



# Arkansas Water Resources Center

## ILLINOIS RIVER WATER QUALITY AUTOMATIC SAMPLER INSTALLATION

Final Report Submitted To:  
Arkansas Soil and Water Conservation Commission

**MSC-227**

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by

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## **EXECUTIVE SUMMARY**

### **Illinois River Water Quality**

#### **Automatic Sampler Installation**

The objectives of this study are two fold. The first being to determine the pollution load in the Illinois River's main channel at the Arkansas/Oklahoma state line. The second is to determine whether Lake Frances is contributing to the nutrient loads in the river.

Sampling stations were located upstream and downstream from Lake Frances which happens to be on either side of the Arkansas/Oklahoma state line. The upstream station was located where Arkansas Highway 59 crosses the Illinois River, and the downstream station was located where U.S. Highway 59 crosses the Illinois River in Oklahoma. The Oklahoma station is frequently referred to as the Watts station because it is located near the town of Watts, Oklahoma.

A USGS flow gauging station was located at each sampling station. The USGS performed flow monitoring at both stations. Automated samplers were used for sample collection. Once a week, the sampler was triggered manually to collect a grab sample. During storm events, additional samples were collected. The number of samples collected depended on the intensity and duration of the storm.

The sampling period for this project was from September 13, 1995 to September 15, 1996. There were one-hundred thirty samples collected at the Arkansas station and ninety-four samples collected at Oklahoma station. These samples were tested for Ammonia, Nitrates, Total Kjeldahl Nitrogen, Total Phosphorus, Total Suspended Solids, and Total Organic Carbon. Table 1 shows the average concentration of the each parameter at both the Arkansas and Oklahoma station. A one tailed T-Test at an alpha of 0.05 was performed to determine whether parameter values were significantly larger in Oklahoma than in Arkansas.

Table 1. Average Concentrations, Percent Difference Calculations, and T-Tests

Nutrient	Average Arkansas Concentration (mg/L)	Average Oklahoma Concentration (mg/L)	Percent Difference (%)	One Tailed T-Test $\alpha$
NO <sub>3</sub> - N	2.13	1.98	-7.30	0.055
NH <sub>3</sub> - N	0.03	0.05	+50.0	0.038
TKN	0.68	0.72	+5.71	0.268
TP	0.28	0.33	+16.4	0.059
TSS	61.9	95.3	+42.5	0.00013
TOC	3.54	3.64	+2.79	0.422

The t-tests were performed by using the software Microsoft Excel. A lower value indicates that there is significant enough difference between the two values being compared to conclude the values are different. A significance level of 0.05 was used for the one-tailed test.

The results indicate that at an  $\alpha$  of 0.05 there is not sufficient evidence to conclude the upstream and downstream concentrations for NO<sub>3</sub>-N, TKN, TP, and TOC are different. The results also indicated that at an  $\alpha$  of 0.05 there is sufficient evidence to conclude that the upstream and downstream concentrations for NH<sub>3</sub>-N and TSS are different. The percent difference calculations agree with the results from the t-tests. The percent difference of 16.4% and t-test result of 0.059 for TP give borderline results as to whether a difference exists in the upstream and downstream TP concentrations.

Tables 2 and 3 show the total yearly flow, total yearly load and total flow weighted average concentration of all parameters at both the Arkansas and Oklahoma stations.

Table 2. Total Flows, Total Loads, and Average Calculated Concentrations for Arkansas

Nutrients	Total Flow (ft <sup>3</sup> /yr)	Total Load (kg/yr)	Average Flow Weighted Concentrations (mg/L)
NO <sub>3</sub> - N	2,675,263	550,000	2.0
NH <sub>3</sub> - N	2,675,263	8,530	0.031
TKN	2,675,263	201,000	0.74
TP	2,675,263	89,900	0.33
TSS	2,675,263	27,500,000	101
TOC	2,675,263	1,130,000	4.2

Table 3. Total Flows, Total Loads, and Average Calculated Concentrations for Oklahoma

Nutrients	Total Flow (ft <sup>3</sup> /yr)	Total Load (kg/yr)	Average Flow Weighted Concentrations (mg/L)
NO <sub>3</sub> - N	3,759,080	814,000	2.1
NH <sub>3</sub> - N	3,759,080	19,100	0.050
TKN	3,759,080	269,000	0.70
TP	3,759,080	122,000	0.32
TSS	3,759,080	36,000,000	94
TOC	3,759,080	1,520,000	4.0

A comparison of pollutant concentrations above and below Lake Frances showed some increase in the average concentrations for all parameters except NO<sub>3</sub>-N . However, the results obtained from a t-test analysis indicate there is not sufficient evidence at an  $\alpha$  of 0.05 to conclude that the concentrations for NO<sub>3</sub>-N, TKN, TP, and TOC upstream and downstream from Lake Frances are different. The t-test results also indicate that there is sufficient evidence at an  $\alpha$  of 0.05 to conclude that the concentrations for NH<sub>3</sub>-N and TSS upstream and downstream from Lake Frances are different. The flow weighted average concentrations show that the differences in parameter values for NO<sub>3</sub>-N, TKN, TP, and TOC is only 5% or less between Arkansas and Oklahoma which supports the concept that there is probably no significant difference between these values.

Although there was no direct correlation of TP concentrations and TSS concentrations to flow in general, high peak concentrations appear to be associated with high peak runoff events.

A regression analysis performed showed that there was a correlation between TSS concentrations and TP concentrations.

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## **Introduction**

The Illinois River drainage headwaters are located in Benton and Washington counties in Arkansas. The Illinois River has many tributaries serving as receiving streams for non-point source discharges and several point source discharges. Figure 1 (pg. 2) shows a map of the Illinois River drainage headwaters. In Oklahoma, the Illinois River is considered a scenic waterway which feeds Tenkiller Lake. Oklahoma is concerned that nutrient levels from Arkansas are causing eutrophication in Tenkiller Lake. Phosphorus has been identified as the primary nutrient of concern. Research is ongoing to determine sources and quantities of pollution into the Illinois River.

The Illinois River flows through Lake Frances which is located on the Arkansas/Oklahoma state line approximately five miles south of Siloam Springs, AR. Approximately ten years ago the upper half of Lake Frances' dam failed. What was once part of Lake Frances is now a lake bed containing sediments deposited over the reservoir's lifetime. Both Arkansas and Oklahoma have expressed concerns as to whether or not Lake Frances' sediment deposits are a contributing factor to the Illinois River's nutrient levels.



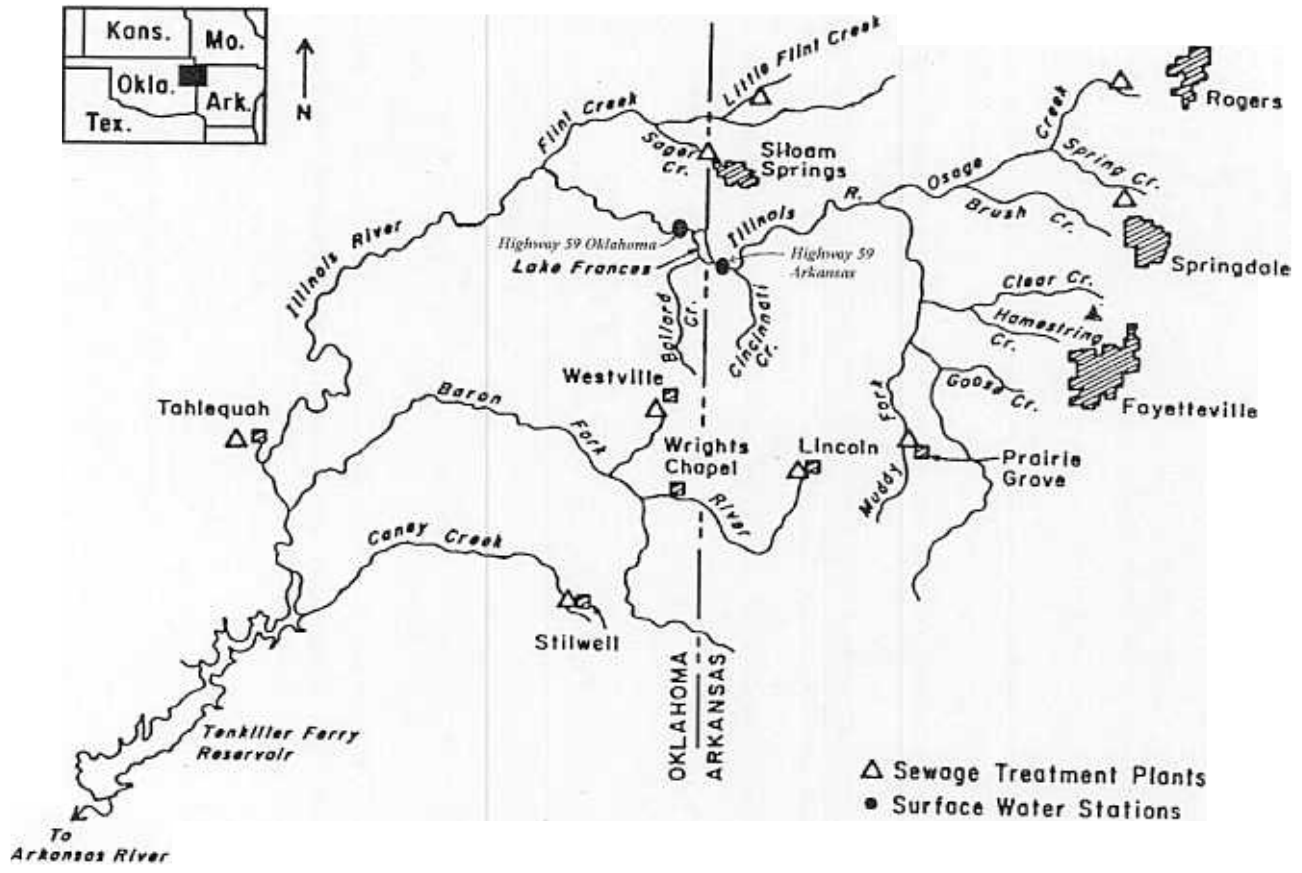


Figure 1 Illinois River Drainage Headwaters

## Objective

The objectives of this study are two fold. The first being to determine the pollution load in the Illinois River's main channel at the Arkansas/Oklahoma state line. The second is to determine whether Lake Frances is contributing to the nutrient loads in the river.

## Scope

Sampling stations were located upstream and downstream from Lake Frances which happens to be on either side of the Arkansas/Oklahoma state line. The upstream station was located where Arkansas Highway 59 crosses the Illinois River, and the downstream station was located where U.S. Highway 59 crosses the Illinois River in Oklahoma. The Oklahoma station is frequently referred to as the Watts station because it is located near the town of Watts, Oklahoma.

A USGS flow gauging station was located at each sampling station. The USGS performed flow monitoring at both stations. Automated samplers were used for sample collection. Once a week, the sampler was triggered manually to collect a grab sample. During storm events, additional samples were collected. The number of samples collected depended on the intensity and duration of the storm.

The sampling period for this project was from September 13, 1995 to September 15, 1996. There were one-hundred thirty samples collected at the Arkansas station and ninety-four samples collected at Oklahoma station. These samples were tested for Ammonia, Nitrates, Total Kjeldahl Nitrogen, Total Phosphorus, Total Suspended Solids, and Total Organic Carbon.

## Sampling Procedures

A USGS gauging station was located at each sampling station. Each station was equipped with an automated sampler which was used to collect the samples. Each week a manual sample was collected during base flow conditions.

At the Arkansas station, the automated sampler was connected to the USGS gauging station. Here, the river's stage was used as the triggering mechanism. During storm events, when the stage height reached a pre determined height, the trigger would signal the sampler to begin the sampling process. At this point, the sampler would collect a sample approximately one liter in volume. Sampling would continue every four hours until the stage dropped back below the pre determined height. Samples were retrieved from the sampler within twenty-four hours of the collection of the first sample.

At the Oklahoma station, the automated sampler was not connected to the USGS gauging station. Atmospheric and flow conditions were monitored using weather forecasts and the USGS predicted hydrograph posted on the Internet. Once a storm was anticipated, the predicted hydrograph was consulted and a judgment was made whether or not to start the sampling process. The sampling interval and volume was the same as the Arkansas station, but the sampling process ended when the samples were retrieved within twenty-four hours. This method proved to be adequate resulting in the downstream samples being collected approximately one or two hours after the upstream samples.

Once the samples were collected, they were transported to the Arkansas Water Resource Center water quality laboratory for testing. The samples were analyzed according to EPA QA/QC methods.

## **Results**

Once the laboratory analysis was complete, the process of data compilation and data evaluation began. Using the results from the lab, spreadsheets were set up for each station with data in columns of dates and times, flows, and sample concentrations. The Arkansas and Oklahoma sample data are shown in Table 1 (pp. 6-9) and Table 2 (pp. 10-12), respectively. The first and second columns of this table describe the date and time that the sample was collected. Columns three through eight are the sample data received from the water quality lab. There were thirty-six more samples collected in Arkansas than in Oklahoma. The difference in the number of samples can be attributed to the inaccessibility of the Oklahoma station during inclement weather, and at the start of the study the Arkansas sampler was automatically triggered during storm events and the method of sampling at the Oklahoma station had not been established.

Several values in the data set for the Arkansas sample data were not reported from the water quality laboratory. These values were: TP for December 18, 1995 at 03:00 hours, TP for December 19, 1995 at 15:00 hours, and NO<sub>3</sub> - N for January 18, 1996 at 01:00 hours. Values for these concentrations were approximated by averaging the sample values preceding and proceeding the missing value. These approximations are shaded in the sample data table.

Samples collected on May 6, 1996 and May 10, 1996 at the Oklahoma station were considered to be contaminated because it was observed that the sampling tube inlet had dropped into the river bottom sediment. This observation was confirmed by the extremely high values for TSS reported during these dates. Therefore, it was decided to eliminate these samples from any further data evaluation.

### **Load Calculations**

Hourly flows provided by the USGS were used to calculate the pollutant loads. In order to calculate the loads, it was determined that a weighted flow should be used. Only one manual sample was collected each week (low flows), but during storm events (high flows) many samples were collected. Therefore, if the storm flow samples were treated in the same manner as base flow samples, that is storm flows and base flows were treated as having equal time duration, the loads calculated would be greater than what actually existed. For each sample collected, a total flow volume was determined for each

Table 1. Arkansas Sample Data

Date	Time (hrs)	Arkansas Concentrations					
		NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
13-Sep-95	12:00	1.90	0.02	0.40	0.26	12.37	4.52
20-Sep-95	15:00	1.87	0.03	0.54	0.22	7.90	6.58
28-Sep-95	13:00	2.20	0.03	0.46	0.25	4.60	3.01
03-Oct-95	14:00	2.18	0.03	0.57	0.30	7.00	0.75
03-Oct-95	18:00	2.18	0.04	0.45	0.28	7.15	0.45
03-Oct-95	22:00	2.23	0.04	0.41	0.29	9.70	0.53
04-Oct-95	02:00	2.11	0.03	0.46	0.27	5.60	1.39
04-Oct-95	06:00	2.02	0.03	0.57	0.27	8.50	0.73
04-Oct-95	10:00	2.17	0.03	0.42	0.28	6.20	2.15
04-Oct-95	12:00	2.20	0.04	0.42	0.28	7.90	1.87
11-Oct-95	15:00	2.13	0.04	0.70	0.26	9.20	3.45
18-Oct-95	14:00	2.11	0.03	0.51	0.24	3.93	2.21
25-Oct-95	12:00	2.10	0.03	0.51	0.27	2.75	1.48
01-Nov-95	14:00	1.96	0.01	0.53	0.27	2.95	1.57
08-Nov-95	14:00	2.01	0.03	0.53	0.30	2.90	2.13
16-Nov-95	15:00	1.83	0.02	0.55	0.23	3.15	1.45
22-Nov-95	10:00	1.92	0.03	0.48	0.23	2.40	1.92
30-Nov-95	12:00	1.98	0.01	0.47	0.25	2.32	2.24
06-Dec-95	14:00	1.93	0.06	0.62	0.28	4.85	1.07
13-Dec-95	14:00	2.30	0.02	0.44	0.23	3.35	1.25
17-Dec-95	23:00	2.18	0.02	0.54	0.24	11.60	1.60
18-Dec-95	03:00	2.21	0.01	0.68	0.24	29.67	0.68
18-Dec-95	07:00	2.15	0.02	0.53	0.24	20.73	1.44
18-Dec-95	11:00	2.12	0.01	0.63	0.34	25.40	2.63
18-Dec-95	15:00	1.89	0.02	0.61	0.30	37.73	3.12
18-Dec-95	19:00	1.78	0.02	0.65	0.30	28.40	3.16
18-Dec-95	23:00	1.77	0.03	0.80	0.26	23.13	2.79
19-Dec-95	03:00	1.78	0.41	0.56	0.23	22.27	2.91
19-Dec-95	07:00	1.87	0.09	0.59	0.29	19.87	2.91
19-Dec-95	11:00	2.00	0.03	0.70	0.28	64.13	2.90
19-Dec-95	15:00	2.10	0.01	0.74	0.32	63.30	2.82
19-Dec-95	19:00	2.01	0.04	0.65	0.36	46.95	3.64
19-Dec-95	23:00	1.83	0.02	0.84	0.25	33.33	3.83
20-Dec-95	03:00	1.86	0.02	0.77	0.27	29.80	3.77
20-Dec-95	07:00	1.91	0.02	0.70	0.28	23.53	3.82
20-Dec-95	11:00	1.99	0.01	0.70	0.27	19.13	3.64
11-Jan-96	12:00	2.56	0.03	0.44	0.12	3.20	1.92
12-Jan-96	07:00	2.56	0.01	0.52	0.13	3.45	0.46
12-Jan-96	11:00	2.56	0.01	0.52	0.13	3.00	1.10

