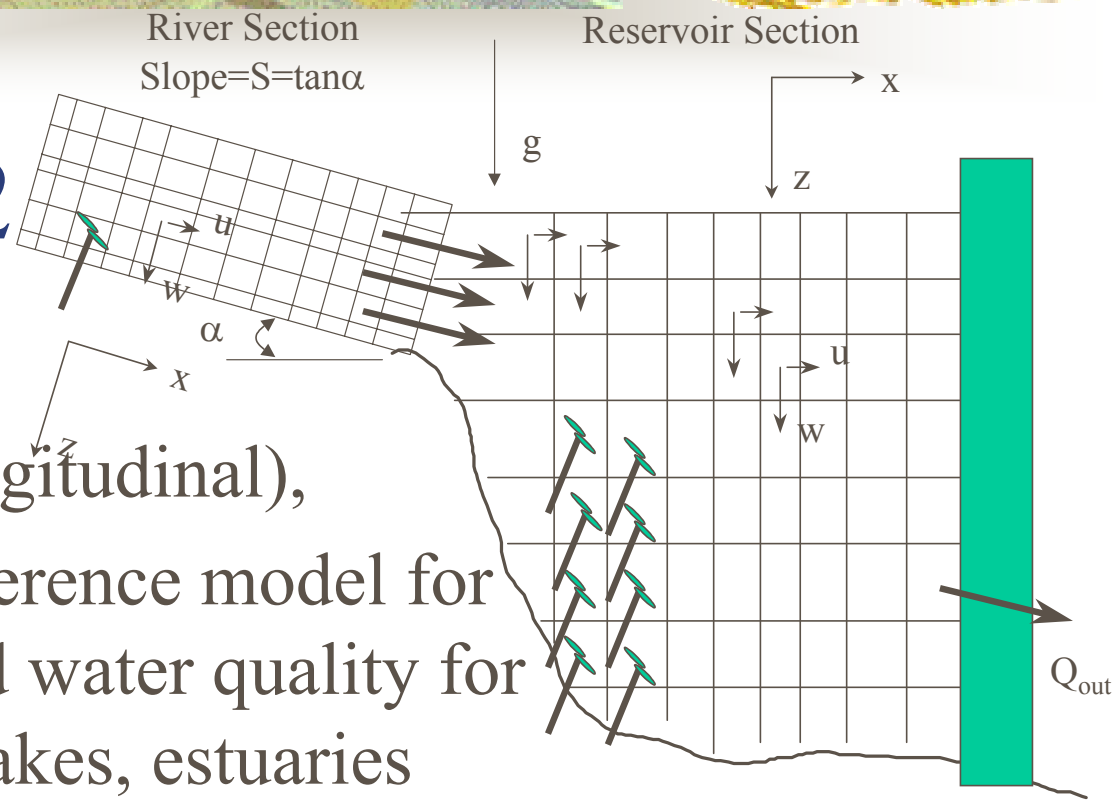
The Spokane River – Long Lake System Model

Chris Berger, Scott Wells, Rob Annear, Tom Cole
Department of Civil and Environmental Engineering
Portland State University and ACOE WES

Spokane River Model

- Review of model chosen – CE-QUAL-W2
- Review of earlier model calibration 1991 and 2000
- Results of current calibration 2001
- Update on enlarging the system model to Lake Coeur D'Alene

CE-QUAL-W2

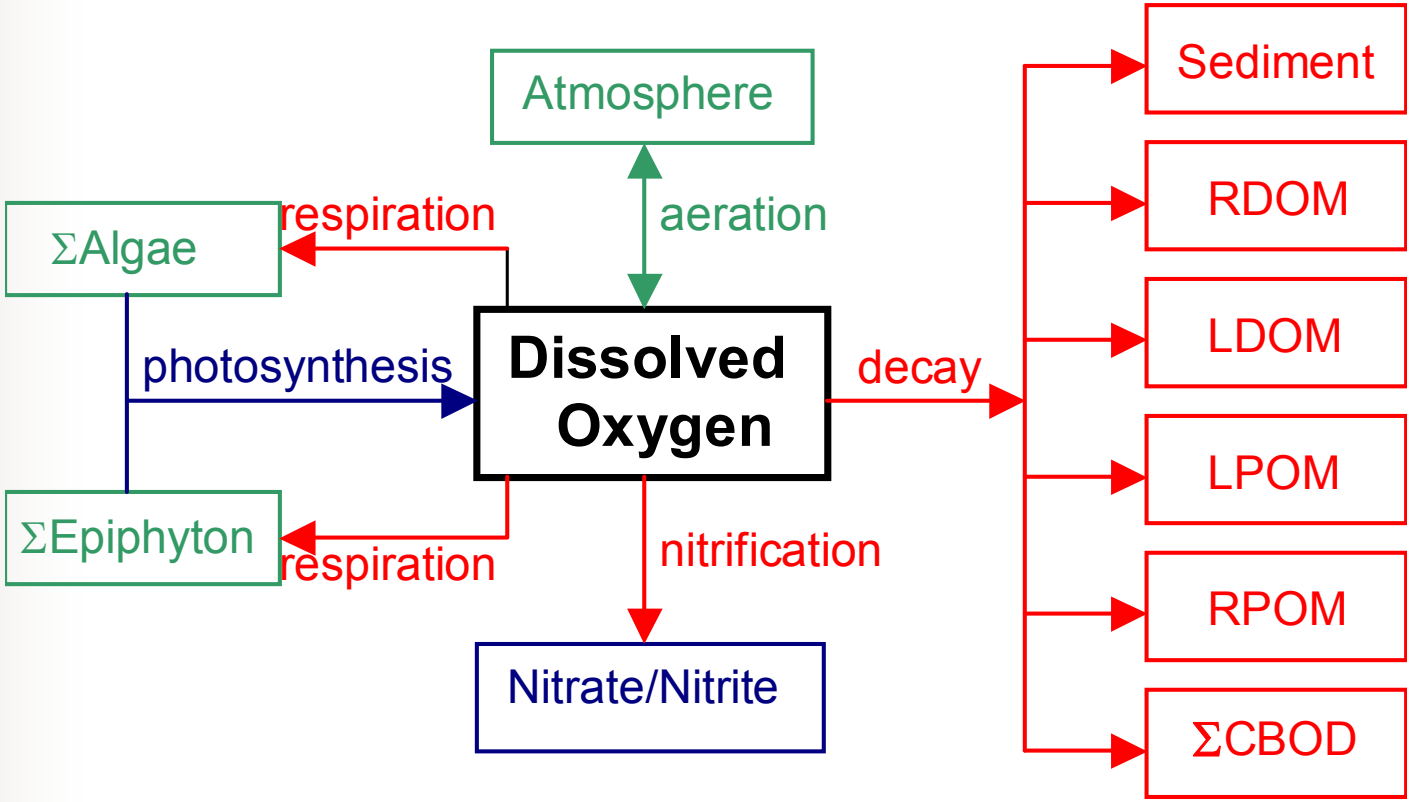


- A 2-D (vertical-longitudinal), unsteady finite difference model for hydrodynamics and water quality for rivers, reservoirs, lakes, estuaries supported by Waterways Experiment Station, ACOE
  - Applied to over 400 reservoir/river/lake/estuary systems in USA and abroad

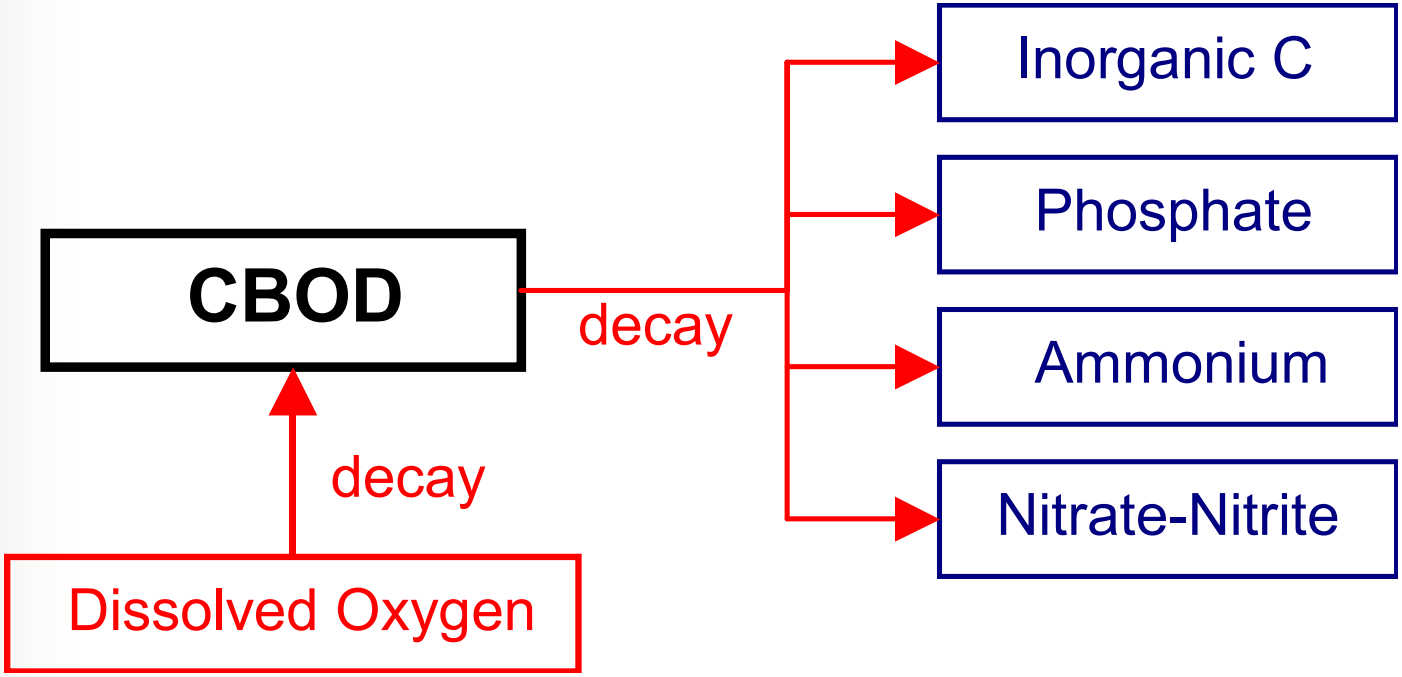
CE-QUAL-W2 Modeling Capabilities

- Temperature, velocity (U, W), Water surface elevation
- TDS
- # Arbitrary Constituents (such as bacteria, tracer, water age, toxics)
- # Inorganic suspended solids groups
- labile and refractory dissolved organic matter groups
- Dissolved and particulate silica
- Total inorganic carbon
- labile and refractory particulate organic matter fractions
- # different algal groups
- # different periphyton groups
- NH_4-N
- PO_4-P
- NO_3-N+NO_2-N
- Iron
- # CBOD groups
- Alkalinity
- pH and carbonate system (HCO_3, CO_3, H_2CO_3)
- Sediment Model

Example: Dissolved Oxygen Modeling Algorithm



Example: CBOD Modeling Algorithm

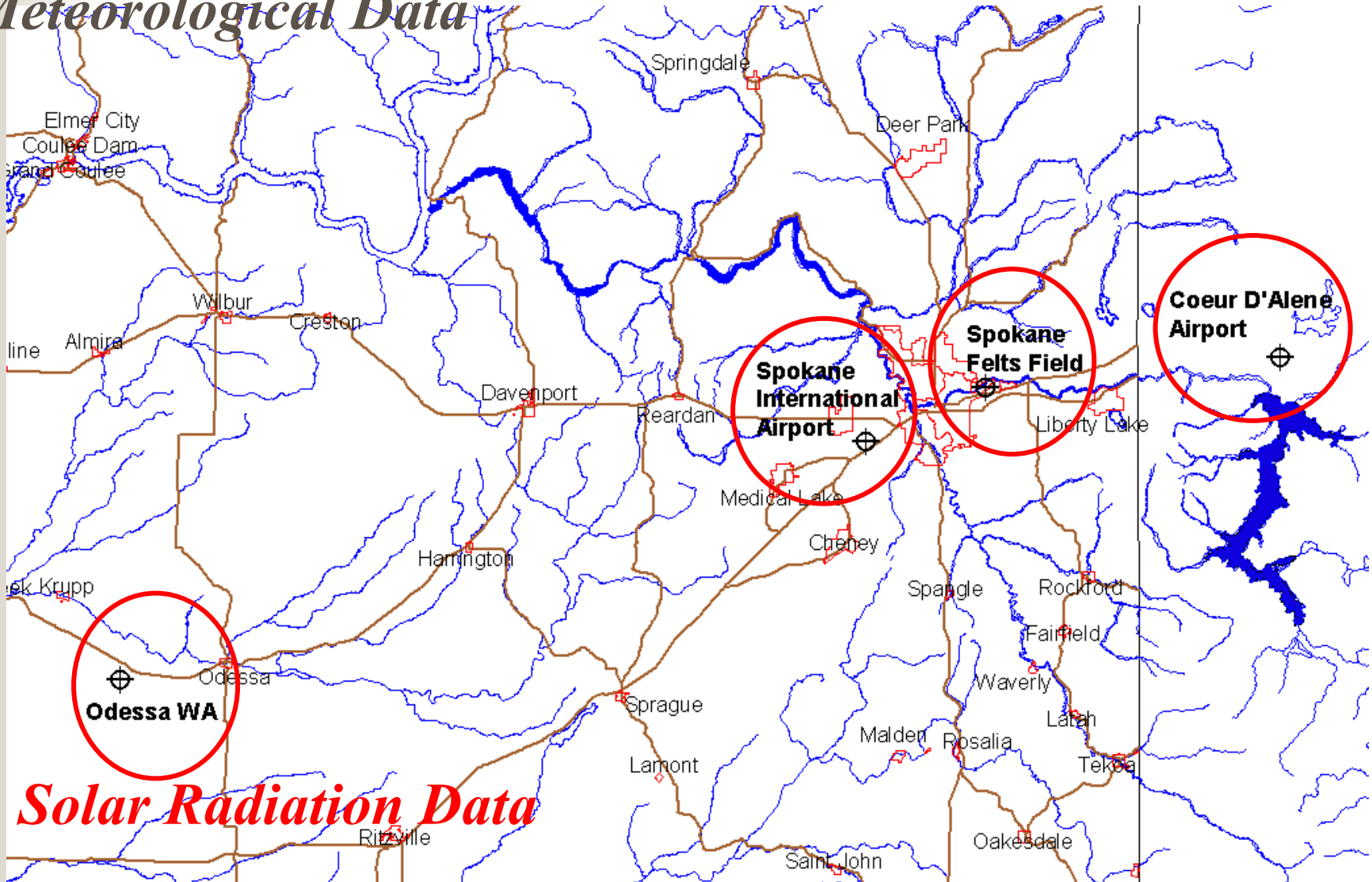


Data Requirements: CE-QUAL-W2

- Meteorological data (air temp, dew point, wind speed, wind direction, cloud cover, solar radiation)
- Inflow data: flow rate, temperature and water quality
- Bathymetry data

