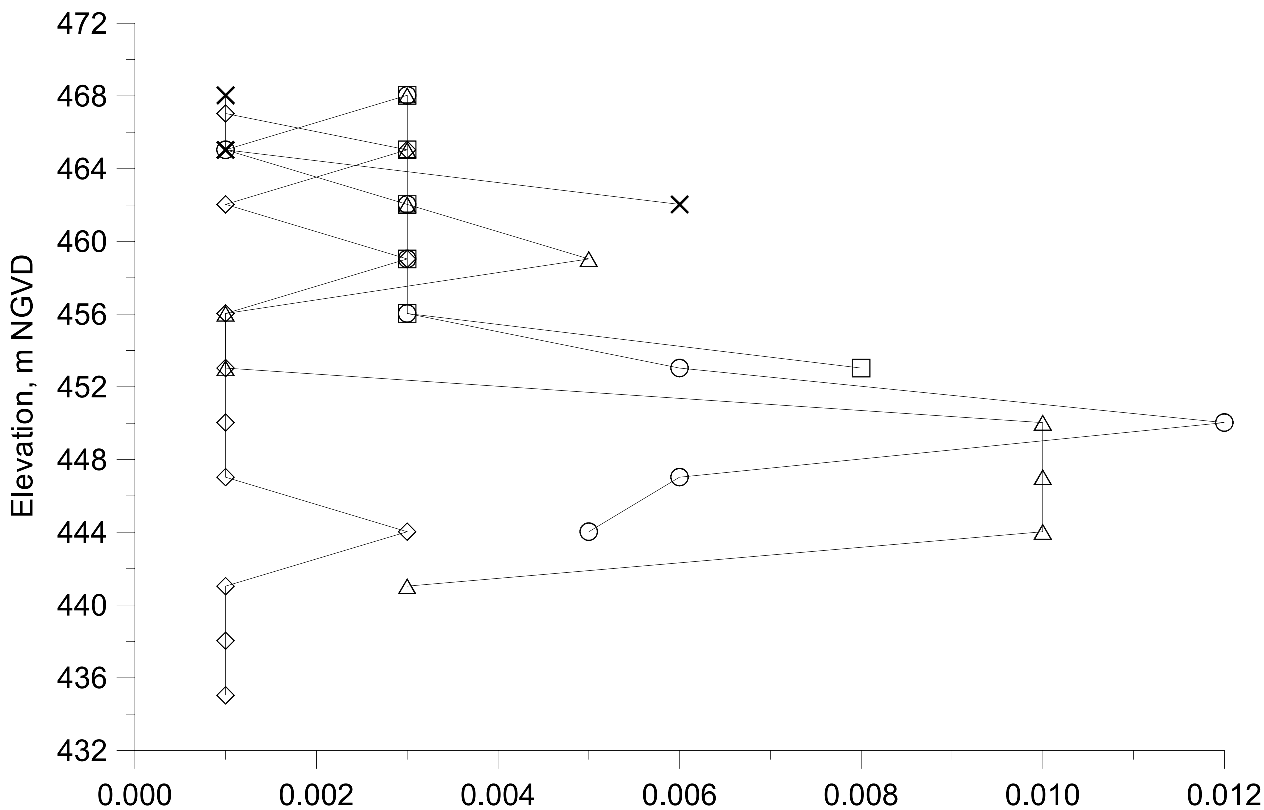


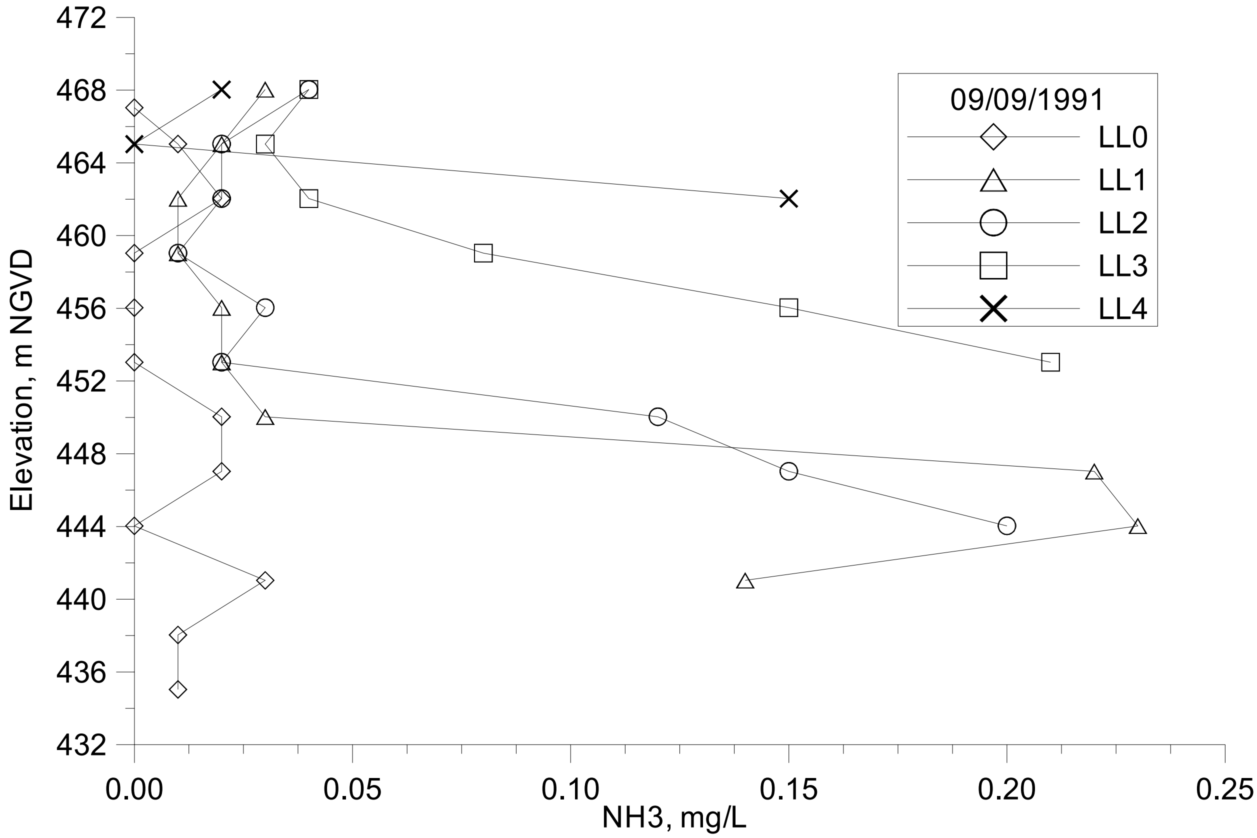
Elevation, m NGVD
pH
09/09/1991
LL0
LL1
LL2
LL3
LL4

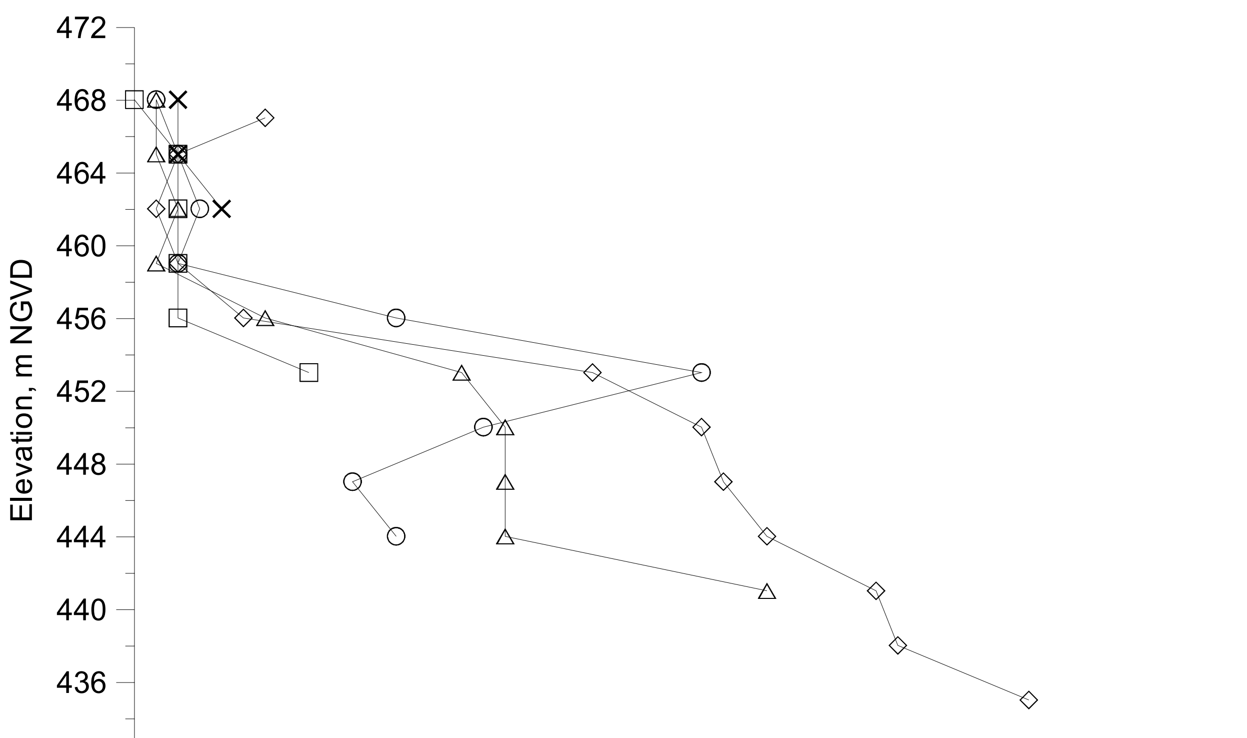


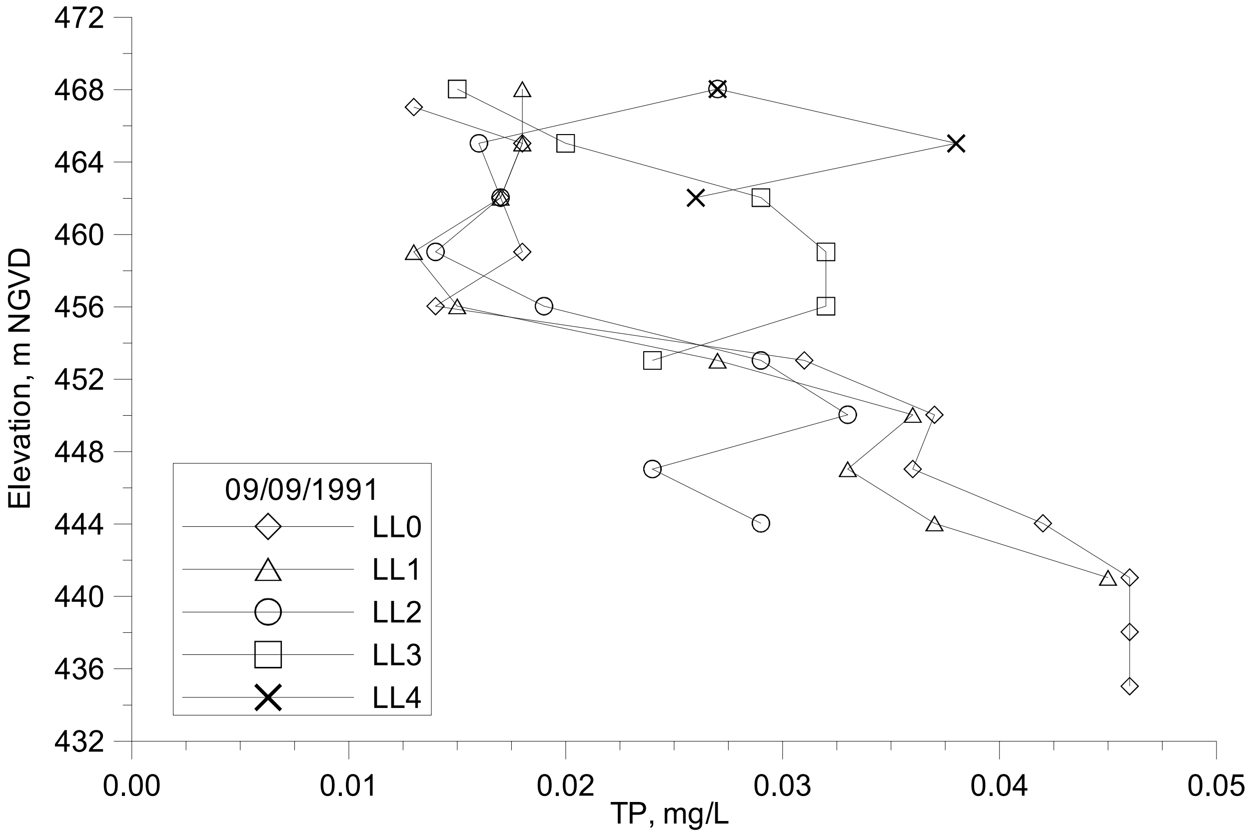
Elevation, m NGVD
Dissolved Oxygen, mg/L


09/09/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NO3, mg/L

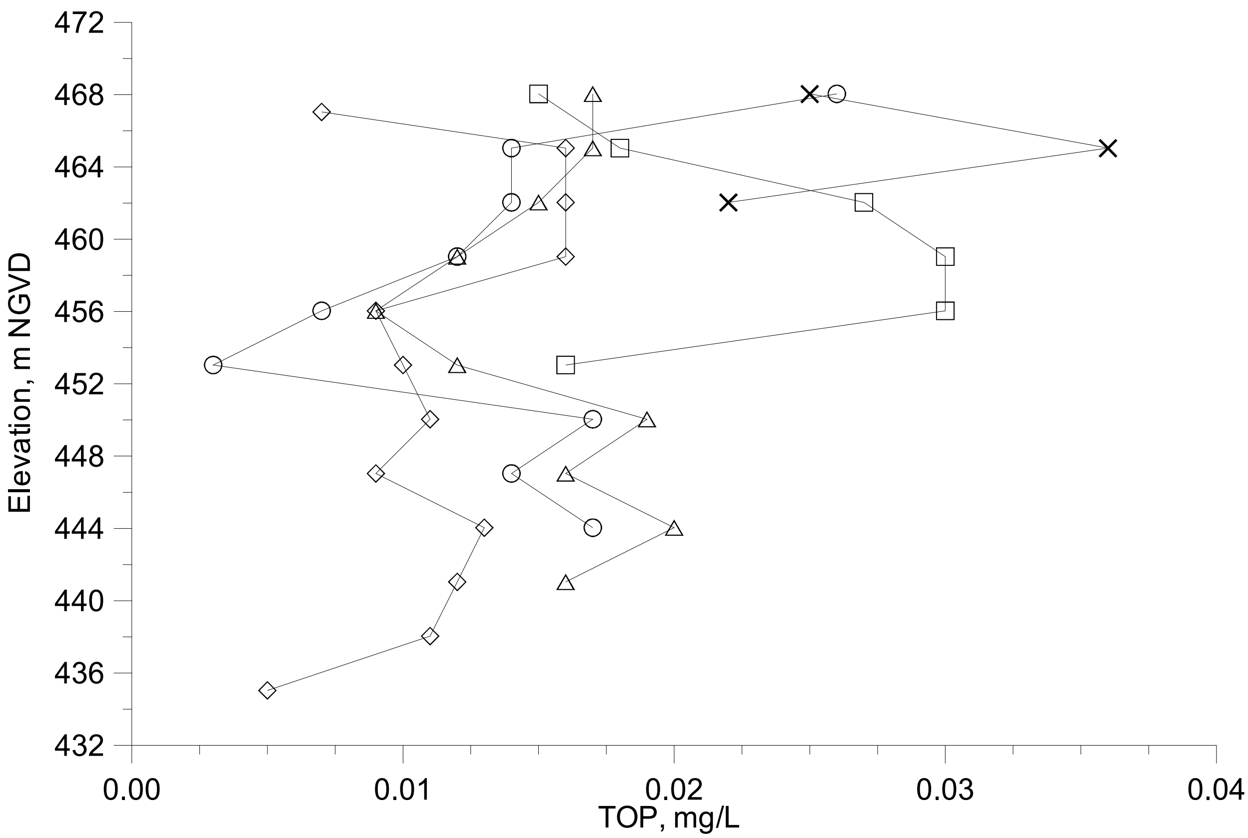

Elevation, m NGVD
NO2, mg/L


09/09/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NH3, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.05
0.10
0.15
0.20
0.25

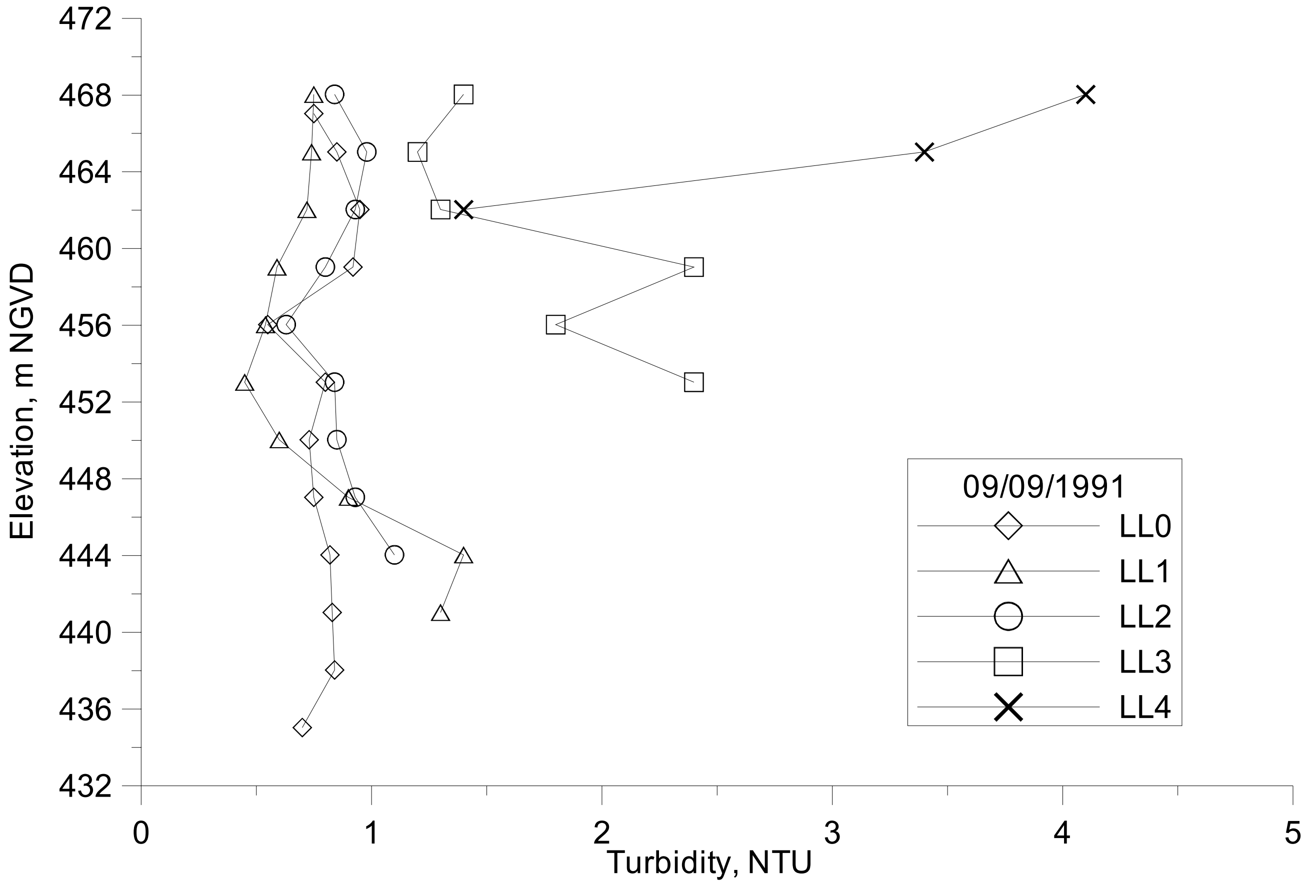

Elevation, m NGVD
SRP, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.01
0.02
0.03
0.04
0.05



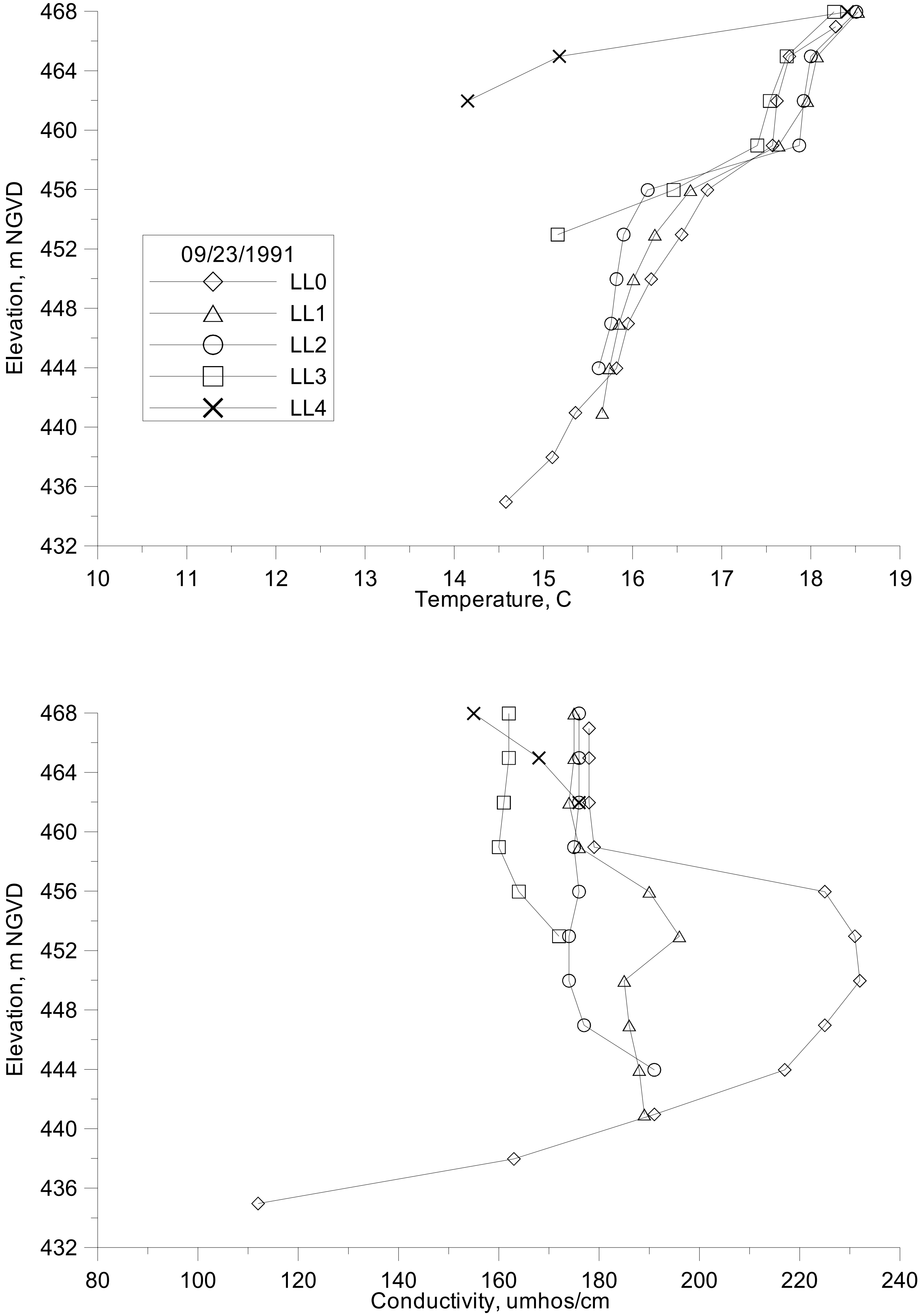
09/09/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
TP, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.01
0.02
0.03
0.04
0.05

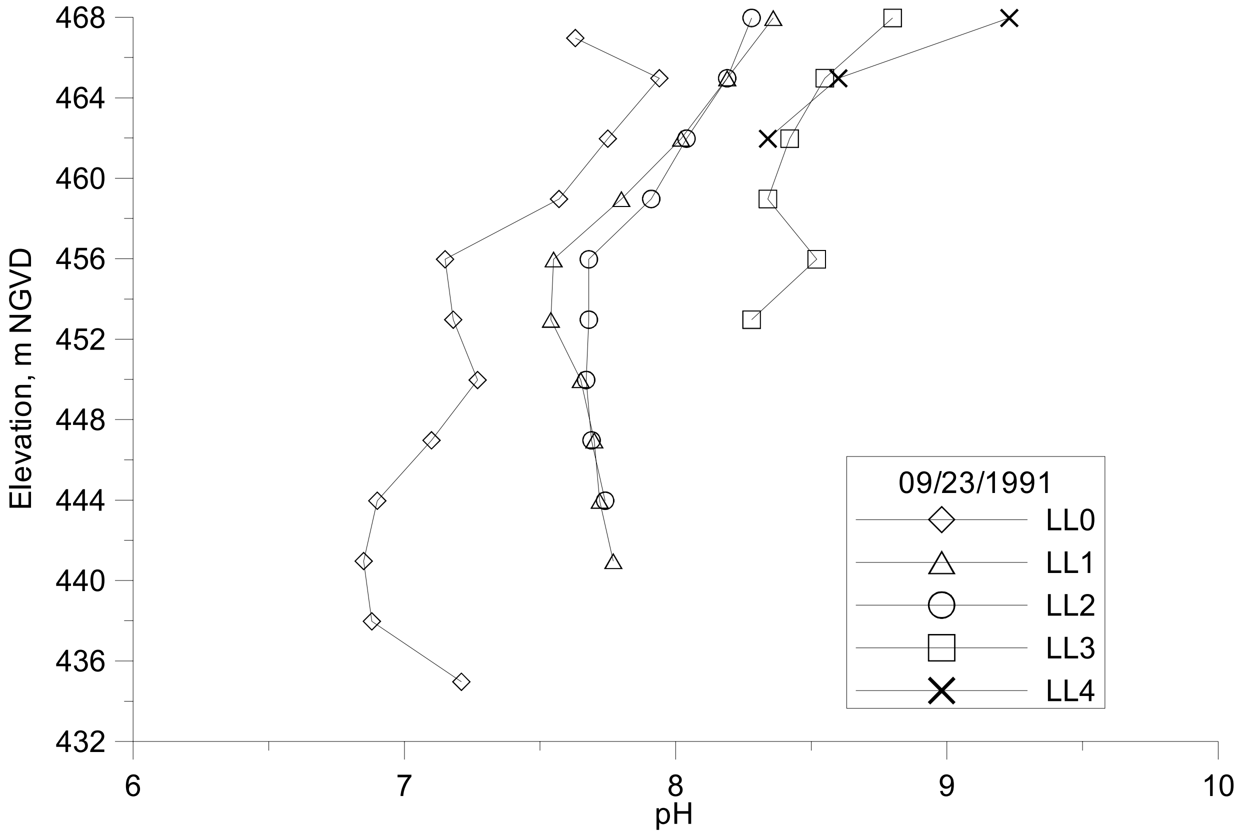


Elevation, m NGVD
TOP, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.00
0.01
0.02
0.03
0.04

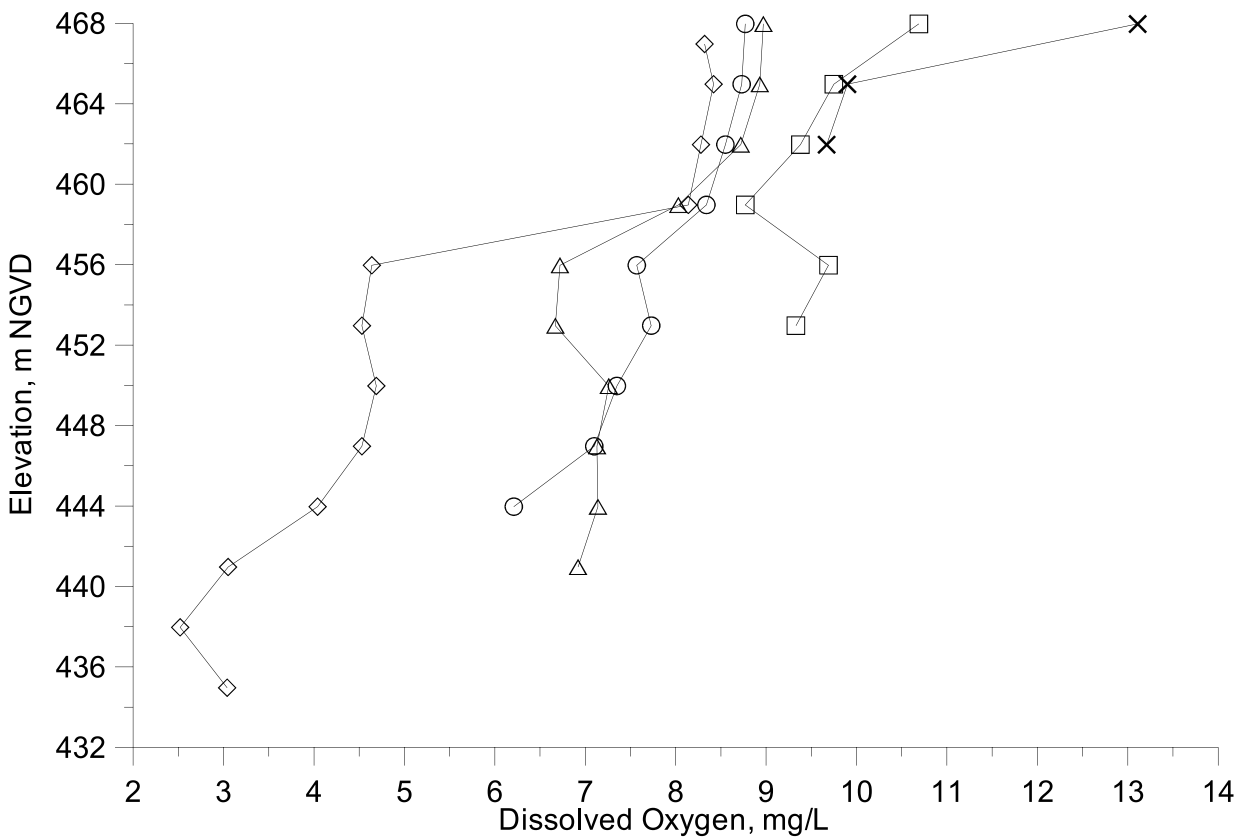


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
5
Turbidity, NTU
09/09/1991
LL0
LL1
LL2
LL3
LL4

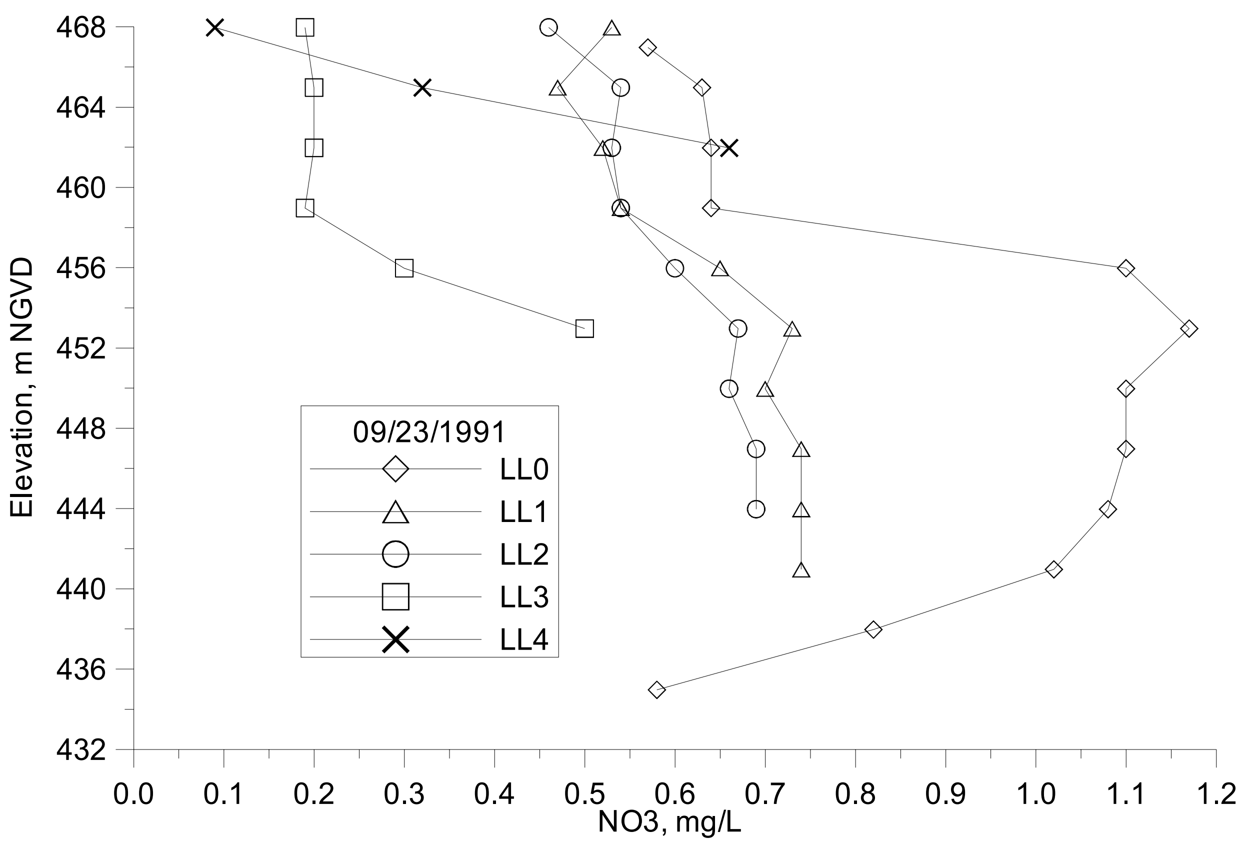

09/23/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Temperature, C
Elevation, m NGVD
Conductivity, umhos/cm



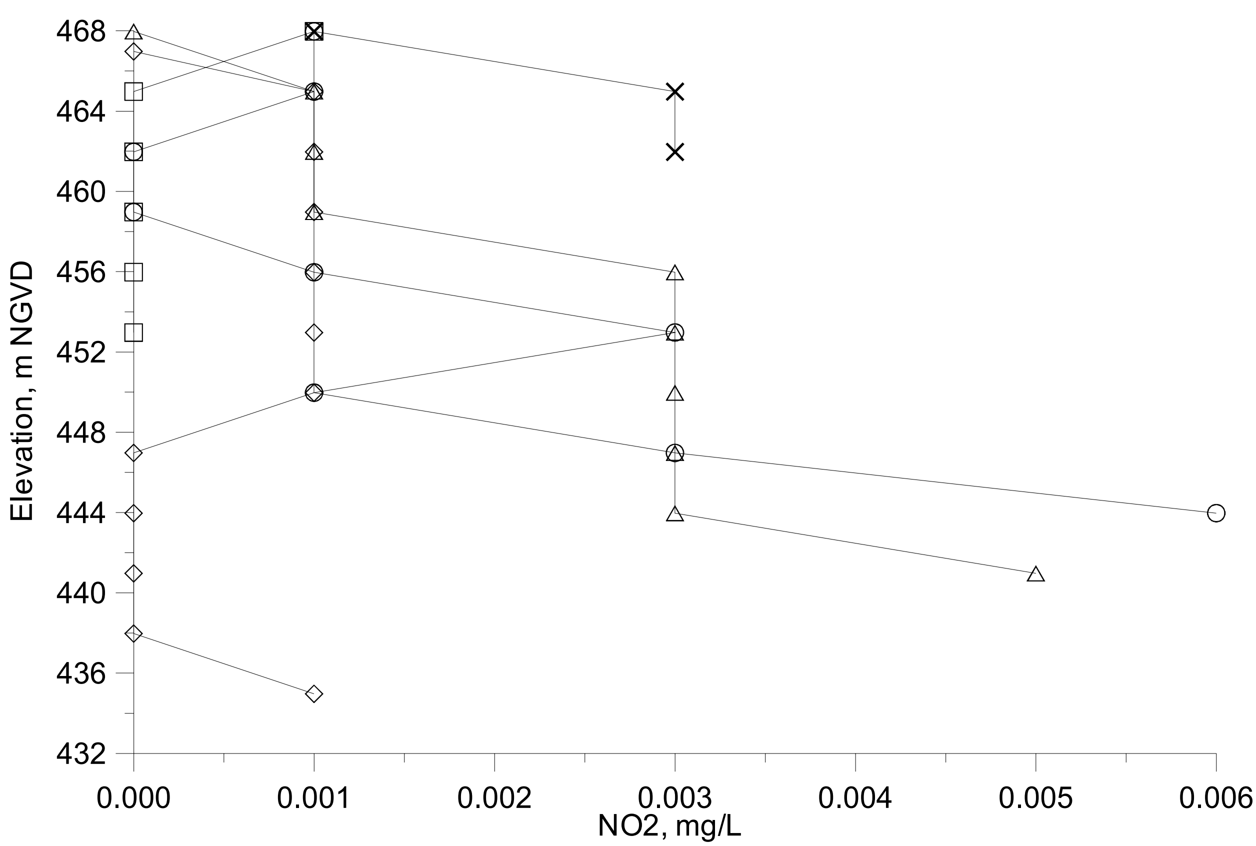
Elevation, m NGVD
pH
09/23/1991
LL0
LL1
LL2
LL3
LL4



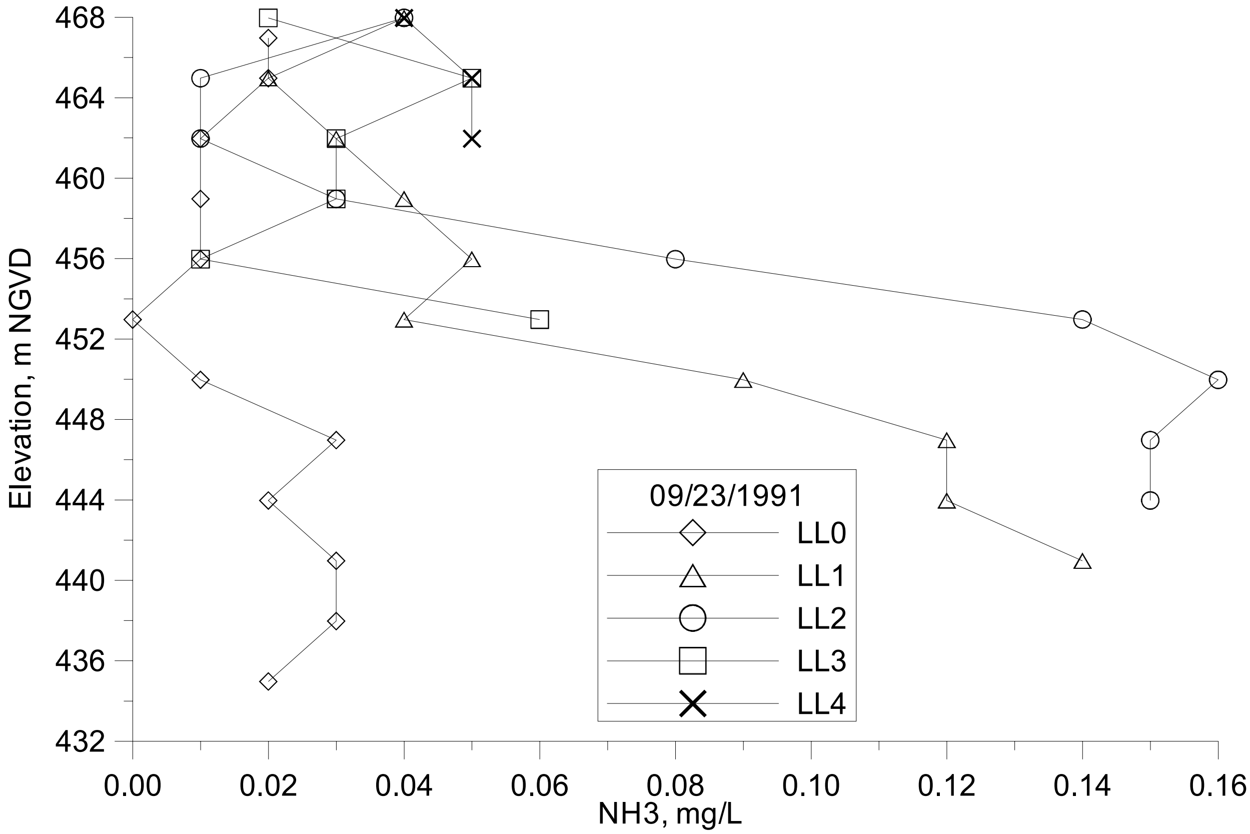
Elevation, m NGVD
Dissolved Oxygen, mg/L



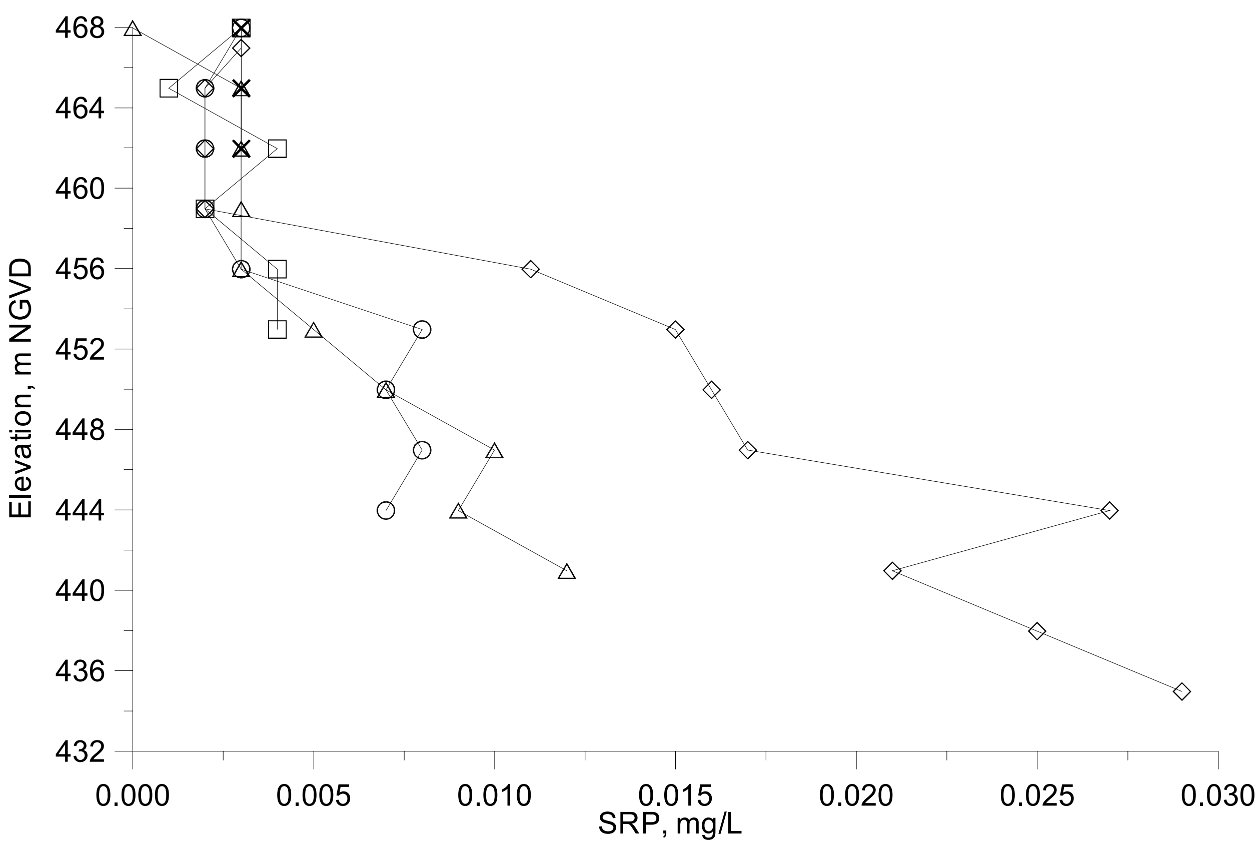
Elevation, m NGVD
NO3, mg/L
09/23/1991
LL0
LL1
LL2
LL3
LL4



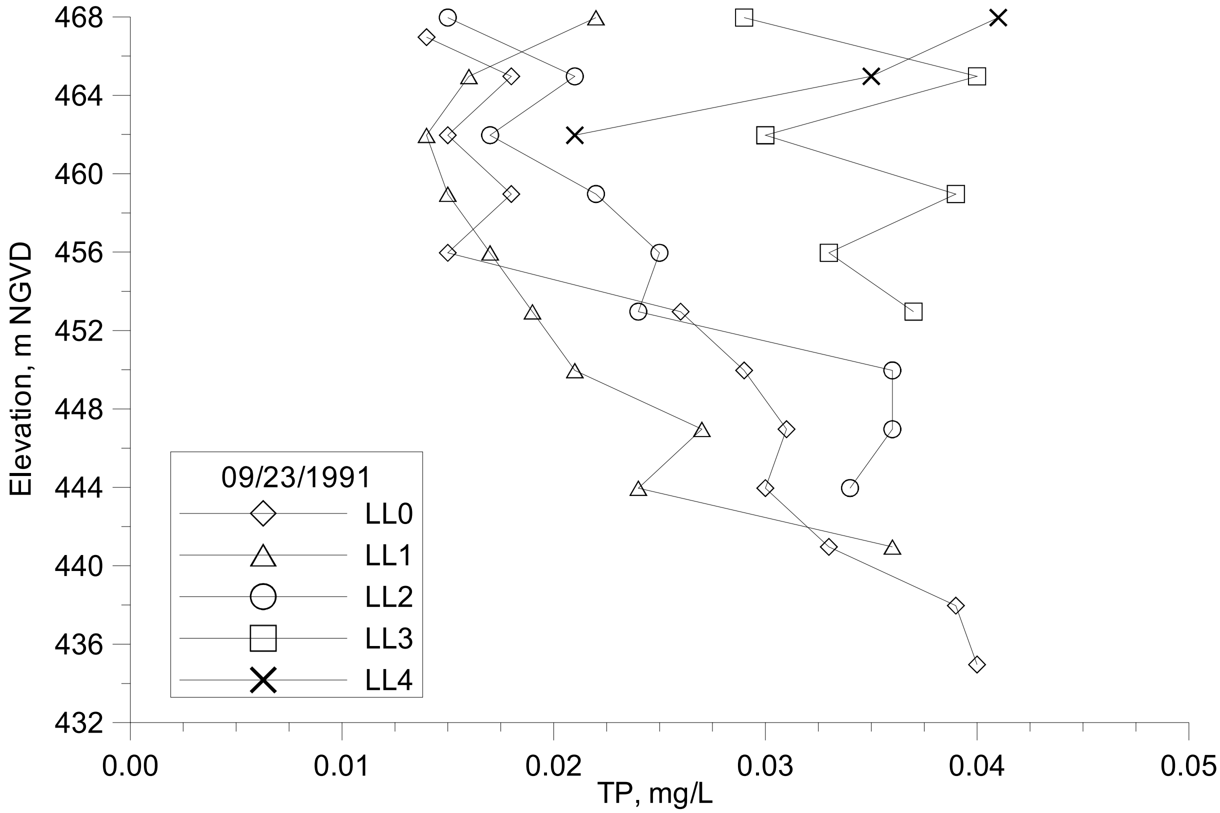
Elevation, m NGVD
NO2, mg/L

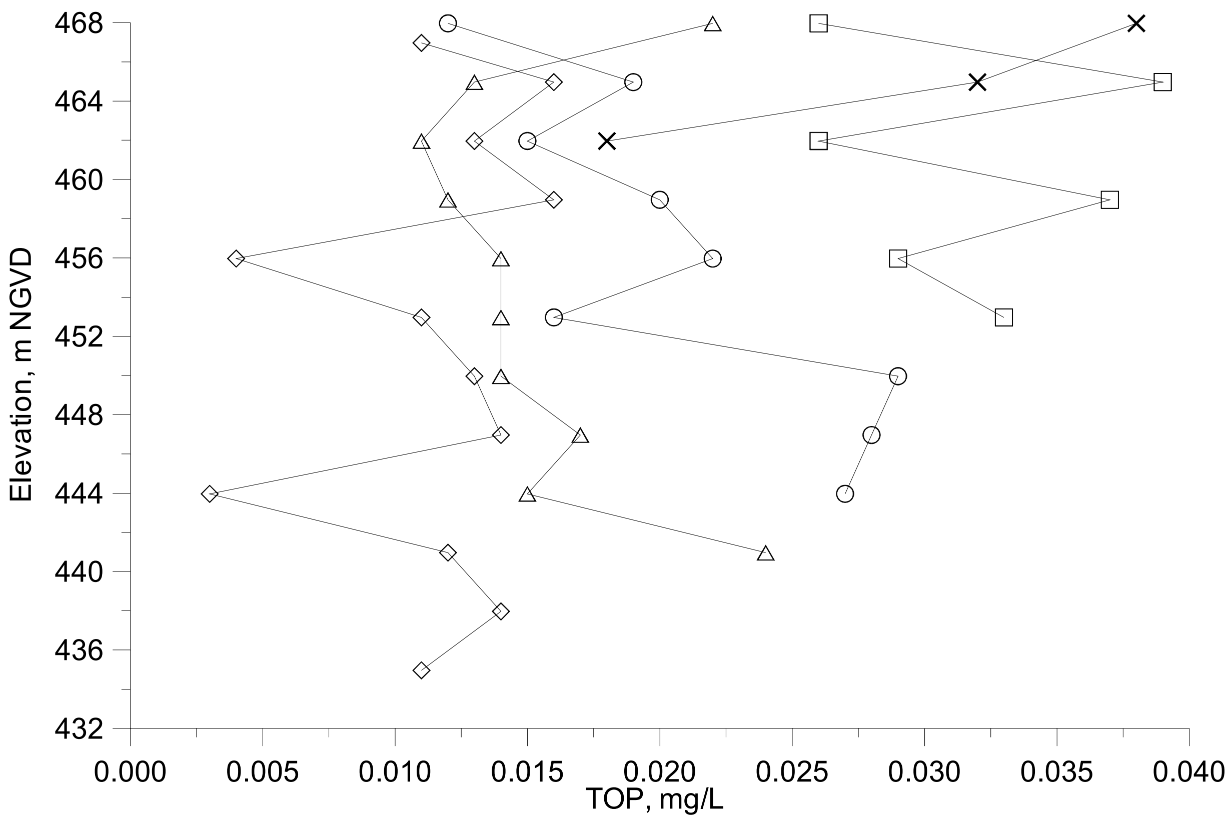


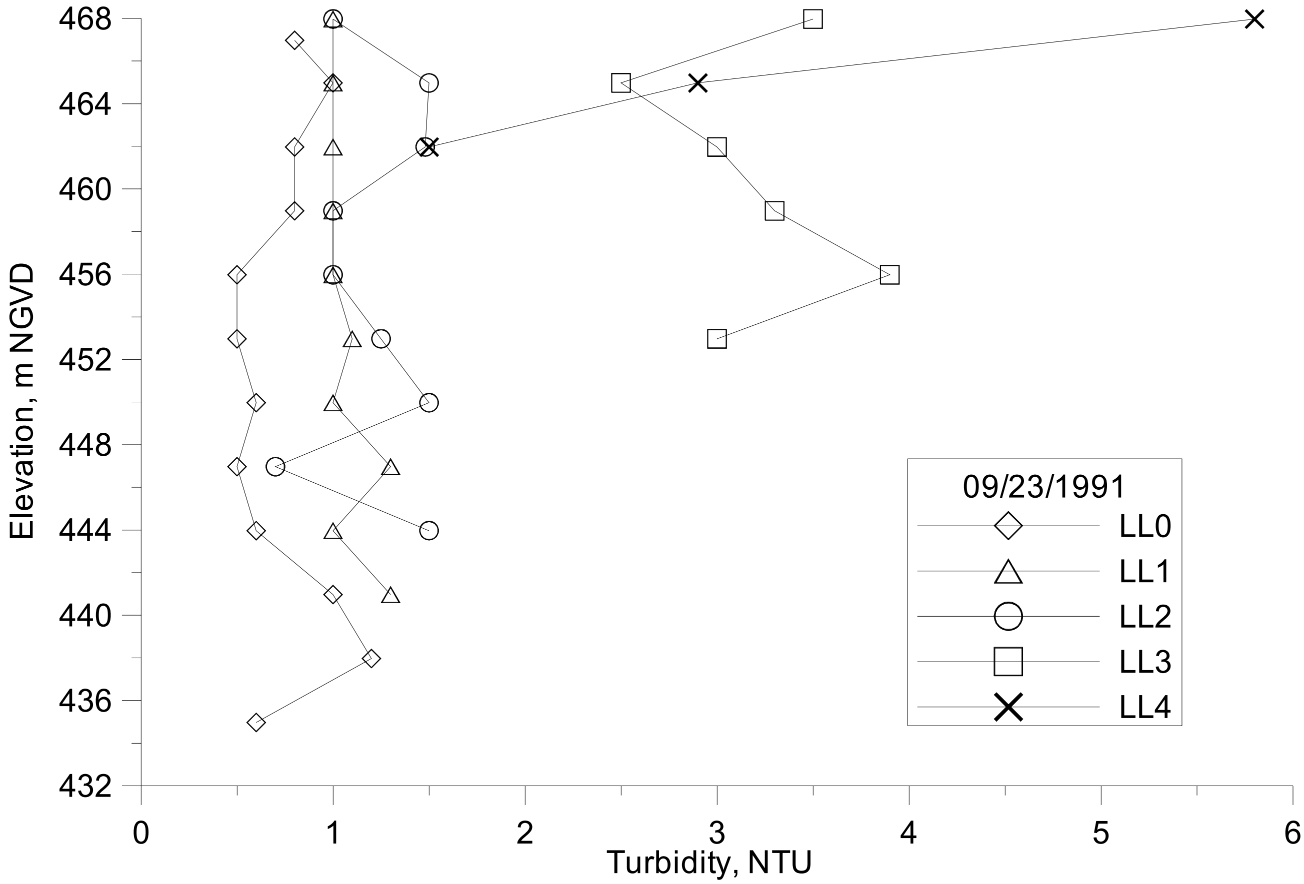
09/23/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NH3, mg/L

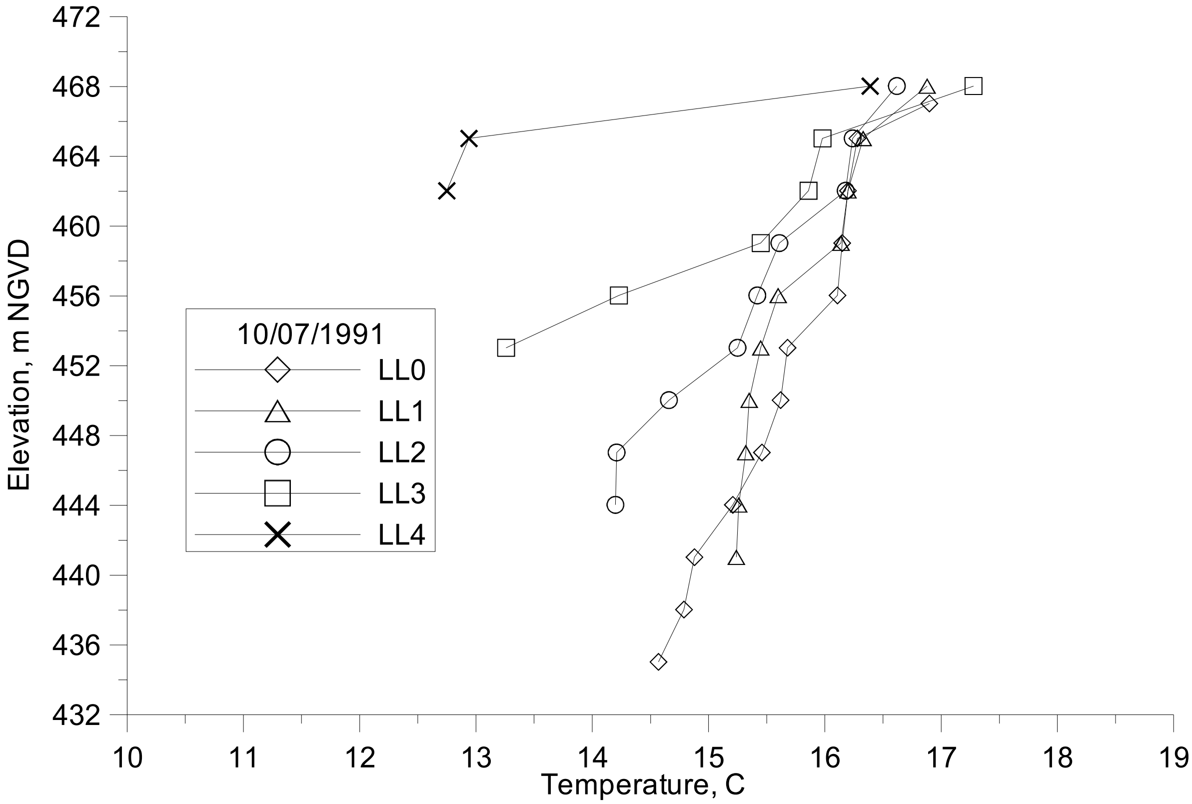


Elevation, m NGVD
SRP, mg/L

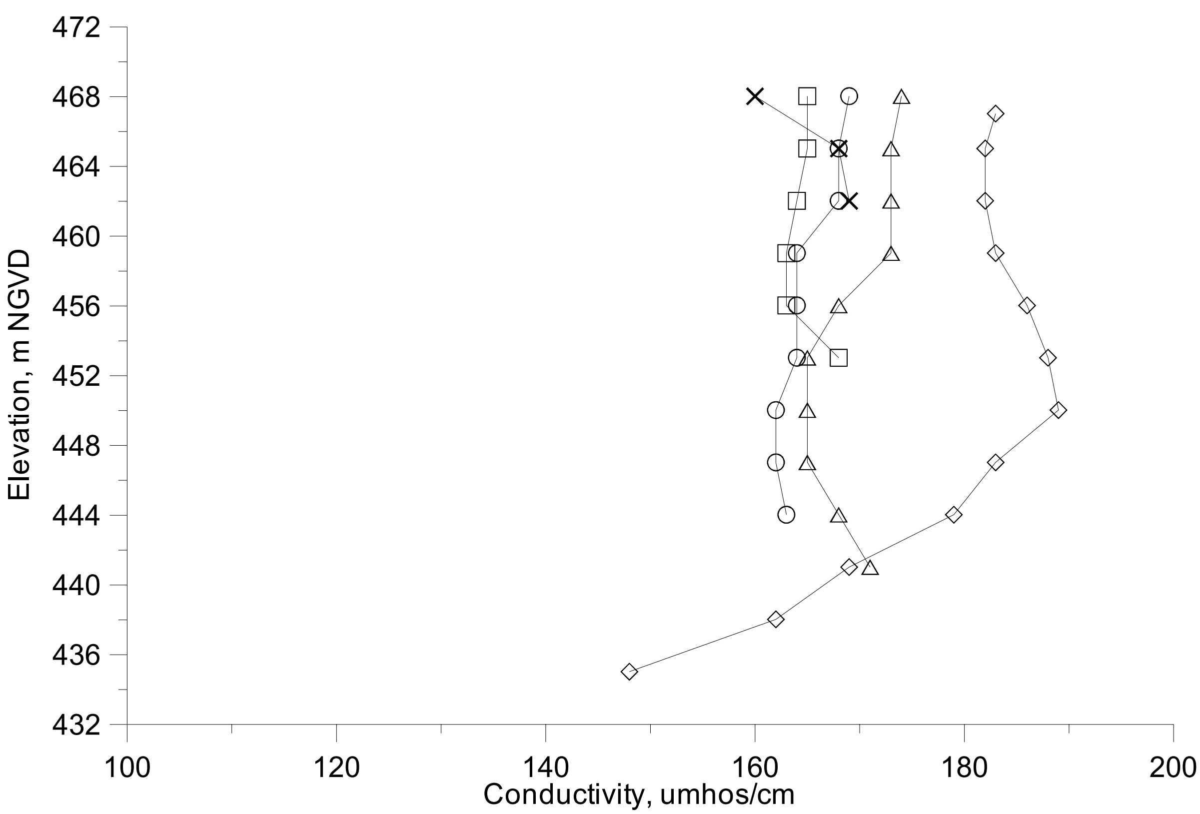

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
09/23/1991
LL0
LL1
LL2
LL3
LL4
0.00
0.01
0.02
0.03
0.04
0.05
TP, mg/L


468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
TOP, mg/L

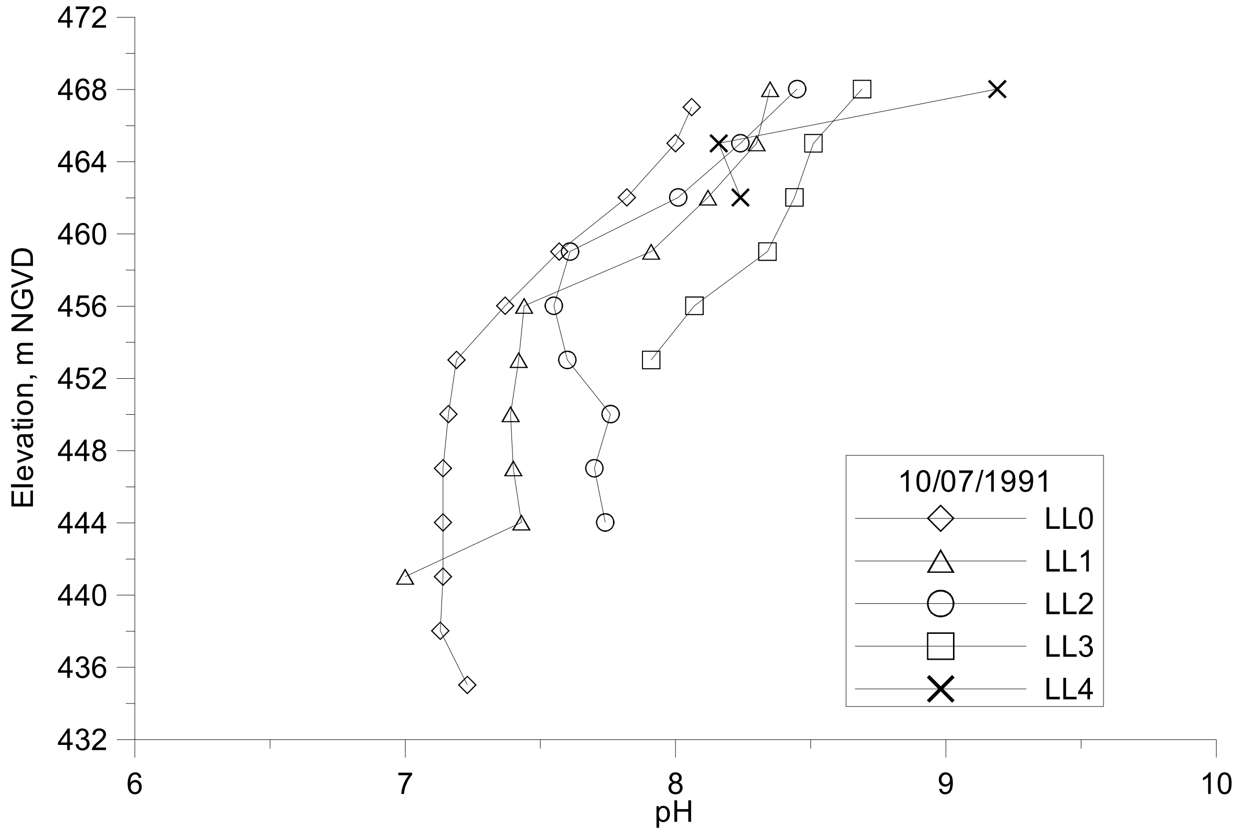

09/23/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Turbidity, NTU
468
464
460
456
452
448
444
440
436
432
0
1
2
3
4
5
6