Table 1. Arkansas Sample Data

Date	Time (hrs)	Arkansas Concentrations					
		NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
12-Jan-96	15:00	2.50	0.02	0.59	0.13	2.45	0.78
12-Jan-96	19:00	2.45	0.01	0.44	0.16	2.55	1.18
12-Jan-96	23:00	2.46	0.01	0.47	0.14	2.85	0.96
13-Jan-96	03:00	2.46	0.01	0.58	0.15	3.40	0.99
15-Jan-96	15:00	2.45	0.01	0.52	0.14	3.35	0.95
18-Jan-96	01:00	2.86	0.10	1.28	0.56	102.13	4.97
19-Jan-96	01:00	3.27	0.02	0.92	0.16	31.30	1.53
19-Jan-96	05:00	3.39	0.04	0.72	0.15	20.30	1.47
22-Jan-96	15:00	3.56	0.06	0.58	0.12	11.80	1.07
22-Jan-96	19:00	3.56	0.01	0.39	0.13	9.00	1.09
22-Jan-96	23:00	3.57	0.01	0.42	0.12	20.20	1.24
23-Jan-96	03:00	3.55	0.04	0.49	0.13	9.93	1.15
23-Jan-96	07:00	3.51	0.01	0.50	0.12	10.00	1.04
23-Jan-96	19:00	3.56	0.04	0.34	0.11	10.50	0.81
23-Jan-96	23:00	3.31	0.06	0.48	0.13	10.50	1.12
24-Jan-96	15:00	3.26	0.07	0.50	0.12	9.85	1.65
25-Jan-96	15:00	3.06	0.06	0.47	0.05	9.90	1.99
29-Jan-96	15:00	3.24	0.01	0.26	0.05	7.40	0.53
06-Feb-96	15:00	3.33	0.01	0.48	0.17	2.27	0.56
14-Feb-96	15:00	2.73	0.01	0.29	0.05	8.20	1.29
20-Feb-96	14:00	2.62	0.04	0.36	0.13	16.73	1.55
01-Mar-96	10:00	2.50	0.02	0.32	0.05	6.65	1.23
06-Mar-96	15:00	2.57	0.01	0.35	0.19	6.35	1.73
15-Mar-96	15:00	2.38	0.03	0.48	0.28	3.90	1.61
20-Mar-96	15:00	2.42	0.03	0.05	0.29	18.30	1.87
27-Mar-96	13:00	2.14	0.02	0.26	0.40	12.70	0.54
29-Mar-96	02:00	2.23	0.01	0.45	0.31	24.50	1.67
29-Mar-96	06:00	2.13	0.01	0.47	0.09	23.30	1.87
29-Mar-96	10:00	2.03	0.01	0.49	0.09	17.10	2.35
29-Mar-96	14:00	1.88	0.01	0.50	0.08	17.80	2.78
29-Mar-96	18:00	1.79	0.01	0.61	0.27	17.00	2.43
29-Mar-96	22:00	1.87	0.01	0.63	0.08	16.10	2.75
30-Mar-96	02:00	1.90	0.01	0.57	0.07	13.70	2.67
30-Mar-96	06:00	1.89	0.01	0.56	0.07	13.00	2.86
31-Mar-96	14:00	1.88	0.06	0.32	0.15	13.60	3.26
05-Apr-96	08:00	1.74	0.01	0.45	0.15	278.00	3.09
12-Apr-96	08:00	1.57	0.02	0.54	0.19	26.60	1.70
13-Apr-96	05:00	1.65	0.01	0.30	0.19	50.10	1.95
13-Apr-96	09:00	1.63	0.01	0.49	0.20	62.30	1.59

Table 1. Arkansas Sample Data

Date	Time (hrs)	Arkansas Concentrations					
		NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
13-Apr-96	17:00	2.07	0.50	2.26	0.73	169.70	5.79
14-Apr-96	01:00	1.73	0.15	1.27	0.37	64.20	4.72
14-Apr-96	09:00	1.72	0.06	0.91	0.24	34.40	3.87
15-Apr-96	01:00	1.81	0.01	0.66	0.18	8.60	3.02
15-Apr-96	05:00	1.71	0.01	0.53	0.15	22.80	1.97
19-Apr-96	08:00	1.45	0.01	0.73	0.22	32.80	7.50
22-Apr-96	04:00	1.80	0.01	2.28	0.83	257.60	9.02
22-Apr-96	08:00	1.65	0.04	2.55	0.87	338.00	12.47
22-Apr-96	12:00	1.36	0.01	2.58	0.77	544.20	5.47
22-Apr-96	18:00	1.60	0.16	3.65	1.49	778.70	12.91
23-Apr-96	02:00	1.55	0.07	1.85	0.86	563.10	11.15
23-Apr-96	10:00	1.47	0.05	1.99	0.87	371.40	11.71
23-Apr-96	20:00	2.02	0.02	1.03	0.35	131.90	8.68
24-Apr-96	06:00	2.33	0.03	0.70	0.27	83.80	5.47
25-Apr-96	09:00	2.40	0.03	0.75	0.16	49.20	6.80
25-Apr-96	21:00	2.44	0.04	0.58	0.18	40.60	7.35
26-Apr-96	09:00	2.84	0.03	0.43	0.18	27.20	5.87
27-Apr-96	10:00	2.95	0.04	0.32	0.17	27.10	4.93
27-Apr-96	22:00	2.65	0.02	0.38	0.14	16.20	5.10
28-Apr-96	10:00	2.72	0.02	0.36	0.15	11.60	4.74
03-May-96	10:00	2.01	0.02	0.45	0.21	28.60	6.07
06-May-96	15:00	2.00	0.04	0.68	0.15	29.50	6.11
06-May-96	17:00	2.09	0.03	0.48	0.17	30.70	4.54
06-May-96	21:00	2.07	0.05	0.43	0.15	41.80	4.98
07-May-96	01:00	2.19	0.04	0.55	0.29	56.10	6.80
07-May-96	05:00	2.05	0.06	0.85	0.40	66.80	8.44
10-May-96	18:00	1.72	0.04	0.76	0.36	171.40	4.24
10-May-96	22:00	1.37	0.22	3.88	1.88	1051.80	9.51
11-May-96	10:00	1.34	0.08	2.88	1.46	771.60	9.17
12-May-96	10:00	2.01	0.02	0.53	0.28	51.70	5.00
14-May-96	18:00	2.64	0.01	0.27	0.17	21.20	2.82
24-May-96	17:00	2.52	0.01	0.41	0.23	62.00	3.99
31-May-96	08:00	1.67	0.01	1.00	0.27	54.90	14.81
01-Jun-96	20:00	1.91	0.003	0.71	0.09	65.20	4.92
02-Jun-96	00:00	2.40	0.014	0.43	0.34	37.80	3.87
02-Jun-96	04:00	2.52	0.025	0.34	0.31	30.70	3.62
02-Jun-96	08:00	2.46	0.003	0.35	0.28	24.80	3.24
06-Jun-96	17:00	1.62	0.014	0.69	0.28	36.10	7.52
14-Jun-96	09:00	1.89	0.019	0.83	0.27	51.80	12.76

Table 1 Arkansas Sample Data

Date	Time (hrs)	Arkansas Concentrations					
		NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
18-Jun-96	11:00	1.89	0.004	1.03	0.31	47.00	15.63
25-Jun-96	10:00	1.79	0.004	0.24	0.27	10.40	3.64
03-Jul-96	13:00	0.88	0.003	0.92	0.41	83.20	6.25
12-Jul-96	11:00	1.58	0.003	0.16	0.29	2.90	2.99
15-Jul-96	15:00	1.80	0.003	0.22	0.29	19.80	3.29
24-Jul-96	16:00	1.13	0.006	0.18	0.31	8.80	1.29
01-Aug-96	14:00	1.34	0.003	0.30	0.11	7.20	1.44
05-Aug-96	11:00	1.24	0.040	0.30	0.29	13.10	1.10
15-Aug-96	14:00	0.98	0.045	0.13	0.28	6.70	1.87
23-Aug-96	13:00	1.06	0.007	0.19	0.28	6.10	1.67
30-Aug-96	19:00	1.19	0.003	0.26	0.24	6.50	0.72
07-Sep-96	11:00	1.11	0.017	0.24	0.28	3.60	0.05
15-Sep-96	15:00	1.17	0.009	0.26	0.30	24.40	3.52
Average		2.13	0.03	0.68	0.28	61.89	3.54



Table 2. Oklahoma Sample Data

Date	Time	Oklahoma Concentrations					
		NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
13-Sep-95	12:00	1.73	0.08	0.48	0.29	19.47	3.74
28-Sep-95	13:00	2.05	0.04	0.48	0.26	13.40	1.36
04-Oct-95	13:00	2.02	0.04	0.50	0.31	20.16	25.89
11-Oct-95	16:00	2.00	0.05	0.43	0.24	11.70	1.71
18-Oct-95	14:00	1.94	0.03	0.52	0.24	11.55	0.55
25-Oct-95	13:00	1.96	0.04	0.51	0.26	11.50	0.78
01-Nov-95	15:00	1.86	0.01	0.45	0.25	8.60	0.05
08-Nov-95	15:00	1.85	0.04	0.49	0.30	12.40	0.96
16-Nov-95	16:00	1.75	0.02	0.40	0.24	6.47	1.28
22-Nov-95	10:00	1.79	0.04	0.40	0.25	8.85	1.86
30-Nov-95	13:00	1.80	0.30	0.48	0.18	3.25	1.59
06-Dec-95	15:00	2.06	0.03	0.62	0.26	0.20	2.32
13-Dec-95	15:00	2.16	0.04	0.43	0.23	3.28	0.05
18-Dec-95	17:00	2.01	0.02	0.61	0.30	77.13	1.64
18-Dec-95	21:00	2.07	0.01	0.59	0.23	41.53	1.93
19-Dec-95	01:00	1.97	0.02	0.59	0.25	44.80	2.15
19-Dec-95	05:00	1.87	0.01	0.81	0.30	45.27	2.26
19-Dec-95	09:00	1.81	0.02	0.69	0.35	66.40	2.81
19-Dec-95	13:00	1.83	0.02	0.72	0.30	72.87	3.31
19-Dec-95	17:00	1.89	0.01	0.92	0.23	169.20	3.26
19-Dec-95	21:00	2.07	0.02	0.92	0.30	162.80	3.07
20-Dec-95	01:00	2.10	0.02	0.88	0.35	107.80	3.28
20-Dec-95	05:00	1.97	0.02	0.85	0.33	83.47	3.74
20-Dec-95	09:00	2.03	0.03	0.79	0.26	66.10	3.64
20-Dec-95	13:00	2.01	0.02	0.79	0.25	50.50	3.53
15-Jan-96	15:00	2.40	0.03	0.43	0.13	7.85	0.78
29-Jan-96	16:00	3.24	0.01	0.29	0.05	7.40	0.53
06-Feb-96	16:00	3.22	0.02	0.30	0.20	1.73	0.48
14-Feb-96	16:00	2.67	0.02	0.32	0.12	7.70	0.72
20-Feb-96	15:00	2.73	0.01	0.22	0.12	16.40	1.82
01-Mar-96	10:00	2.30	0.04	0.38	0.15	7.10	0.57
06-Mar-96	16:00	2.32	0.03	0.38	0.09	24.24	0.90
15-Mar-96	16:00	2.12	0.06	0.88	0.25	17.30	1.52
20-Mar-96	16:00	2.42	0.04	0.36	0.28	18.50	2.06
27-Mar-96	14:00	2.04	0.56	0.29	0.25	12.40	0.47
29-Mar-96	16:00	2.09	0.01	0.73	0.31	149.90	2.63
29-Mar-96	20:00	1.94	0.01	0.65	0.24	77.20	2.96
30-Mar-96	19:00	1.95	0.02	1.88	0.74	730.60	3.26
31-Mar-96	03:00	1.88	0.05	0.62	0.43	154.20	3.31

Table 2. Oklahoma Sample Data

Date	Time	Oklahoma Concentrations					
		NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
31-Mar-96	11:00	1.96	0.05	0.76	0.25	158.20	3.15
31-Mar-96	19:00	2.00	0.04	0.69	0.26	130.90	3.14
05-Apr-96	09:00	1.91	0.01	1.25	0.50	227.40	1.16
12-Apr-96	09:00	1.59	0.02	0.30	0.16	28.40	3.00
13-Apr-96	13:00	1.84	0.03	0.87	0.35	122.20	5.53
13-Apr-96	17:00	2.04	0.39	1.94	0.57	150.70	5.53
14-Apr-96	01:00	2.00	0.19	1.24	0.50	69.50	4.95
14-Apr-96	09:00	1.85	0.10	0.95	0.28	56.80	4.17
14-Apr-96	17:00	1.85	0.07	0.91	0.26	44.70	3.94
15-Apr-96	14:00	1.91	0.05	0.91	0.43	143.90	2.85
15-Apr-96	18:00	1.88	0.02	0.66	0.25	68.50	2.29
19-Apr-96	09:00	1.78	0.03	0.52	0.22	48.60	5.24
22-Apr-96	12:00	1.43	0.19	3.25	1.26	584.80	13.05
22-Apr-96	19:00	1.60	0.13	3.25	1.71	713.90	12.31
23-Apr-96	02:00	1.55	0.12	2.46	0.94	440.00	10.68
23-Apr-96	12:00	1.58	0.05	1.91	0.78	316.60	11.14
23-Apr-96	20:00	1.79	0.03	1.30	0.58	150.60	8.68
24-Apr-96	03:00	2.19	0.02	0.83	0.38	92.30	6.90
24-Apr-96	21:00	2.55	0.06	0.59	0.21	56.00	6.90
25-Apr-96	09:00	2.65	0.03	0.44	0.21	54.00	6.54
26-Apr-96	10:00	2.82	0.06	0.38	0.20	52.30	5.56
27-Apr-96	11:00	2.96	0.06	0.32	0.18	35.40	4.86
27-Apr-96	22:00	2.94	0.04	0.43	0.20	50.00	4.83
28-Apr-96	10:00	2.92	0.06	0.39	0.20	51.30	4.61
03-May-96	10:00	2.50	0.03	0.27	0.22	34.50	2.19
06-May-96	16:00	2.30	0.05	0.38	0.22	68.70	3.70
12-May-96	11:00	2.02	0.04	0.64	0.29	75.30	5.66
14-May-96	19:00	2.61	0.03	0.40	0.17	53.10	3.50
24-May-96	18:00	2.48	0.01	0.49	0.26	92.80	4.09
31-May-96	09:00	2.09	0.05	0.74	0.18	162.30	3.48
01-Jun-96	21:00	2.33	0.016	0.79	0.52	209.30	3.49
02-Jun-96	01:00	2.28	0.012	1.59	0.85	220.10	3.85
02-Jun-96	05:00	2.38	0.018	0.93	0.61	356.10	3.43
02-Jun-96	09:00	2.50	0.023	1.00	0.71	289.40	3.59
06-Jun-96	17:00	2.11	0.030	1.44	0.61	325.70	3.85
14-Jun-96	09:00	1.95	0.037	0.37	0.26	52.15	6.37
18-Jun-96	10:00	1.91	0.030	0.43	0.25	22.50	5.27
25-Jun-96	09:00	1.49	0.053	0.38	0.28	22.80	3.86
03-Jul-96	13:00	1.32	0.003	0.32	0.26	15.70	4.75

Table 2. Oklahoma Sample Data

Date	Time	Oklahoma Concentrations					
		NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
12-Jul-96	10:00	1.34	0.009	0.23	0.26	15.60	2.99
15-Jul-96	14:00	1.52	0.003	0.22	0.30	29.90	3.08
24-Jul-96	15:00	0.94	0.076	0.35	0.29	20.70	1.52
01-Aug-96	15:00	1.14	0.031	0.40	0.31	18.80	1.63
05-Aug-96	10:00	1.01	0.038	0.38	0.29	17.80	2.48
15-Aug-96	15:00	0.70	0.070	0.40	0.26	8.80	1.80
23-Aug-96	13:00	0.99	0.016	0.41	0.26	25.70	1.69
30-Aug-96	18:00	1.17	0.003	0.33	0.21	10.20	0.70
07-Sep-96	11:00	0.81	0.003	0.33	0.26	12.10	0.37
15-Sep-96	14:00	0.83	0.042	0.45	0.30	25.80	3.07
Average		1.98	0.05	0.72	0.33	95.27	3.64

sample period by summing the flows during half the period preceding the sample collection time and half the period proceeding the sample collection time. The total flow obtained was then divided by the total duration for that sample period to obtain the average flow for the sample collected during that period. The load was calculated by multiplying the average flow, the time period, and the sample concentration. These values were summed to obtain the total load for the entire year. The total loads calculated for Arkansas and Oklahoma are shown in Table 3 (pp. 14-17) and Table 4 (pp. 18-20), respectively. The first and second columns represent the date and time that the samples were collected. Column three is the average flow which occurred during half the period preceding the sample and half the period proceeding the sample. Column four represents the number of hours that the average flow occurred. Columns five through ten contain the loads calculated using the data from Tables 1 & 2, the average flow (Column 3), and the duration of that average flow (Column 4). The average flow for the total time period was calculated, also.

#### **Effects of Lake Frances**

To determine the effects of Lake Frances, the concentrations at the Oklahoma station were compared with the concentrations at the Arkansas station. Loads were not used because of the differences in flows between the two stations. To make this comparison the student t-test was used and a percent difference was calculated, also. The results from the t-test describe the probability of observing a difference by chance alone even if no difference exists. The percent difference was calculated to provide a simple arithmetic relationship between the two stations. The results obtained from the t-tests and percent differences are shown in Table 5 (pg. 21). The first column lists the nutrients. The second and third columns are the average nutrient concentrations for Arkansas and Oklahoma, respectively. The fourth column shows the values calculated for the percent differences. The fifth column contains the results from the one-tailed t-test.