Model Development

Meteorological Data

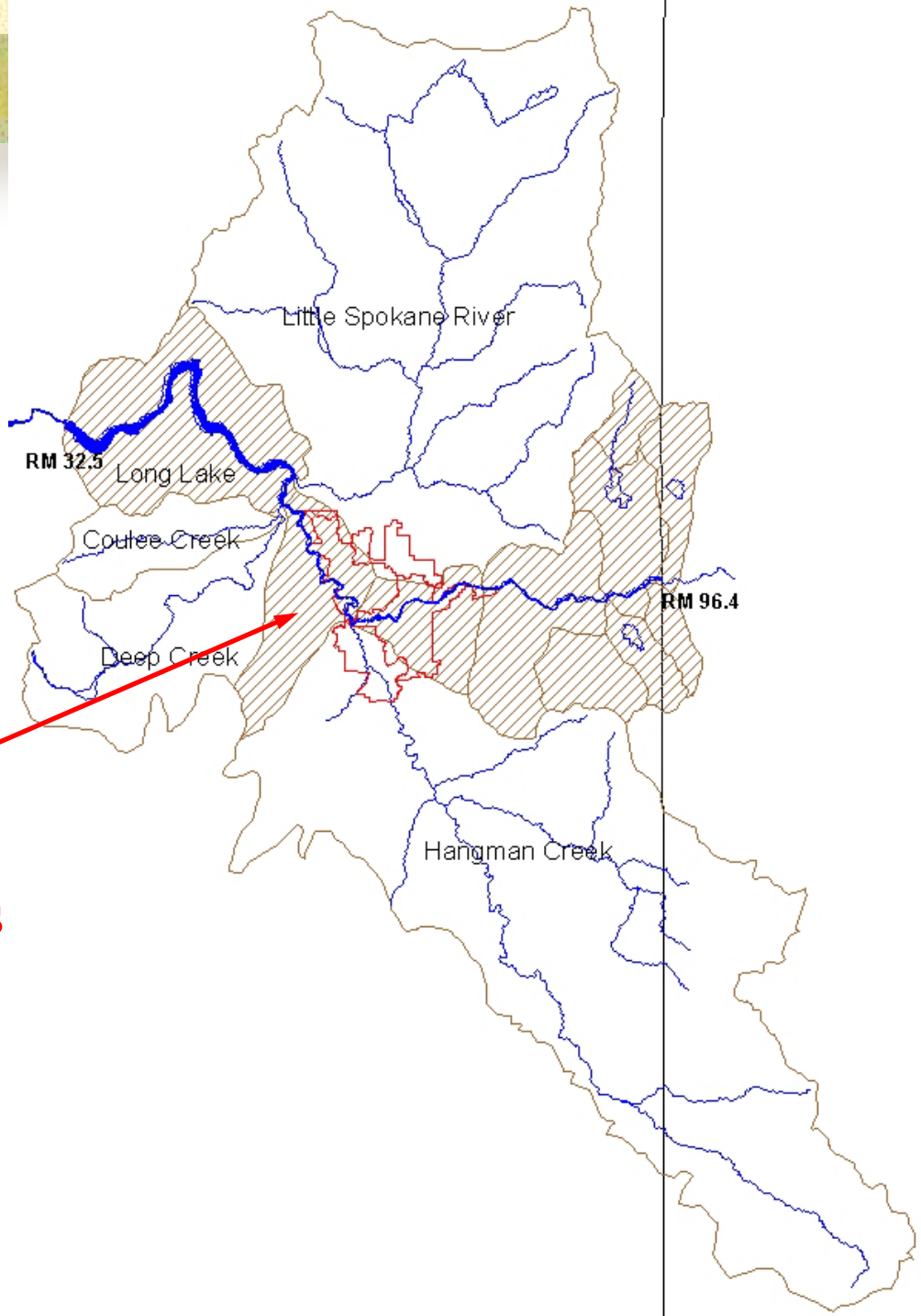


Solar Radiation Data

Model Development

Inflows

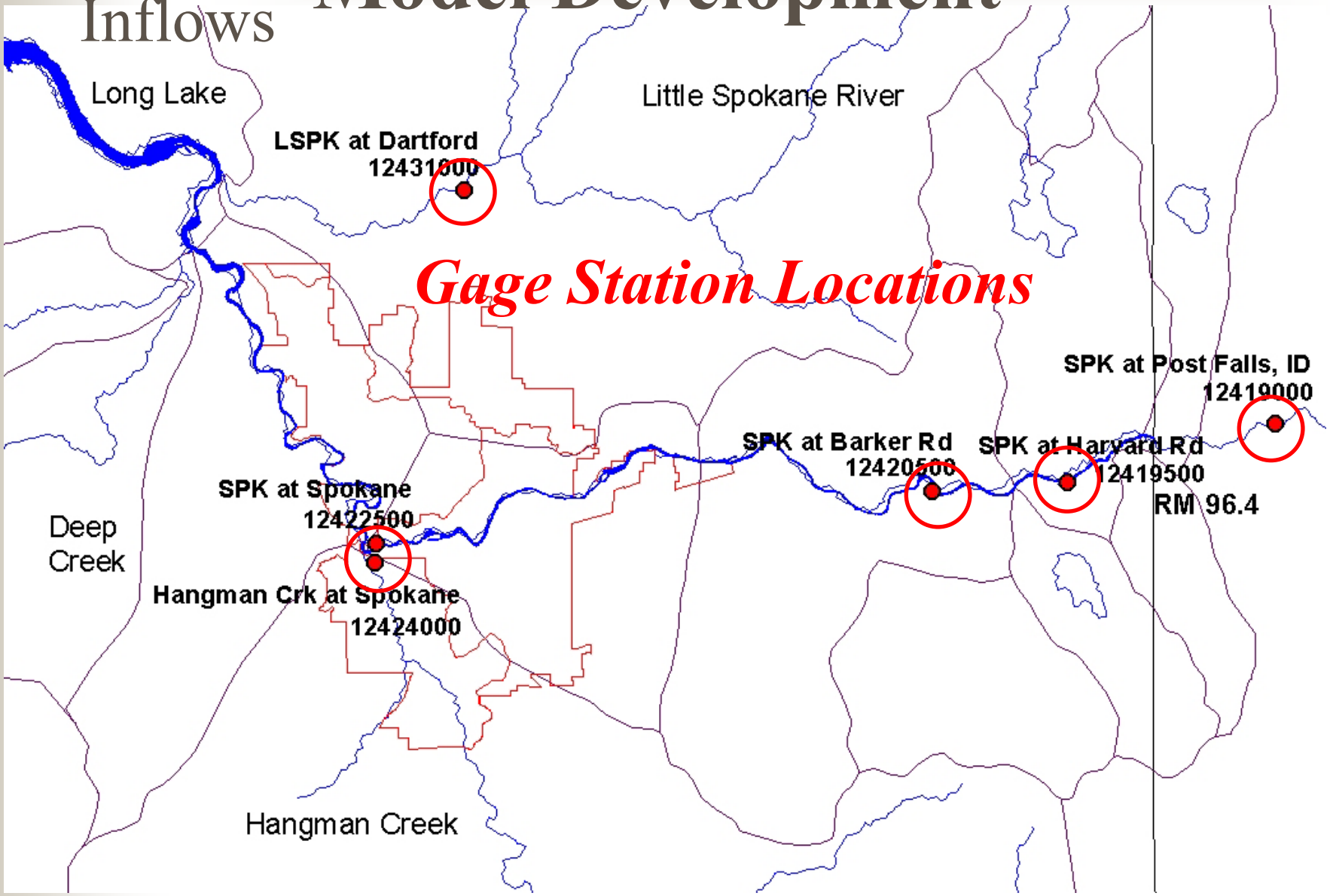
Subbasin Delineation



Distributed
Inflow/Outflow Areas

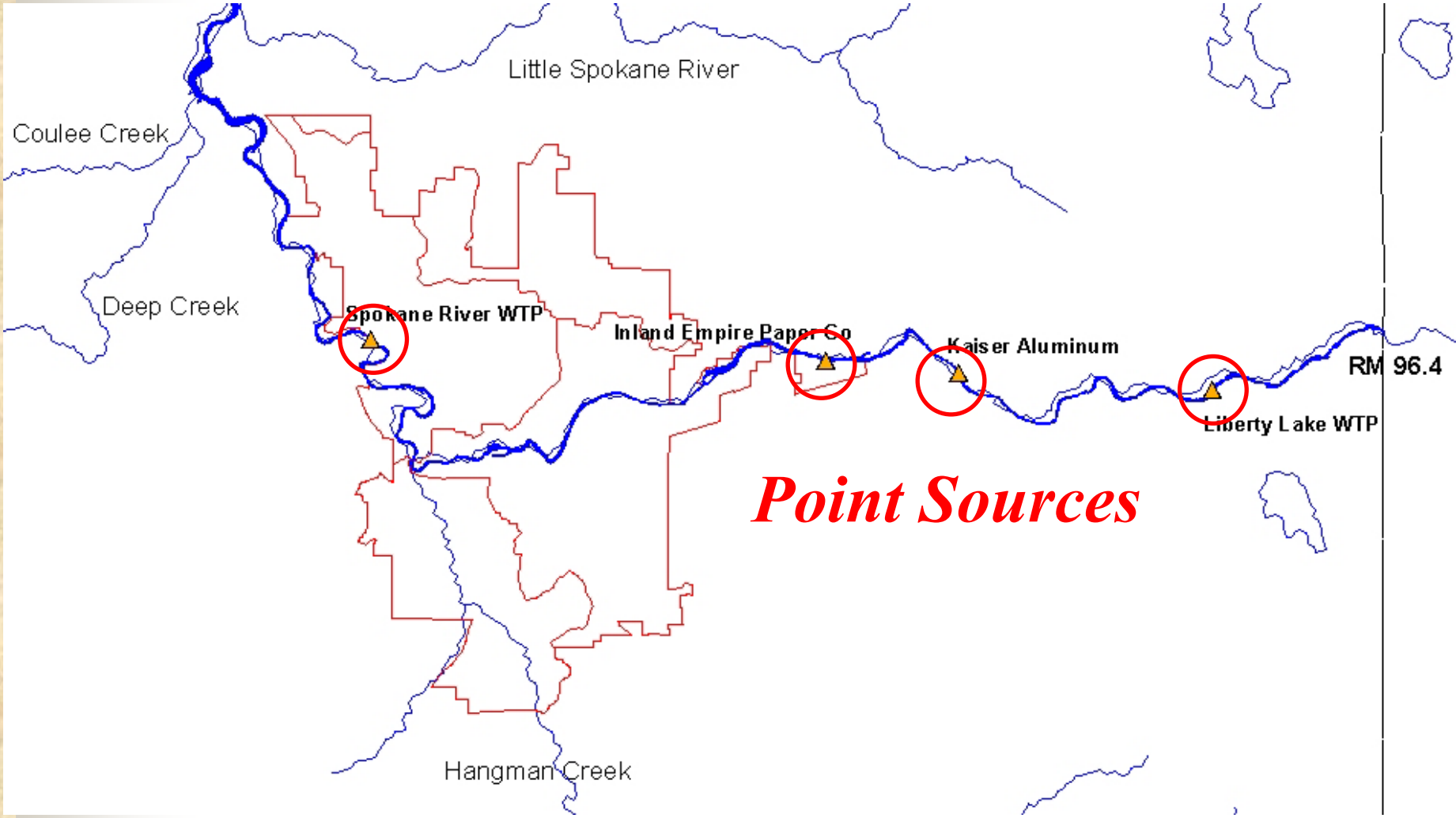
Model Development

Inflows



Model Development

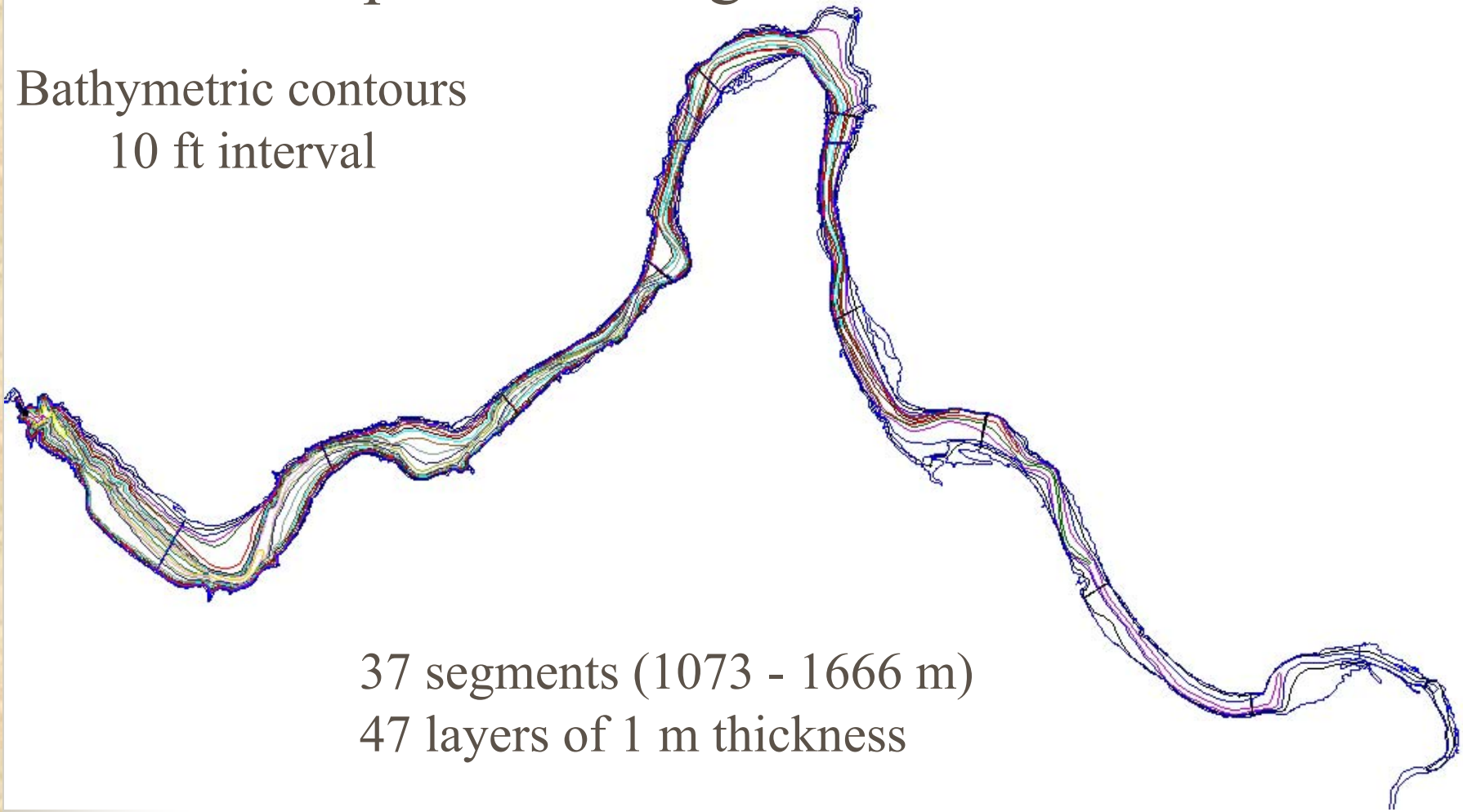
Inflows



Model Development

Grid Development - Long Lake

Bathymetric contours
10 ft interval

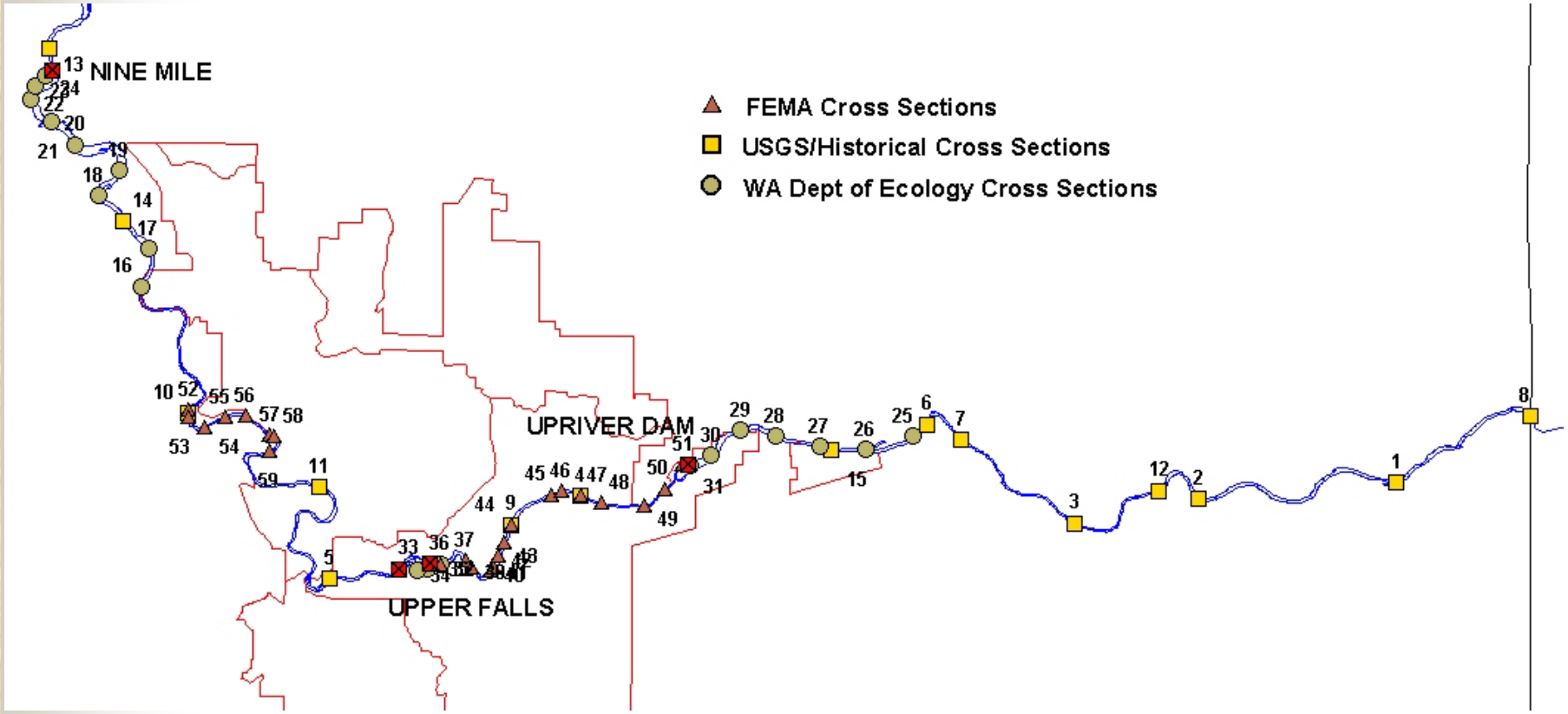


37 segments (1073 - 1666 m)
47 layers of 1 m thickness

Model Development

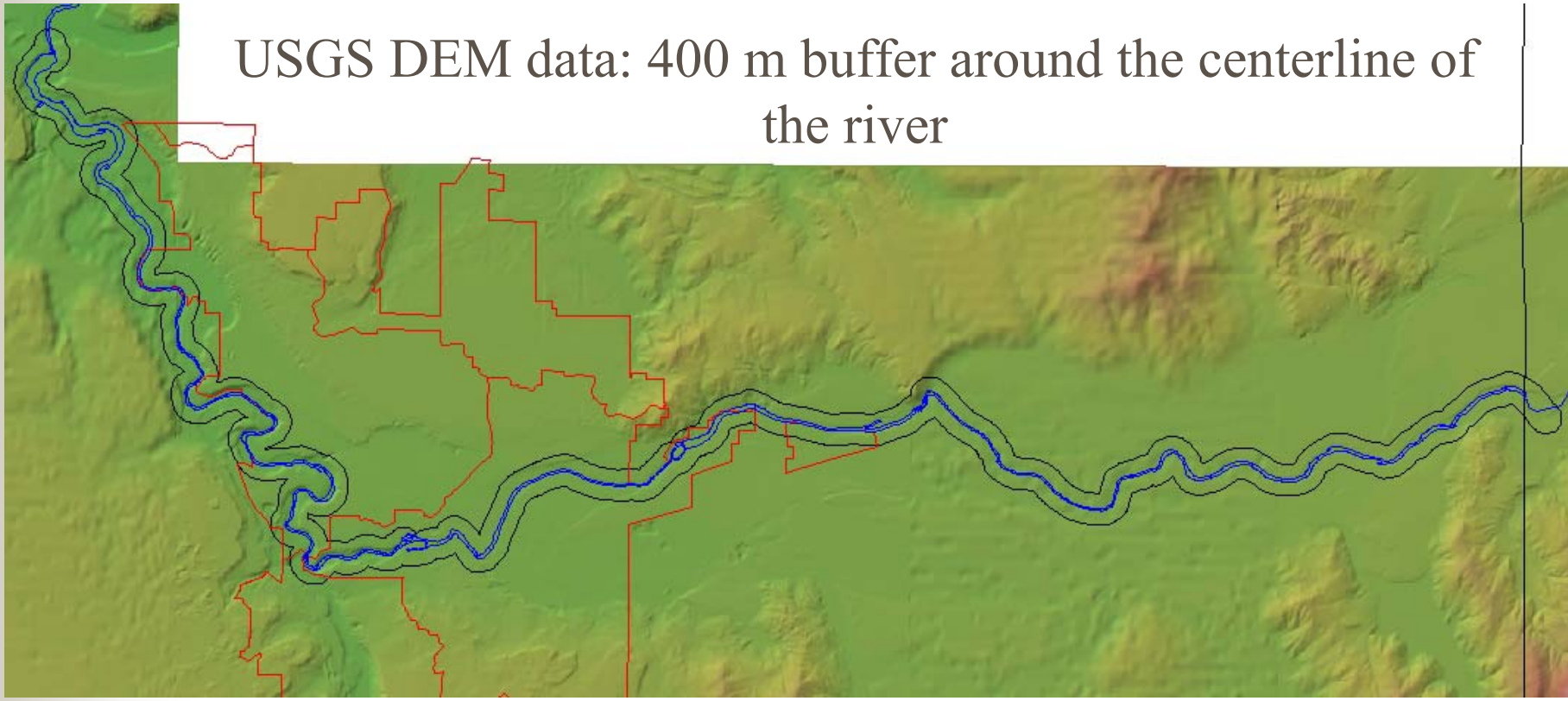
Grid Development - Spokane River

59 Cross Sections from RM 57.4 to 96.4



Model Development

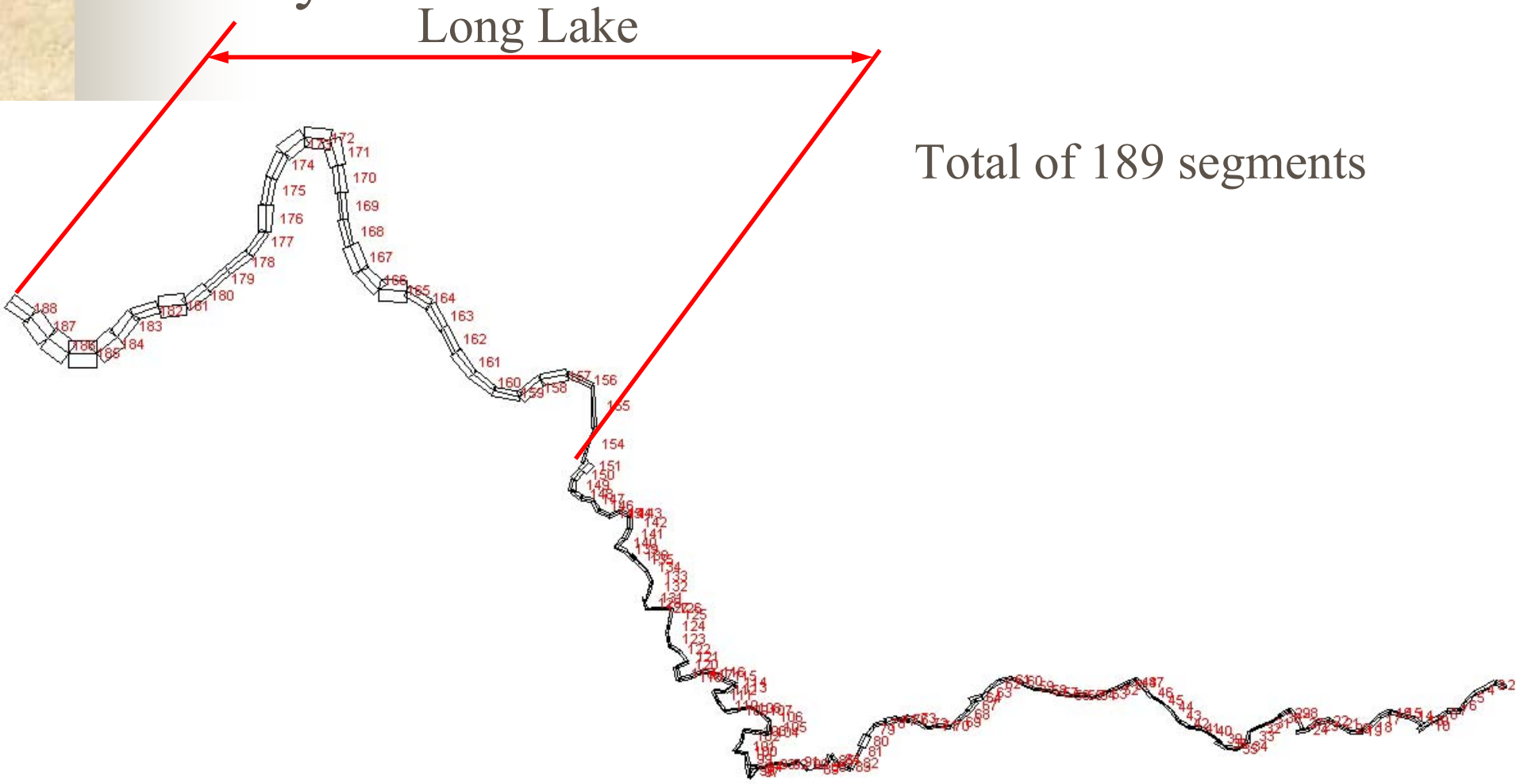
Grid Development - Spokane River



Digital Elevation Model Resolution: X&Y 30 m; Z 1 m

Model Development

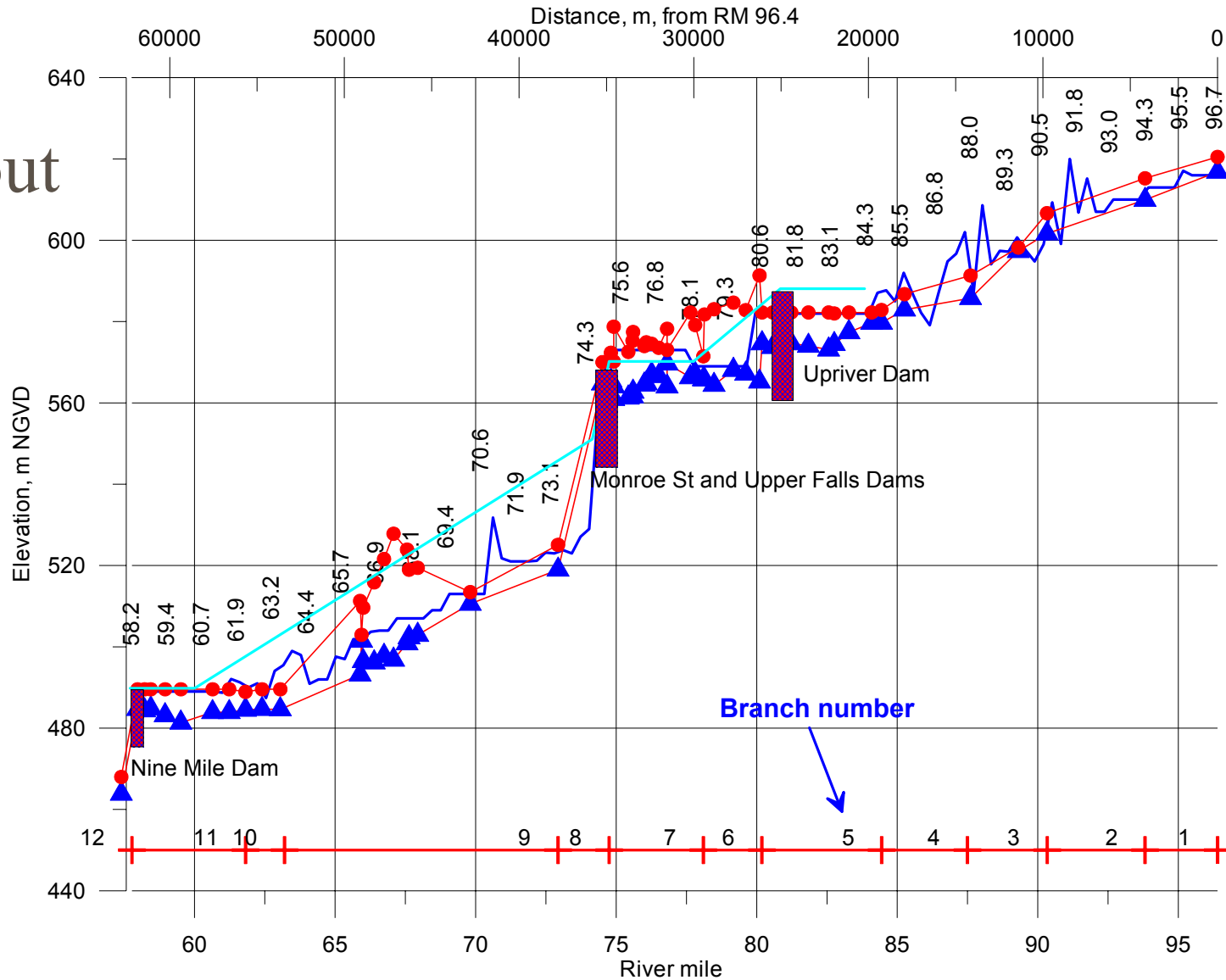
Grid Layout



Total of 189 segments

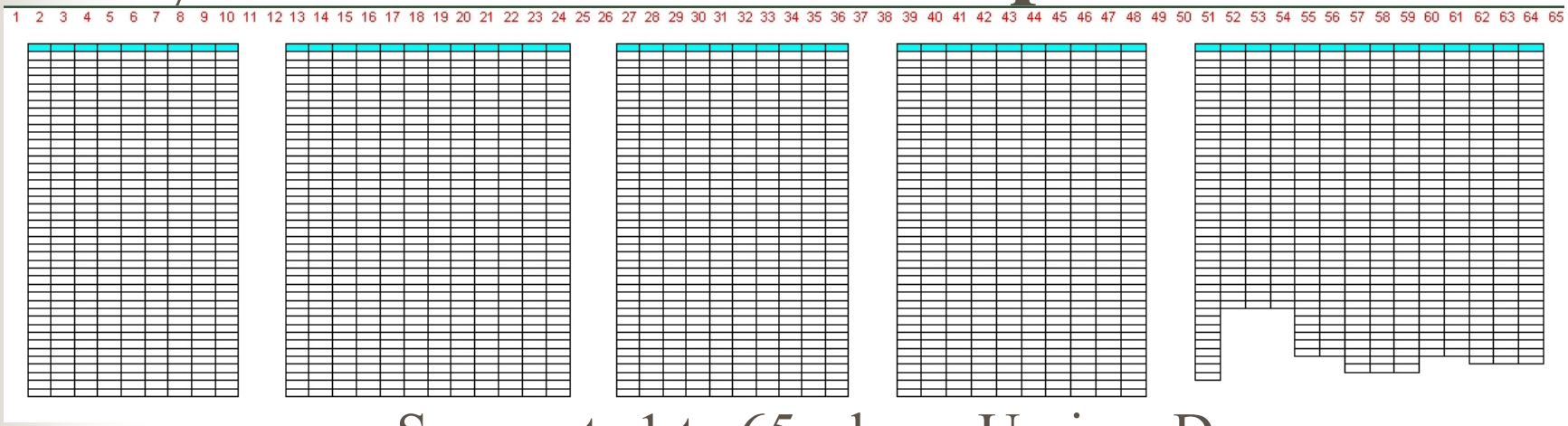
Model Development

Grid Layout

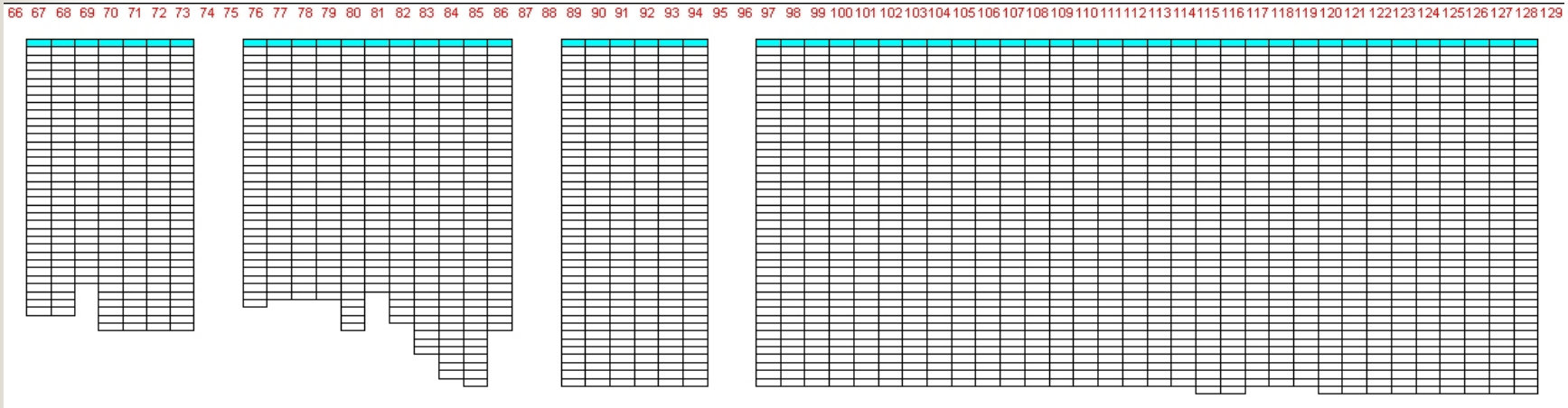


Model Development

Grid Layout

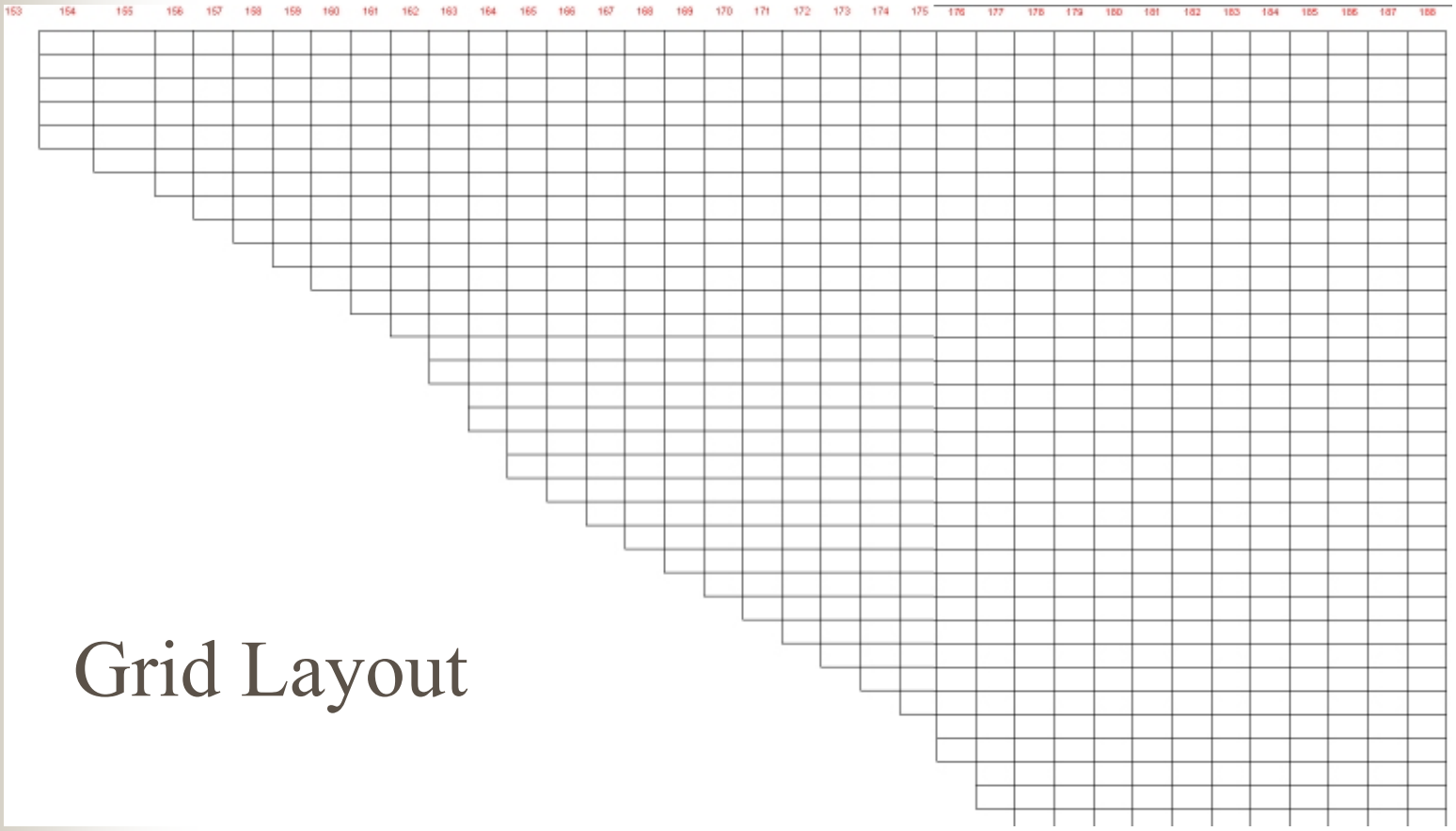


Segments 1 to 65, above Upriver Dam



Segments 66 to 129, below Upriver Dam to Seven Mile Bridge

Model Development



Layer 2

Grid Layout