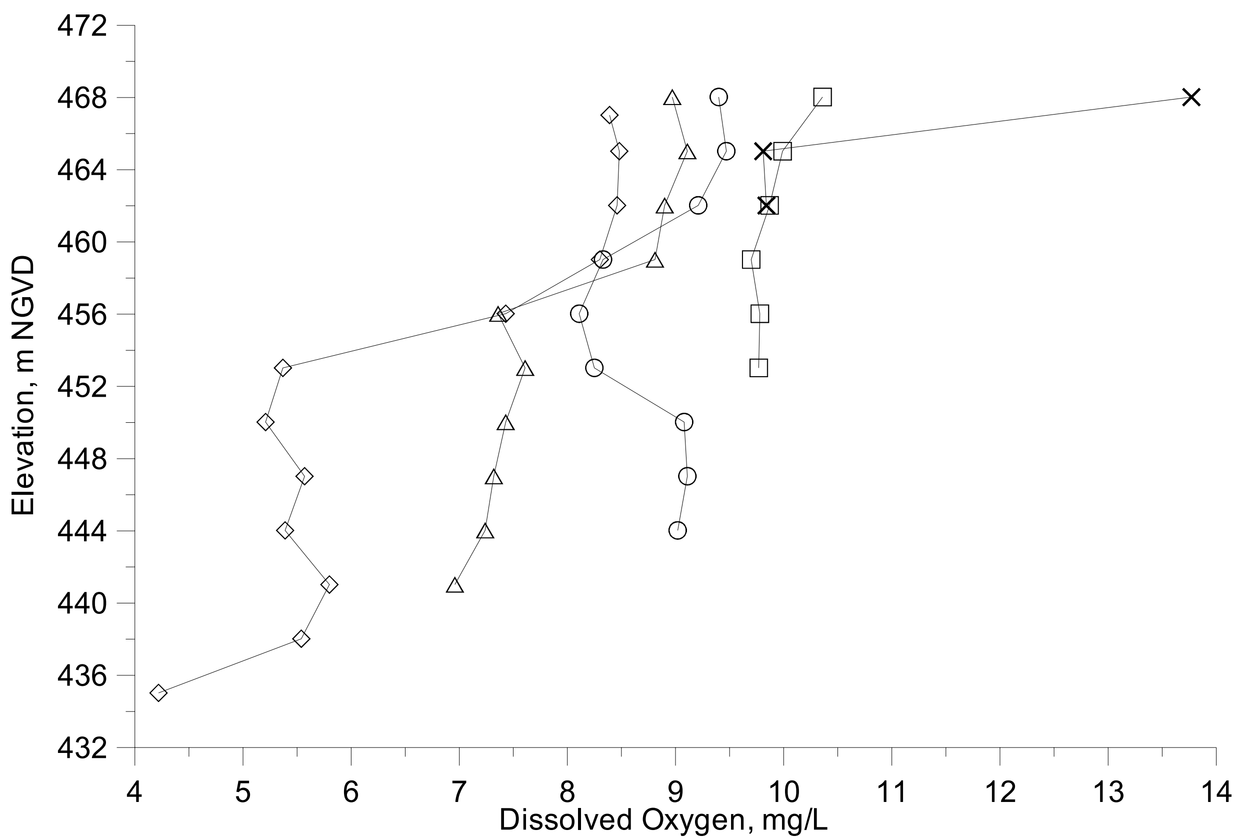


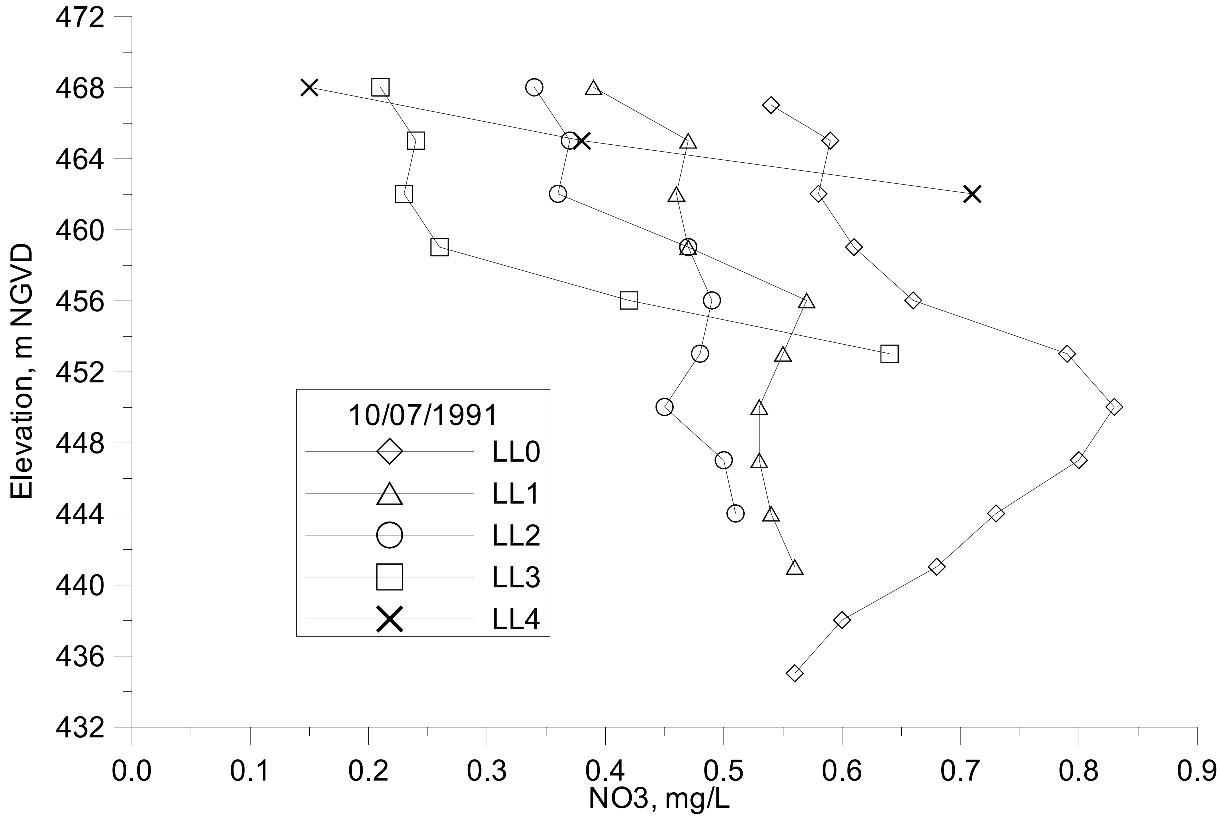
10/07/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Temperature, C
472
468
464
460
456
452
448
444
440
436
432
10
11
12
13
14
15
16
17
18
19

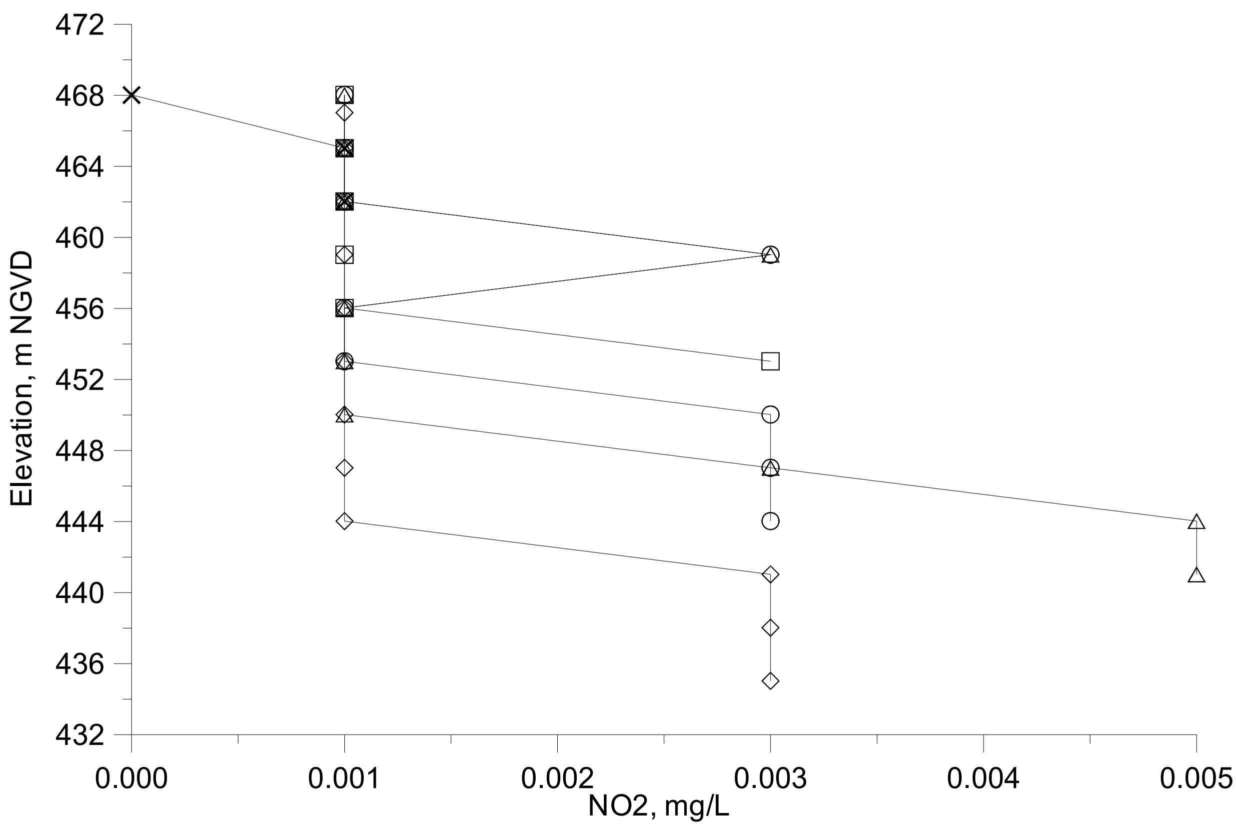


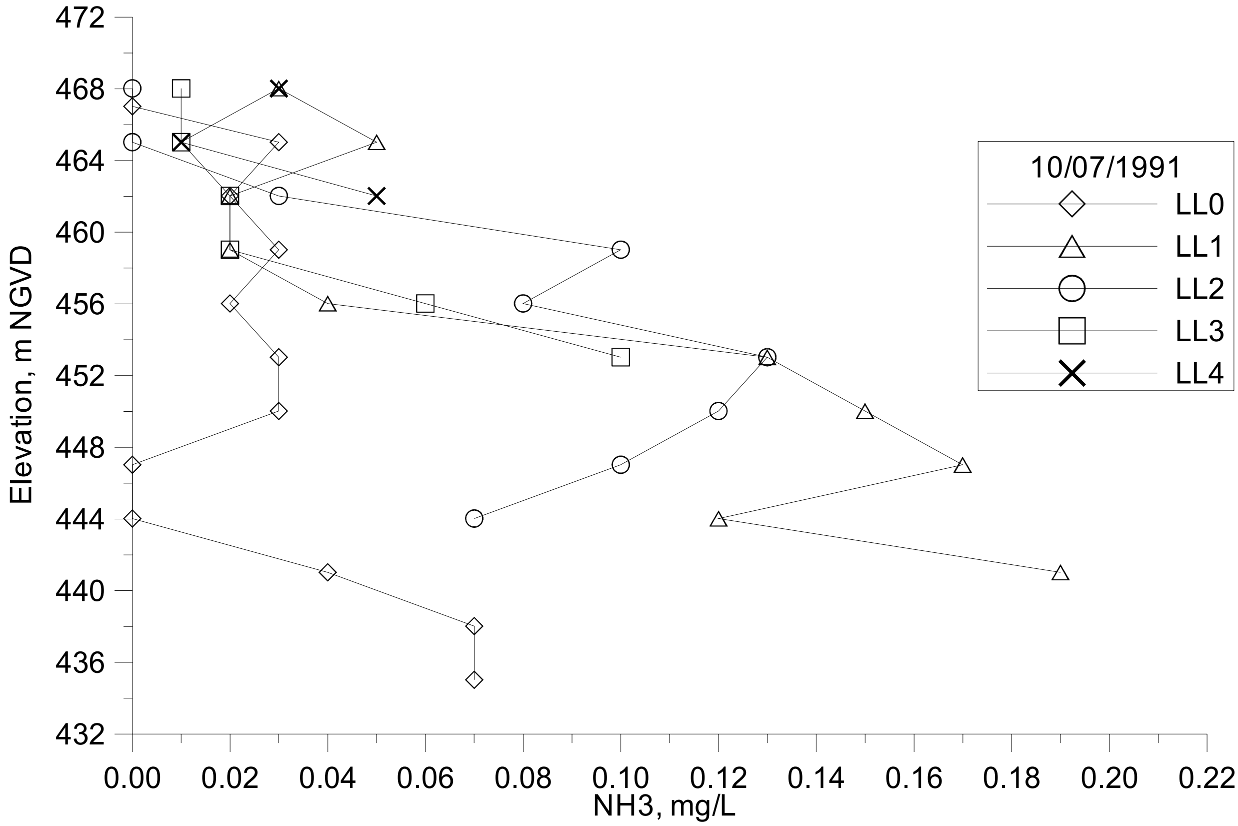
Elevation, m NGVD
Conductivity, umhos/cm
472
468
464
460
456
452
448
444
440
436
432
100
120
140
160
180
200


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
6
7
8
9
10
pH
10/07/1991
LL0
LL1
LL2
LL3
LL4

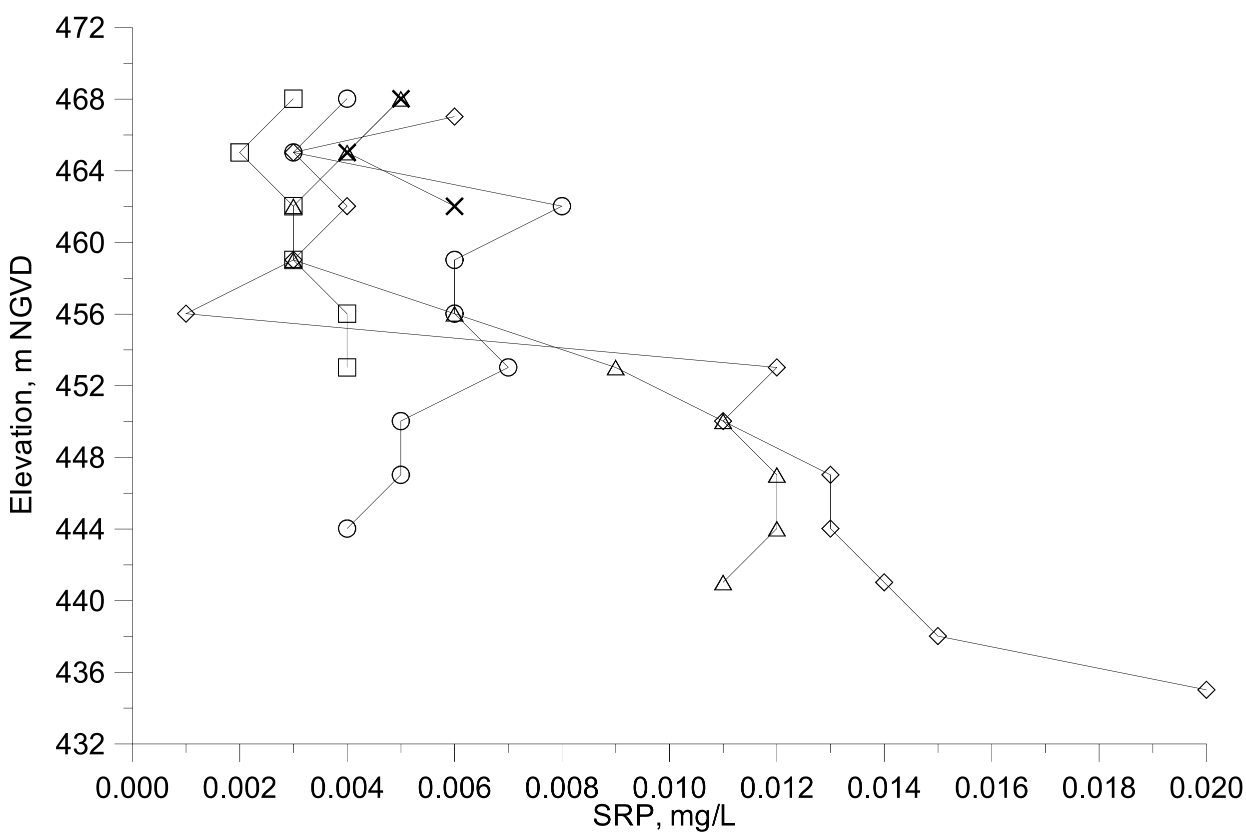

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
4
5
6
7
8
9
10
11
12
13
14
Dissolved Oxygen, mg/L


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
NO3, mg/L
10/07/1991
LL0
LL1
LL2
LL3
LL4

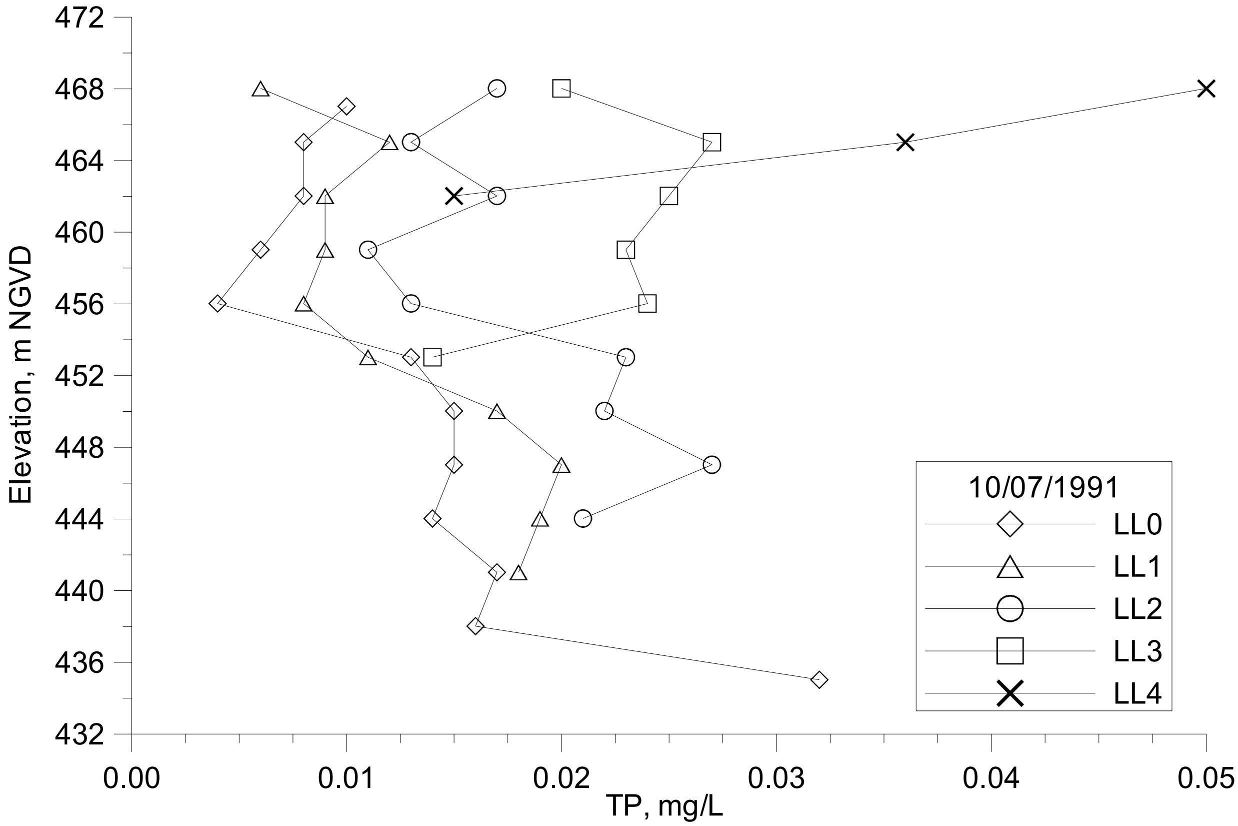

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.001
0.002
0.003
0.004
0.005
NO2, mg/L

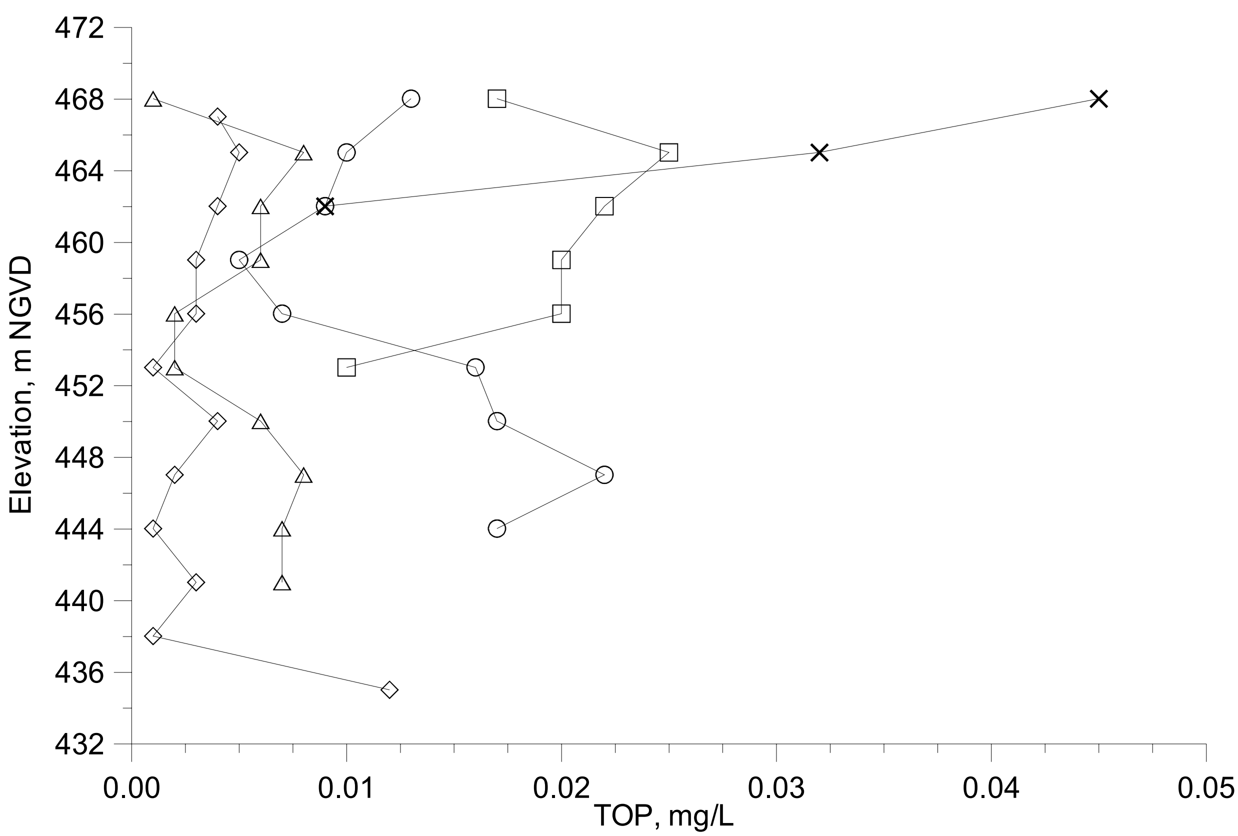


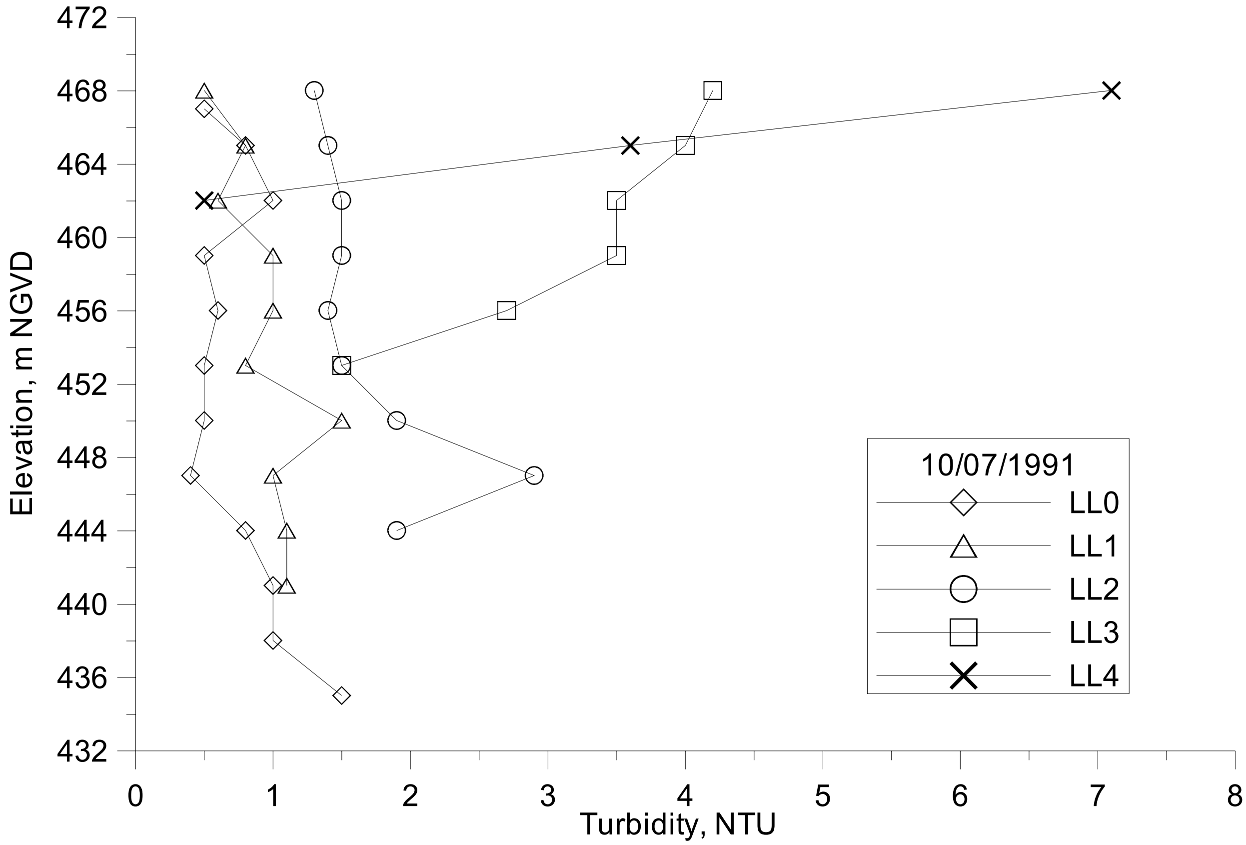
10/07/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NH3, mg/L



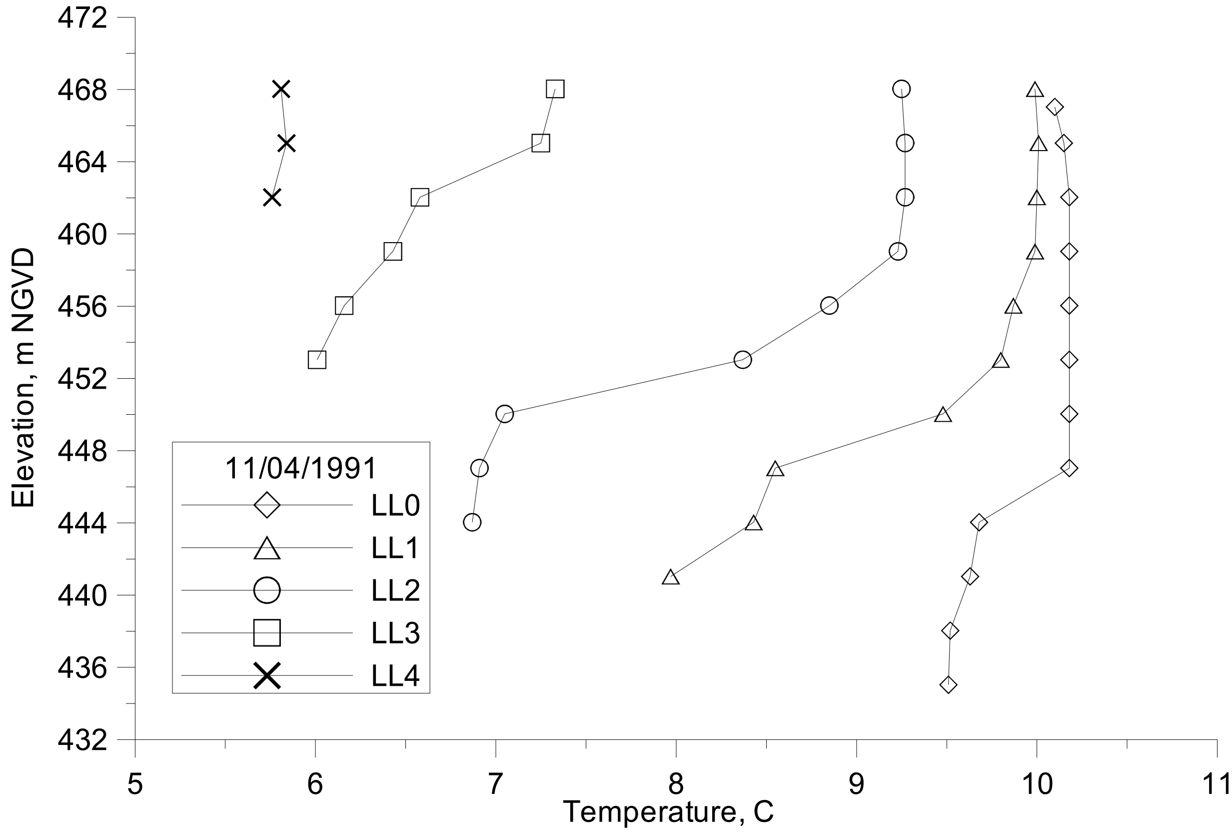
Elevation, m NGVD
SRP, mg/L


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
0.05
TP, mg/L
10/07/1991
LL0
LL1
LL2
LL3
LL4

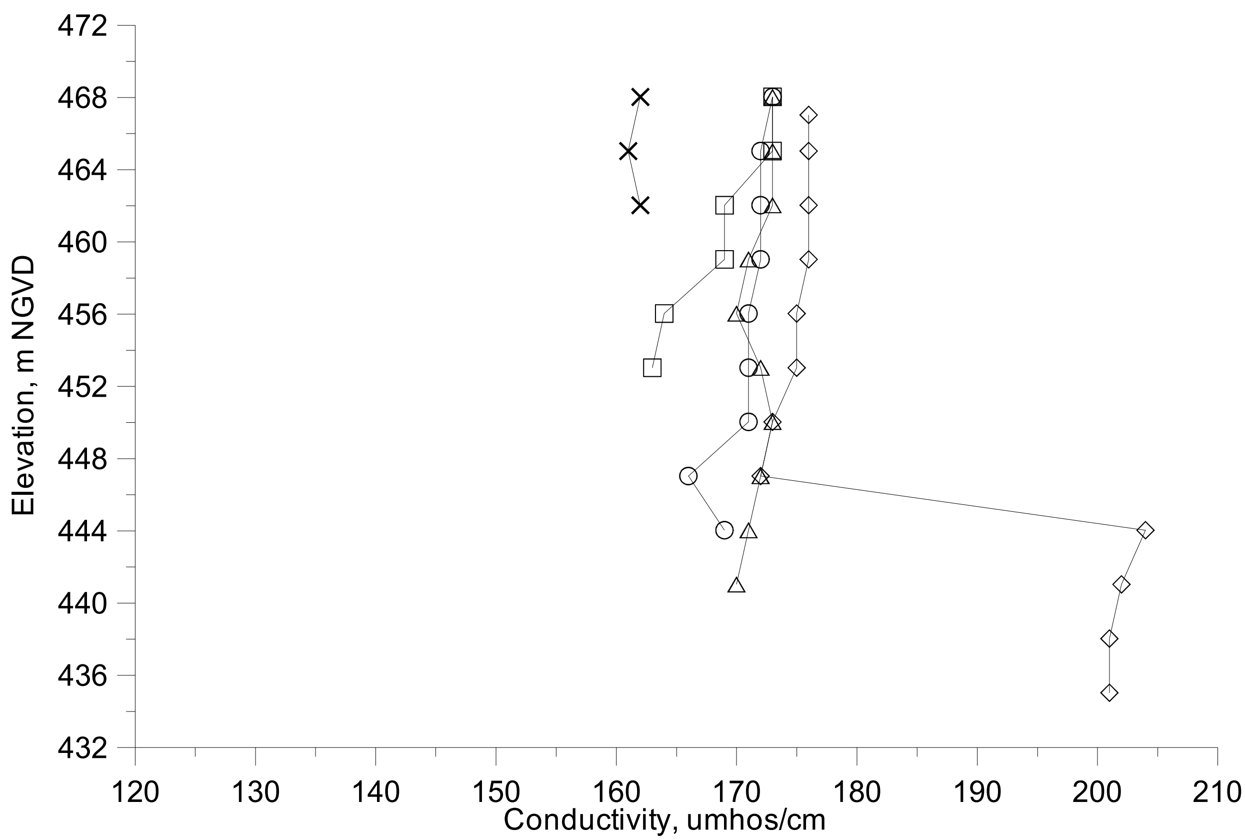

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
0.05
TOP, mg/L



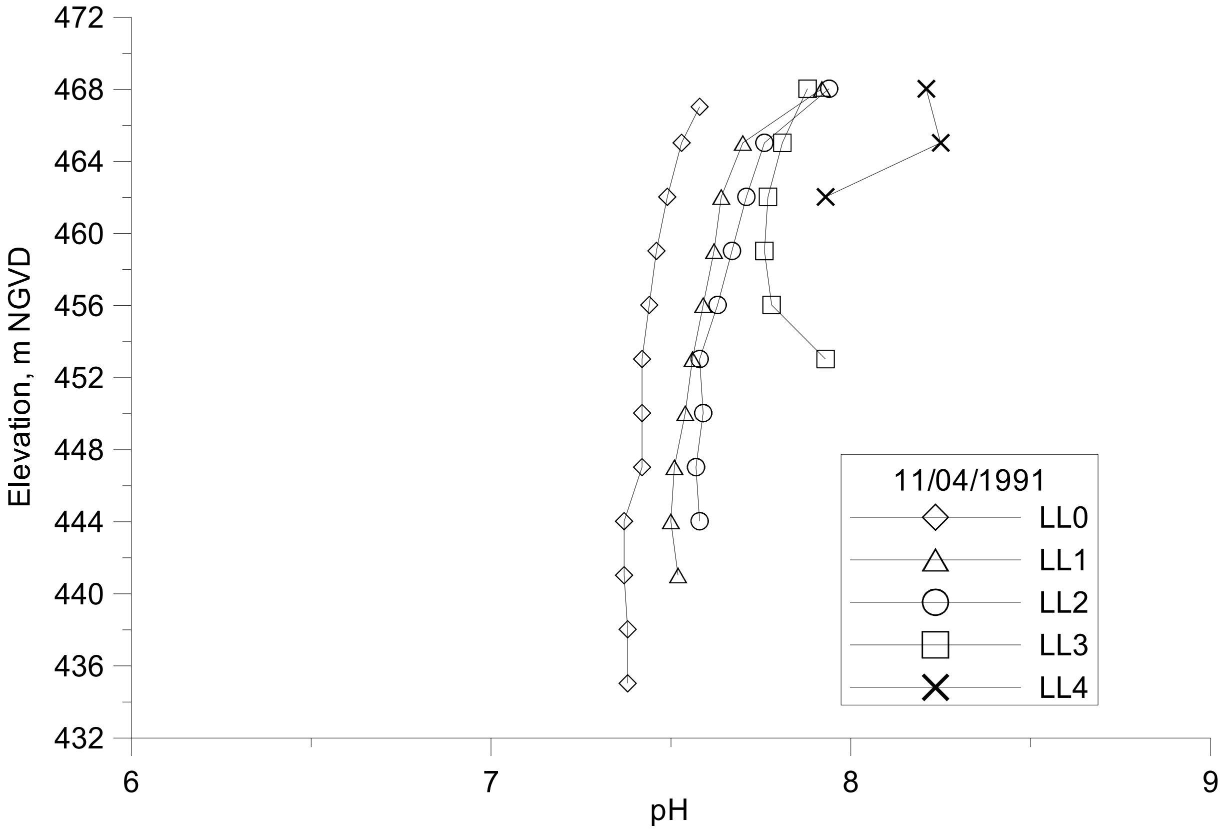
472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
5
6
7
8
Turbidity, NTU
10/07/1991
LL0
LL1
LL2
LL3
LL4

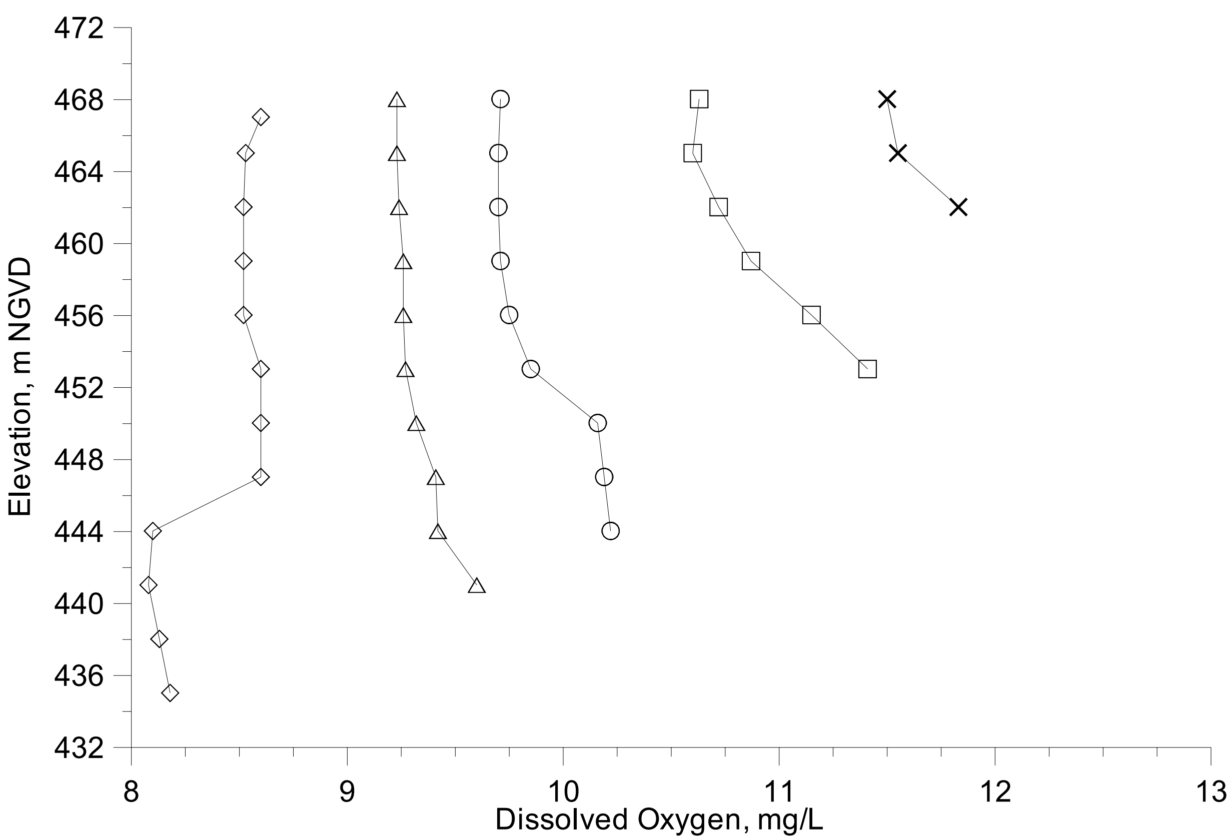


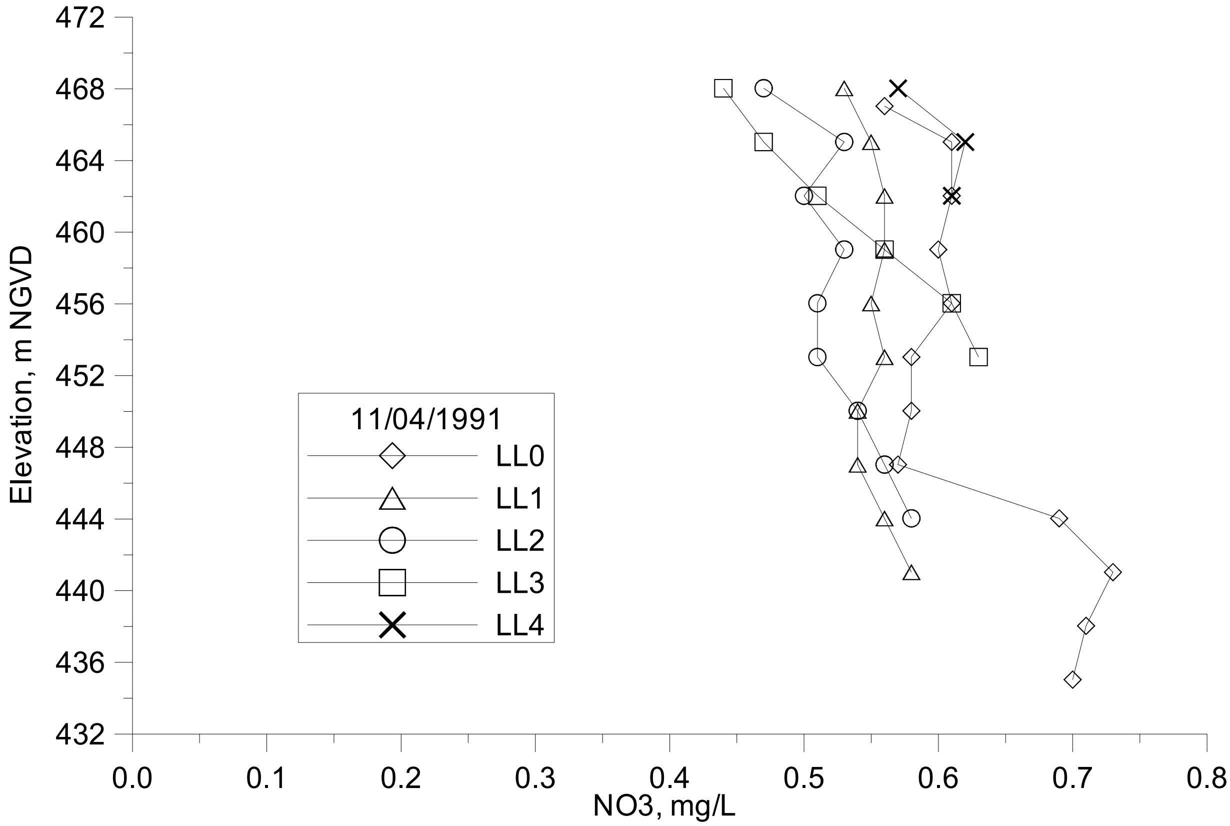
11/04/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
Temperature, C

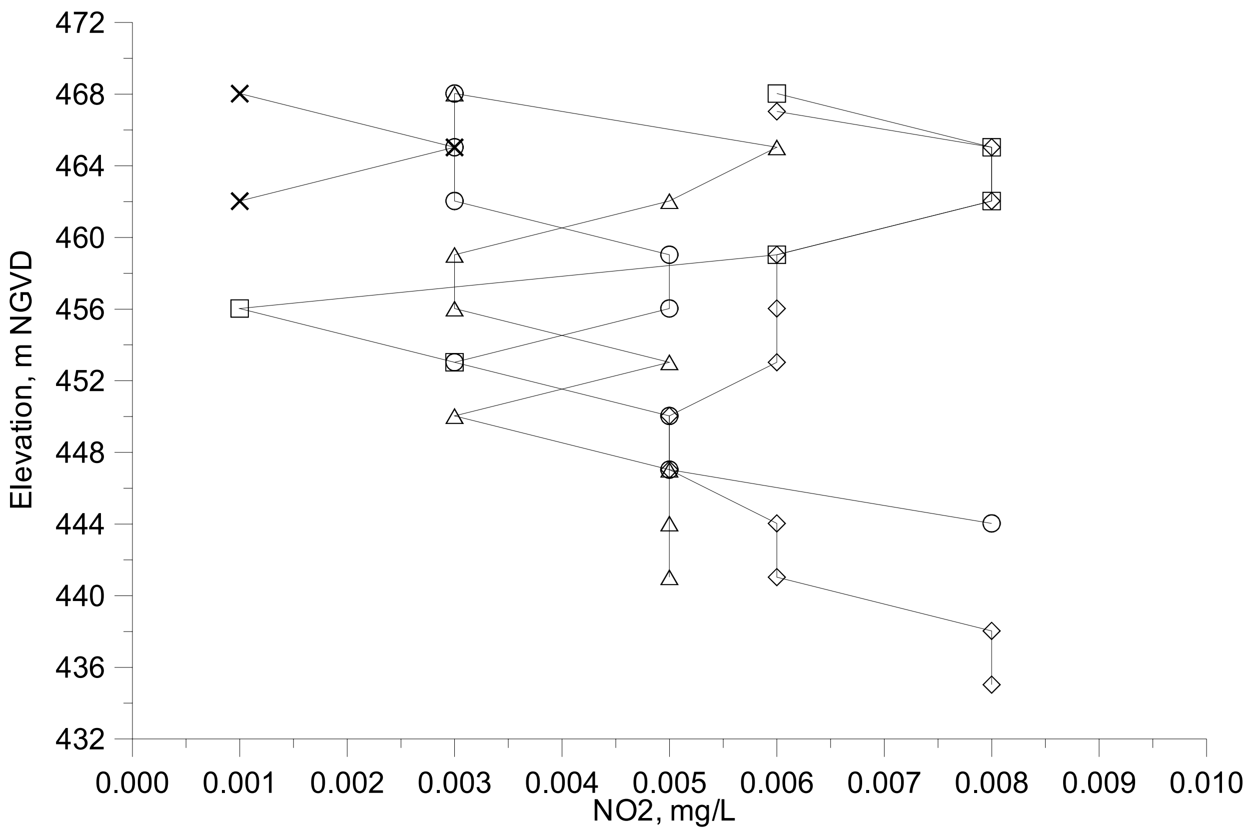


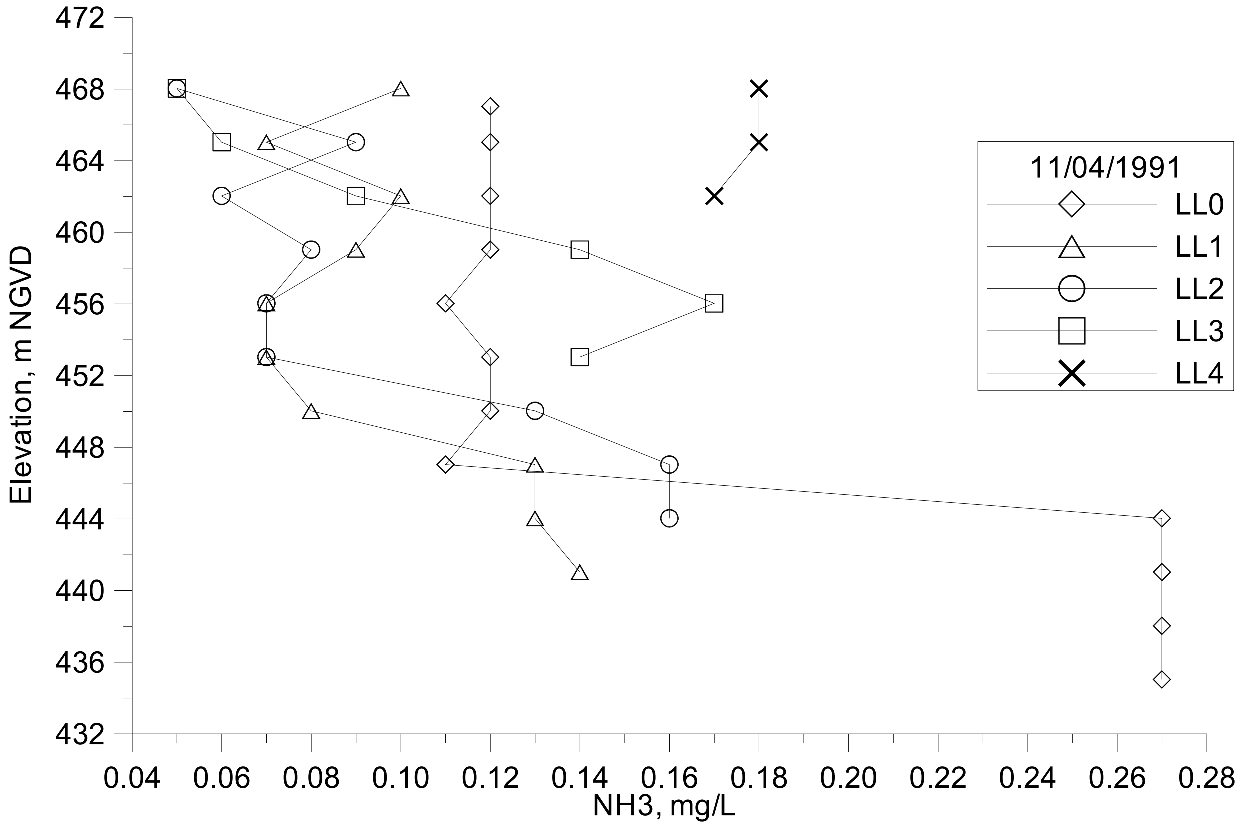
Elevation, m NGVD
Conductivity, umhos/cm


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
6
7
8
9
pH
11/04/1991
LL0
LL1
LL2
LL3
LL4

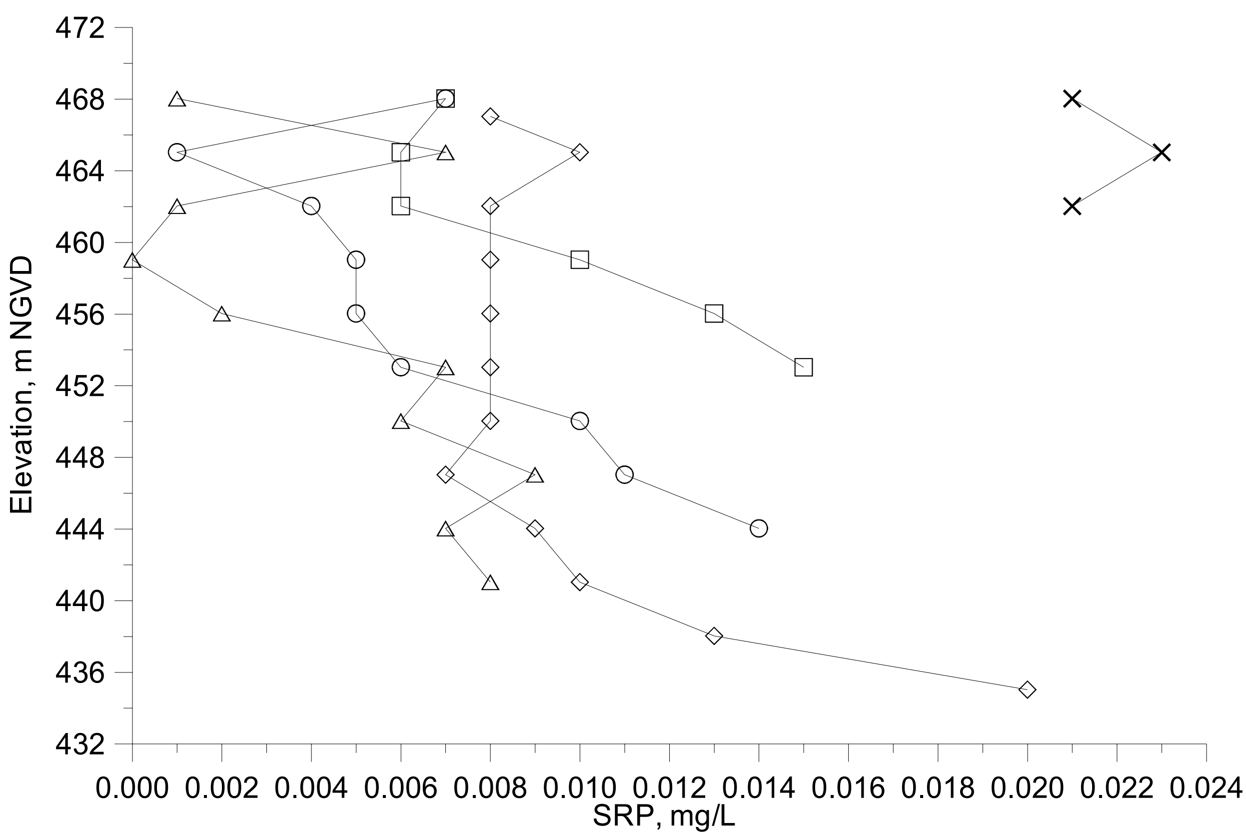

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
8
9
10
11
12
13
Dissolved Oxygen, mg/L


472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
NO3, mg/L
11/04/1991
LL0
LL1
LL2
LL3
LL4

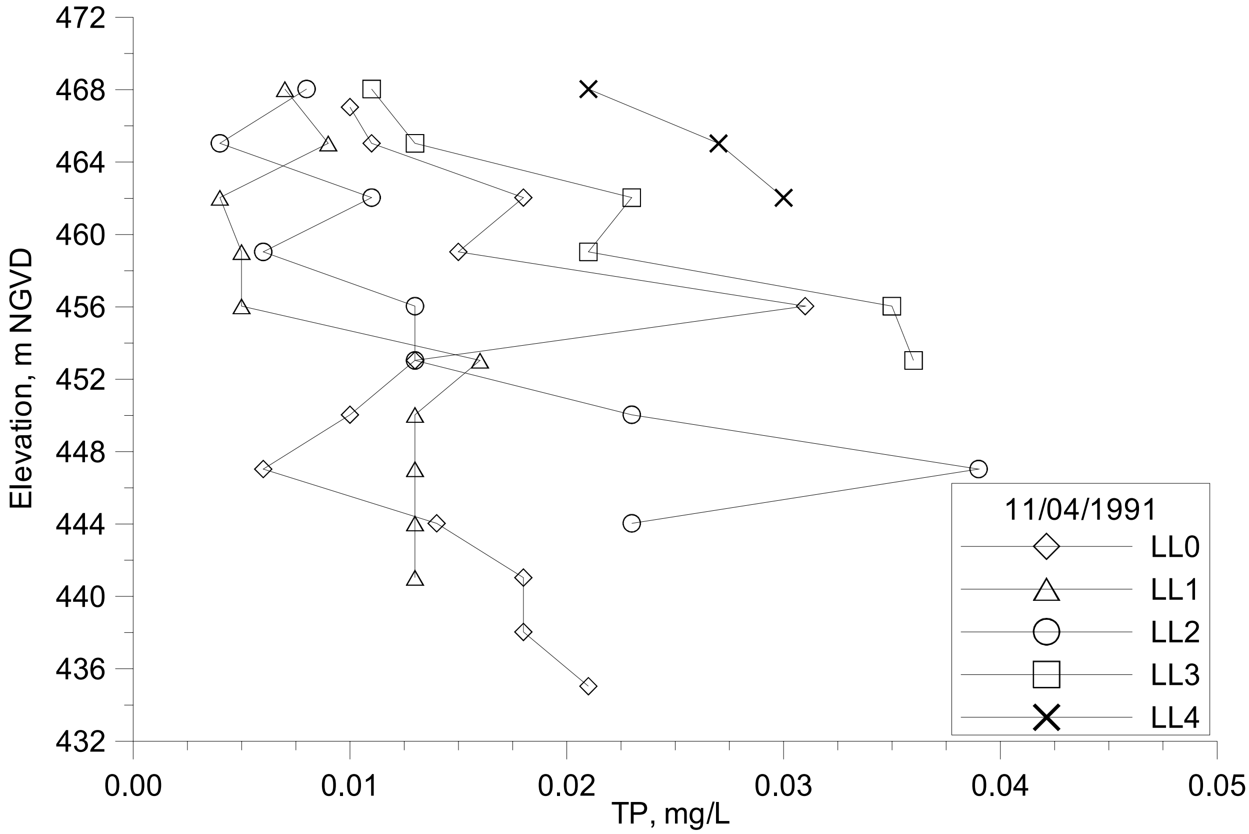

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010
NO2, mg/L

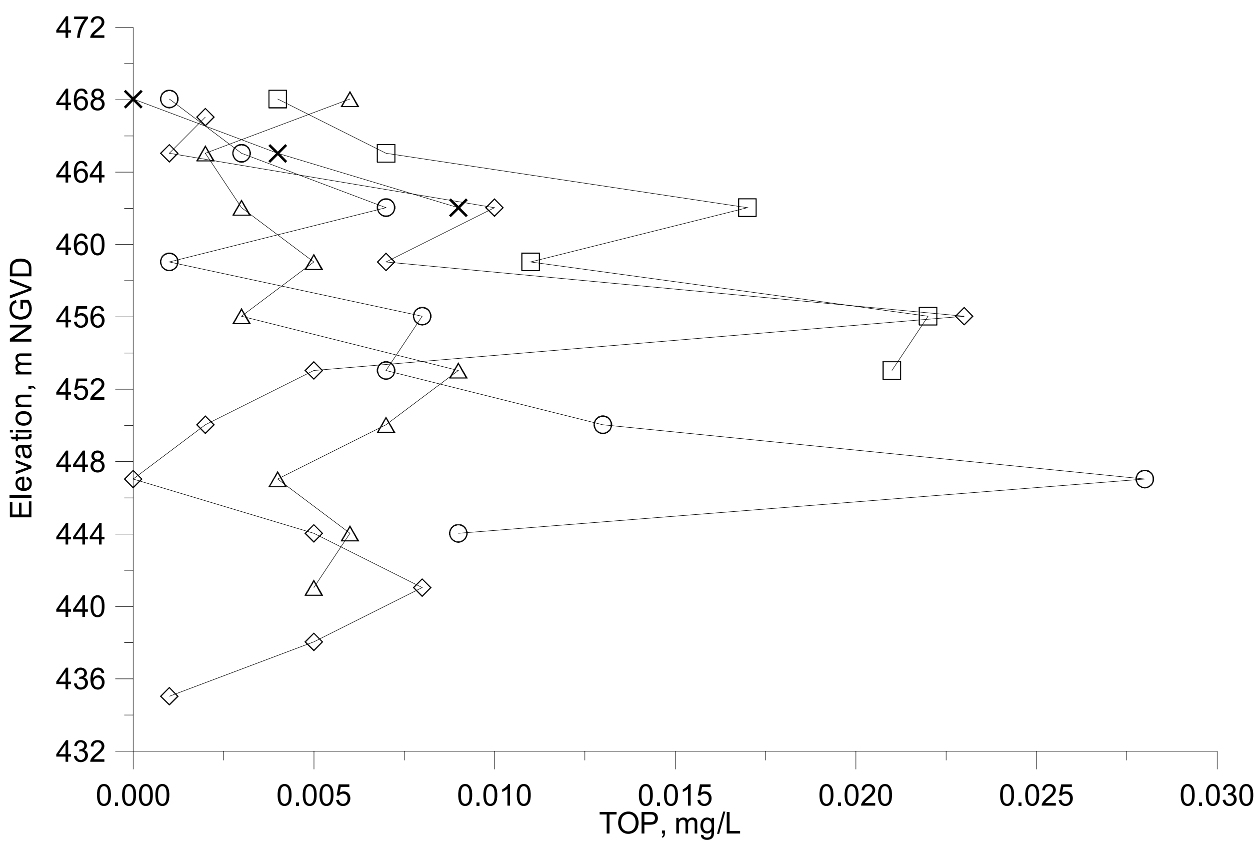


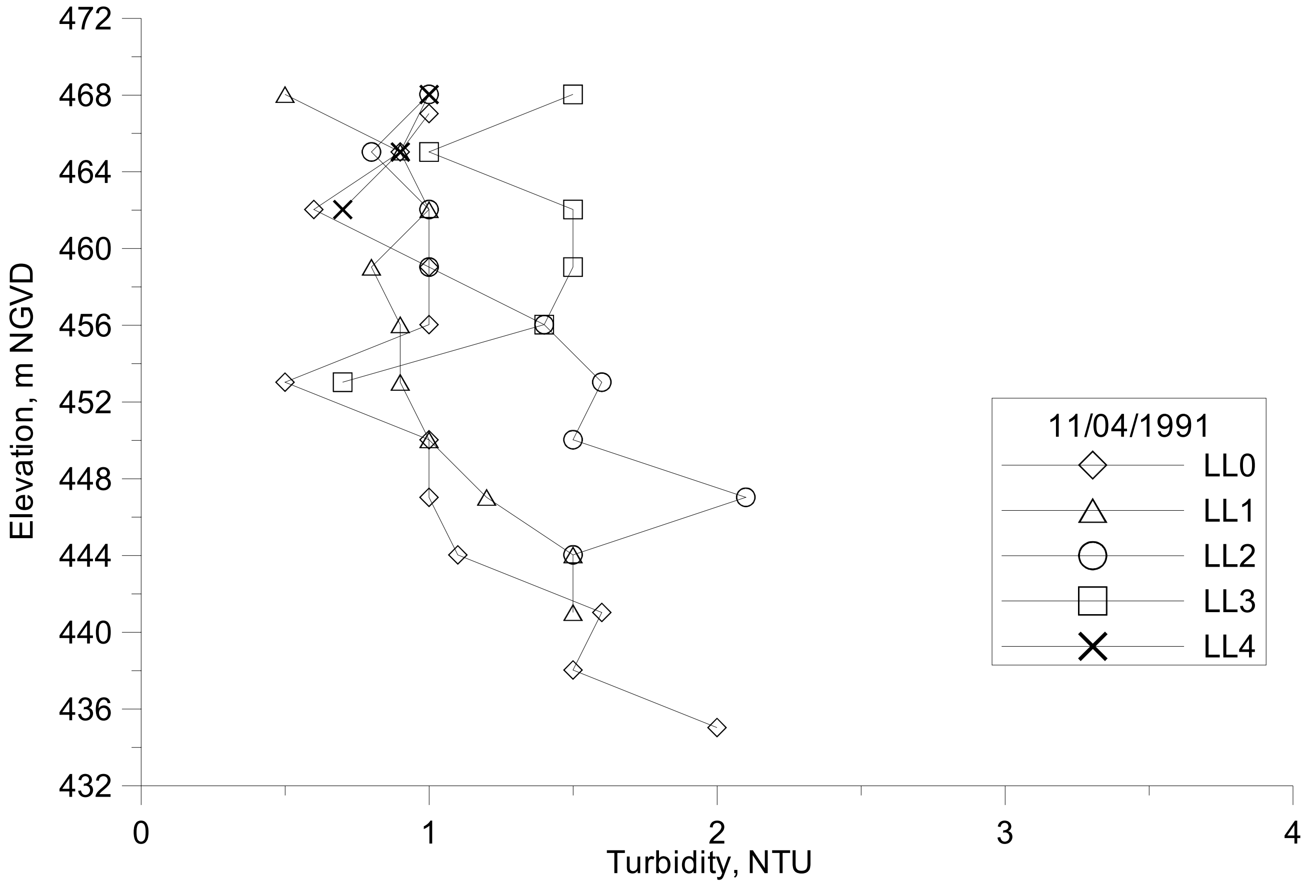
11/04/1991
LL0
LL1
LL2
LL3
LL4
Elevation, m NGVD
NH3, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28



Elevation, m NGVD
SRP, mg/L
472
468
464
460
456
452
448
444
440
436
432
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016
0.018
0.020
0.022
0.024

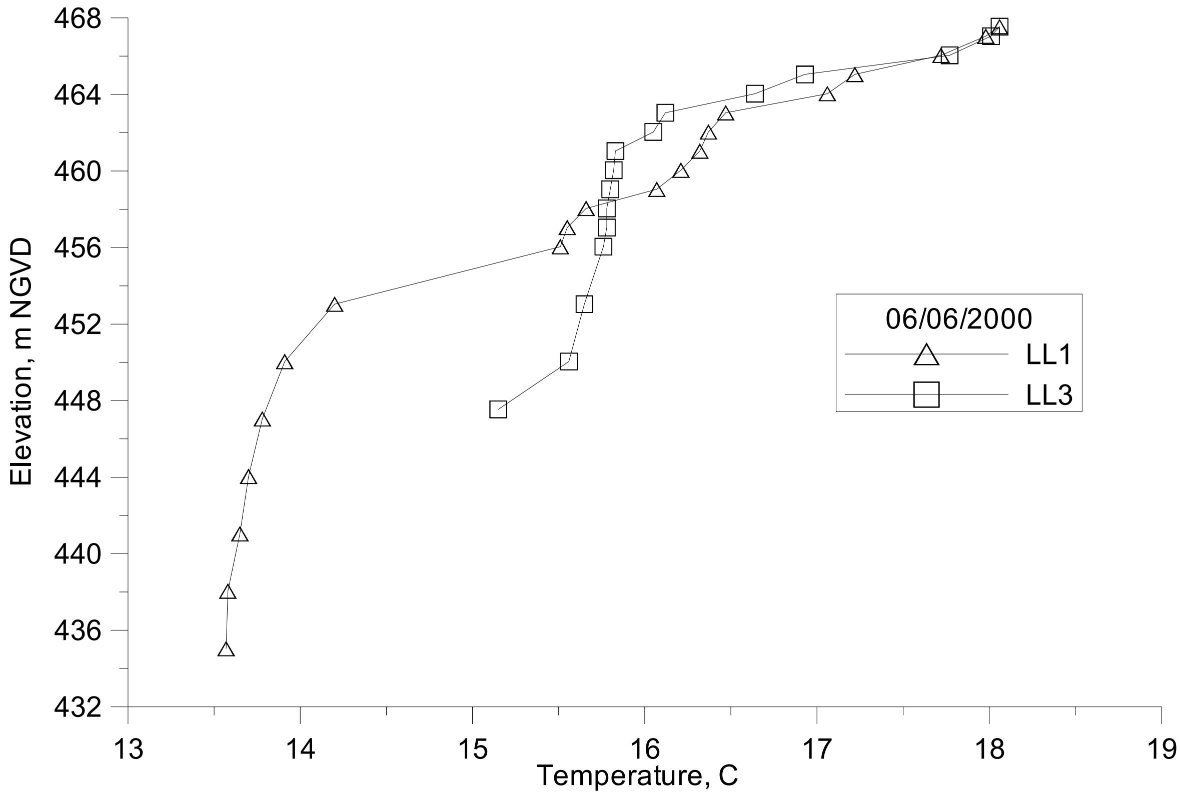

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
0.05
TP, mg/L
11/04/1991
LL0
LL1
LL2
LL3
LL4