Table 3. Arkansas Loads

Date	Time (hrs)	Avg Flow (cfs)	Occurs (hrs)	NO3-N (kg)	NH3-N (kg)	Arkansas Loading			
						TKN (kg)	TP (kg)	TSS (kg)	TOC (kg)
13-Sep-95	12:00	172.31	167	6006	63	1264	822	39104	14289
20-Sep-95	15:00	226.41	180	6732	108	1944	792	28439	23687
28-Sep-95	13:00	176.02	156	2447	33	512	278	5117	3348
03-Oct-95	14:00	233.63	62	208	3	54	29	667	71
03-Oct-95	18:00	346.13	4	308	6	64	40	1009	64
03-Oct-95	22:00	318.14	4	289	5	53	38	1258	69
04-Oct-95	02:00	293.42	4	252	4	55	32	670	166
04-Oct-95	06:00	273.90	4	169	3	48	23	712	61
04-Oct-95	10:00	263.79	3	5076	70	982	655	14502	5029
04-Oct-95	12:00	205.30	87	7780	141	1485	990	27937	6613
11-Oct-95	15:00	163.29	169	5885	111	1934	718	25417	9531
18-Oct-95	14:00	150.58	166	5440	77	1315	619	10133	5698
25-Oct-95	12:00	159.36	168	5764	82	1400	741	7549	4063
01-Nov-95	14:00	159.12	169	5753	29	1556	793	8660	4609
08-Nov-95	14:00	180.74	181	6147	92	1621	917	8868	6513
16-Nov-95	15:00	169.43	166	5246	57	1577	659	9030	4157
22-Nov-95	10:00	157.02	166	5224	82	1306	626	6530	5224
30-Nov-95	12:00	150.14	170	4757	24	1129	601	5574	5382
06-Dec-95	14:00	148.21	157	3994	124	1283	579	10037	2214
13-Dec-95	14:00	149.82	137	1897	16	363	190	2762	1031
17-Dec-95	23:00	172.11	54	153	1	38	17	814	112
18-Dec-95	03:00	625.20	4	563	3	173	61	7563	173
18-Dec-95	07:00	561.93	4	493	5	121	55	4749	330
18-Dec-95	11:00	490.52	4	424	2	126	68	5079	526
18-Dec-95	15:00	448.37	4	345	4	112	55	6897	570
18-Dec-95	19:00	434.09	4	315	4	115	53	5026	559
18-Dec-95	23:00	443.87	4	320	5	145	47	4186	505
19-Dec-95	03:00	471.09	4	342	79	108	44	4277	559
19-Dec-95	07:00	564.91	4	431	21	136	67	4576	670
19-Dec-95	11:00	921.04	4	751	11	263	105	24081	1089
19-Dec-95	15:00	994.01	4	851	4	300	130	25652	1143
19-Dec-95	19:00	875.42	4	717	14	232	128	16756	1299
19-Dec-95	23:00	764.88	4	571	6	262	78	10393	1194
20-Dec-95	03:00	677.55	4	514	6	213	75	8232	1041
20-Dec-95	07:00	612.65	4	477	5	175	70	5877	954
20-Dec-95	11:00	297.74	267	16124	81	5672	2188	155001	29493
11-Jan-96	12:00	246.01	274	17588	206	3023	824	21985	13191
12-Jan-96	07:00	301.83	11	866	3	176	44	1167	156
12-Jan-96	11:00	367.06	4	383	1	78	19	449	165

Table 3. Arkansas Loads

Date	Time (hrs)	Avg Flow (cfs)	Occurs (hrs)	NO3-N (kg)	NH3-N (kg)	Arkansas Loading			
						TKN (kg)	TP (kg)	TSS (kg)	TOC (kg)
12-Jan-96	15:00	394.40	4	402	3	95	21	394	125
12-Jan-96	19:00	404.58	4	404	2	73	26	421	195
12-Jan-96	23:00	396.94	4	398	2	76	23	461	155
13-Jan-96	03:00	367.02	32	2945	12	694	180	4070	1185
15-Jan-96	15:00	321.63	59	4739	19	1006	271	6479	1837
18-Jan-96	01:00	528.97	41	6322	221	2829	1238	225755	10986
19-Jan-96	01:00	4426.93	14	6175	38	1737	302	59108	2889
19-Jan-96	05:00	1323.45	43	10202	120	2167	451	61091	4424
22-Jan-96	15:00	686.66	43	9095	153	1482	307	30145	2734
22-Jan-96	19:00	582.91	4	843	2	92	31	2131	258
22-Jan-96	23:00	580.87	4	834	2	98	28	4717	290
23-Jan-96	03:00	572.81	4	826	9	114	30	2311	268
23-Jan-96	07:00	570.80	8	1598	5	228	55	4553	473
23-Jan-96	19:00	558.35	8	1838	21	176	57	5423	418
23-Jan-96	23:00	633.36	10	2194	40	318	86	6958	743
24-Jan-96	15:00	650.20	20	3378	73	518	124	10206	1710
25-Jan-96	15:00	508.29	60	6866	135	1055	112	22212	4465
29-Jan-96	15:00	366.89	144	17447	54	1400	269	39847	2854
06-Feb-96	15:00	285.45	192	18601	56	2681	950	12680	3128
14-Feb-96	15:00	240.30	168	11233	41	1193	206	33740	5308
20-Feb-96	14:00	206.83	189	10439	159	1434	518	66656	6176
01-Mar-96	10:00	193.61	181	8929	71	1143	179	23752	4393
06-Mar-96	15:00	174.51	170	7771	30	1058	575	19201	5231
15-Mar-96	15:00	188.47	168	7681	97	1549	904	12586	5196
20-Mar-96	15:00	197.04	143	6950	86	144	833	52555	5370
27-Mar-96	13:00	192.62	102	4285	40	521	801	25432	1081
29-Mar-96	02:00	457.83	20	2081	9	420	289	22865	1559
29-Mar-96	06:00	664.44	4	577	3	127	24	6312	507
29-Mar-96	10:00	624.09	4	517	3	125	23	4351	598
29-Mar-96	14:00	590.03	4	452	2	120	19	4282	669
29-Mar-96	18:00	559.85	4	409	2	139	62	3880	555
29-Mar-96	22:00	537.18	4	410	2	138	18	3526	602
30-Mar-96	02:00	524.58	4	406	2	122	15	2930	571
30-Mar-96	06:00	484.71	18	1681	9	498	62	11560	2543
31-Mar-96	14:00	446.95	73	6252	200	1064	499	45226	10841
05-Apr-96	08:00	382.34	141	9561	55	2473	824	1527508	16978
12-Apr-96	08:00	299.50	95	4553	58	1566	551	77139	4930
13-Apr-96	05:00	428.93	12	866	5	157	100	26283	1023
13-Apr-96	09:00	1137.27	6	1134	7	341	139	43328	1106

Table 3. Arkansas Loads

Date	Time (hrs)	Avg Flow (cfs)	Occurs (hrs)	NO3-N (kg)	NH3-N (kg)	Arkansas Loading			
						TKN (kg)	TP (kg)	TSS (kg)	TOC (kg)
13-Apr-96	17:00	1026.01	8	1732	418	1891	611	141969	4844
14-Apr-96	01:00	763.82	8	1077	93	791	230	39984	2940
14-Apr-96	09:00	627.67	12	1320	46	699	184	26408	2971
15-Apr-96	01:00	543.73	10	1003	6	366	100	4766	1674
15-Apr-96	05:00	431.14	52	3907	23	1211	343	52099	4502
19-Apr-96	08:00	324.53	83	3981	27	2004	604	90049	20590
22-Apr-96	04:00	344.92	38	2405	13	3046	1109	344126	12050
22-Apr-96	08:00	1091.17	4	734	18	1134	387	150362	5547
22-Apr-96	12:00	3051.34	5	2115	16	4012	1197	846231	8506
22-Apr-96	18:00	5926.71	7	6766	677	15434	6300	3292698	54589
23-Apr-96	02:00	4831.53	8	6106	276	7288	3388	2218351	43926
23-Apr-96	10:00	5932.11	8	7110	242	9625	4208	1796433	56640
23-Apr-96	20:00	3983.93	10	8202	81	4182	1421	535583	35245
24-Apr-96	06:00	2170.20	14	7215	93	2168	836	259503	16939
25-Apr-96	09:00	1634.65	13	5198	65	1624	347	106562	14728
25-Apr-96	21:00	1249.47	18	5593	92	1330	413	93067	16848
26-Apr-96	09:00	892.91	25	6462	68	978	410	61885	13355
27-Apr-96	10:00	706.10	18	3821	52	415	220	35106	6386
27-Apr-96	22:00	635.02	12	2058	16	295	109	12582	3961
28-Apr-96	10:00	589.44	66	10785	79	1427	595	45995	18795
03-May-96	10:00	430.21	99	8725	87	1953	912	124151	26350
06-May-96	15:00	356.59	39	2835	57	964	213	41814	8661
06-May-96	17:00	716.91	3	458	7	105	37	6730	995
06-May-96	21:00	997.91	4	842	20	175	61	17006	2026
07-May-96	01:00	844.27	4	754	14	189	100	19310	2341
07-May-96	05:00	540.85	45	5085	149	2109	992	165705	20936
10-May-96	18:00	489.58	44	3776	88	1669	790	376320	9309
10-May-96	22:00	3772.88	8	4215	677	11936	5784	3235684	29256
11-May-96	10:00	5784.89	18	14221	849	30565	15495	8188980	97321
12-May-96	10:00	1553.58	40	12731	127	3357	1773	327457	31669
14-May-96	18:00	622.26	148	24780	94	2534	1596	198994	26470
24-May-96	17:00	297.23	199	15192	60	2472	1387	373773	24054
31-May-96	08:00	253.97	97	4193	25	2511	678	137847	37186
01-Jun-96	20:00	446.14	20	1737	3	646	82	59295	4474
02-Jun-96	00:00	703.71	4	689	4	123	98	10845	1110
02-Jun-96	04:00	678.57	4	697	7	94	86	8493	1001
02-Jun-96	08:00	433.84	55	5983	7	851	681	60313	7880
06-Jun-96	17:00	287.46	144	6835	59	2911	1181	152306	31727
14-Jun-96	09:00	197.62	141	5368	54	2357	767	147113	36239

Table 3. Arkansas Loads

Date	Time (hrs)	Avg Flow (cfs)	Occurs (hrs)	NO3-N (kg)	NH3-N (kg)	Arkansas Loading		TSS (kg)	TOC (kg)
						TKN (kg)	TP (kg)		
18-Jun-96	11:00	222.80	133	5708	12	3111	936	141950	47206
25-Jun-96	10:00	171.32	181	5657	13	759	853	32869	11504
03-Jul-96	13:00	158.82	204	2906	10	3038	1354	274744	20639
12-Jul-96	11:00	154.92	145	3617	7	366	664	6640	6846
15-Jul-96	15:00	187.89	147	5067	8	619	816	55739	9262
24-Jul-96	16:00	117.78	203	2754	14	439	755	21445	3144
01-Aug-96	14:00	133.07	143	2599	6	582	213	13964	2793
05-Aug-96	11:00	103.24	168	2192	71	530	513	23158	1945
15-Aug-96	14:00	107.07	217	2321	107	308	663	15866	4428
23-Aug-96	13:00	116.08	182	2282	15	409	603	13135	3596
30-Aug-96	19:00	121.96	179	2648	7	579	534	14463	1602
07-Sep-96	11:00	88.23	190	1897	29	410	478	6151	85
15-Sep-96	15:00	84.87	106	1073	8	238	275	22373	3228
Average Flow =		299.68	Totals	550321	8533	201411	89850	27487199	1130239



Table 4. Oklahoma Loads

Date	Time	Avg Flow (cfs)	Occurs (hrs)	Oklahoma Concentrations					
				NO3-N (kg)	NH3-N (kg)	TKN (kg)	TP (kg)	TSS (kg)	TOC (kg)
13-Sep-95	12:00	188.00	263	8718	403	2419	1461	98118	18848
28-Sep-95	13:00	212.06	252	11166	218	2614	1416	72985	7407
04-Oct-95	13:00	208.79	158	6792	134	1681	1042	67784	87050
11-Oct-95	16:00	182.65	168	6255	156	1345	751	36592	5348
18-Oct-95	14:00	167.12	166	5485	85	1470	679	32658	1555
25-Oct-95	13:00	184.99	168	6208	127	1615	824	36427	2471
01-Nov-95	15:00	187.12	170	6030	32	1459	811	27883	162
08-Nov-95	15:00	196.39	181	6703	145	1775	1087	44925	3478
16-Nov-95	16:00	194.21	168	5820	67	1330	798	21516	4257
22-Nov-95	10:00	170.38	163	5067	113	1132	708	25051	5265
30-Nov-95	13:00	162.45	171	5096	849	1359	510	9202	4502
06-Dec-95	15:00	173.33	157	5714	83	1720	721	555	6435
13-Dec-95	15:00	177.09	145	5653	105	1125	602	8584	131
18-Dec-95	17:00	356.41	63	4600	46	1396	687	176516	3753
18-Dec-95	21:00	537.32	4	453	2	129	50	9098	423
19-Dec-95	01:00	535.56	4	430	4	129	55	9782	469
19-Dec-95	05:00	659.81	4	503	3	218	81	12178	608
19-Dec-95	09:00	823.40	4	608	7	232	117	22290	943
19-Dec-95	13:00	1216.65	4	908	10	357	149	36145	1642
19-Dec-95	17:00	1366.95	4	1053	6	513	128	94294	1817
19-Dec-95	21:00	1228.55	4	1037	10	461	150	81541	1538
20-Dec-95	01:00	1057.16	4	905	9	379	151	46461	1414
20-Dec-95	05:00	917.47	4	737	7	318	123	31221	1399
20-Dec-95	09:00	812.00	4	672	10	262	86	21882	1205
20-Dec-95	13:00	492.02	315	31751	316	12479	3949	797728	55762
15-Jan-96	15:00	516.40	482	60886	761	10909	3298	199147	19788
29-Jan-96	16:00	560.54	264	48868	151	4374	754	111612	7994
06-Feb-96	16:00	305.44	192	19247	120	1793	1195	10341	2869
14-Feb-96	16:00	257.15	168	11756	88	1409	528	33904	3170
20-Feb-96	15:00	212.21	189	11160	41	899	491	67041	7440
01-Mar-96	10:00	188.18	180	7940	138	1312	518	24512	1968
06-Mar-96	16:00	171.51	171	6935	90	1136	269	72458	2690
15-Mar-96	16:00	186.21	168	6760	191	2806	797	55161	4846
20-Mar-96	16:00	198.39	143	6997	116	1041	810	53493	5957
27-Mar-96	14:00	313.01	108	7029	1929	999	861	42724	1619
29-Mar-96	16:00	647.74	27	3725	18	1301	553	267200	4688
29-Mar-96	20:00	753.41	14	2086	11	699	258	82994	3182
30-Mar-96	19:00	623.83	15	1860	19	1793	706	696798	3109
31-Mar-96	03:00	575.18	8	882	23	291	202	72318	1552

Table 4. Oklahoma Loads

Date	Time	Avg Flow (cfs)	Occurs (hrs)	Oklahoma Concentrations					
				NO3-N (kg)	NH3-N (kg)	TKN (kg)	TP (kg)	TSS (kg)	TOC (kg)
31-Mar-96	11:00	590.72	8	944	24	366	120	76199	1517
31-Mar-96	19:00	534.47	59	6428	129	2218	836	420712	10092
05-Apr-96	09:00	402.28	139	10885	57	7124	2850	1295996	6611
12-Apr-96	09:00	371.94	98	5907	74	1115	594	105508	11145
13-Apr-96	13:00	1272.59	16	3819	62	1806	726	253600	11476
13-Apr-96	17:00	1633.80	7	2378	455	2261	664	175663	6446
14-Apr-96	01:00	1283.55	8	2093	199	1298	523	72737	5181
14-Apr-96	09:00	1031.01	8	1555	84	799	235	47750	3506
14-Apr-96	17:00	826.72	15	2338	88	1150	329	56497	4980
15-Apr-96	14:00	666.34	12	1557	41	742	350	117276	2323
15-Apr-96	18:00	506.14	46	4461	47	1566	593	162551	5434
19-Apr-96	09:00	362.91	81	5333	90	1558	659	145610	15699
22-Apr-96	12:00	2832.82	41	16928	2249	38473	14916	6922774	154484
22-Apr-96	19:00	7120.35	7	8128	660	16510	8687	3626659	62536
23-Apr-96	02:00	7533.70	8	9521	737	15111	5774	2702844	65605
23-Apr-96	12:00	7608.90	9	11028	349	13331	5444	2209761	77753
23-Apr-96	20:00	6282.20	8	9169	154	6659	2971	771430	44462
24-Apr-96	03:00	3576.05	12	9579	87	3630	1662	403698	30179
24-Apr-96	21:00	2566.30	15	10005	235	2315	824	219713	27072
25-Apr-96	09:00	1886.25	19	9680	110	1607	767	197250	23889
26-Apr-96	10:00	1365.90	25	9815	209	1323	696	182025	19351
27-Apr-96	11:00	1064.19	18	5779	117	625	351	69114	9489
27-Apr-96	22:00	934.15	11	3079	42	450	209	52366	5059
28-Apr-96	10:00	786.39	66	15447	317	2063	1058	271375	24387
03-May-96	10:00	551.17	99	13904	167	1502	1224	191871	12180
06-May-96	16:00	3491.24	147	120308	2615	19877	11508	3593551	193539
12-May-96	11:00	4032.15	59	48979	970	15518	7032	1825802	137238
14-May-96	19:00	1003.46	148	39507	454	6055	2573	803760	52979
24-May-96	18:00	414.14	199	20832	84	4116	2184	779504	34355
31-May-96	09:00	362.78	97	7496	179	2654	646	582108	12481
01-Jun-96	21:00	531.49	20	2524	17	856	563	226759	3781
02-Jun-96	01:00	892.76	4	830	4	579	309	80110	1401
02-Jun-96	05:00	962.43	4	934	7	365	239	139724	1346
02-Jun-96	09:00	684.07	54	9412	87	3765	2673	1089589	13516
06-Jun-96	17:00	354.05	144	10964	156	7483	3170	1692446	20006
14-Jun-96	09:00	231.55	141	6489	123	1231	865	173535	21197
18-Jun-96	10:00	224.20	131	5718	90	1287	748	67353	15776
25-Jun-96	09:00	223.05	182	6165	219	1572	1159	94336	15971
03-Jul-96	13:00	188.15	205	5189	12	1258	1022	61720	18673

Table 4. Oklahoma Loads

Date	Time	Avg Flow (cfs)	Occurs (hrs)	Oklahoma Concentrations					
				NO3-N (kg)	NH3-N (kg)	TKN (kg)	TP (kg)	TSS (kg)	TOC (kg)
12-Jul-96	10:00	184.78	144	3634	24	624	705	42307	8109
15-Jul-96	14:00	171.80	147	3912	8	566	772	76963	7928
24-Jul-96	15:00	134.28	204	2624	212	977	810	57794	4244
01-Aug-96	15:00	126.30	142	2084	57	731	567	34365	2980
05-Aug-96	10:00	119.05	168	2059	77	775	591	36285	5055
15-Aug-96	15:00	136.82	217	2118	212	1210	787	26629	5447
23-Aug-96	13:00	151.67	182	2785	45	1154	732	72306	4755
30-Aug-96	18:00	120.03	179	2562	7	723	460	22336	1533
07-Sep-96	11:00	97.00	190	1522	6	620	488	22729	695
15-Sep-96	14:00	100.33	106	900	46	488	325	27966	3328
Average Flow =		421.14	Totals	813801	19138	268764	122367	35992075	1515942

Table 5. Average Concentrations, Percent Difference Calculations, and T-Tests

Nutrient	Average Arkansas Concentration (mg/L)	Average Oklahoma Concentration (mg/L)	Percent Difference (%)	One Tailed T-Test $\alpha$
NO <sub>3</sub> - N	2.13	1.98	-7.30	0.055
NH <sub>3</sub> - N	0.03	0.05	+50.0	0.038
TKN	0.68	0.72	+5.71	0.268
TP	0.28	0.33	+16.4	0.059
TSS	61.9	95.3	+42.5	0.00013
TOC	3.54	3.64	+2.79	0.422

The t-tests were performed by using the software Microsoft Excel. A lower value indicates that there is significant enough difference between the two values being compared to conclude the values are different. A significance level of 0.05 was used for the one-tailed test.

The results indicate that at an  $\alpha$  of 0.05 there is not sufficient evidence to conclude the upstream and downstream concentrations for NO<sub>3</sub>-N, TKN, TP, and TOC are different. The results also indicated that at an  $\alpha$  of 0.05 there is sufficient evidence to conclude that the upstream and downstream concentrations for NH<sub>3</sub>-N and TSS are different. The percent difference calculations agree with the results from the t-tests. The percent difference of 16.4% and t-test result of 0.059 for TP give borderline results as to whether a difference exists in the upstream and downstream TP concentrations.