Layer 34

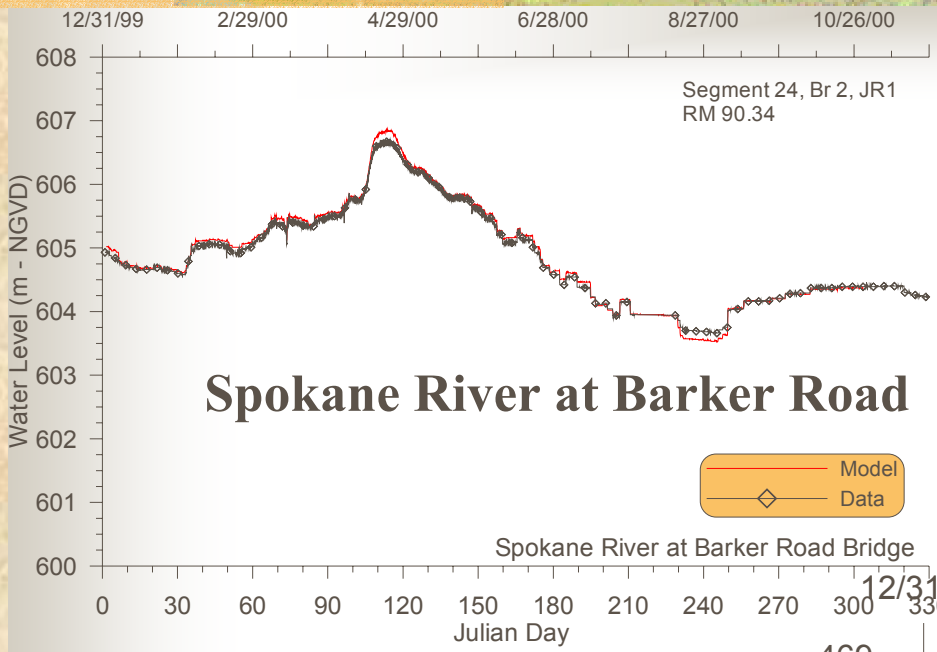
Bottom Layer: 47

Segments 153 - 189, Nine Mile Dam to Long Lake Dam

Model Calibration

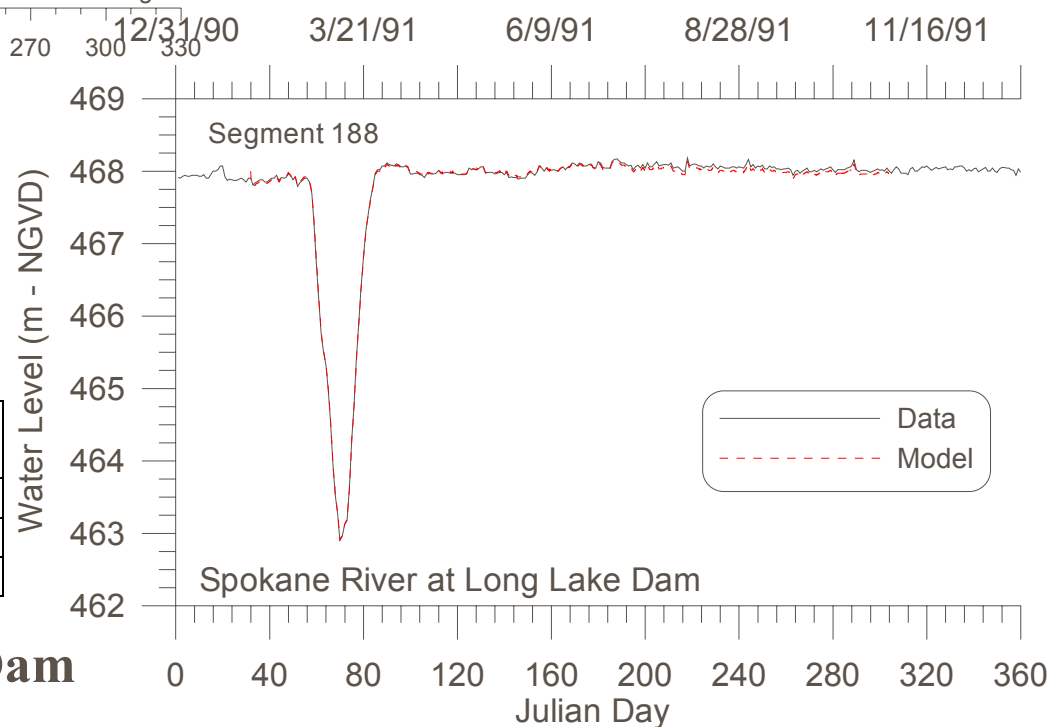
- Time Period for Calibration:
  - February 1, 1991 to October 31, 1991
  - January 1, 2000 to October 31, 2000
  - April 30, 2001 to September 30, 2001
- Calibration Sequence:
  - Hydrodynamics – water level, flow
  - Temperature
  - Water Quality

Water Level Prediction 1991, 2000



Spokane River at Barker Road

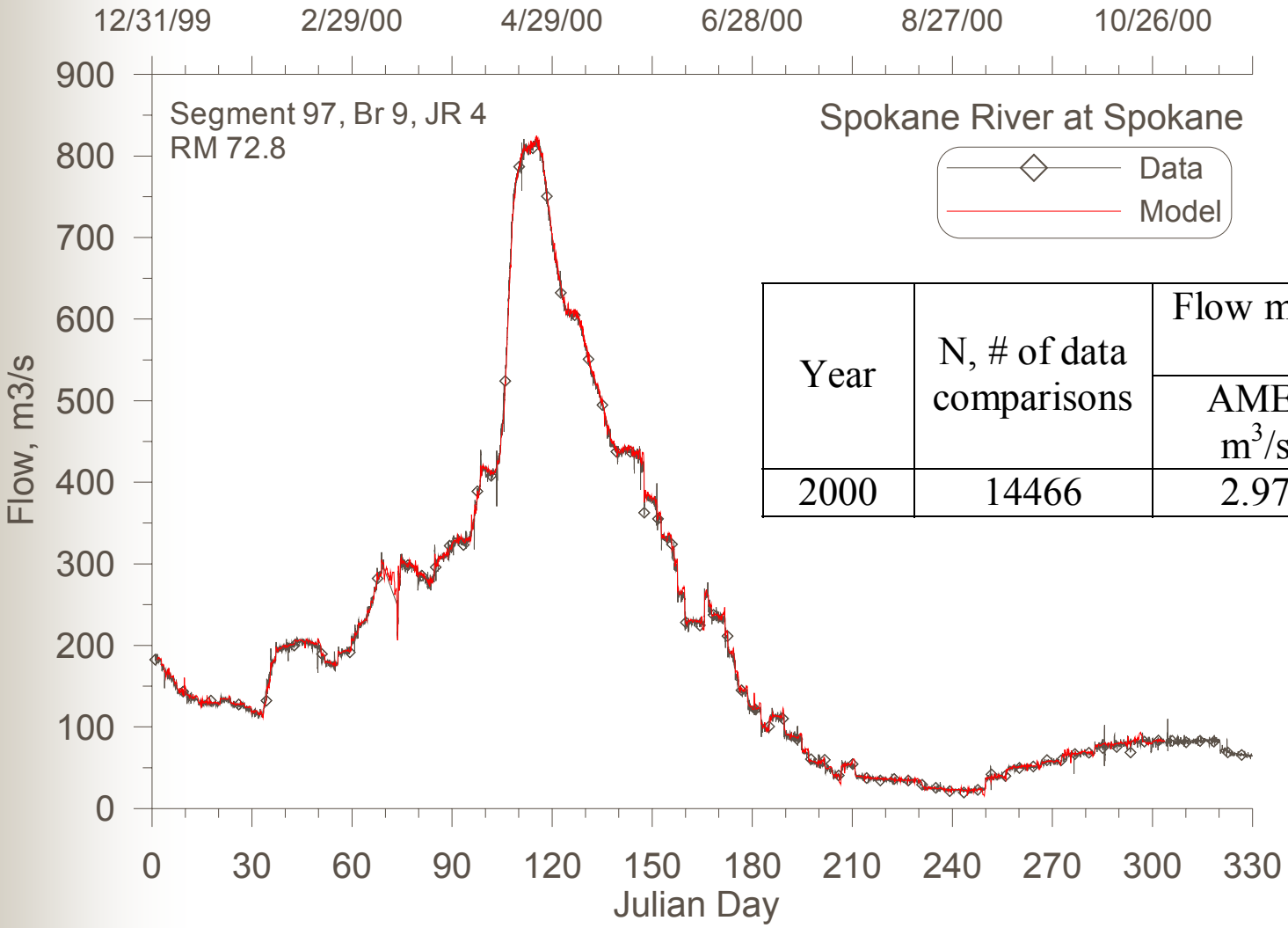
Year	N, # of data comparisons	Water level model –data error statistics	
		AME, m	RMS error, m
2000	28933	0.06	0.07



Year	N, # of data comparisons	Water level model –data error statistics	
		AME, m	RMS error, m
1991	271	0.029	0.034
2000	303	0.030	0.034

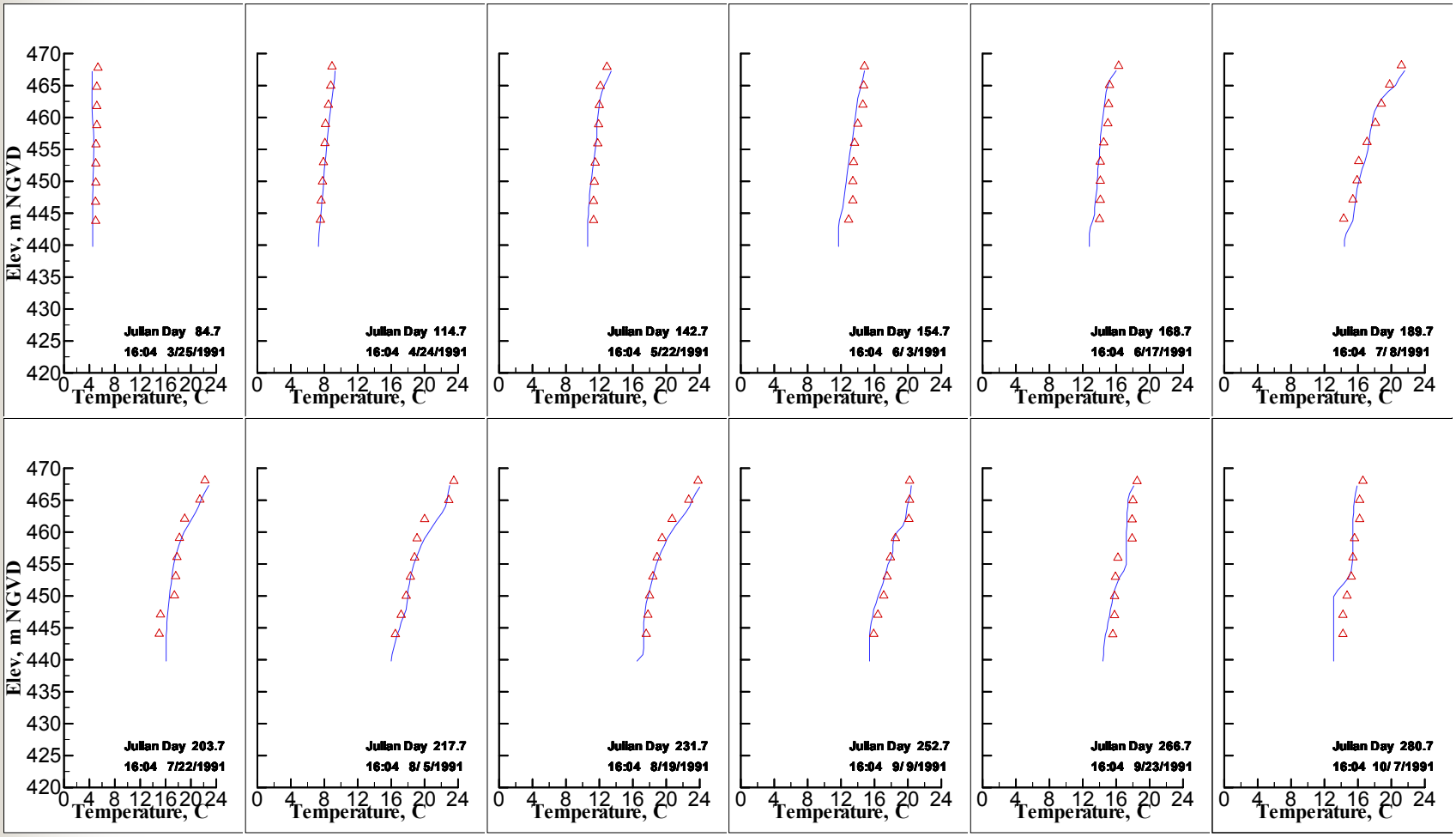
Spokane River at Long Lake Dam

Flow Prediction 2000



Year	N, # of data comparisons	Flow model –data error statistics	
		AME, m^3/s	RMS, m^3/s
2000	14466	2.97	4.31

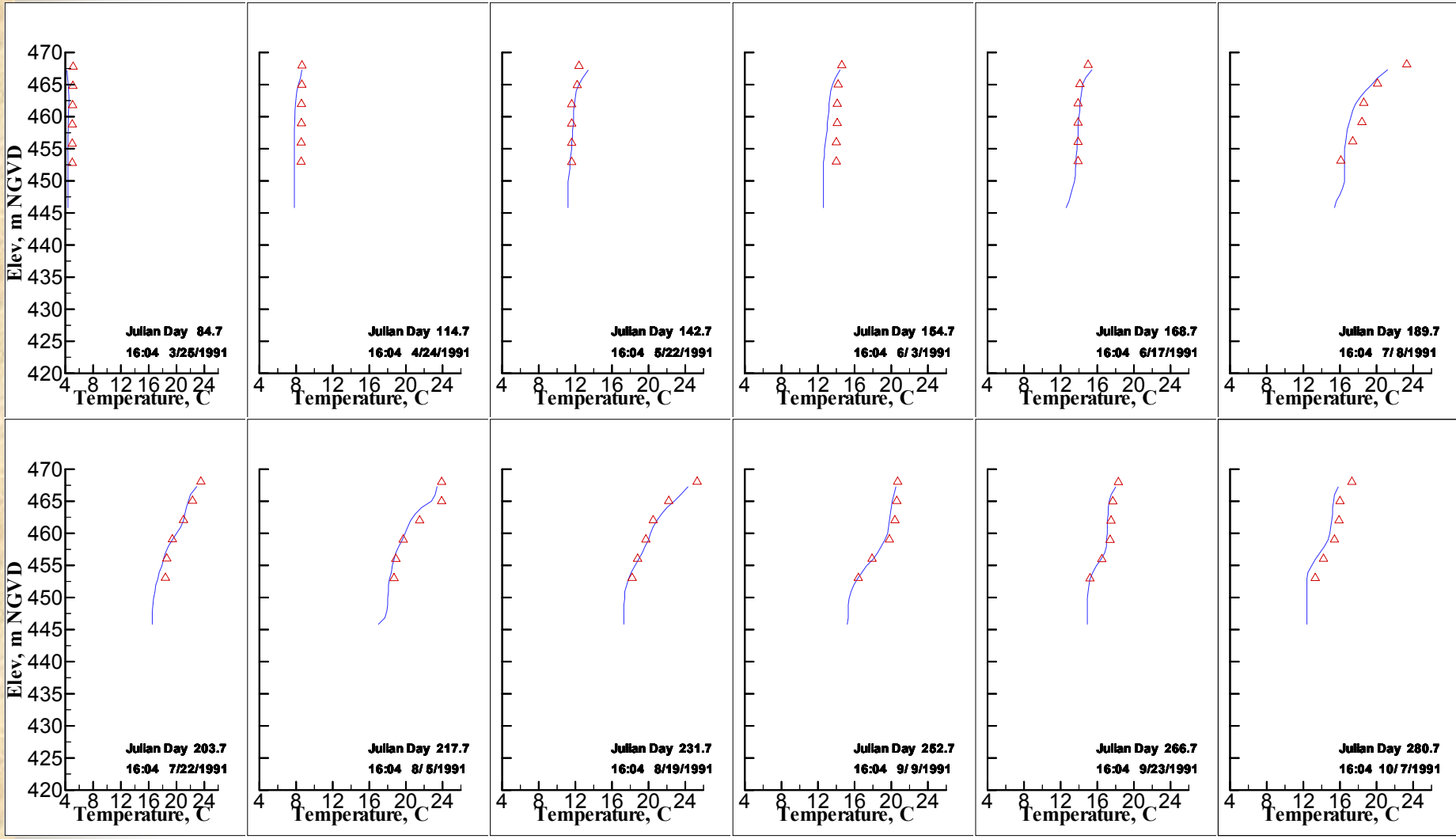
Temperature Prediction – Long Lake, 1991



(LL2, segment 174)

Open triangles are data and the line is the model

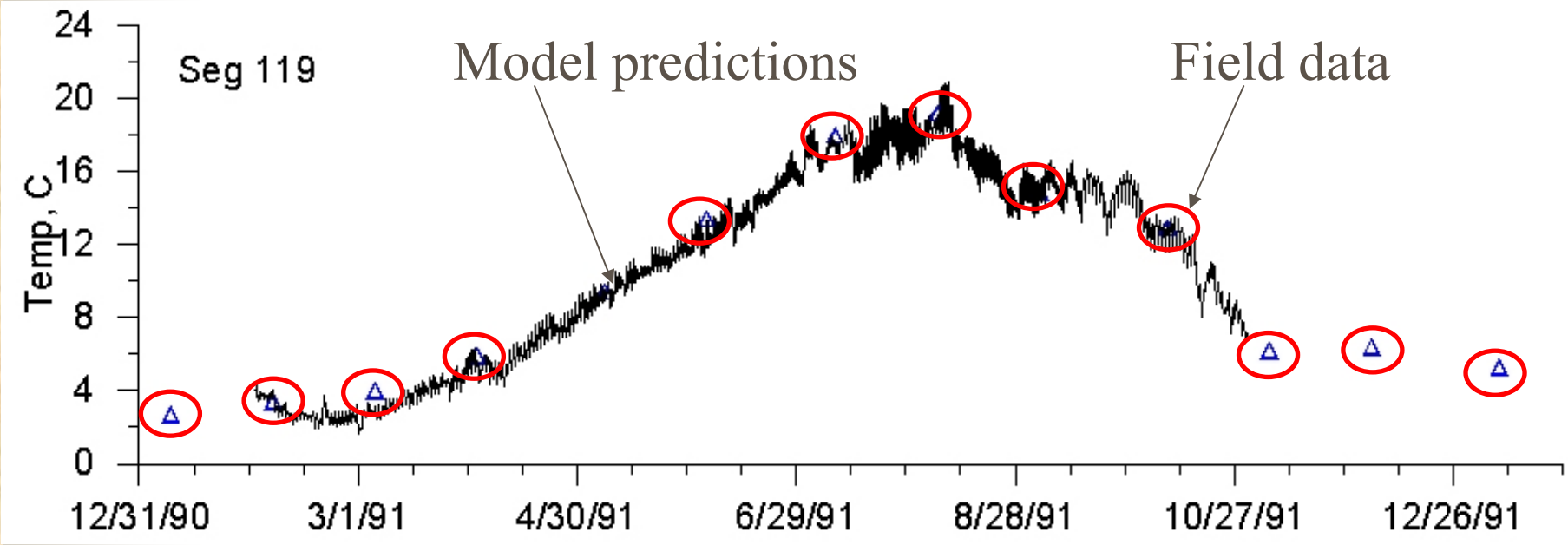
Temperature Prediction – Long Lake, 1991



(Site LL3, segment 168)