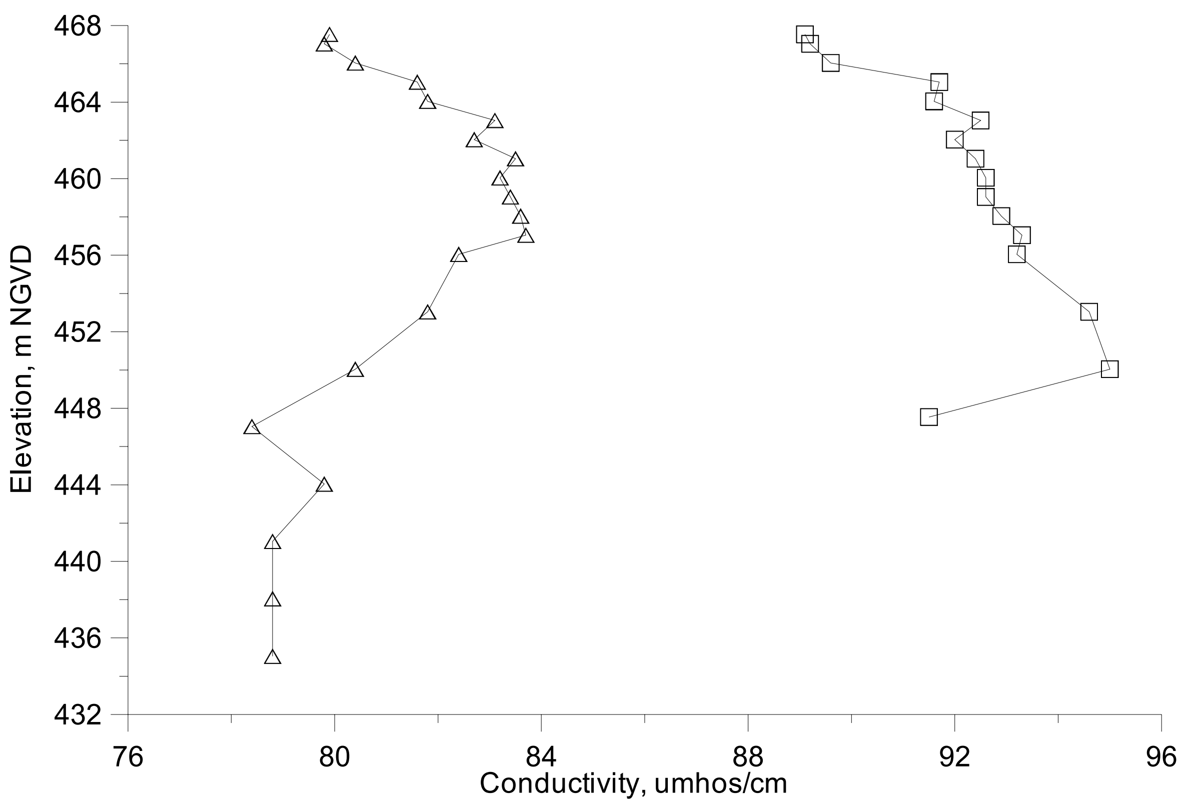

472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.005
0.010
0.015
0.020
0.025
0.030
TOP, mg/L

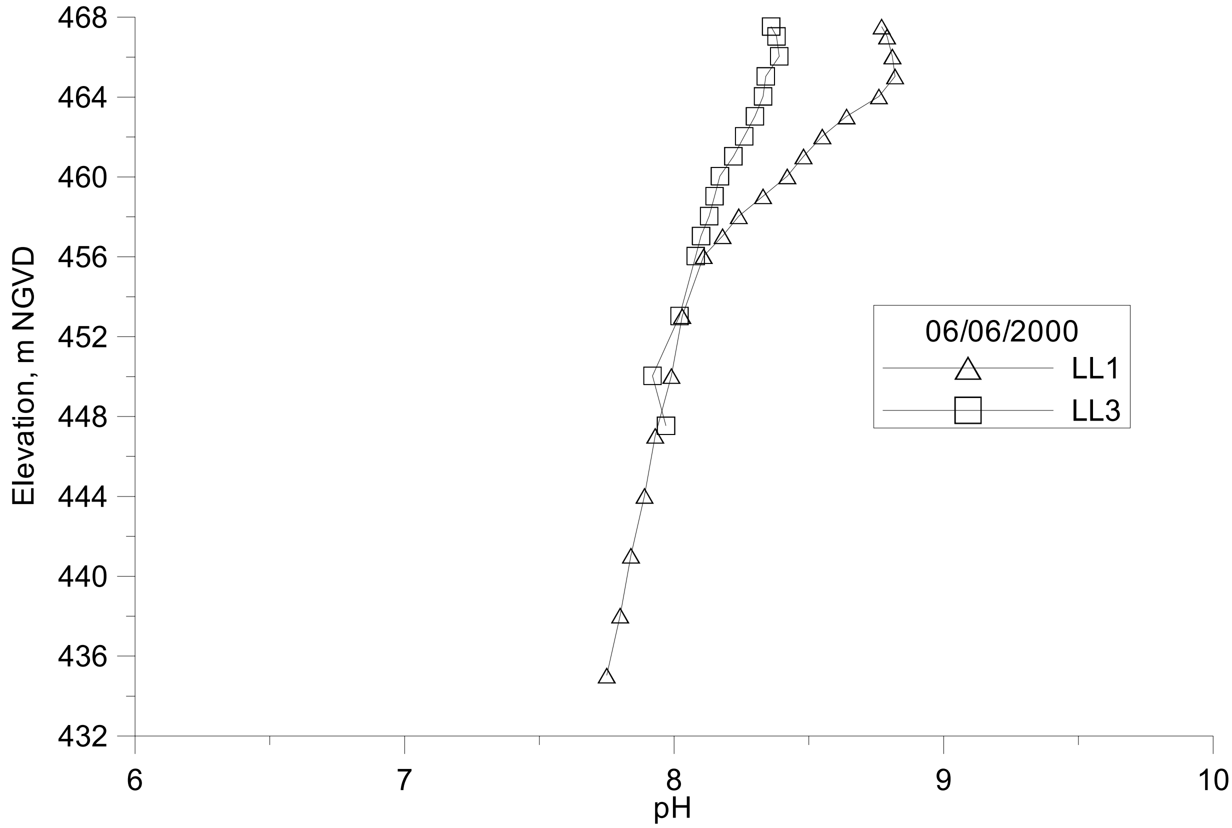


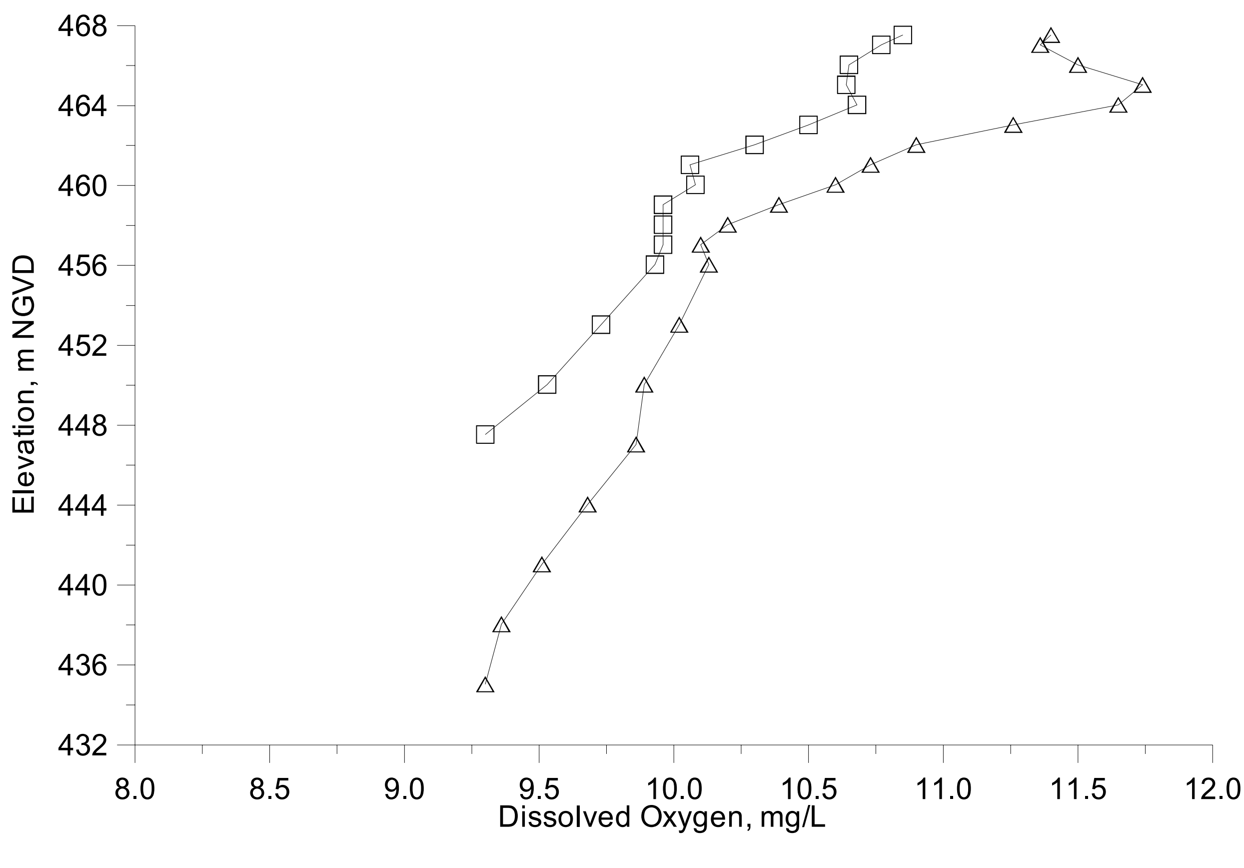
472
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
1
2
3
4
Turbidity, NTU
11/04/1991
LL0
LL1
LL2
LL3
LL4

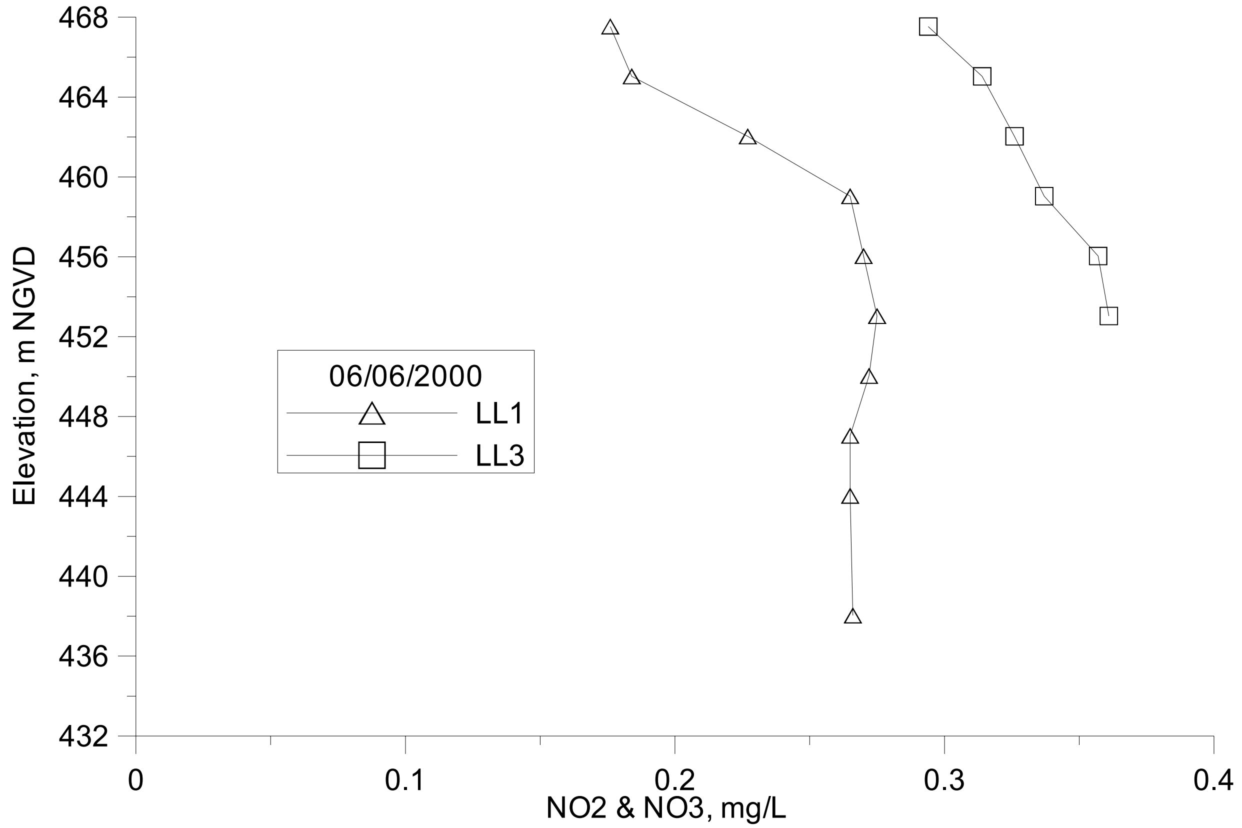
Appendix D: 2000 Long Lake Vertical Profiles

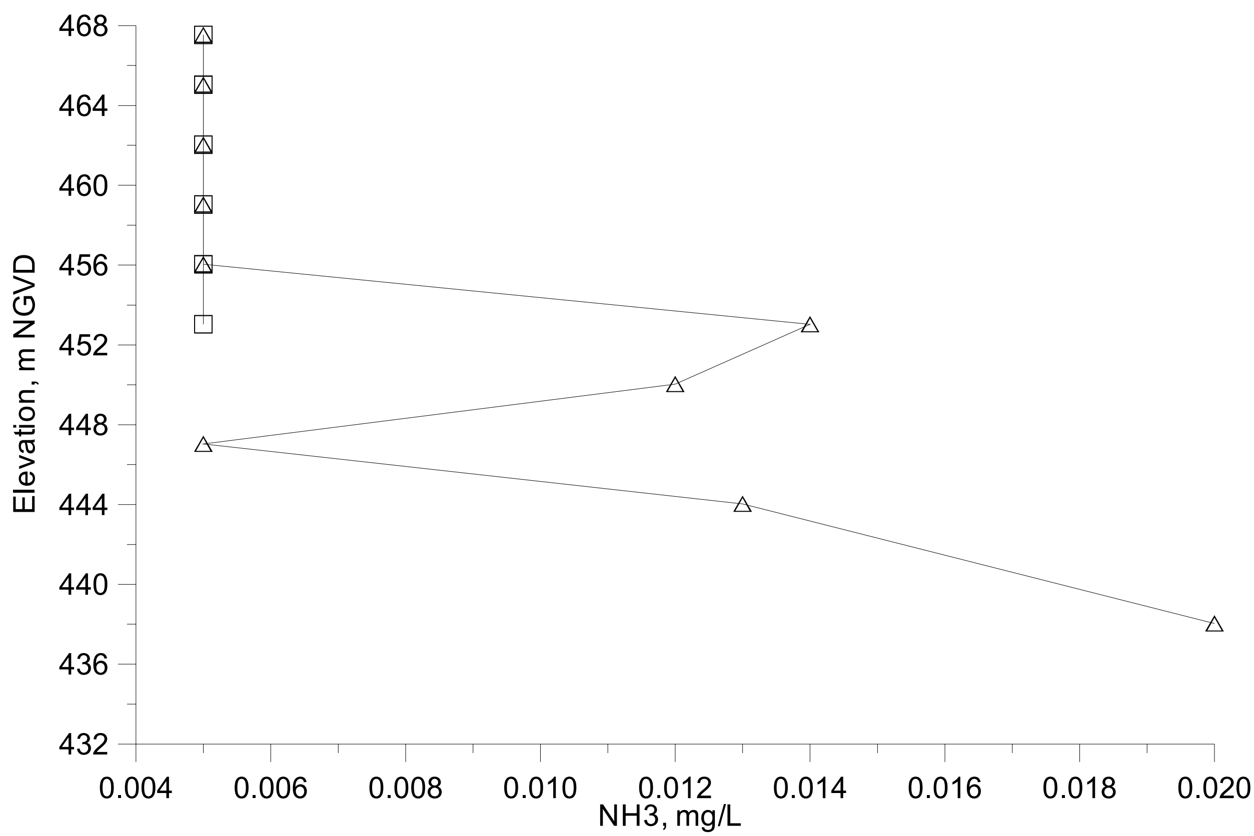


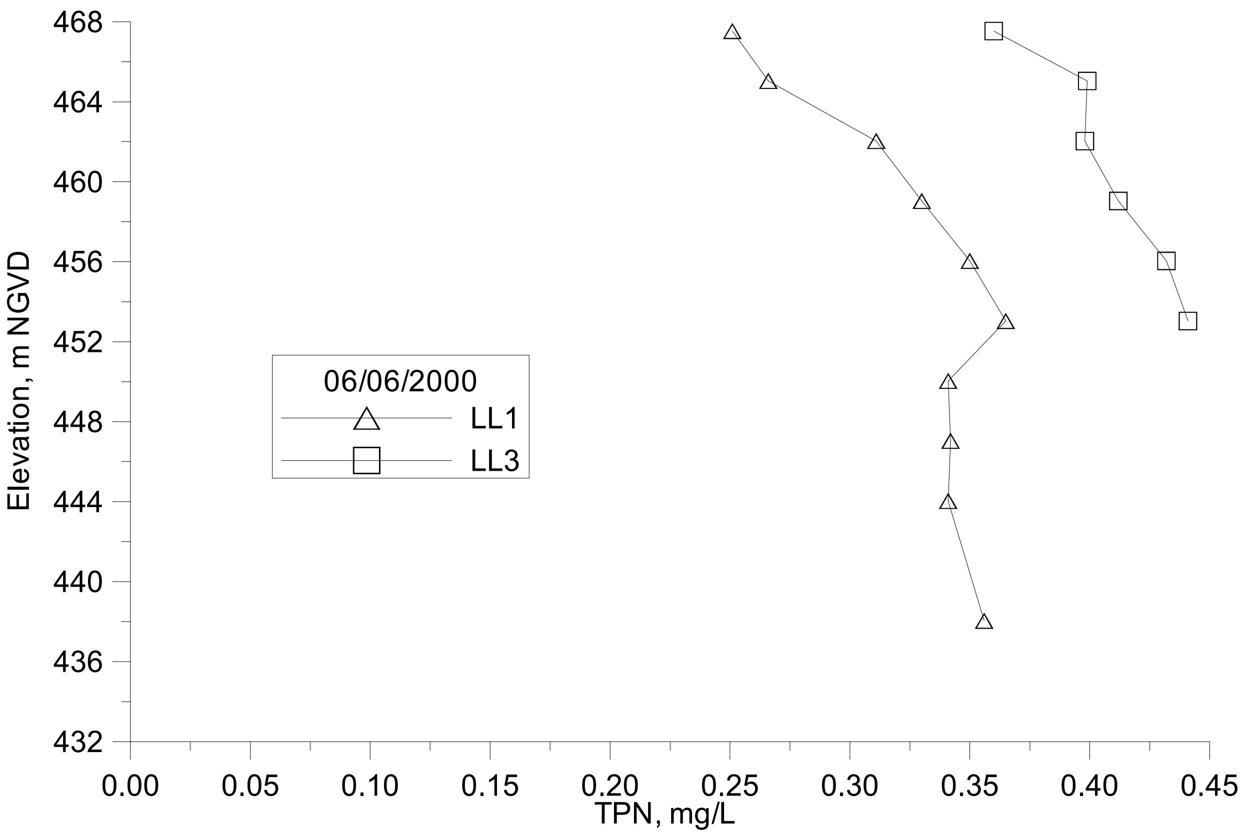


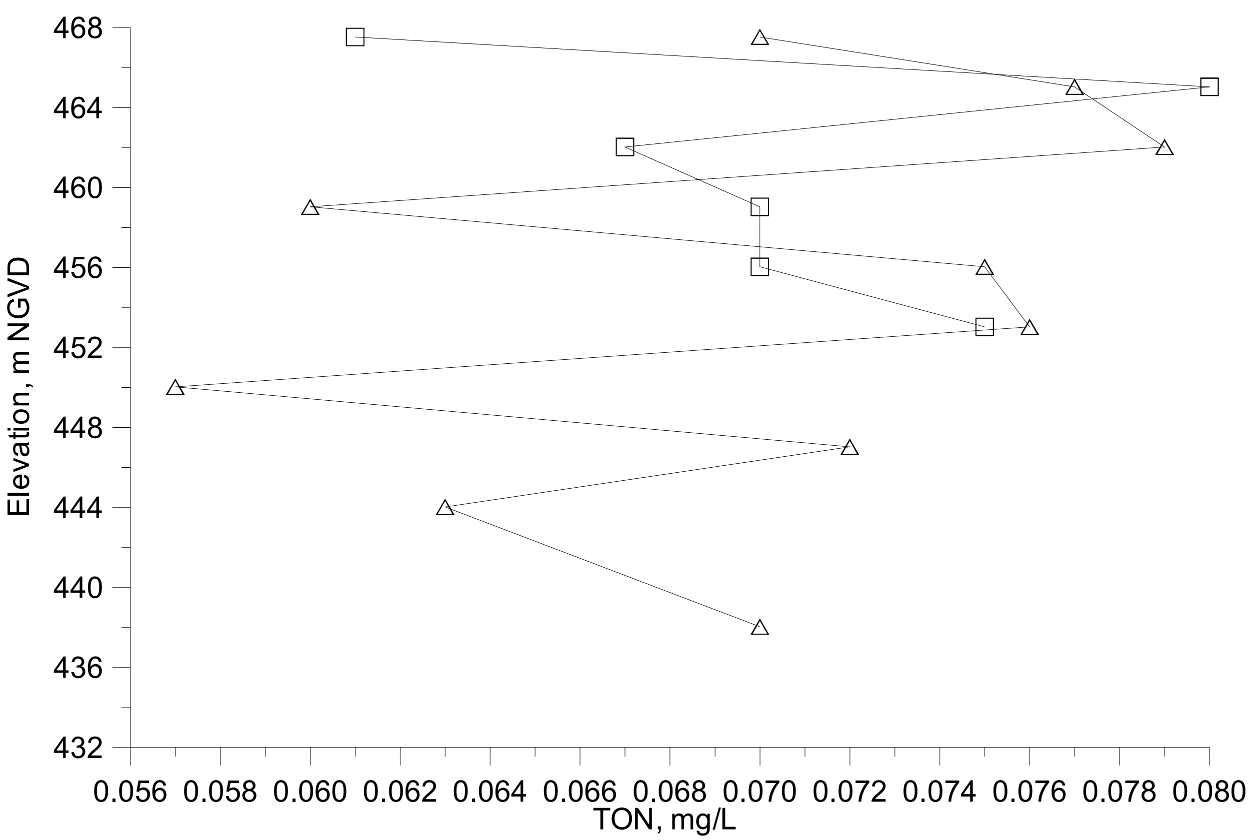

06/06/2000
LL1
LL3
Elevation, m NGVD
pH
468
464
460
456
452
448
444
440
436
432
6
7
8
9
10

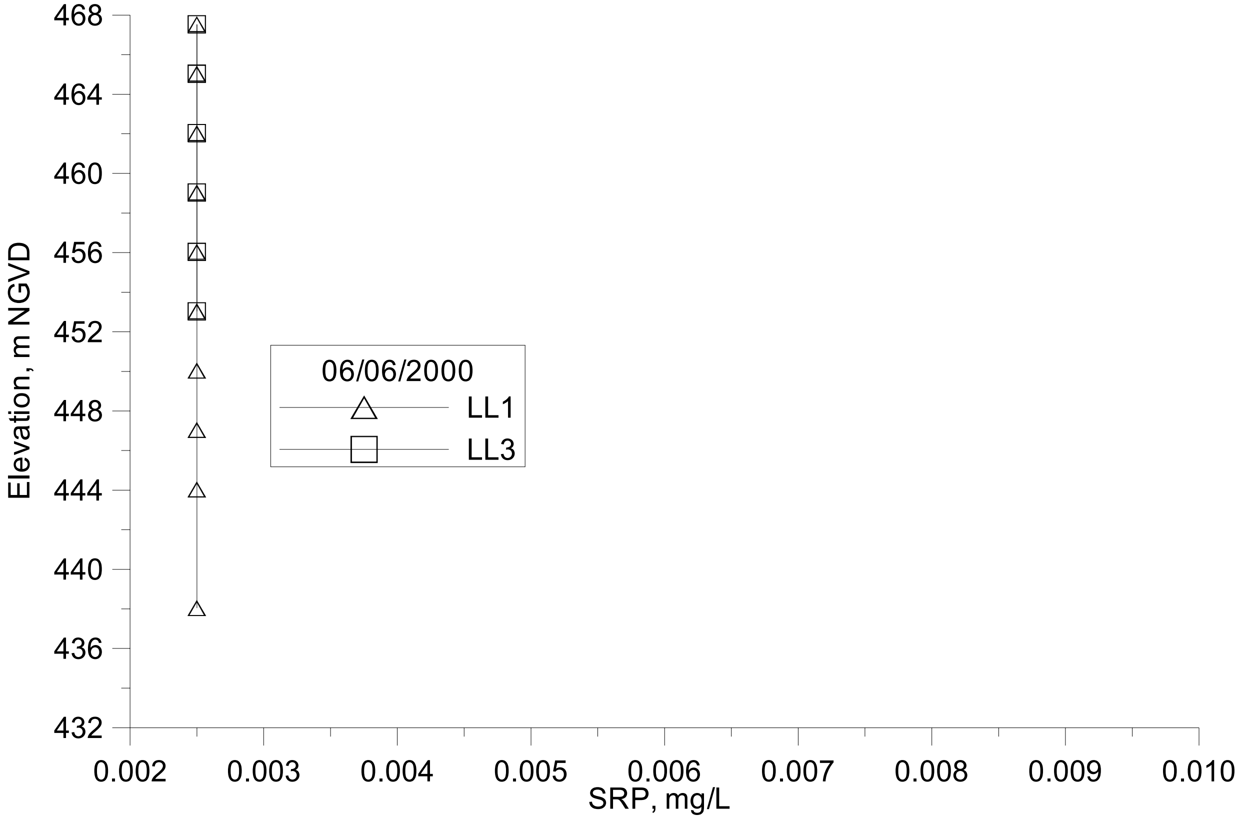

Elevation, m NGVD
Dissolved Oxygen, mg/L
468
464
460
456
452
448
444
440
436
432
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0


06/06/2000
LL1
LL3
Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
0
0.1
0.2
0.3
0.4
NO2 & NO3, mg/L

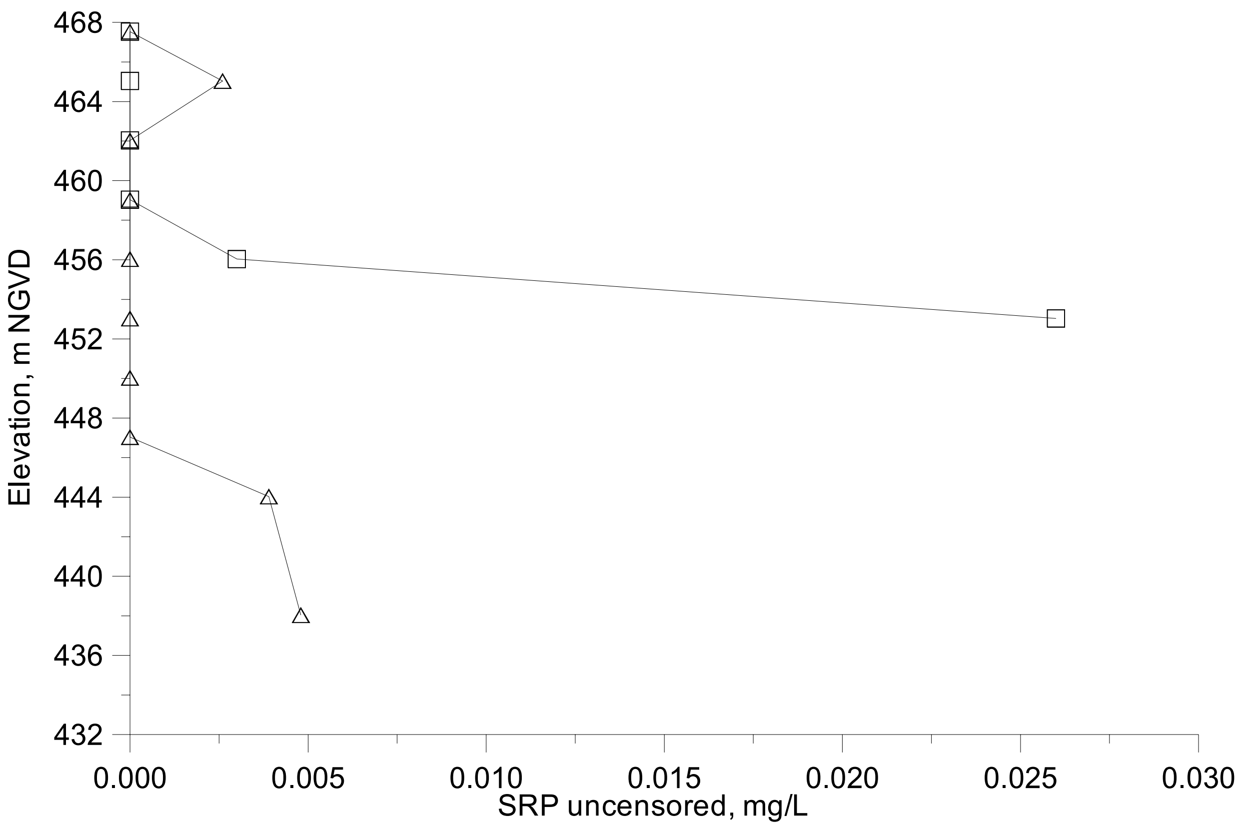

Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
0.004
0.006
0.008
0.010
0.012
0.014
0.016
0.018
0.020
NH3, mg/L


06/06/2000
LL1
LL3
Elevation, m NGVD
TPN, mg/L

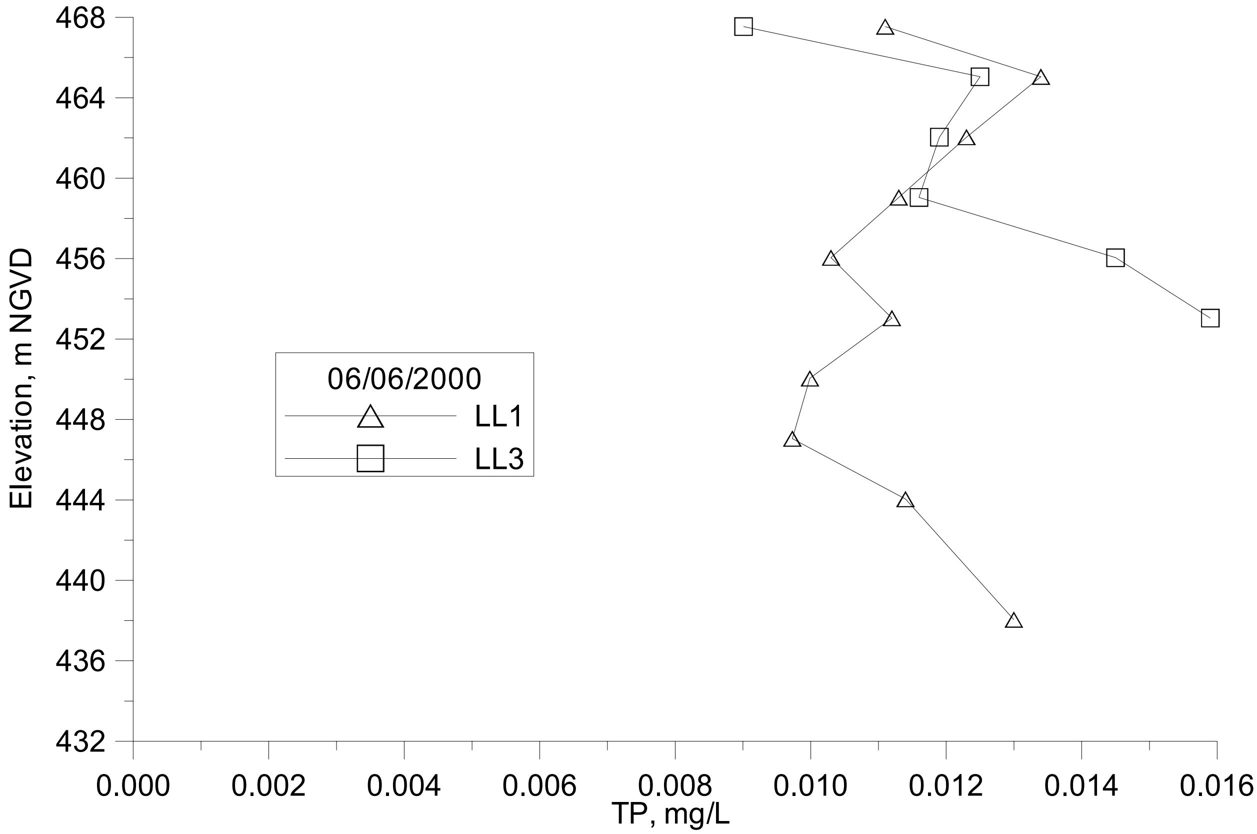

Elevation, m NGVD
TON, mg/L

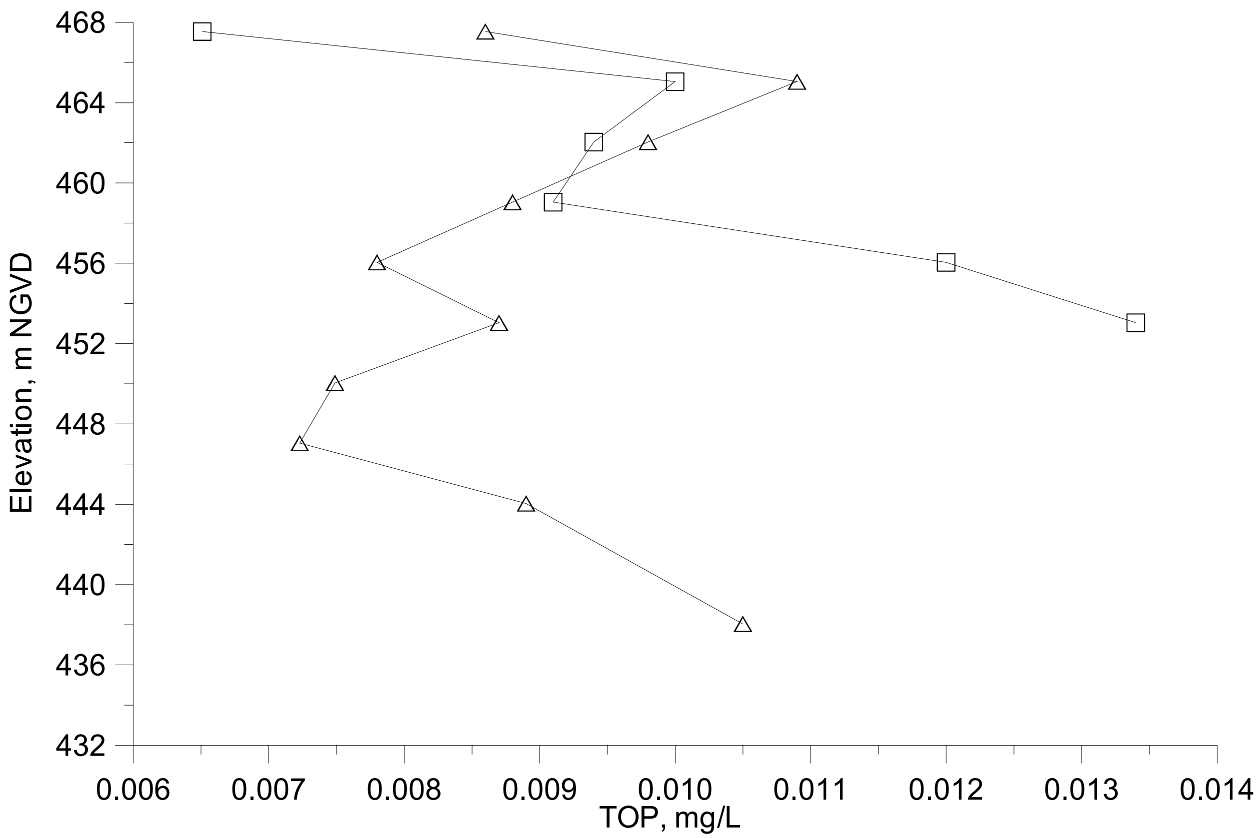


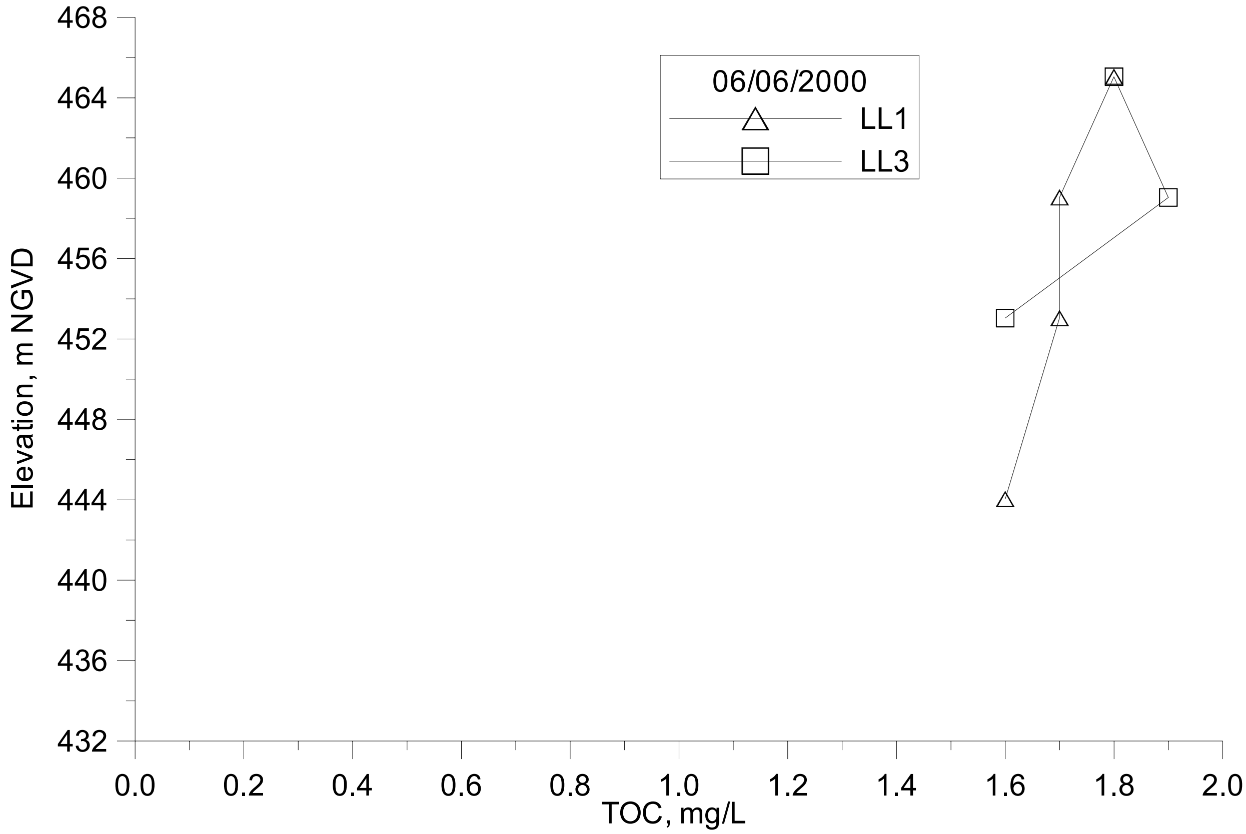
06/06/2000
LL1
LL3
Elevation, m NGVD
SRP, mg/L
468
464
460
456
452
448
444
440
436
432
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010

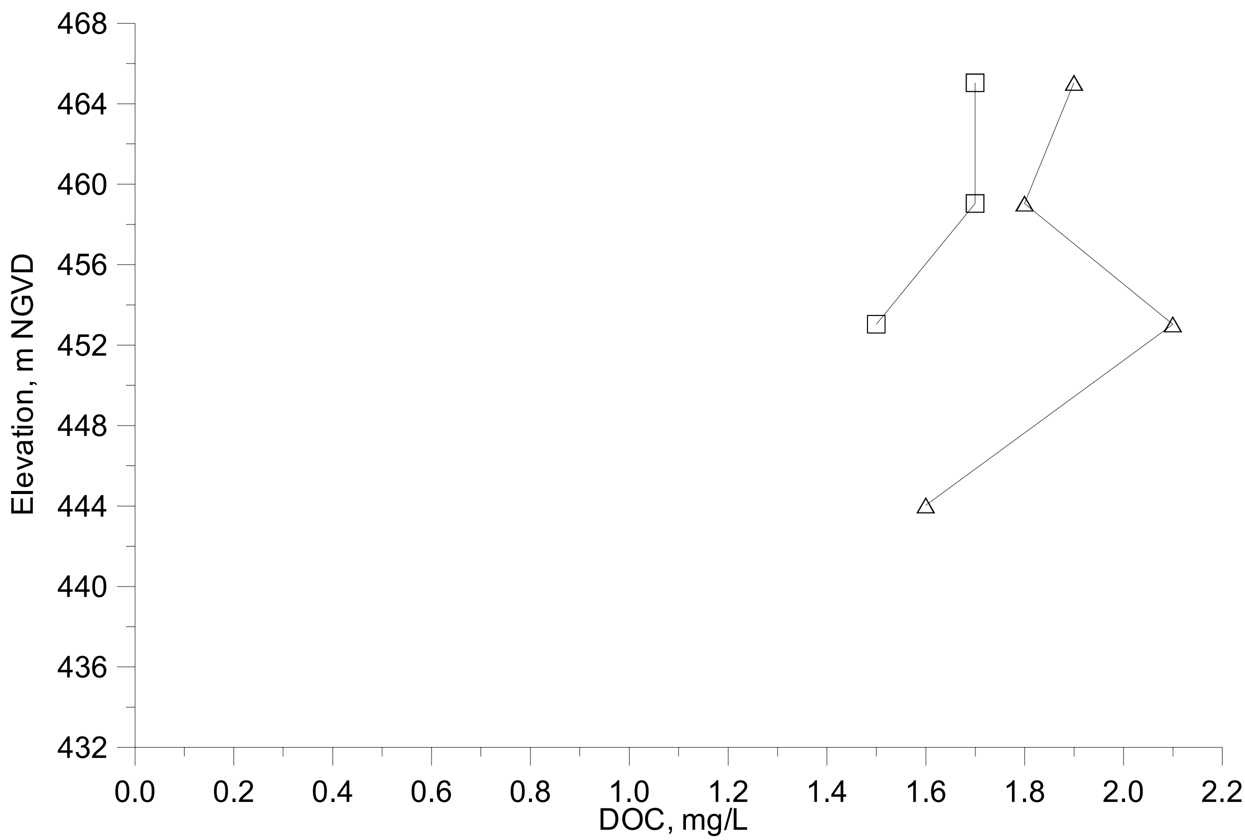


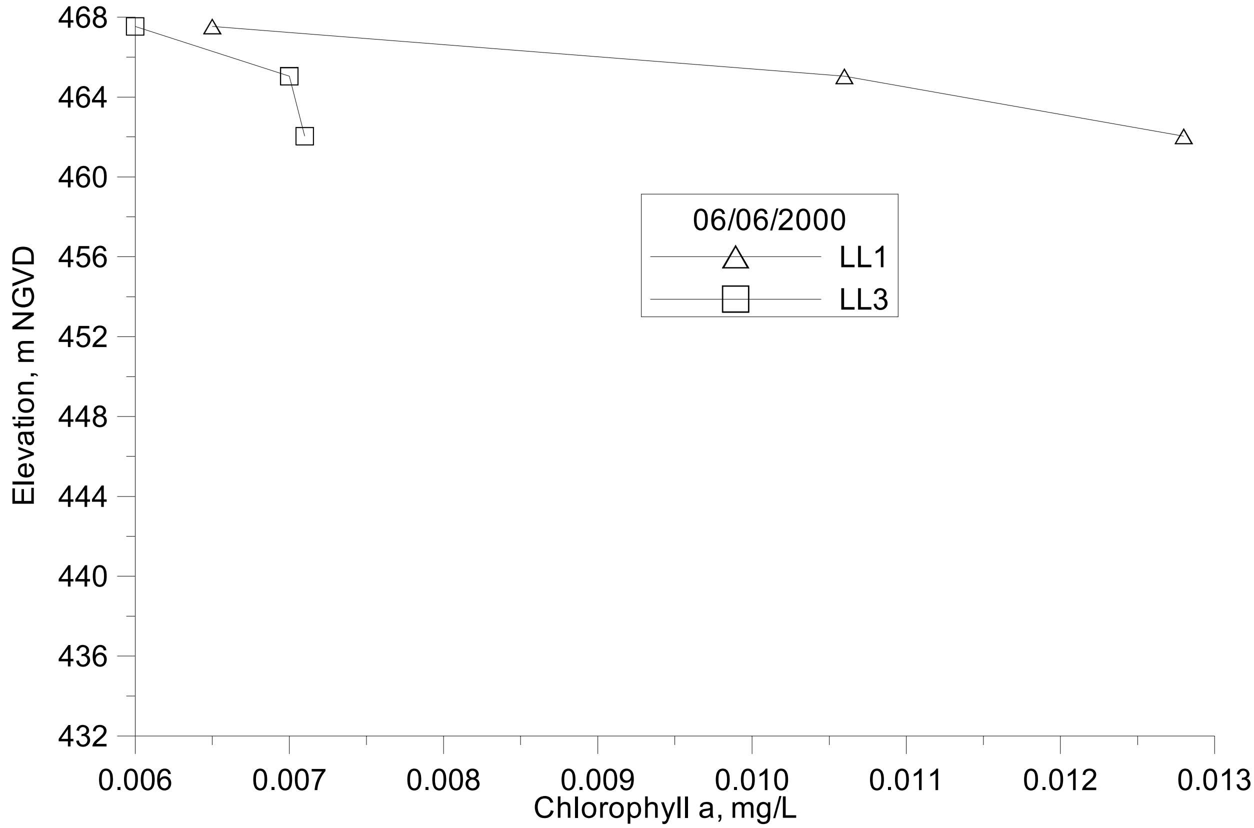
Elevation, m NGVD
SRP uncensored, mg/L
468
464
460
456
452
448
444
440
436
432
0.000
0.005
0.010
0.015
0.020
0.025
0.030


06/06/2000
LL1
LL3
Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016
TP, mg/L

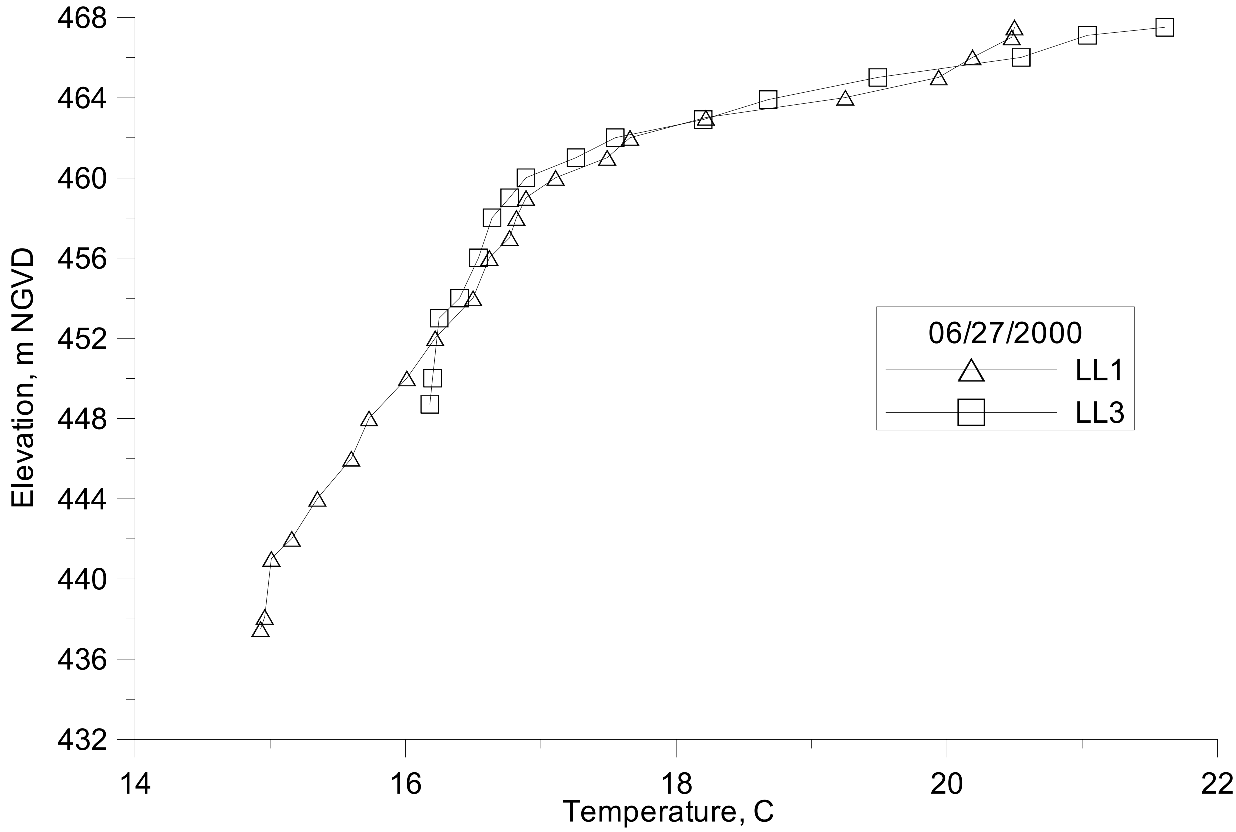

Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
0.006
0.007
0.008
0.009
0.010
0.011
0.012
0.013
0.014
TOP, mg/L

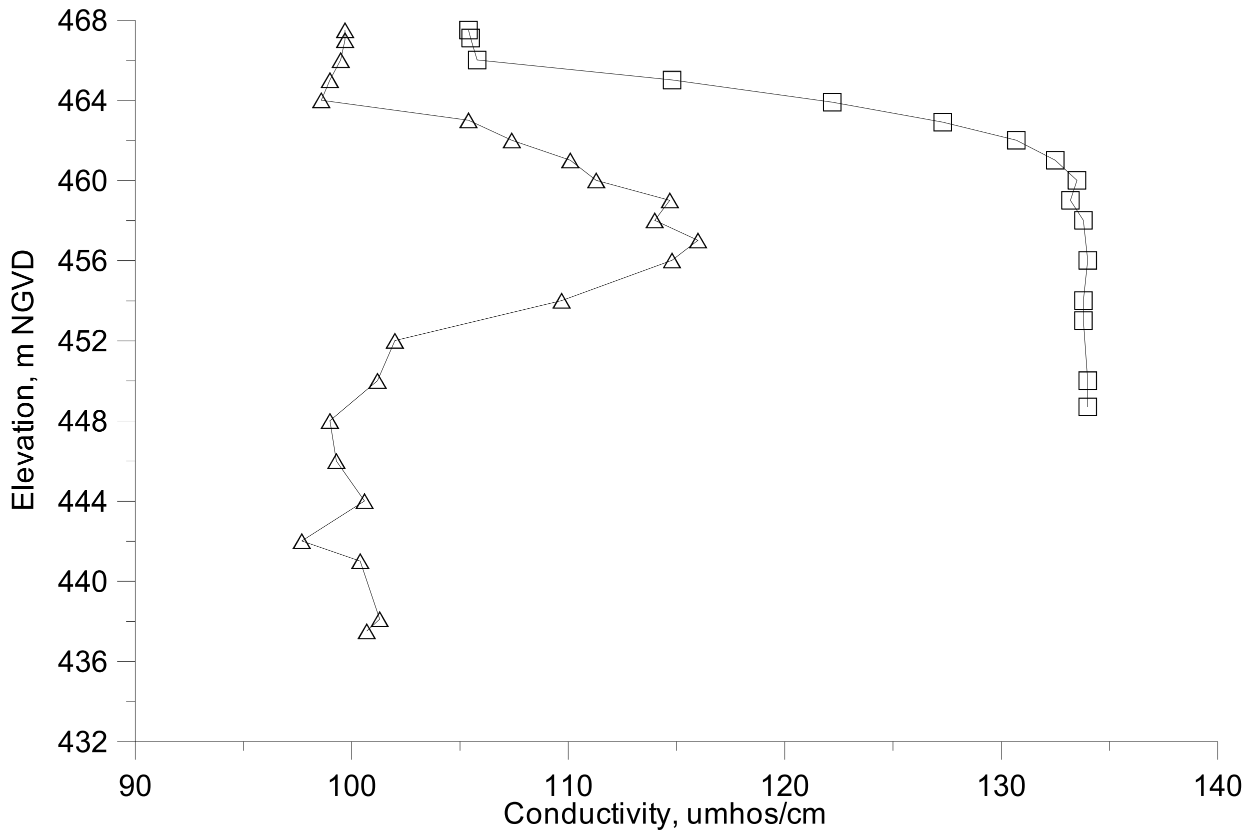

06/06/2000
LL1
LL3
Elevation, m NGVD
TOC, mg/L

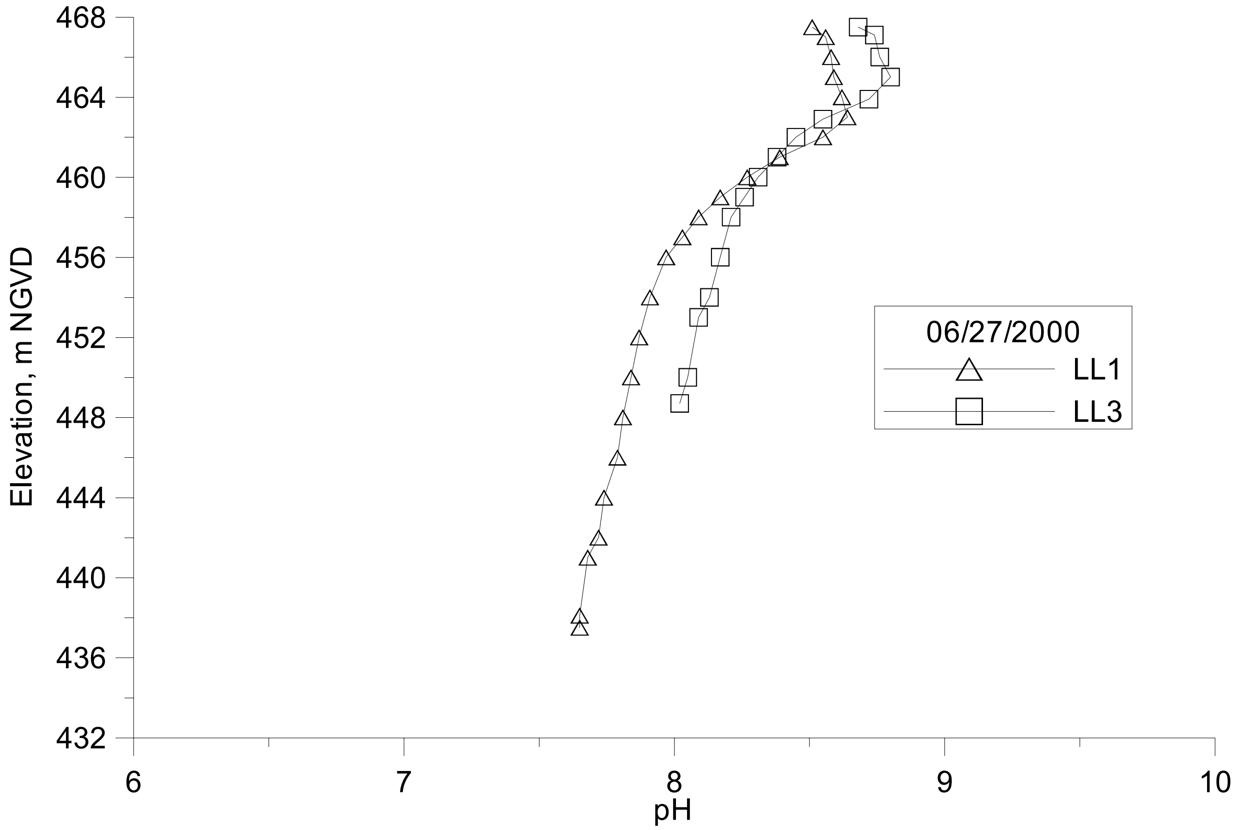

Elevation, m NGVD
DOC, mg/L



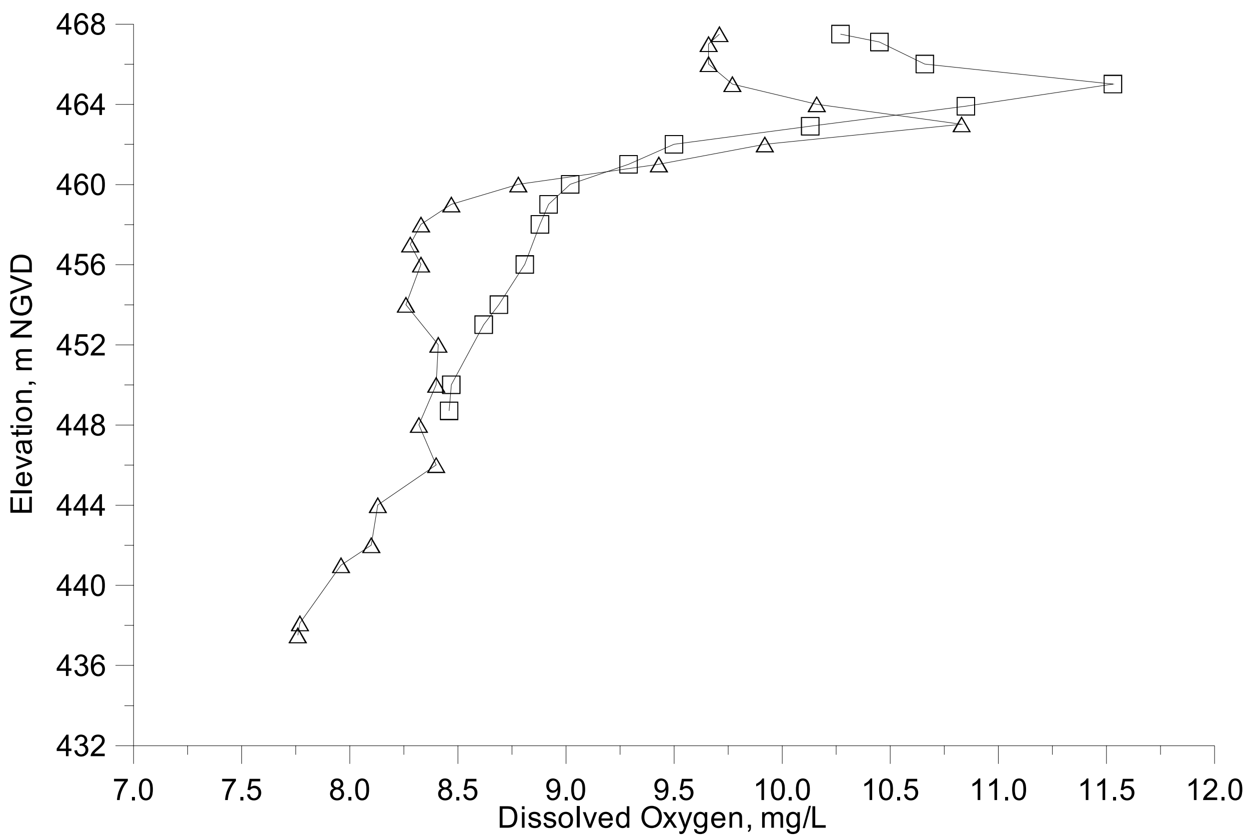
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.006
0.007
0.008
0.009
0.010
0.011
0.012
0.013
Chlorophyll a, mg/L
06/06/2000
LL1
LL3


468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
14
16
18
20
22
Temperature, C
06/27/2000
LL1
LL3

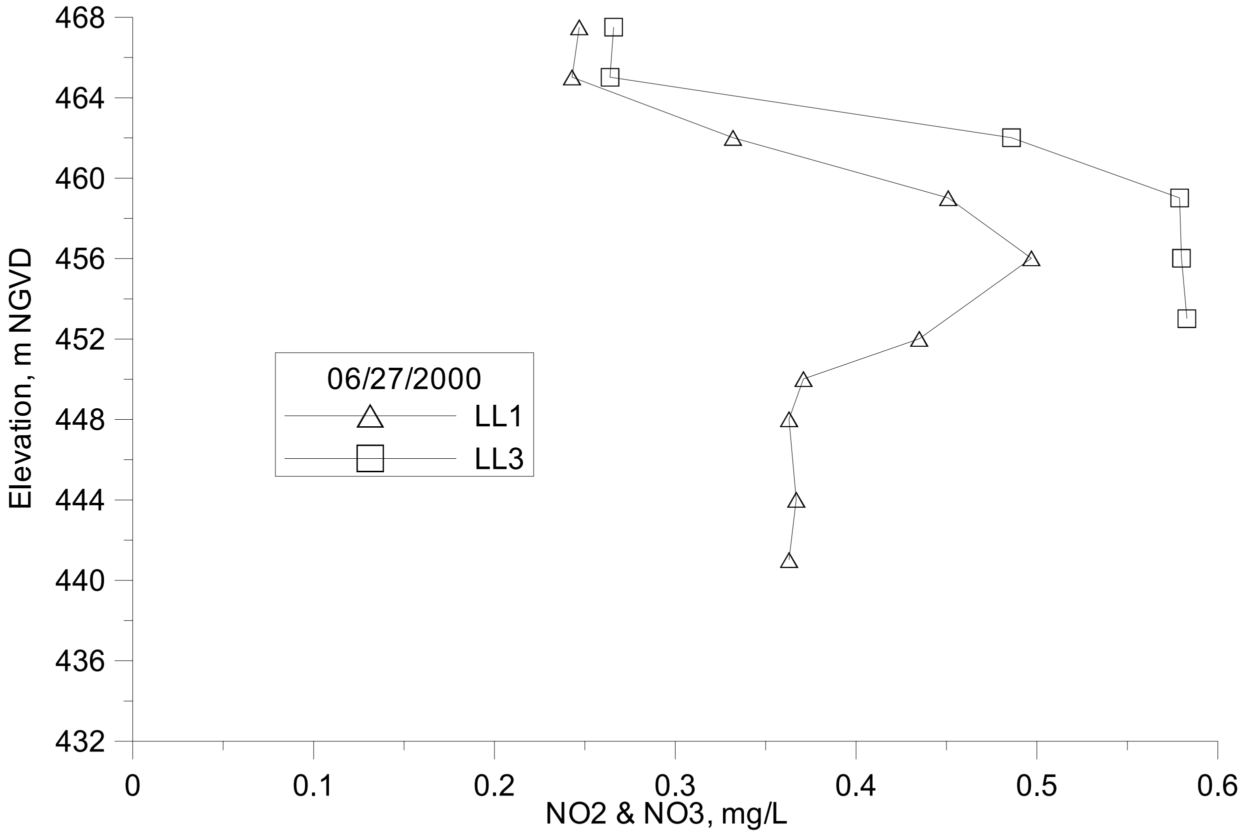

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
90
100
110
120
130
140
Conductivity, umhos/cm

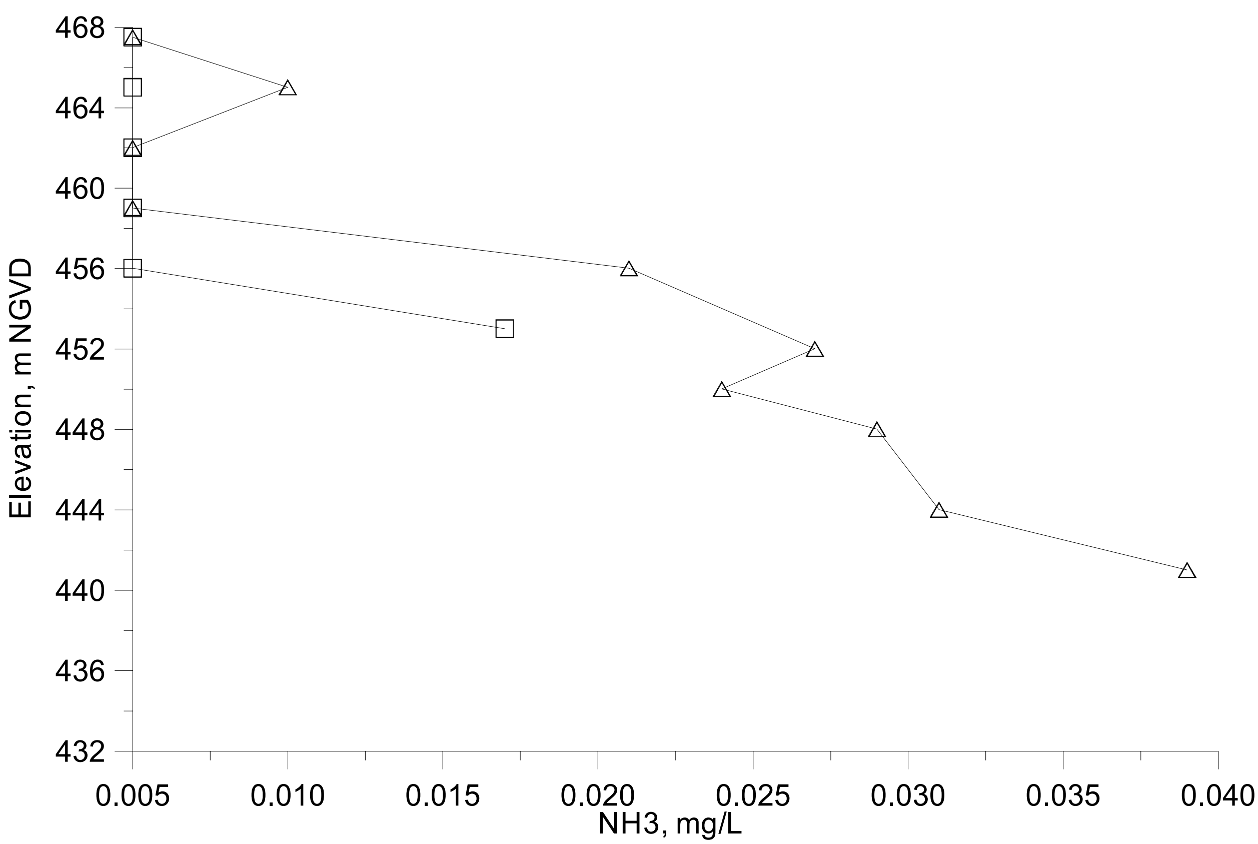


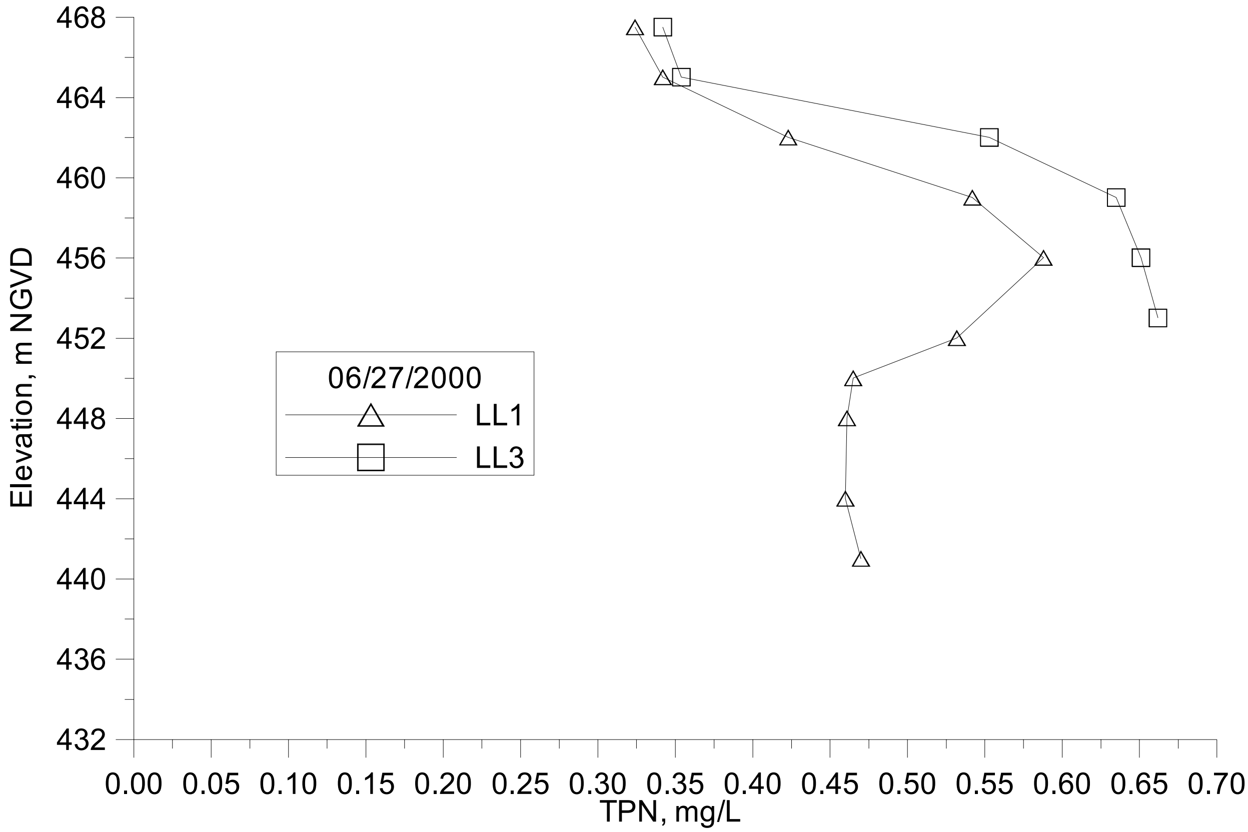
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
6
7
8
9
10
pH
06/27/2000
LL1
LL3