## Discussion

The concentration and load of total phosphorus in the Illinois River is the primary focus of this discussion. Looking at the sample data tables, there appears to be a sharp increase in the TP concentrations in April and May for Arkansas. Increases in the TP concentrations for Oklahoma occurred in April, May, and early June. Figure 2 (pg. 23) illustrates the increases in TP concentrations during these months for Arkansas and Oklahoma.

Historical data suggests that the average flow for the period in which this study was conducted was very low. The average annual flow at the Oklahoma station for 1992 through 1995 ranged from a low of 680 cfs to a high of 1100 cfs. During this study, the average flow for Arkansas was 300 cfs and the average flow for Oklahoma was 421 cfs. The Oklahoma flow was 121 cfs or 40.3% larger than the Arkansas flow. This can be attributed, in part, to the additional tributaries to Lake Frances located between the flow monitoring stations. The fact that only one year of data was available to establish an accurate rating curve for the Arkansas station may also contribute to the flow differences. Other than the Illinois River, Ballard Creek is the major tributary feeding Lake Frances. In order to fully comprehend what is occurring, the effects of Ballard Creek should be investigated. A summary of the values obtained for the total flow, the total load, and the average flow weighted concentrations for Arkansas are shown in Table 6 (pg. 24). A summary of the values obtained for the total flow, the total load, and the average flow weighted concentrations for Oklahoma are shown in Table 7 (pg. 24).

Although the flow for the year was well below average, the effects of the flow or increase in flow on the sample concentrations were evident. For instance, when a flow increase occurred, especially a large increase, the TP concentrations increased dramatically. These effects are shown on pages A-1 through A-13 for Arkansas and on pages A-14 through A-26 for Oklahoma in Appendix A. In these figures, the continuous line represents the flow, and the x's represent the TP concentrations. The larger TP concentrations were associated with large runoff events. Large runoff events were considered to be events whose peak flow was greater than 1000 cfs.

Figure 2. TP Concentration vs Time

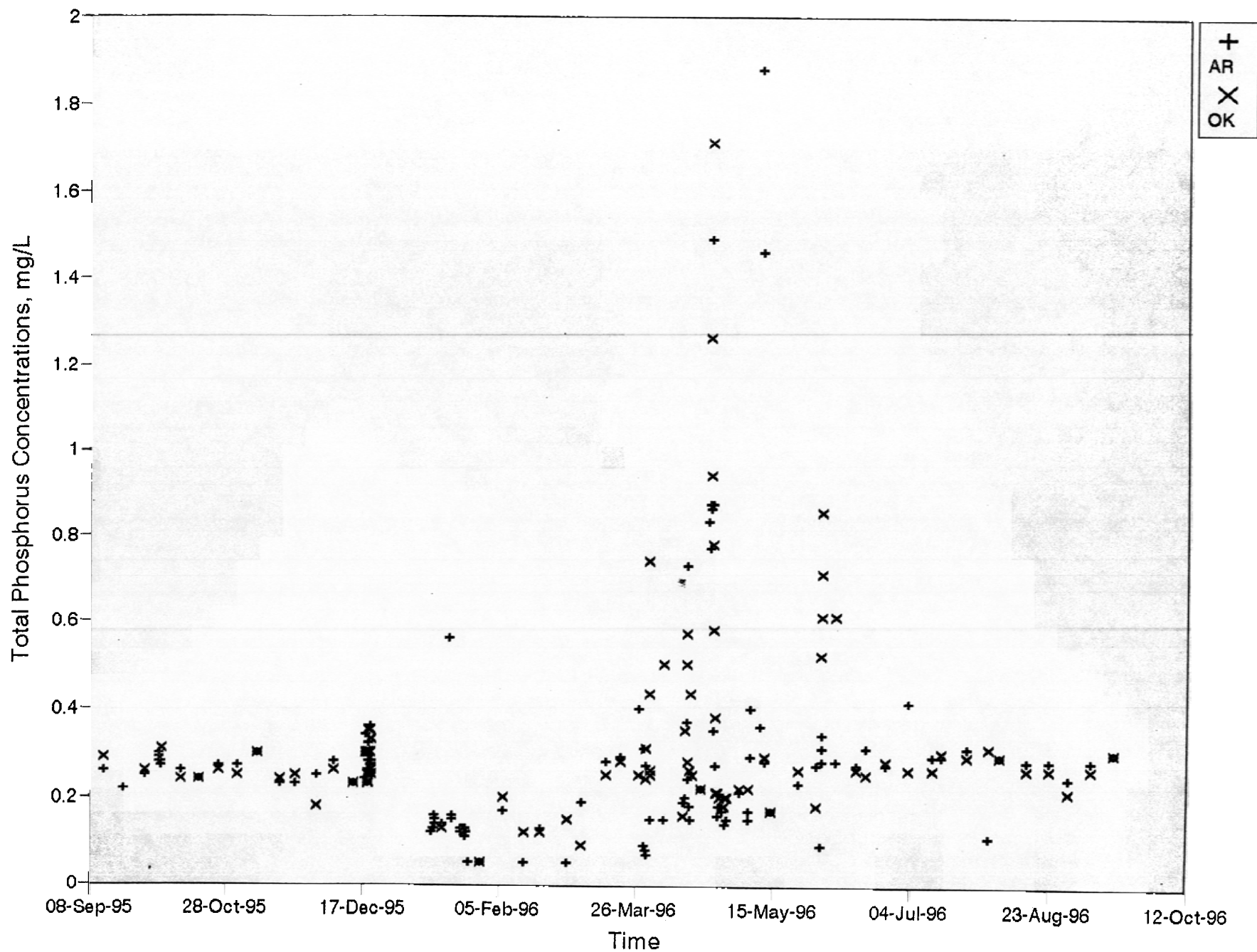


Table 6. Total Flows, Total Loads, and Average Calculated Concentrations for Arkansas

Nutrients	Total Flow (ft <sup>3</sup> /yr)	Total Load (kg/yr)	Average Flow Weighted Concentrations (mg/L)
NO <sub>3</sub> - N	2,675,263	550,000	2.0
NH <sub>3</sub> - N	2,675,263	8,530	0.031
TKN	2,675,263	201,000	0.74
TP	2,675,263	89,900	0.33
TSS	2,675,263	27,500,000	101
TOC	2,675,263	1,130,000	4.2

Table 7. Total Flows, Total Loads, and Average Calculated Concentrations for Oklahoma

Nutrients	Total Flow (ft <sup>3</sup> /yr)	Total Load (kg/yr)	Average Flow Weighted Concentrations (mg/L)
NO <sub>3</sub> - N	3,759,080	814,000	2.1
NH <sub>3</sub> - N	3,759,080	19,100	0.050
TKN	3,759,080	269,000	0.70
TP	3,759,080	122,000	0.32
TSS	3,759,080	36,000,000	94
TOC	3,759,080	1,520,000	4.0

In Arkansas, note the TP concentration increases during large runoff events in April (pg. A-8) and May (pg. A-9). However, a large runoff event occurred in January (pg. A-5) whose peak flow was 6000 cfs which resulted in a maximum TP concentration of only 0.56 mg/L. This relatively small increase in TP concentration may have been the result of samples not being collected at the peak of the runoff event. Had the peak been sampled, the runoff event may have yielded higher TP concentrations. Also, there was a large runoff event in December (pg. A-4) whose peak was sampled and no increase in TP concentration occurred.

In Oklahoma, TP concentrations increases were observed in March (pg. A-20), April (pg. A-21), and early June (pg. A-23). Large runoff events occurred in January (pg. A-18) and May (pg. A-22) whose peaks were not sampled, and a large runoff event in December (pg. A-17) produced no increase in TP concentrations. There was one additional large runoff event in March (pg. A-20) whose peak flow was noticeably larger than the peak produced in Arkansas. This produced an increase in TP concentration not experienced in Arkansas. The difference may be attributed to a storm event that was localized to a part of the drainage basin which would bypass the Arkansas station.

The patterns of decrease in TP concentrations at both stations were similar. After the large increases, the concentrations underwent a rapid decrease in a parabolic pattern down to normal levels. This rapid decrease may in part be caused by the dilution effects of the larger flows.

The different reactions of TP concentrations to flow raises a question concerning the relationship of TP concentrations to flow. The relationship of TP concentration to flow is shown in Figure 3 (pg. 26) for Arkansas. The relationship of TP concentration to flow is shown in Figure 4 (pg. 27) for Oklahoma. What these two figures show is that there is not a clear relationship between TP concentration and flow in general, but that TP concentrations are more related to increases in flow. For example, in Arkansas a peak flow of 6000 cfs resulted in a TP concentration of 0.56 mg/L, a peak flow of 7000 cfs resulted in a TP concentration of 1.49 mg/L, and a peak flow of 9500 cfs resulted in a TP concentration of 1.88 mg/L. Thus, it appears that higher peak flows generally resulted in higher peak TP concentrations. A linear regression was performed using the software Microsoft Excel. The  $R^2$  values were 0.49 and 0.44 for Arkansas and Oklahoma, respectively. The  $R^2$  value represents the percent of variance of the data sets.



Figure 3. Total Phosphorus vs Flow  
Illinois River at Arkansas Highway 59

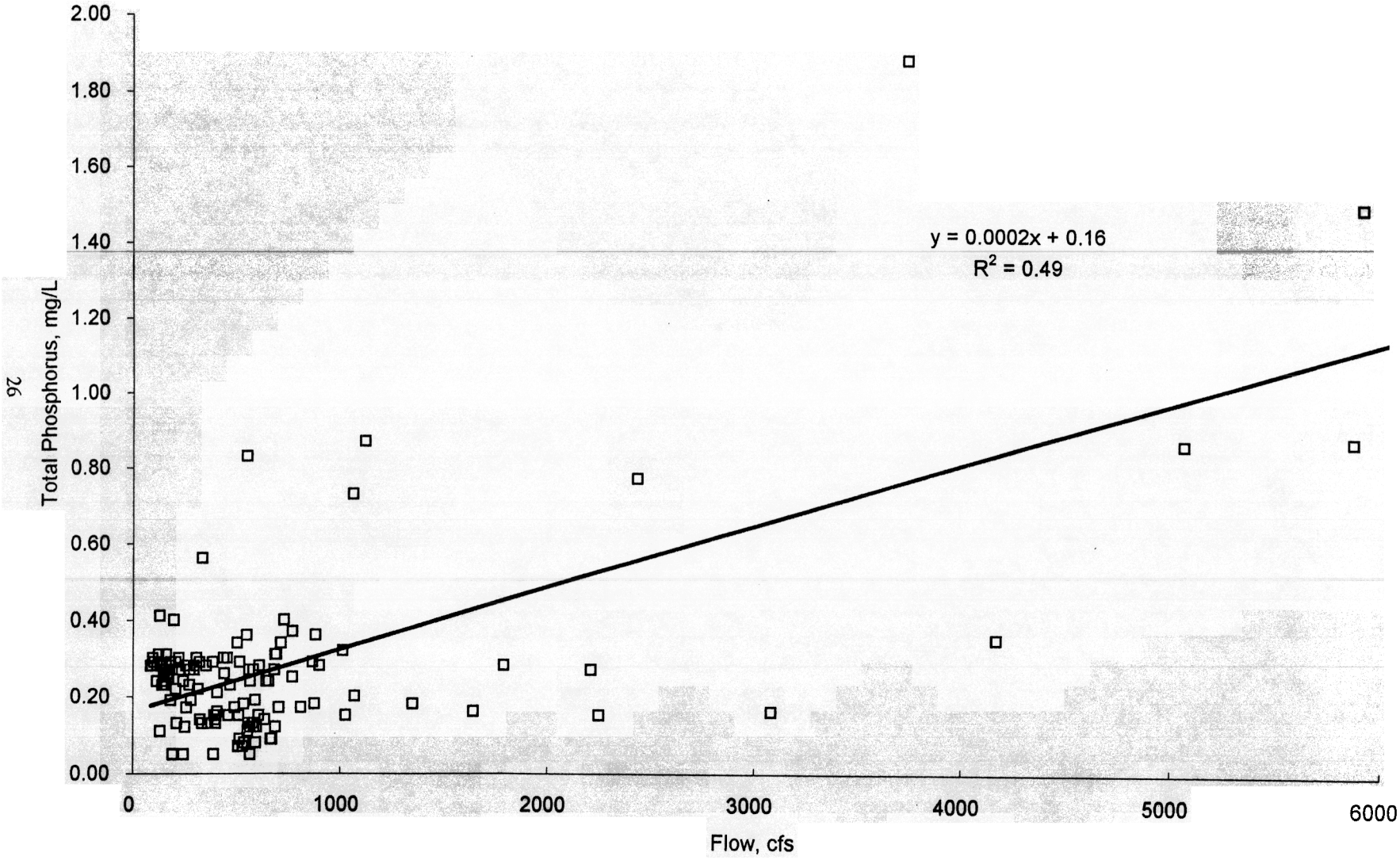
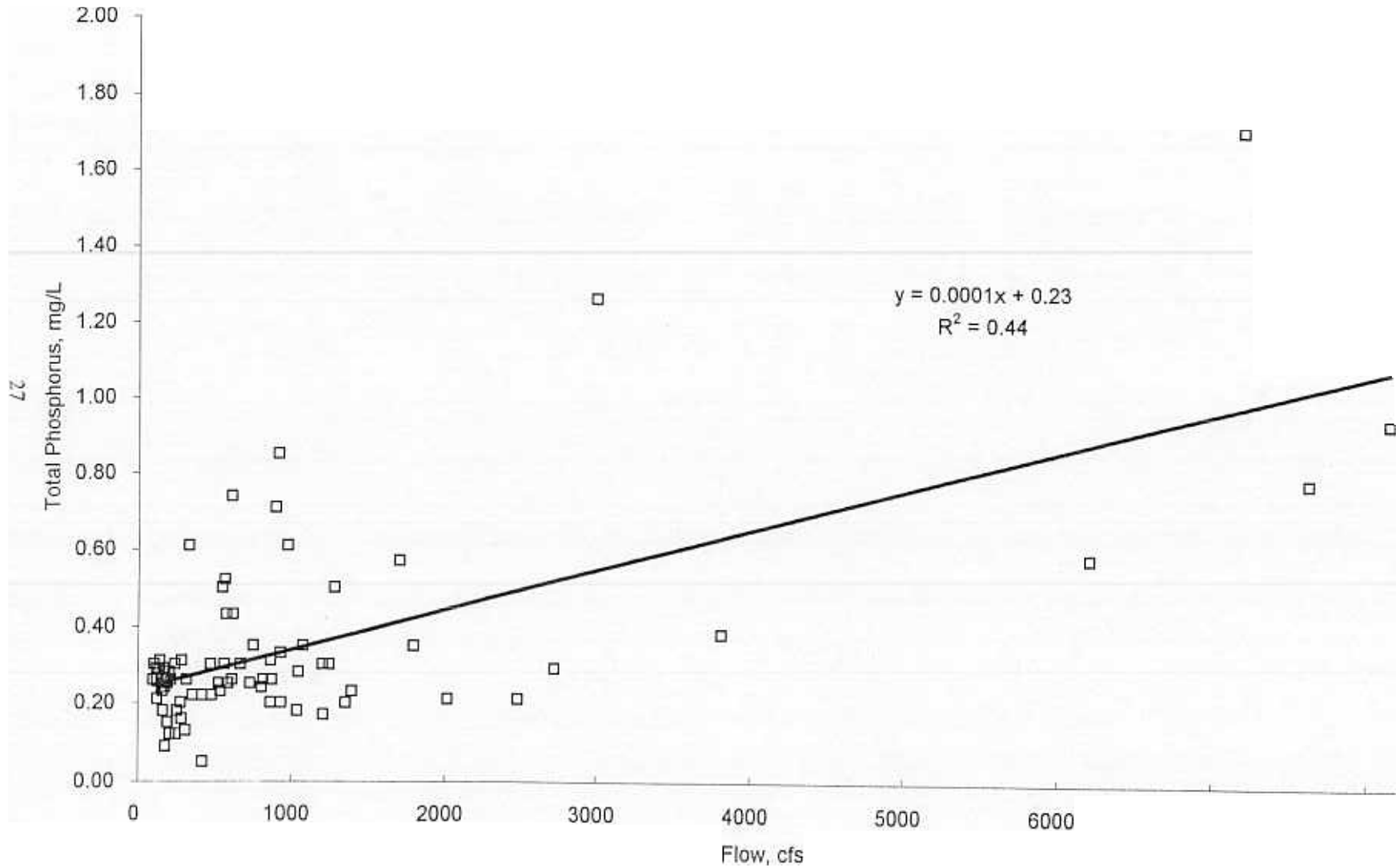


Figure 4. Total Phosphorus vs Flow  
Illinois River at Oklahoma Highway 59



As  $R^2$  approaches 1.0, the variance between the data sets is smaller.

TSS concentrations behaved in much the same manner as the TP concentrations at both stations. The effects of flow on TSS concentrations are shown on pages B-1 through B-13 for Arkansas, and on pages B-14 through B-26 for Oklahoma in Appendix B. In these figures, the continuous line represents the flow, and the x's represent the TSS concentrations. Patterns of increase in TSS concentrations were similar to the patterns of increase of TP concentrations. This is shown in Figure 5 (pg. 29) and Figure 6 (pg. 30) for Arkansas and Oklahoma, respectively.

Also similar to TP concentration, there appeared to be no direct relationship between TSS concentration and flow. The relationship between TSS concentration and flow is shown in Figure 7 (pg. 31) and Figure 8 (pg. 32) for Arkansas and Oklahoma, respectively. A linear regression was performed yielding an  $R^2$  values of 0.025 and 0.33 for the Arkansas and Oklahoma stations.

Next, the correlation of TP concentrations to TSS concentrations was determined. This relationship is shown in Figure 9 (pg. 33) and Figure 10 (pg. 34) for Arkansas and Oklahoma, respectively. These figures seem to suggest that the levels of TP and TSS do correlate to one another. A linear regression was performed yielding  $R^2$  values of 0.85 and 0.76 for the Arkansas and Oklahoma stations. These  $R^2$  values support the theory that the levels of TP and TSS do correlate to one another.

The effects of flow on  $\text{NO}_3 - \text{N}$  were similar to that of TP and TSS, but they were also dissimilar. Similarities occurred in that concentrations did increase with an increase in flow. The dissimilarities were that the reaction to the flow increase was not as dramatic. In fact, the concentrations of  $\text{NO}_3 - \text{N}$  actually lagged the hydrograph peaks, and the drop in  $\text{NO}_3 - \text{N}$  concentrations were very gradual instead of rapid. These effects are shown on pages C-1 through C-13 for Arkansas, and on pages C-14 through C-26 for Oklahoma in Appendix C. In these figures, the continuous line represent the flow and the x's represent the  $\text{NO}_3 - \text{N}$  concentrations.