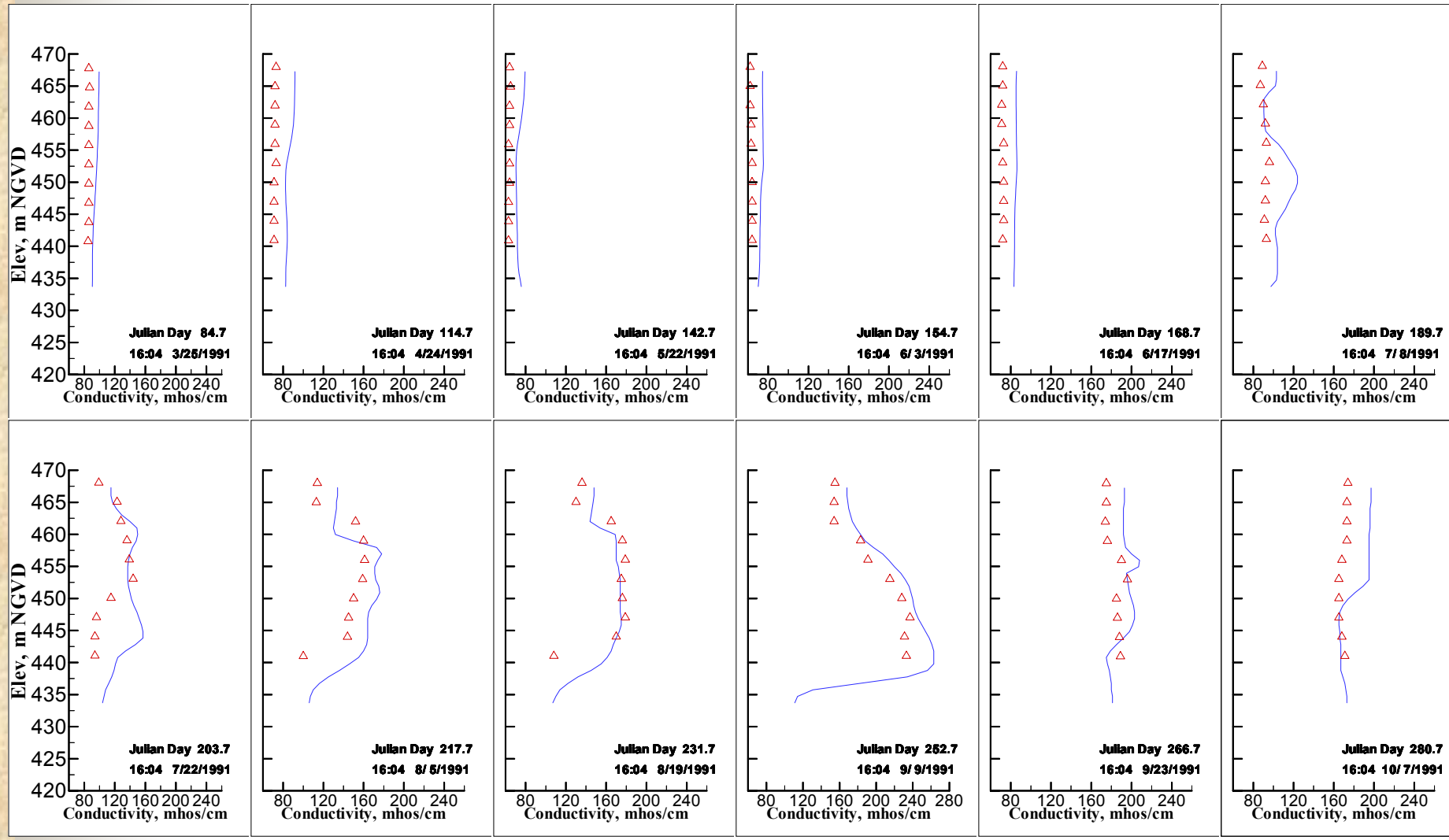
AME: 0.52 °C RMS: 0.57 °C

Temperature Prediction Time Series, 1991



(Spokane River at Riverside State Park, segment 119)

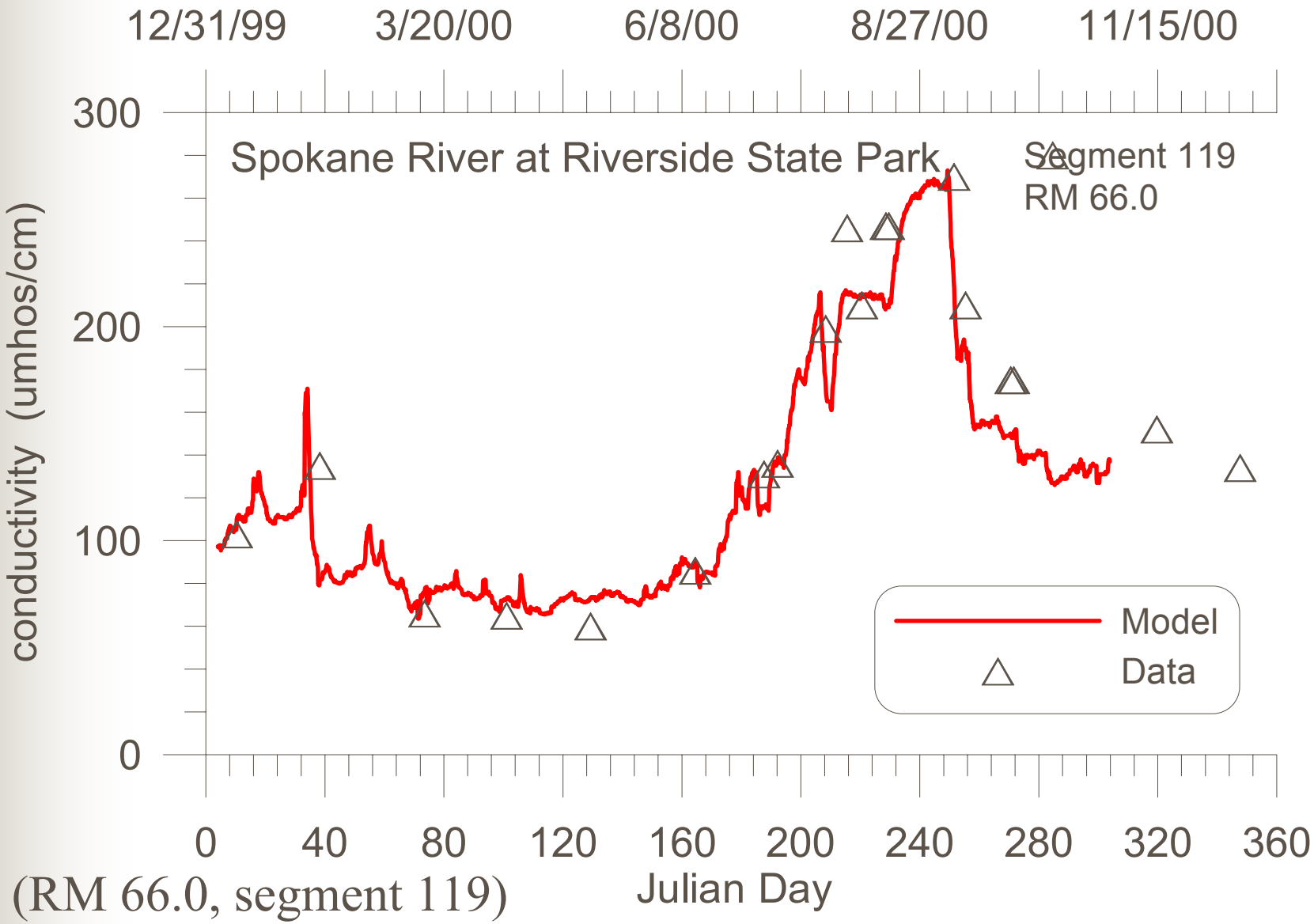
Conductivity Prediction – Long Lake, 1991



(Site LL1, segment 180)

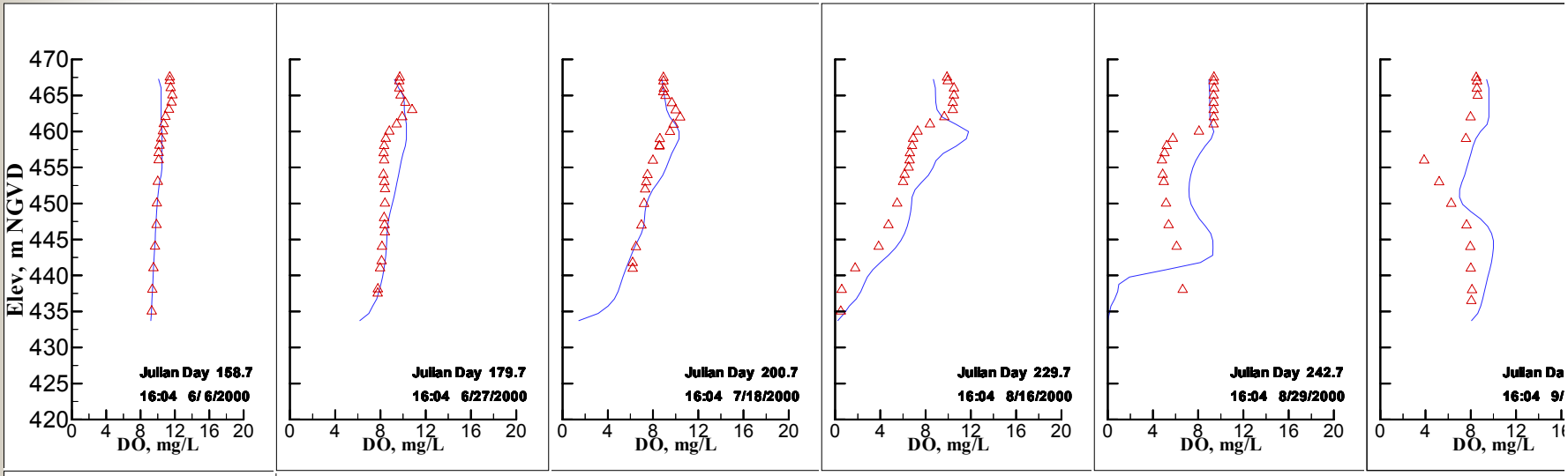
AME: 14.7 mhos/cm RMS: 17.2 mhos/cm

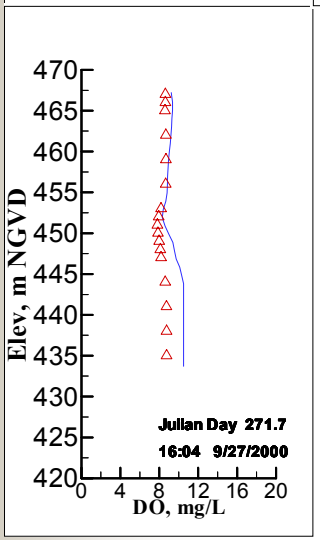
Conductivity – Riverside State Park, 2000



(RM 66.0, segment 119)

Dissolved Oxygen – Long Lake, 2000

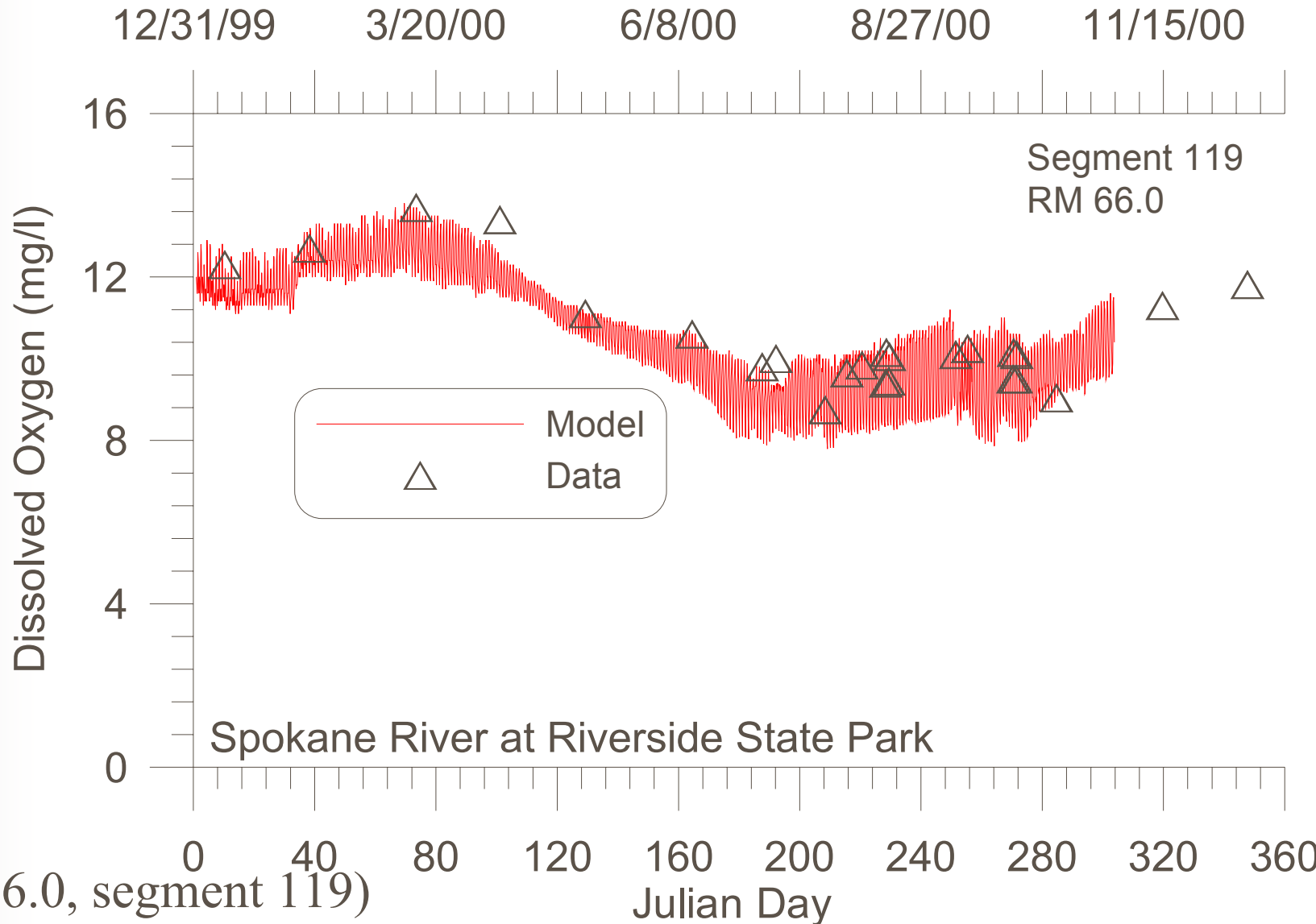




AME: 1.2 mg/L RMS: 1.5 mg/L

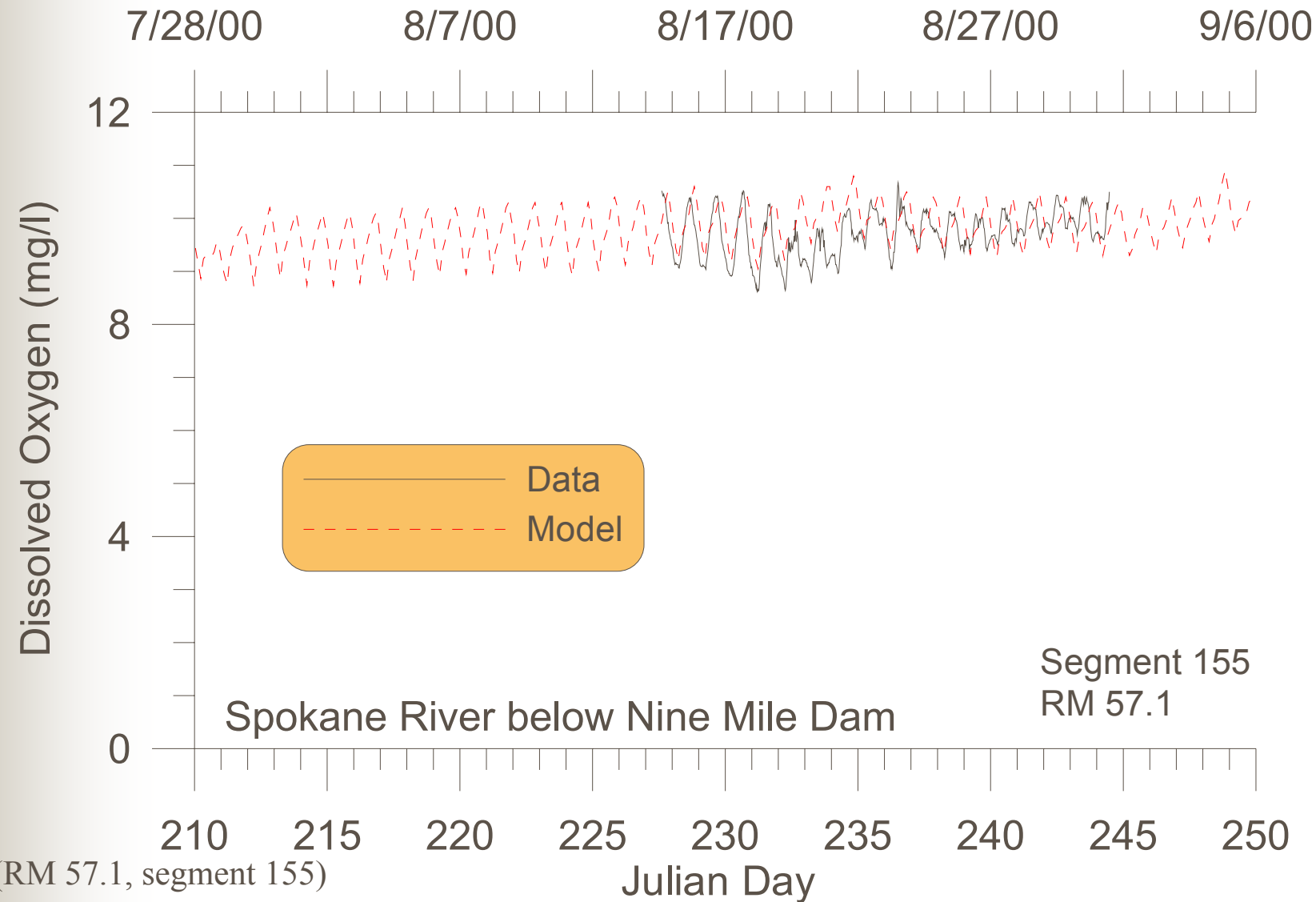
(Site LL1, segment 180)

Dissolved Oxygen – Riverside State Park, 2000



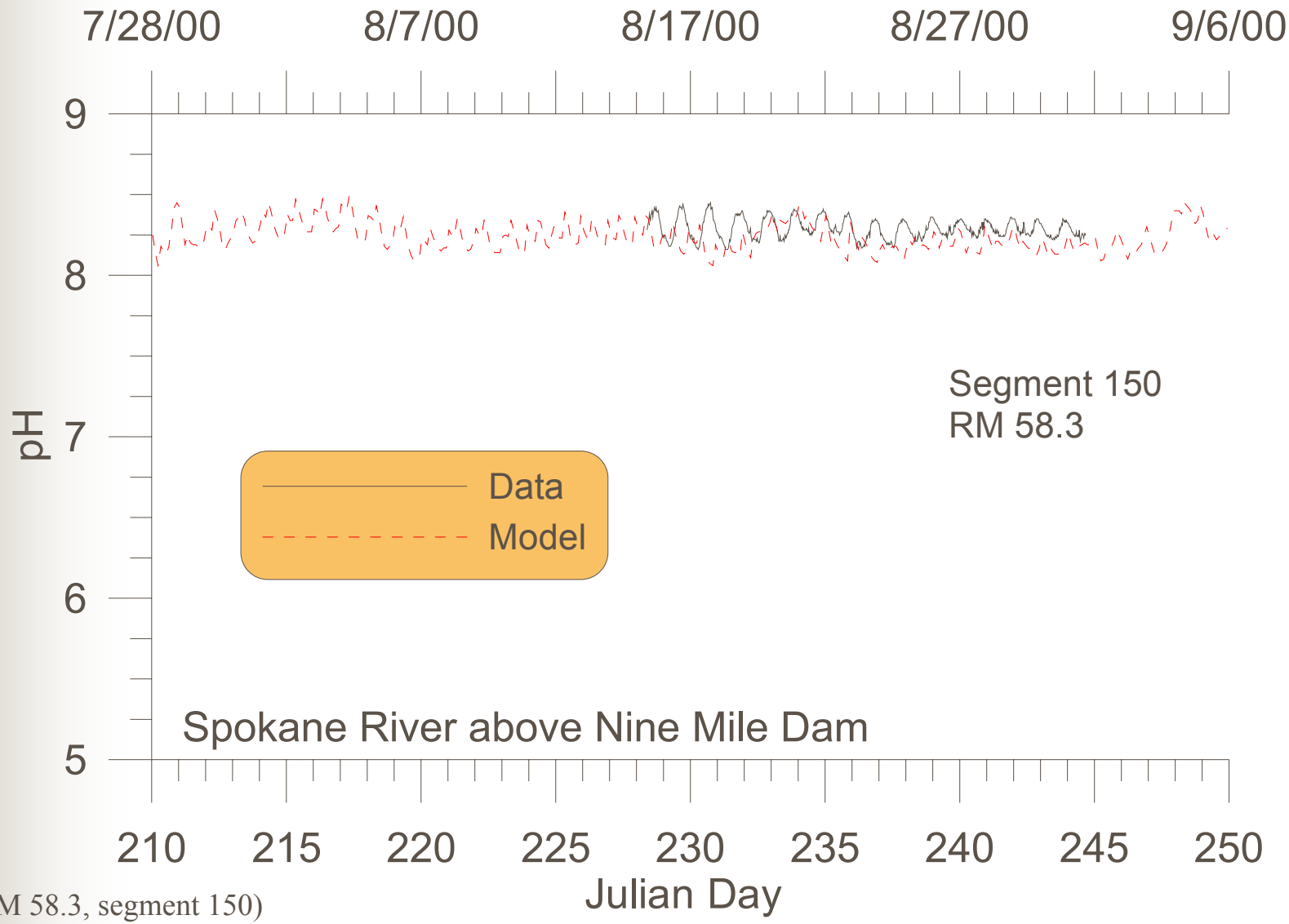
(RM 66.0, segment 119)