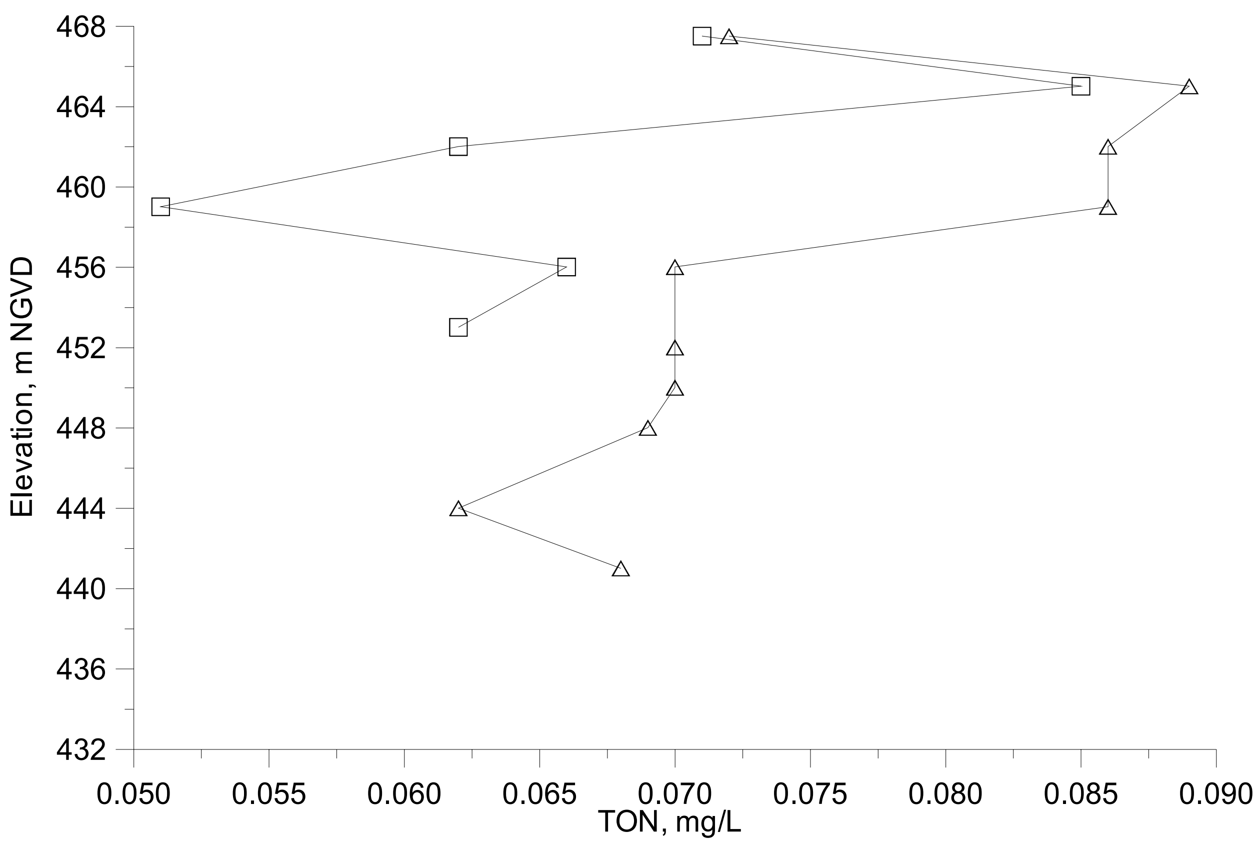
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
Dissolved Oxygen, mg/L


468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
0.1
0.2
0.3
0.4
0.5
0.6
NO2 & NO3, mg/L
06/27/2000
LL1
LL3

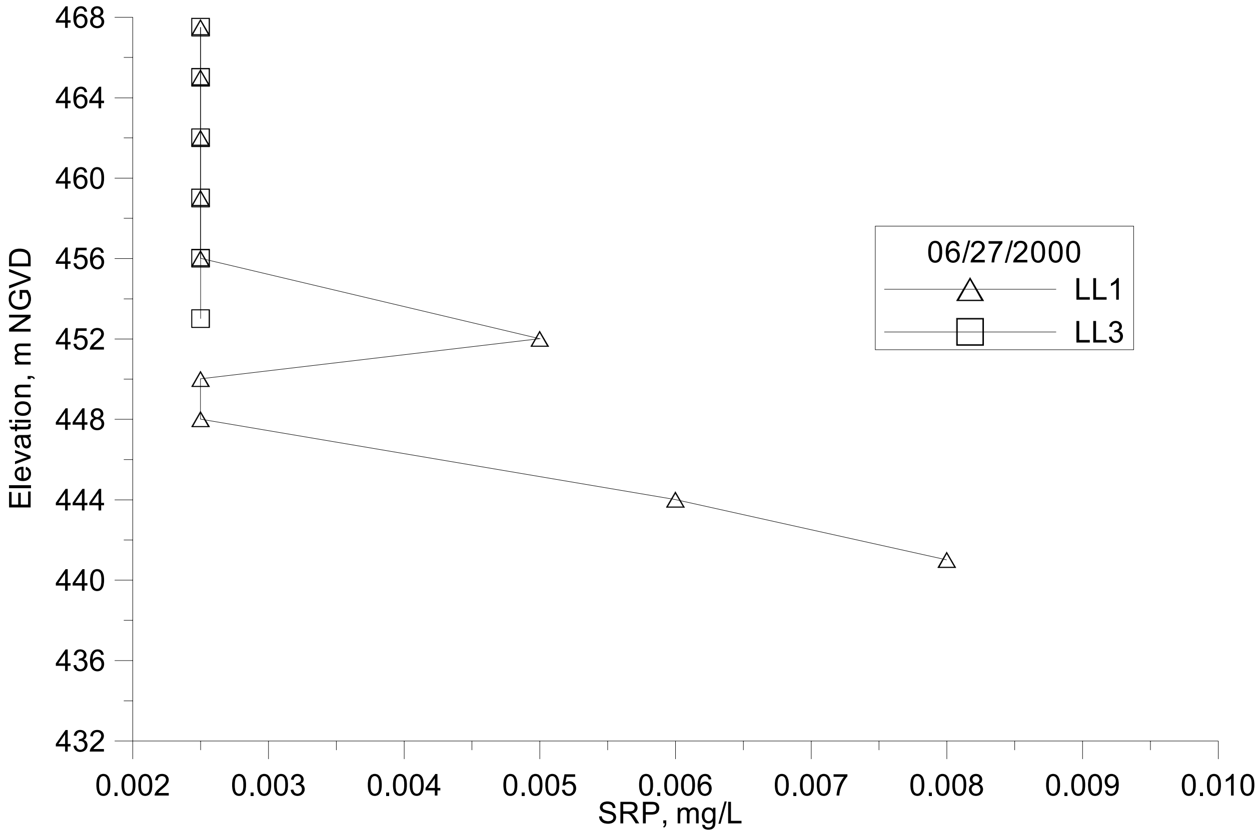

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
NH3, mg/L

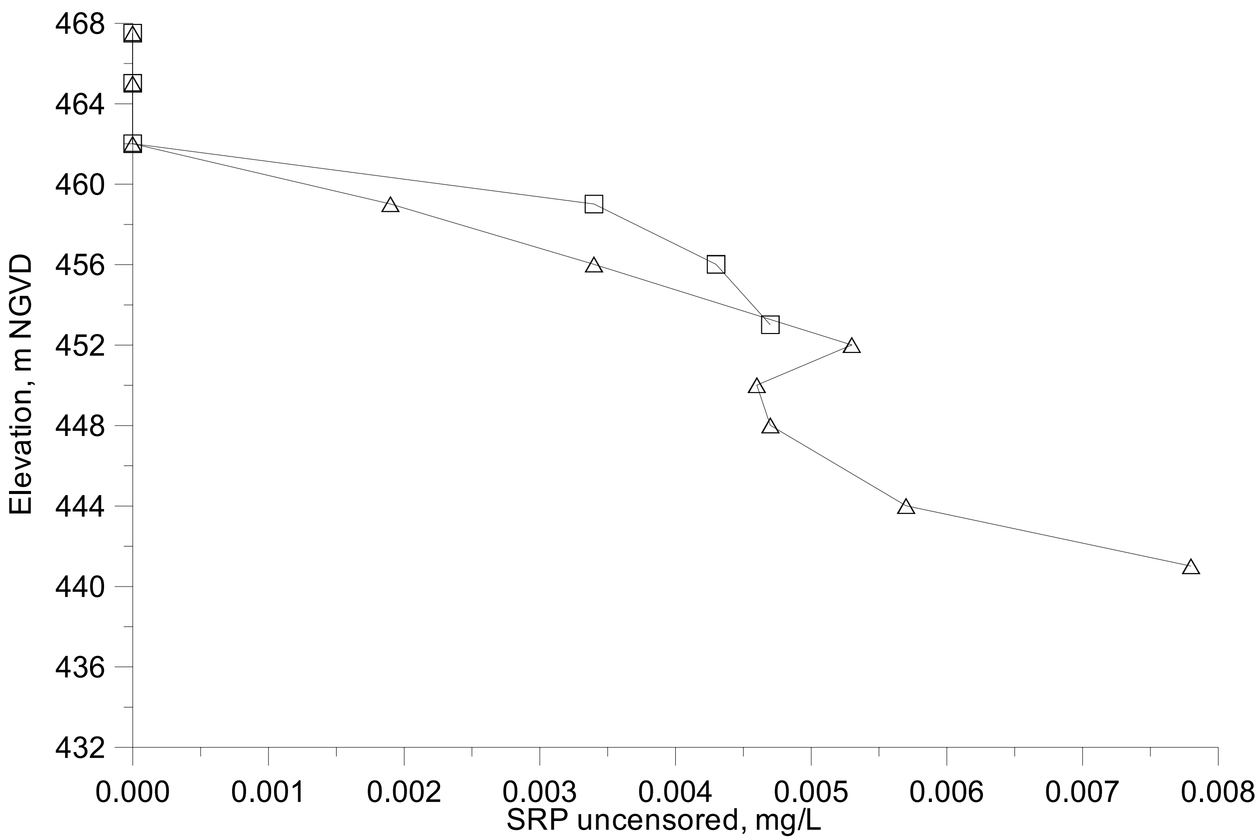


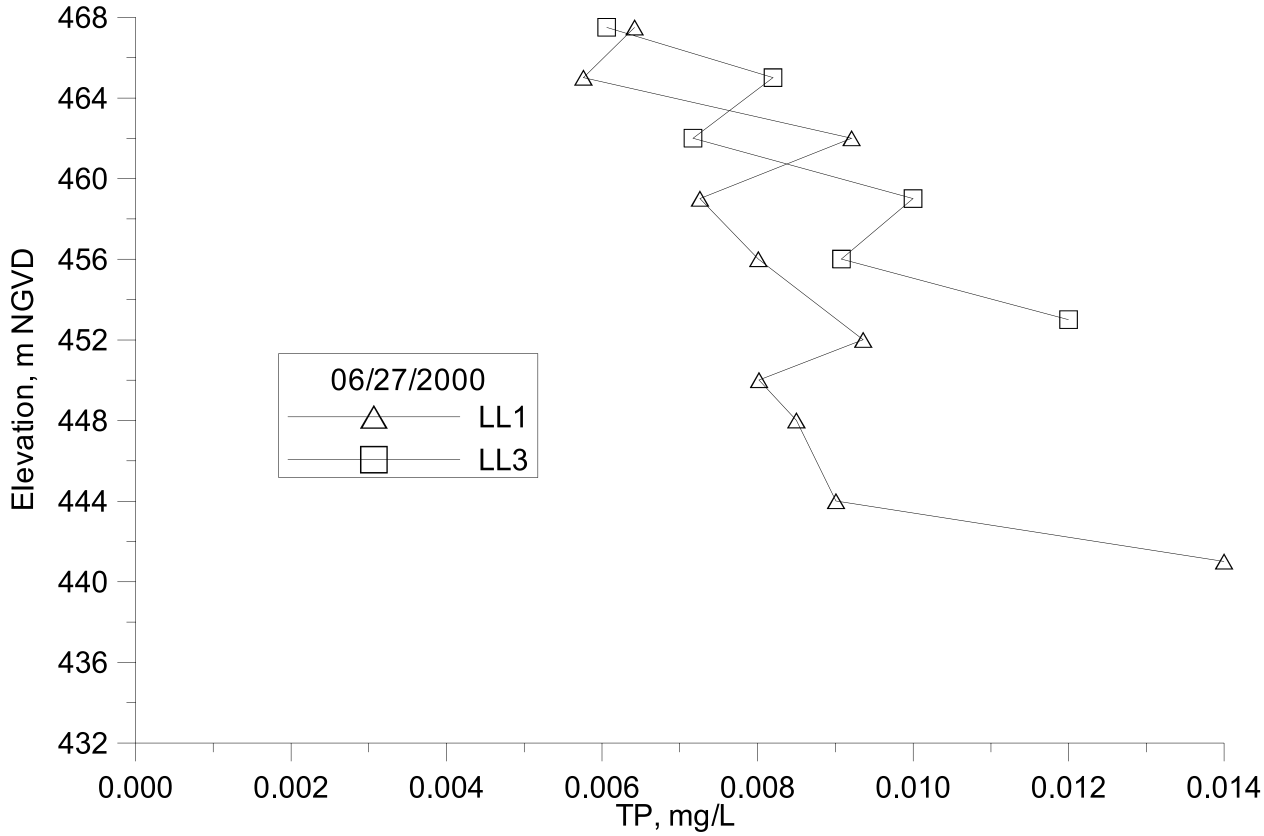
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
06/27/2000
LL1
LL3
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70
TPN, mg/L

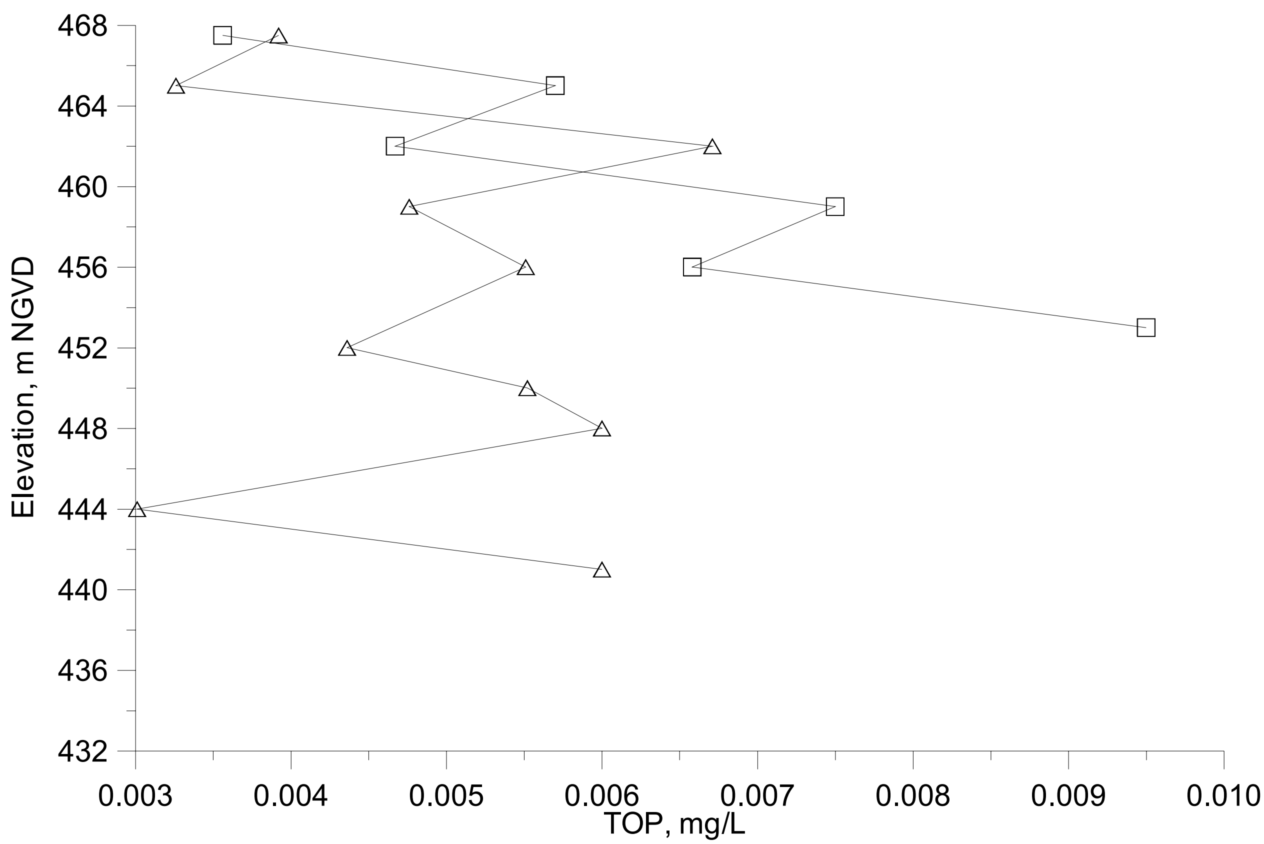


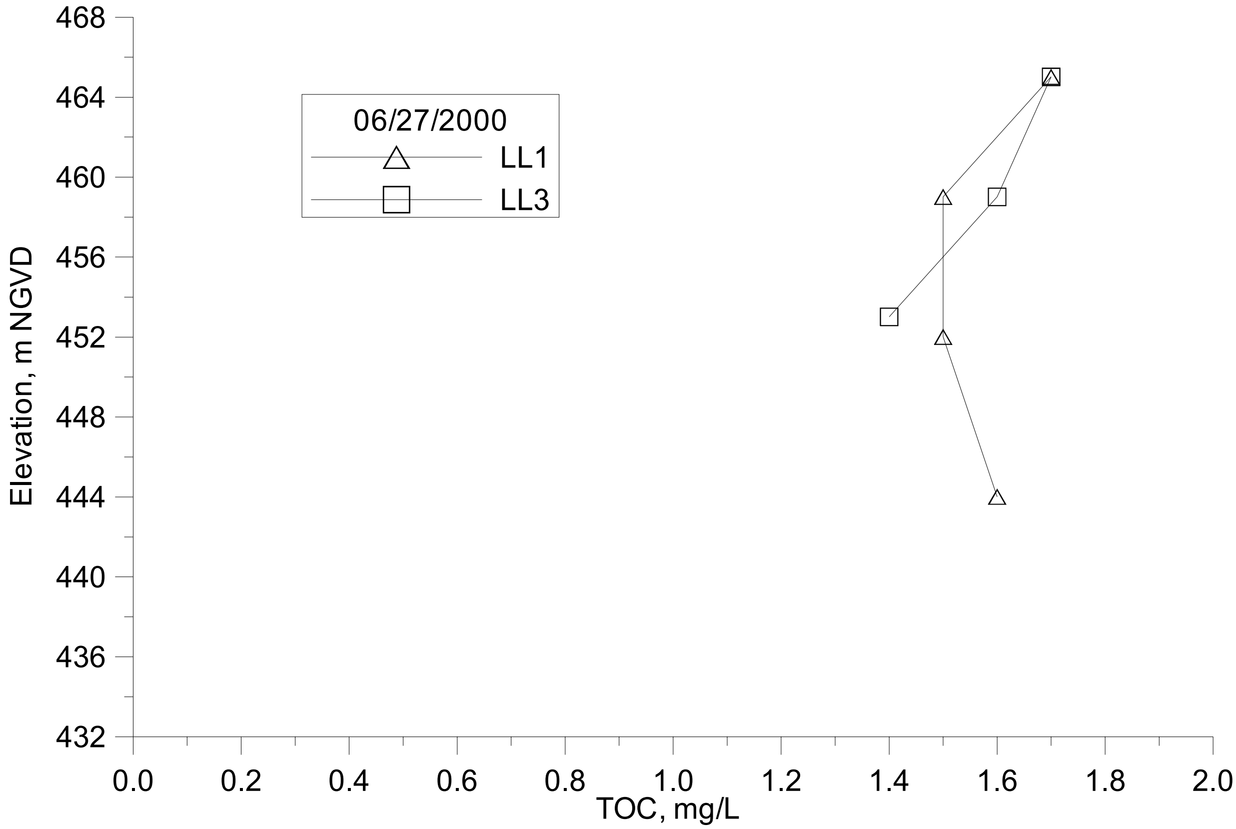
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.050 0.055 0.060 0.065 0.070 0.075 0.080 0.085 0.090
TON, mg/L

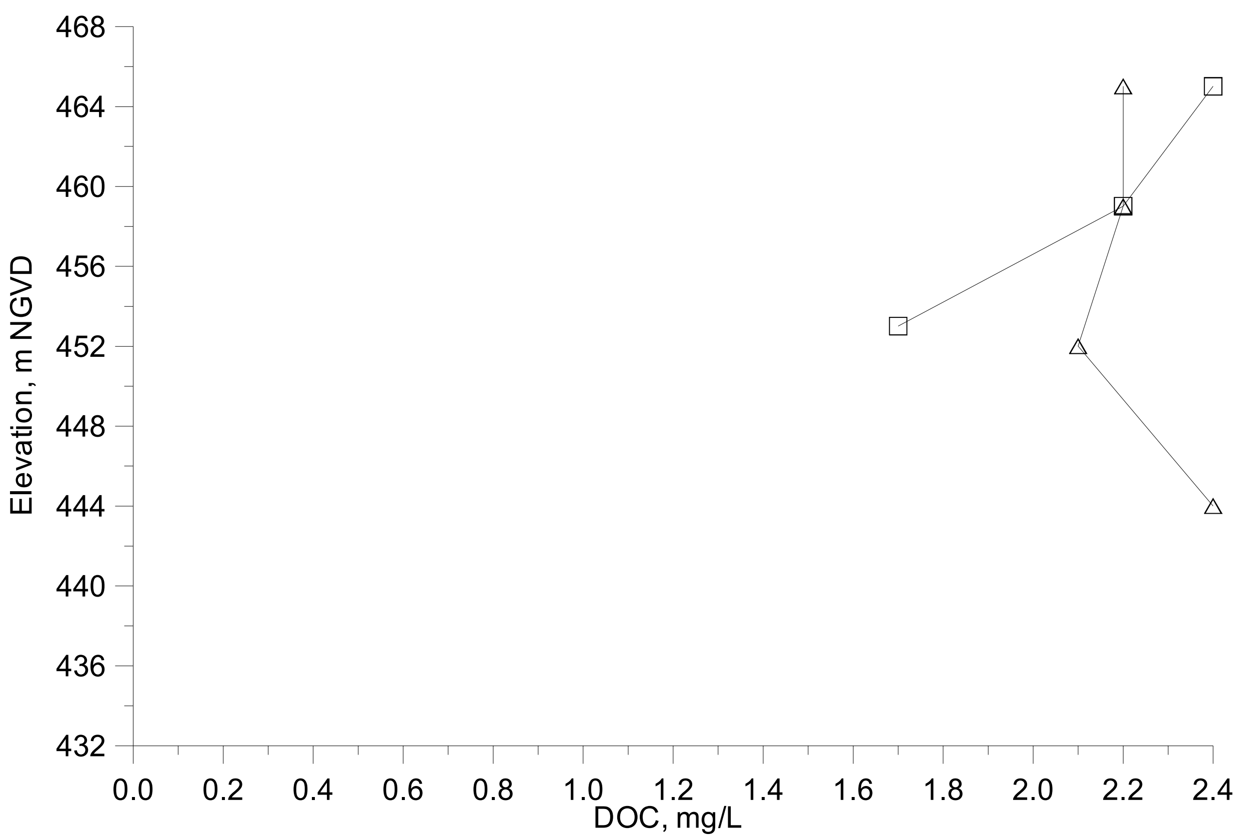

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010
SRP, mg/L
06/27/2000
LL1
LL3

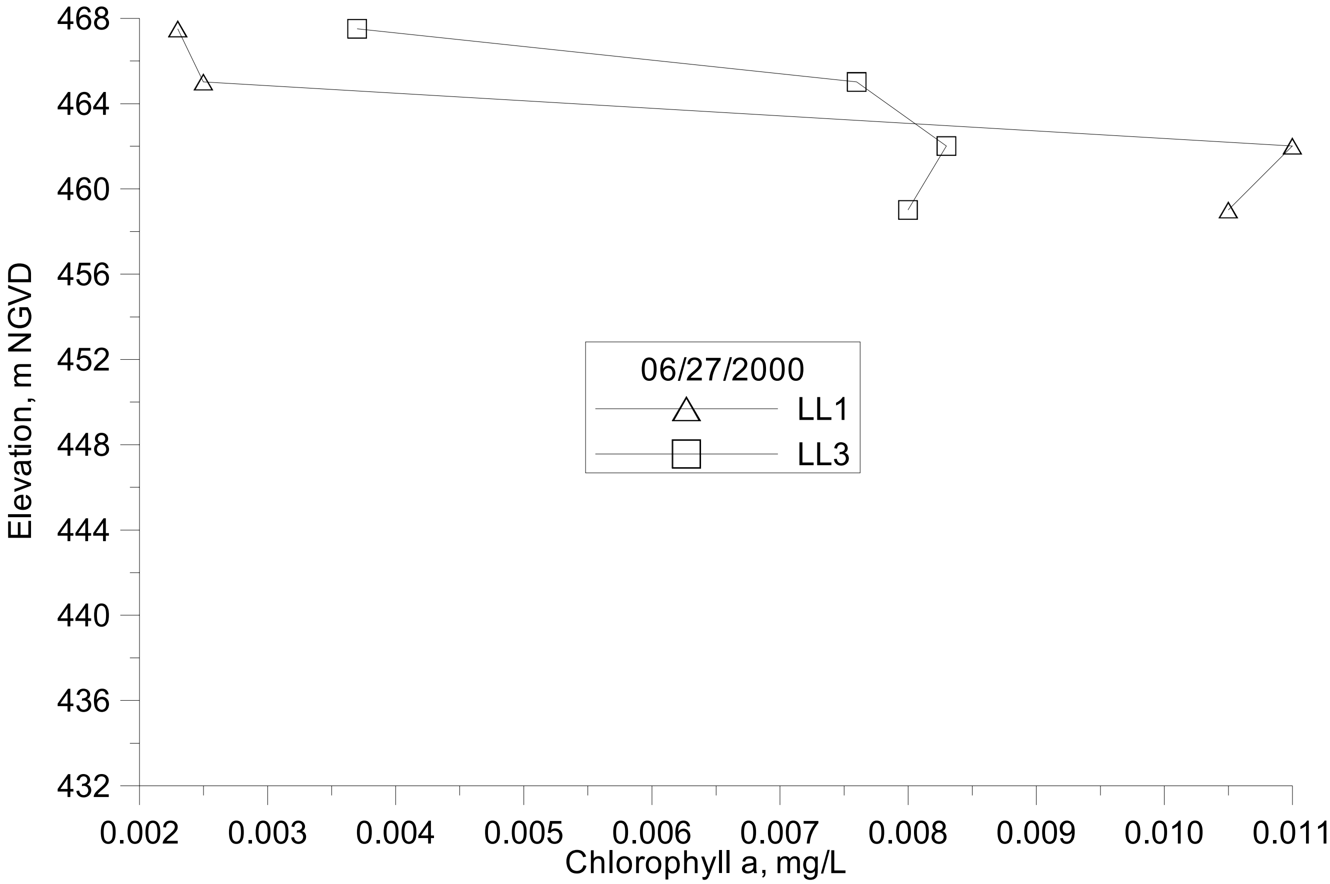

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
SRP uncensored, mg/L


Elevation, m NGVD
TP, mg/L
06/27/2000
LL1
LL3
468
464
460
456
452
448
444
440
436
432
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014

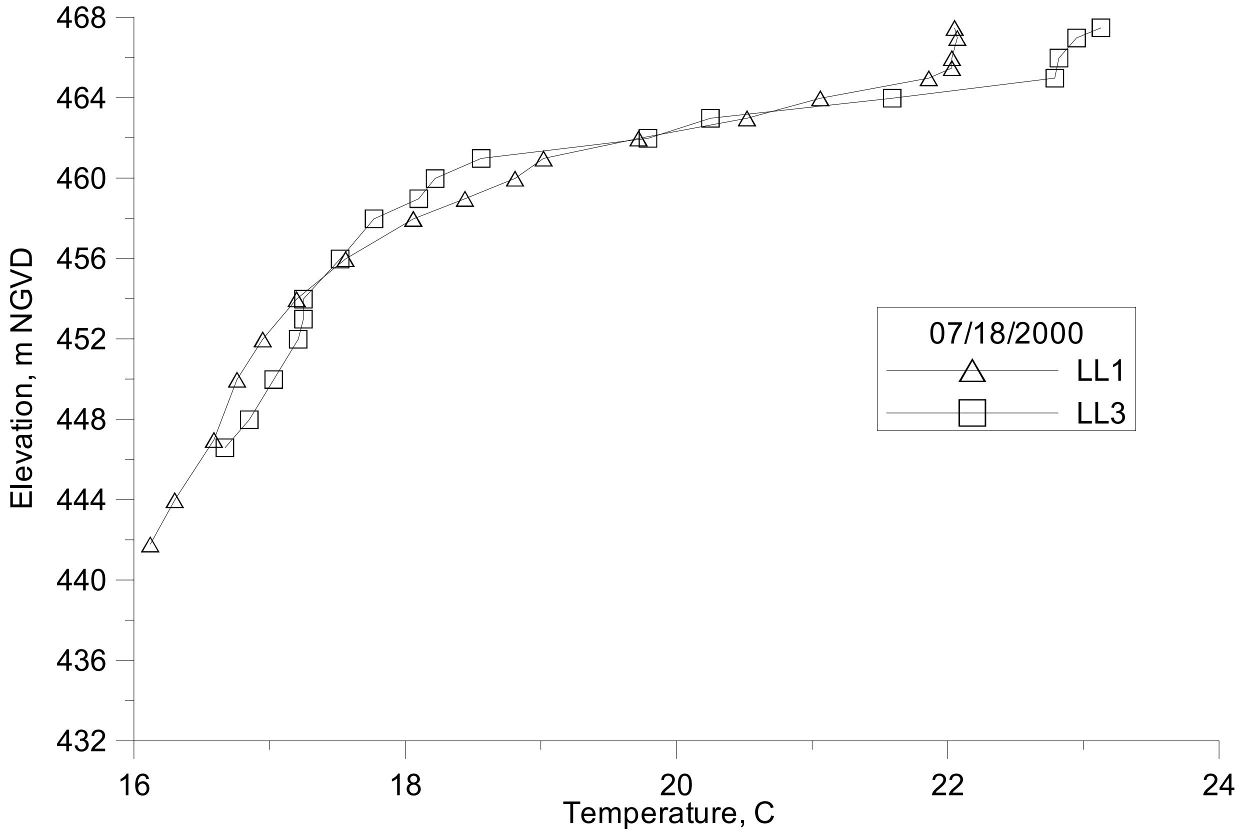

Elevation, m NGVD
TOP, mg/L
468
464
460
456
452
448
444
440
436
432
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010

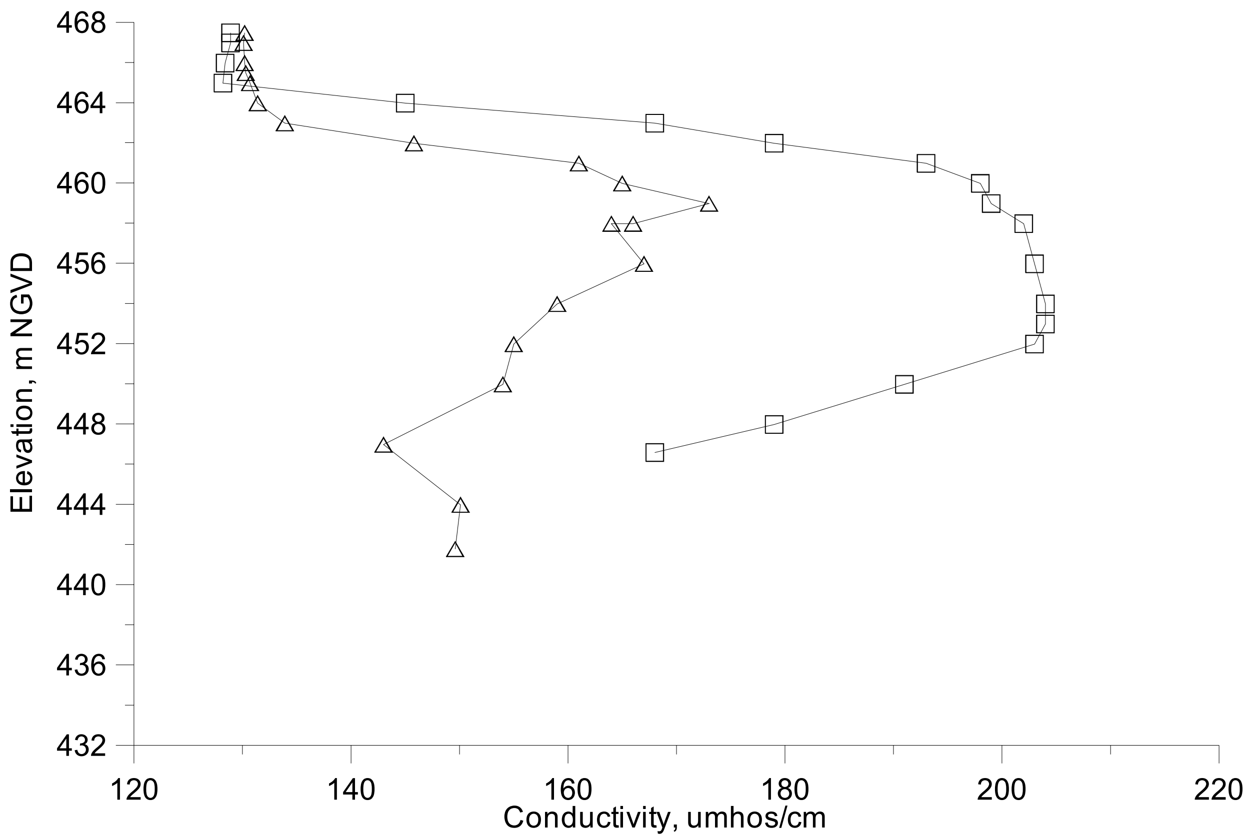

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
06/27/2000
LL1
LL3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TOC, mg/L

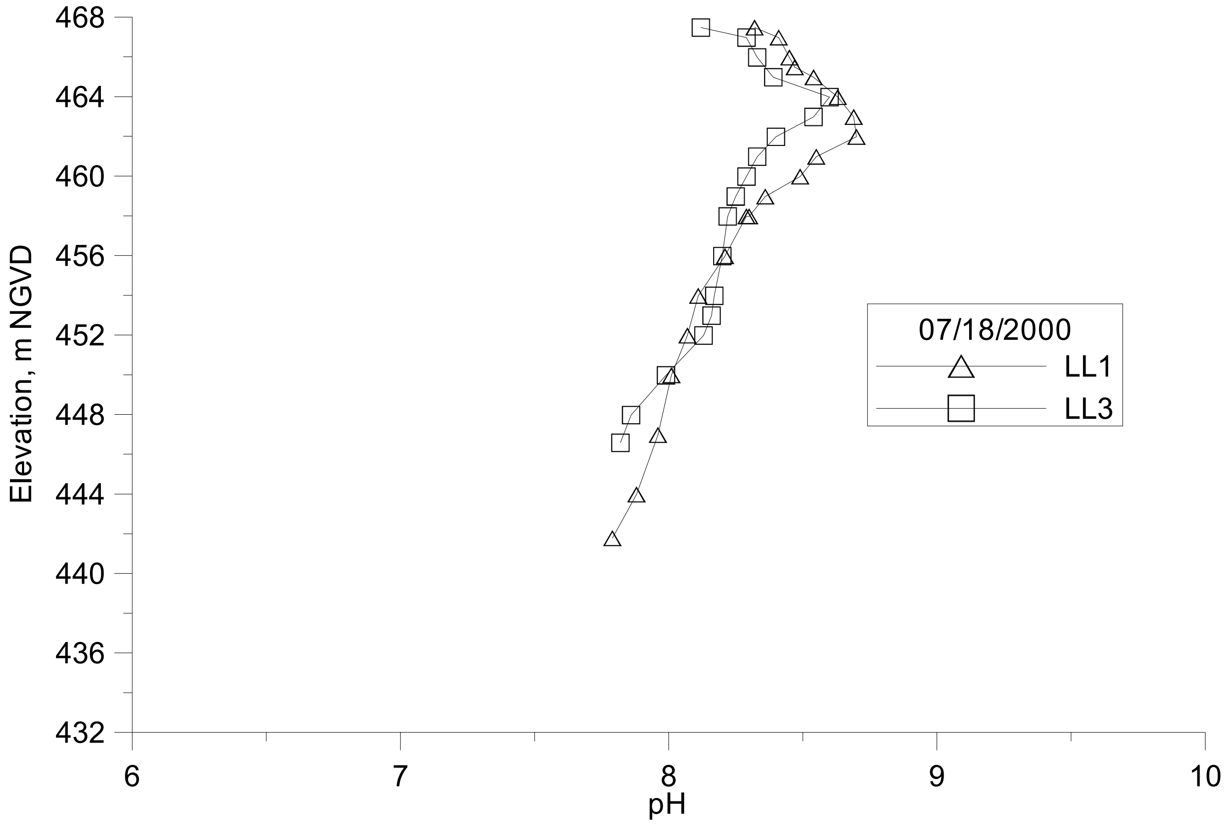

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
DOC, mg/L

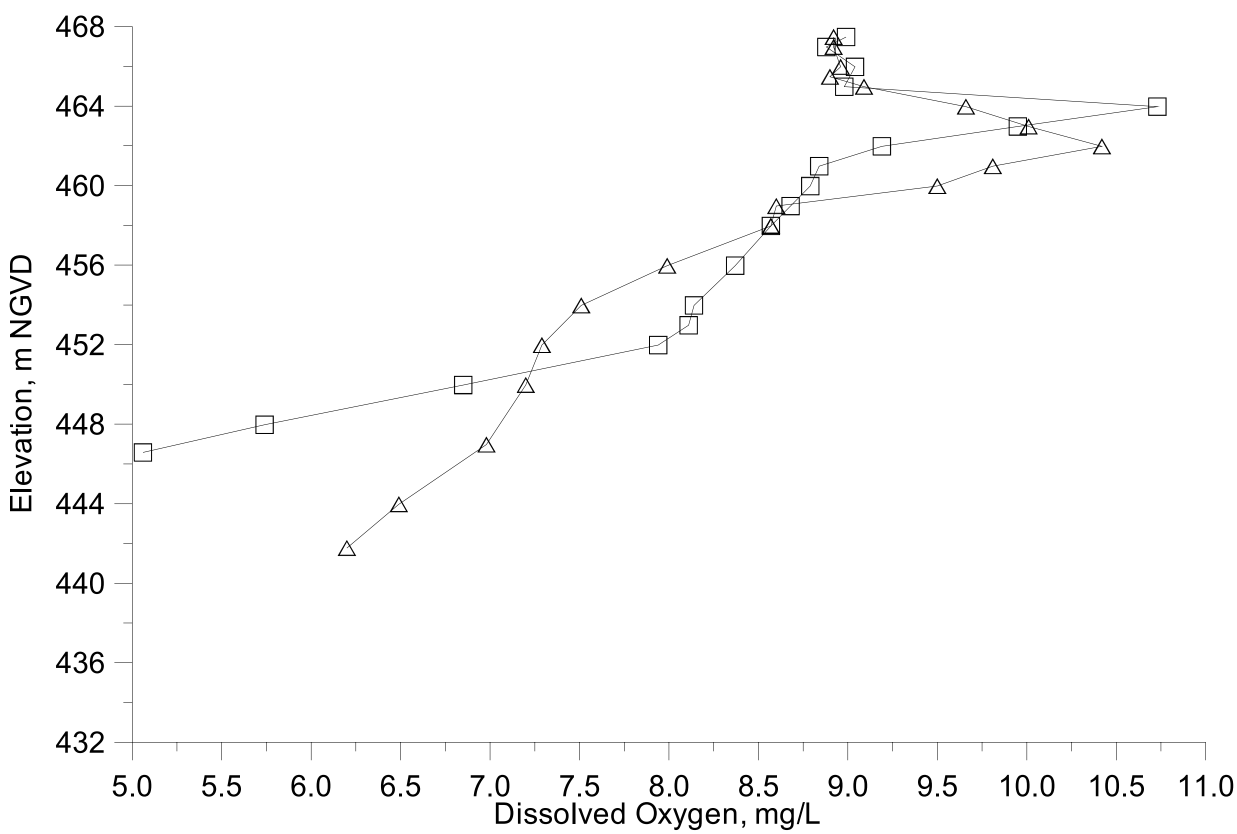


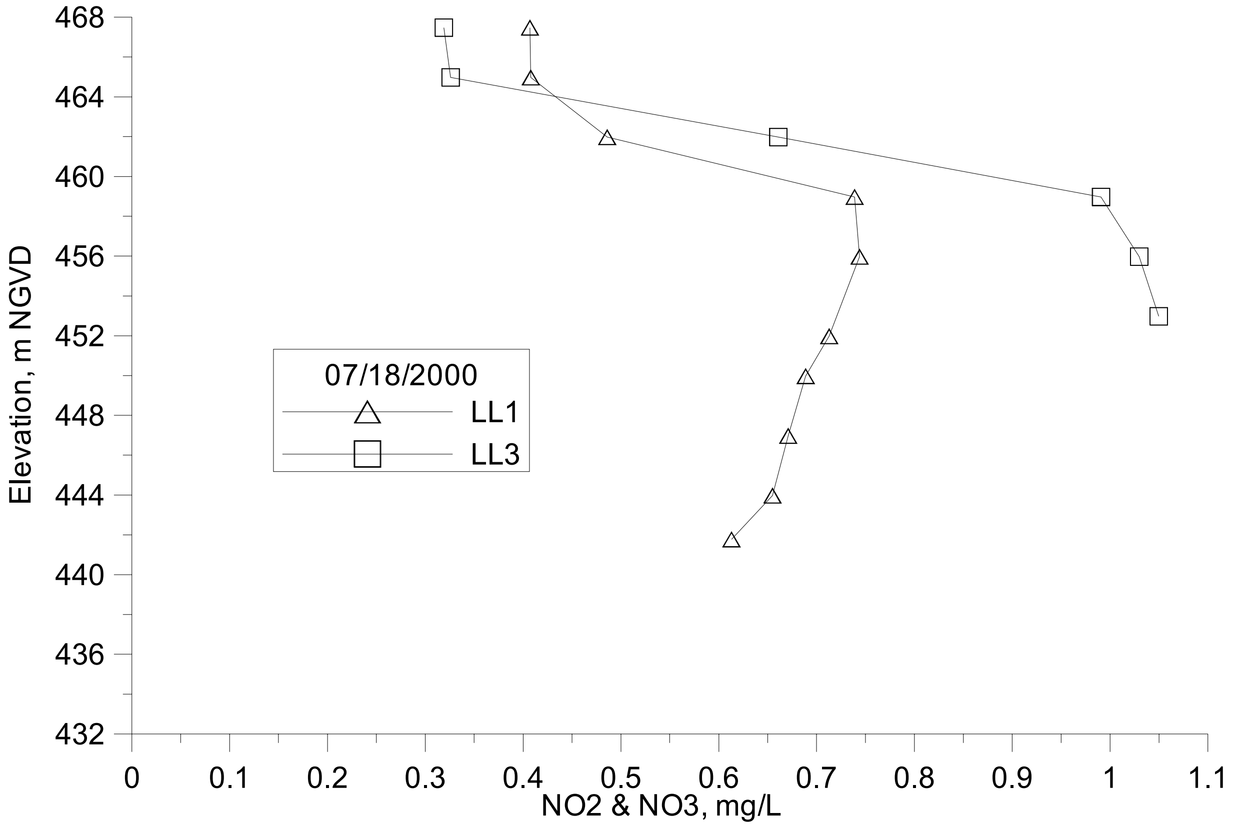
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
06/27/2000
LL1
LL3
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010
0.011
Chlorophyll a, mg/L

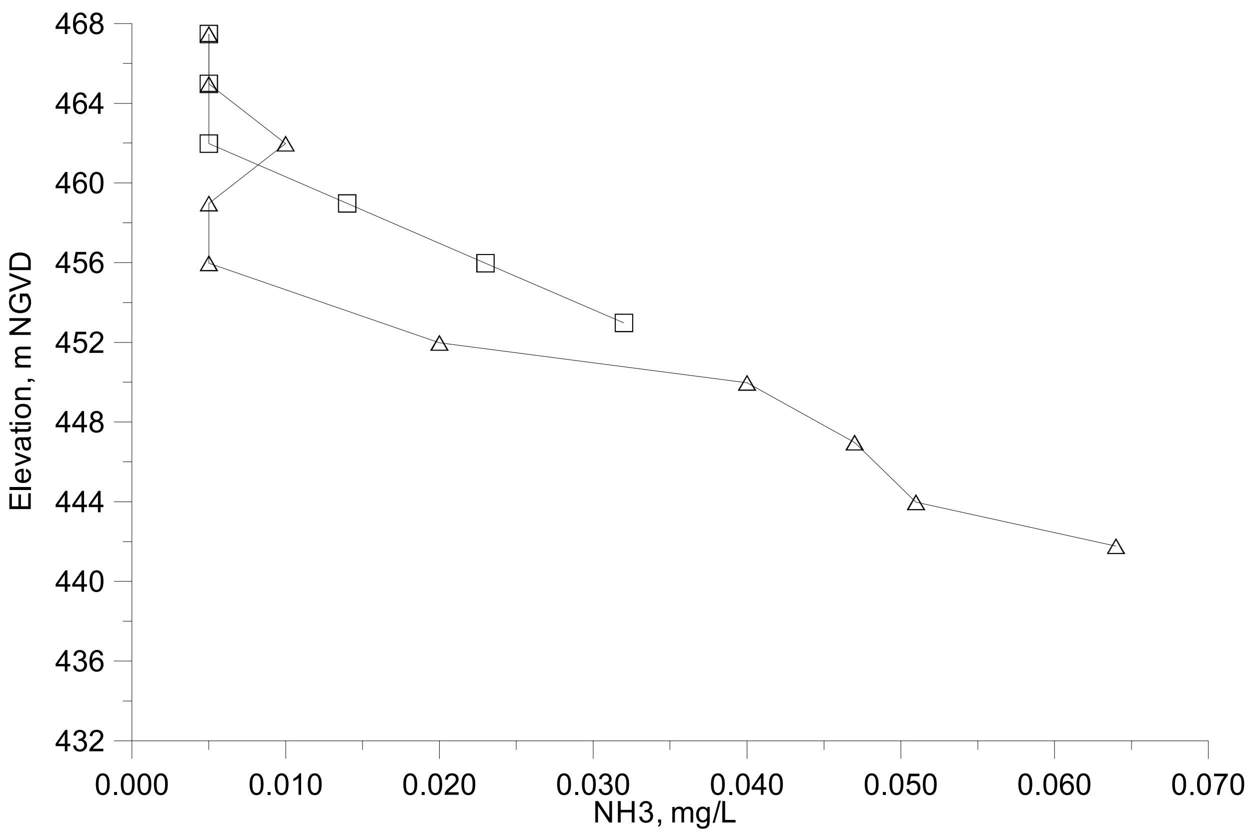

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
16
18
20
22
24
Temperature, C
07/18/2000
LL1
LL3

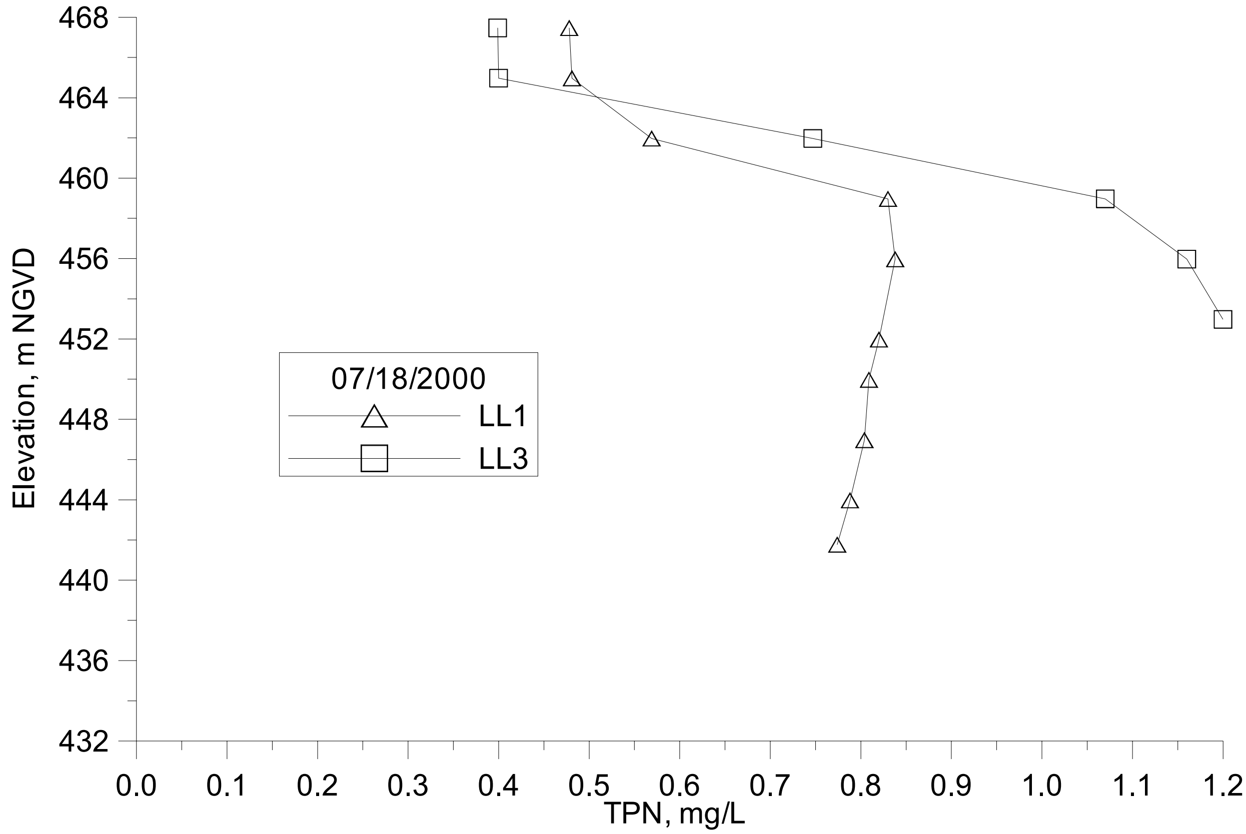

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
120
140
160
180
200
220
Conductivity, umhos/cm

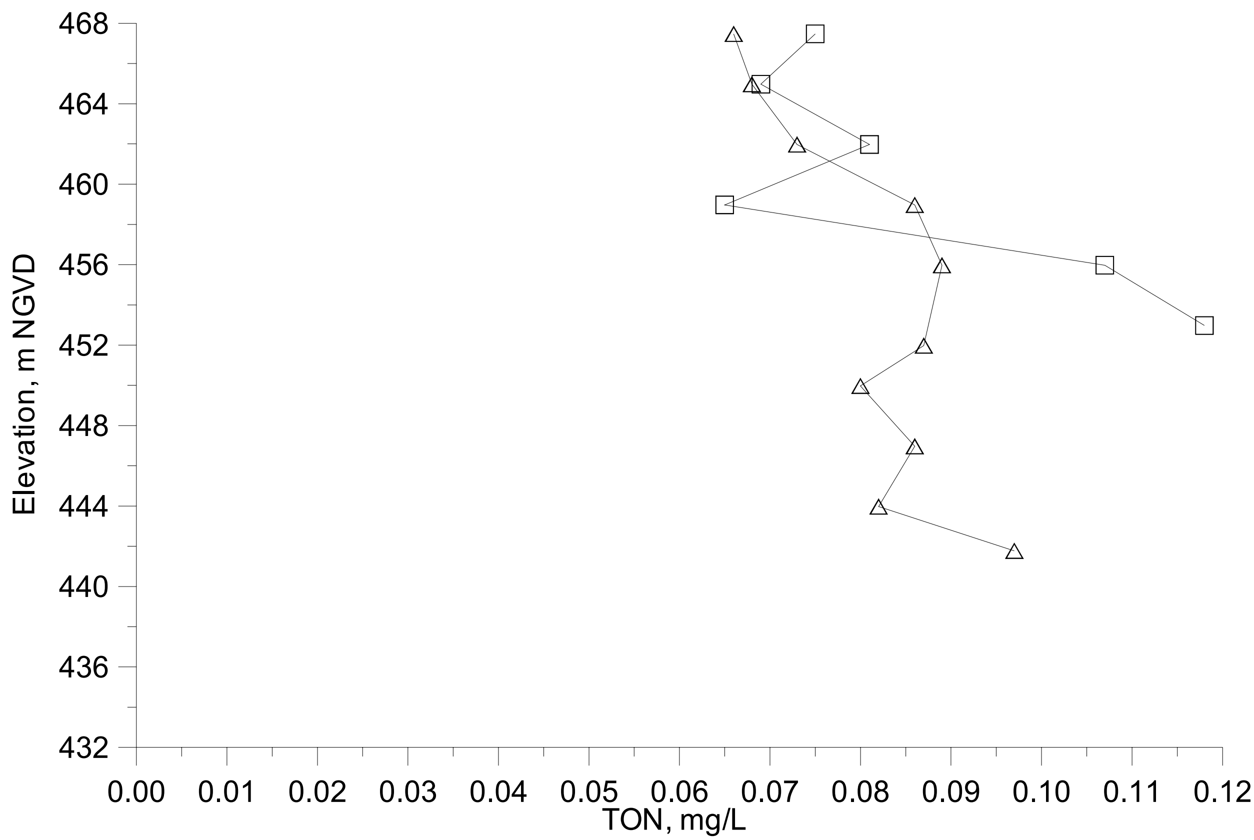

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
6
7
8
9
10
pH
07/18/2000
LL1
LL3

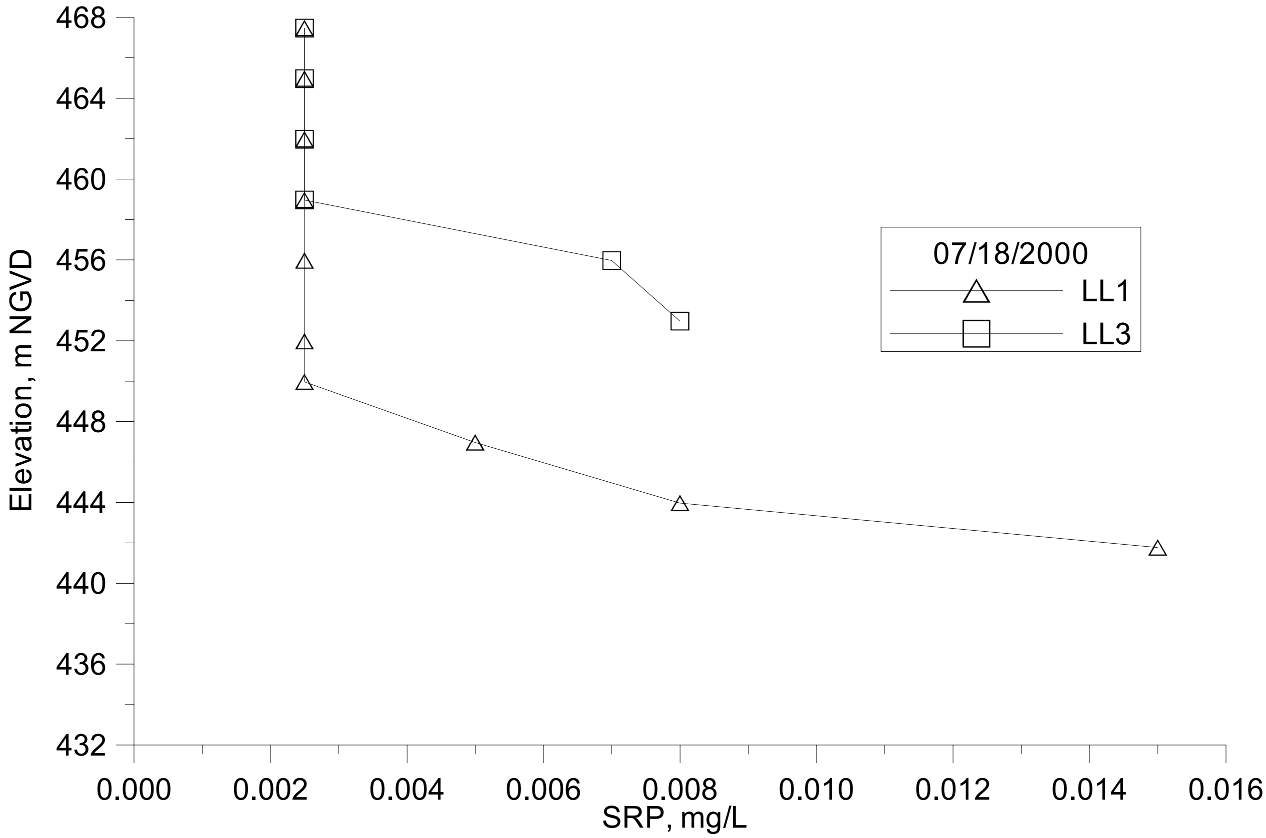

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Dissolved Oxygen, mg/L

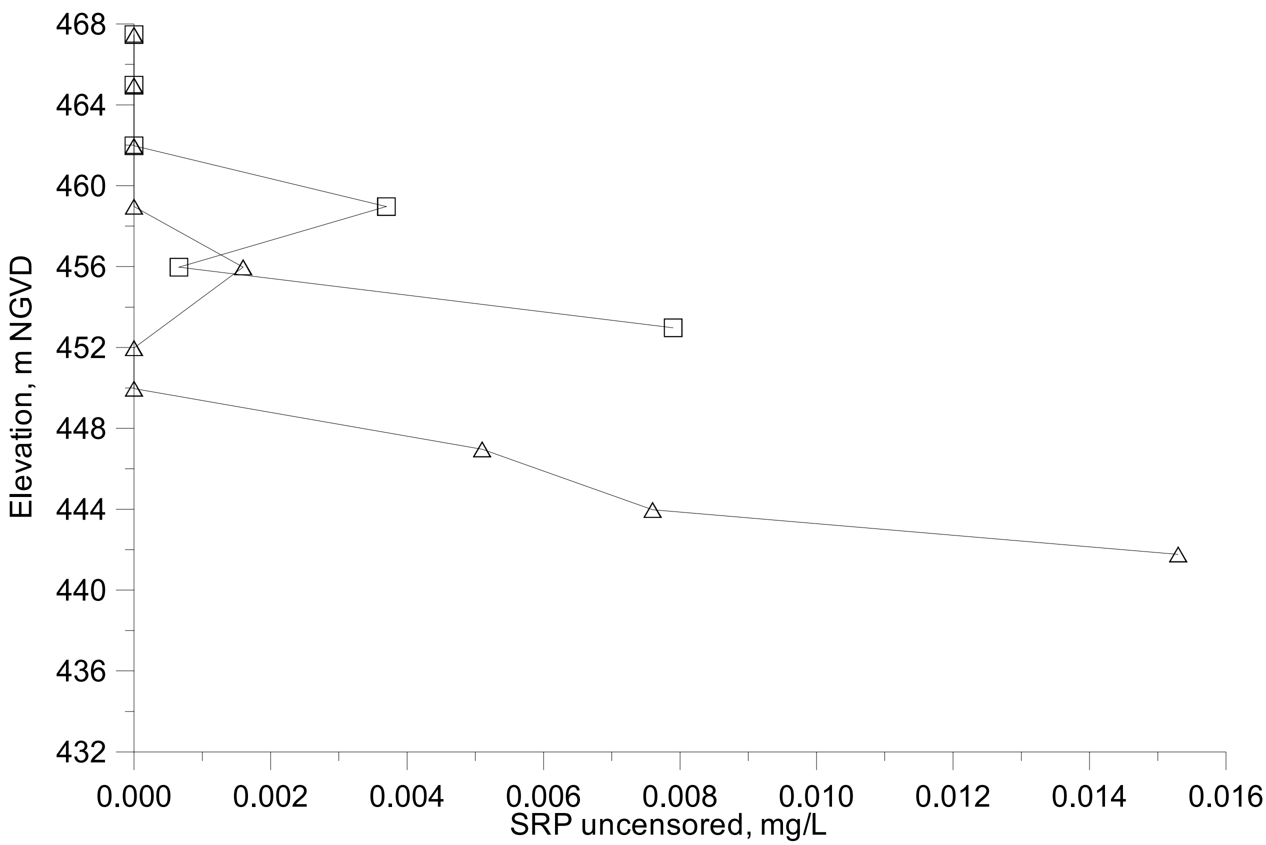

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
NO2 & NO3, mg/L
07/18/2000
LL1
LL3

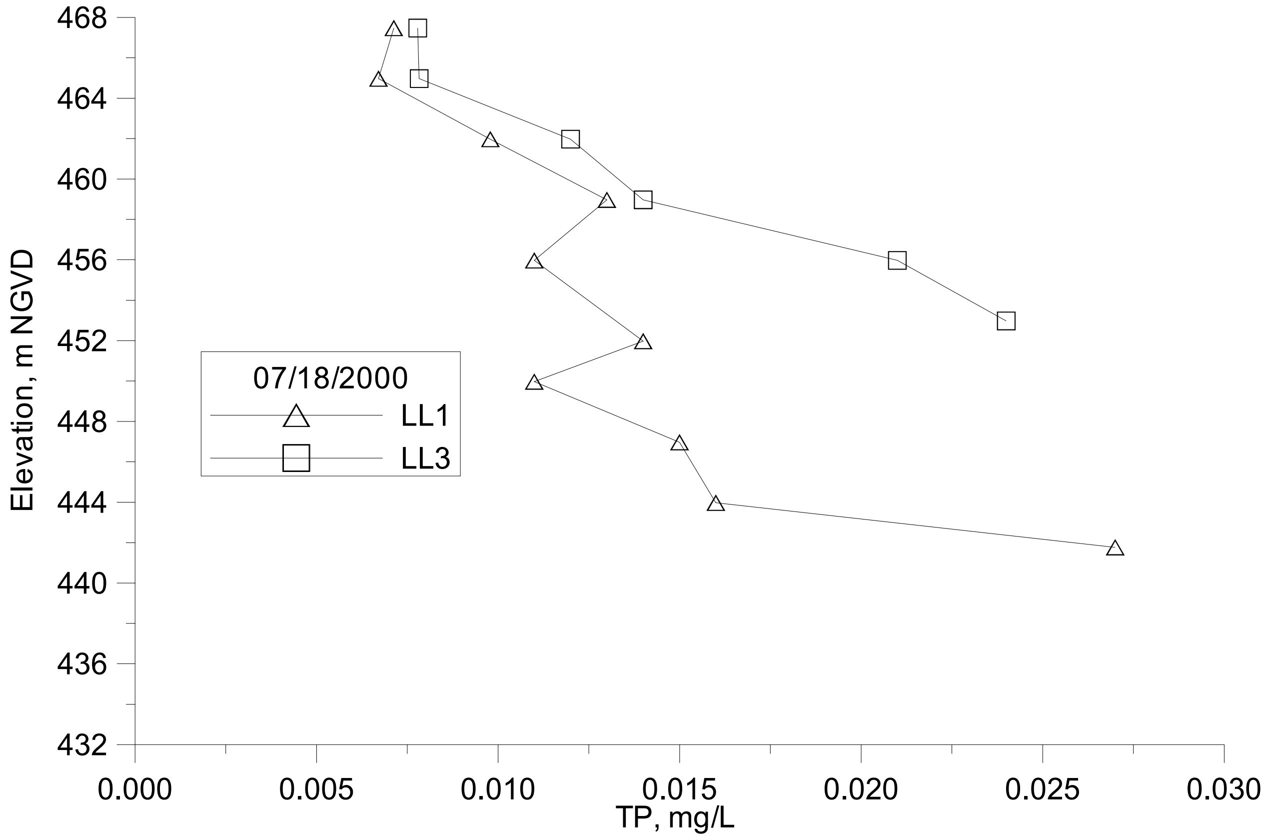

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
NH3, mg/L


468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
TPN, mg/L
07/18/2000
LL1
LL3