Figure 5. TP and TSS vs Time  
inois River at Arkansas Highway 59

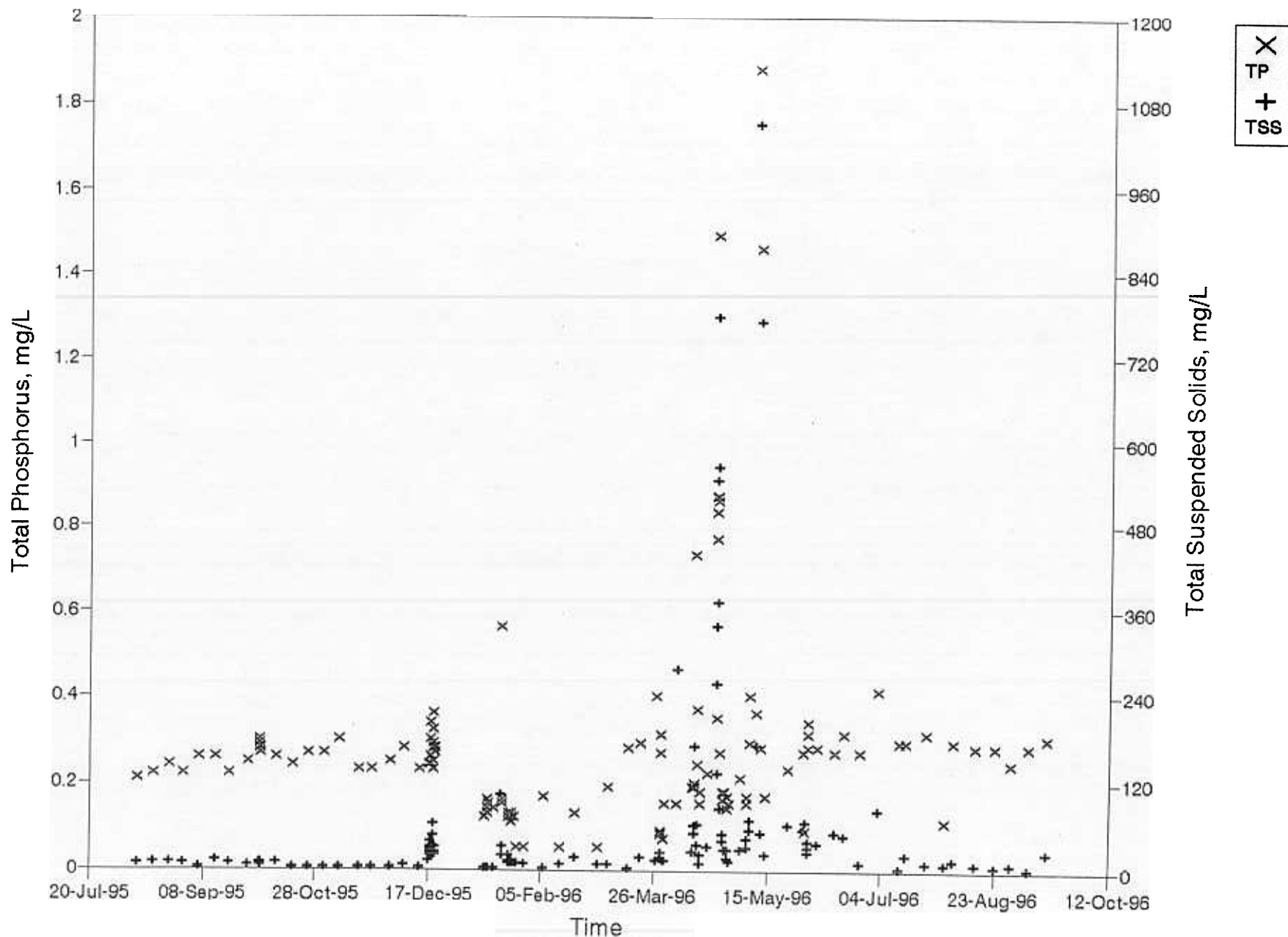


Figure 6. TP and TSS vs Time  
 Illinois River at Oklahoma Highway 59

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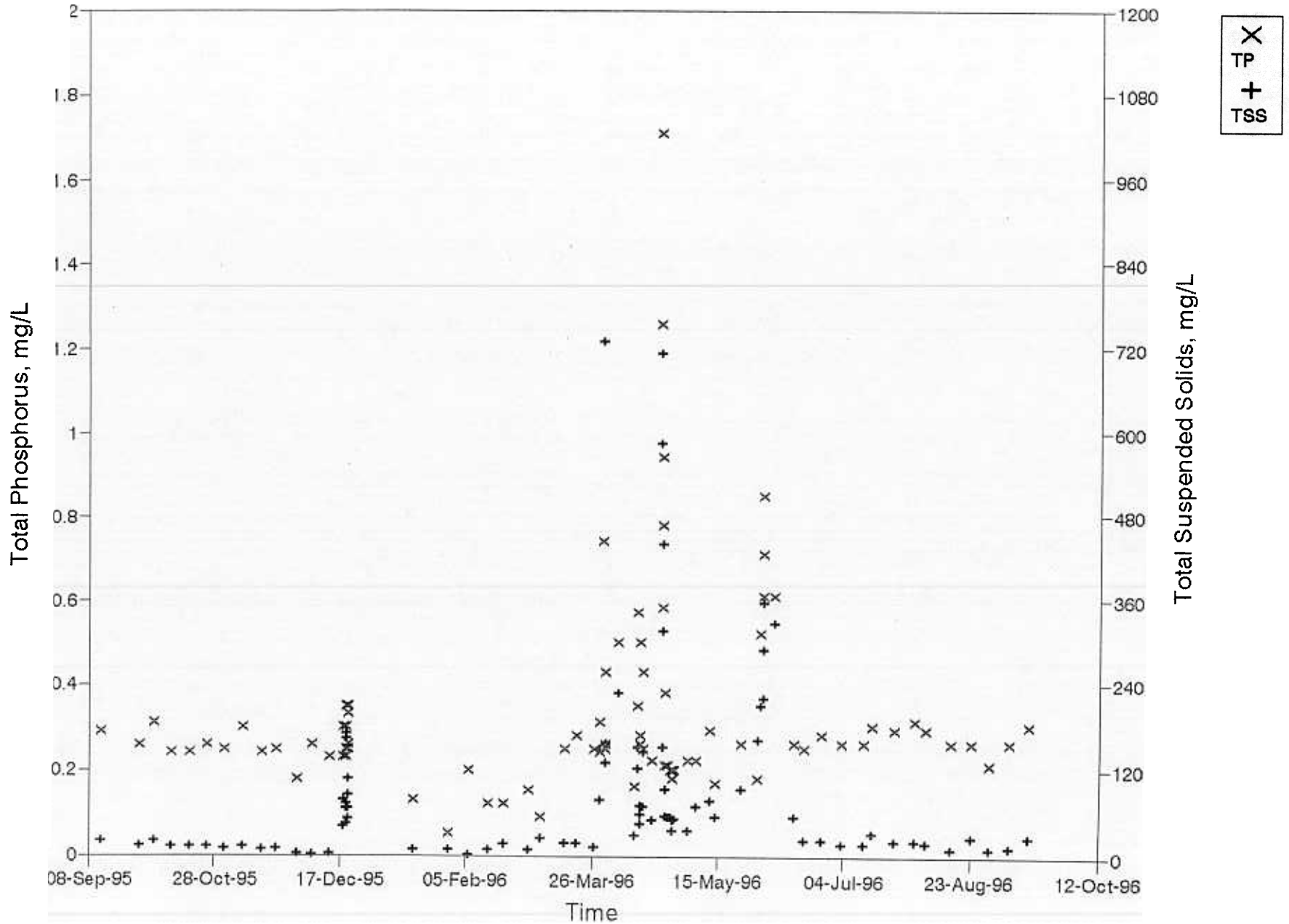