Dissolved Oxygen below Nine Mile Dam, 2000



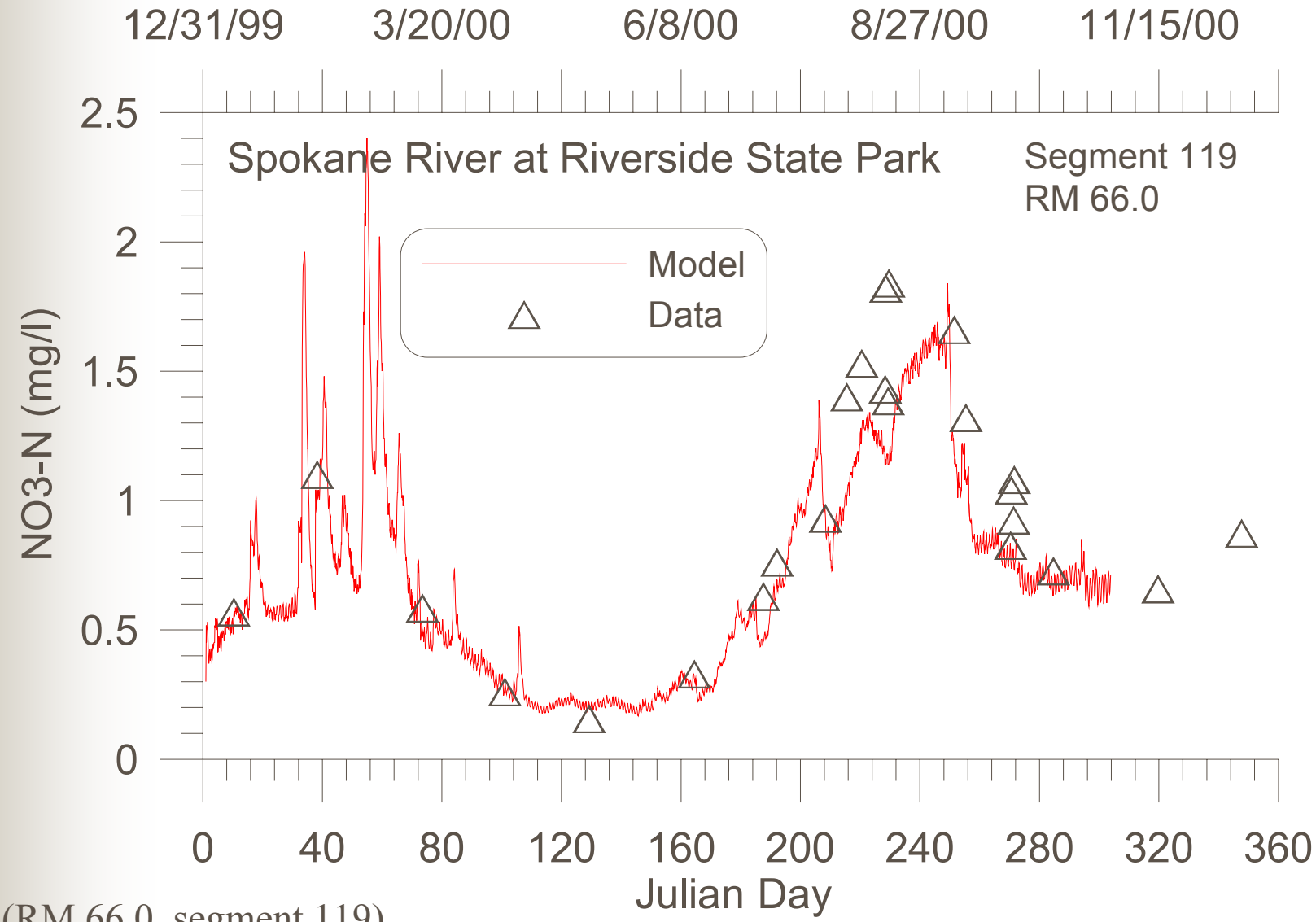
(RM 57.1, segment 155)

pH above Nine Mile Dam, 2000



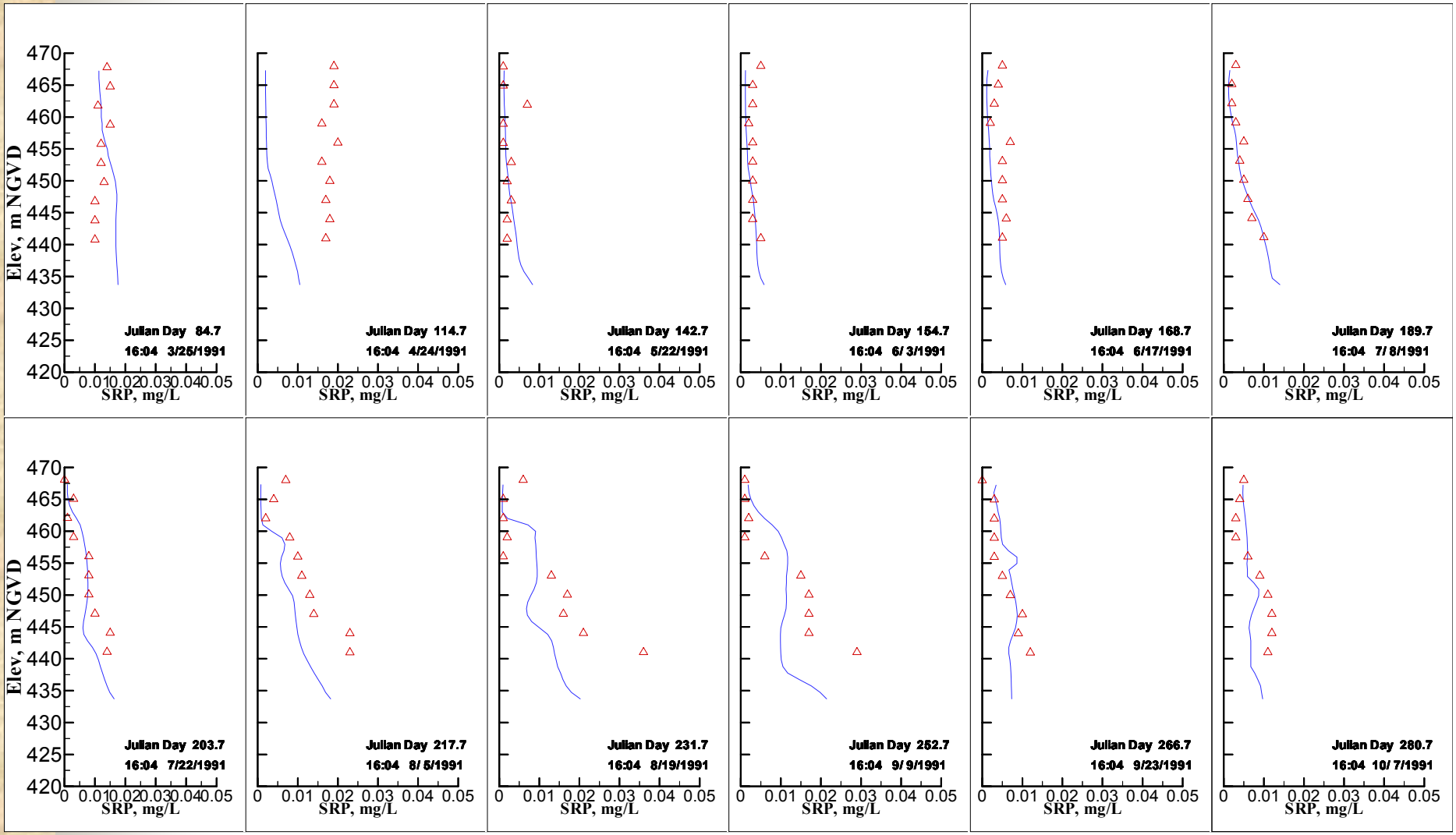
(RM 58.3, segment 150)

Nitrate – Riverside State Park, 2000



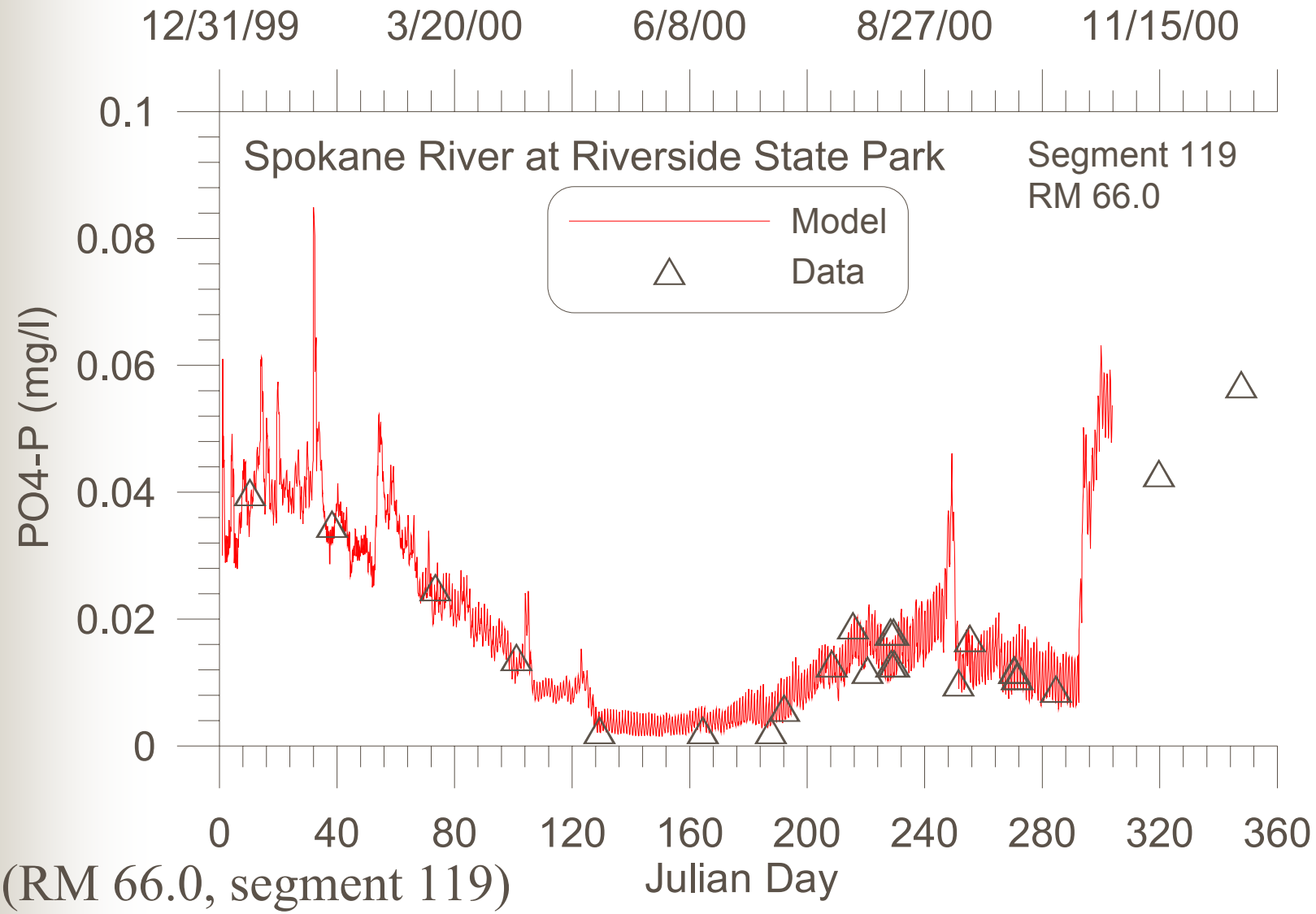
(RM 66.0, segment 119)

Ortho-Phosphate – Long Lake, 1991



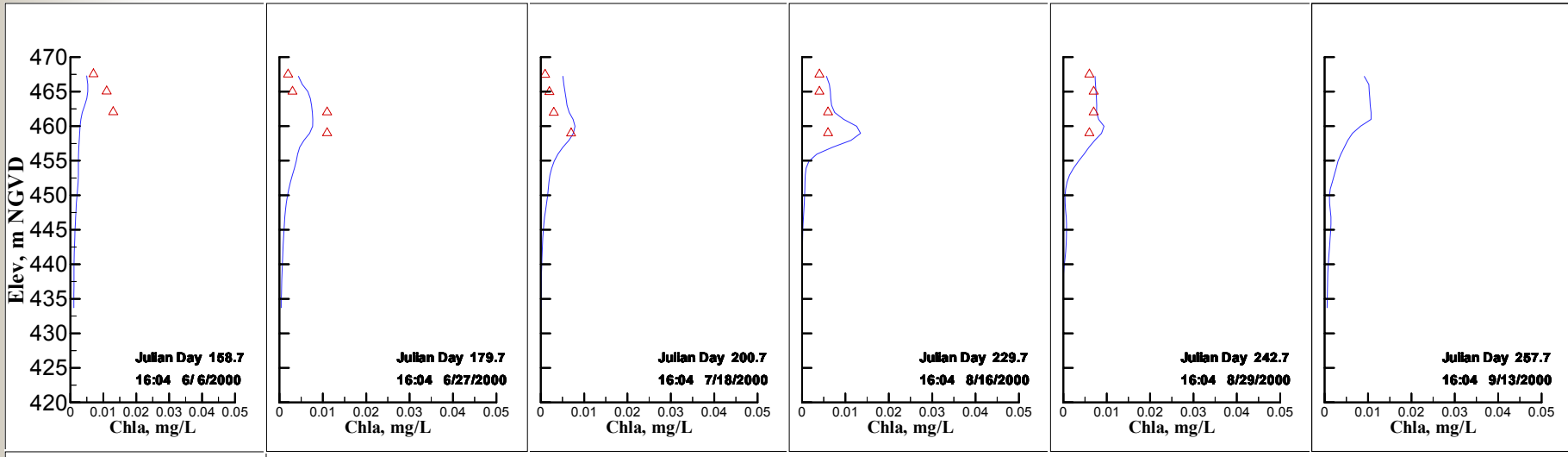
(Site LL1, segment 180) **AME: 0.004 mg/L RMS: 0.005 mg/L**

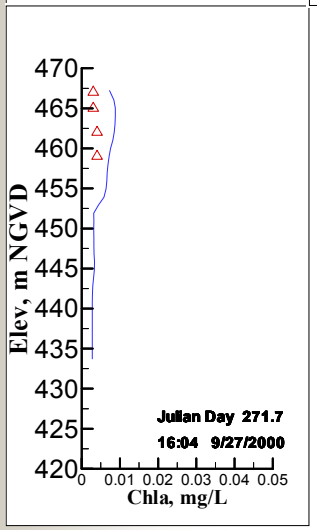
Ortho-Phosphate – Riverside State Park, 2000



(RM 66.0, segment 119)

Chlorophyll a – Long Lake, 2000

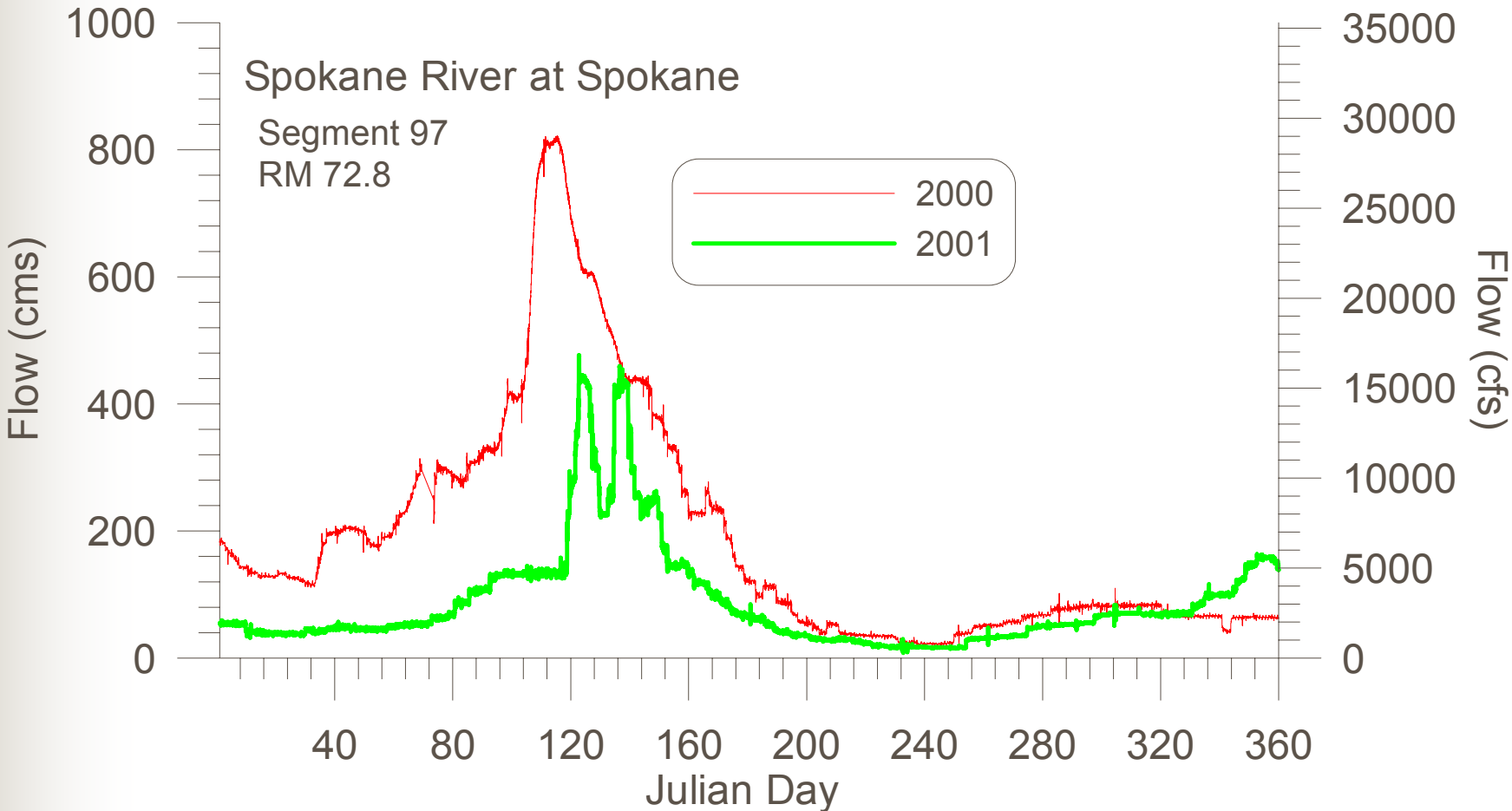




AME: 0.004 mg/L RMS: 0.005 mg/L

(Site LL1, segment 180)

Why 2001 Calibration?



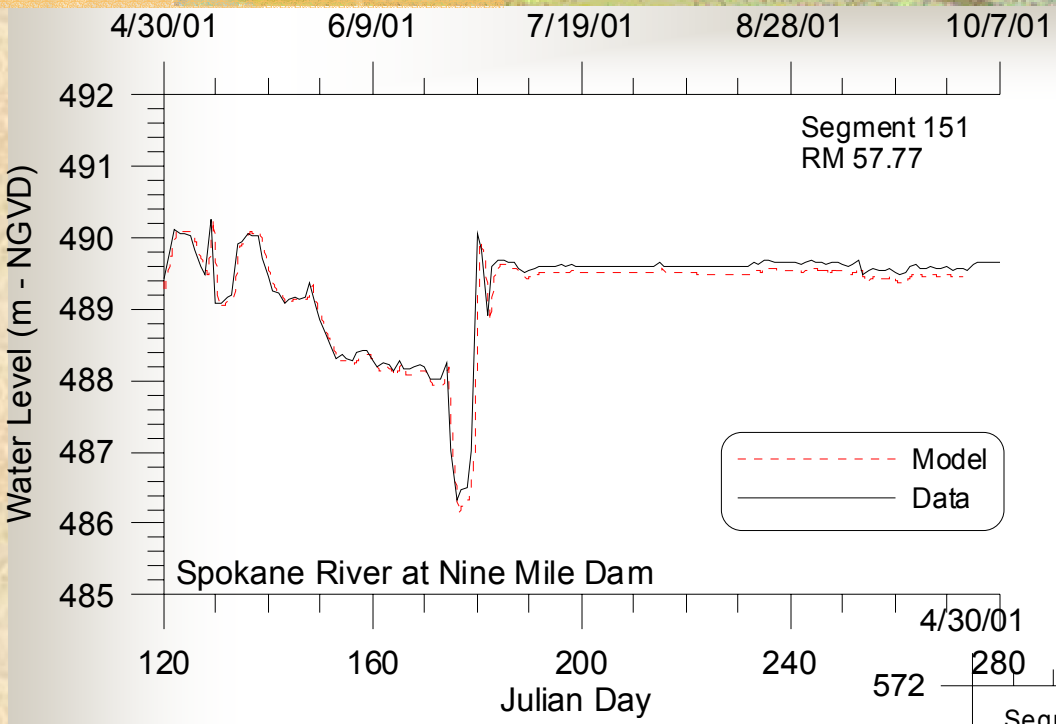
2001 Model Calibration

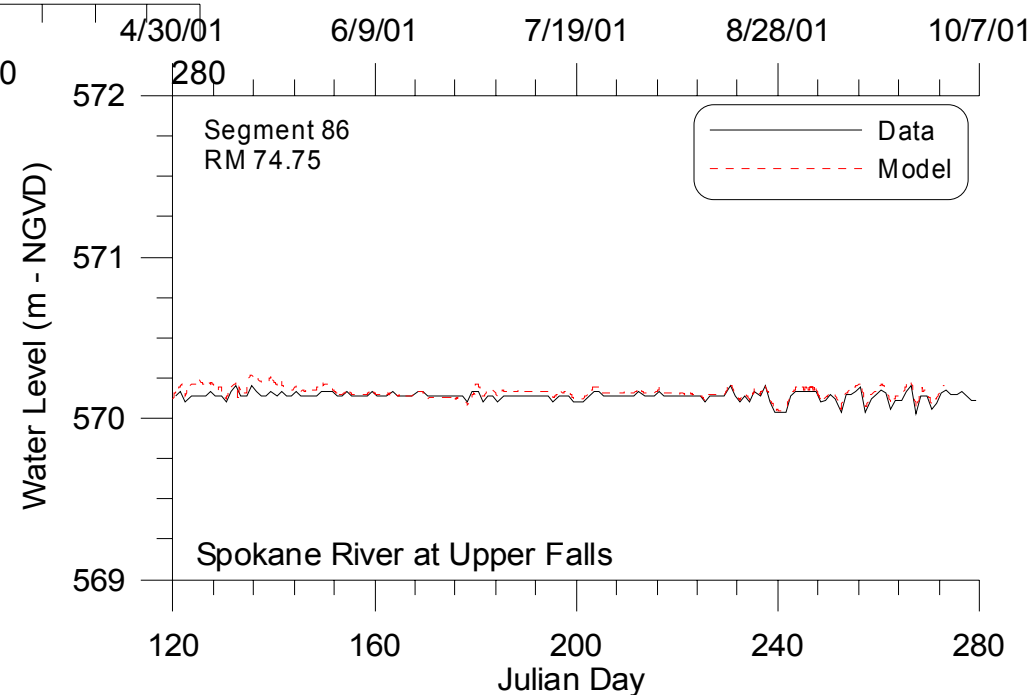
- Changes from 1991, 2000 Calibration
  - Epiphyton Growth rate
  - Groundwater water quality data
  - 2001 Boundary conditions
- Calibration Results
  - Hydraulics
  - Temperature
  - Water Quality

Groundwater Quality 2001 vs 1991, 2000

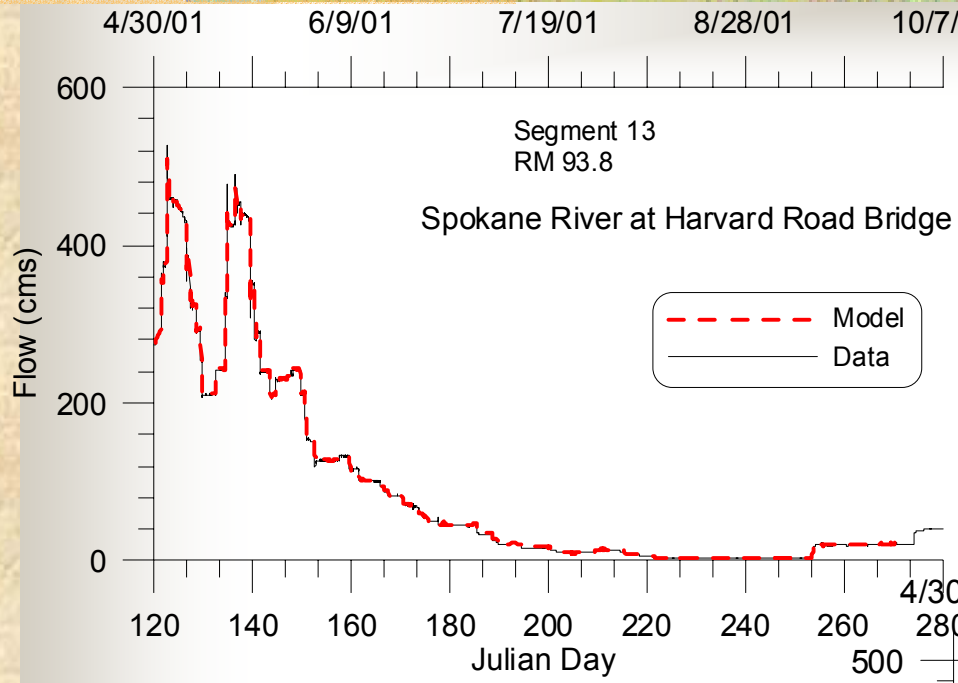
	Well data	TDS	Cond mhos/cm	Chloride mg/l	PO4-P mg/l	NH4-N mg/l	NoX-N mg/l	D. O. mg/l	TIC mg/l	ALK mg/l
Year 1991 and 2000										
All Branches	Cluster of 3 wells near Sullivan Road RM 87.5	142.0	250.2	1.53	0.0060	0.0	1.00	7.50	29.60	118.00
Year 2001										
Branches 1 to 4	Sullivan Road well data	129.6	240.4	1.53	0.0060	0.0	0.89	8.22	18.31	71.67
Branch 5 (Upriver reservoir)	Felts Field monitoring well	117.1	207.9	1.53	0.0226	0.1	1.14	7.30	18.23	73.00
Branch 6 (Upriver dam to Green Street)	GE MW-22 and Hale's Ale Nested Site (RM79.65)	174.7	294.7	1.53	0.0074	0.1	1.44	8.64	26.52	104.33
Branches 7 to 11 (Green Street to Upper Falls Dam, and from Upper Falls to Nine Mile)	Average of 4 wells along this reach for branch 7, used same for branches 8-11 since no nearby well data	137.9	242.7	1.53	0.0090	0.1	1.20	6.40	21.98	83.63