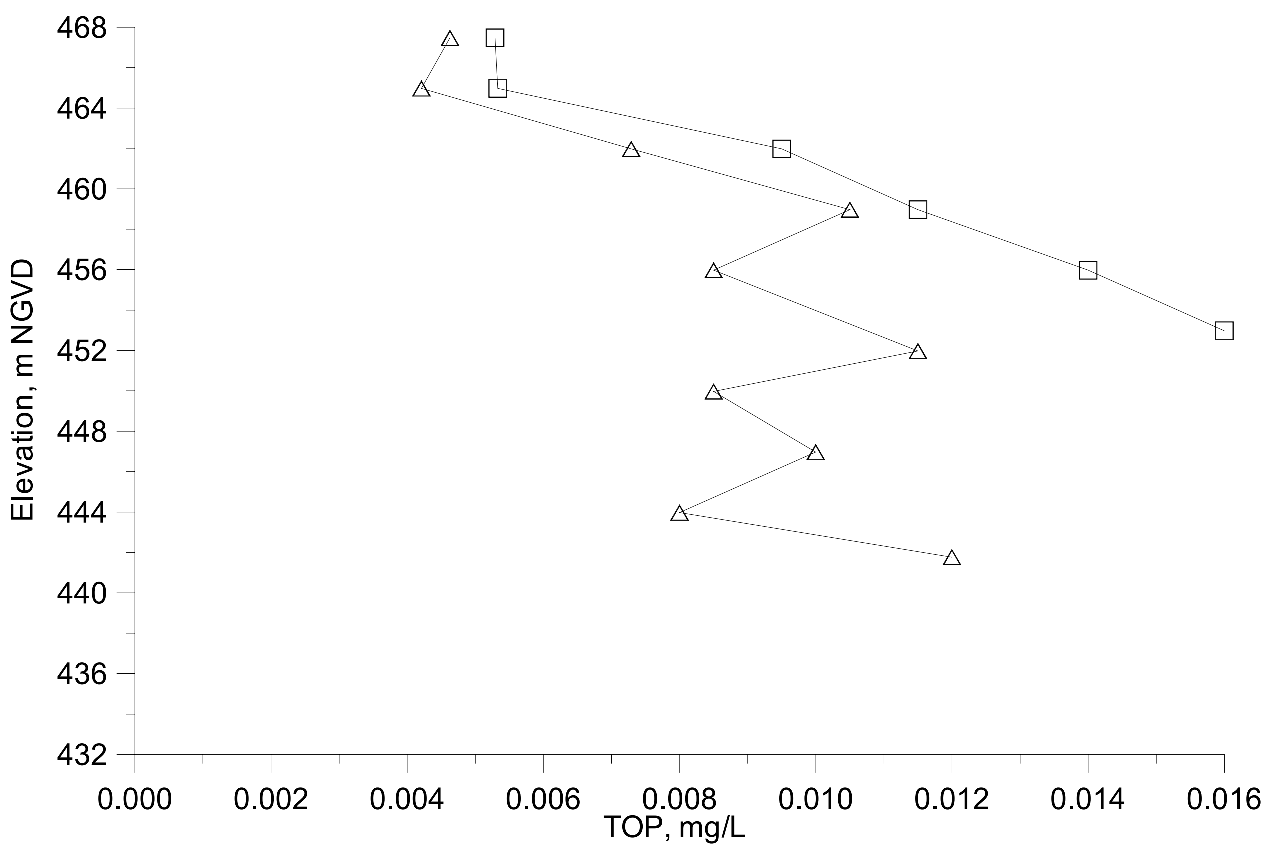

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
TON, mg/L


07/18/2000
LL1
LL3
Elevation, m NGVD
SRP, mg/L
468
464
460
456
452
448
444
440
436
432
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016

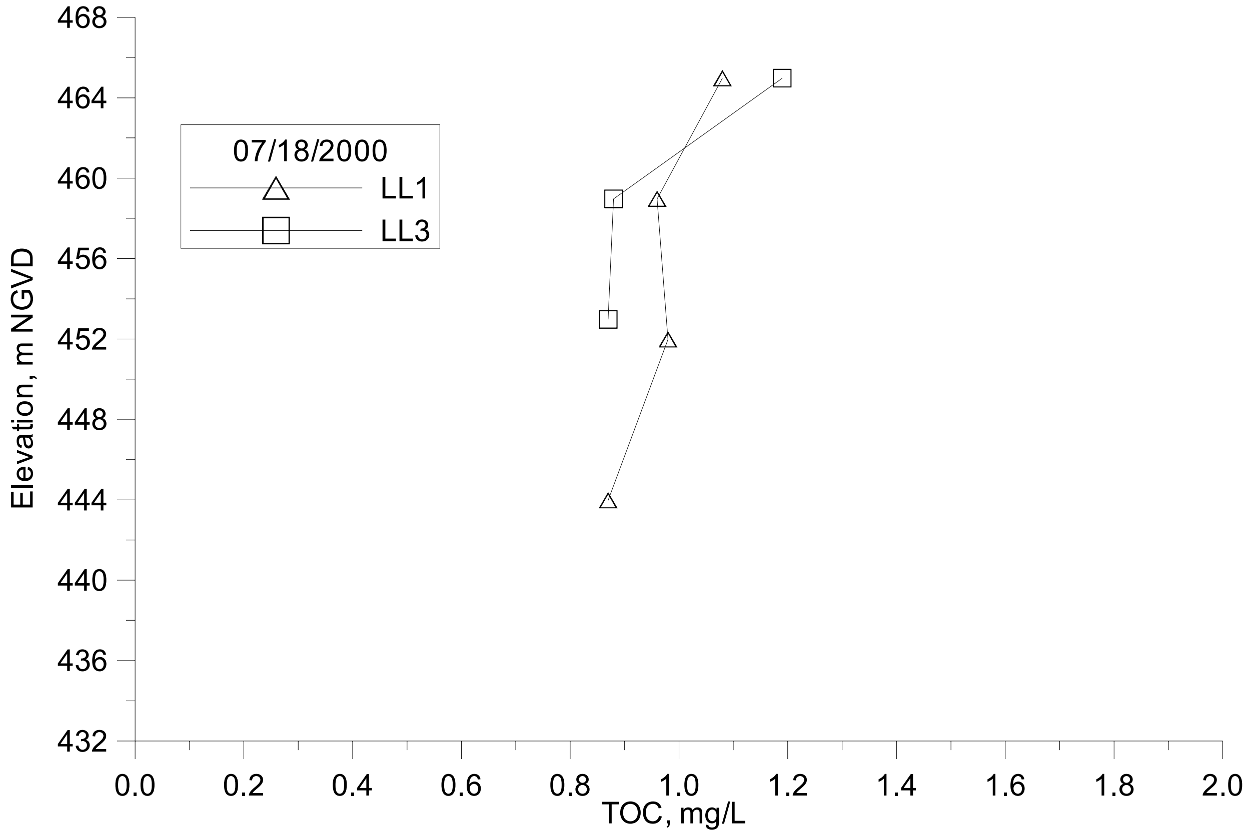

Elevation, m NGVD
SRP uncensored, mg/L
468
464
460
456
452
448
444
440
436
432
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016

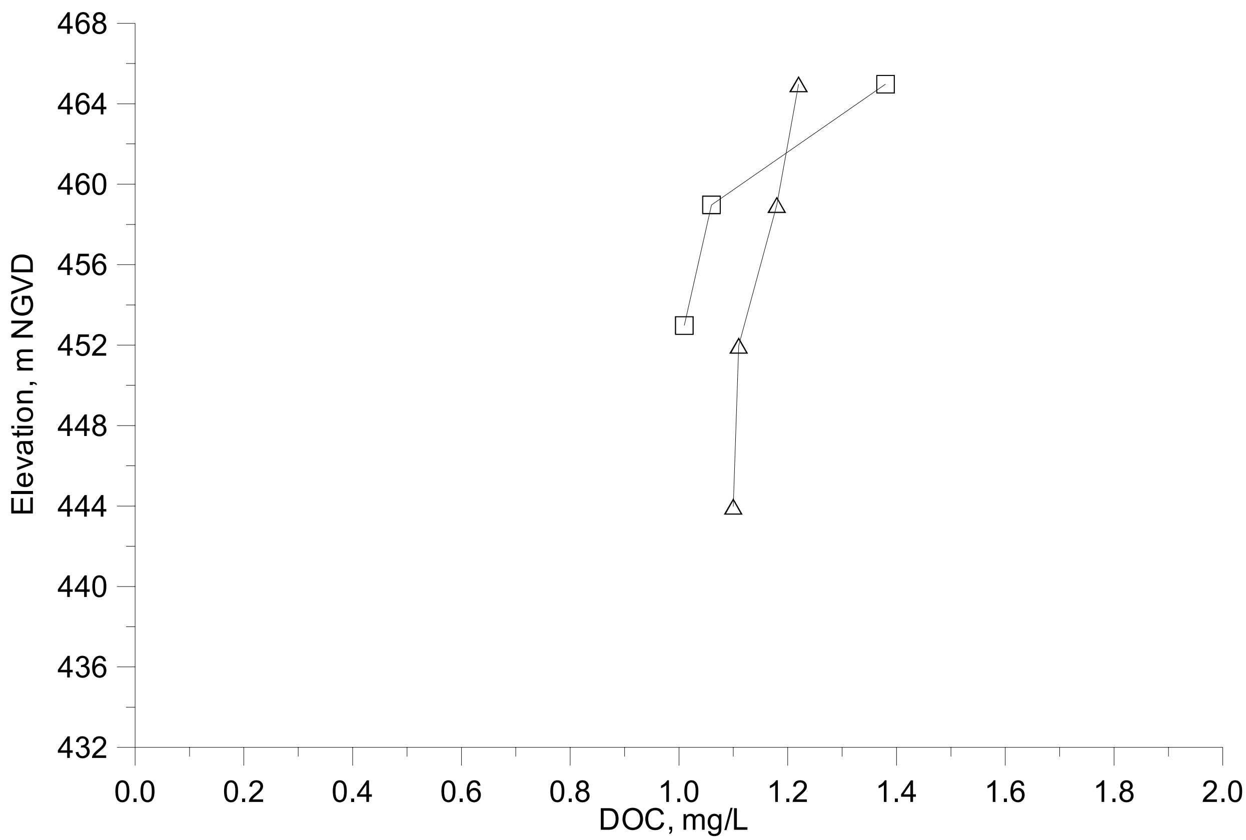


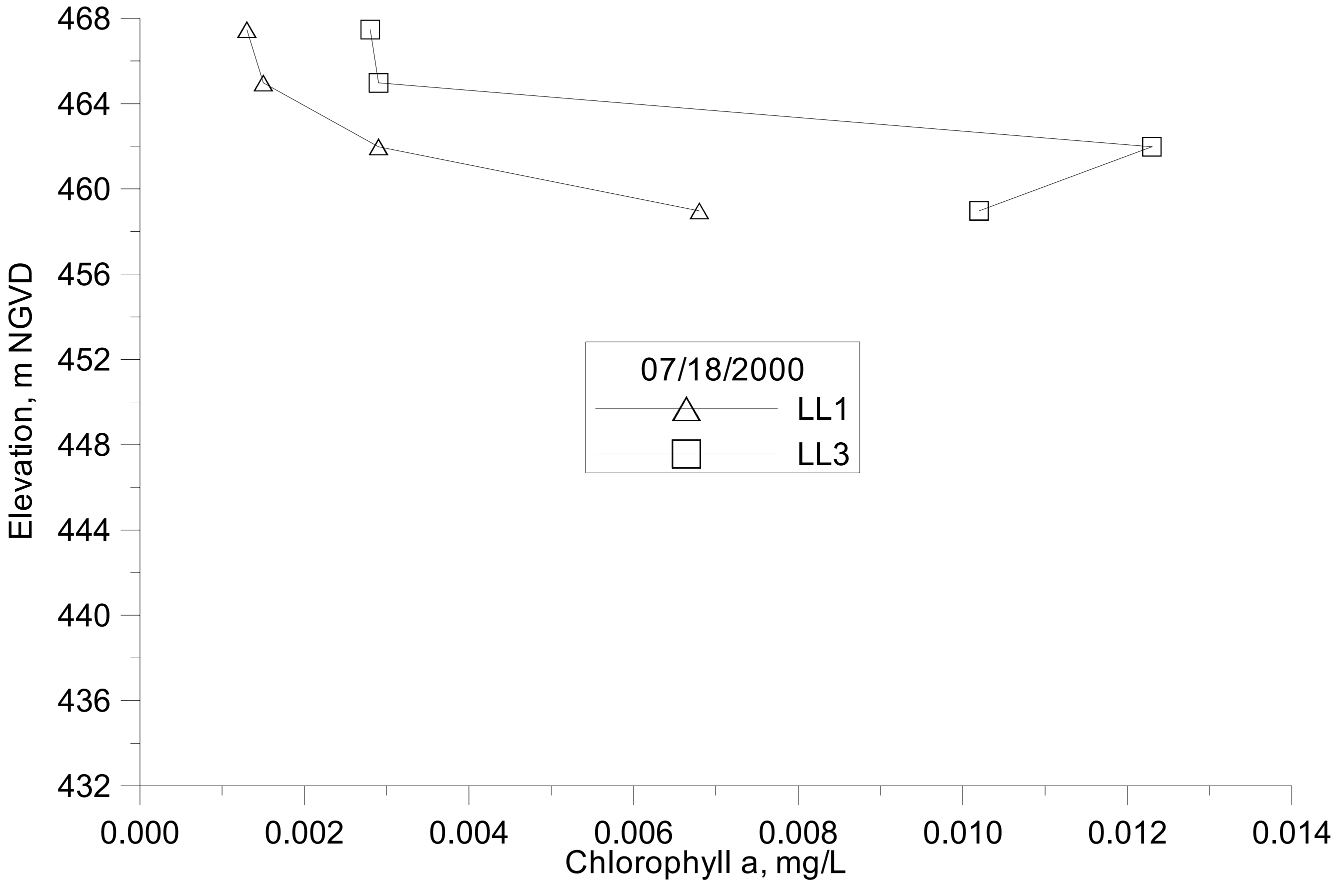
07/18/2000
LL1
LL3
Elevation, m NGVD
TP, mg/L



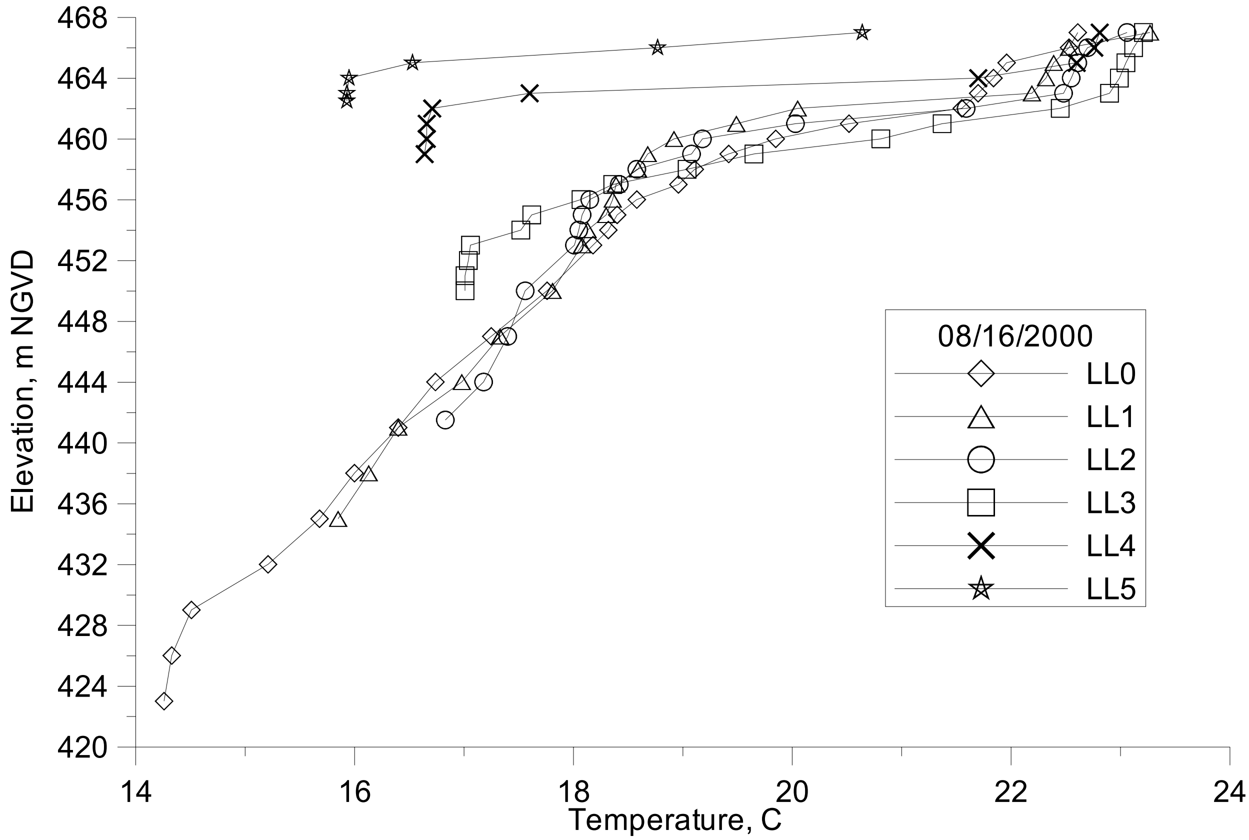
Elevation, m NGVD
TOP, mg/L


468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
07/18/2000
LL1
LL3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TOC, mg/L

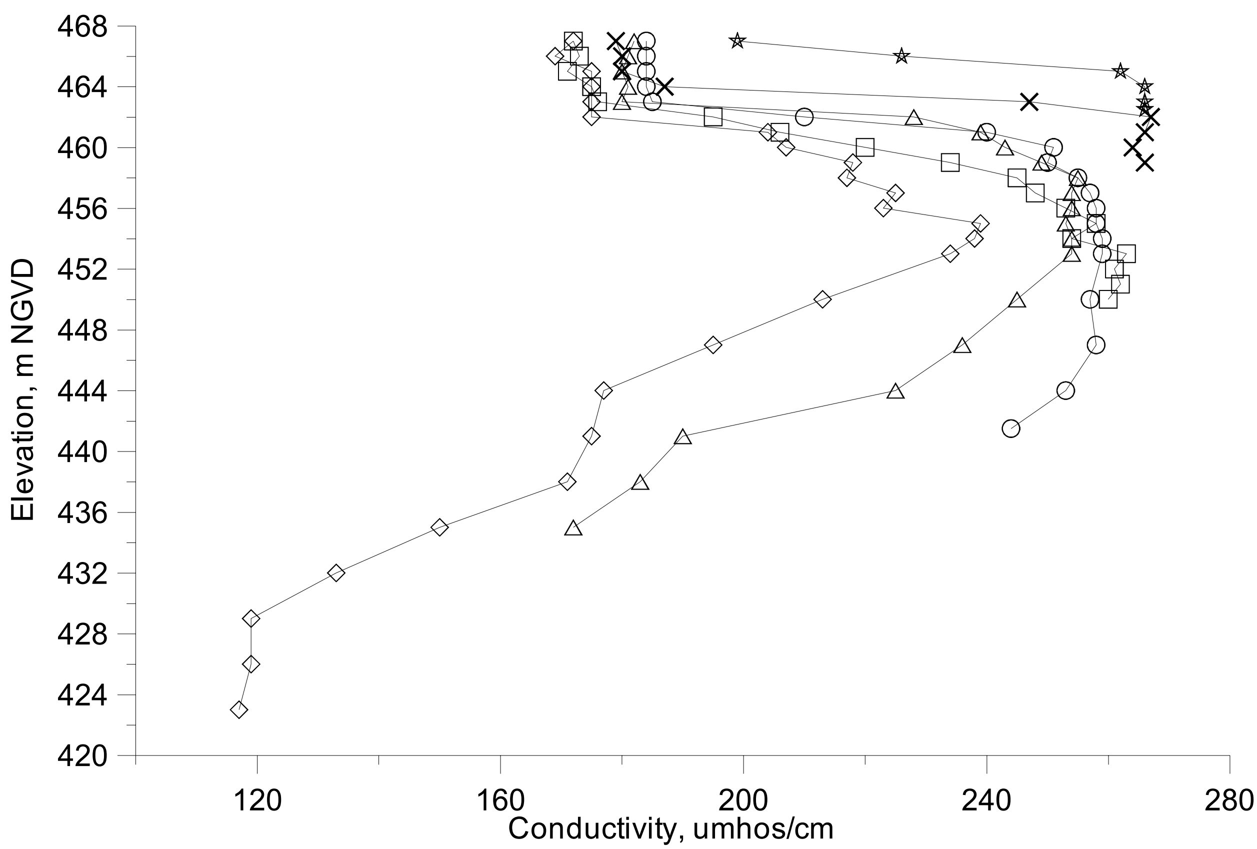

468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
DOC, mg/L



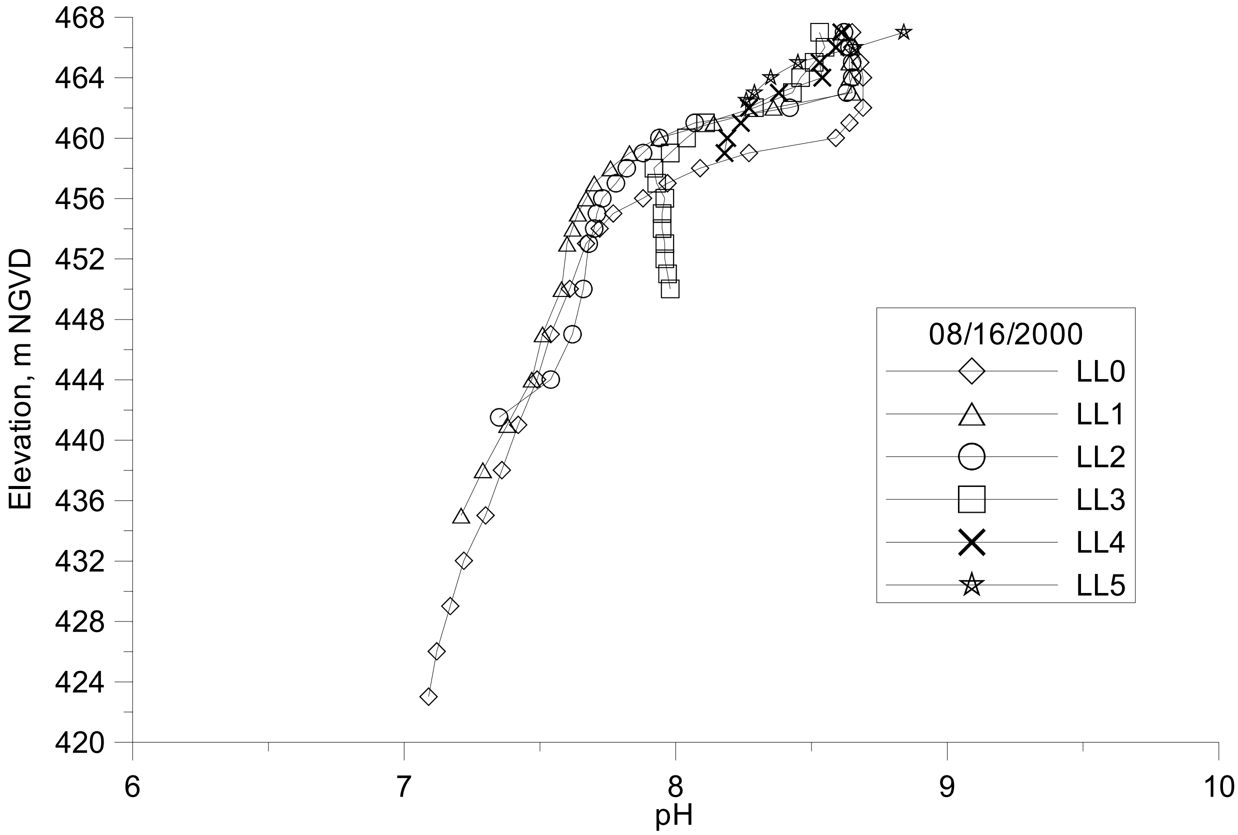
468
464
460
456
452
448
444
440
436
432
Elevation, m NGVD
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Chlorophyll a, mg/L
07/18/2000
LL1
LL3



Elevation, m NGVD
Temperature, C
08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5



Elevation, m NGVD
Conductivity, umhos/cm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464
460
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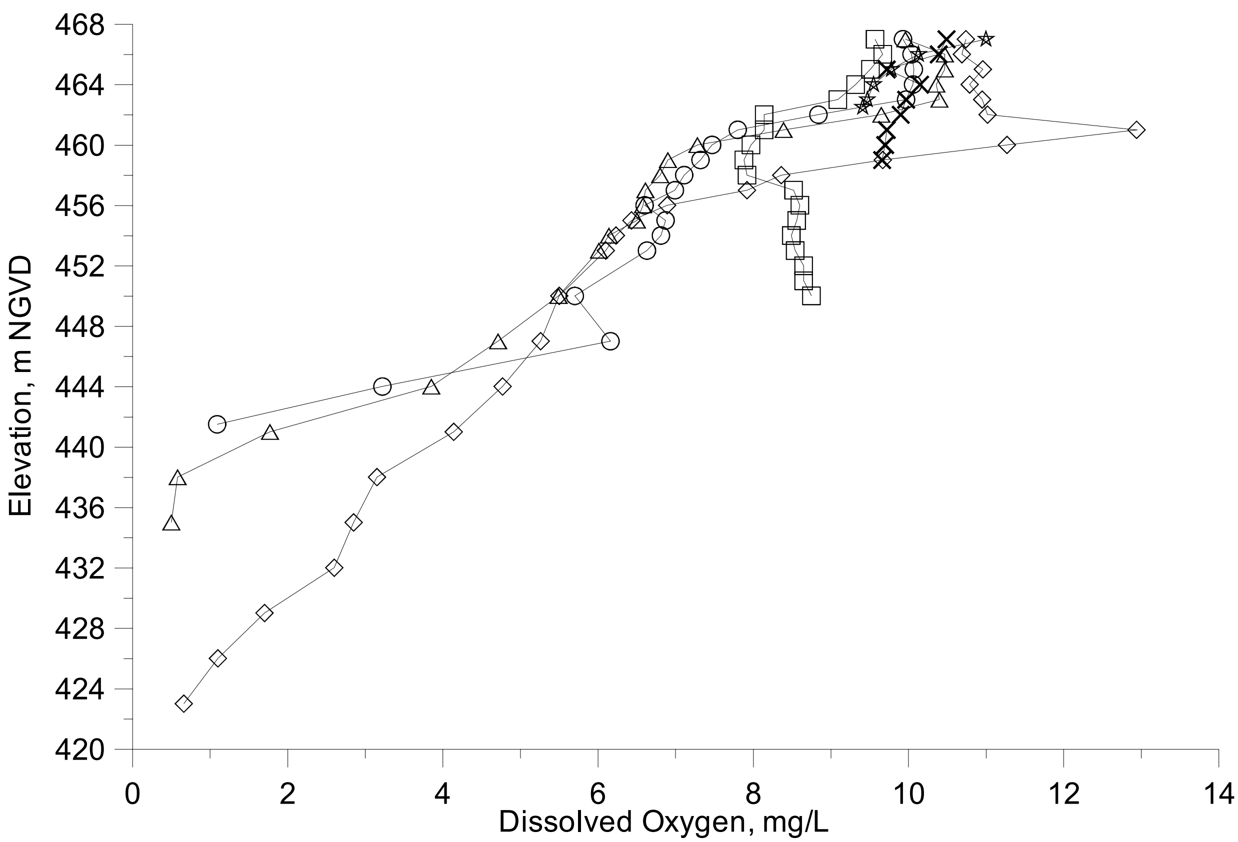
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
6
7
8
9
10
pH
08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5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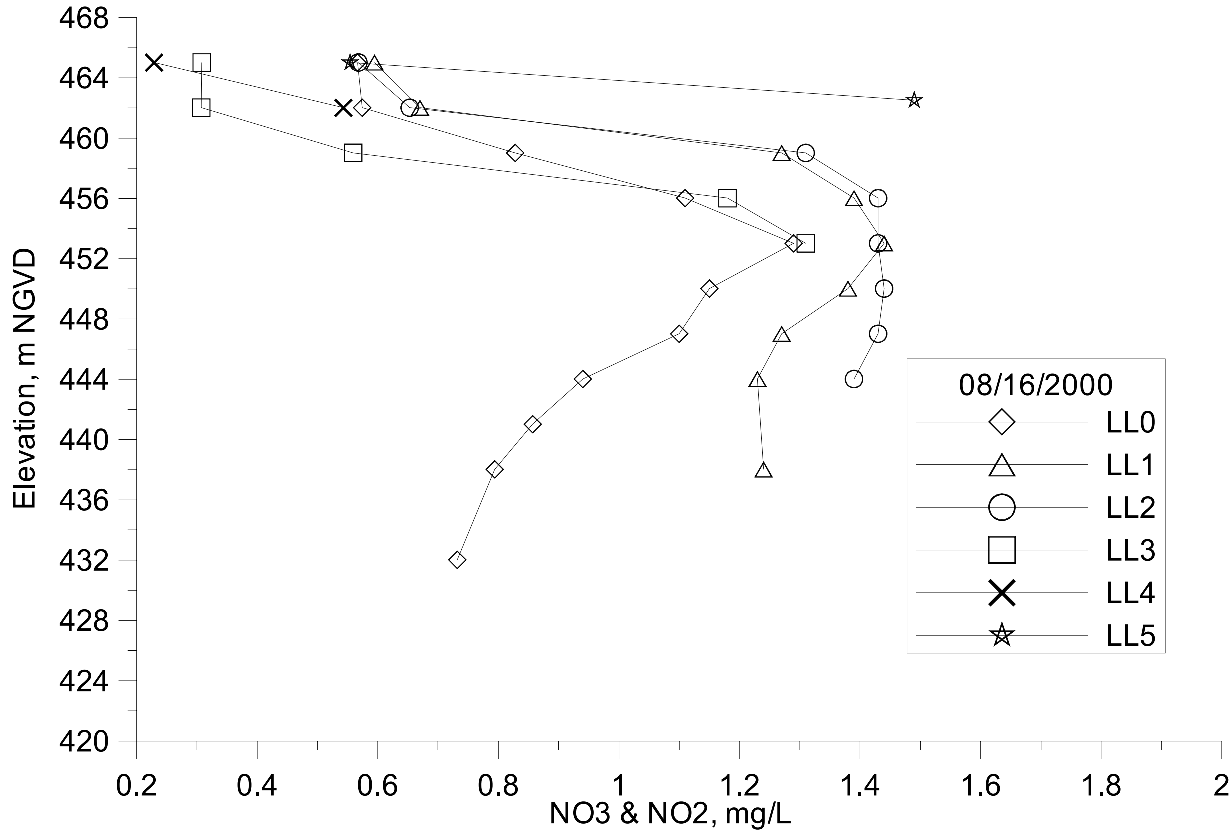
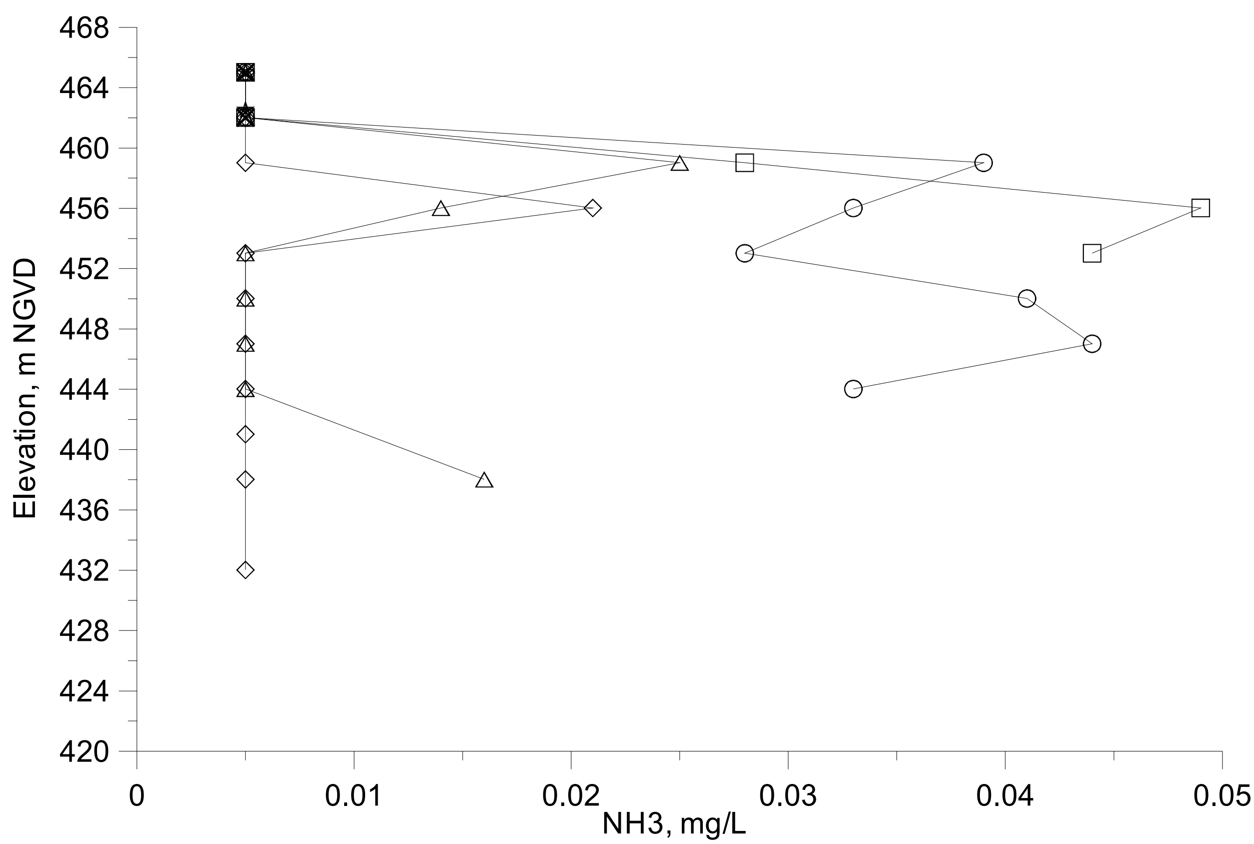
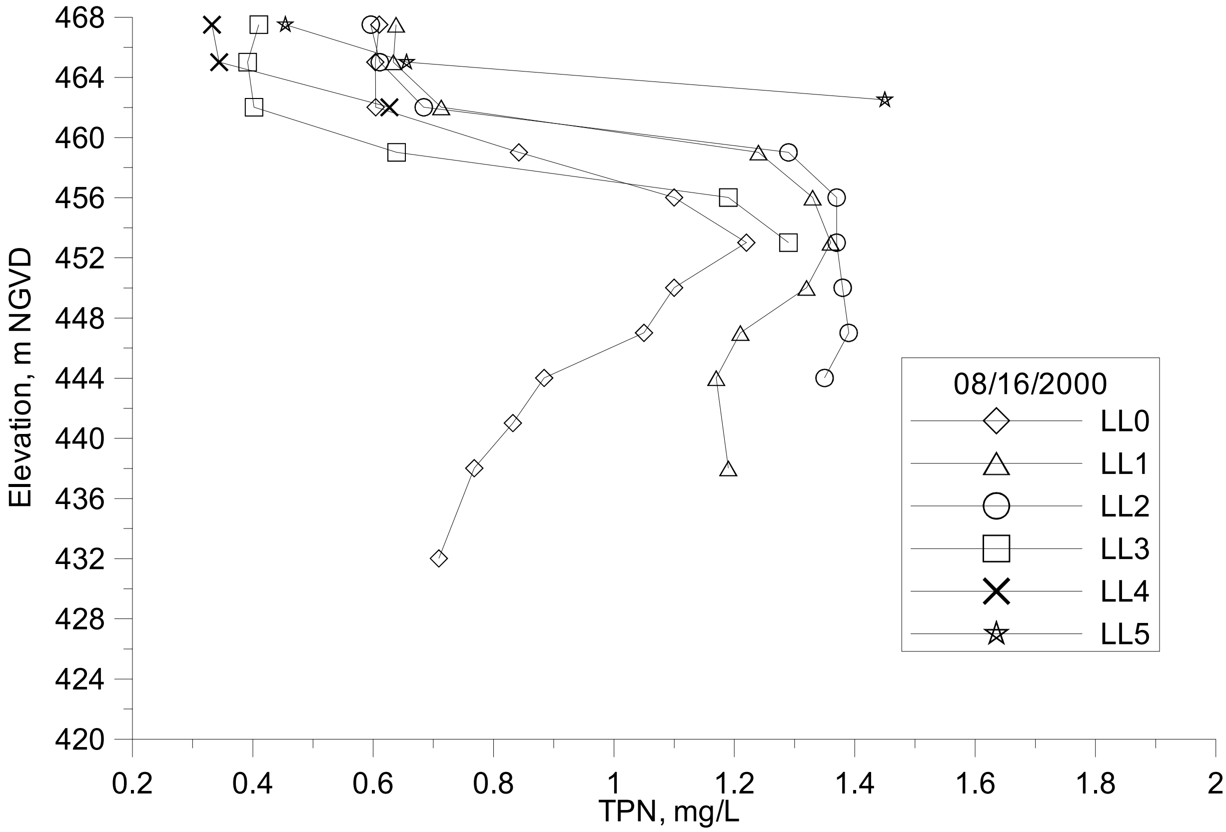
424
420
Elevation, m NGVD
0
2
4
6
8
10
12
14
Dissolved Oxygen, mg/L



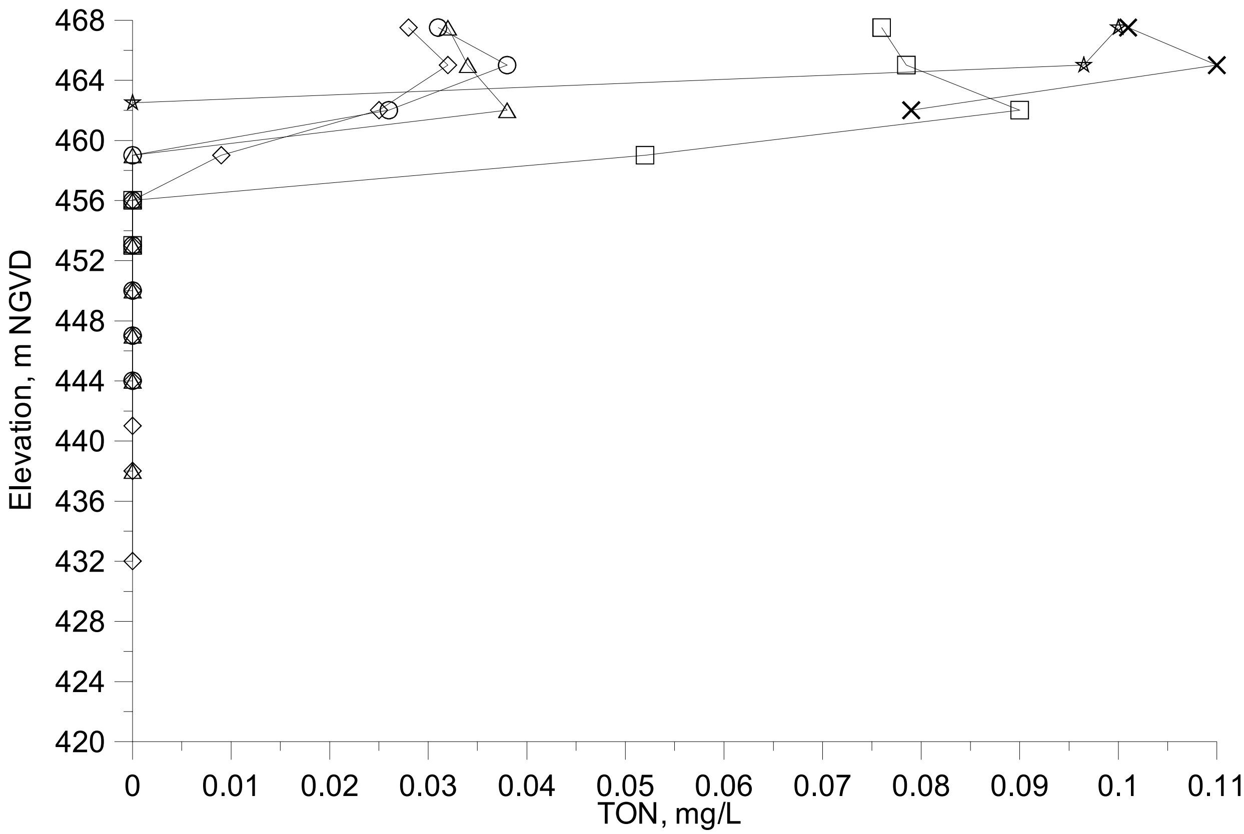
468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
NO3 & NO2, mg/L
08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5



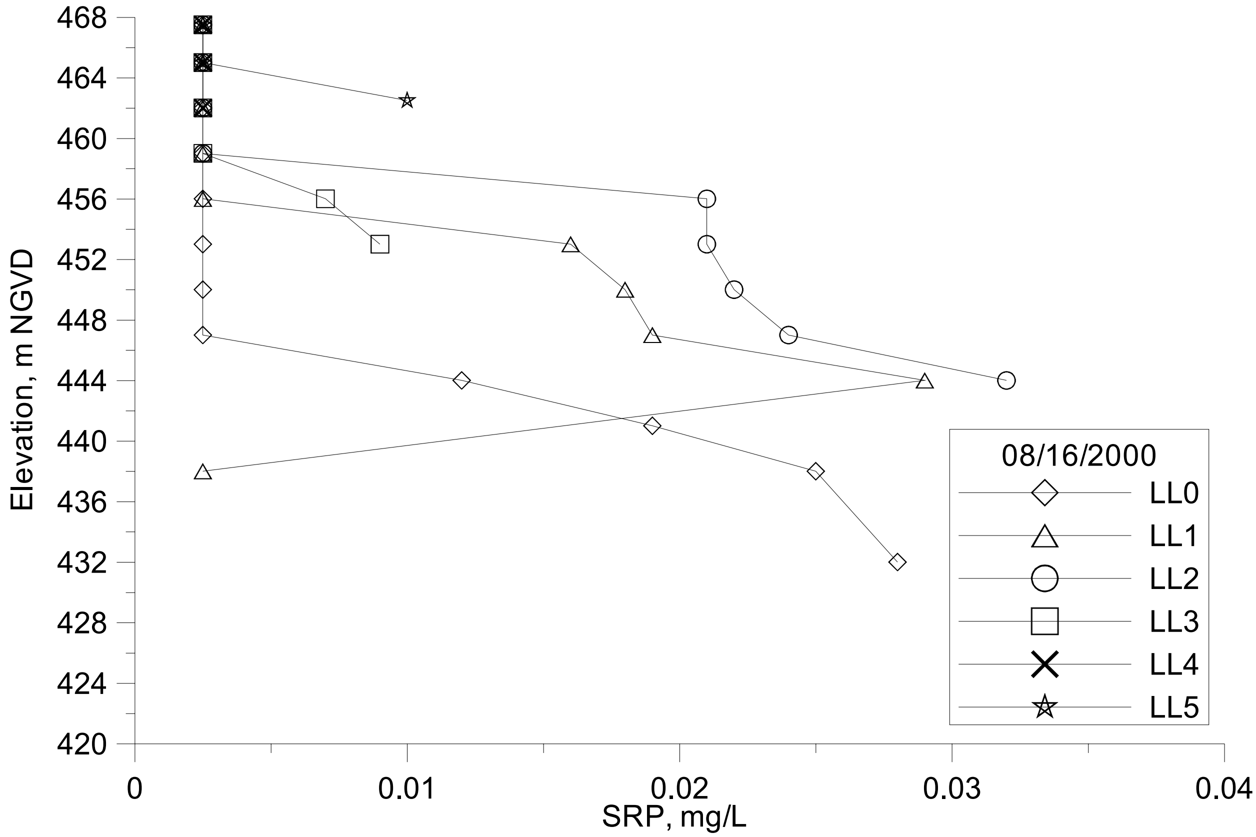
468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0
0.01
0.02
0.03
0.04
0.05
NH3, mg/L



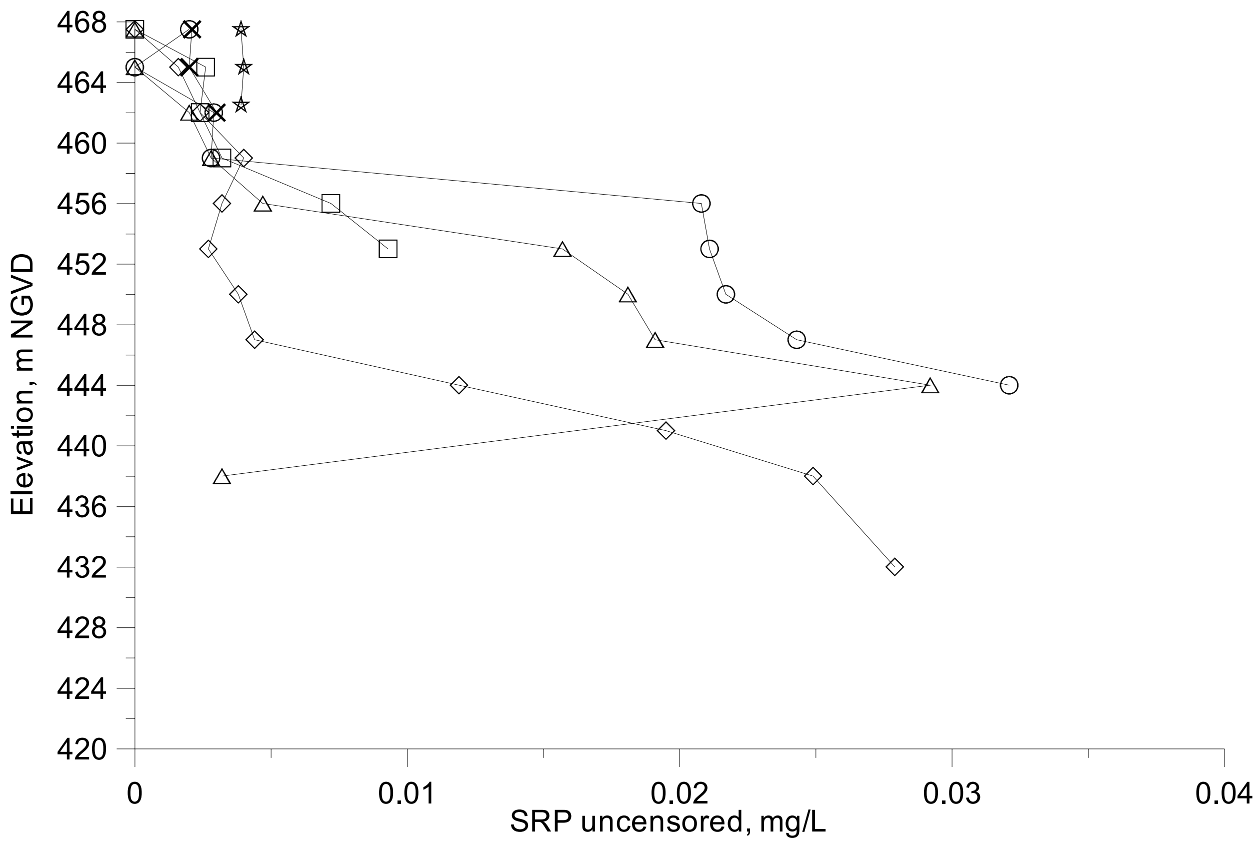
08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5
Elevation, m NGVD
TPN, mg/L



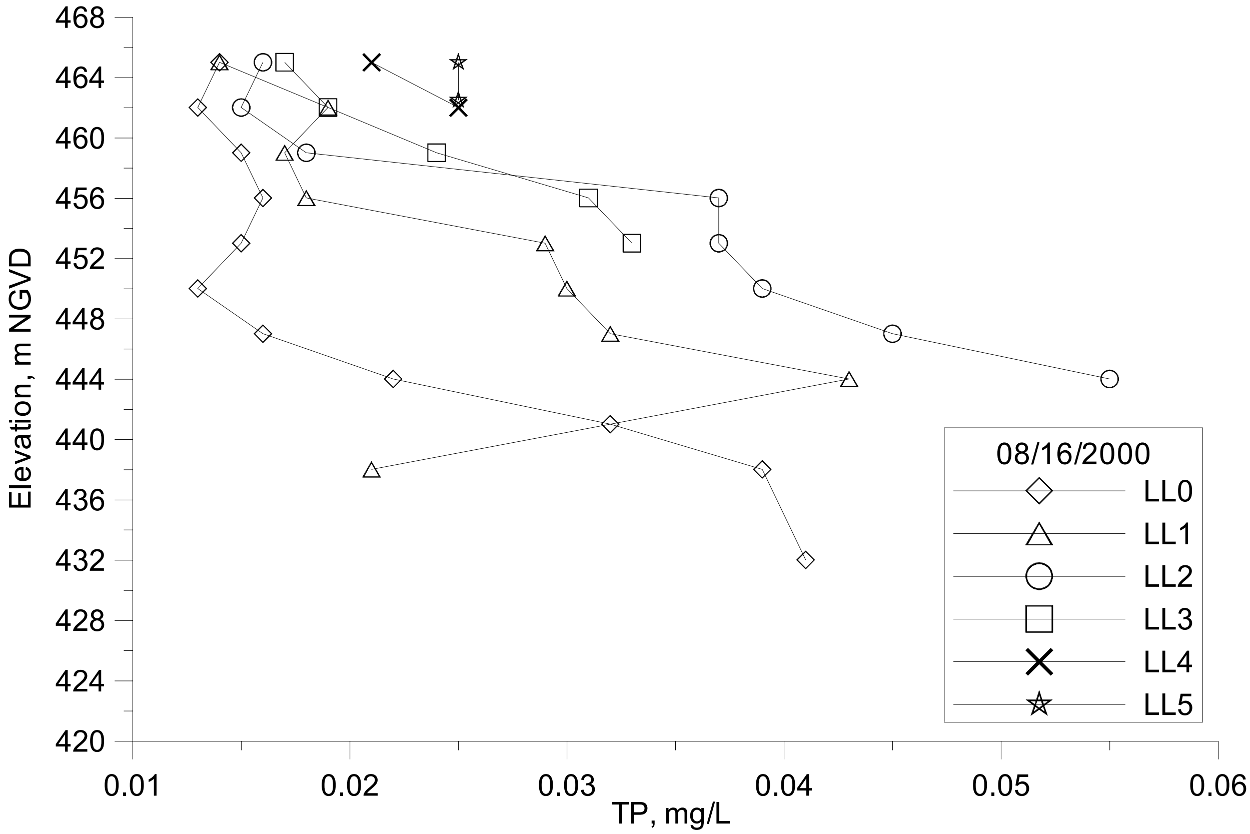
Elevation, m NGVD
TON, mg/L



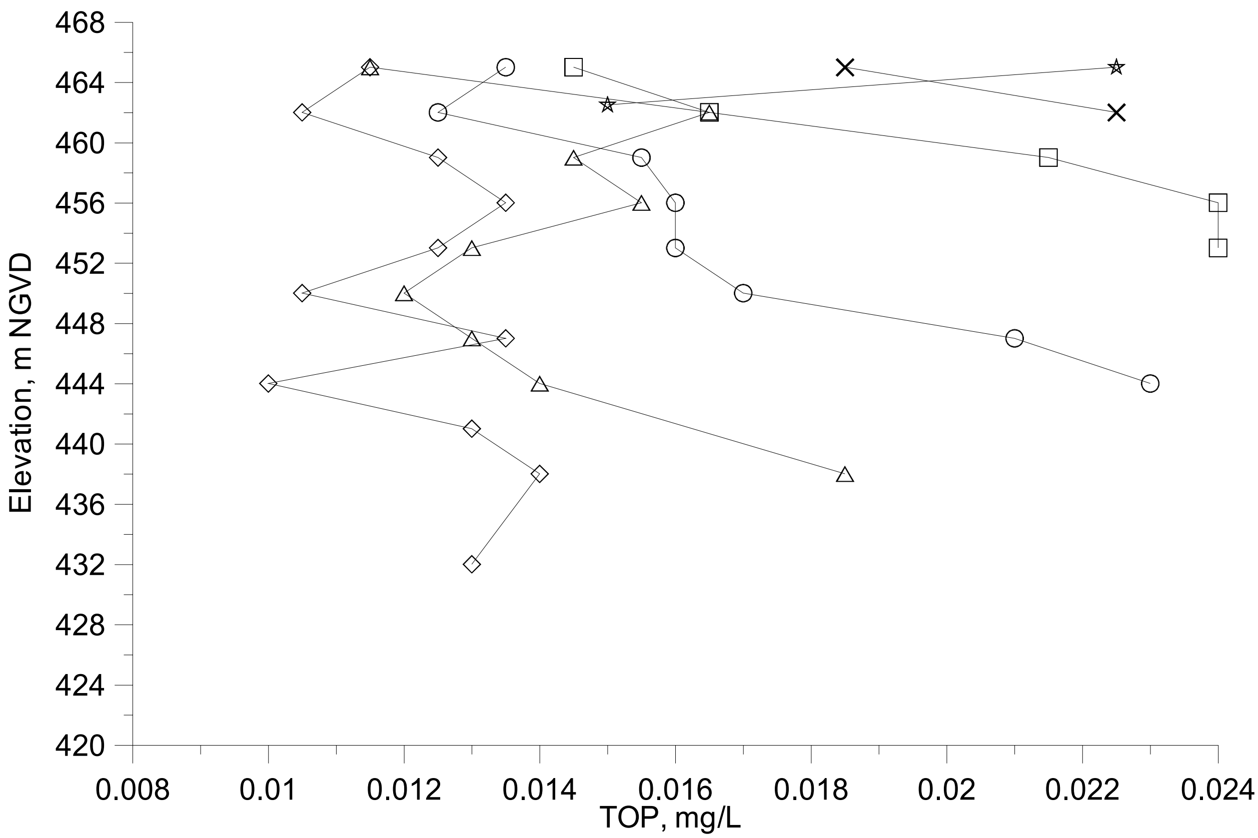
Elevation, m NGVD
SRP, mg/L
08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5



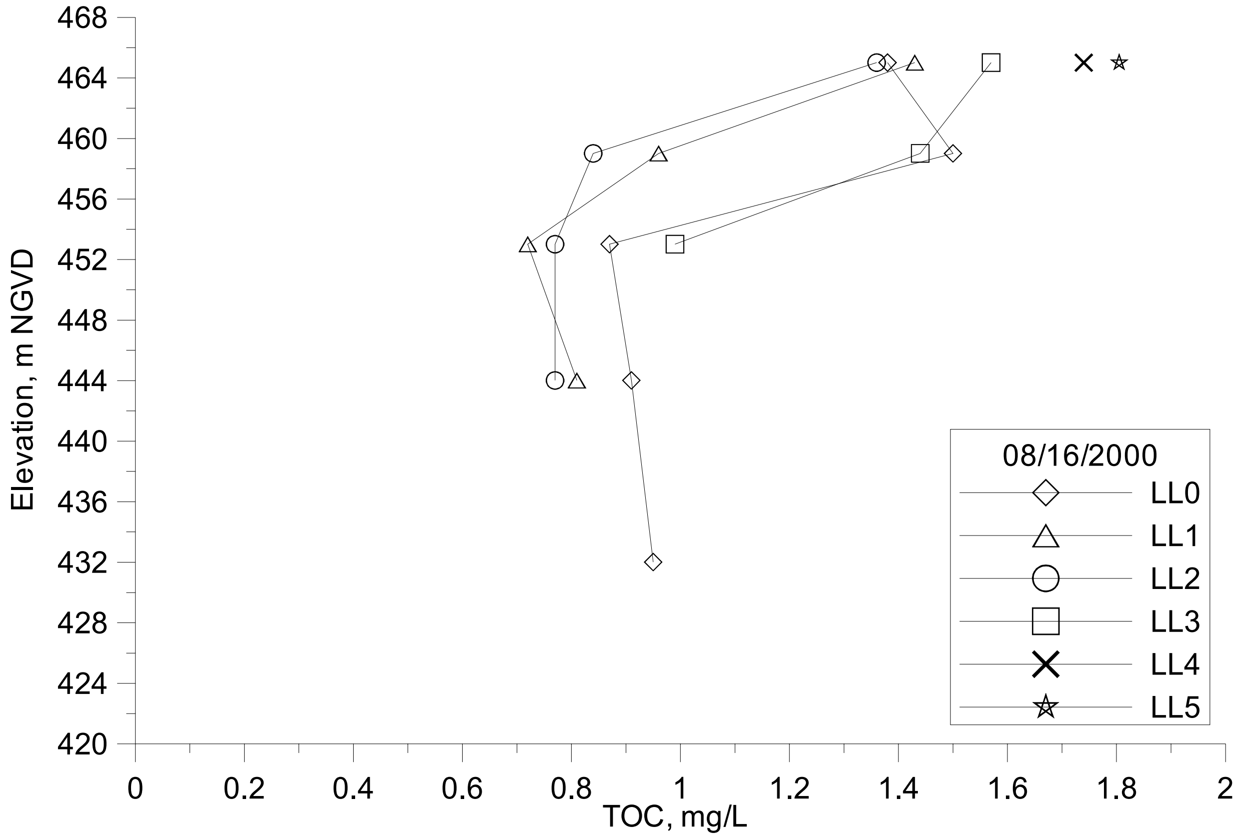
Elevation, m NGVD
SRP uncensored, mg/L

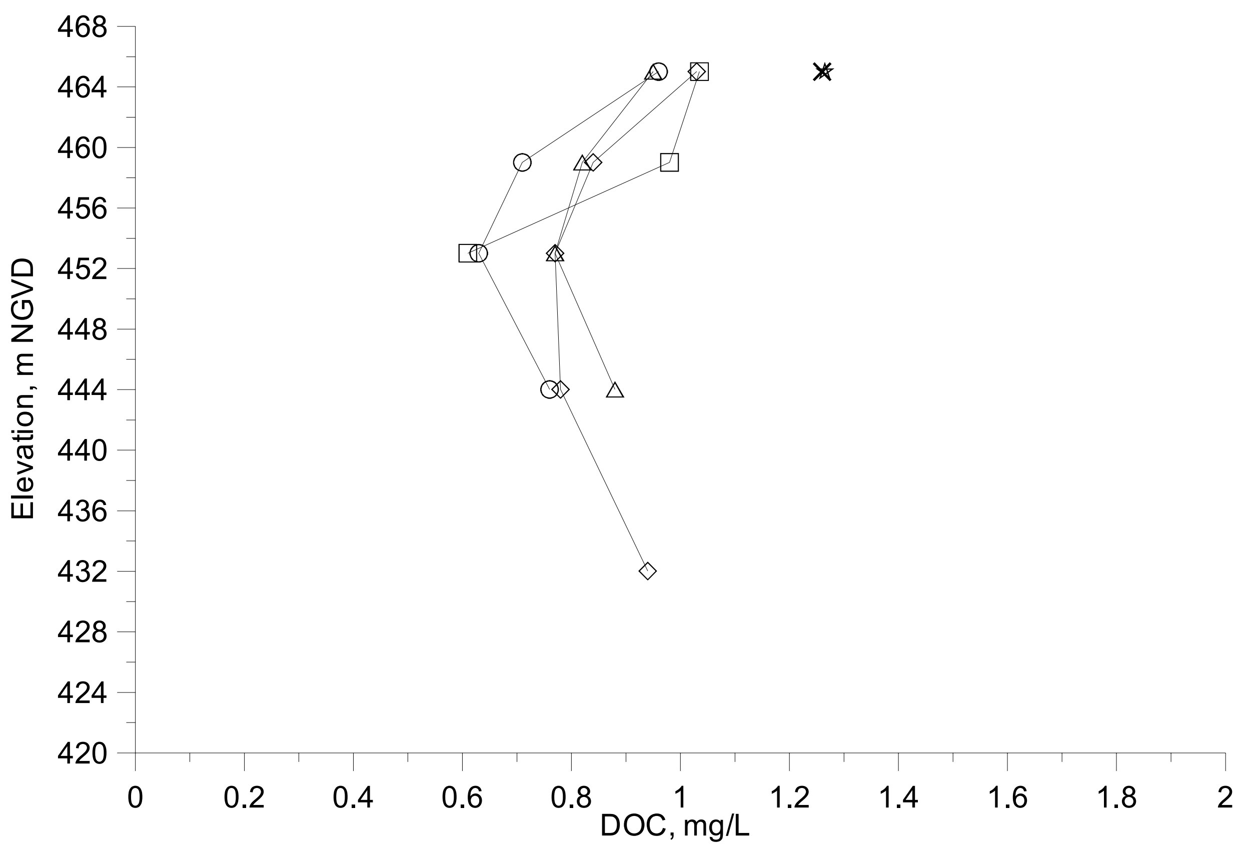


08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5
Elevation, m NGVD
TP, mg/L



Elevation, m NGVD
TOP, mg/L


468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TOC, mg/L
08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5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460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
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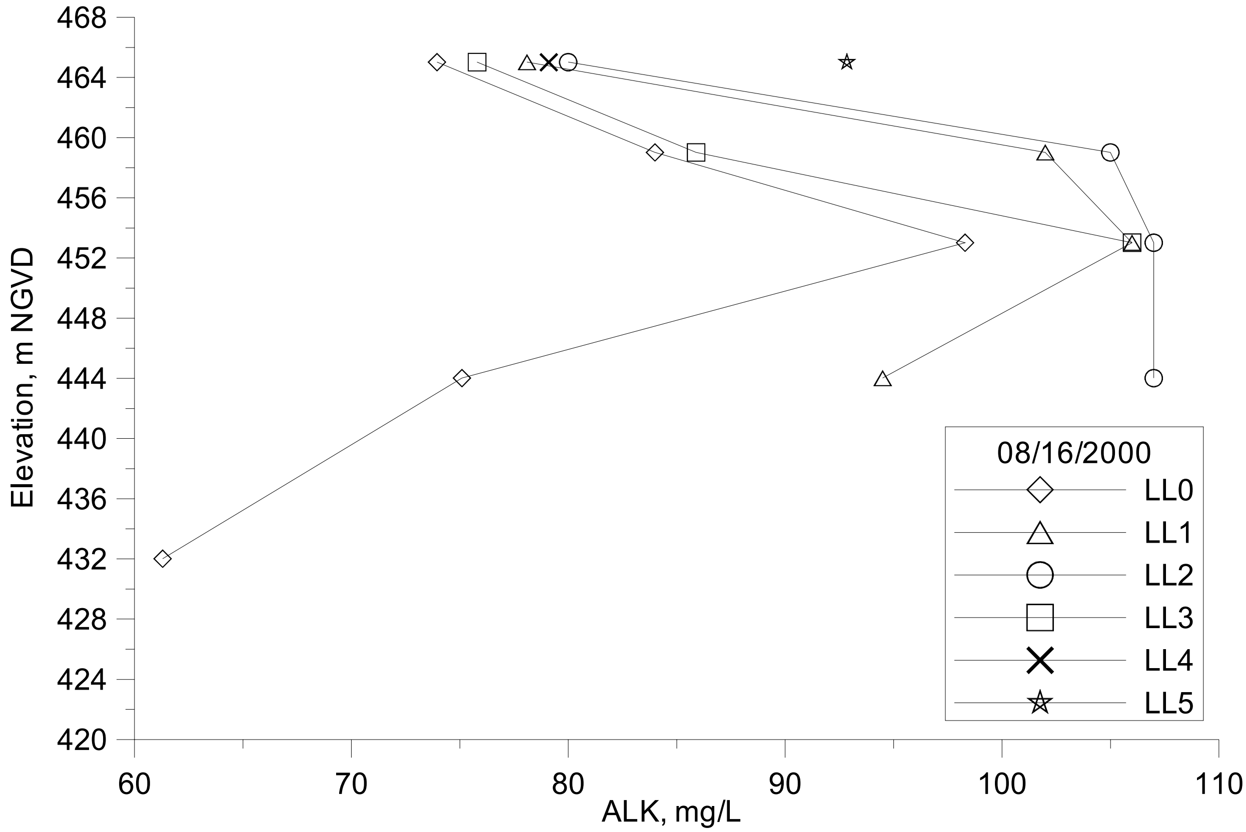
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
DOC, mg/L