Figure 7. Total Suspended Solids vs Flow  
Illinois River at Arkansas Highway 59

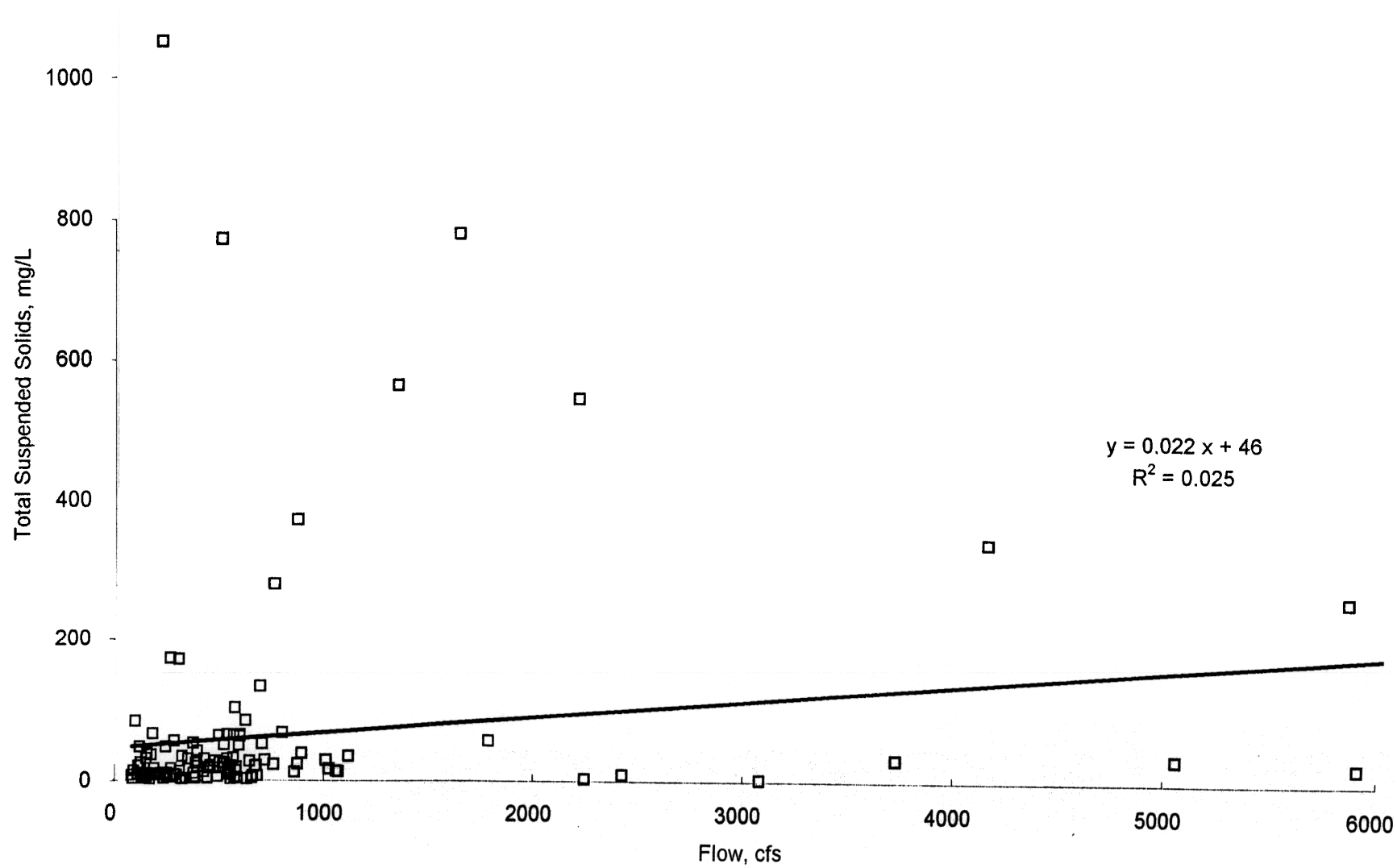


Figure 8. Total Suspended Solids vs Flow  
Illinois River at Oklahoma Highway 59

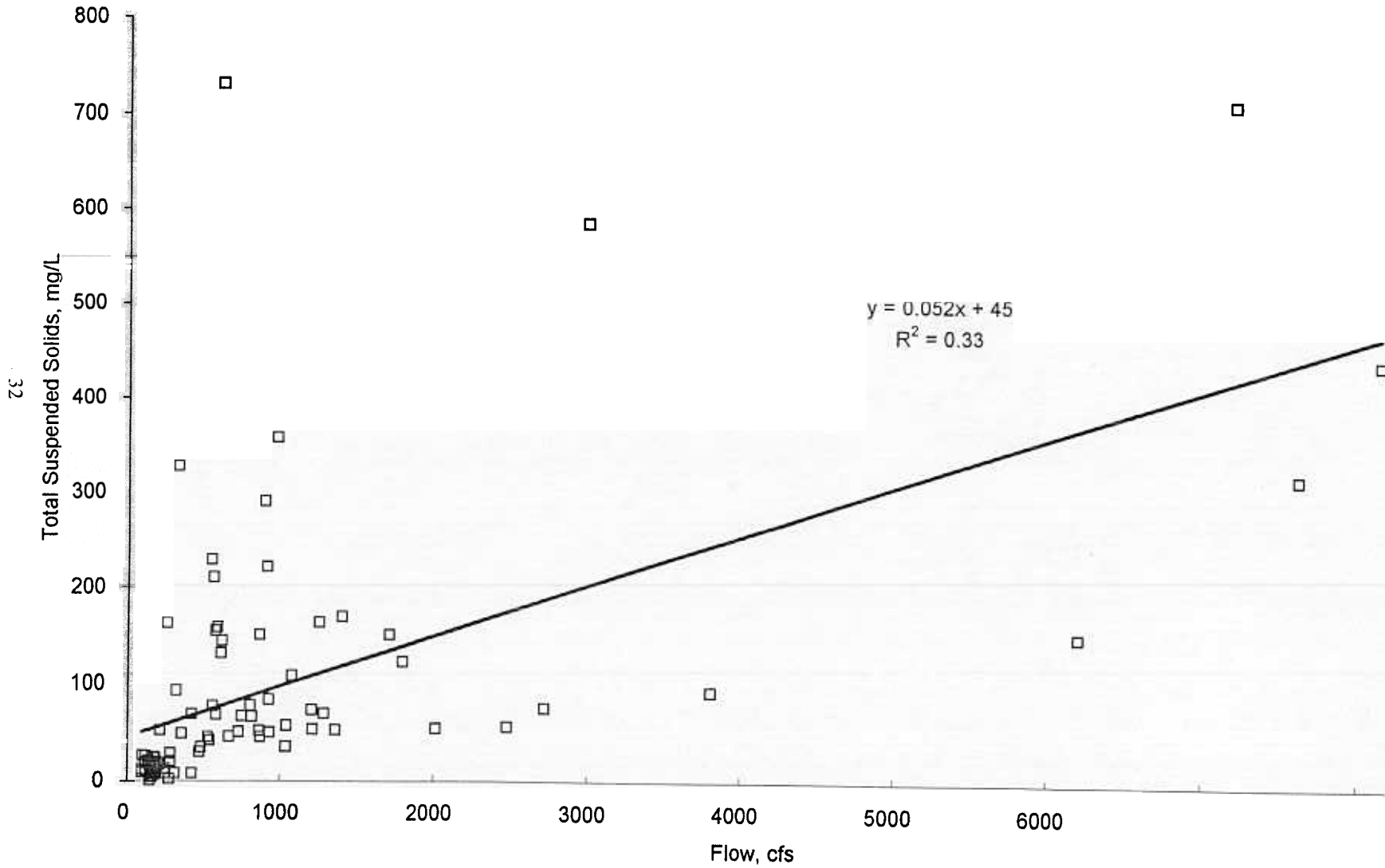


Figure 9. TP vs TSS  
Illinois River at Arkansas Highway 59

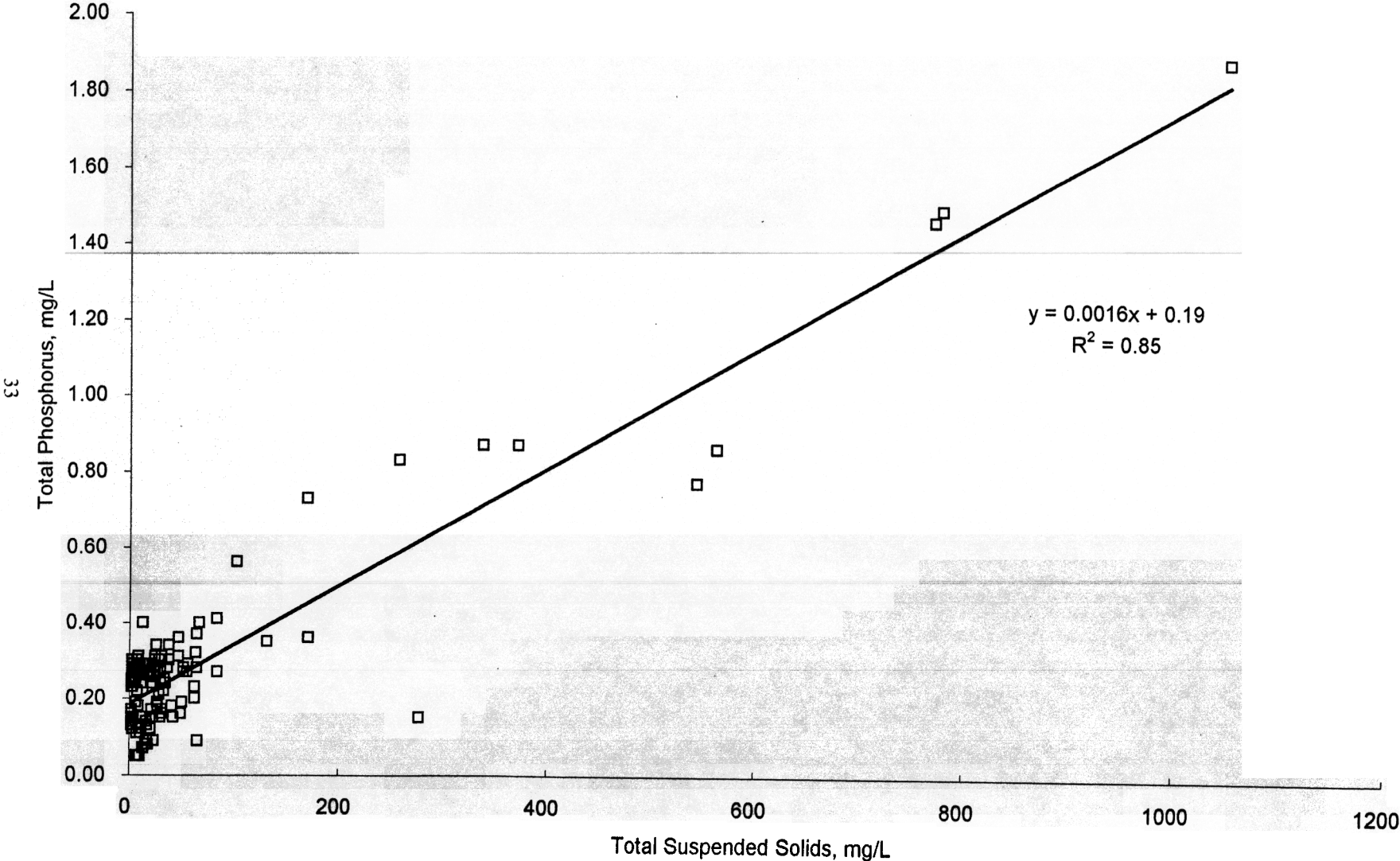
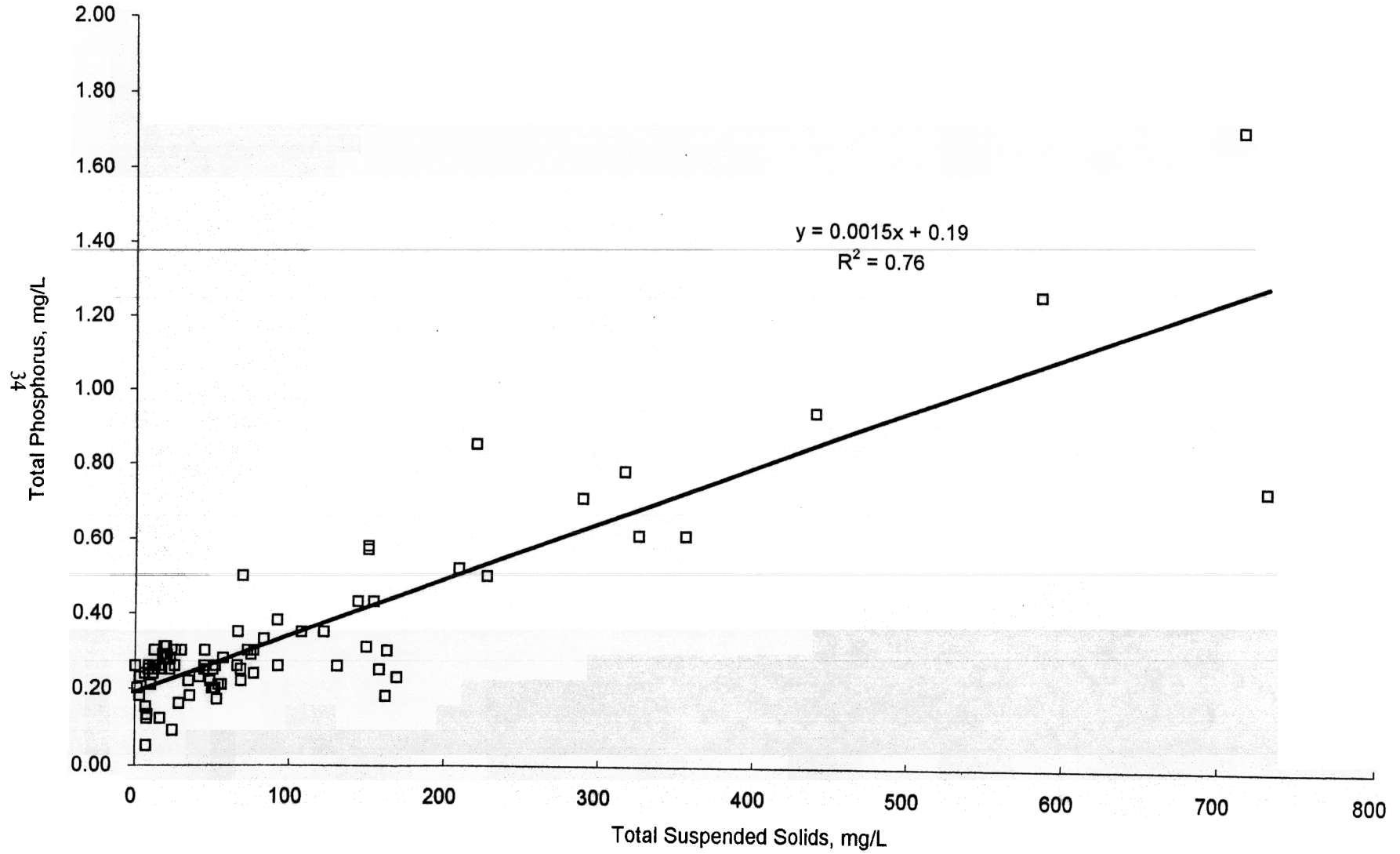




Figure 10. TP vs TSS  
Illinois River at Oklahoma Highway 59



## Conclusions

The pollutant loads calculated in the Illinois River at Arkansas Hwy 59 and Oklahoma Hwy 59 are shown in Table 8.

Table 8. Average Flows and Pollutant Loads Calculated at Arkansas Hwy 59 and US Hwy 59 in Oklahoma

	Arkansas	Oklahoma
Average Flow, (cfs)	300	421
NO <sub>3</sub> -N Load, (kg/yr)	550,000	814,000
NH <sub>3</sub> -N Load, (kg/yr)	8,530	19,100
TKN Load, (kg/yr)	201,000	269,000
TP Load, (kg/yr)	89,900	122,000
TSS Load, (kg/yr)	27,500,000	36,000,000
TOC Load, (kg/yr)	1,130,000	1,520,000

A comparison of pollutant concentrations above and below Lake Frances showed some increase in the average concentrations for all parameters except NO<sub>3</sub>-N . However, the results obtained from a t-test analysis indicate there is not sufficient evidence at an  $\alpha$  of 0.05 to conclude that the concentrations for NO<sub>3</sub>-N, TKN, TP, and TOC upstream and downstream from Lake Frances are different. The t-test results also indicate that there is sufficient evidence at an  $\alpha$  of 0.05 to conclude that the concentrations for NH<sub>3</sub>-N and TSS upstream and downstream from Lake Frances are different. A comparison of the flow weighted average concentrations show that the differences in parameter values for NO<sub>3</sub>-N, TKN, TP, and TOC is only 5% or less between Arkansas and Oklahoma which supports the concept that there is probably no significant difference between these values.

Although there was no direct correlation of TP concentrations and TSS concentrations to flow, in general, high peak concentrations appear to be associated with high peak runoff events.

A regression analysis performed showed that there was a correlation between TSS concentrations and TP concentrations.

## **Bibliography**

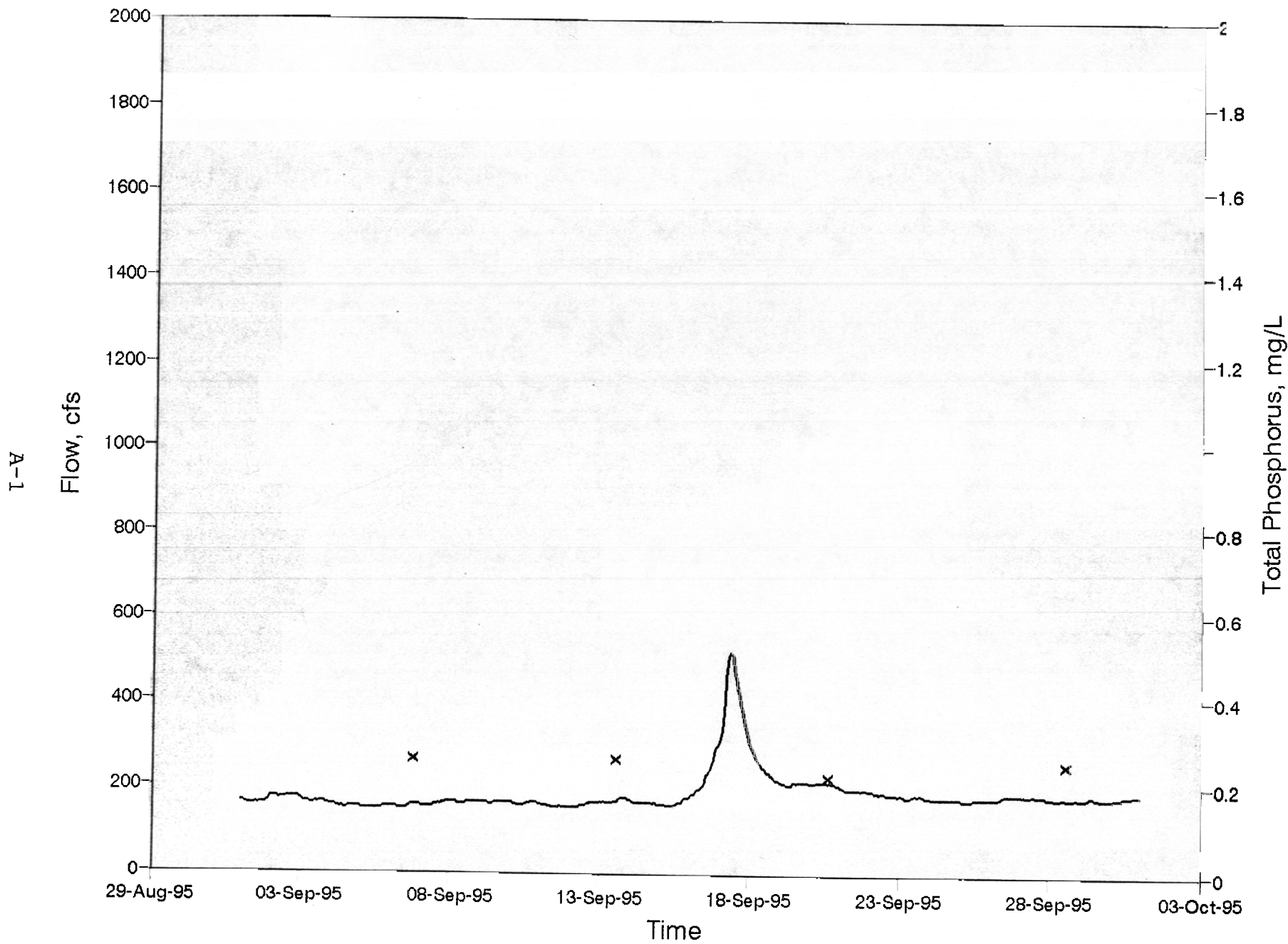
<sup>1</sup>Oklahoma Water Resources Board, United States Army Corps of Engineers, and Oklahoma State University, Final Report for Cooperative “Clean-Lakes” Project, Phase I, Diagnostic and Feasibility Study on Tenkiller Lake, Oklahoma.

**Pollution Load and Effects of Arkansas and  
Lake Frances on the Illinois River**

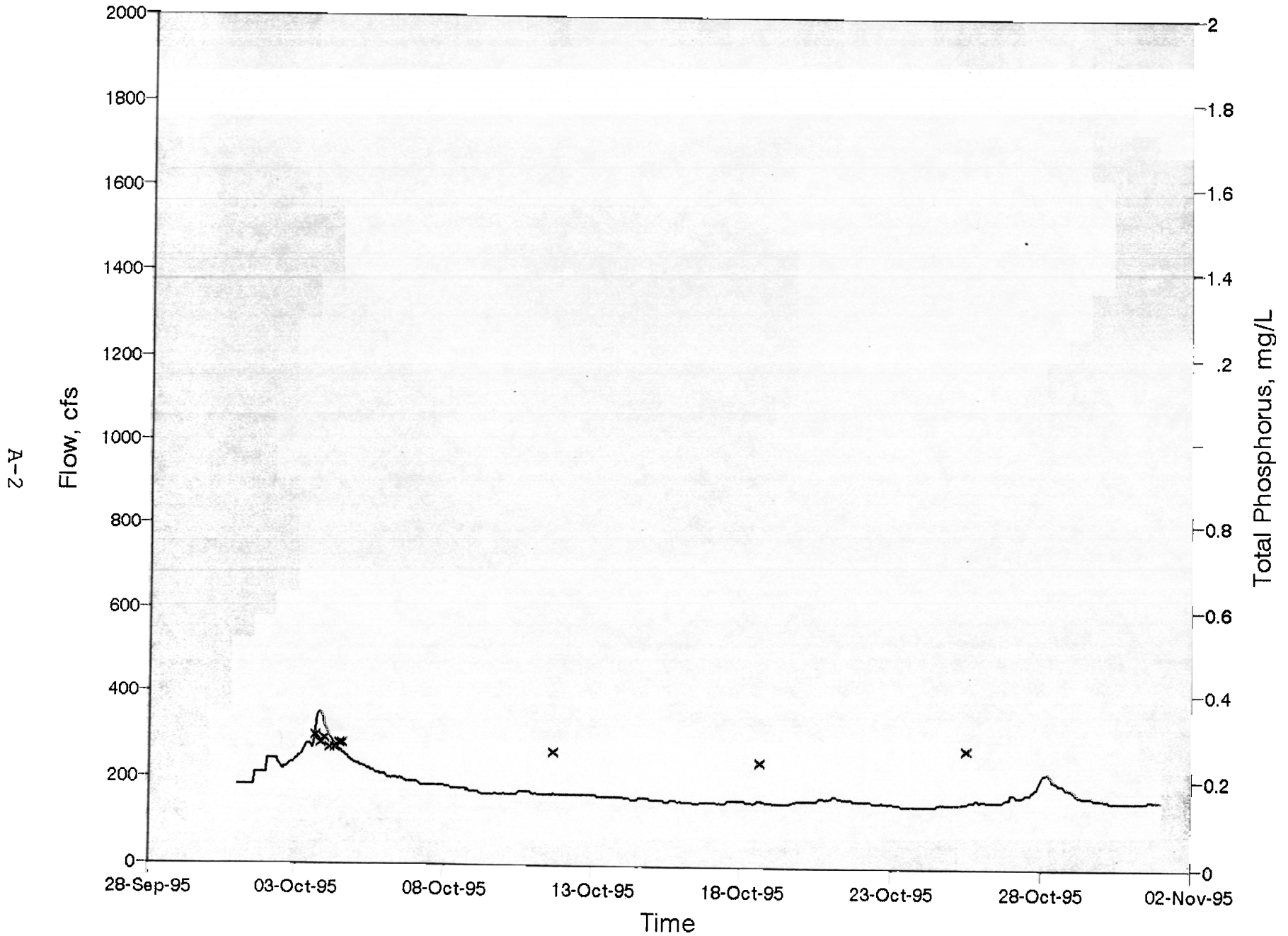
**Appendix A**

**TP Concentrations & Flow vs Time  
for Arkansas and Oklahoma**

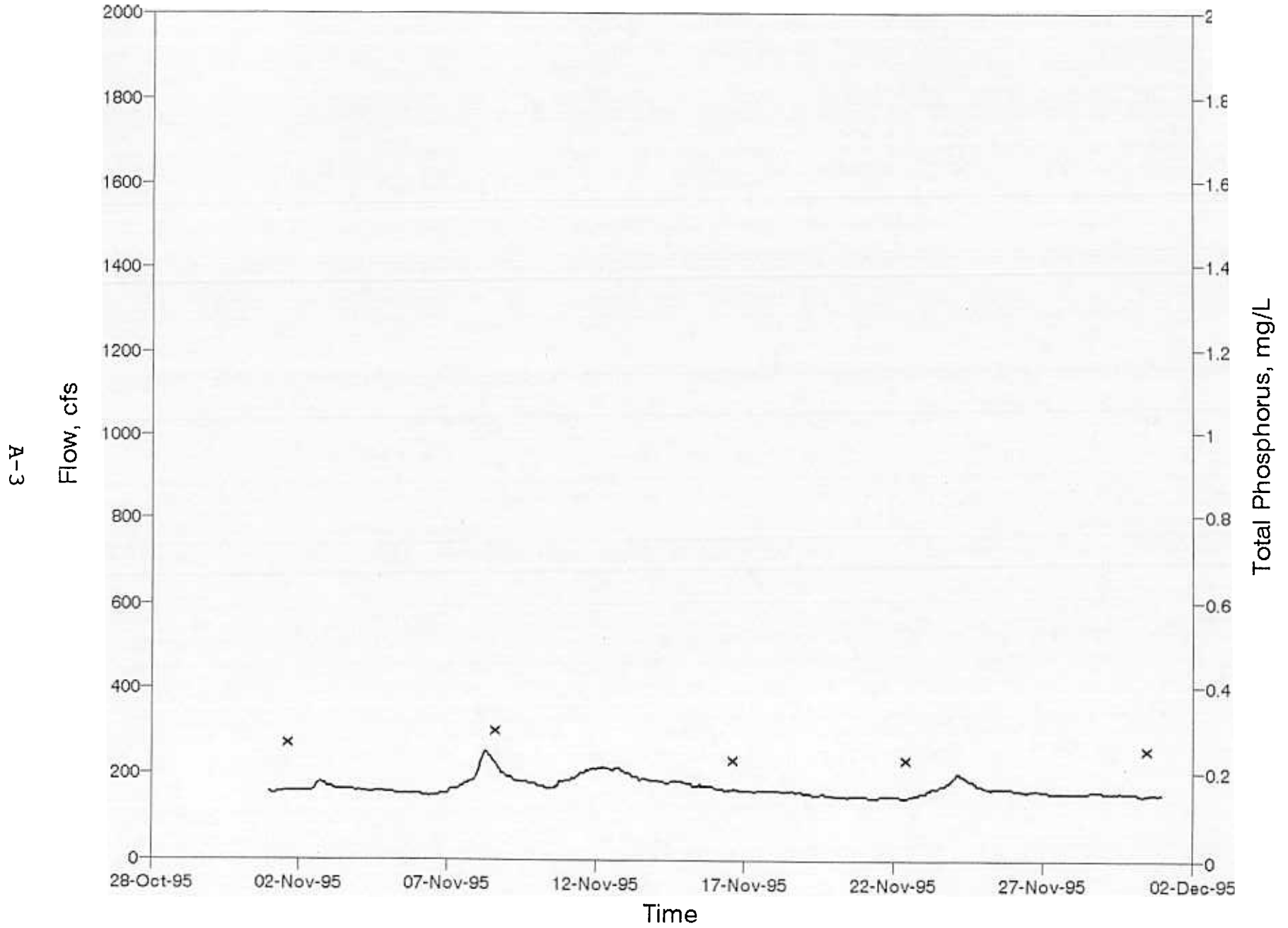
Illinois River at Arkansas Highway 59  
September 1995