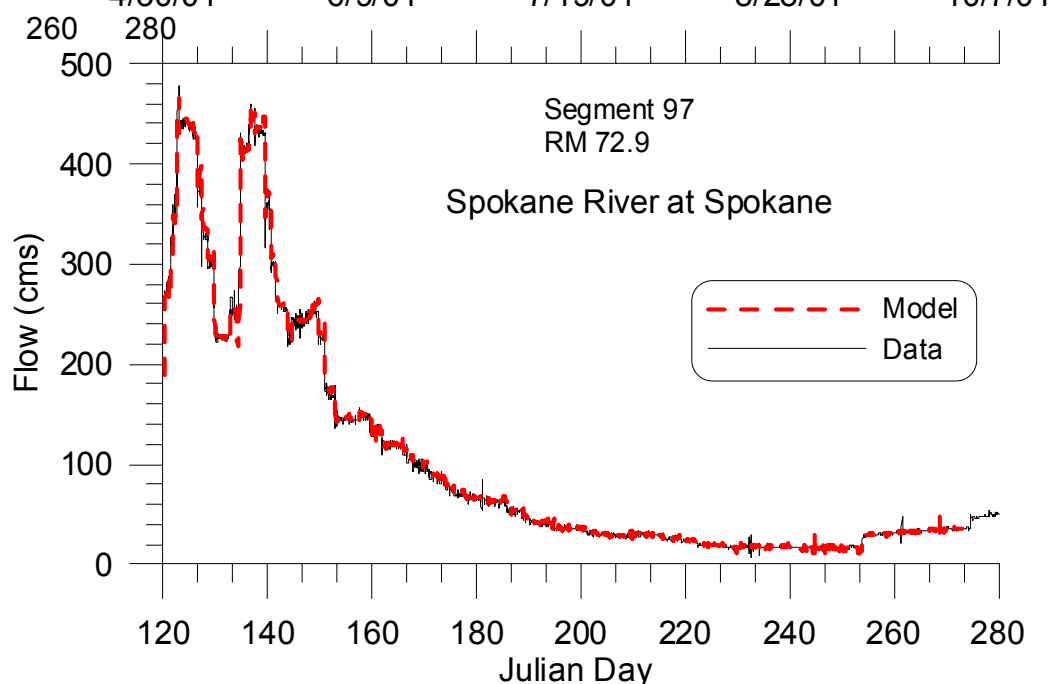
Water Level 2001



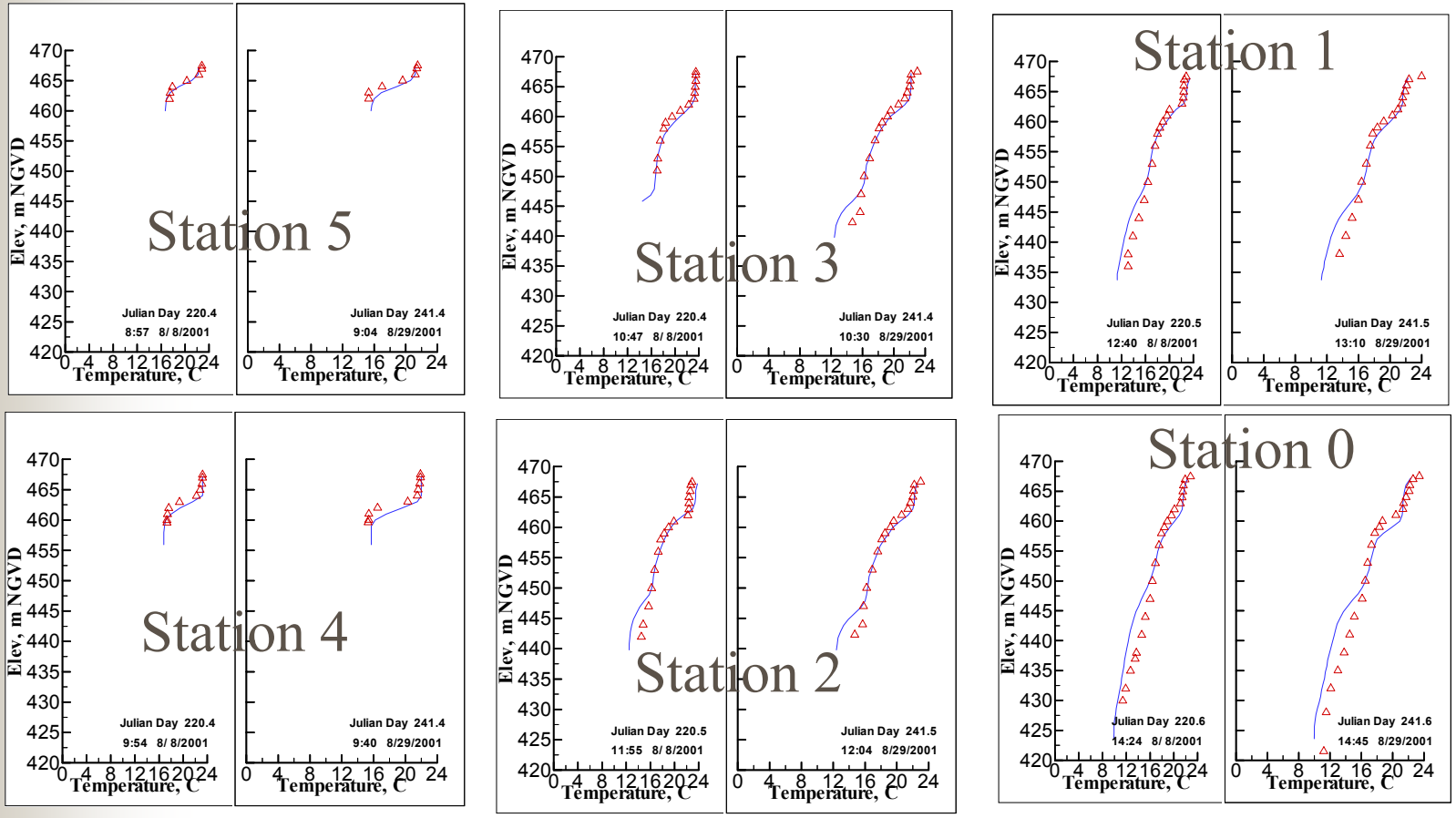


Flow 2001

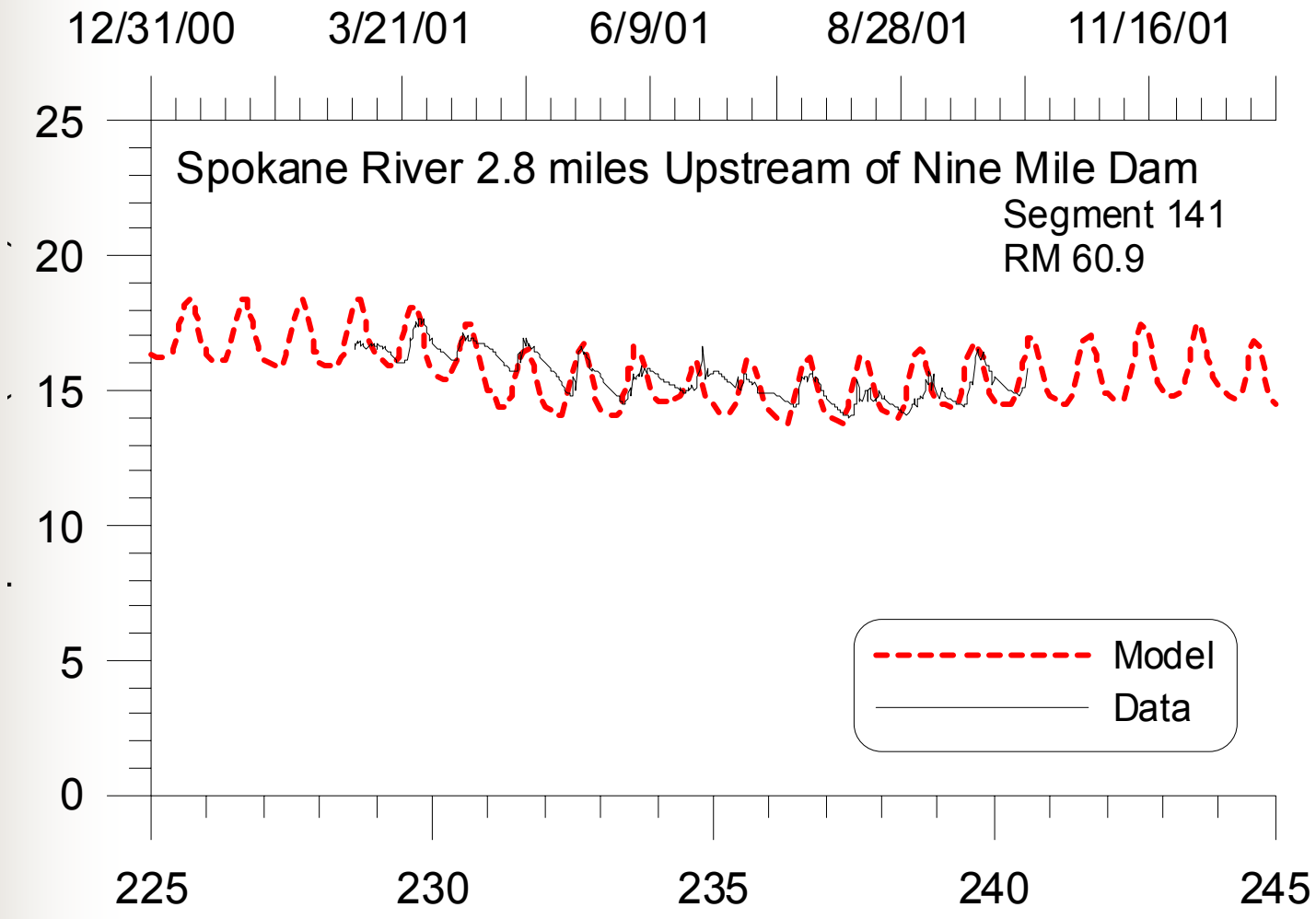

4/30/01
6/9/01
7/19/01
8/28/01
10/7/01
Segment 13
RM 93.8
Spokane River at Harvard Road Bridge
Model
Data
Flow (cms)
600
400
200
0
120
140
160
180
200
220
240
260
280
Julian Day


4/30/01
6/9/01
7/19/01
8/28/01
10/7/01
Segment 97
RM 72.9
Spokane River at Spokane
Model
Data
Flow (cms)
500
400
300
200
100
0
120
140
160
180
200
220
240
260
280
Julian Day