08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5
Elevation, m NGVD
ALK, mg/L
468
464
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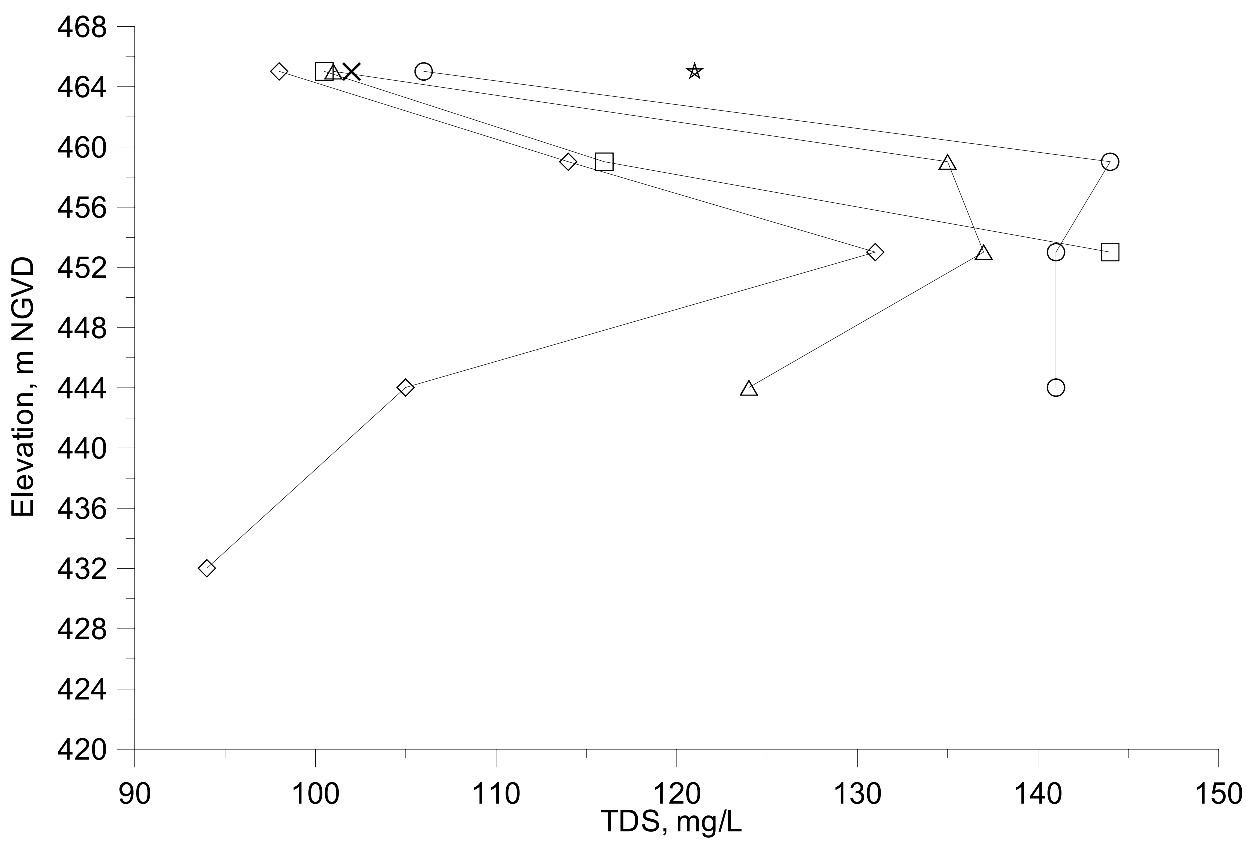
456
452
448
444
440
436
432
428
424
420
60
70
80
90
100
110



Elevation, m NGVD
TDS, mg/L
468
464
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452
448
444
440
436
432
428
424
420
90
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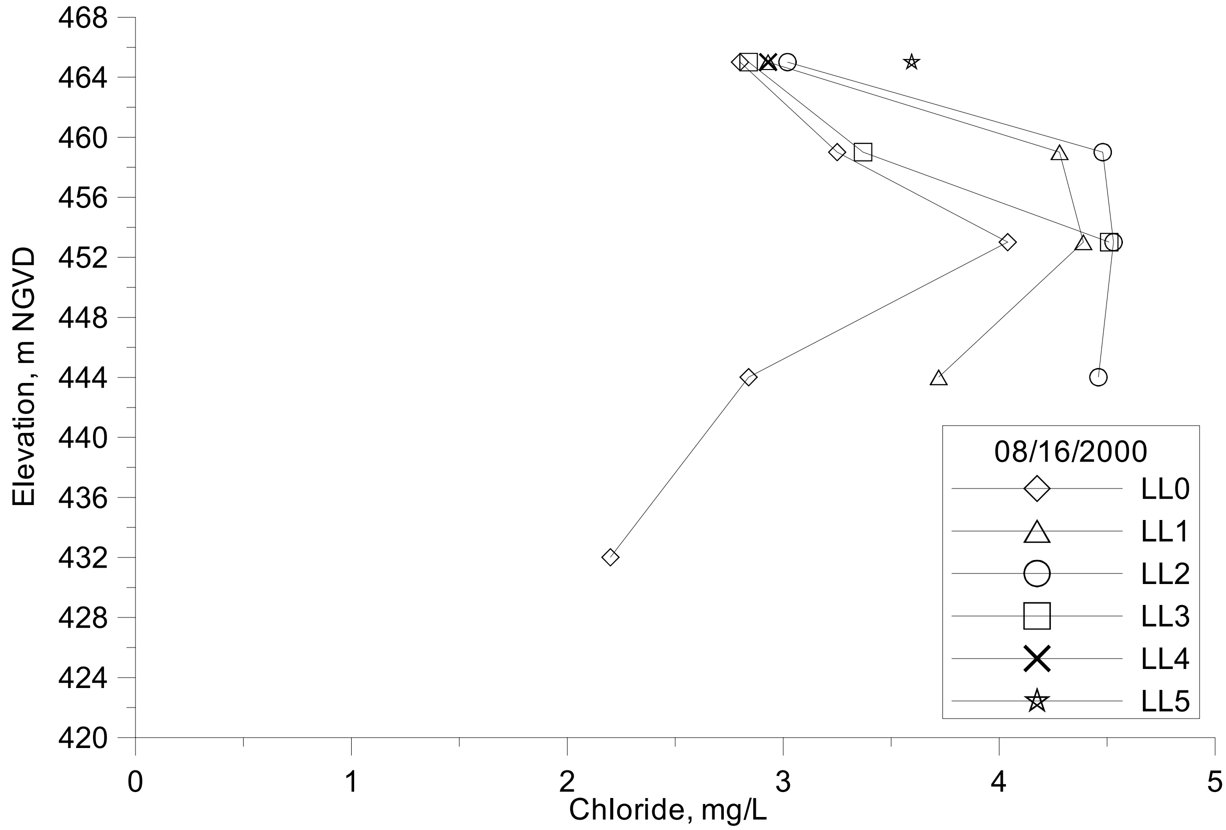
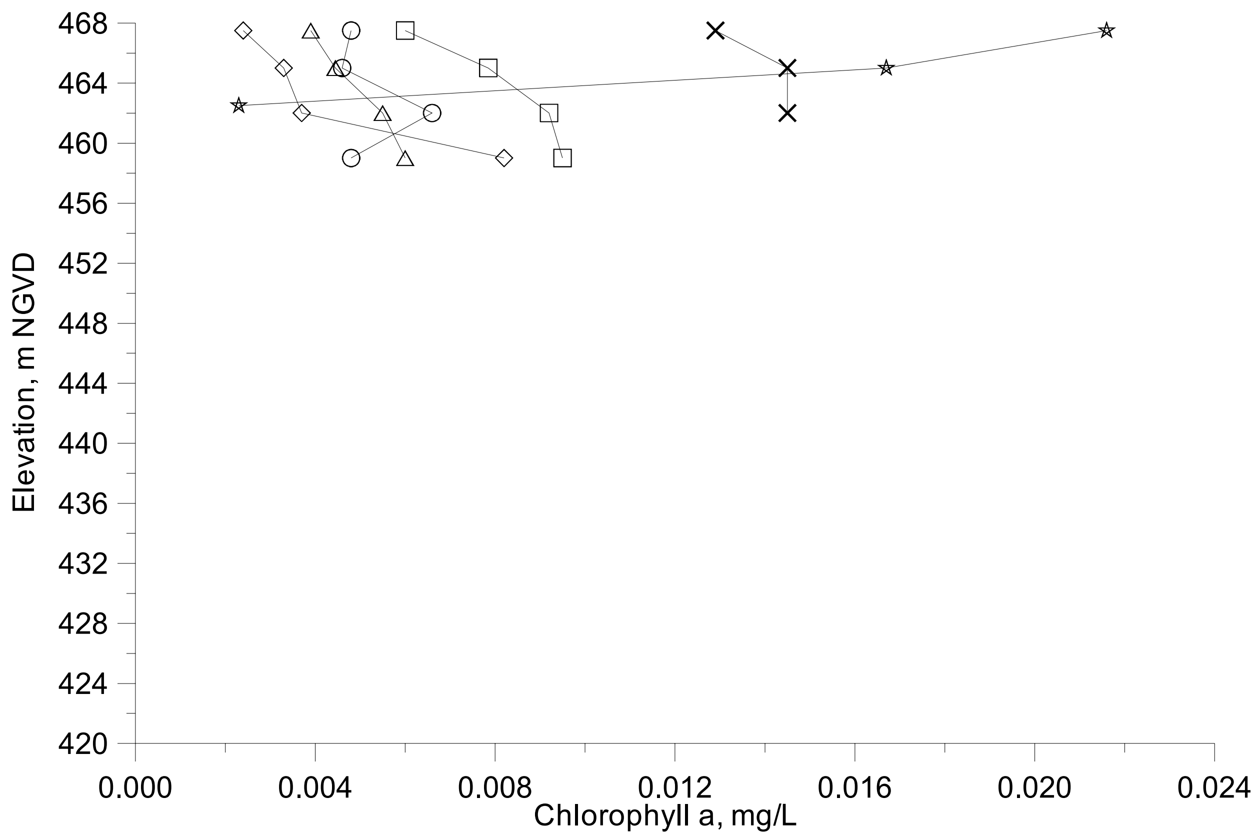
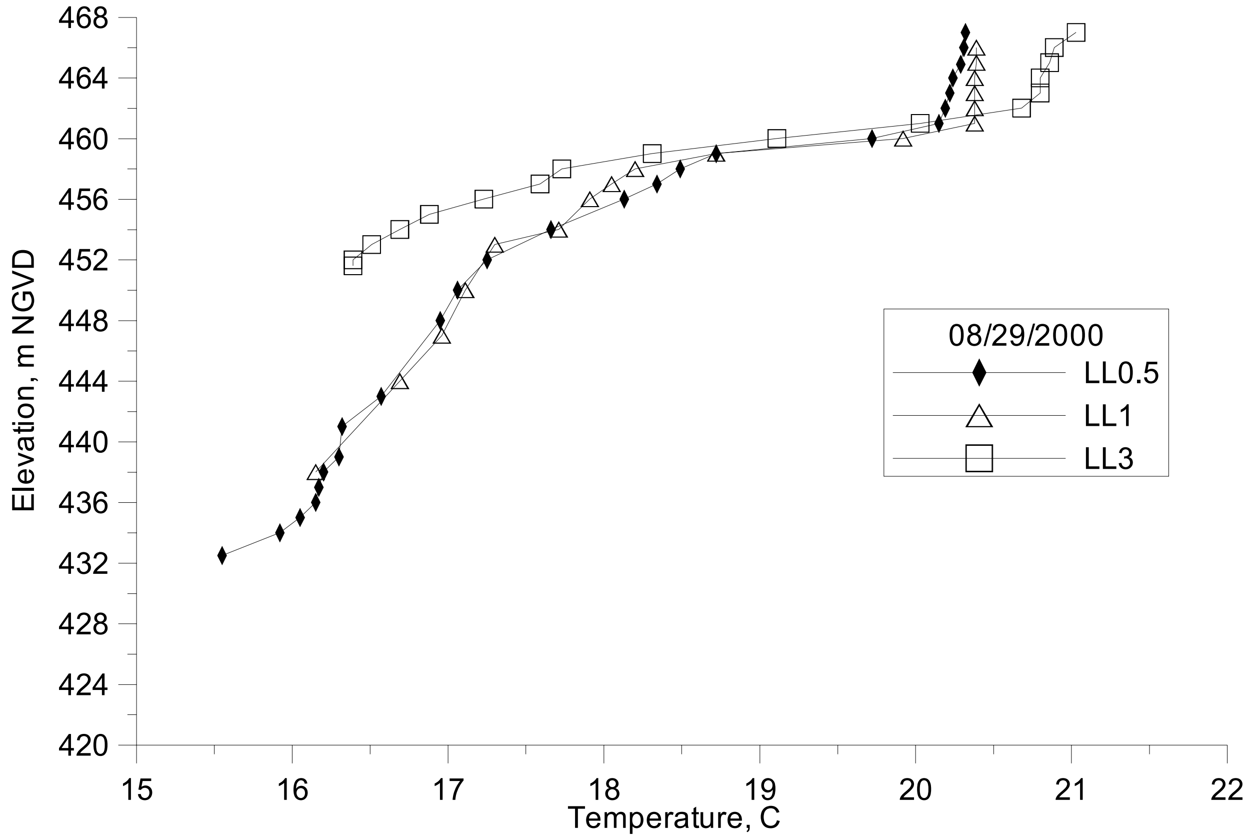
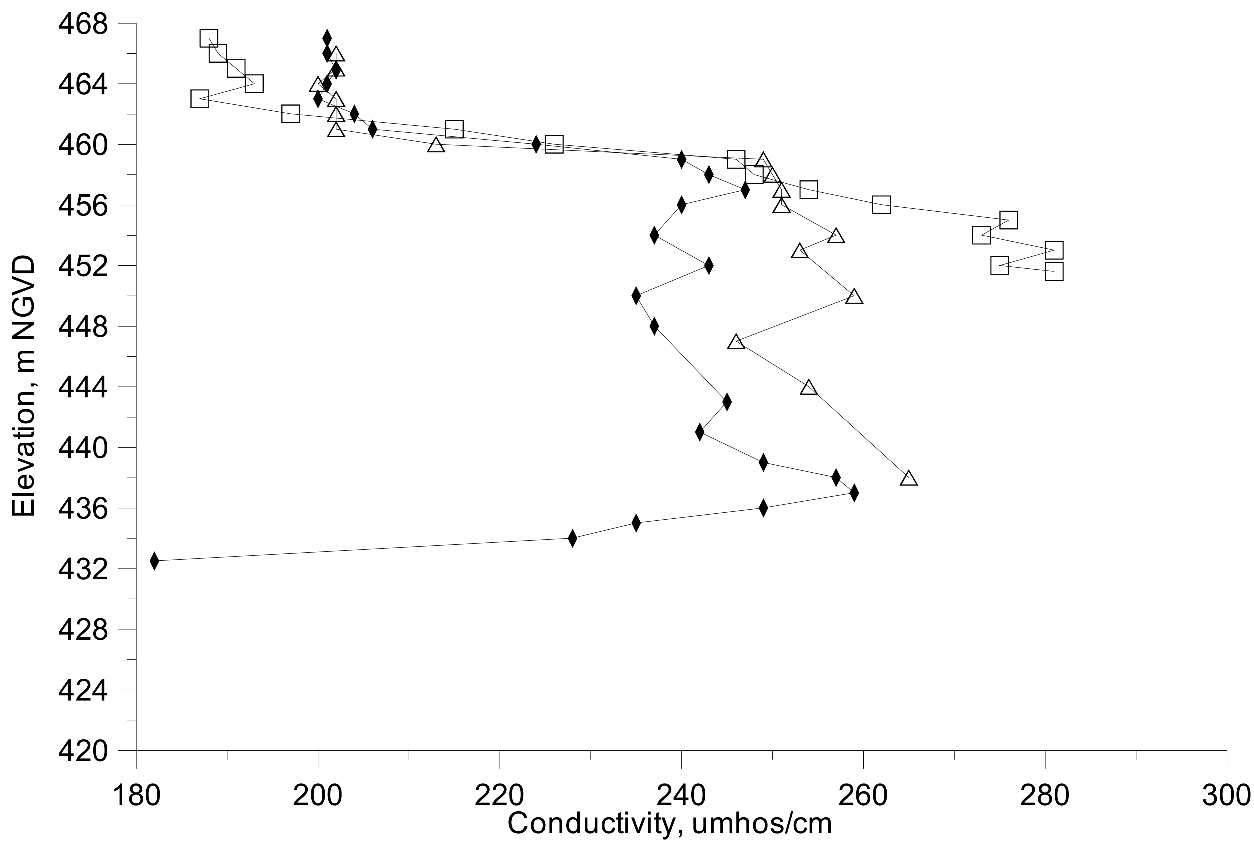
110
120
130
140
150


468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0
1
2
3
4
5
Chloride, mg/L
08/16/2000
LL0
LL1
LL2
LL3
LL4
LL5

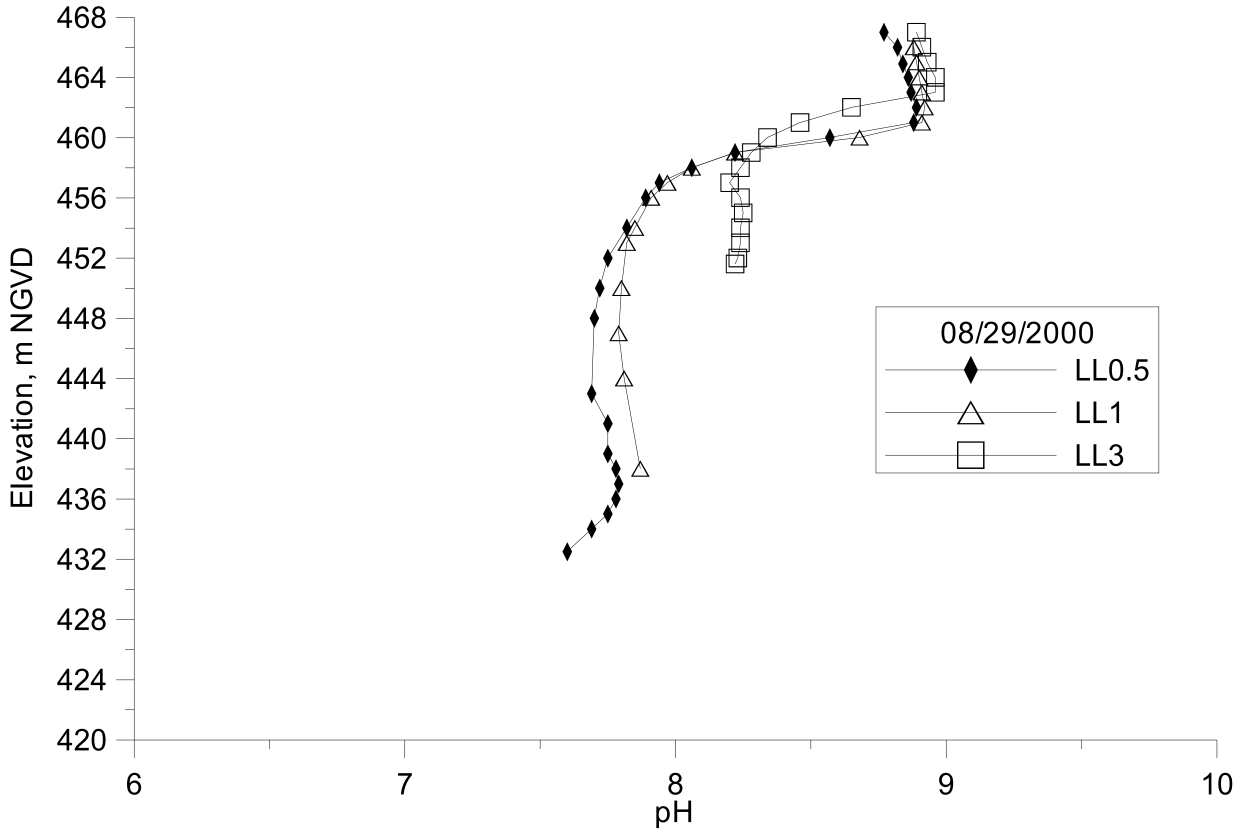

468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.000
0.004
0.008
0.012
0.016
0.020
0.024
Chlorophyll a, mg/L

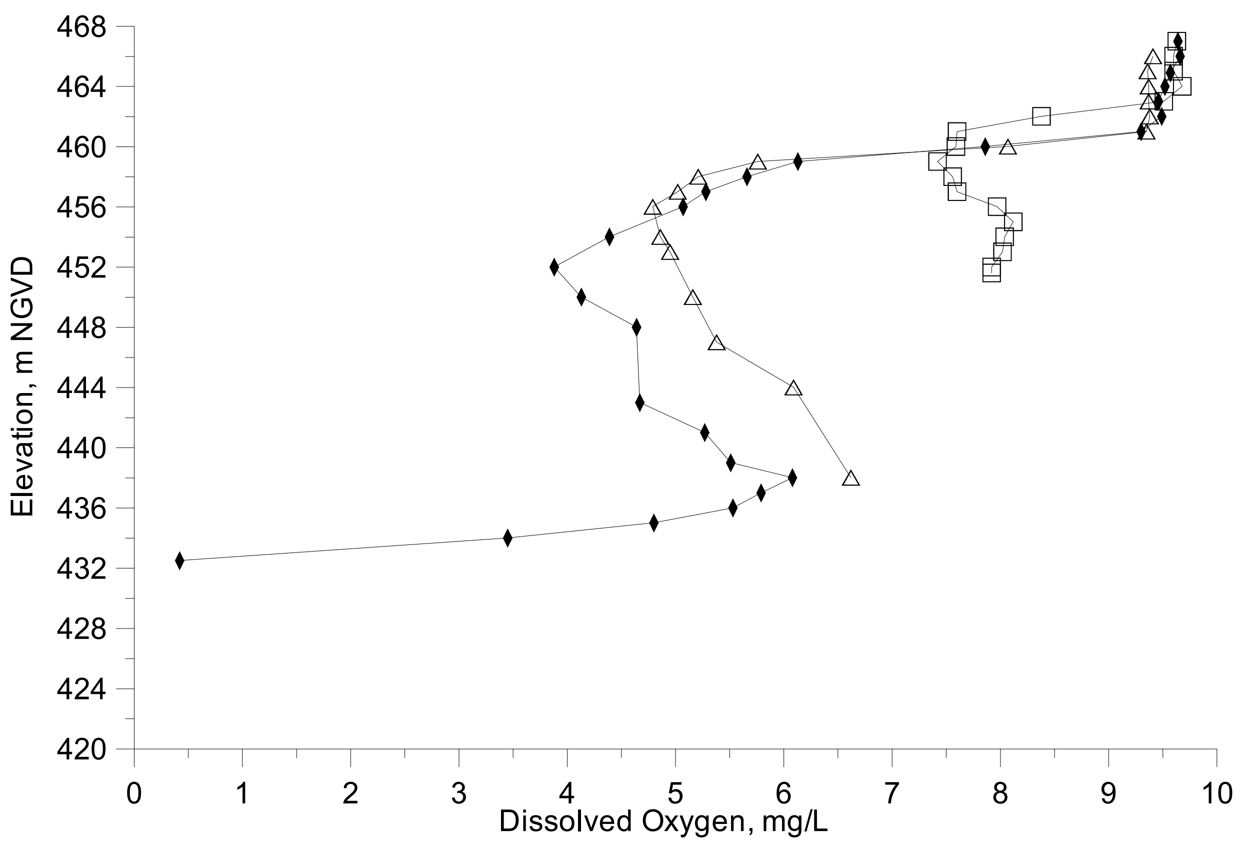


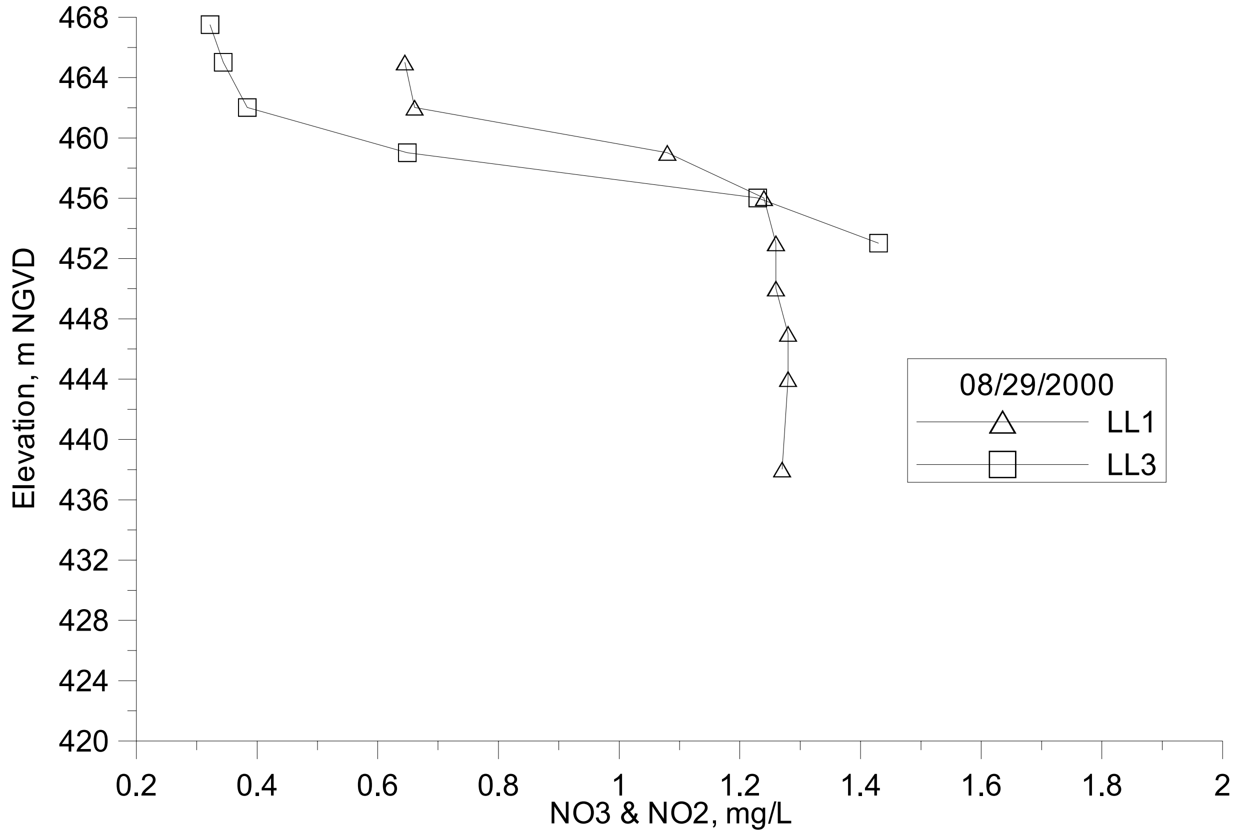
Elevation, m NGVD
Temperature, C
08/29/2000
LL0.5
LL1
LL3

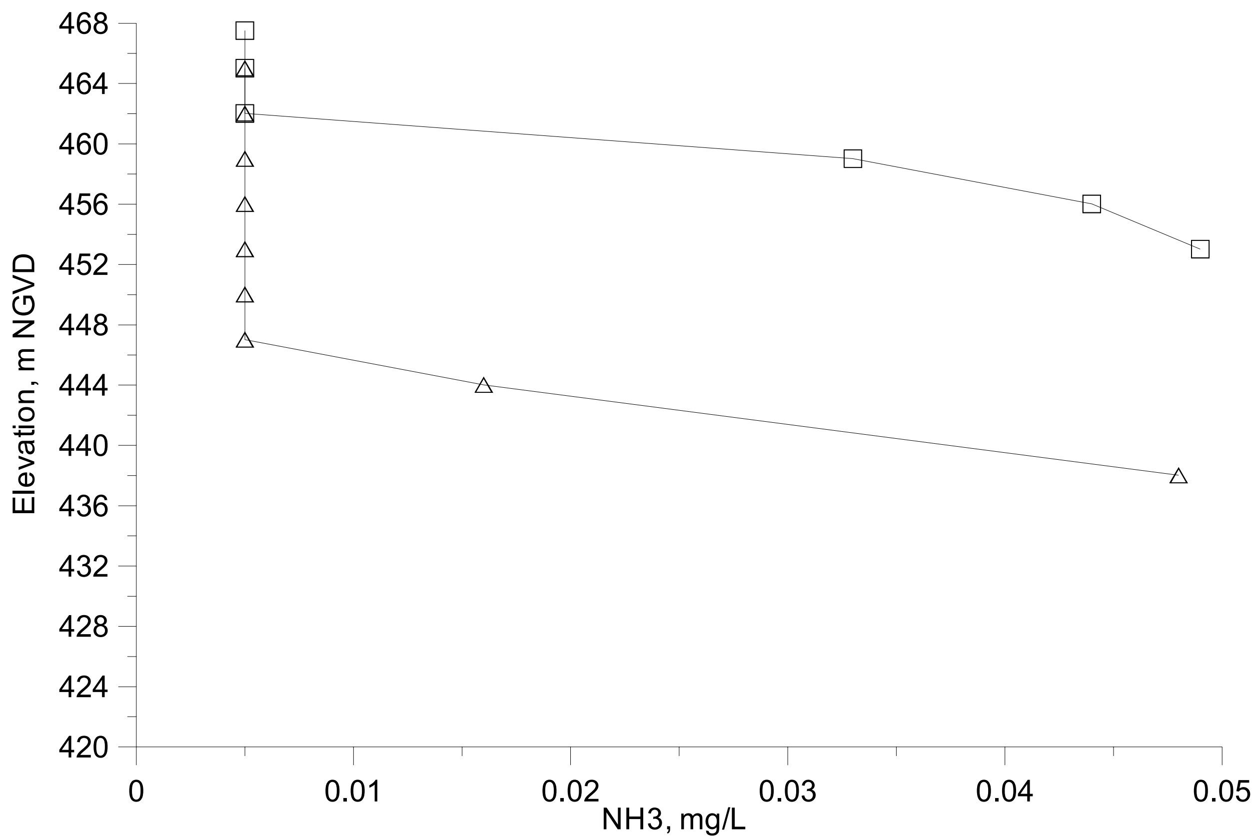


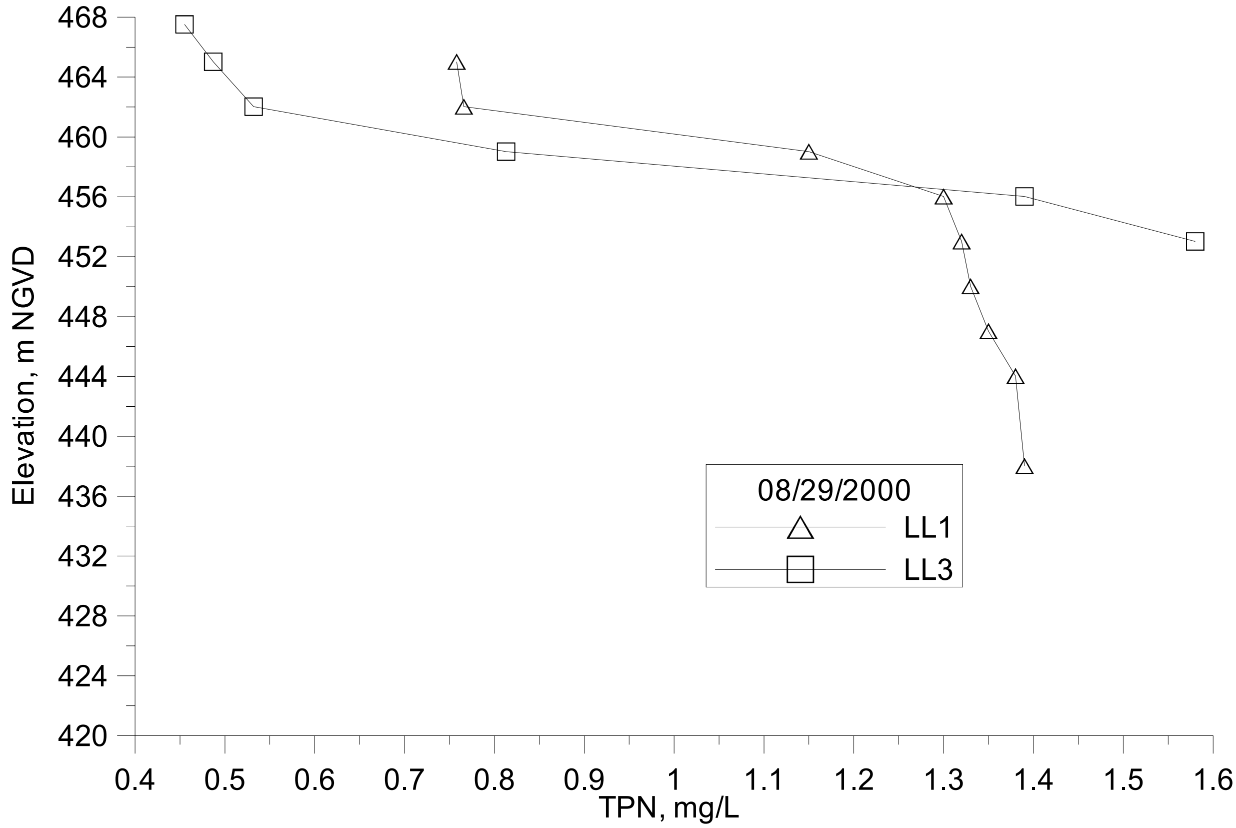
Elevation, m NGVD
Conductivity, umhos/cm


468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
6
7
8
9
10
pH
08/29/2000
LL0.5
LL1
LL3

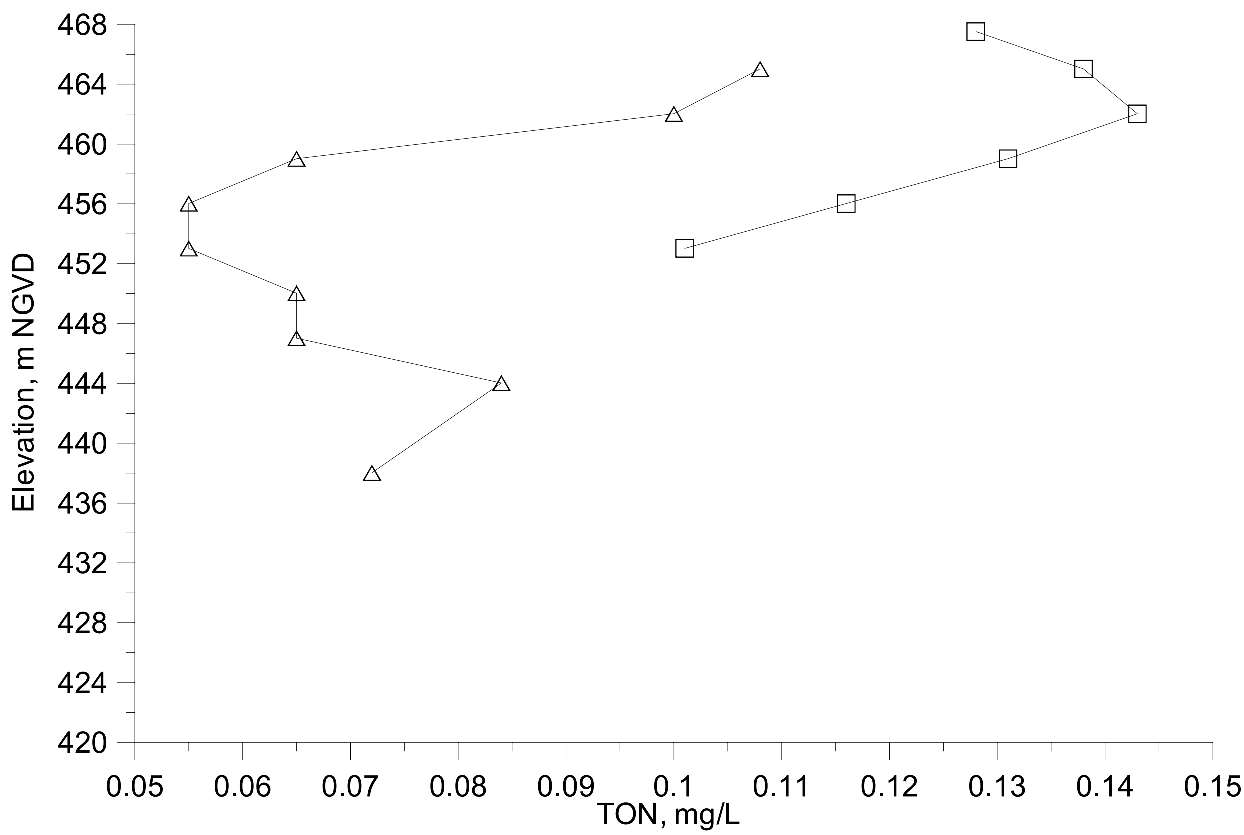

468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0
1
2
3
4
5
6
7
8
9
10
Dissolved Oxygen, mg/L


08/29/2000
LL1
LL3
Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
428
424
420
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
NO3 & NO2, mg/L


Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
428
424
420
0
0.01
0.02
0.03
0.04
0.05
NH3, mg/L



468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
TPN, mg/L
08/29/2000
LL1
LL3



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464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.05
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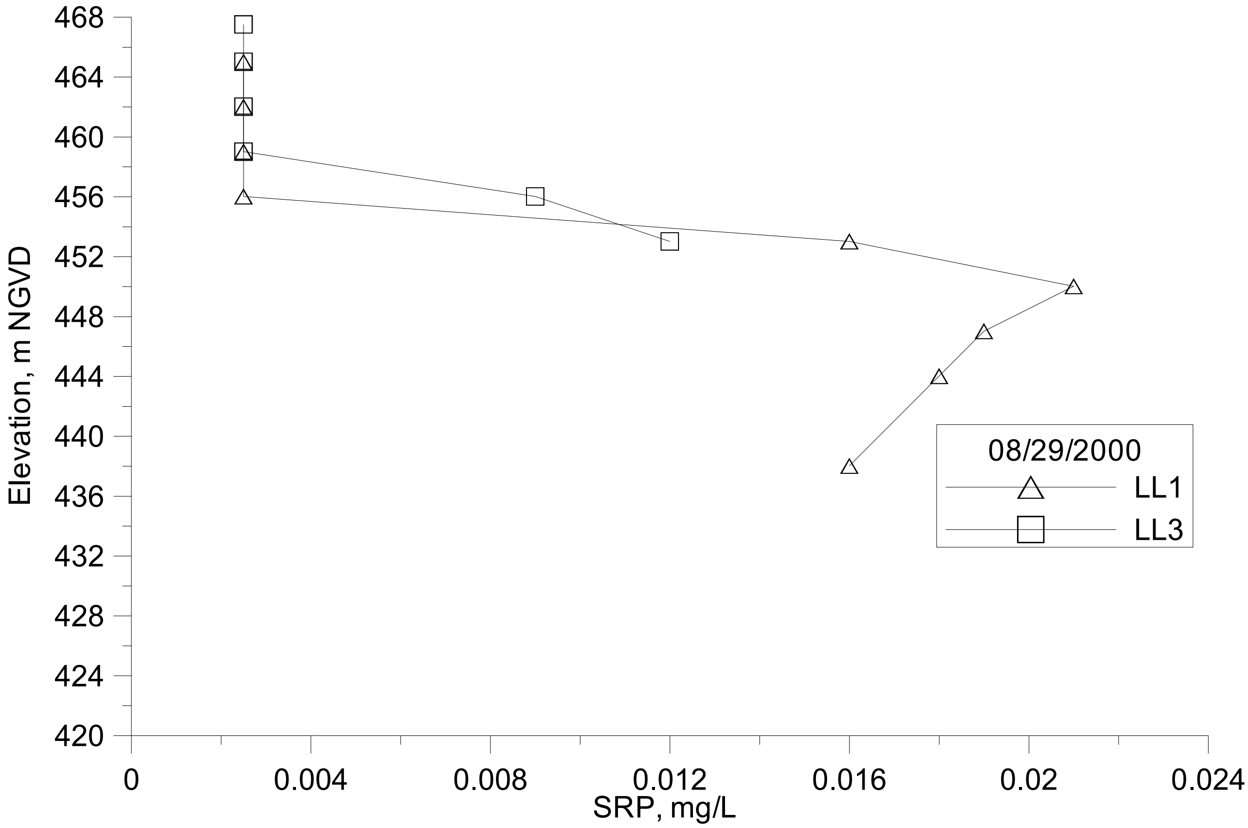
0.07
0.08
0.09
0.1
0.11
0.12
0.13
0.14
0.15
TON, mg/L


Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
428
424
420
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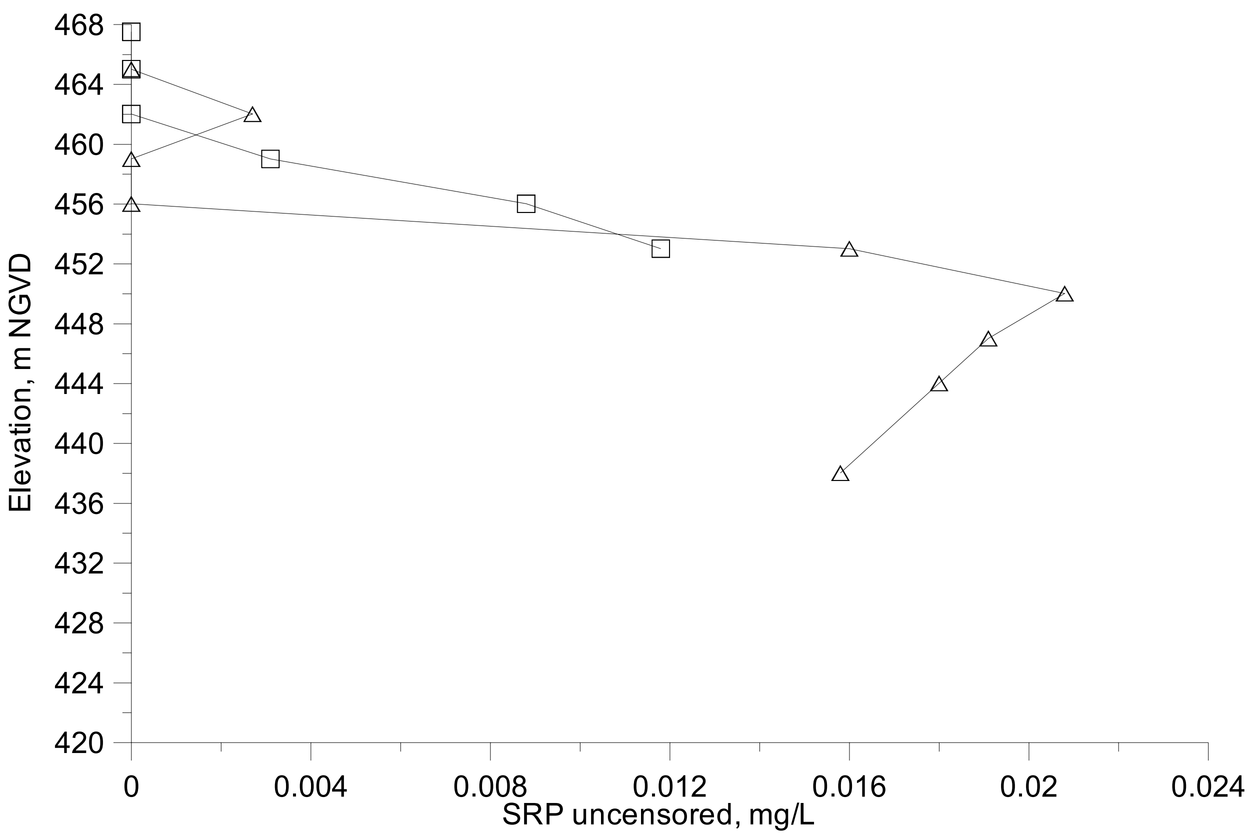
0.008
0.012
0.016
0.02
0.024
SRP, mg/L
08/29/2000
LL1
LL3


Elevation, m NGVD
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464
460
456
452
448
444
440
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432
428
424
420
0
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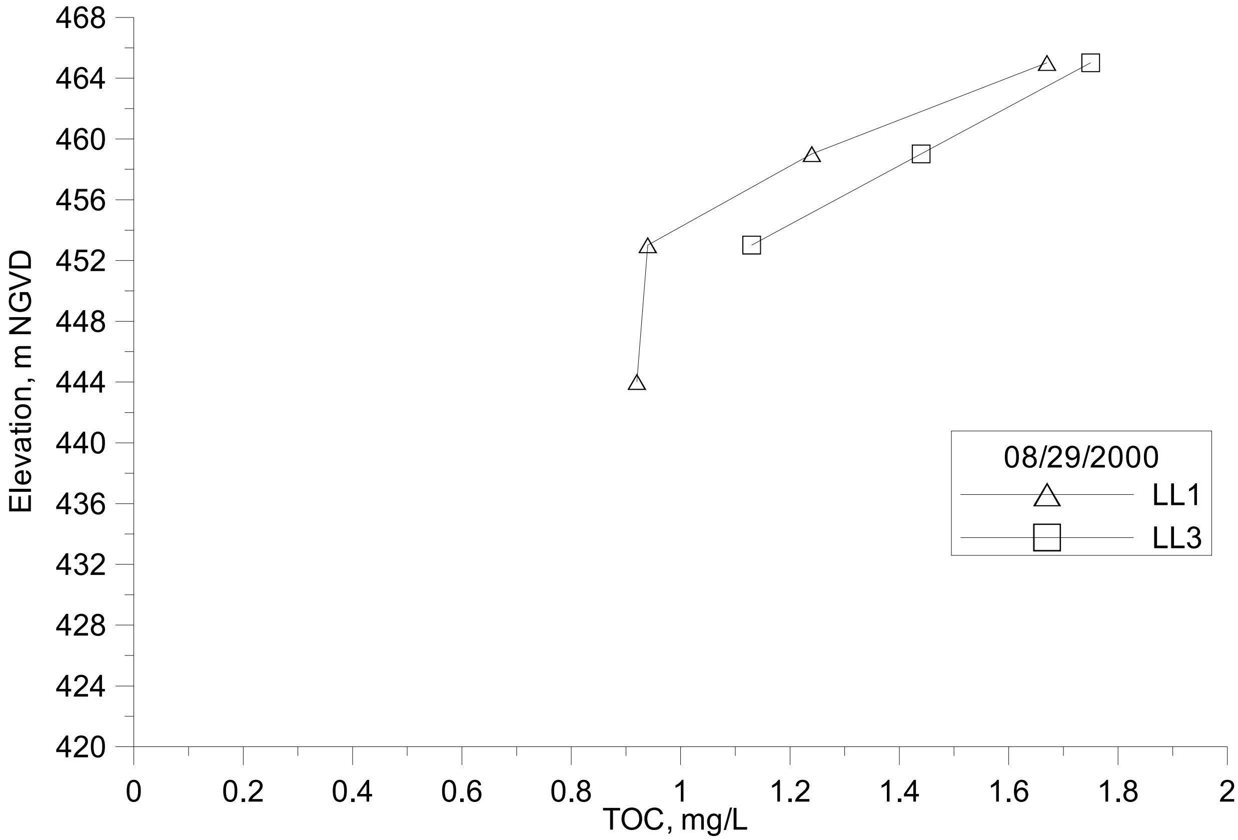
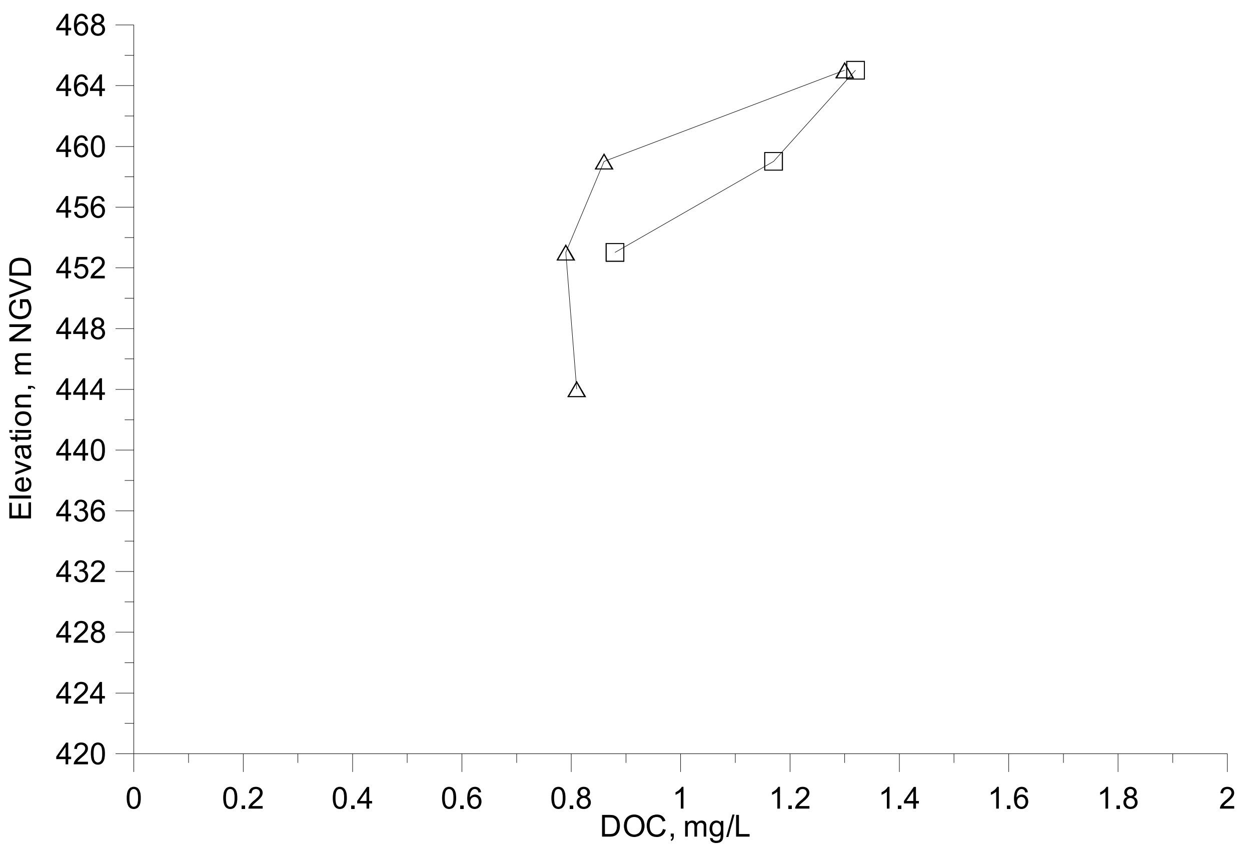
0.008
0.012
0.016
0.02
0.024
SRP uncensored, mg/L



Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
428
424
420
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TOC, mg/L
08/29/2000
LL1
LL3



Elevation, m NGVD
468
464
460
456
452
448
444
440
436
432
428
424
420
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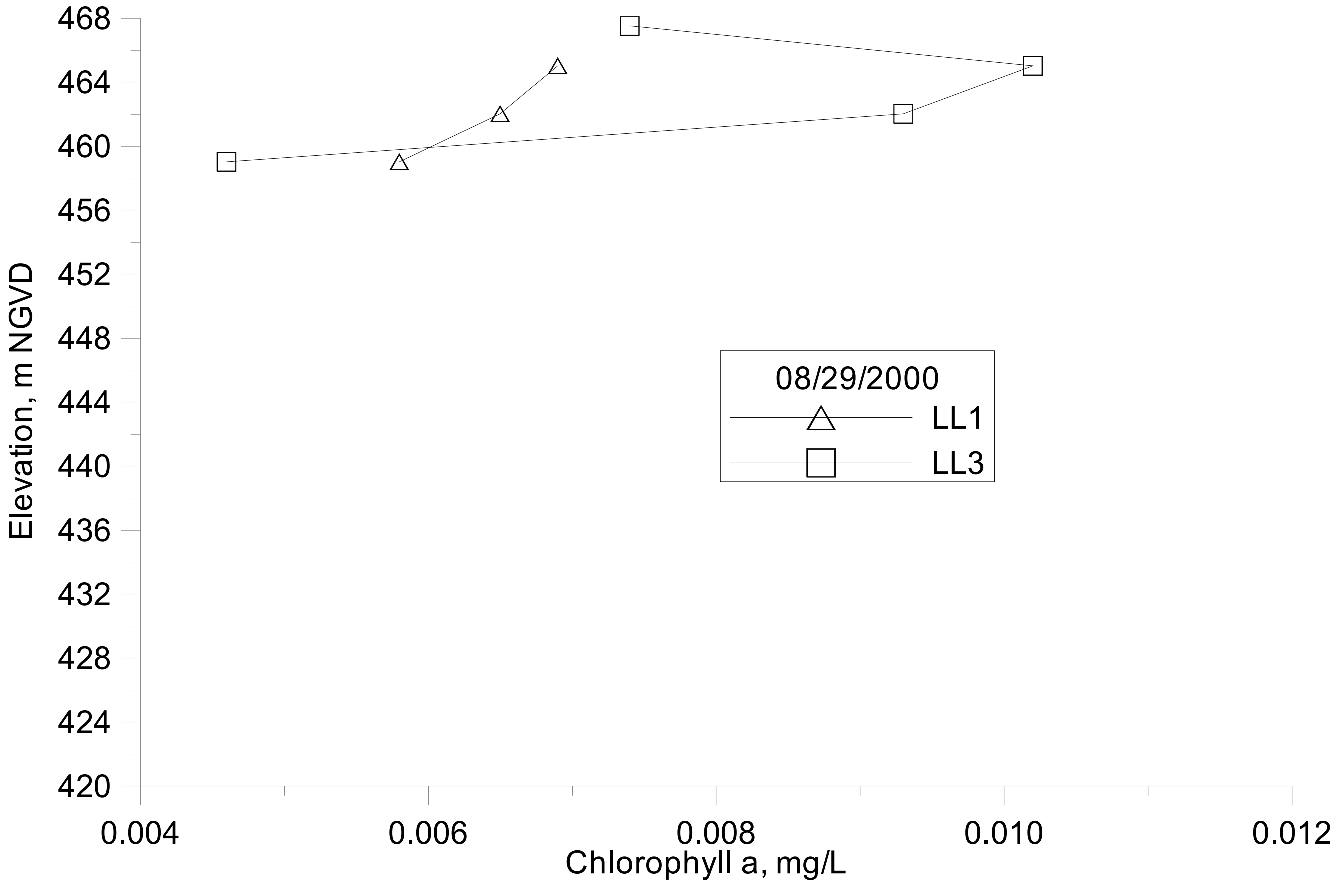
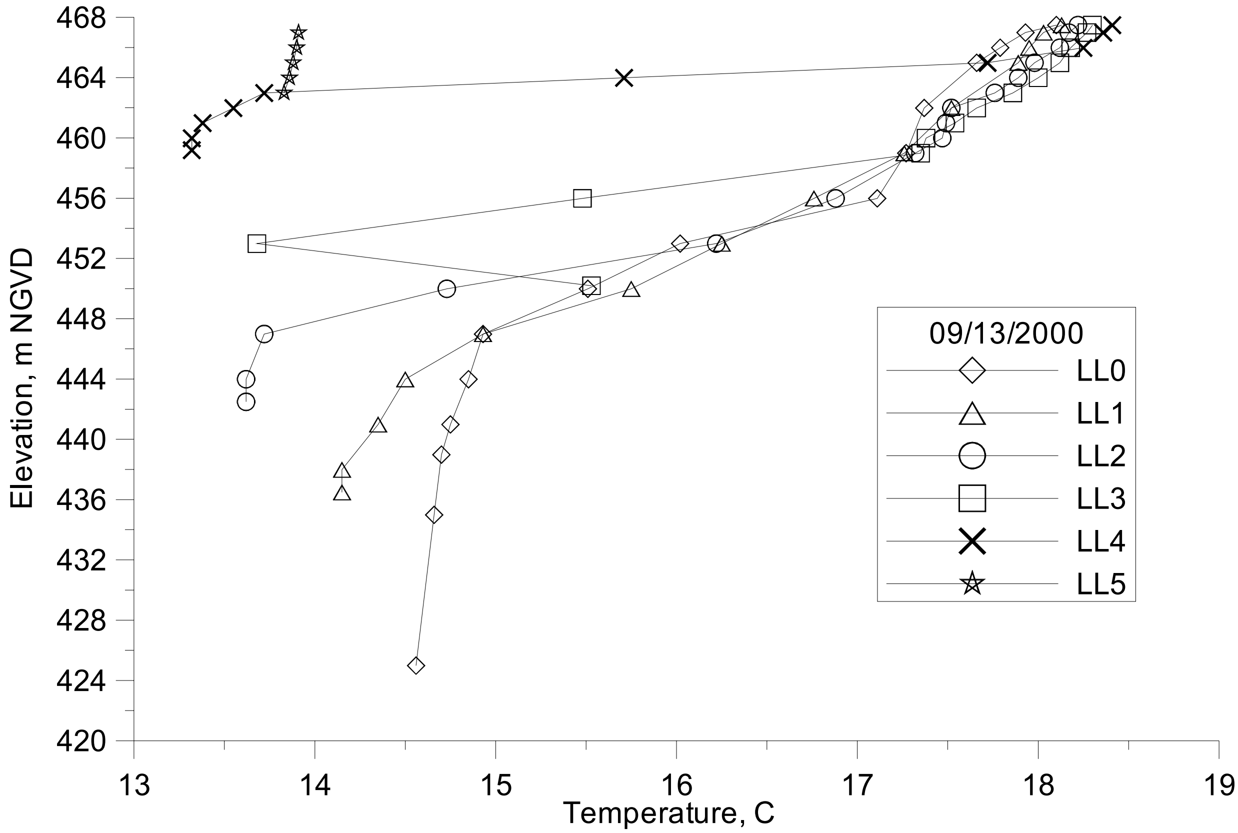
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
DOC, mg/L



468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.004
0.006
0.008
0.010
0.012
Chlorophyll a, mg/L
08/29/2000
LL1
LL3



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464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
13
14
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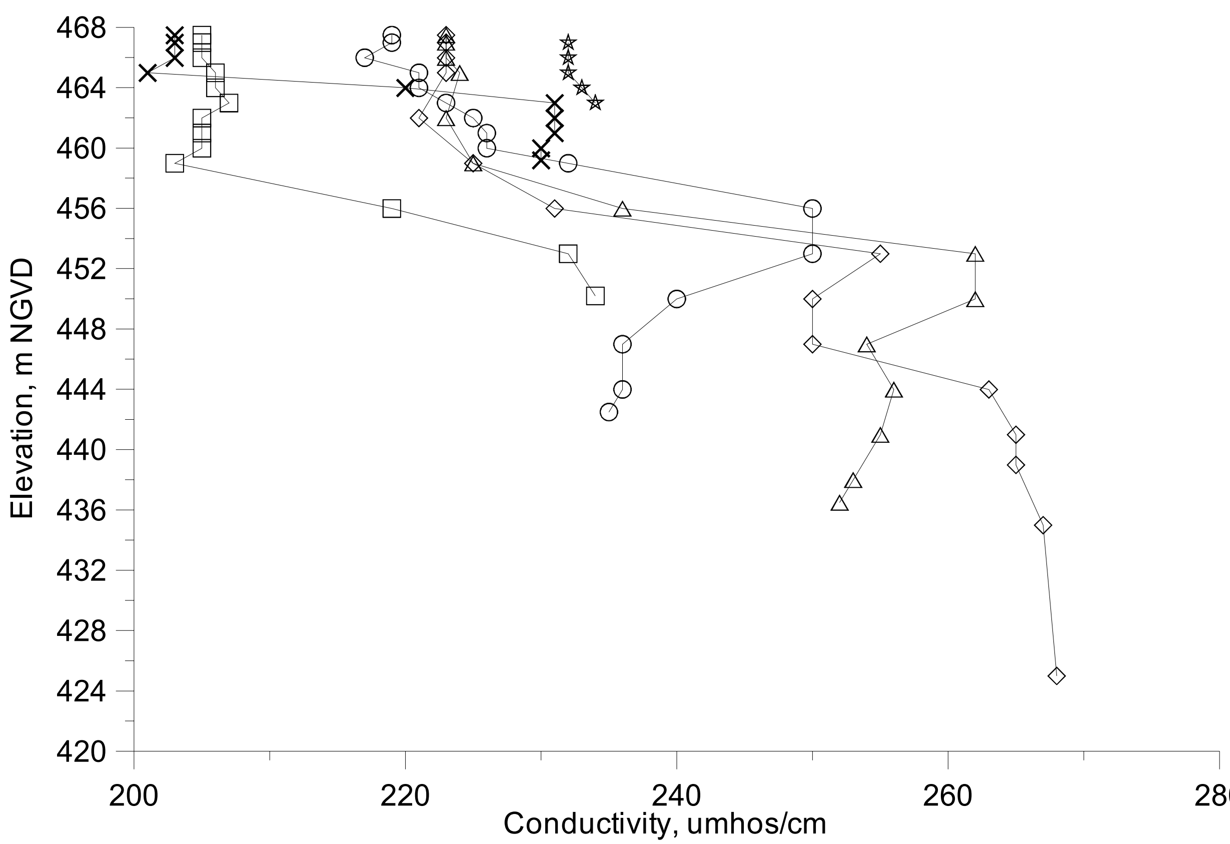
16
17
18
19
Temperature, C
09/13/2000
LL0
LL1
LL2
LL3
LL4
LL5