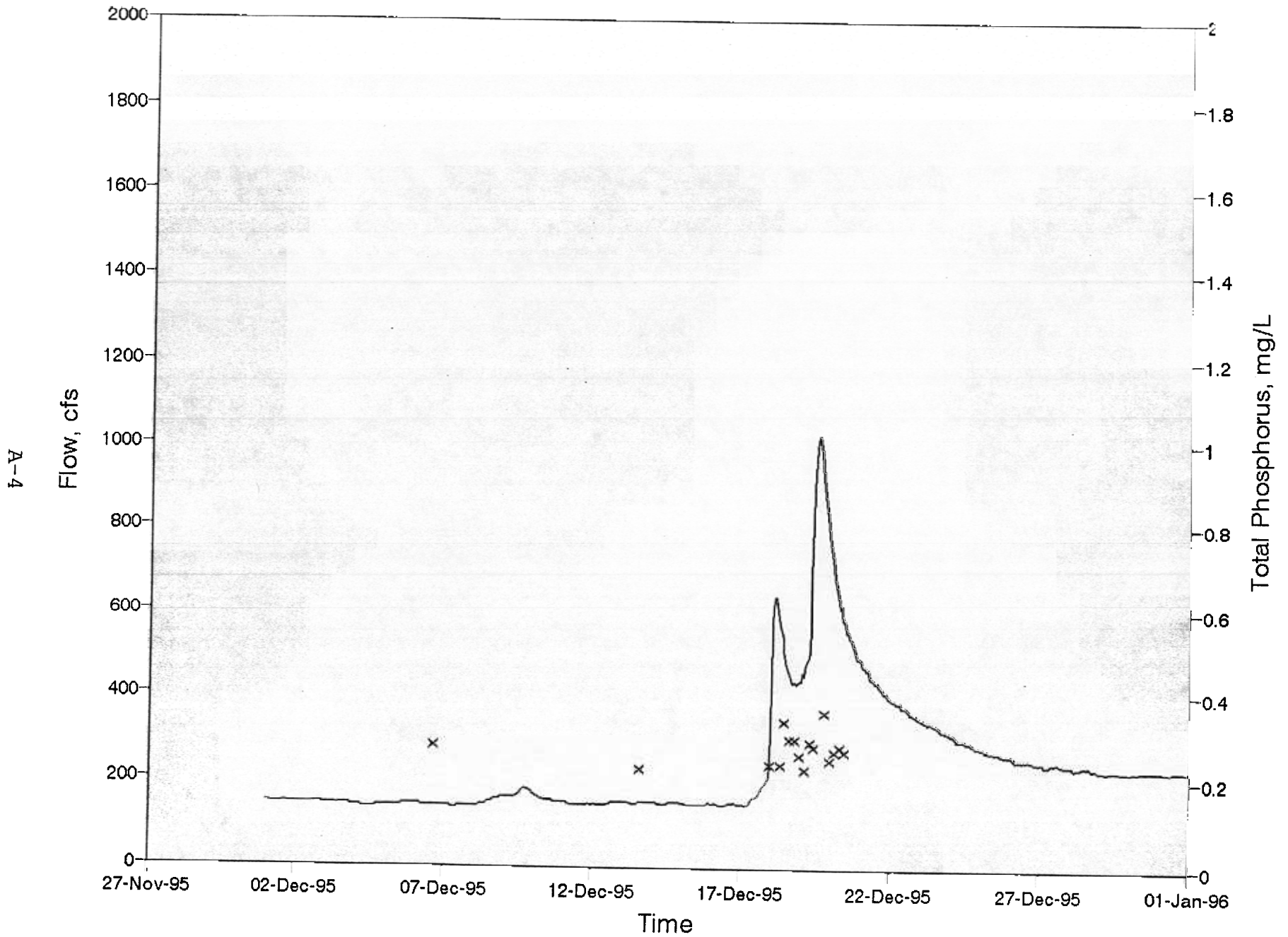
Illinois River at Arkansas Highway 59  
October 1995



Illinois River at Arkansas Highway 59  
November 1995

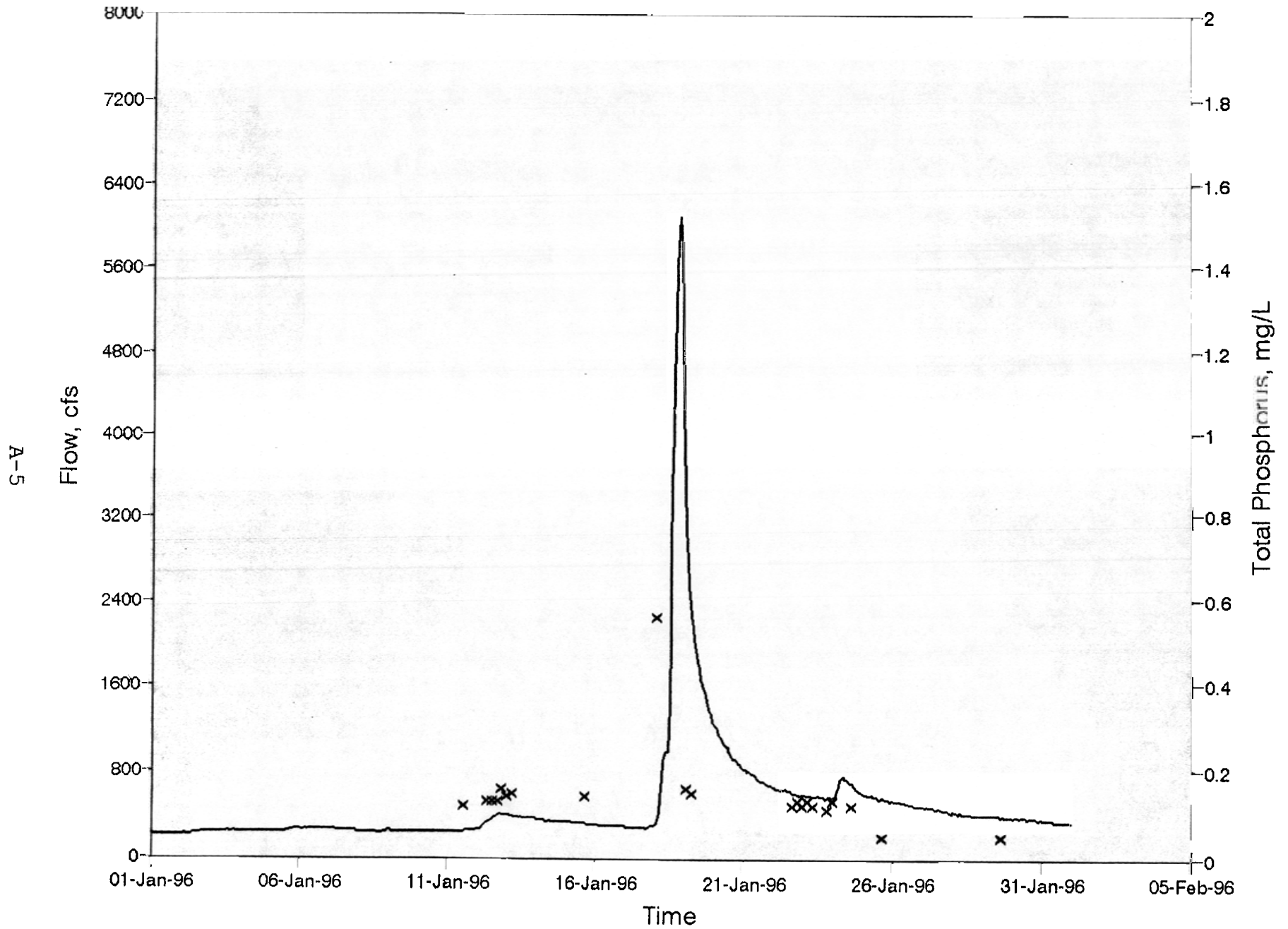


Illinois River at Arkansas Highway 59  
December 1995

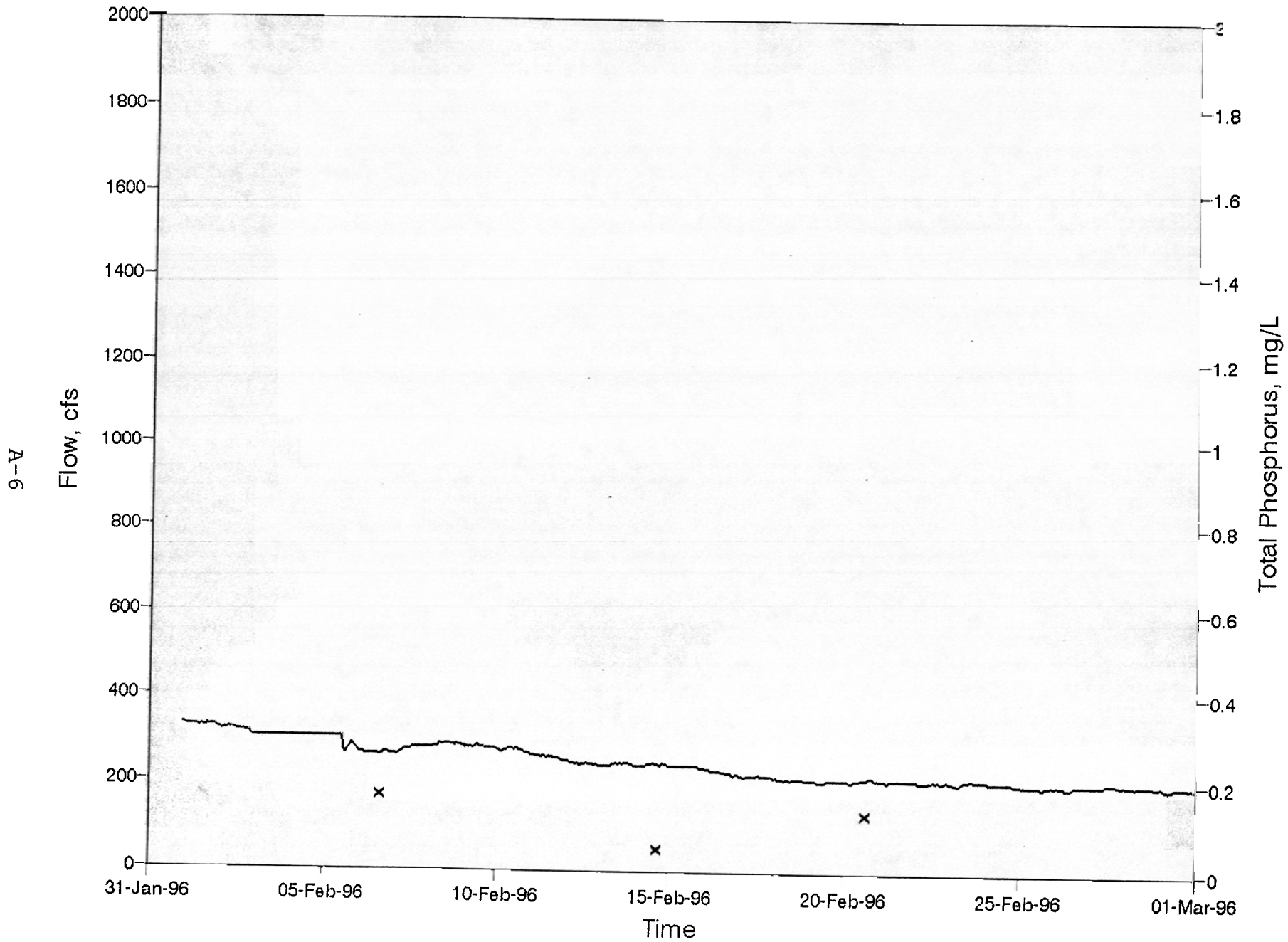




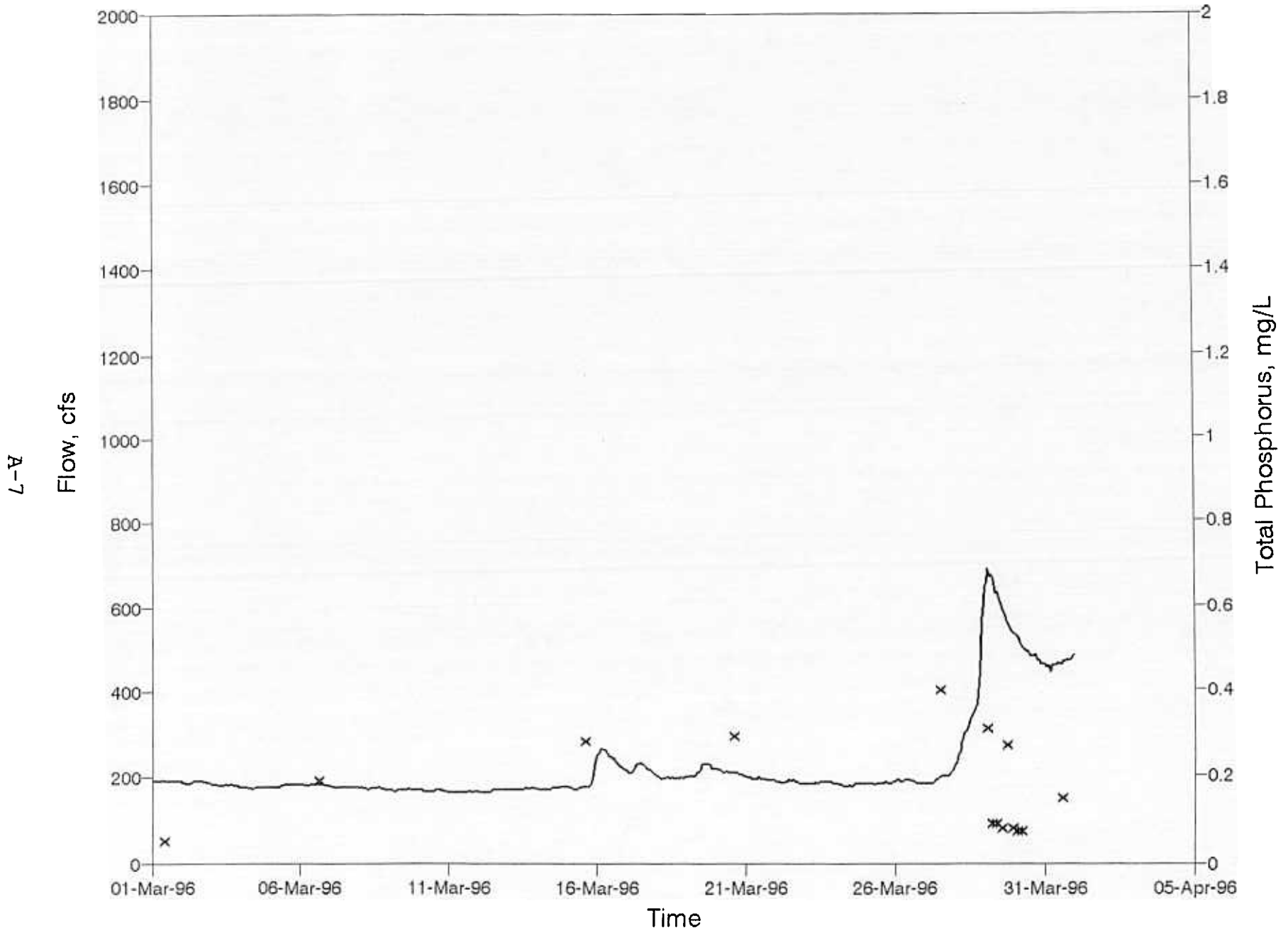
# Illinois River at Arkansas Highway 59 January 1996



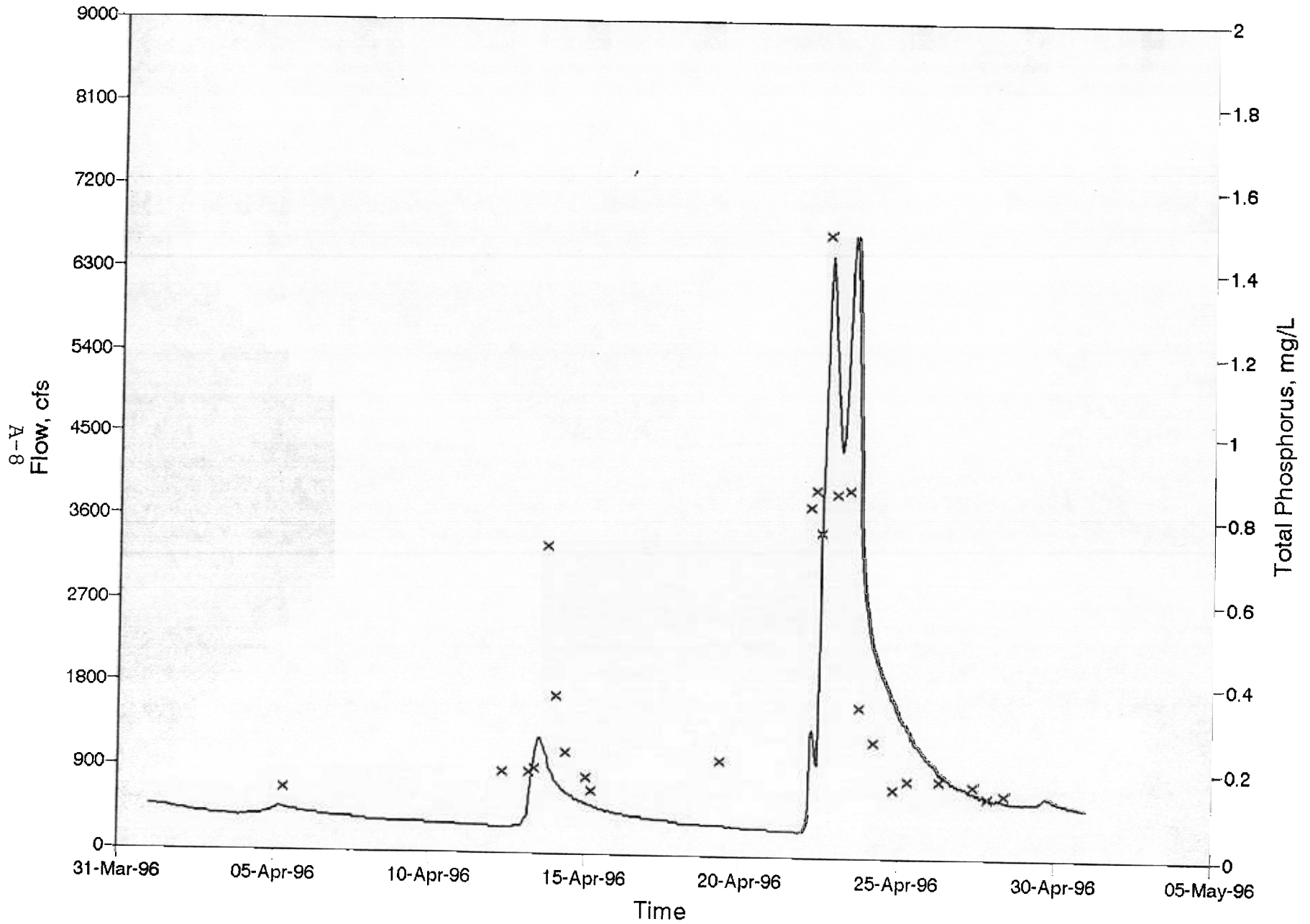
Illinois River at Arkansas Highway 59  
February 1996