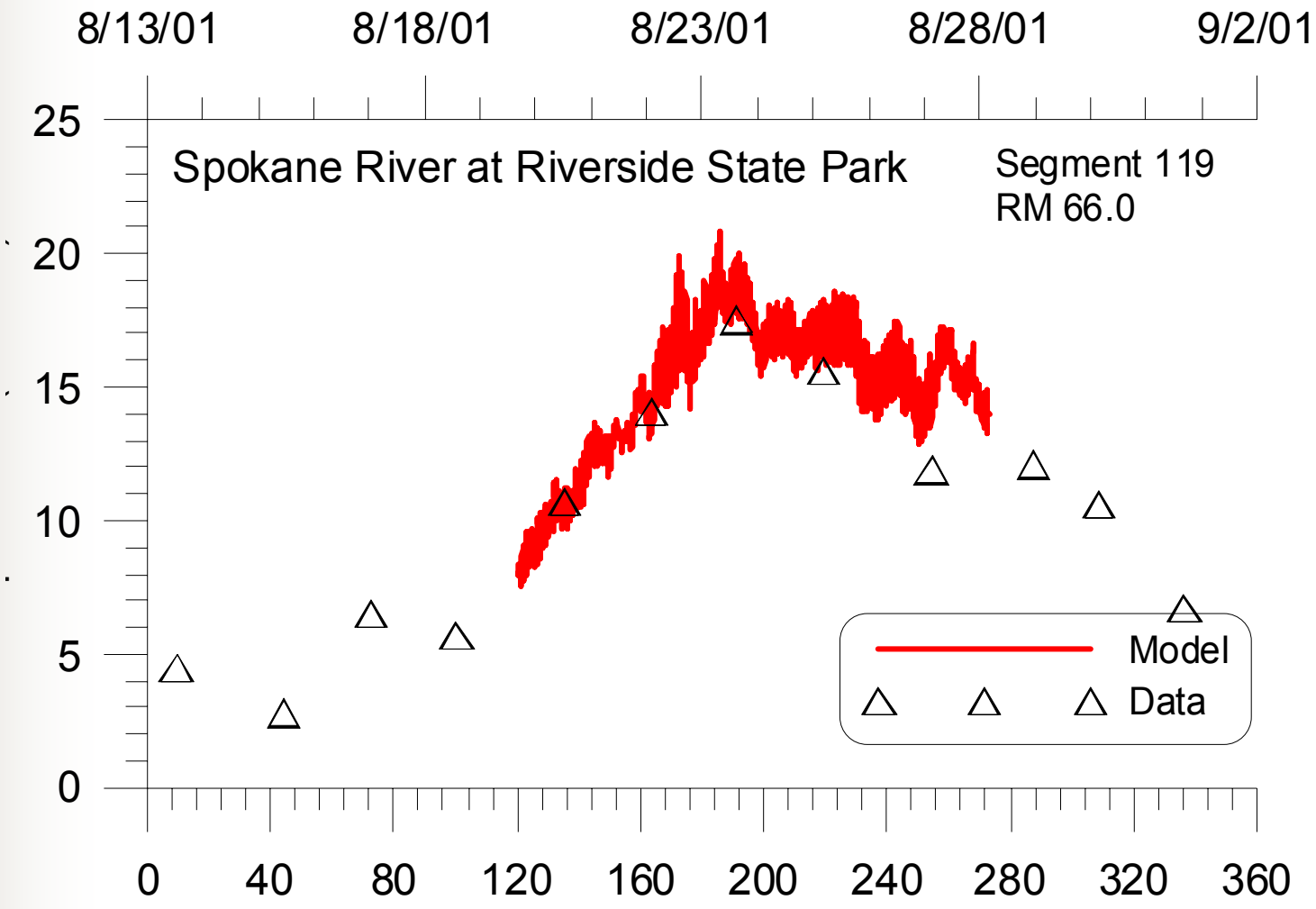
Temperature Long Lake 2001



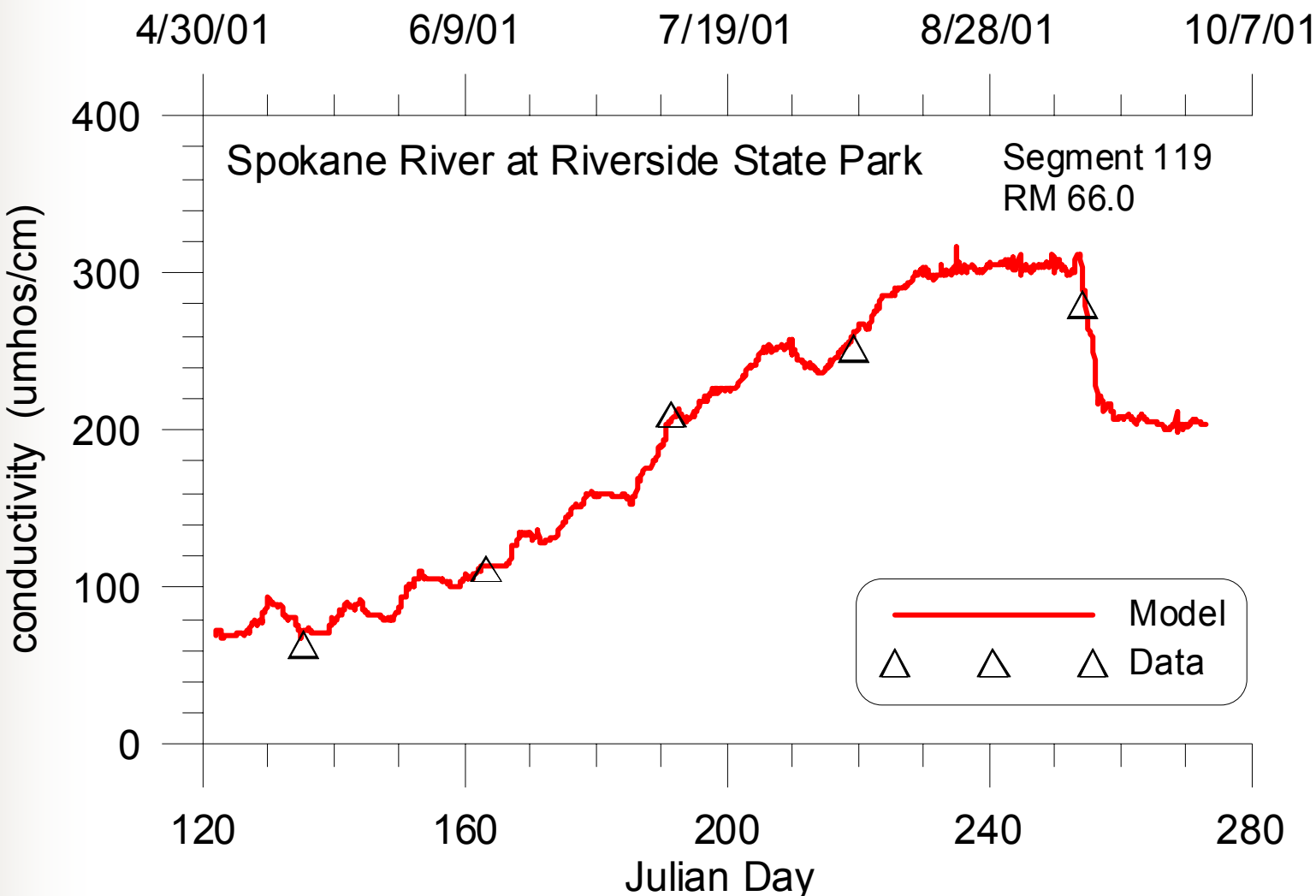
Temperature 2001



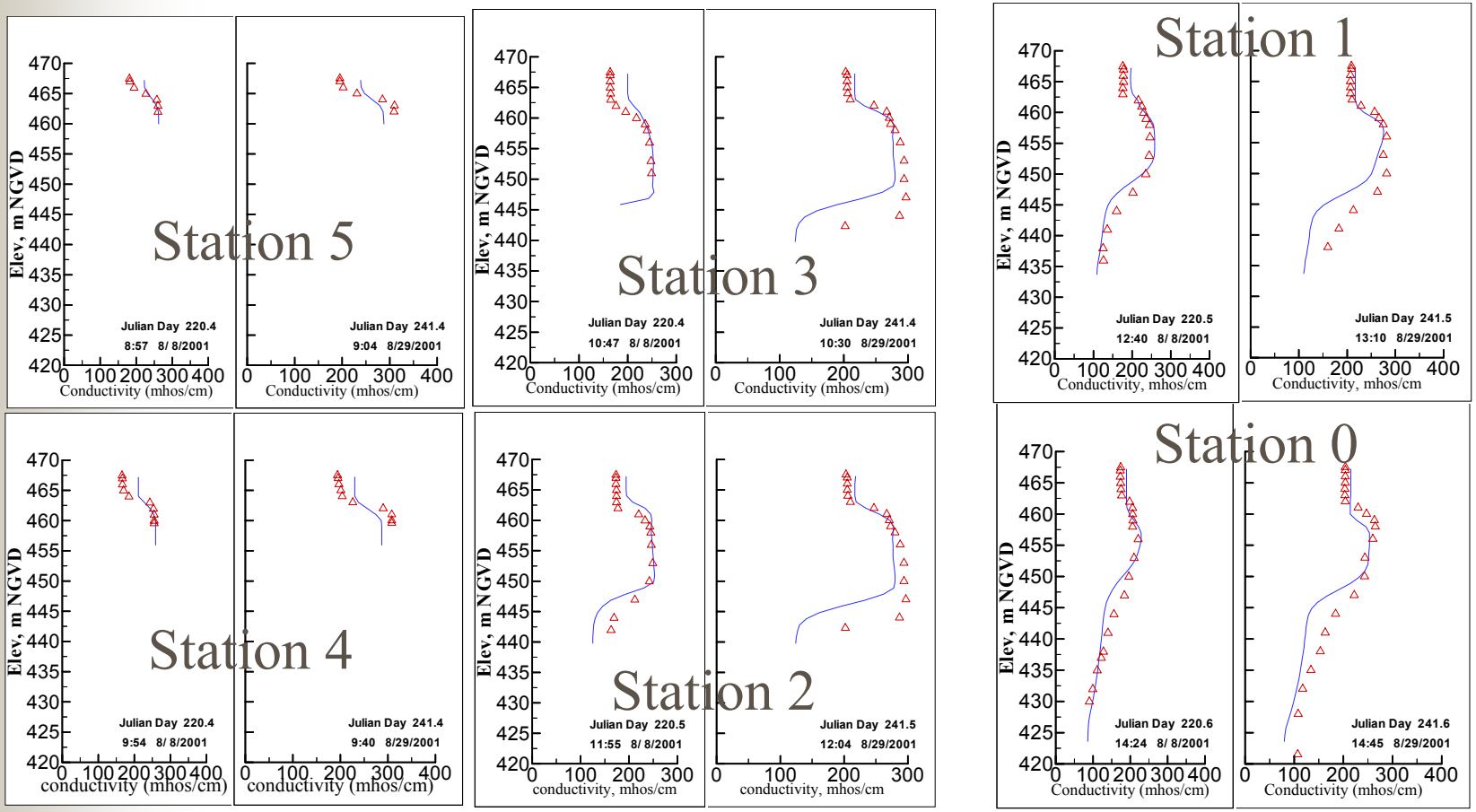
Temperature 2001



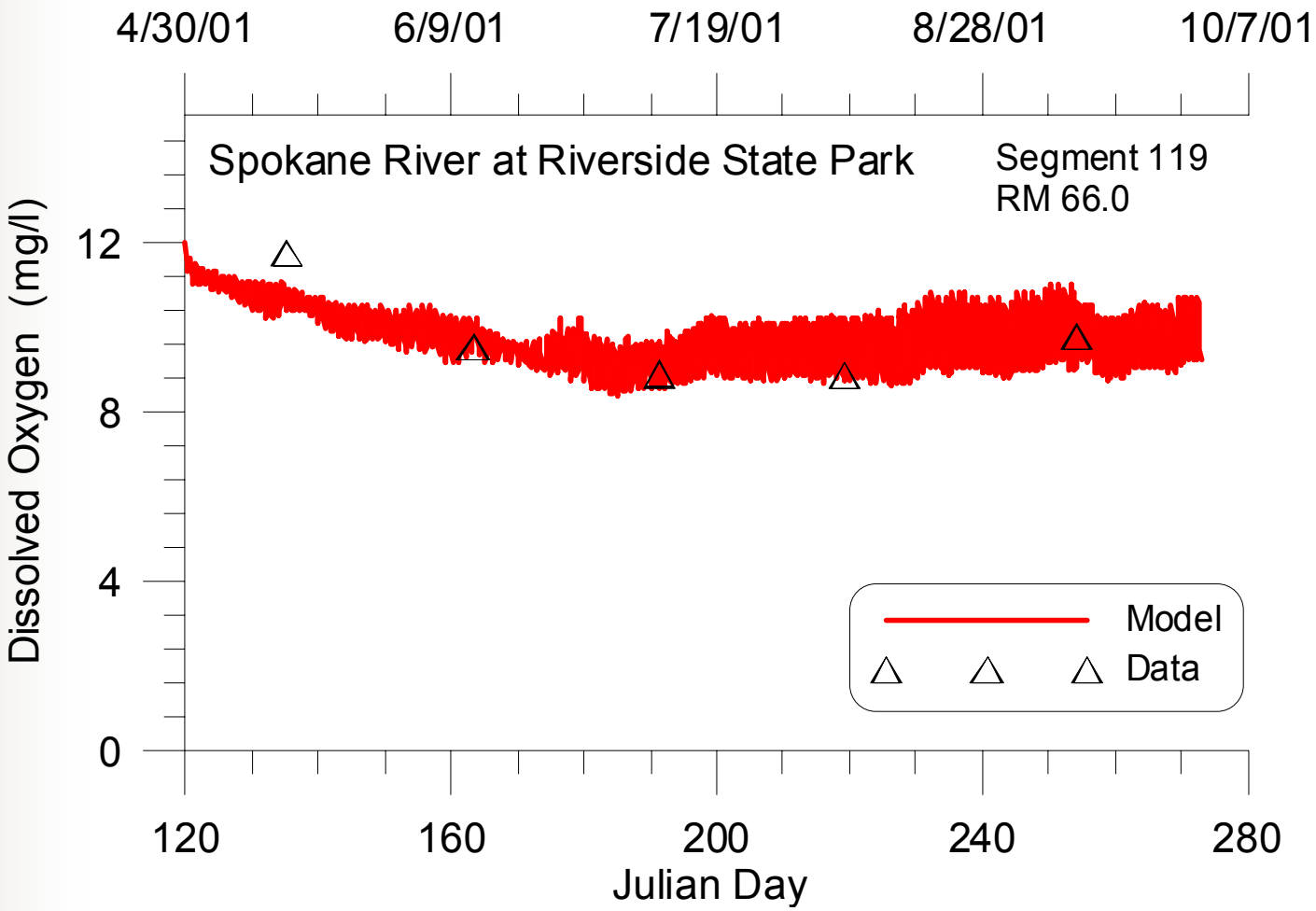
Conductivity 2001



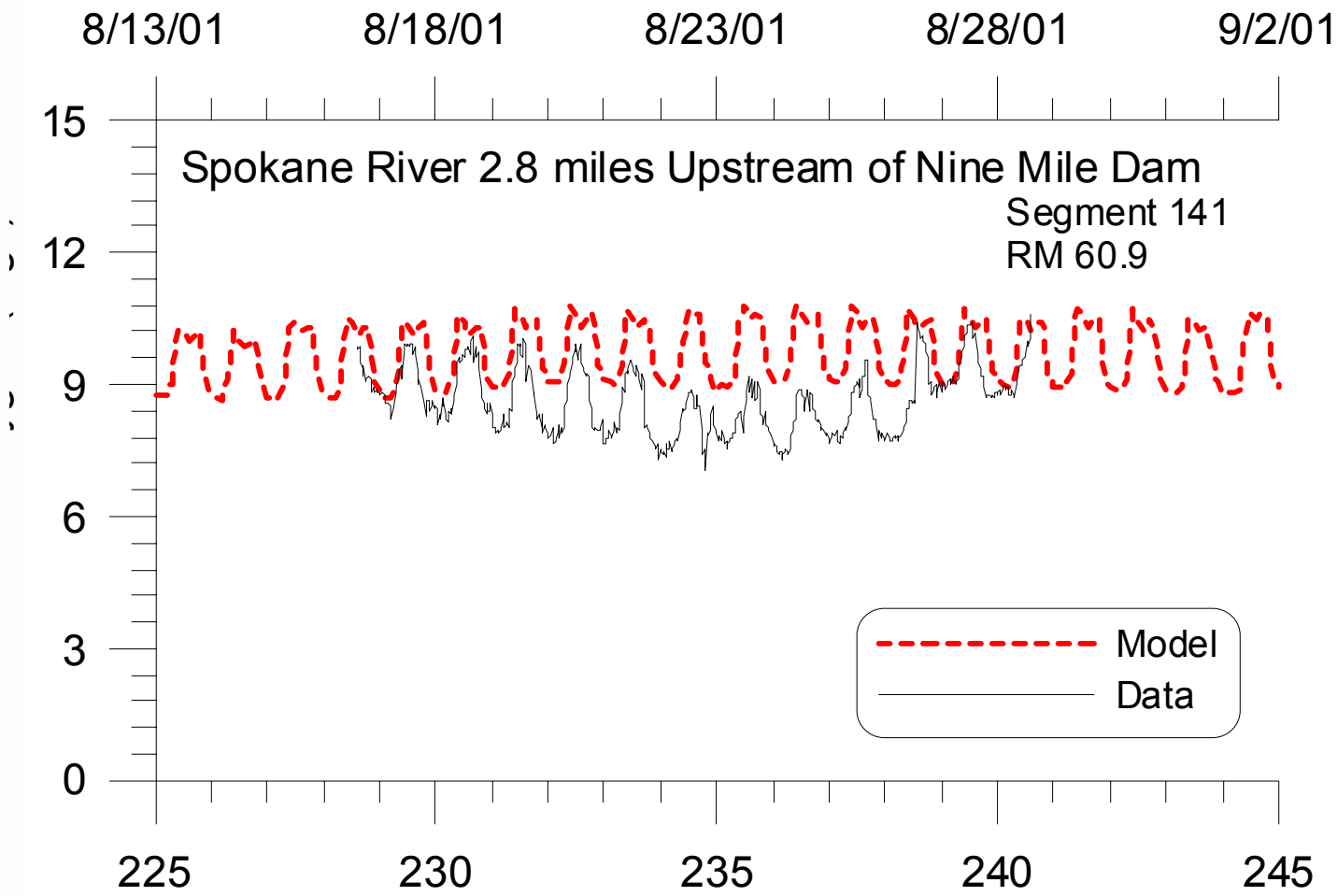
Conductivity Long Lake 2001



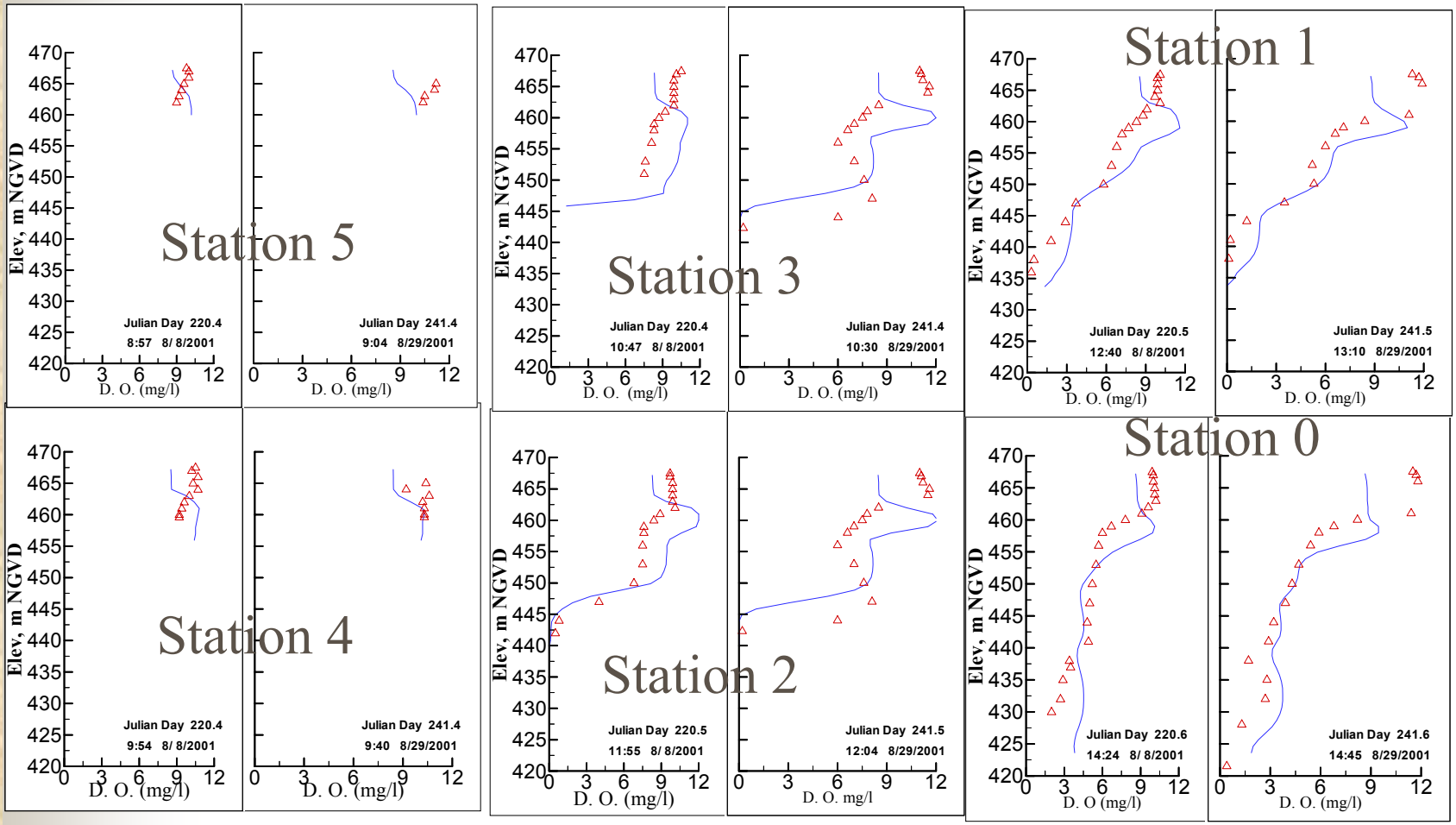
Dissolved Oxygen 2001



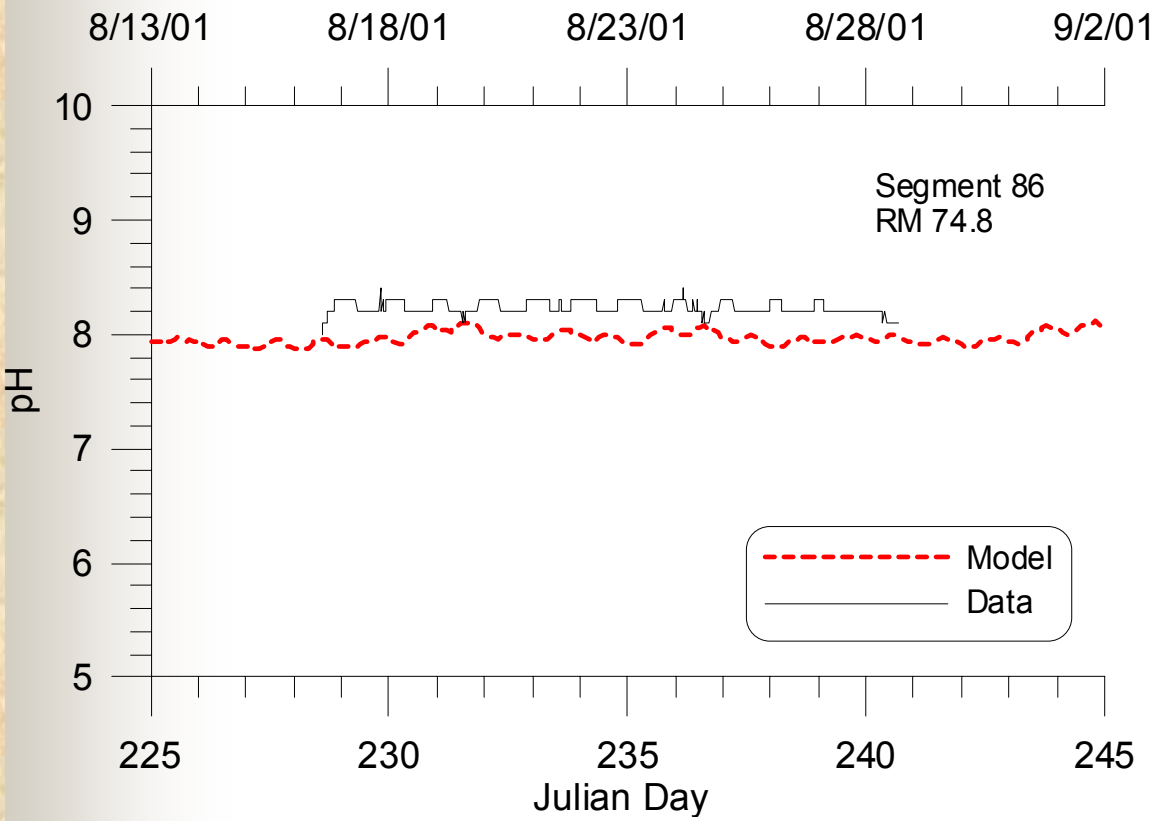
Dissolved Oxygen 2001



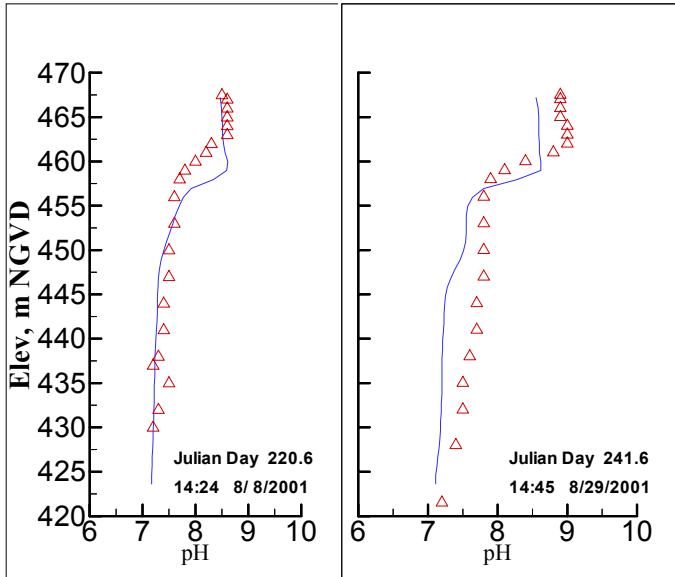
Dissolved Oxygen Long Lake 2001



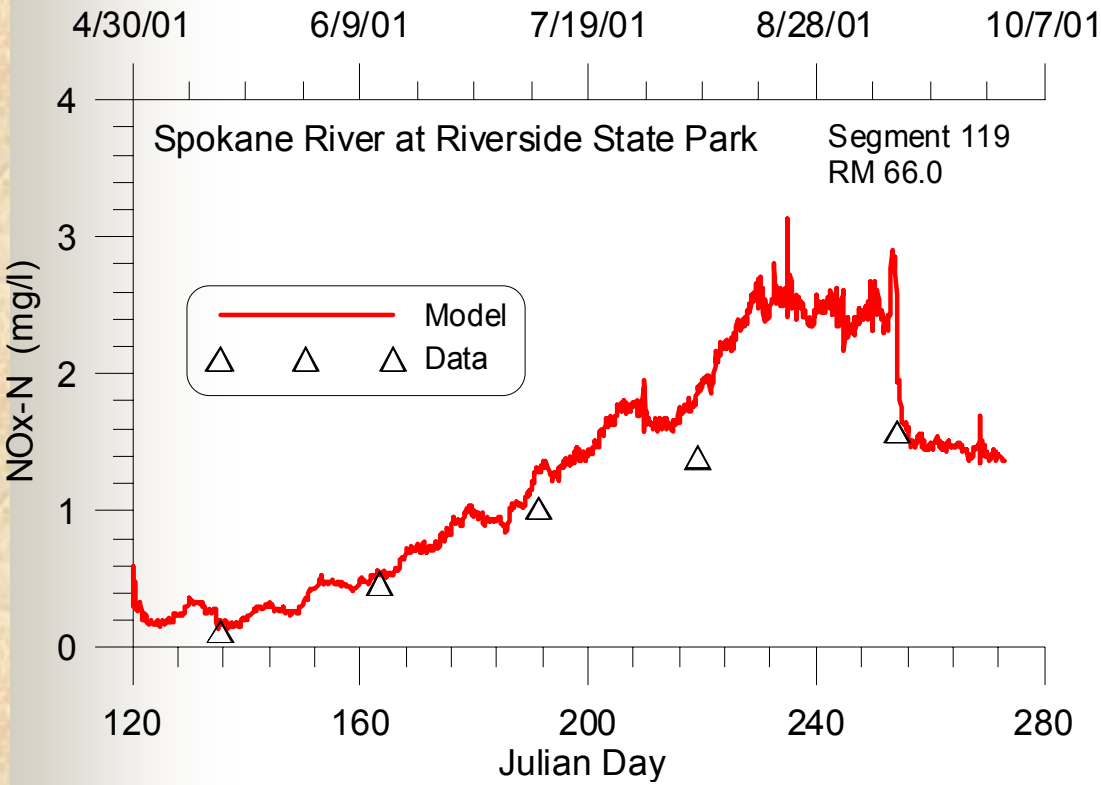
pH 2001



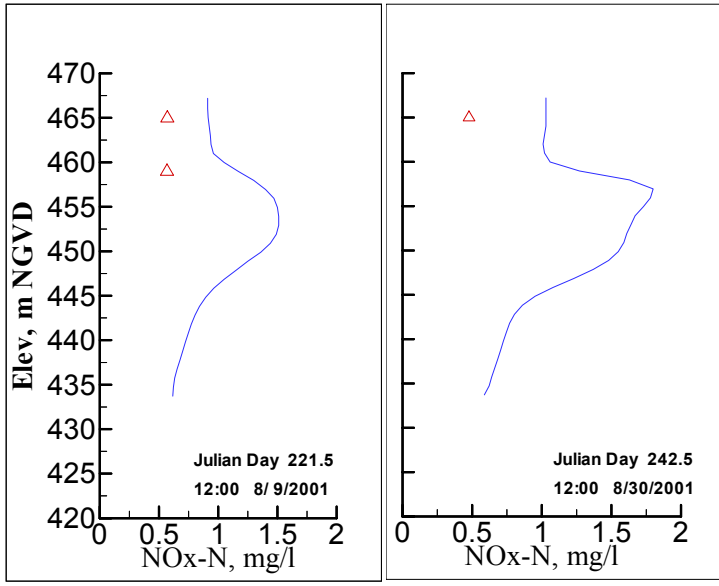
Long Lake Station 0



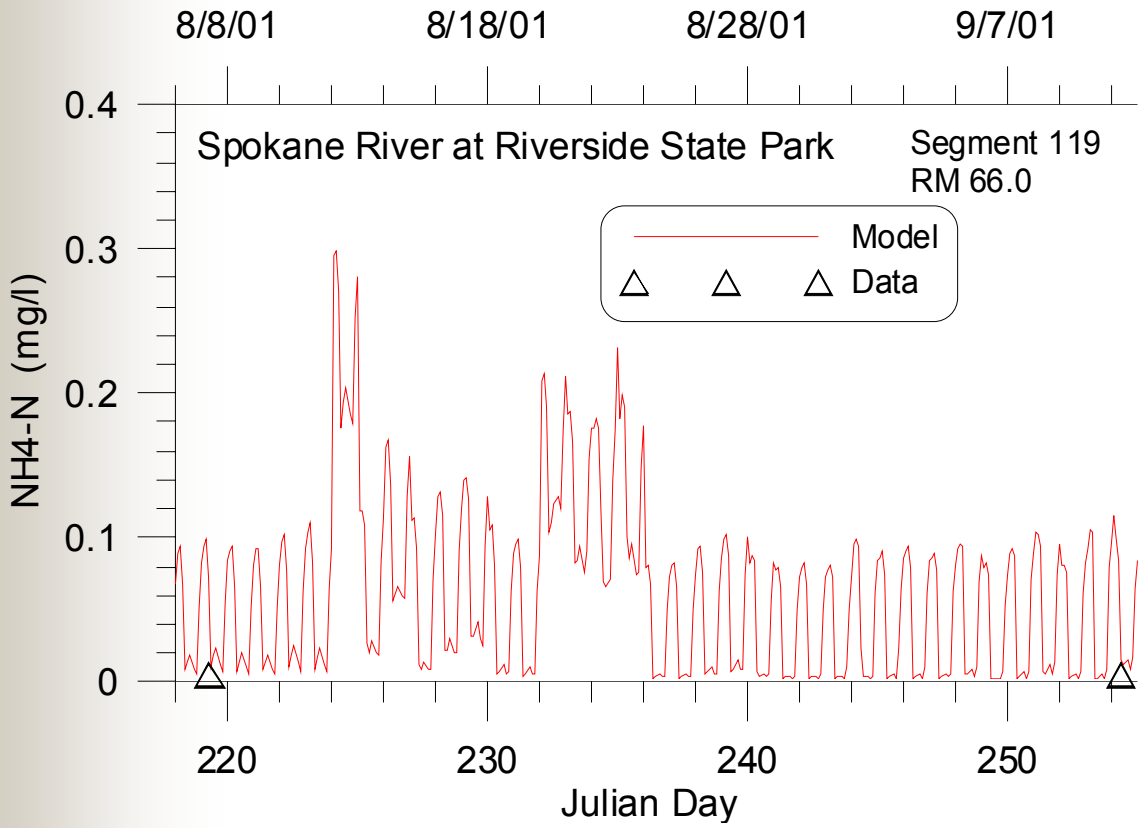
NOX 2001



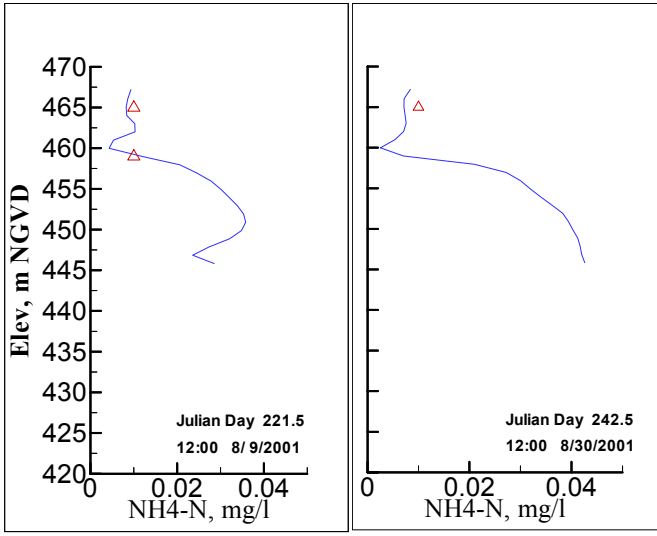
Long Lake Station 0



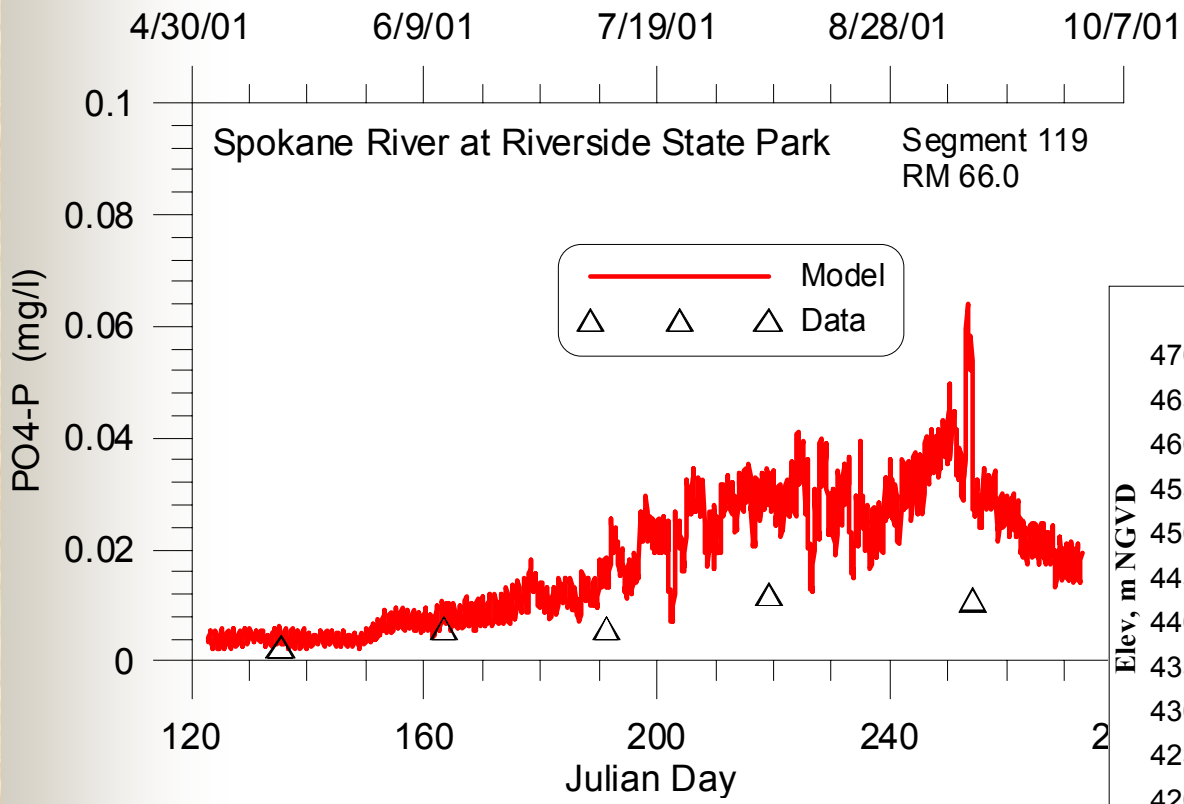
NH4 2001



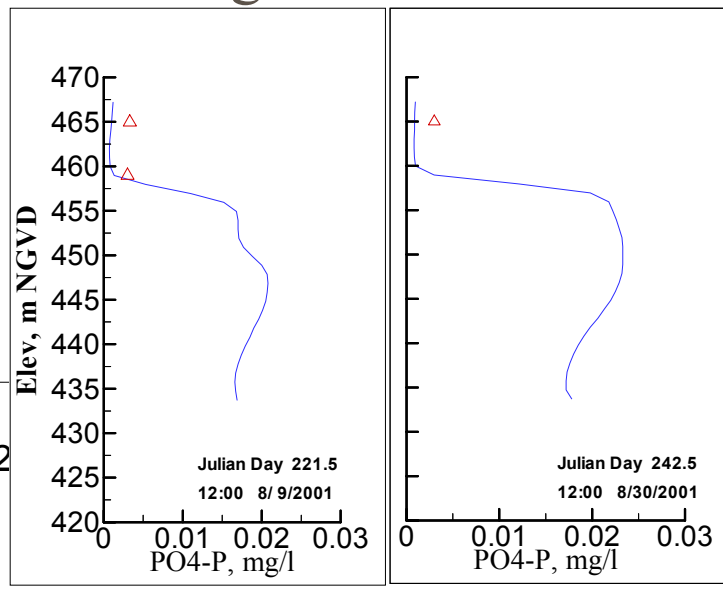
Long Lake Station 0



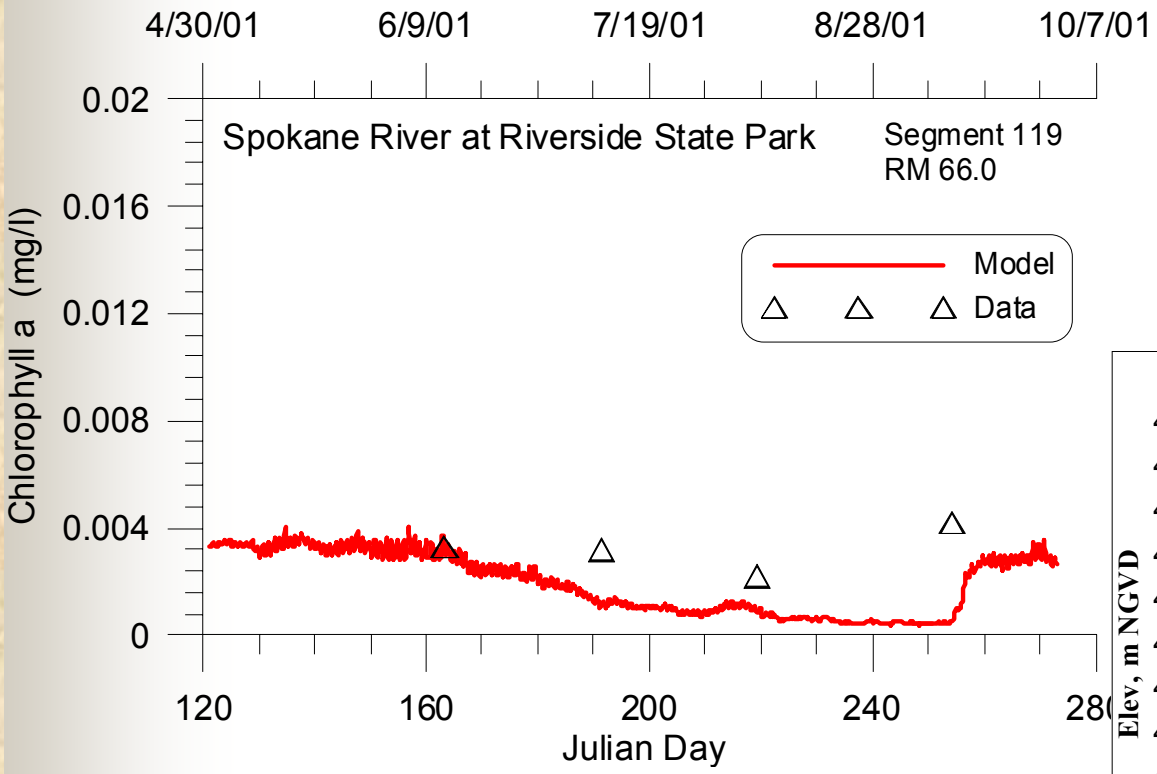
PO4 2001



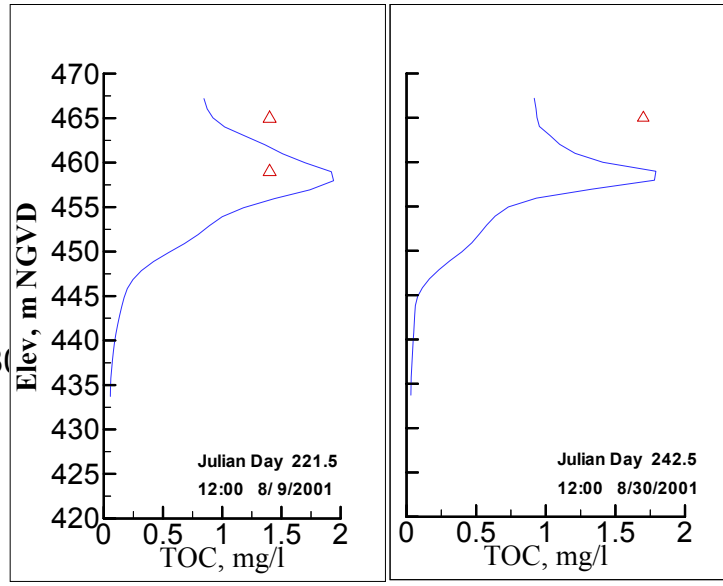
Long Lake Station 1



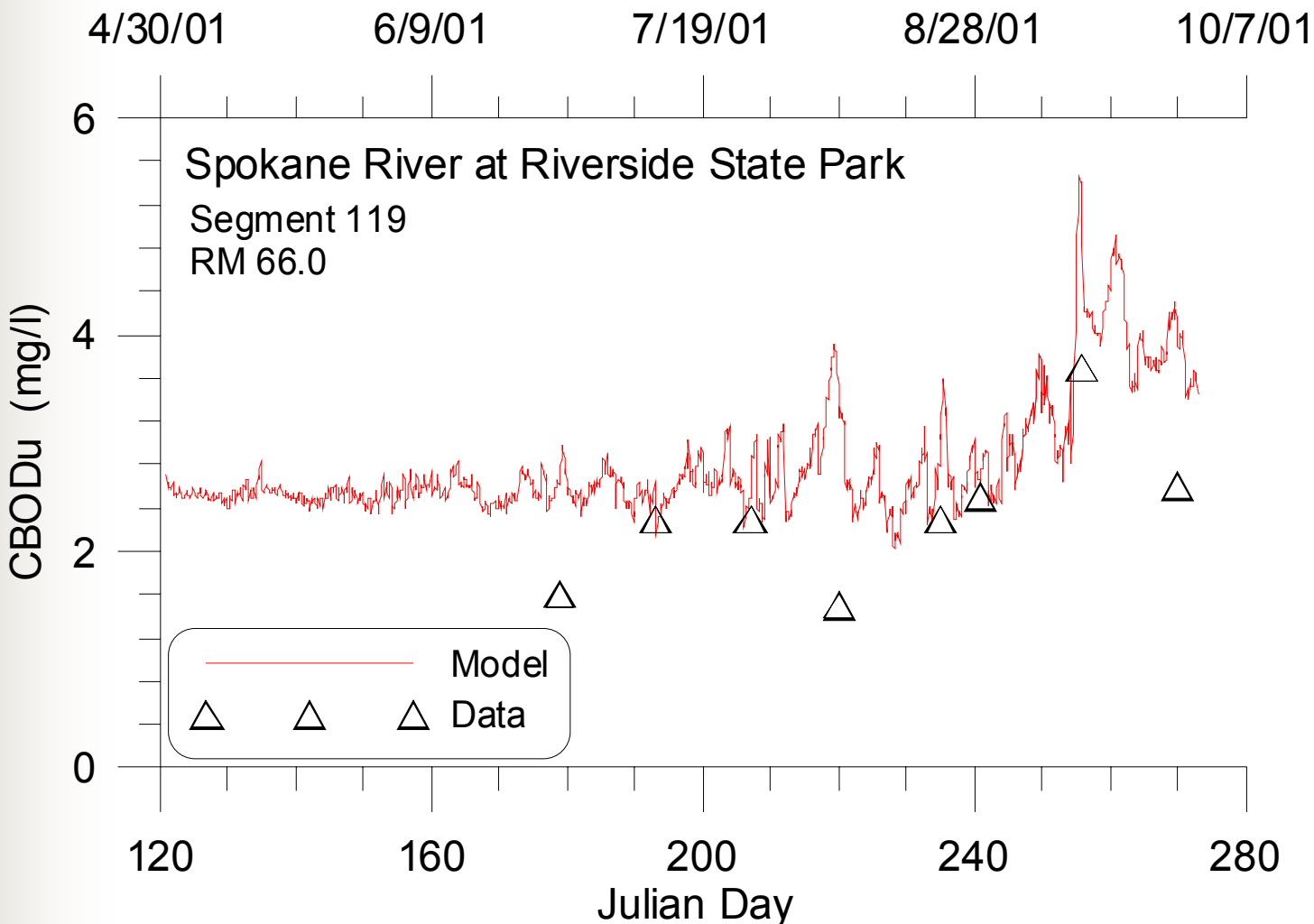
Chlorophyll a 2001



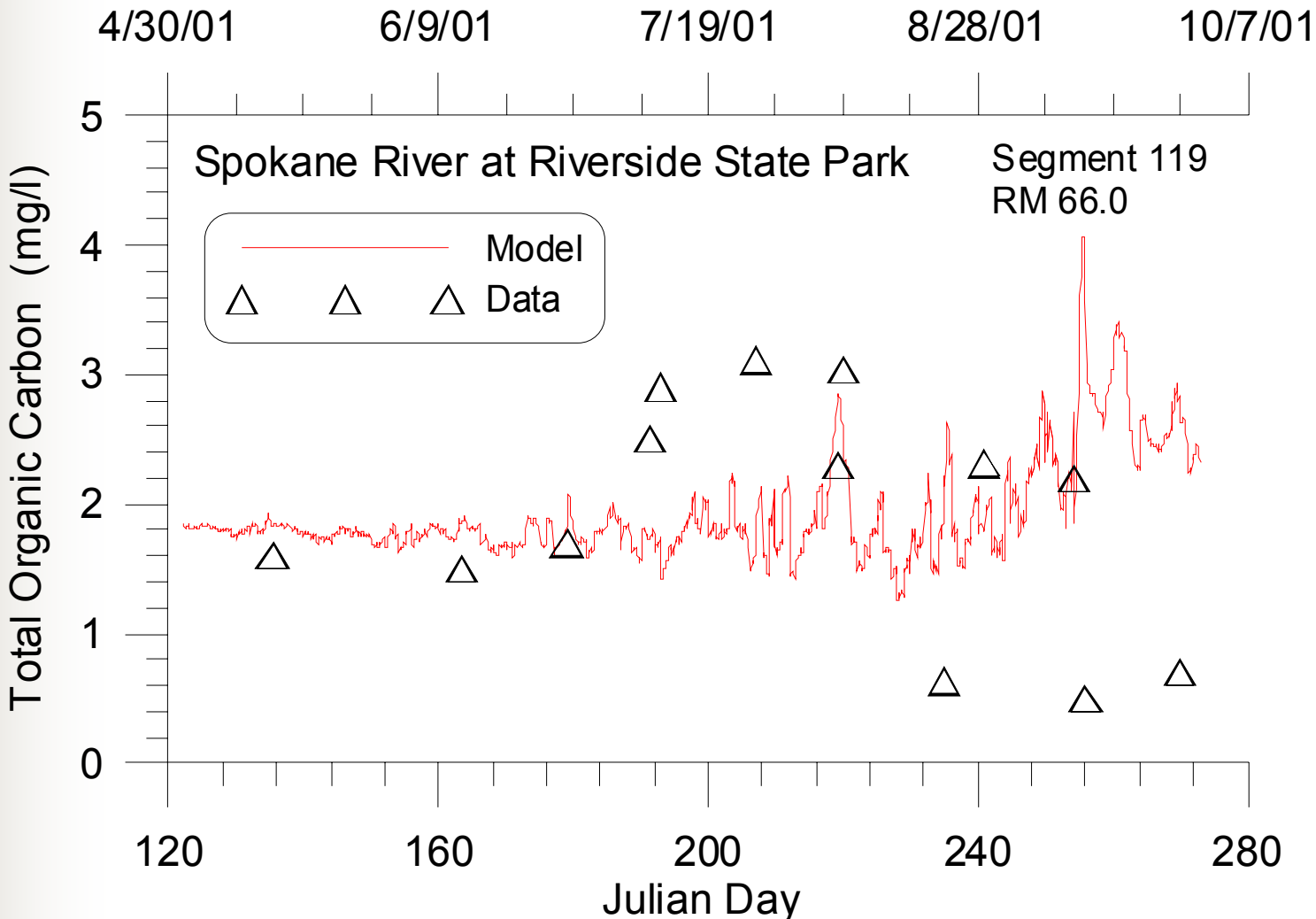
Long Lake Station 1



CBOD 2001


4/30/01
6/9/01
7/19/01
8/28/01
10/7/01
Spokane River at Riverside State Park