468
464
460
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448
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436
432
428
424
420
Elevation, m NGVD
200
220
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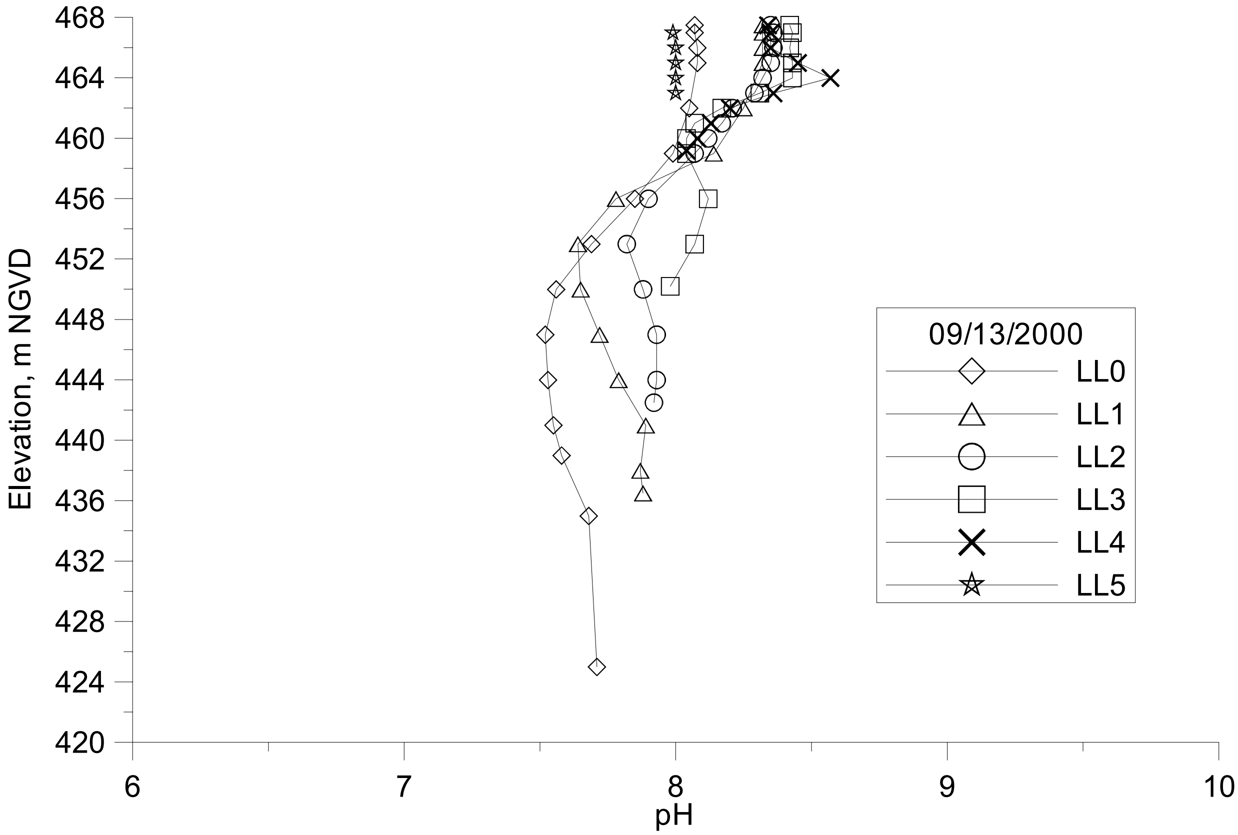
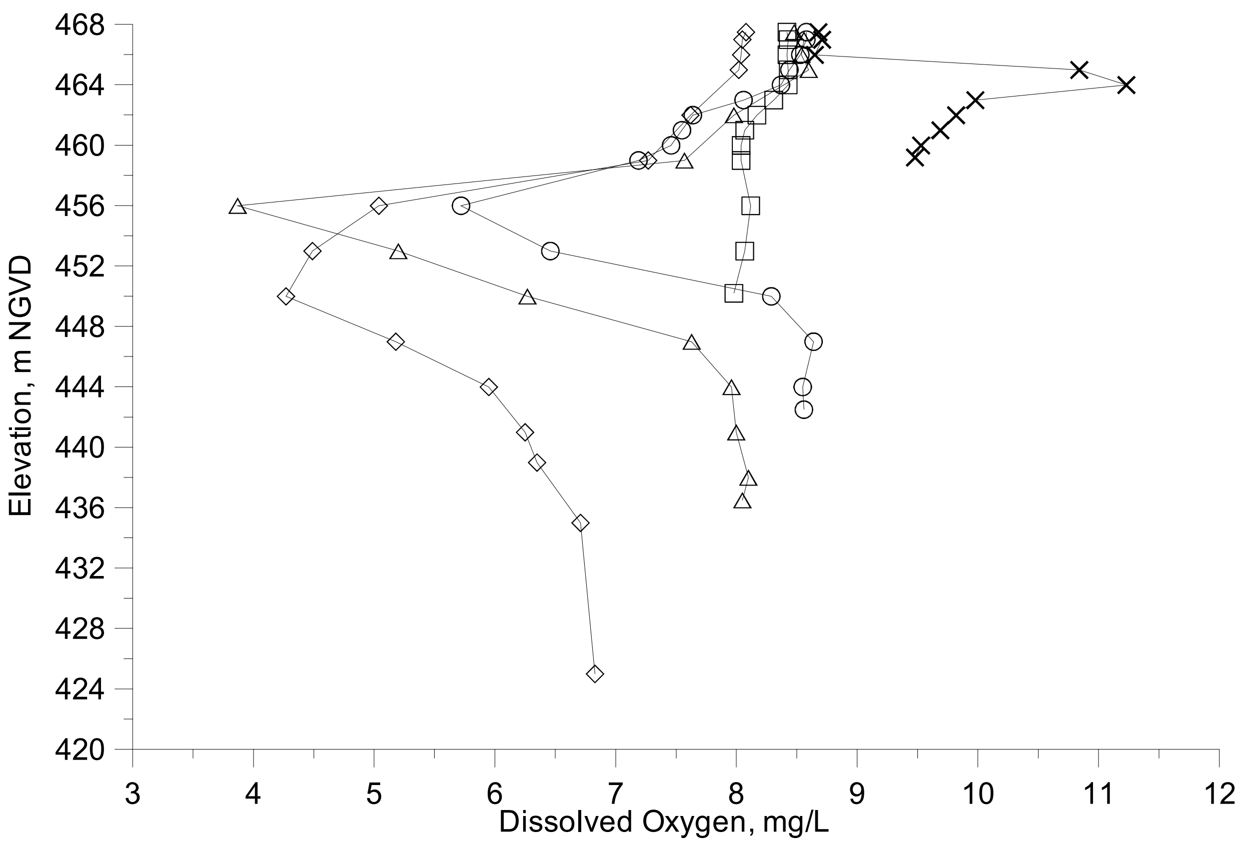
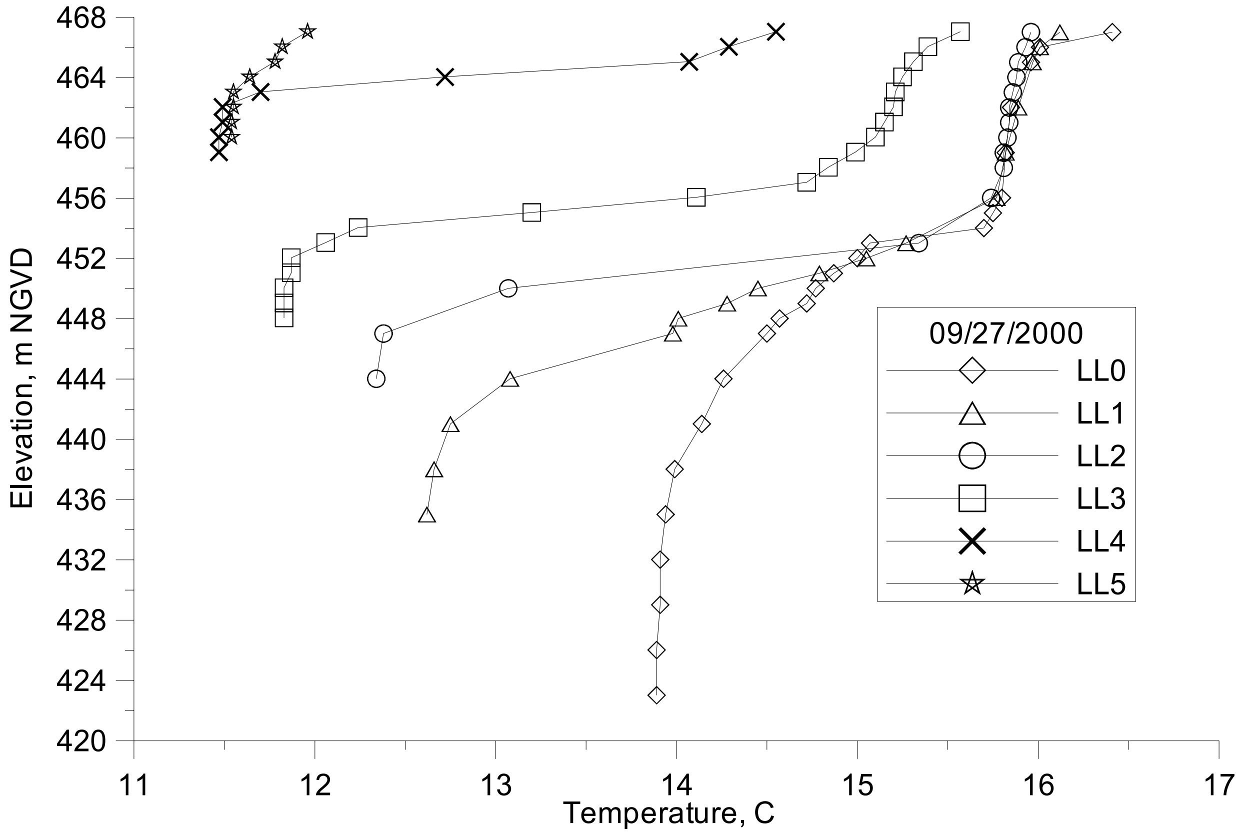
260
280
Conductivity, umhos/cm

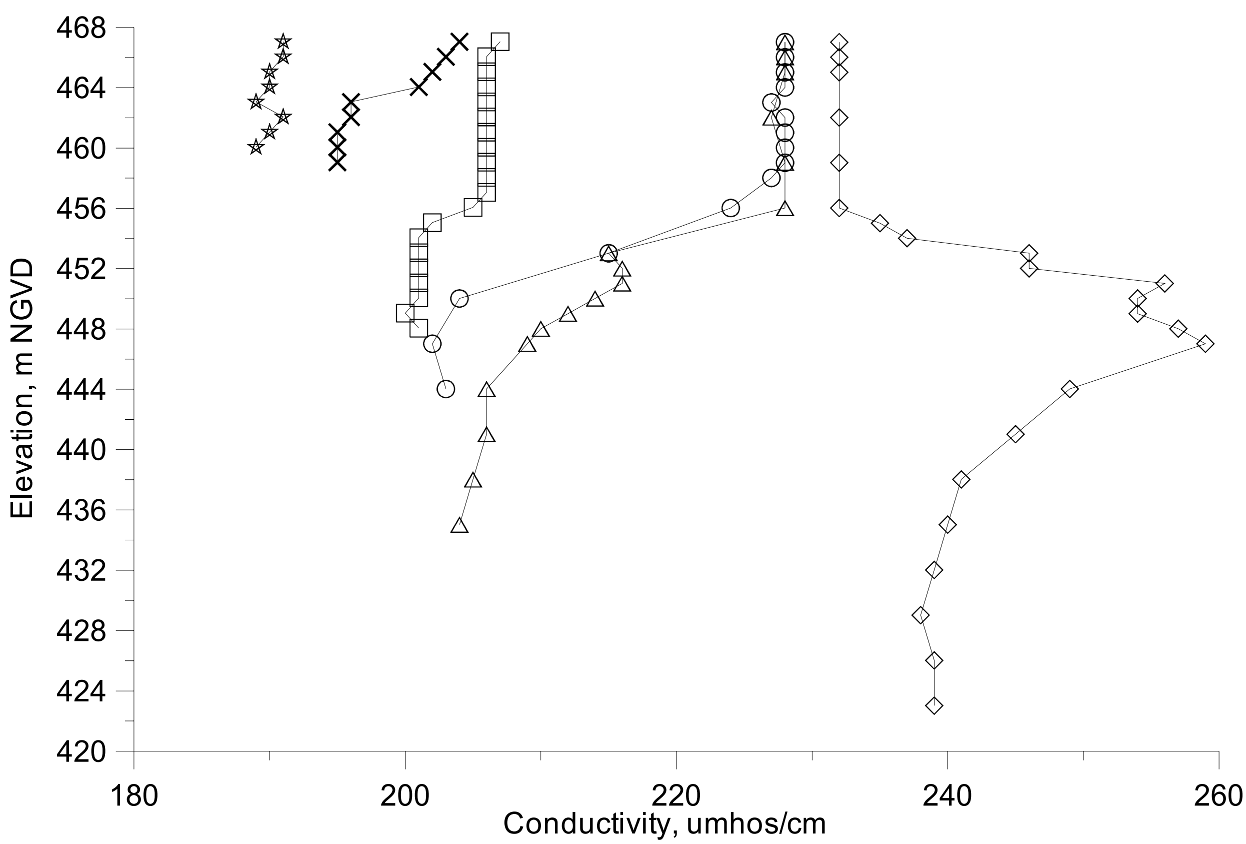


468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
6
7
8
9
10
pH
09/13/2000
LL0
LL1
LL2
LL3
LL4
LL5



468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
3
4
5
6
7
8
9
10
11
12
Dissolved Oxygen, mg/L


468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
11
12
13
14
15
16
17
Temperature, C
09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5


468
464
460
456
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448
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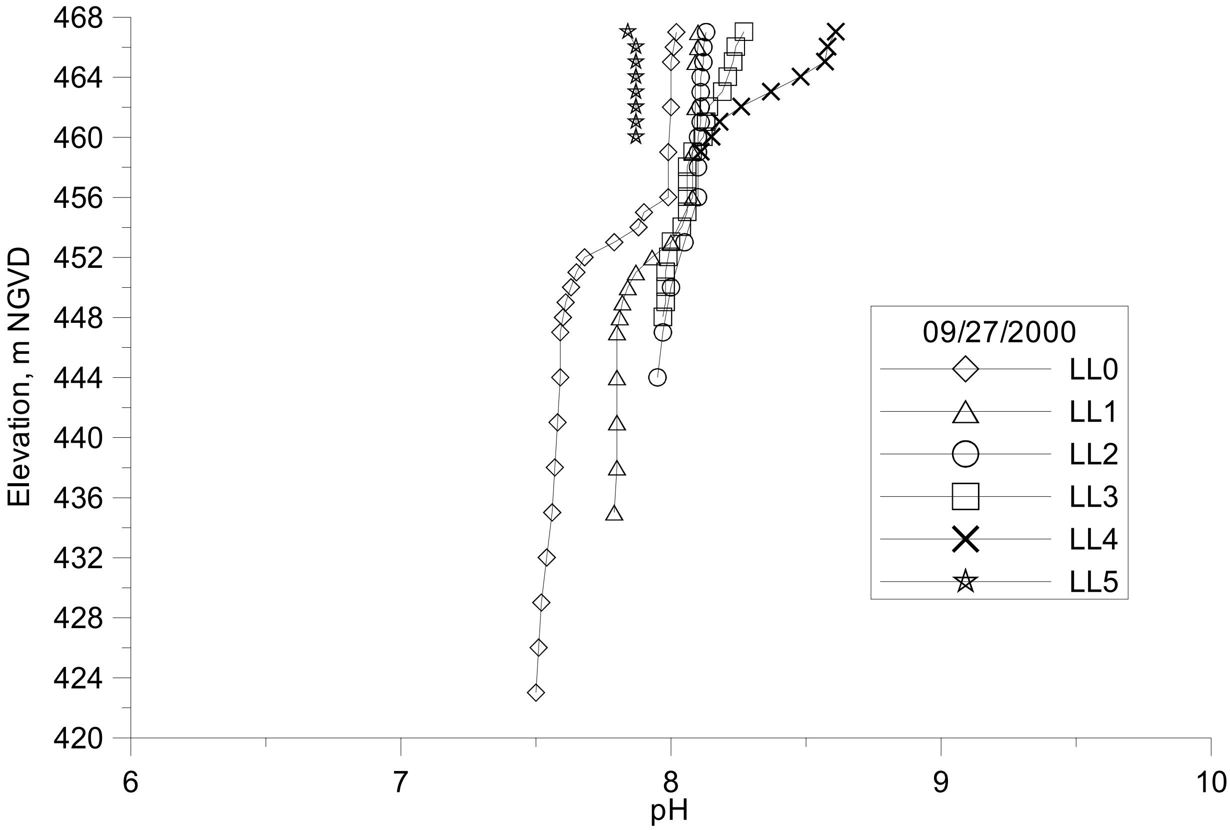
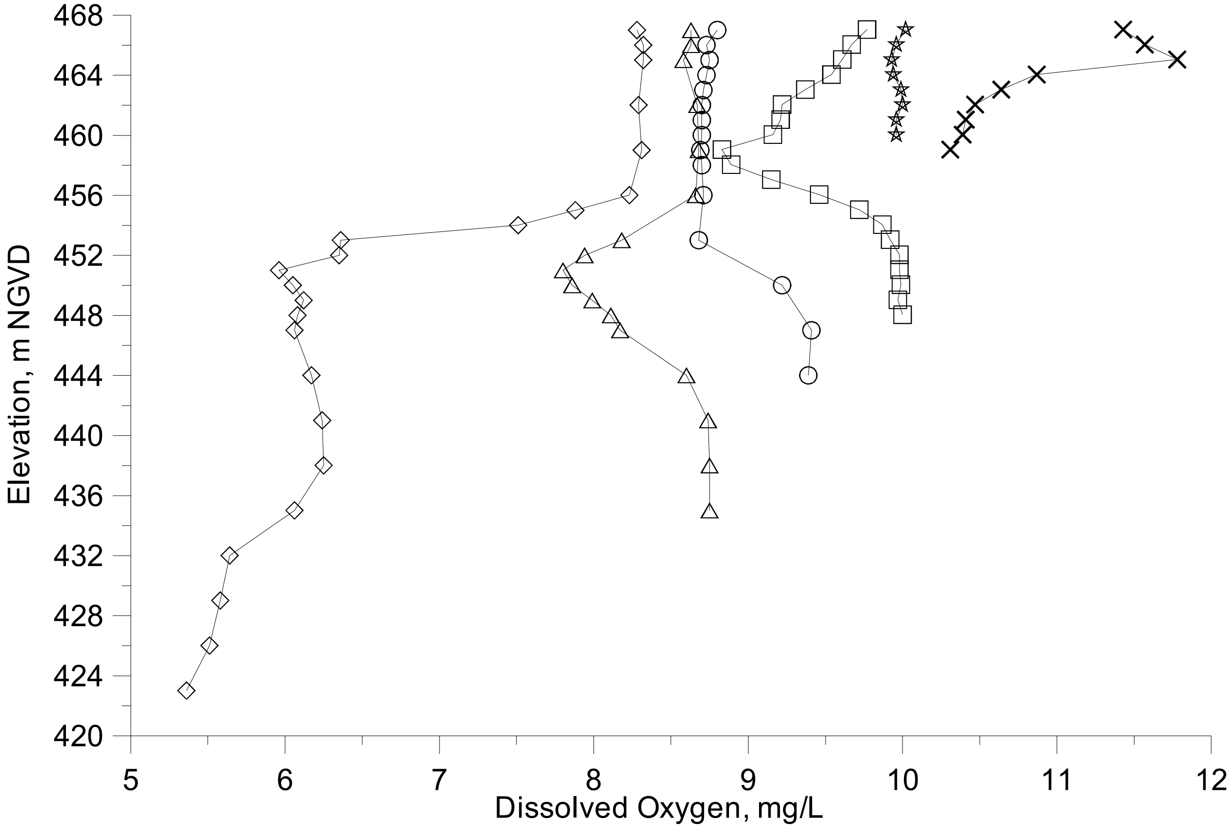
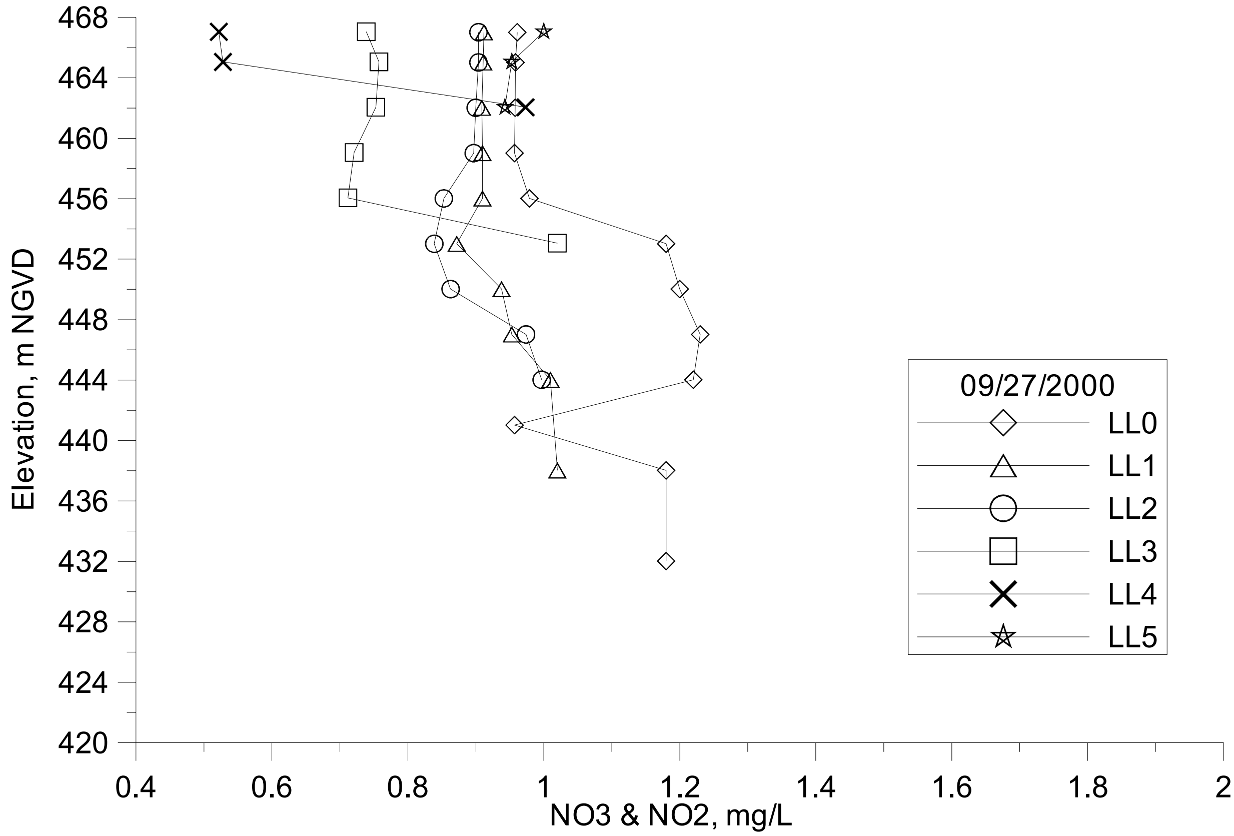
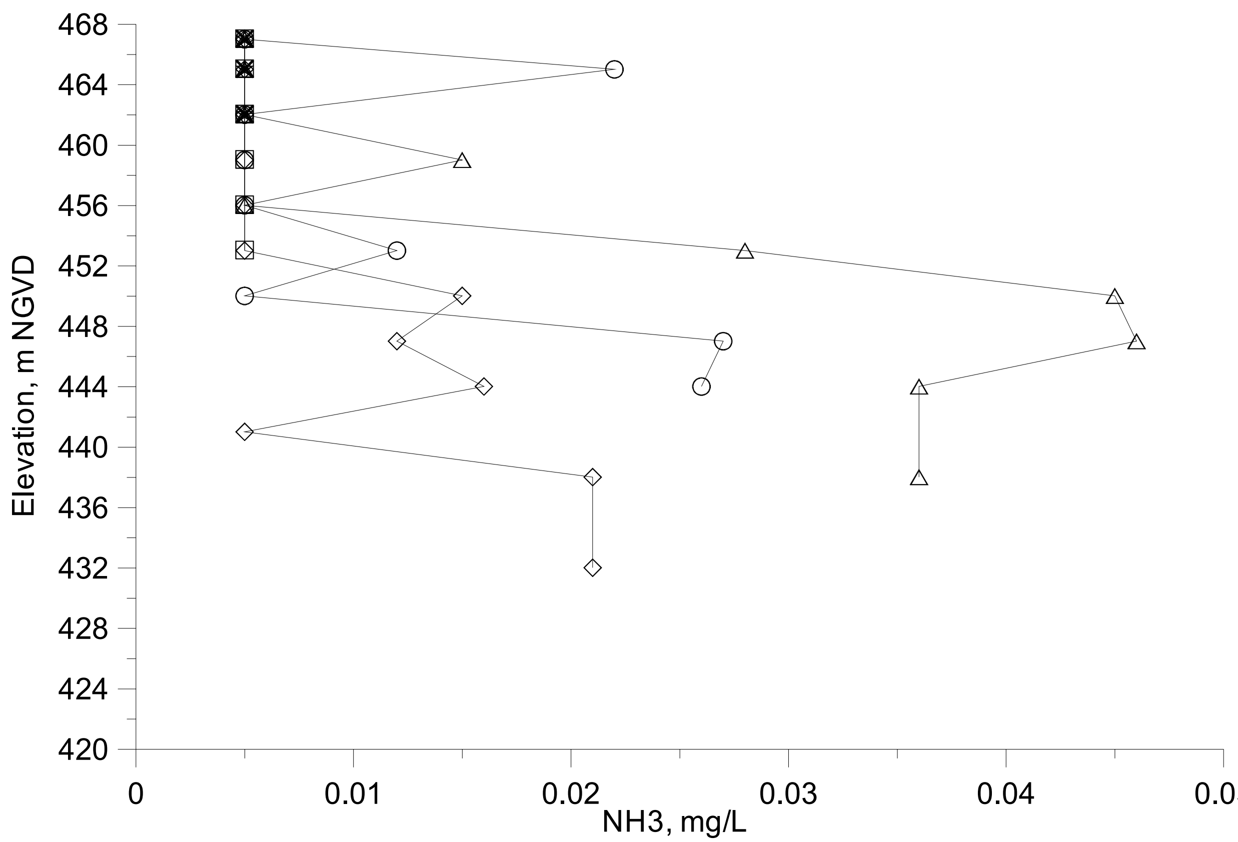
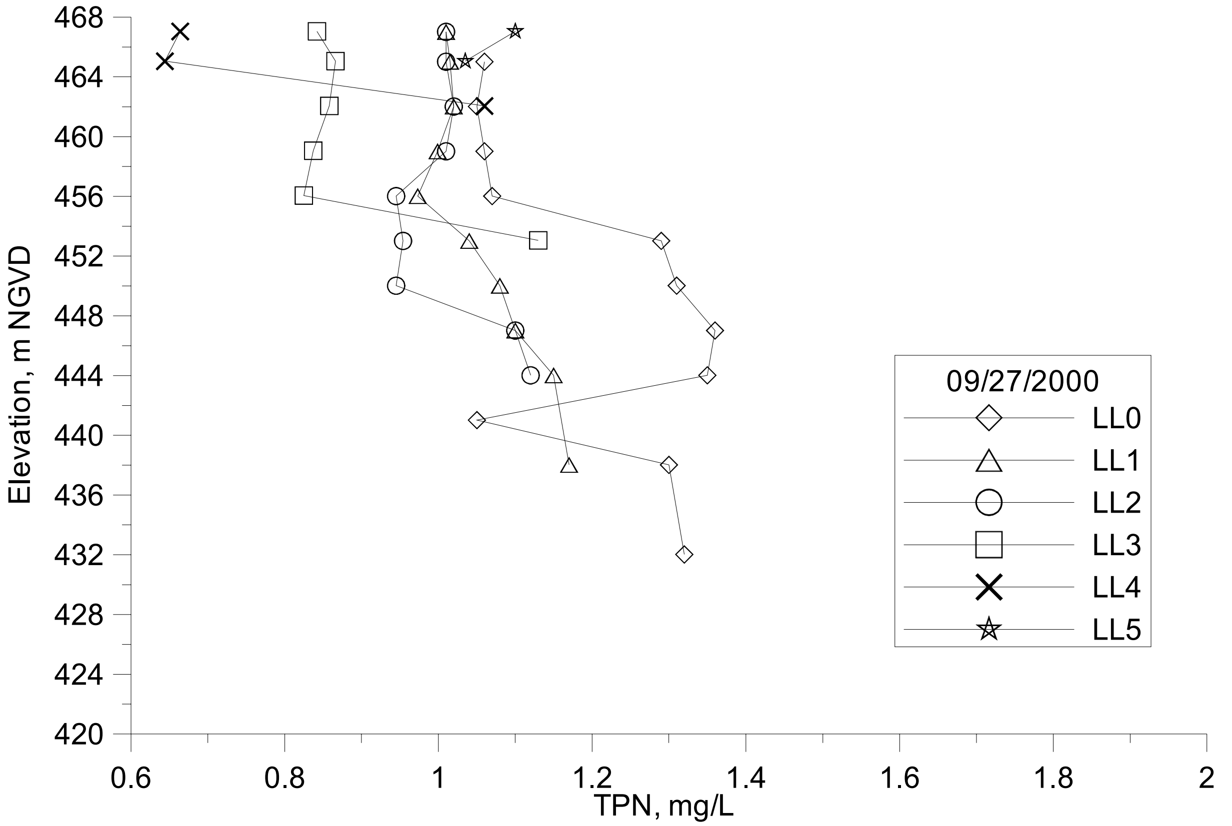
440
436
432
428
424
420
Elevation, m NGVD
180
200
220
240
260
Conductivity, umhos/cm

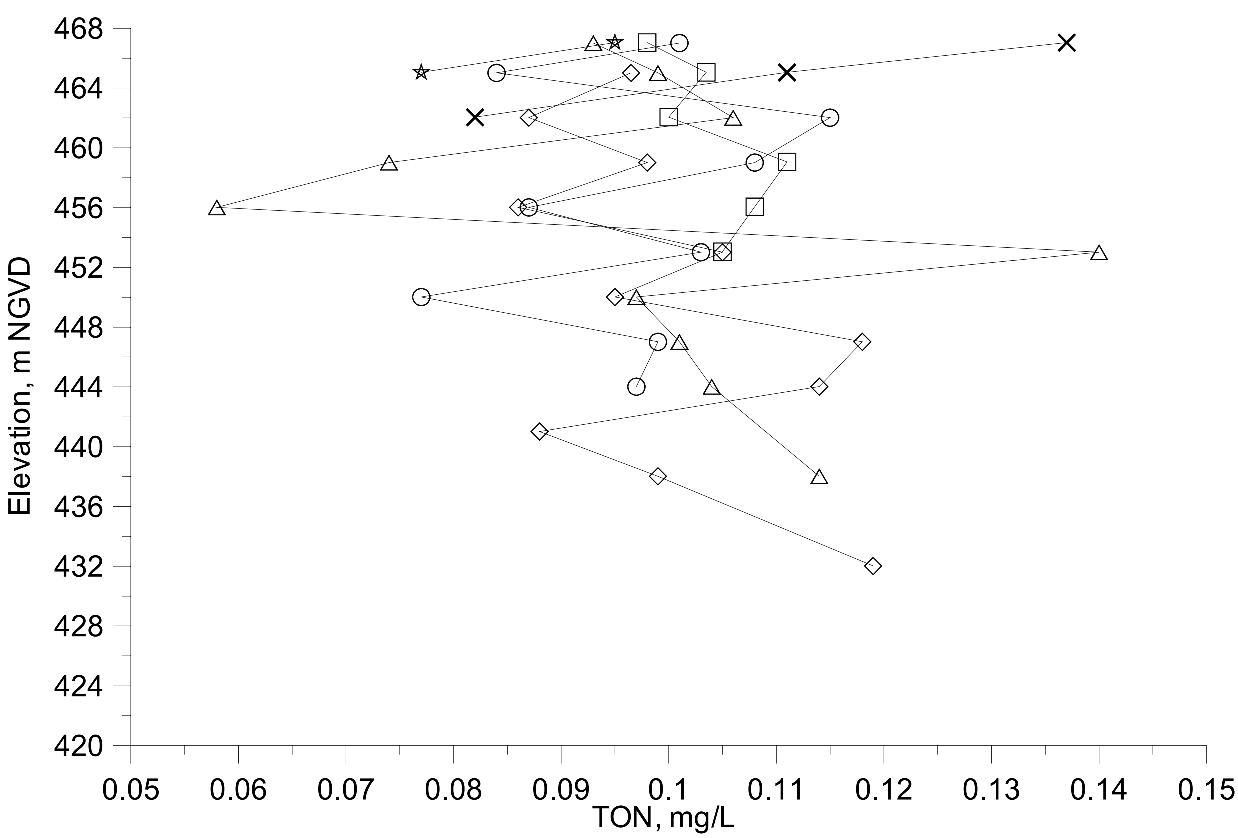

Elevation, m NGVD
pH
09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5

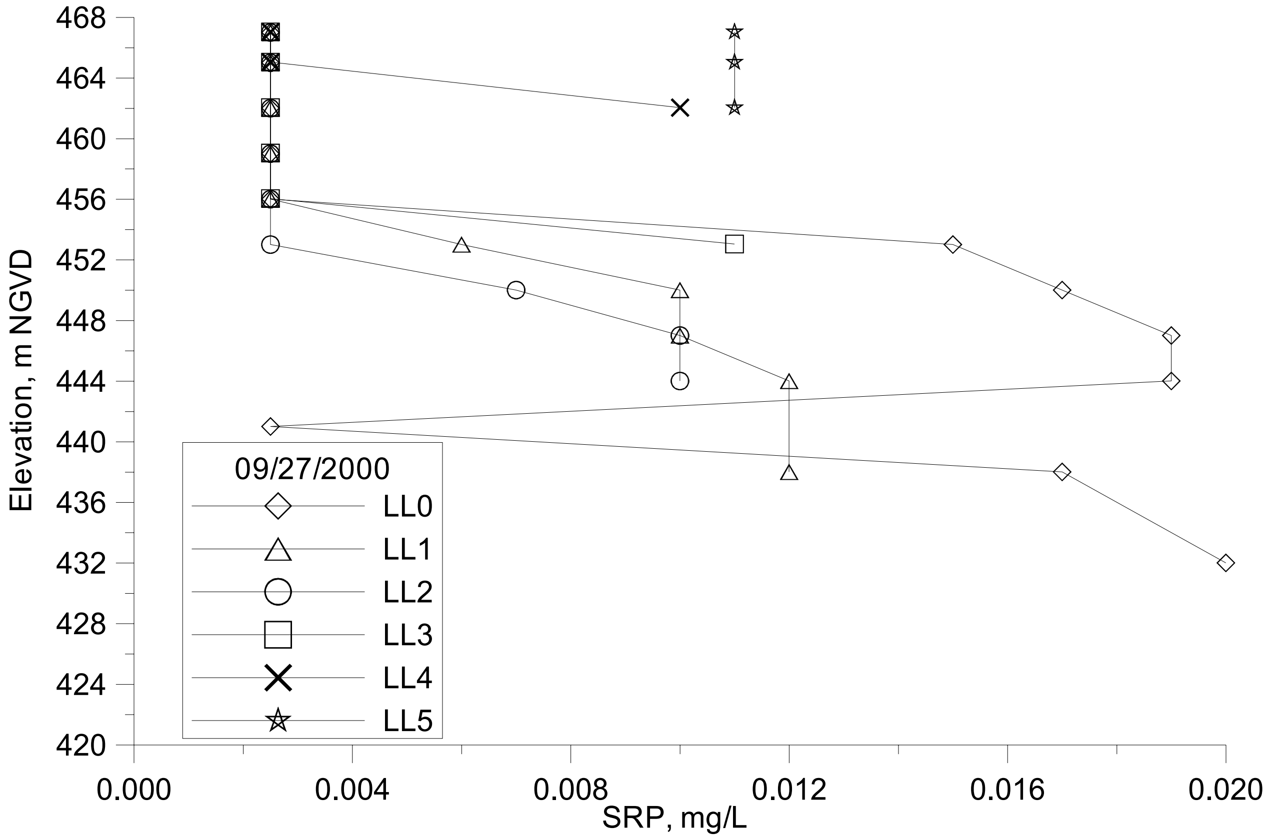

Elevation, m NGVD
Dissolved Oxygen, mg/L

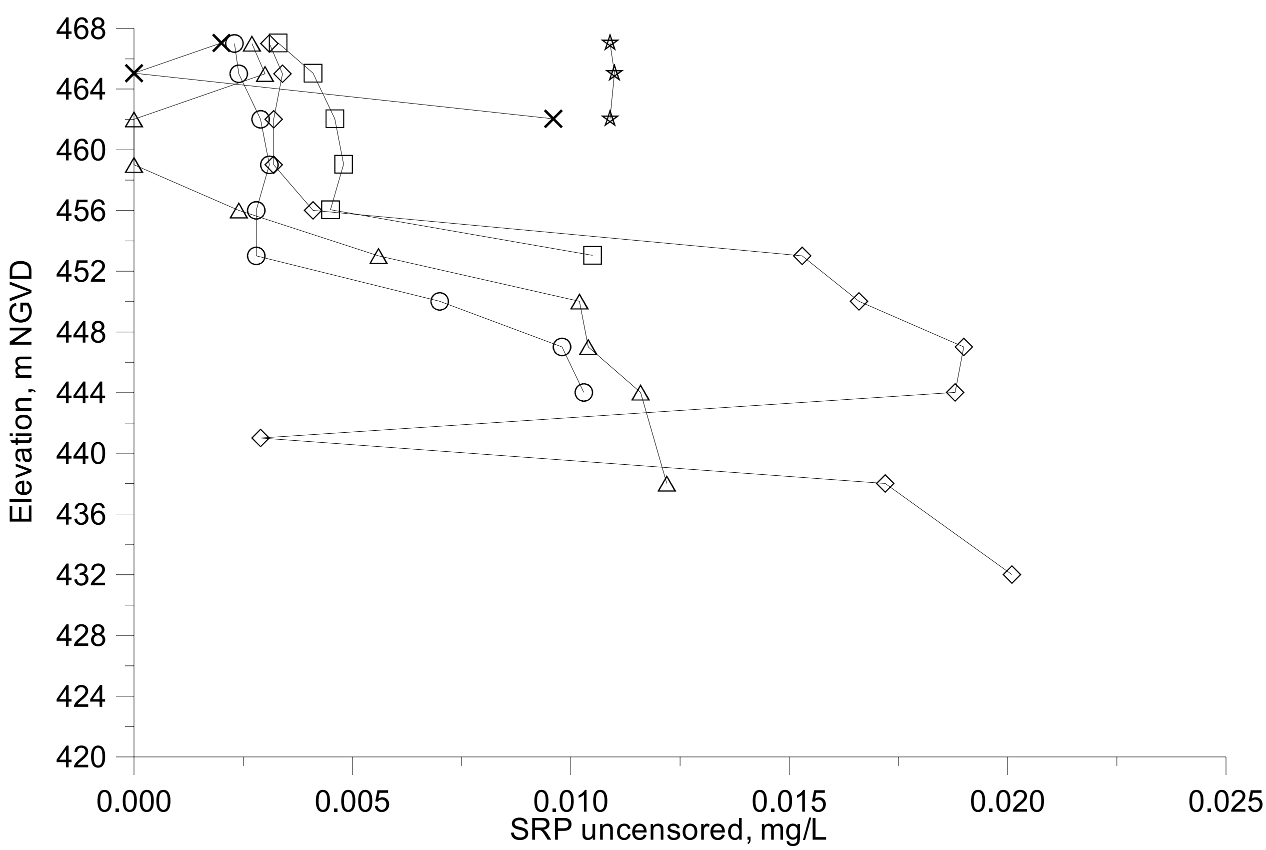

468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
NO3 & NO2, mg/L
09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5

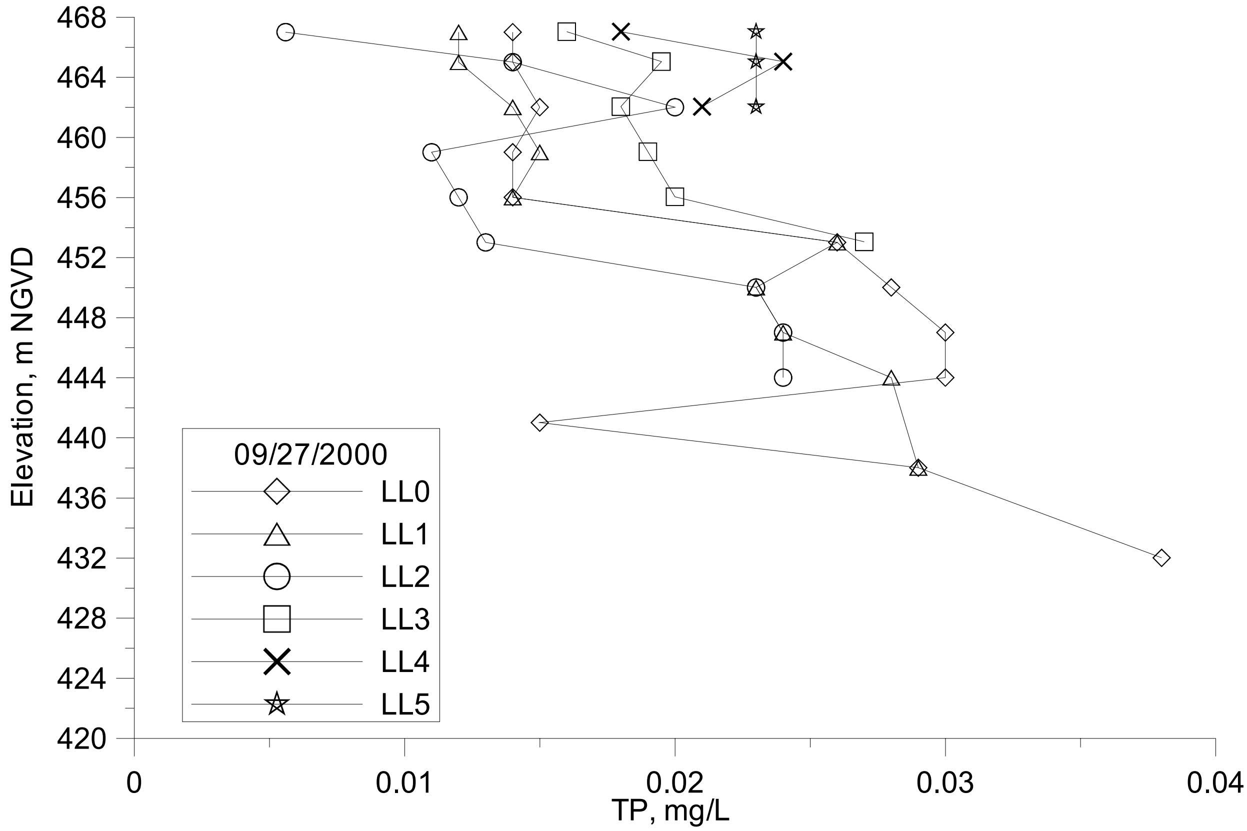

468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0
0.01
0.02
0.03
0.04
0.05
NH3, mg/L


09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5
Elevation, m NGVD
TPN, mg/L

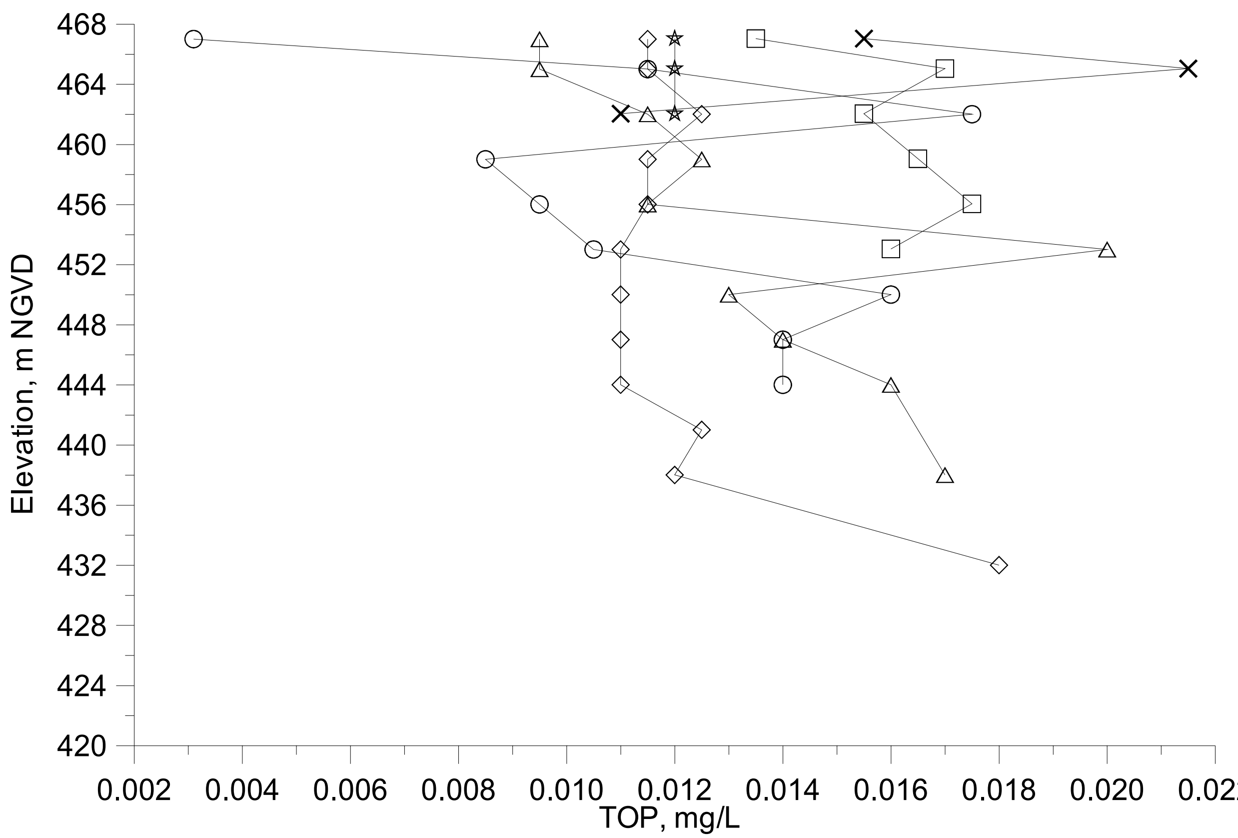

Elevation, m NGVD
TON, mg/L


09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5
Elevation, m NGVD
SRP, mg/L
468
464
460
456
452
448
444
440
436
432
428
424
420
0.000
0.004
0.008
0.012
0.016
0.020

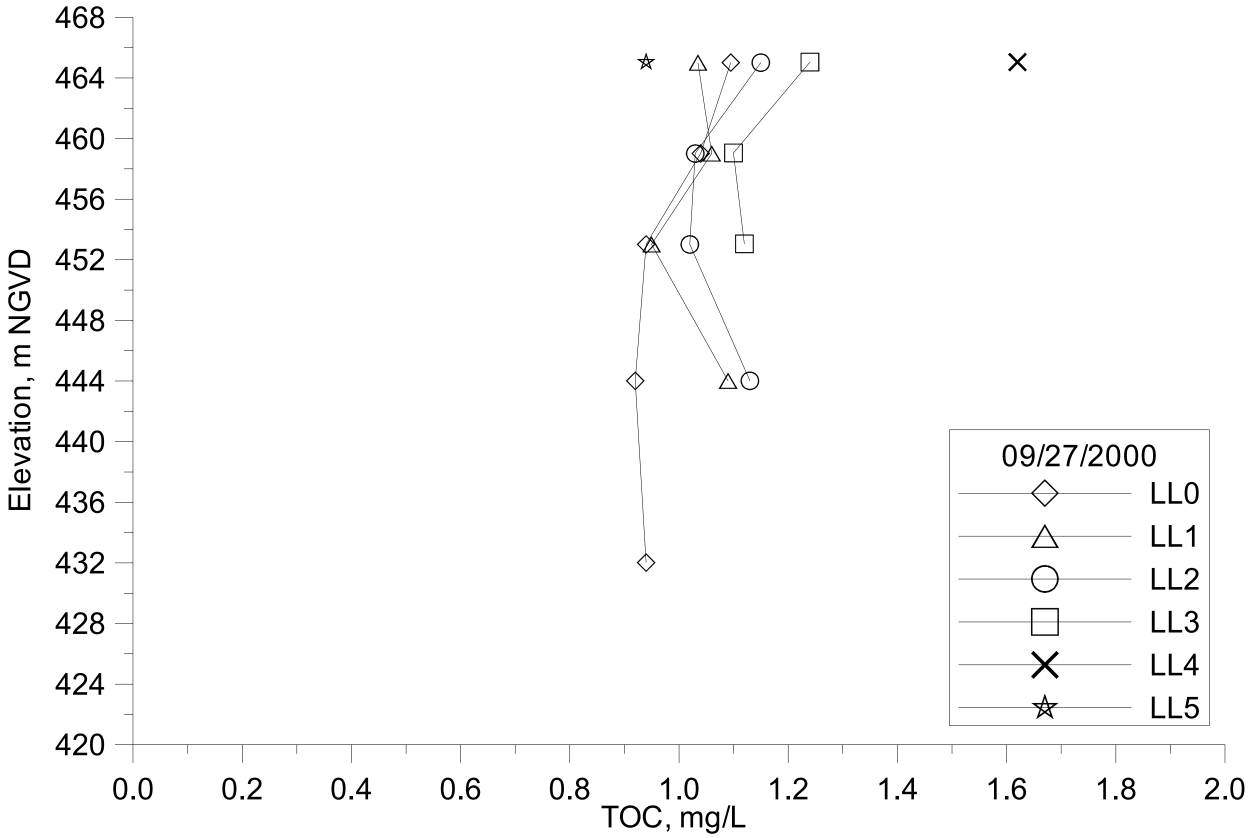

Elevation, m NGVD
SRP uncensored, mg/L
468
464
460
456
452
448
444
440
436
432
428
424
420
0.000
0.005
0.010
0.015
0.020
0.025

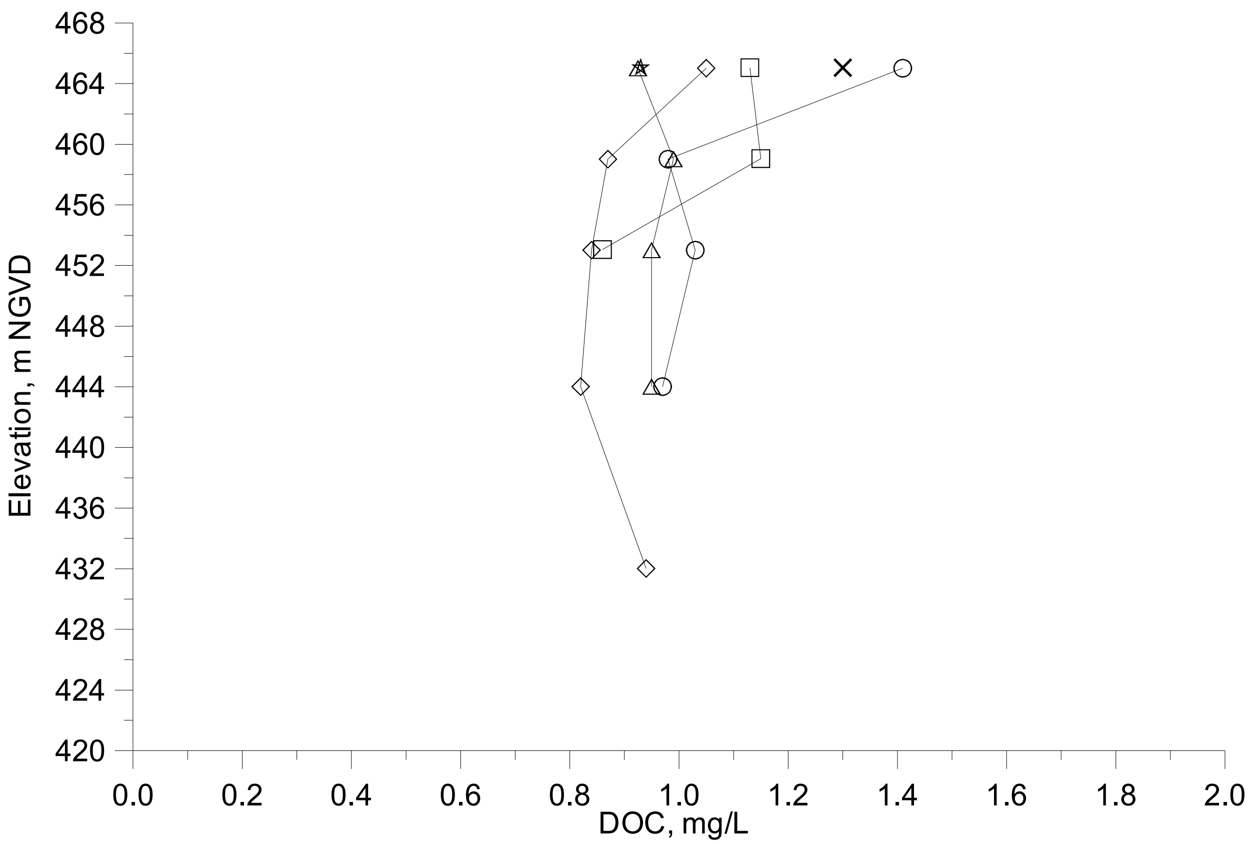


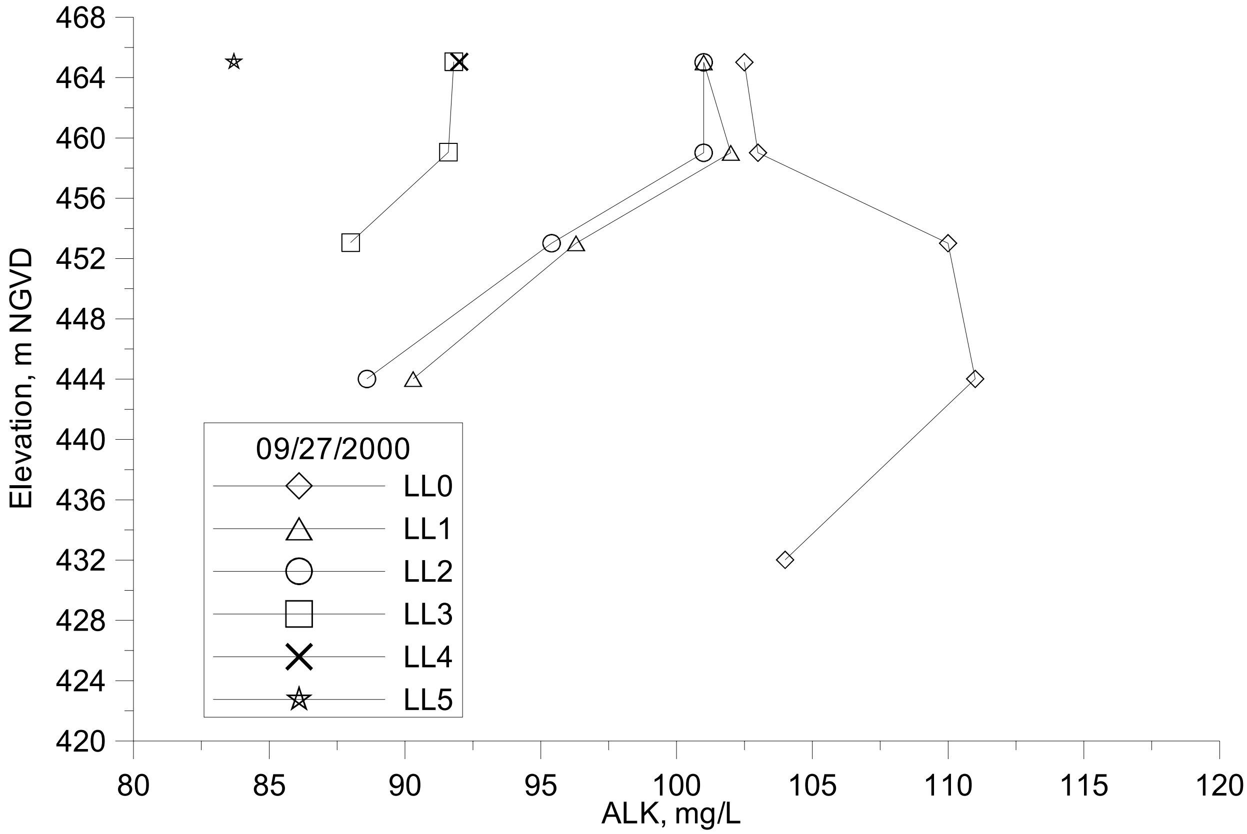
Elevation, m NGVD
TP, mg/L
09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5
468
464
460
456
452
448
444
440
436
432
428
424
420
0
0.01
0.02
0.03
0.04



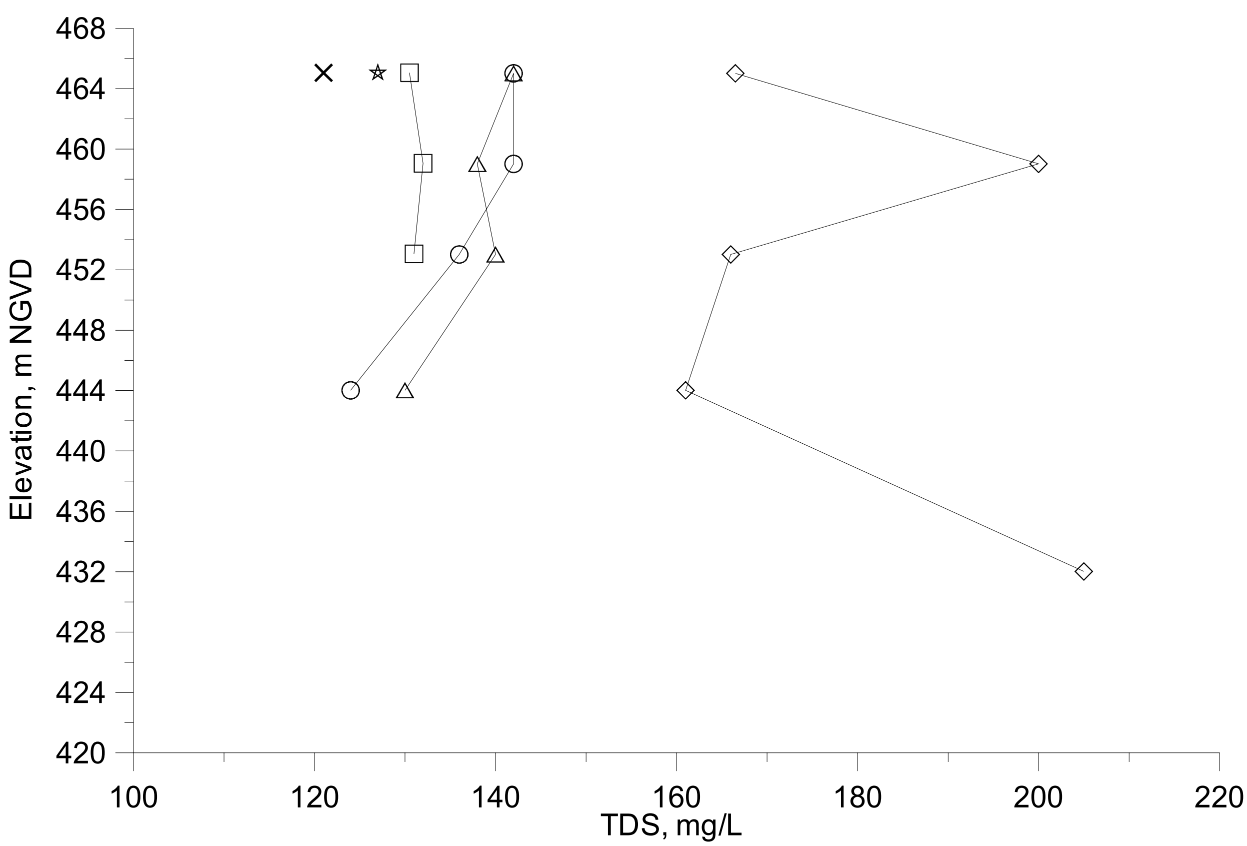
Elevation, m NGVD
TOP, mg/L
468
464
460
456
452
448
444
440
436
432
428
424
420
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016
0.018
0.020
0.022


468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TOC, mg/L
09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5

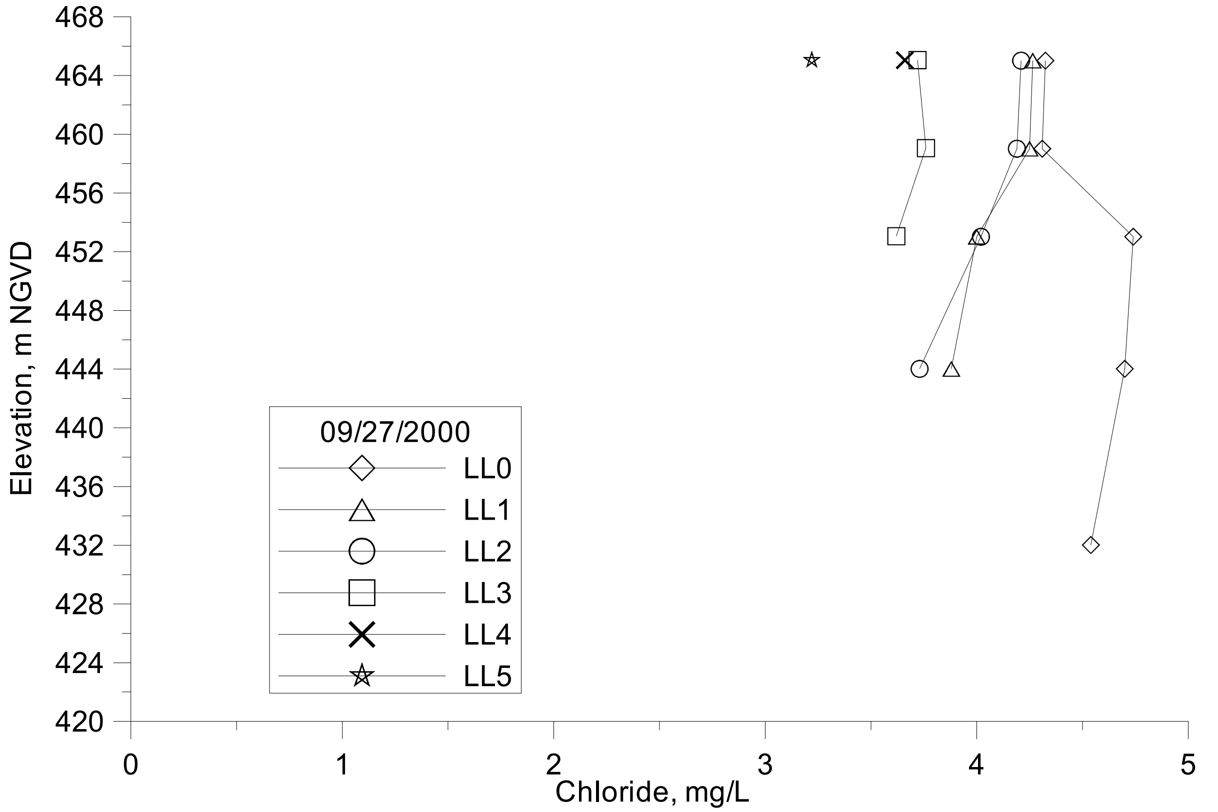

468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
DOC, mg/L

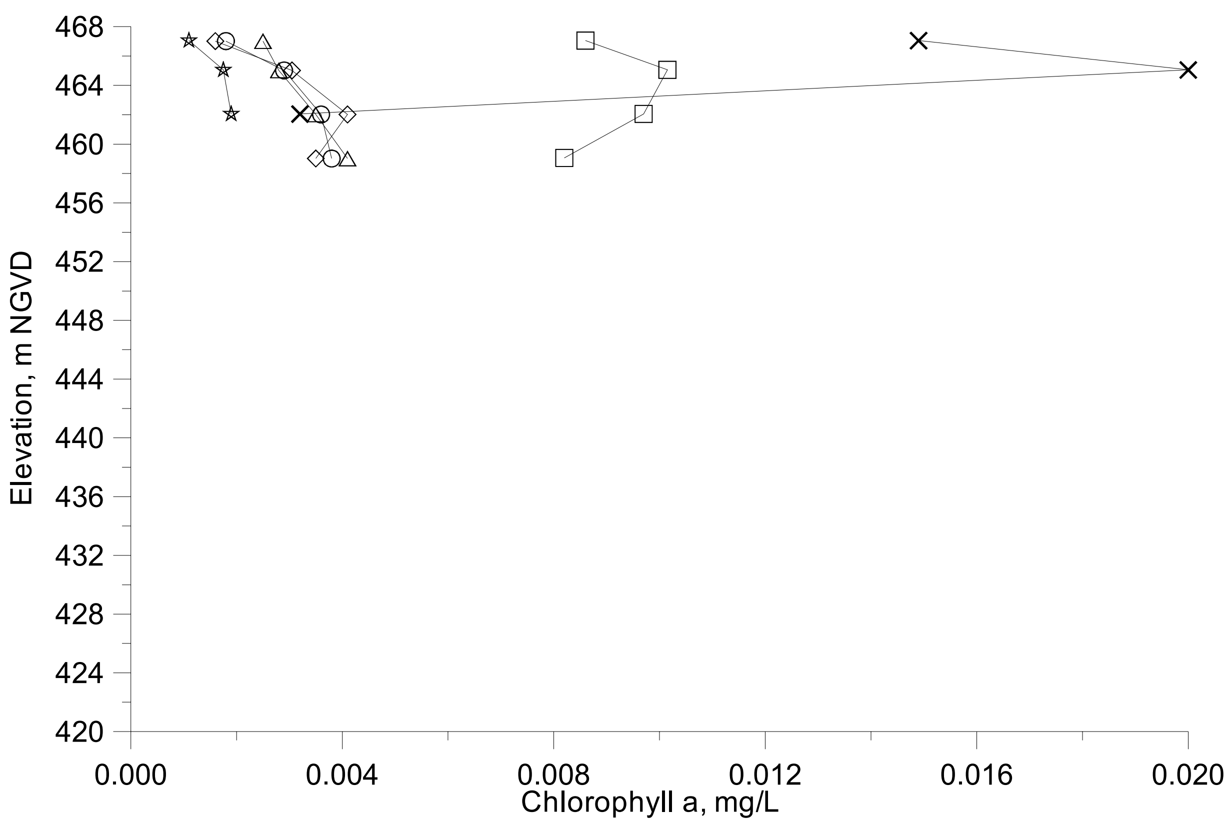


09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5
Elevation, m NGVD
ALK, mg/L