Segment 119
RM 66.0
CBODu (mg/l)
6
4
2
0
Model
Data
120
160
200
240
280
Julian Day

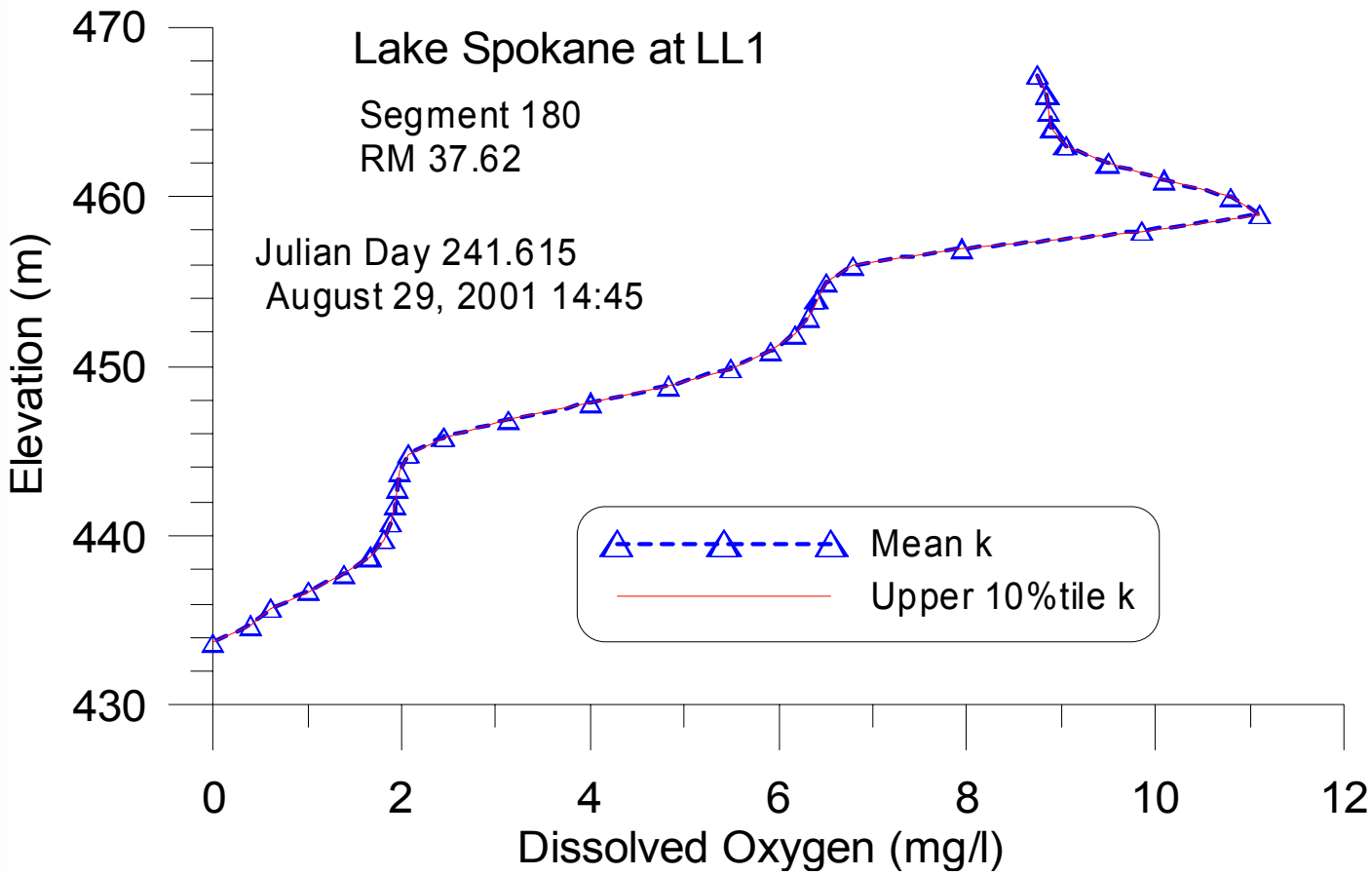
TOC 2001


4/30/01
6/9/01
7/19/01
8/28/01
10/7/01
Spokane River at Riverside State Park
Segment 119
RM 66.0
Model
Data
Total Organic Carbon (mg/l)
0
1
2
3
4
5
120
160
200
240
280
Julian Day

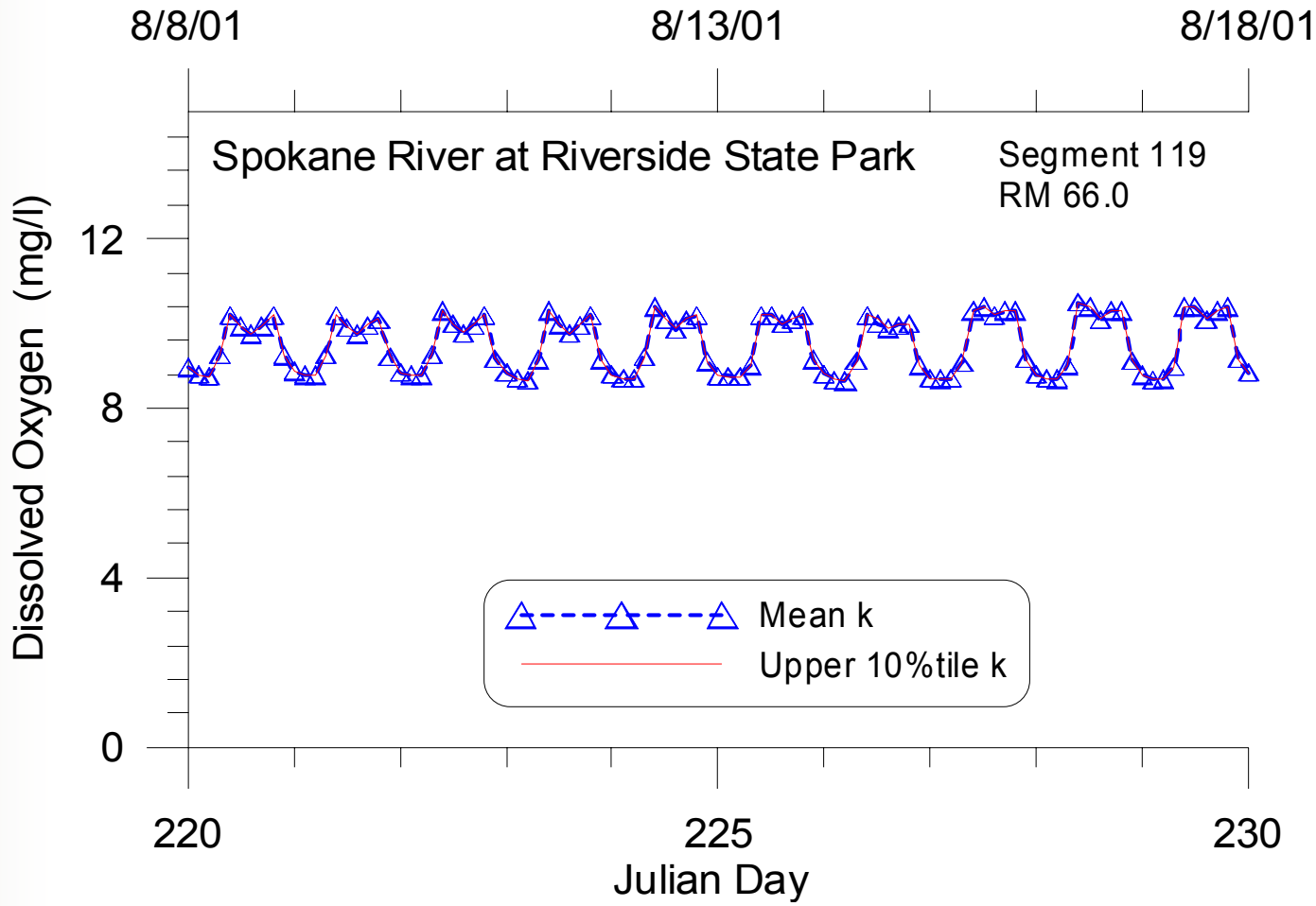
Effect of Average vs Upper 10%tile percentile CBOD decay rates on DO

CBOD compartment	Description	Mean Decay rate, day^{-1}	Upper 10%tile Decay rate, day^{-1}
1	Liberty WTP	0.0456	0.0585
2	Kaiser Aluminum	0.1275	0.210
3	Inland Empire Paper	0.0186	0.0247
4	Spokane WTP	0.0736	0.1250
5	Coulee Creek, Hangman Creek, Little Spokane River, Upstream Boundary Condition	0.0660	0.101

Effect of Average vs Upper 10%tile percentile CBOD decay rates on DO

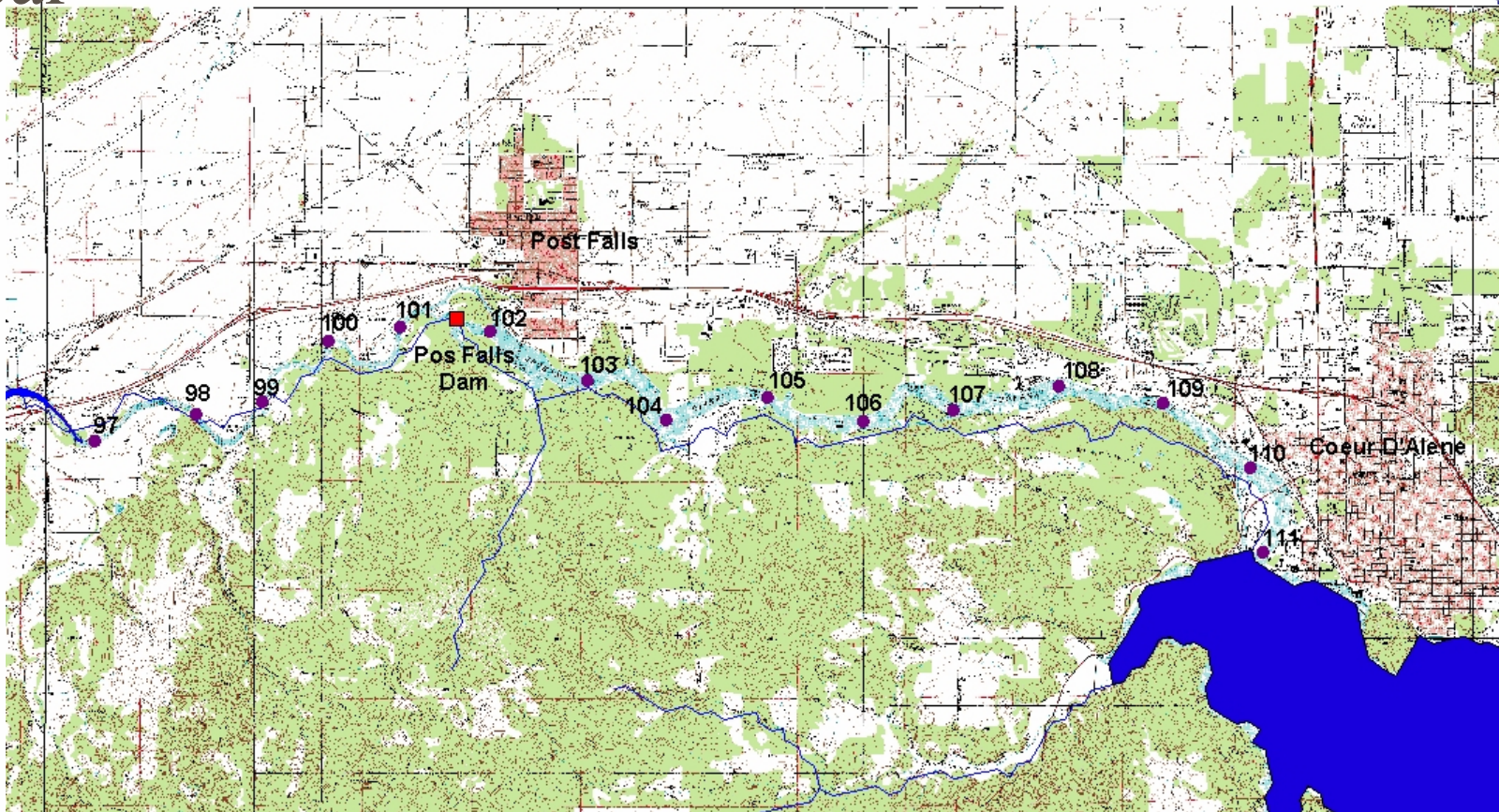


Effect of Average vs Upper 10%tile percentile CBOD decay rates on DO



Further work tasks

- Complete W2 model grid from Couer d'Alene to Washington State Line, run model for 2001 year



Further work tasks

- Fine tune model calibration for 2001
- Final reports:
  - 2001 Data report - draft
  - 2001 Calibration Report - draft
  - W2 model from WA to Coeur d'Alene Report