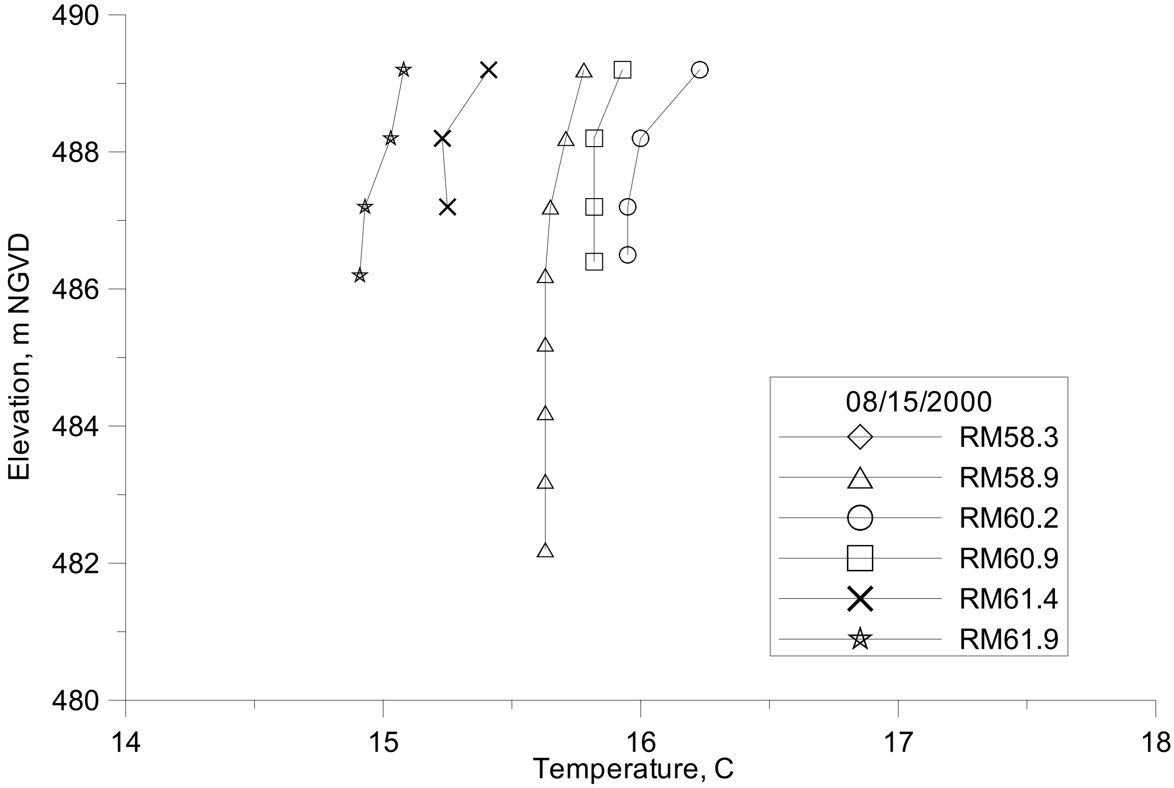


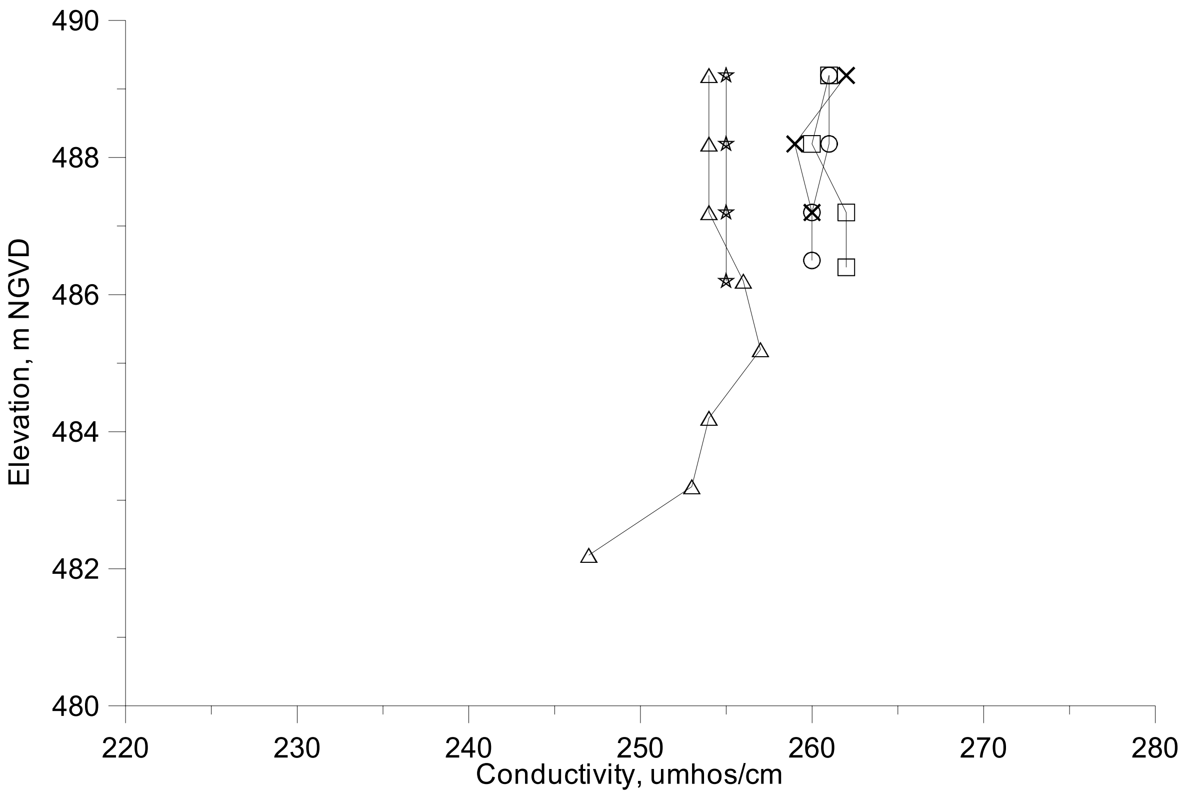
Elevation, m NGVD
TDS, mg/L

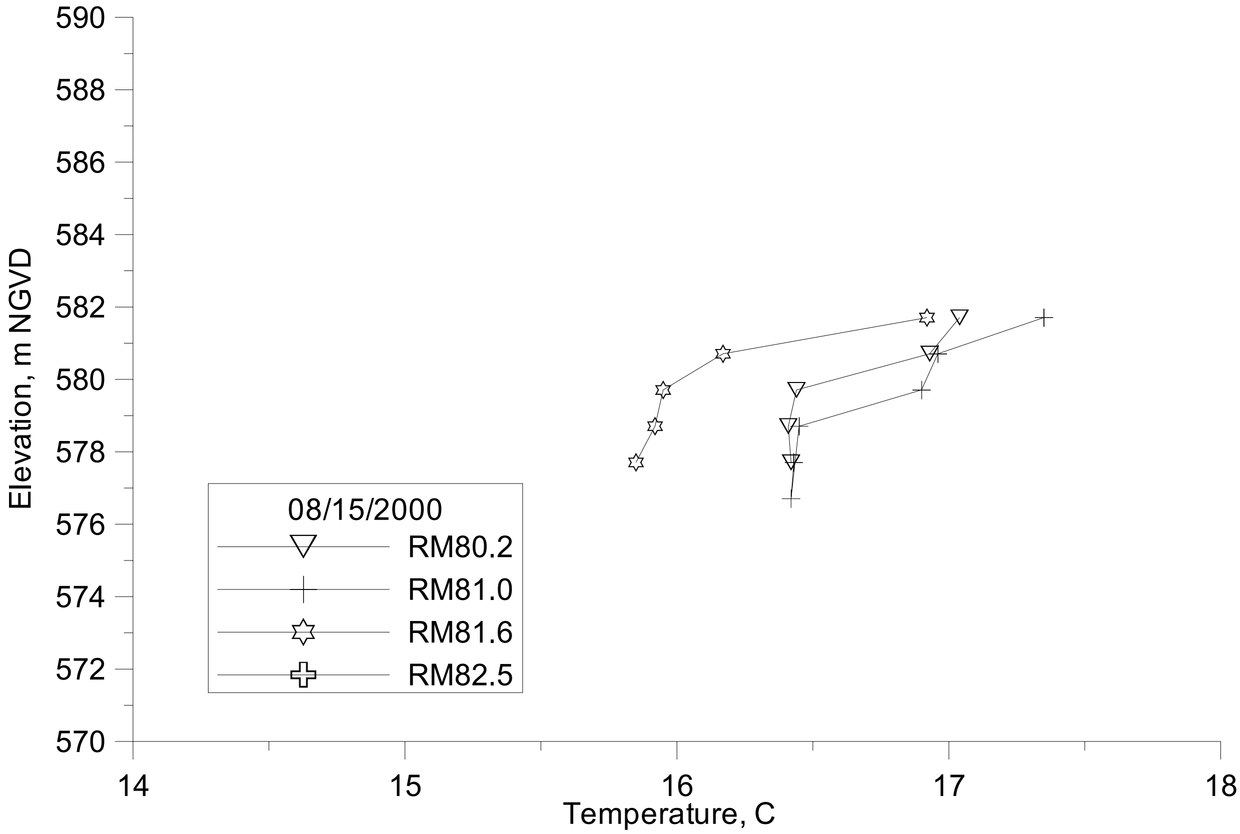

468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0
1
2
3
4
5
Chloride, mg/L
09/27/2000
LL0
LL1
LL2
LL3
LL4
LL5

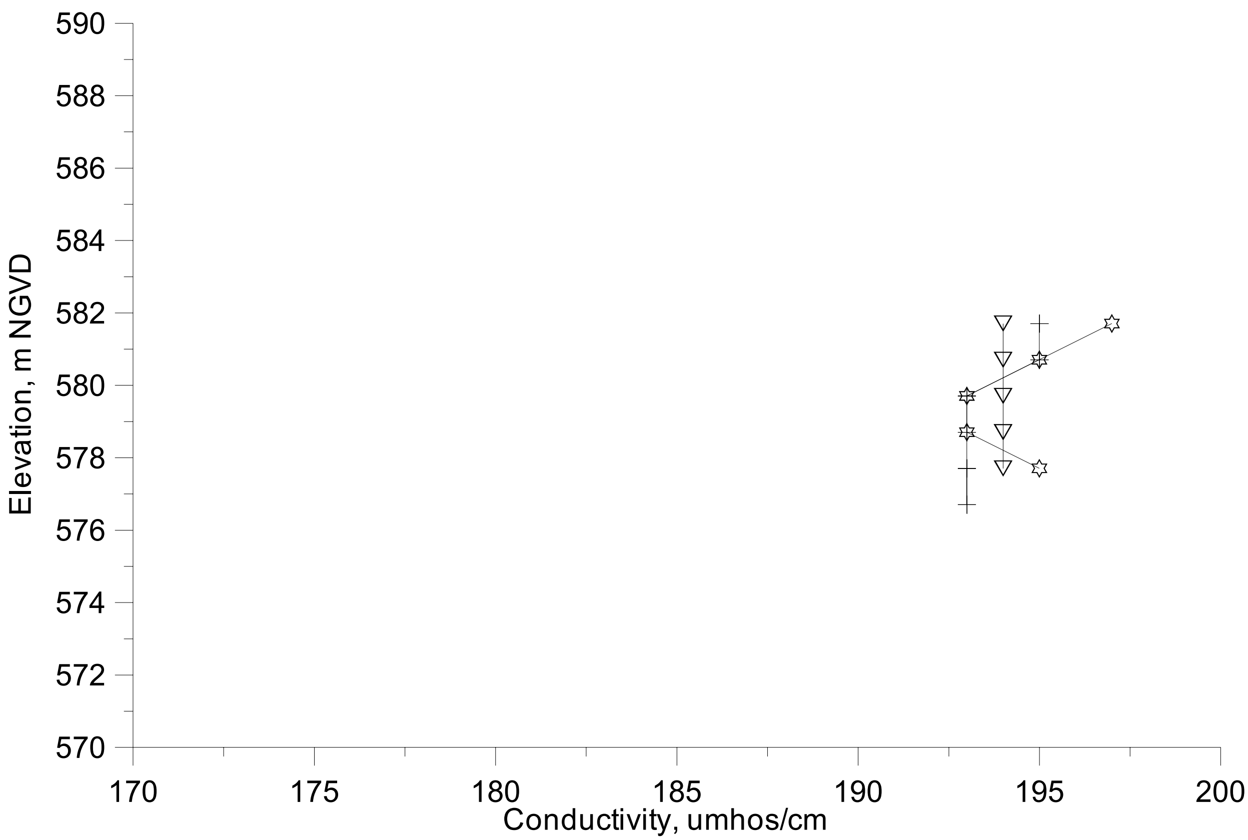

468
464
460
456
452
448
444
440
436
432
428
424
420
Elevation, m NGVD
0.000
0.004
0.008
0.012
0.016
0.020
Chlorophyll a, mg/L

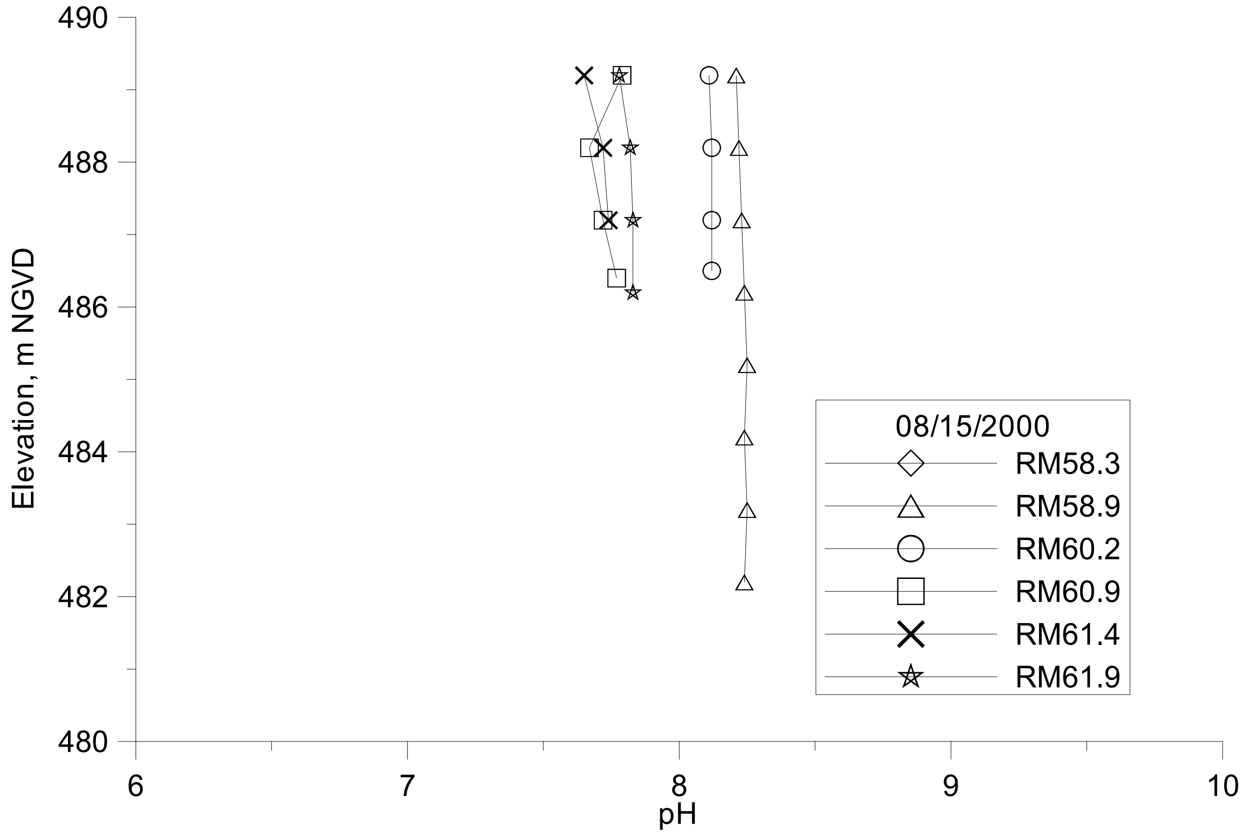
Appendix E: 2000 Spokane River Vertical Profiles



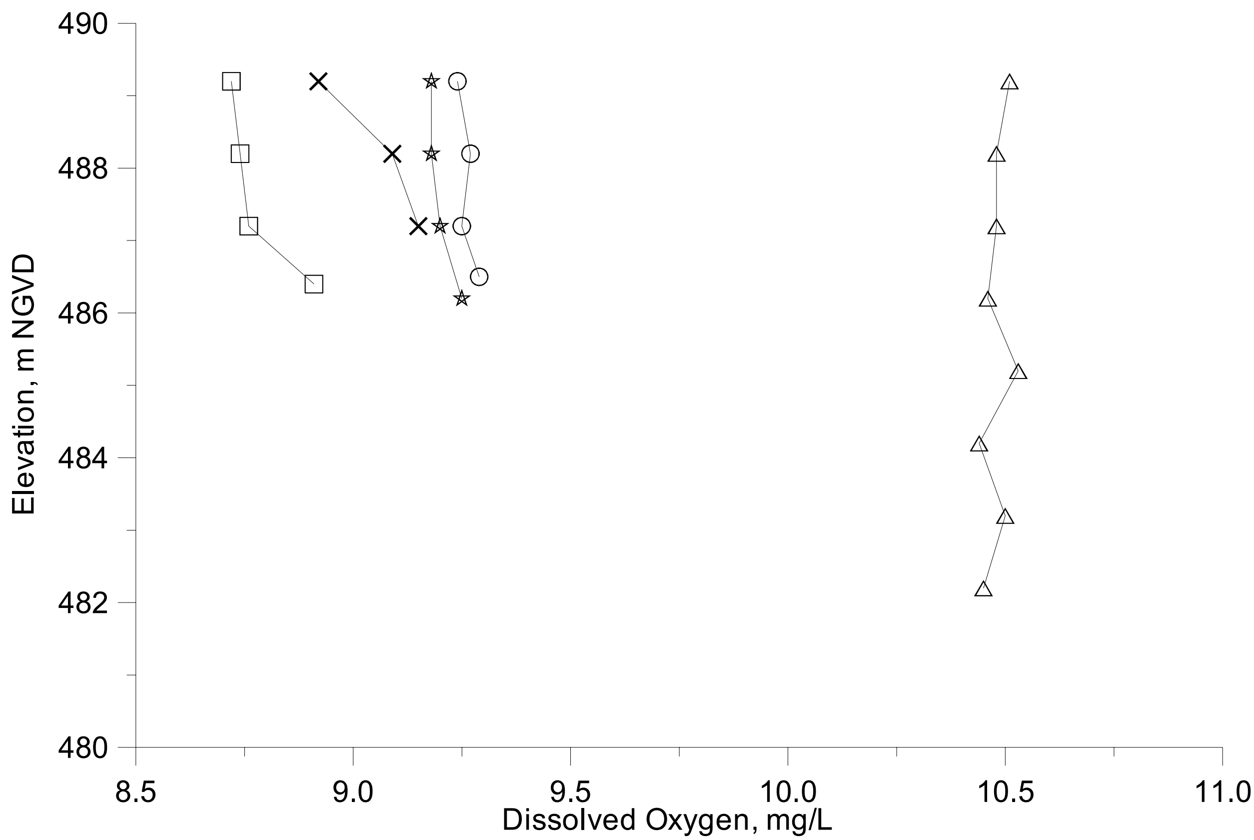



590
588
586
584
582
580
578
576
574
572
570
Elevation, m NGVD
08/15/2000
RM80.2
RM81.0
RM81.6
RM82.5
14
15
16
17
18
Temperature, C

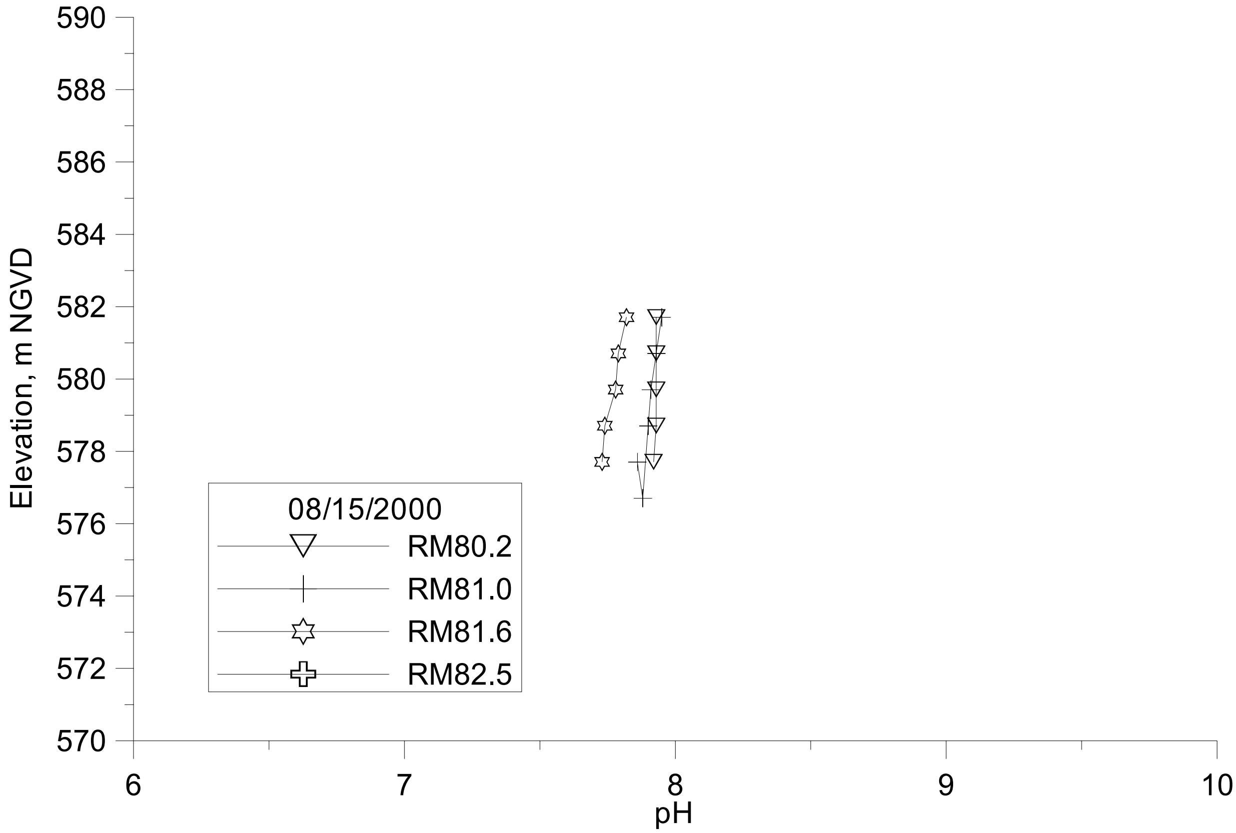

590
588
586
584
582
580
578
576
574
572
570
Elevation, m NGVD
170
175
180
185
190
195
200
Conductivity, umhos/cm

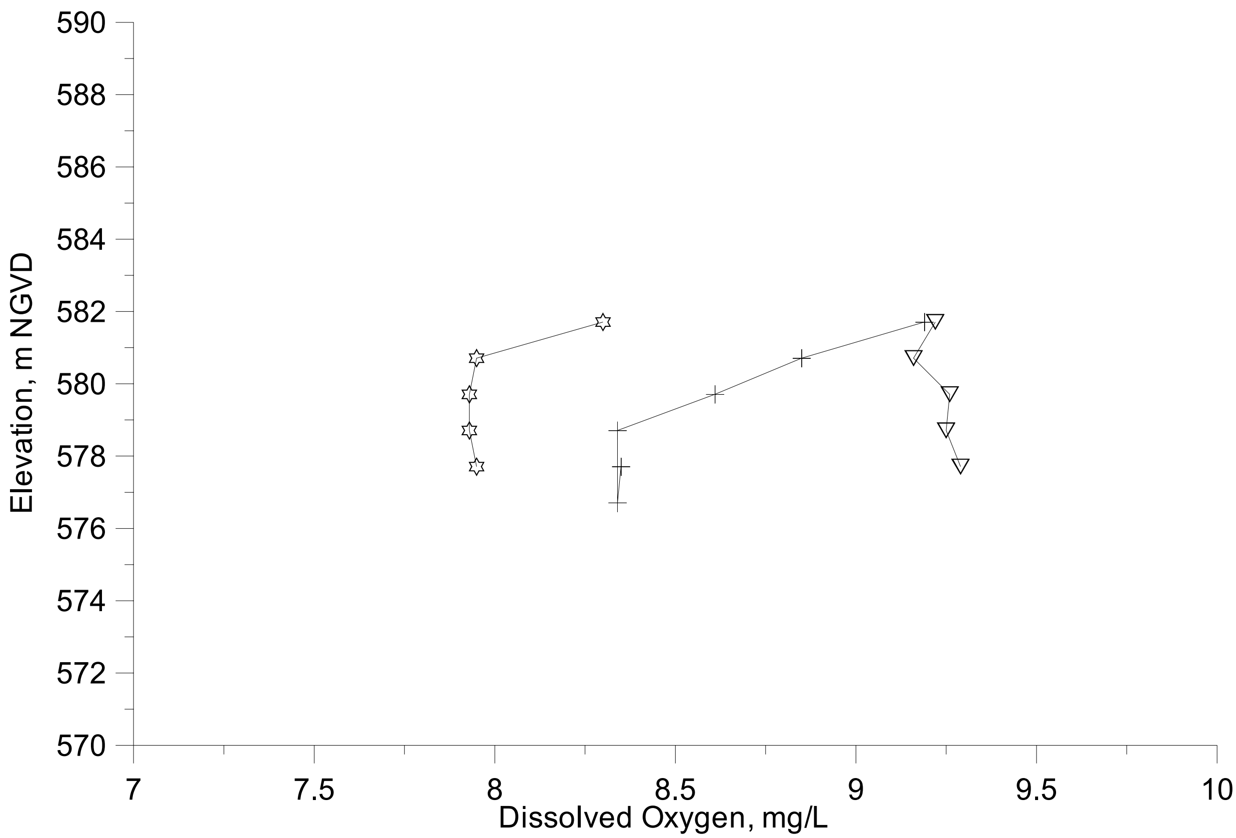


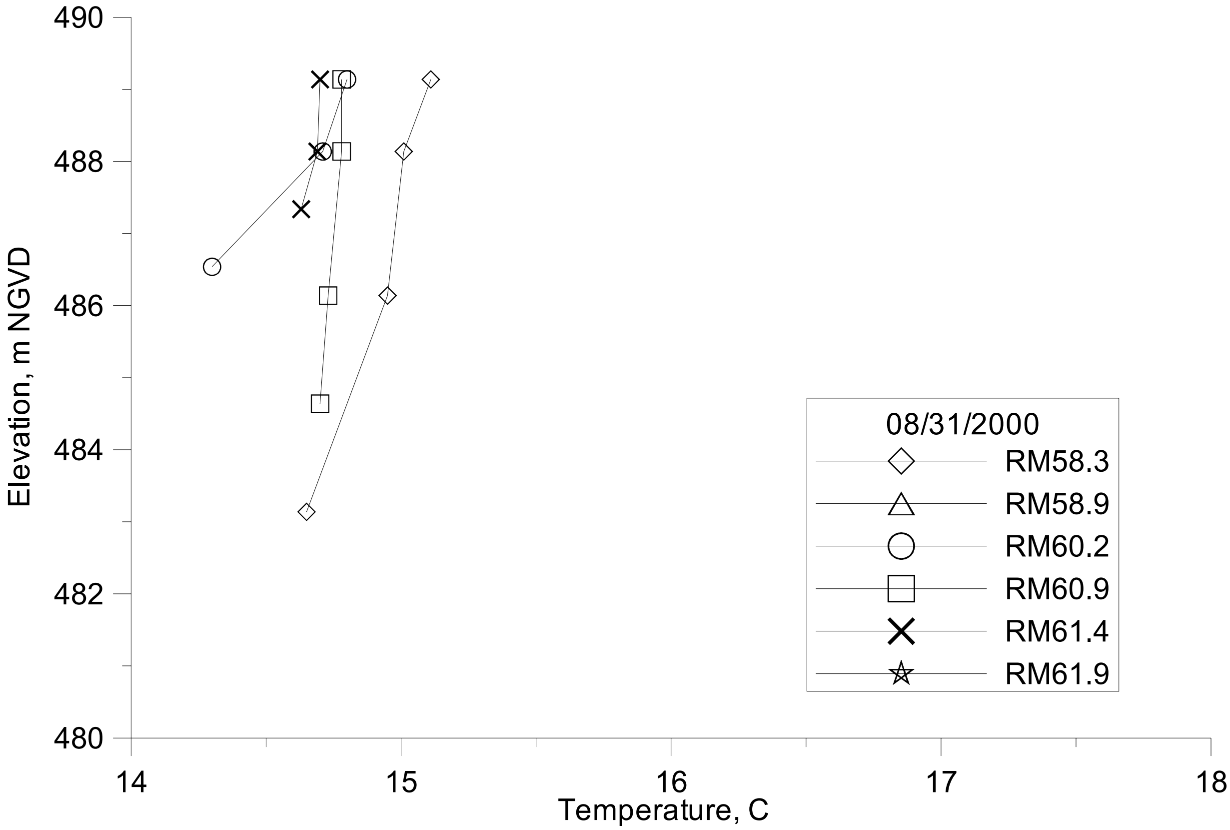
490
488
486
484
482
480
Elevation, m NGVD
6
7
8
9
10
pH
08/15/2000
RM58.3
RM58.9
RM60.2
RM60.9
RM61.4
RM61.9

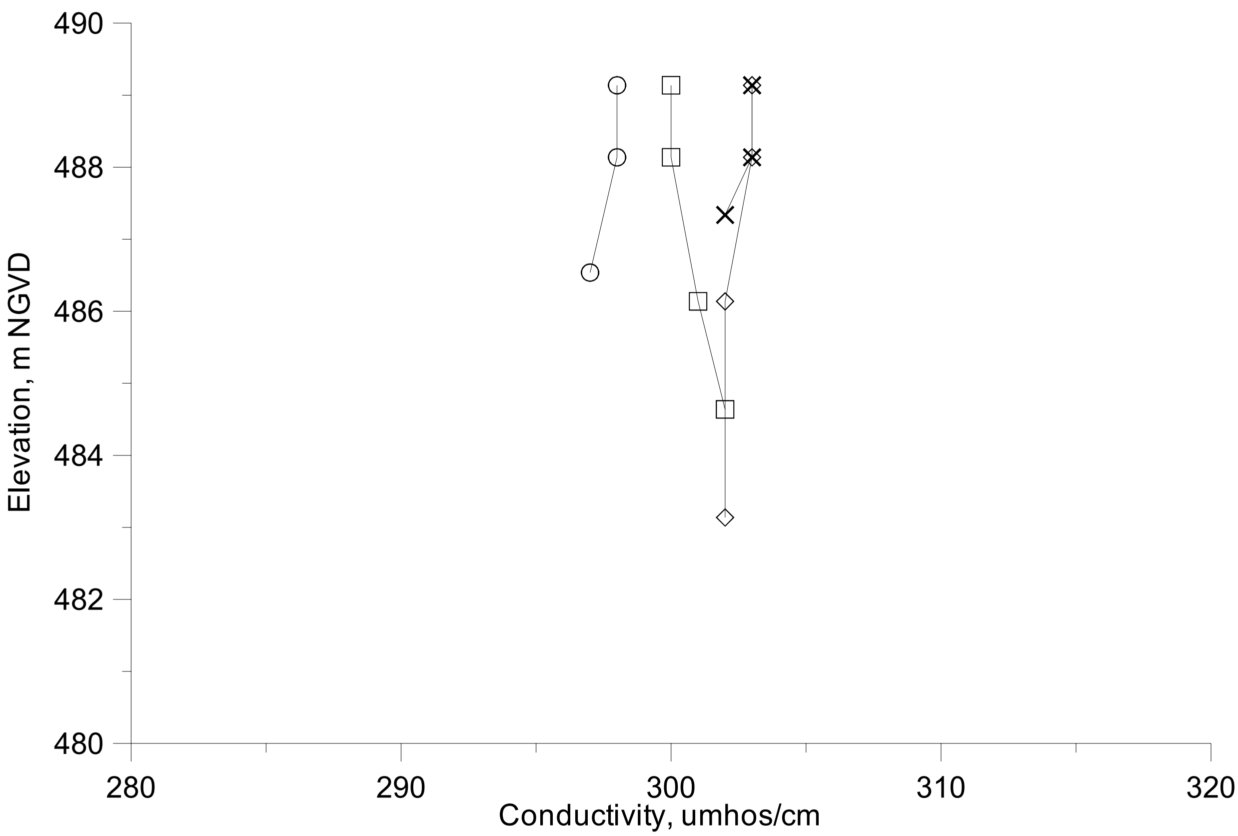


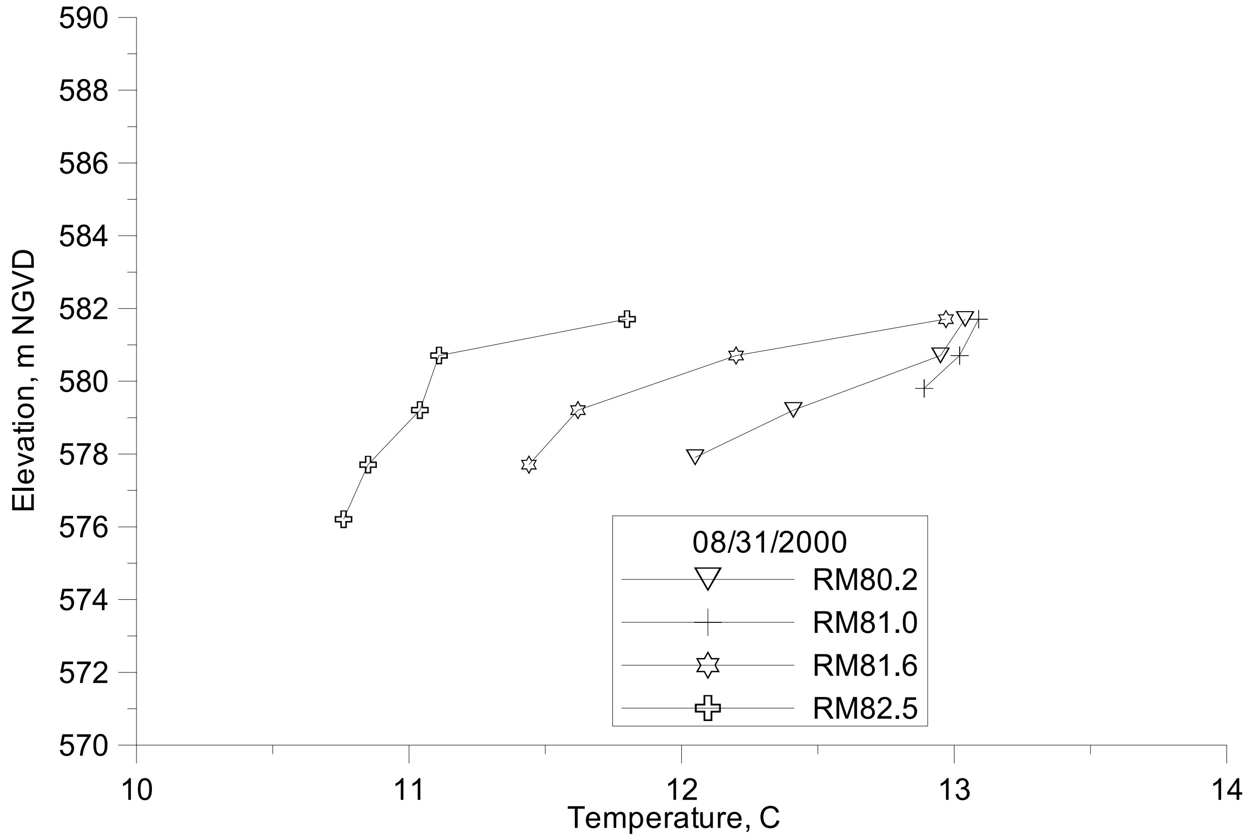
490
488
486
484
482
480
Elevation, m NGVD
8.5
9.0
9.5
10.0
10.5
11.0
Dissolved Oxygen, mg/L

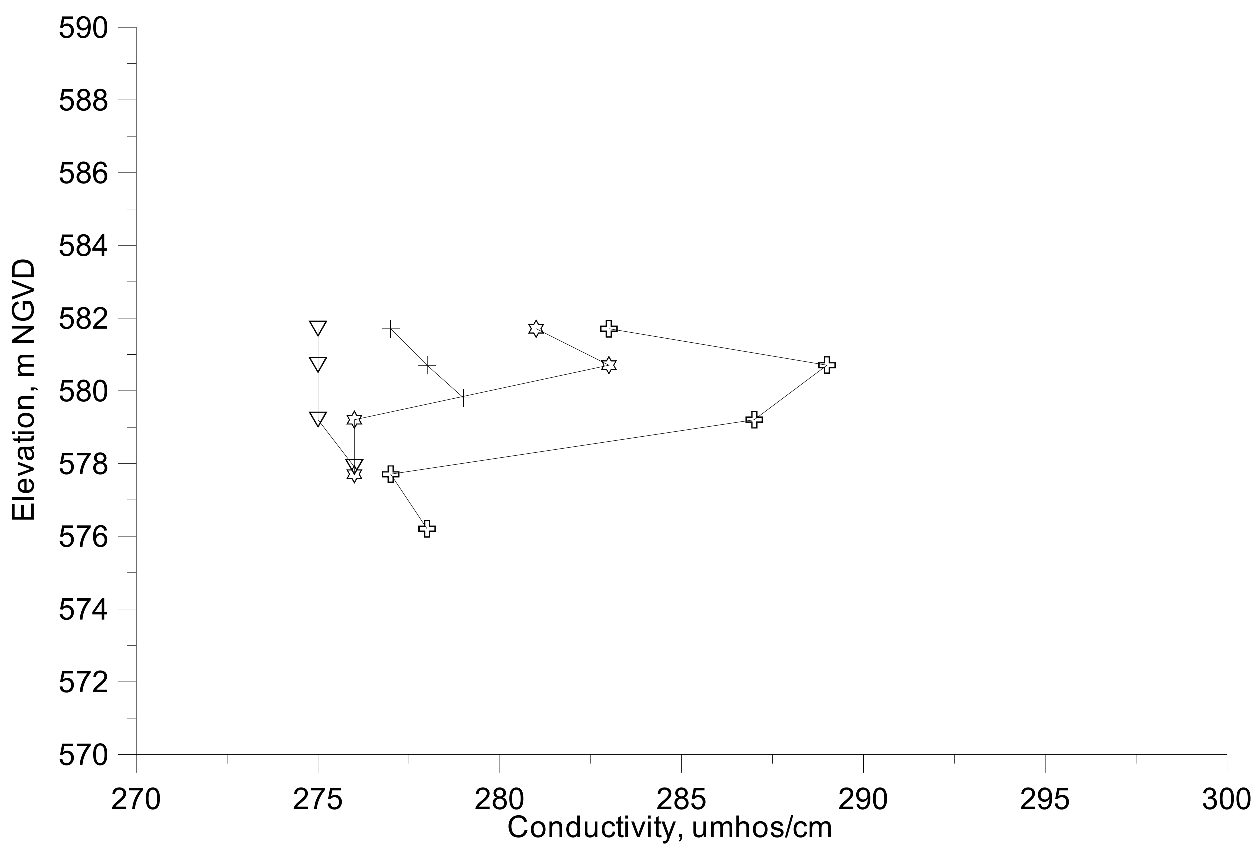

590
588
586
584
582
580
578
576
574
572
570
Elevation, m NGVD
6
7
8
9
10
pH
08/15/2000
RM80.2
RM81.0
RM81.6
RM82.5

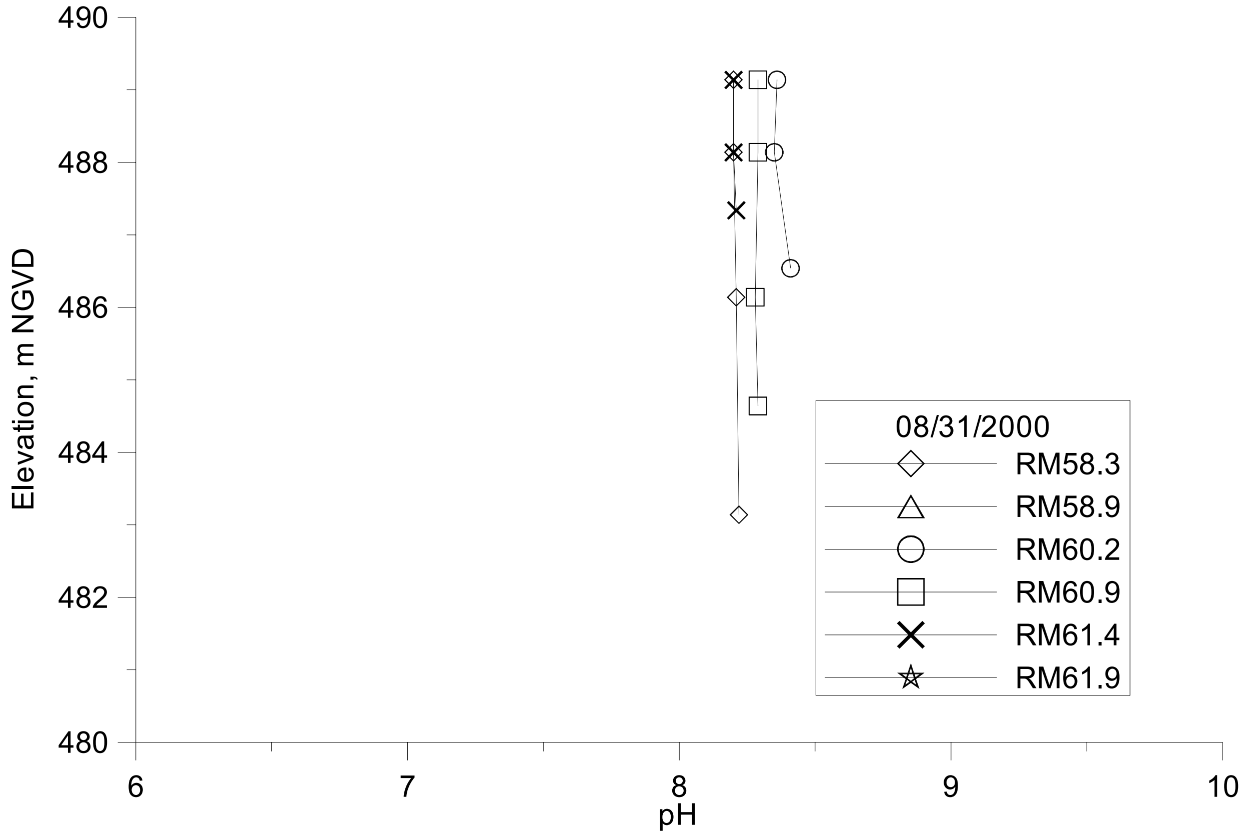

590
588
586
584
582
580
578
576
574
572
570
Elevation, m NGVD
7
7.5
8
8.5
9
9.5
10
Dissolved Oxygen, mg/L

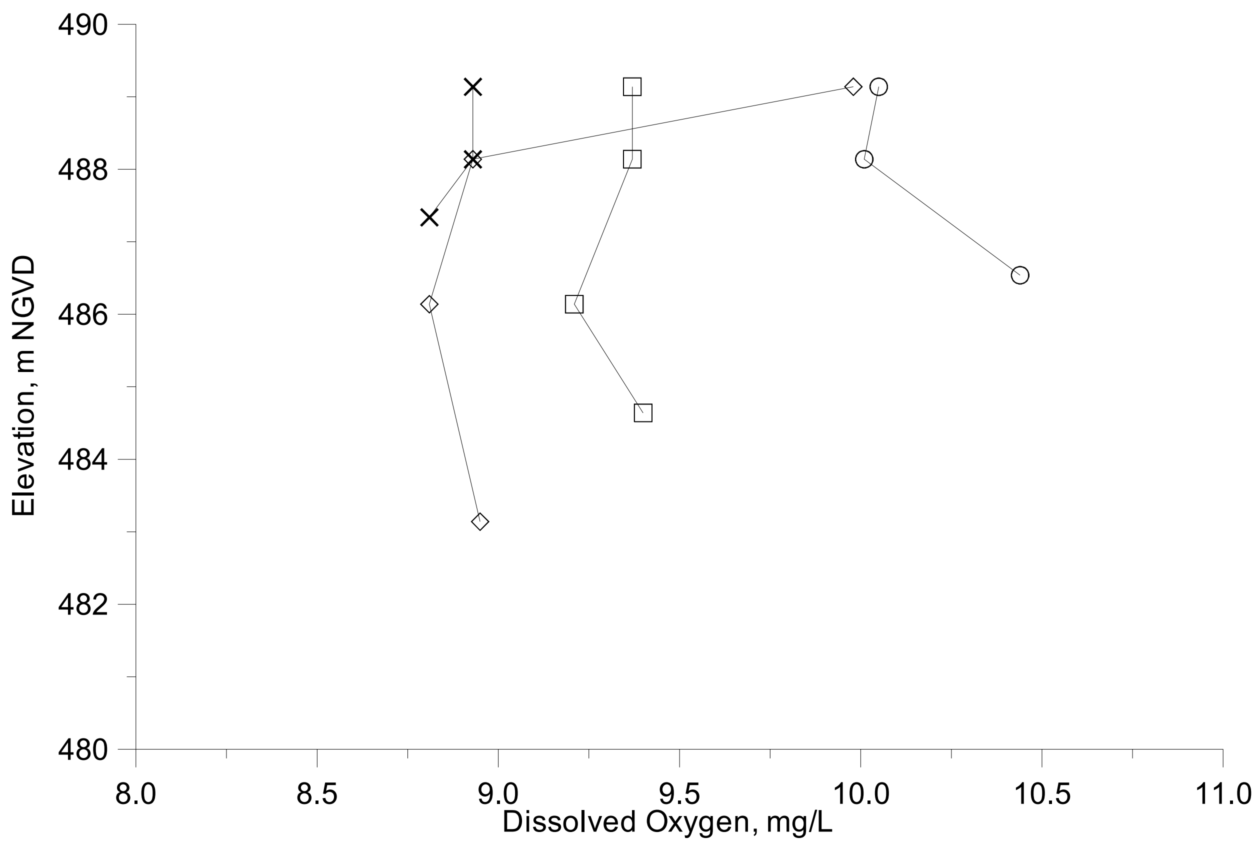

490
488
486
484
482
480
Elevation, m NGVD
14
15
16
17
18
Temperature, C
08/31/2000
RM58.3
RM58.9
RM60.2
RM60.9
RM61.4
RM61.9

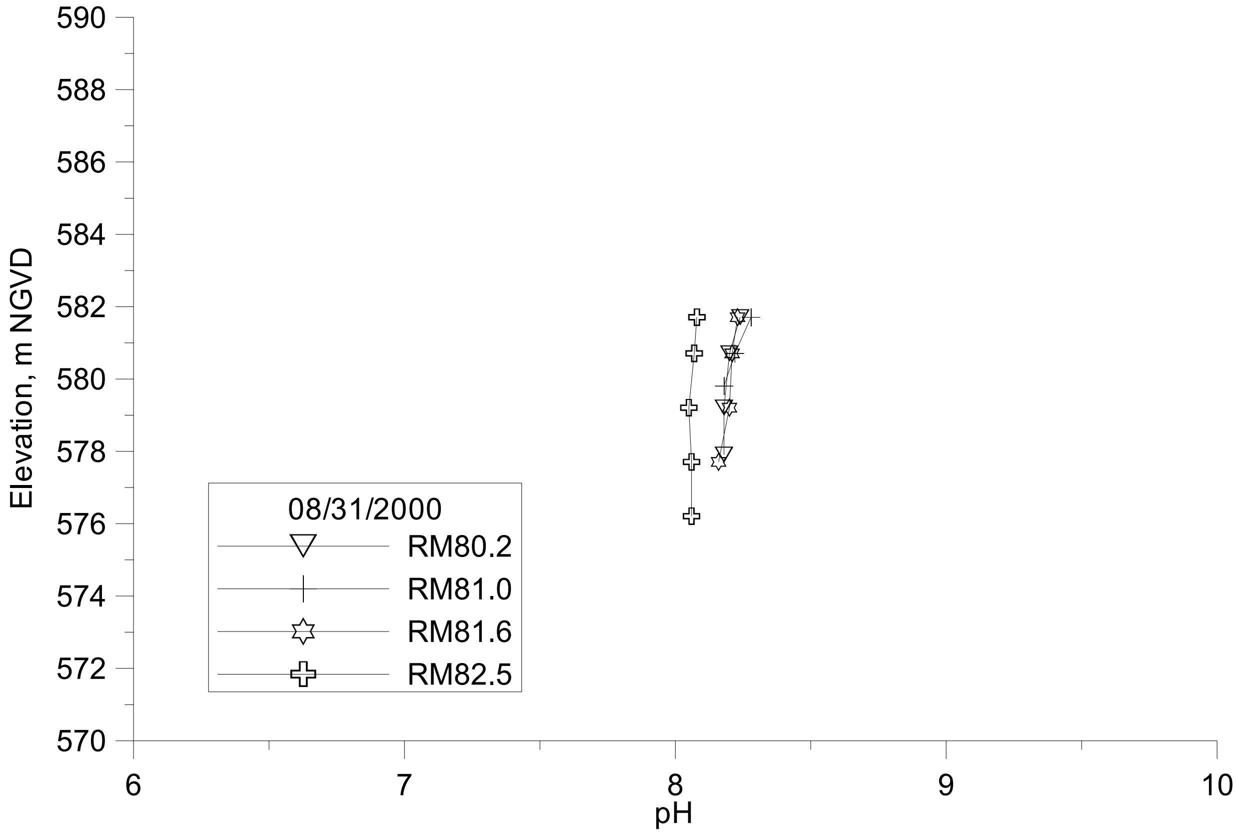

490
488
486
484
482
480
Elevation, m NGVD
280
290
300
310
320
Conductivity, umhos/cm

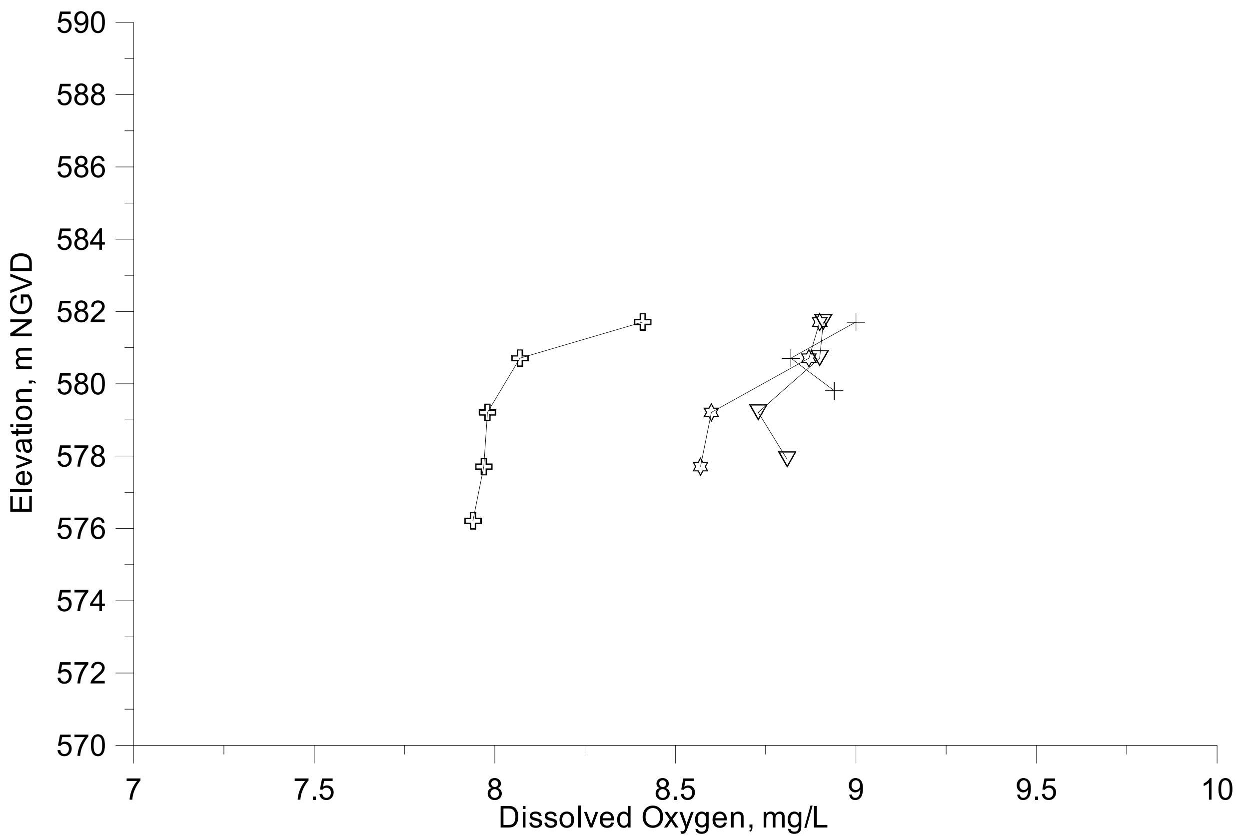

Elevation, m NGVD
Temperature, C
08/31/2000
RM80.2
RM81.0
RM81.6
RM82.5
590
588
586
584
582
580
578
576
574
572
570
10
11
12
13
14


Elevation, m NGVD
Conductivity, umhos/cm
590
588
586
584
582
580
578
576
574
572
570
270
275
280
285
290
295
300

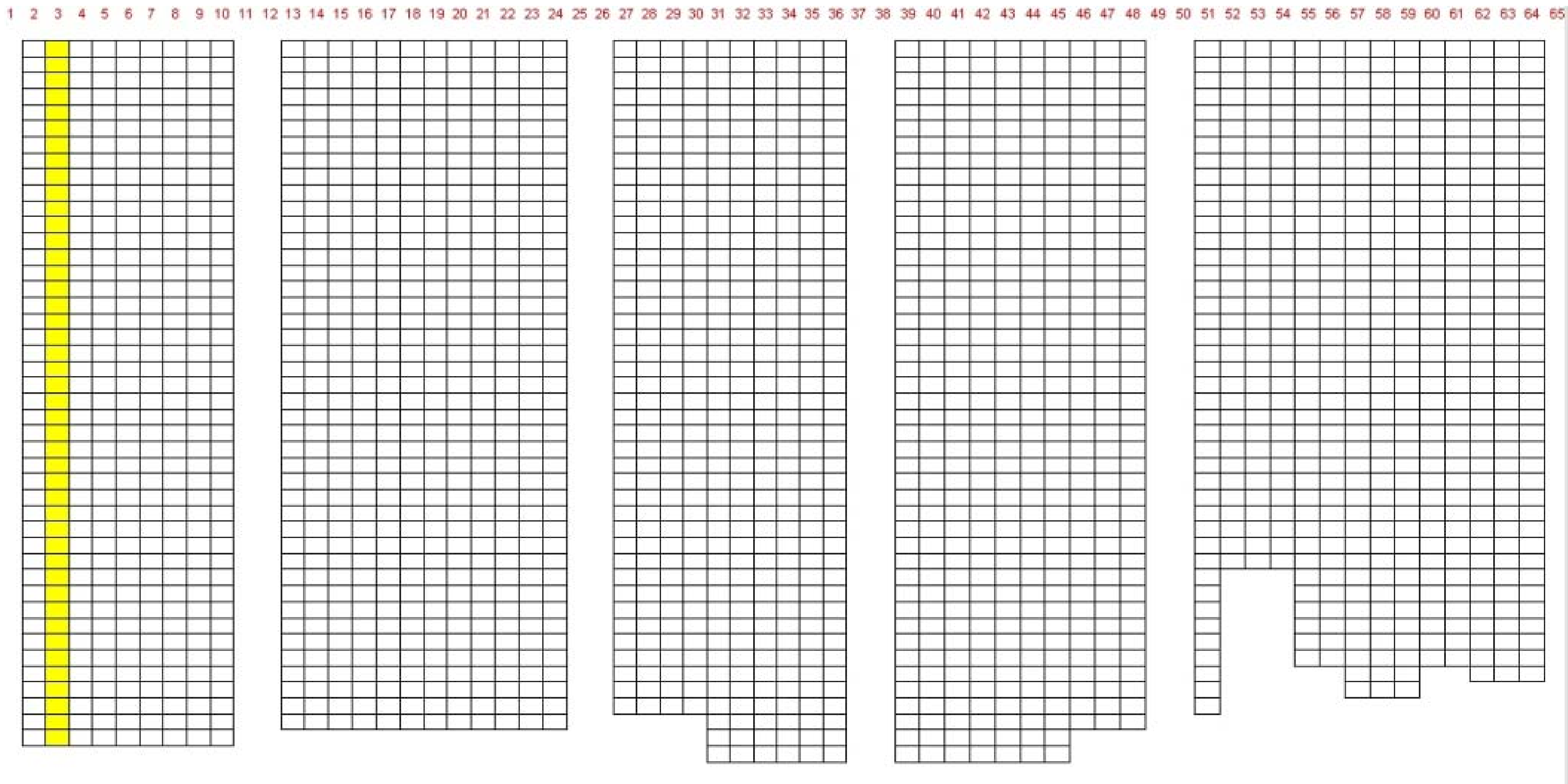

490
488
486
484
482
480
Elevation, m NGVD
6
7
8
9
10
pH
08/31/2000
RM58.3
RM58.9
RM60.2
RM60.9
RM61.4
RM61.9

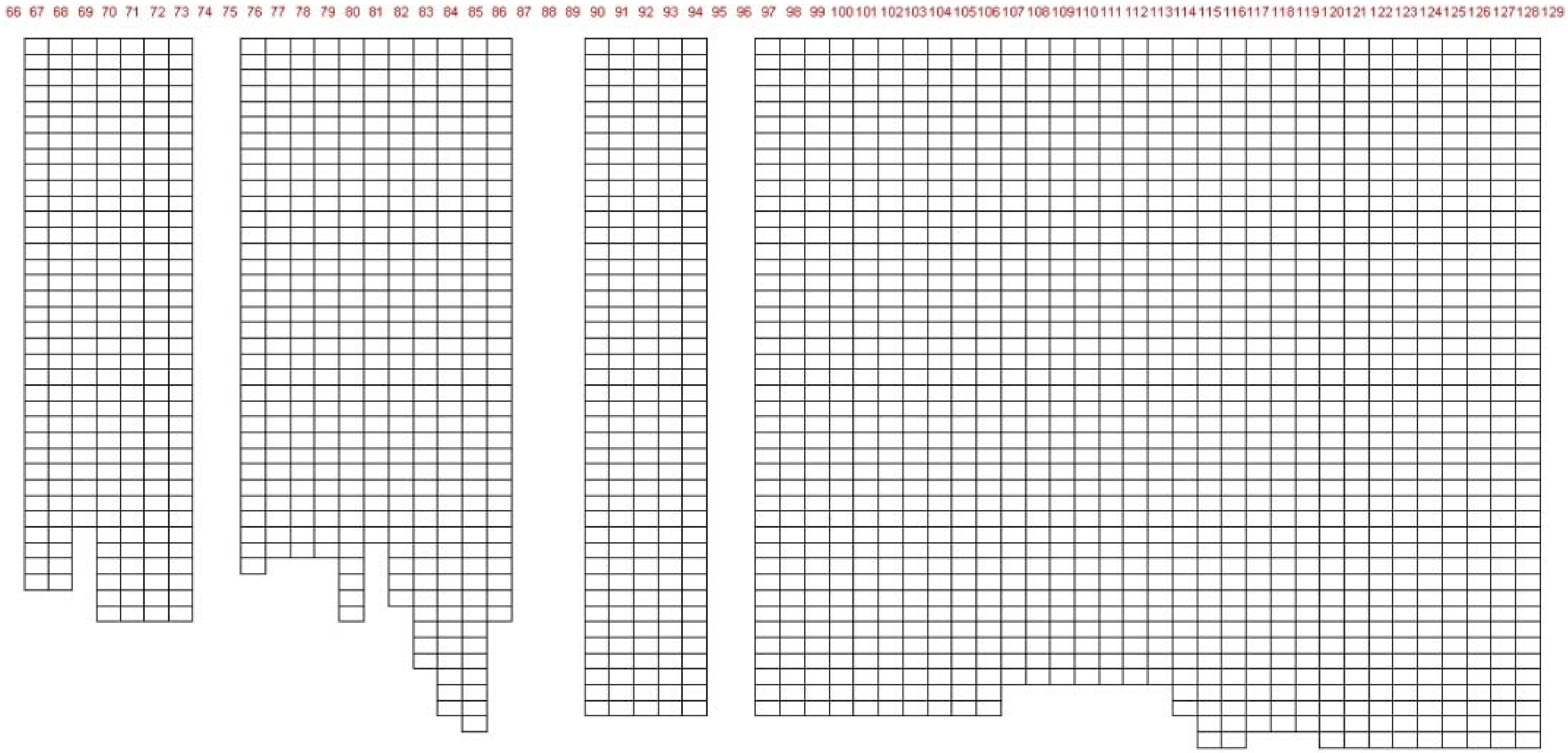

490
488
486
484
482
480
Elevation, m NGVD
8.0
8.5
9.0
9.5
10.0
10.5
11.0
Dissolved Oxygen, mg/L

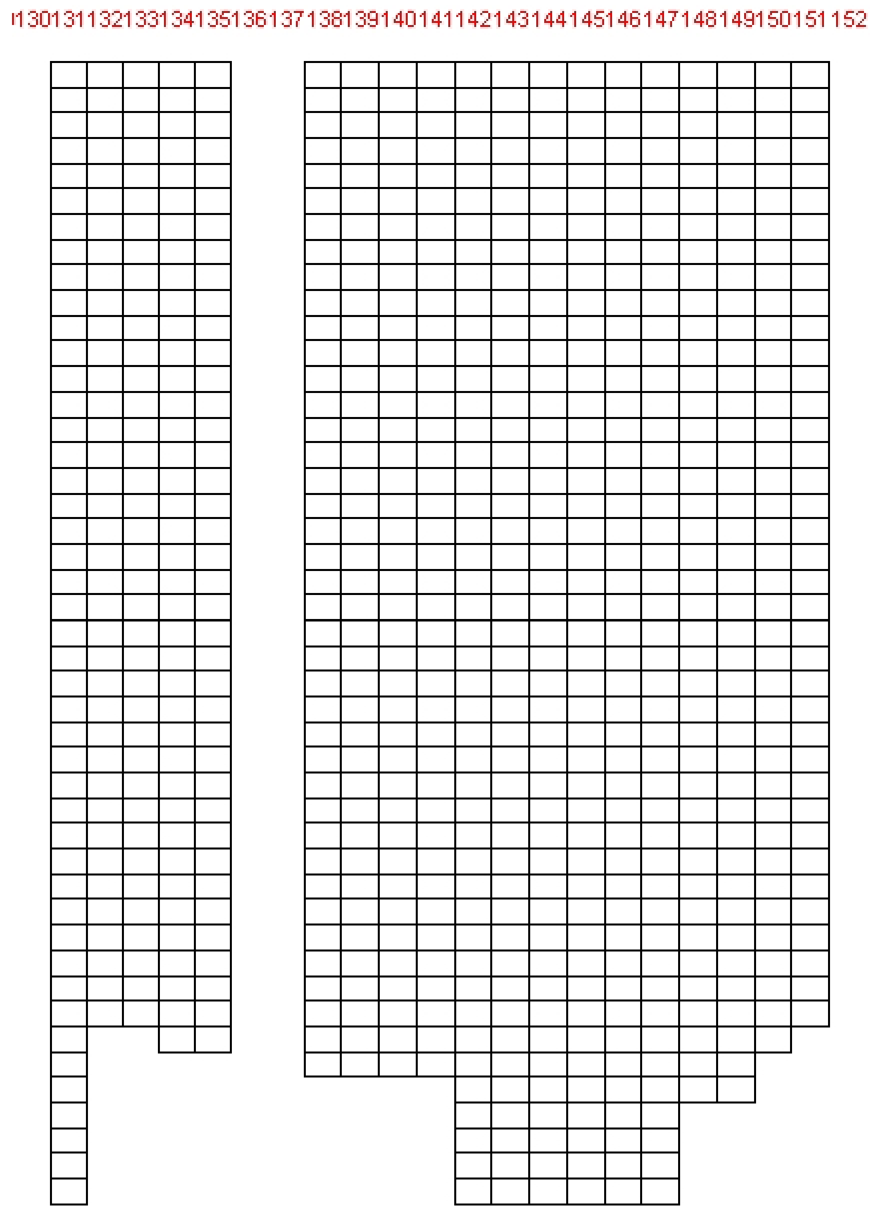

590
588
586
584
582
580
578
576
574
572
570
Elevation, m NGVD
6
7
8
9
10
pH
08/31/2000
RM80.2
RM81.0
RM81.6
RM82.5

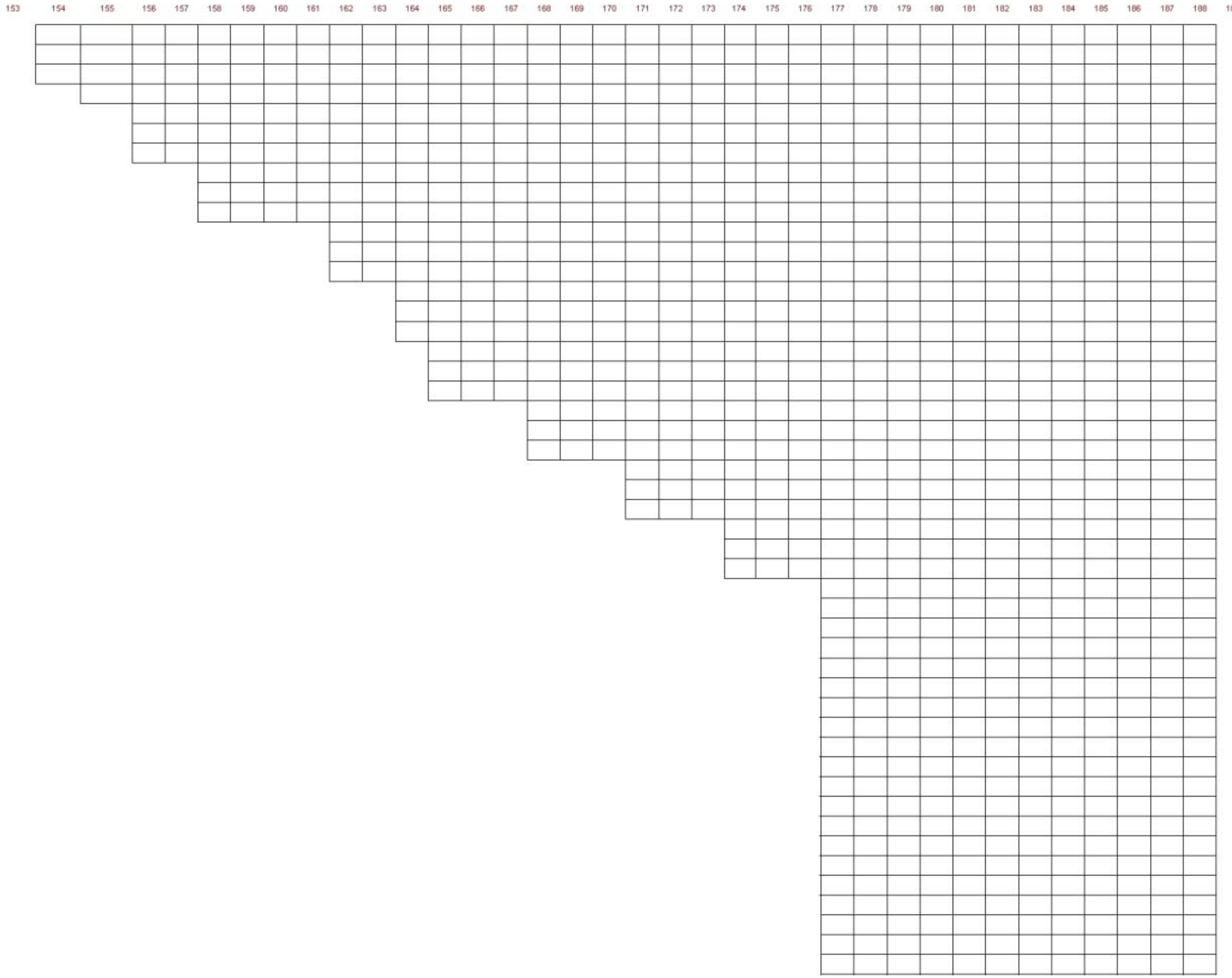

590
588
586
584
582
580
578
576
574
572
570
Elevation, m NGVD
7
7.5
8
8.5
9
9.5
10
Dissolved Oxygen, mg/L

Appendix F: Model Grid x-z plots




66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129


130131132133134135136137138139140141142143144145146147148149150151152


153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189