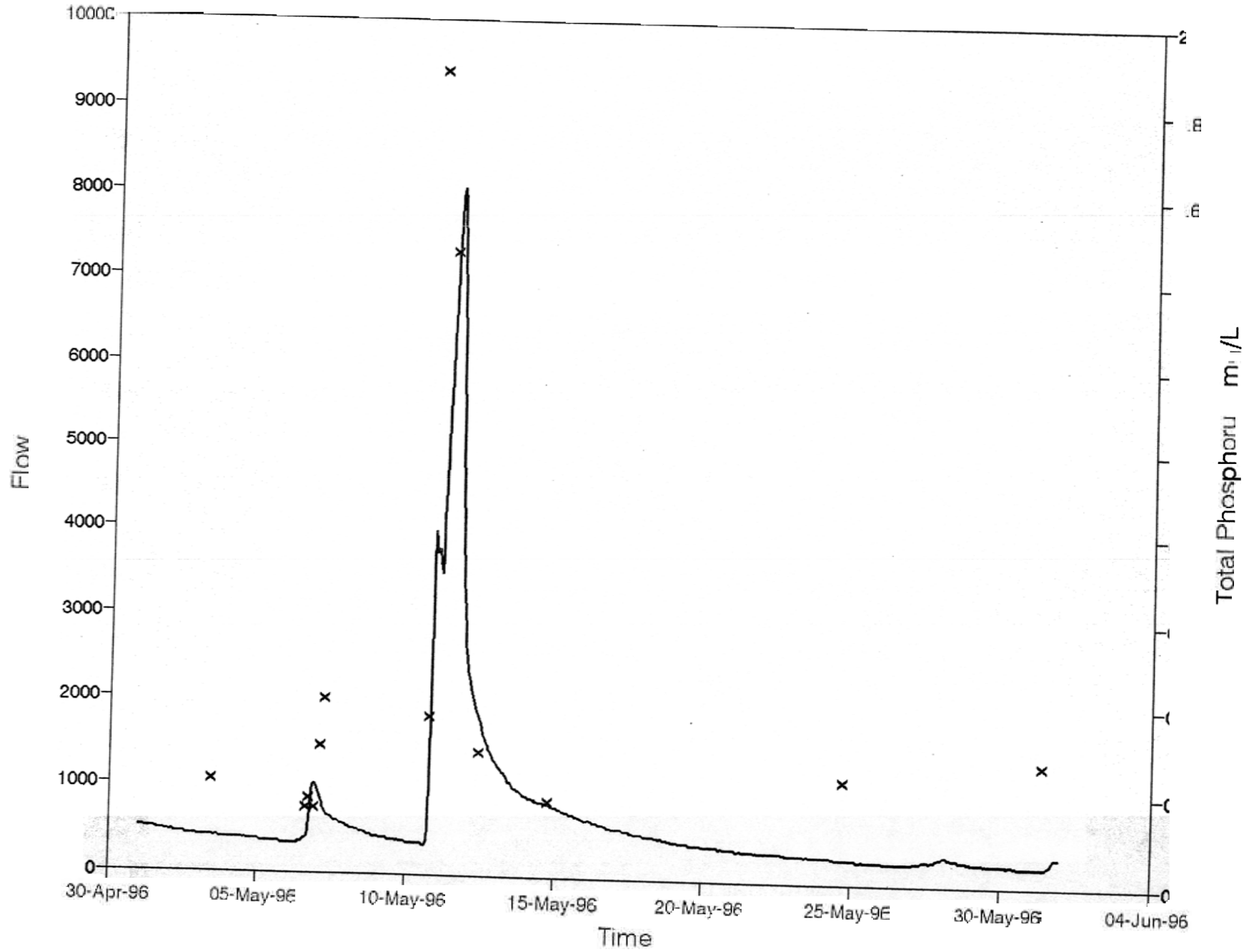
# Illinois River at Arkansas Highway 59 March 1996



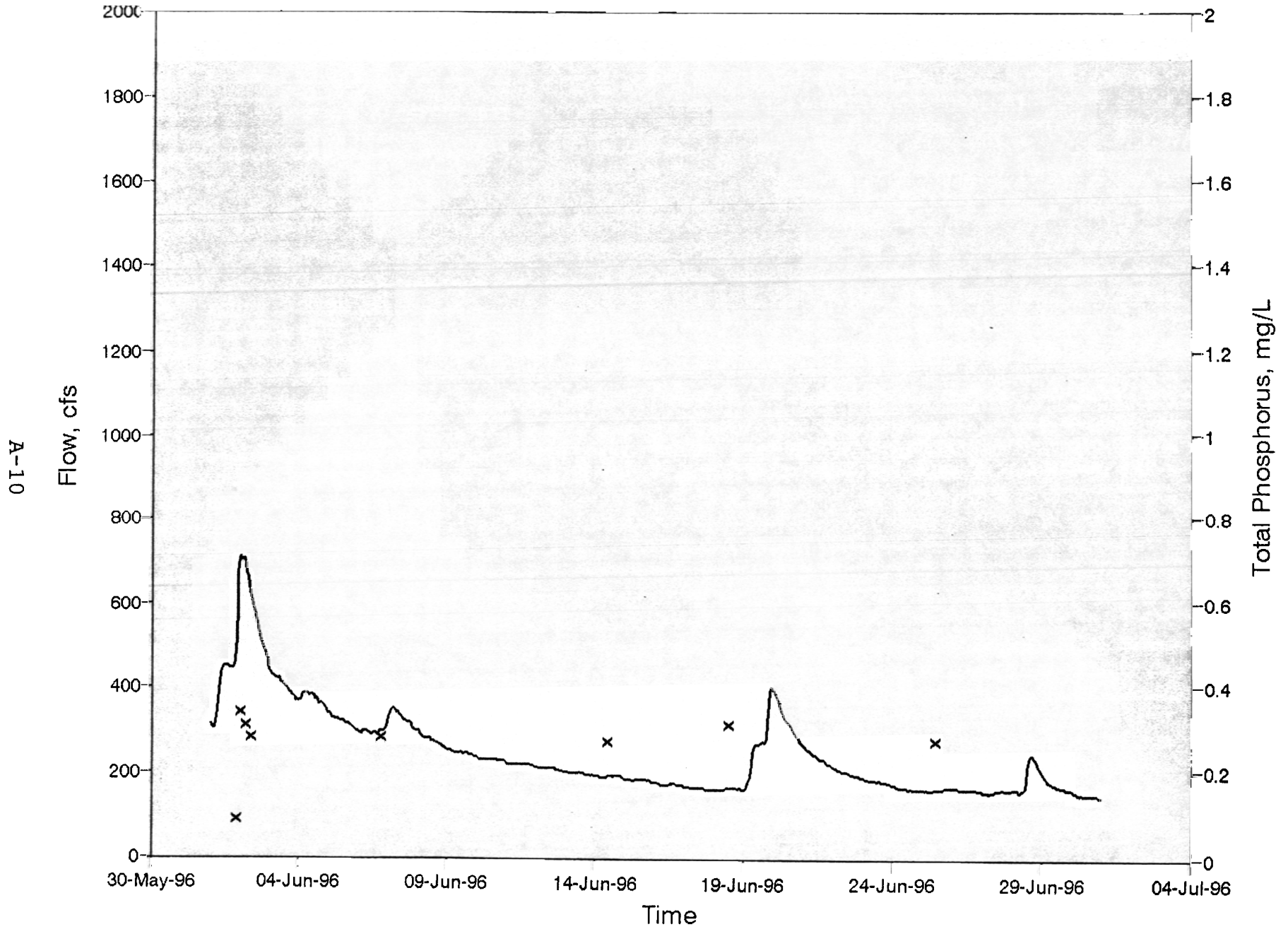
# Illinois River at Arkansas Highway 59 April 1996



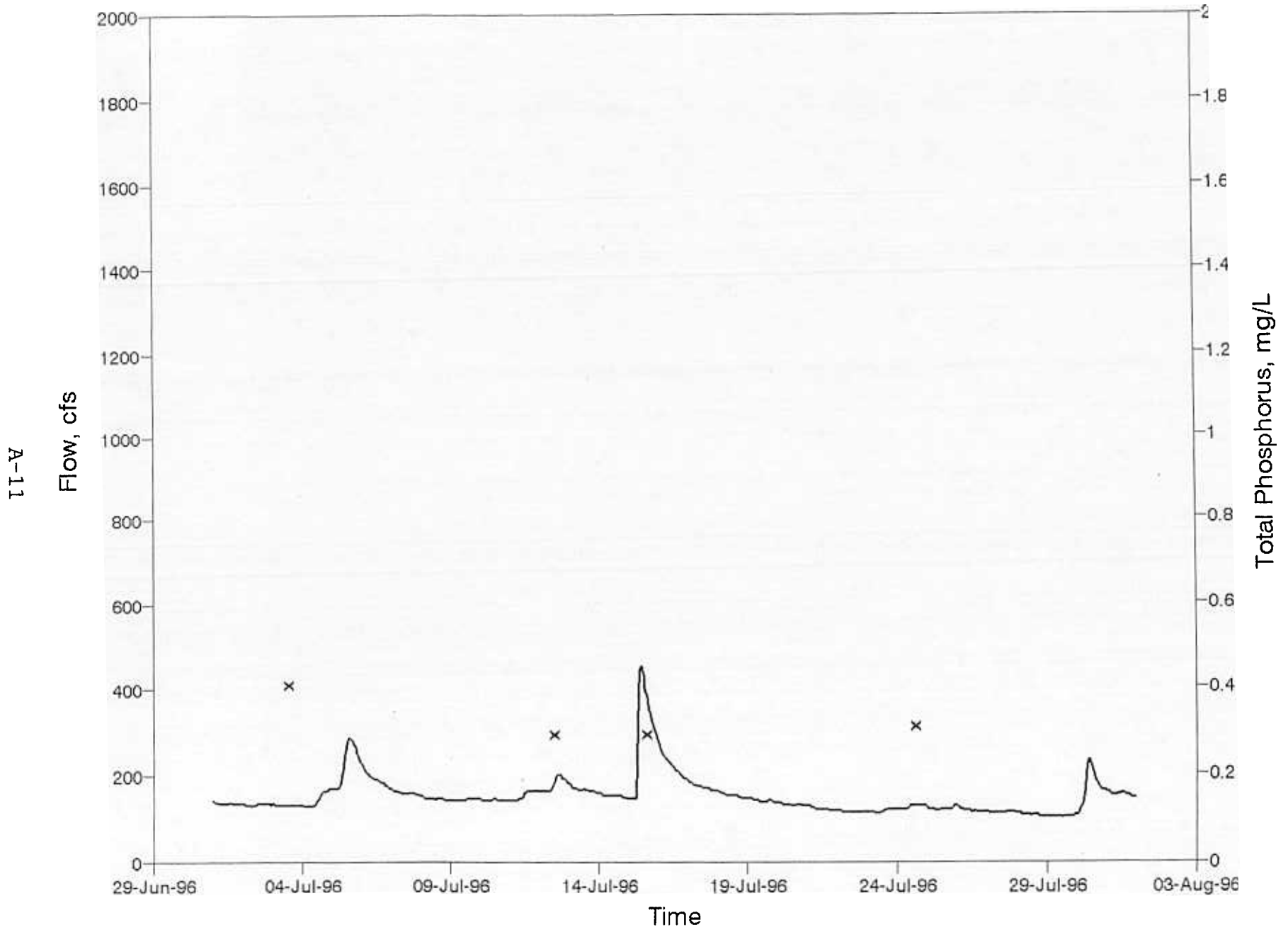
# Illinois River at Arkansas Highway 59 May 1996



Illinois River at Arkansas Highway 59  
June 1996

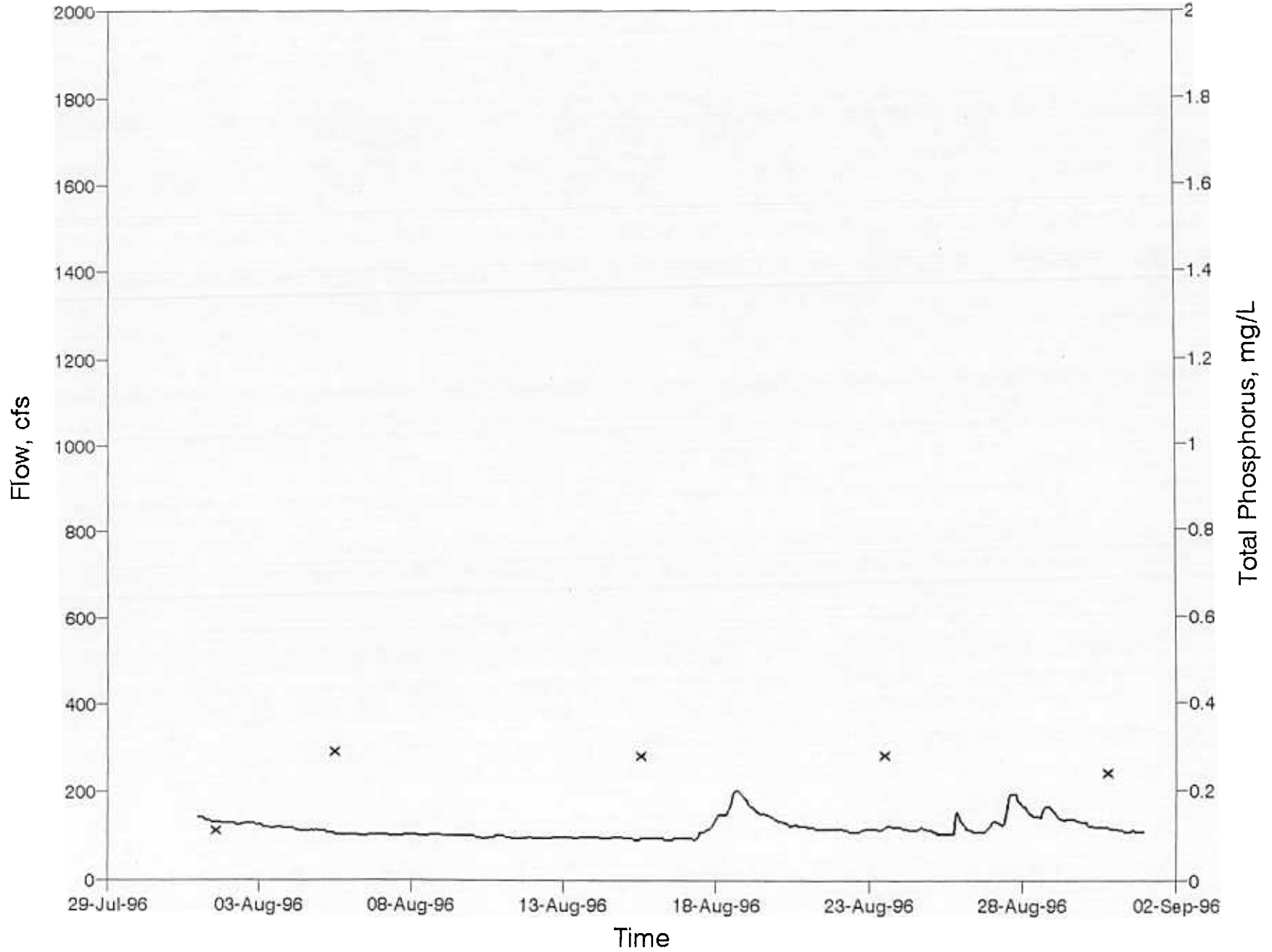


Illinois River at Arkansas Highway 59  
July 1996



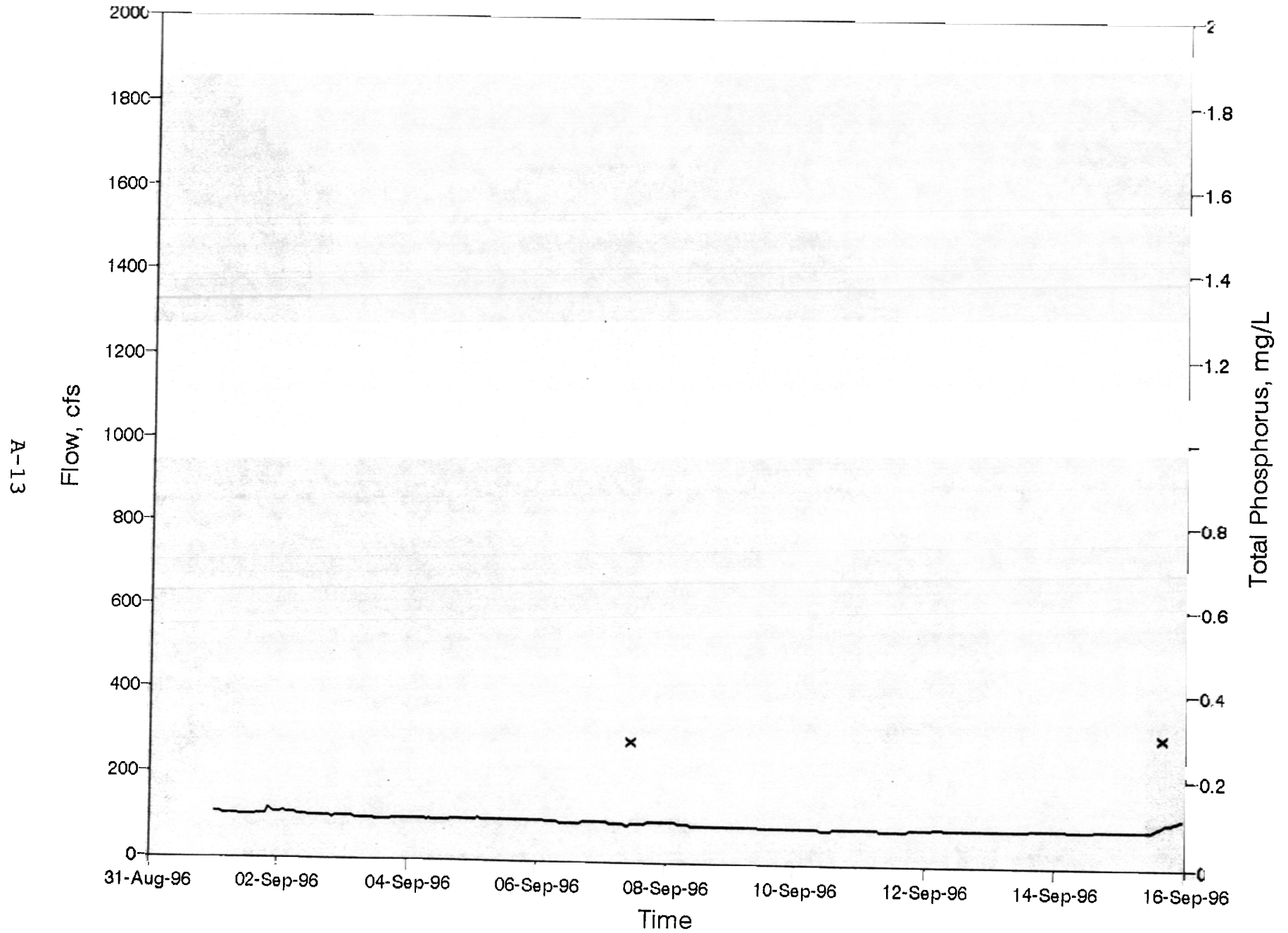
Illinois River at Arkansas Highway 59  
August 1996

A-12

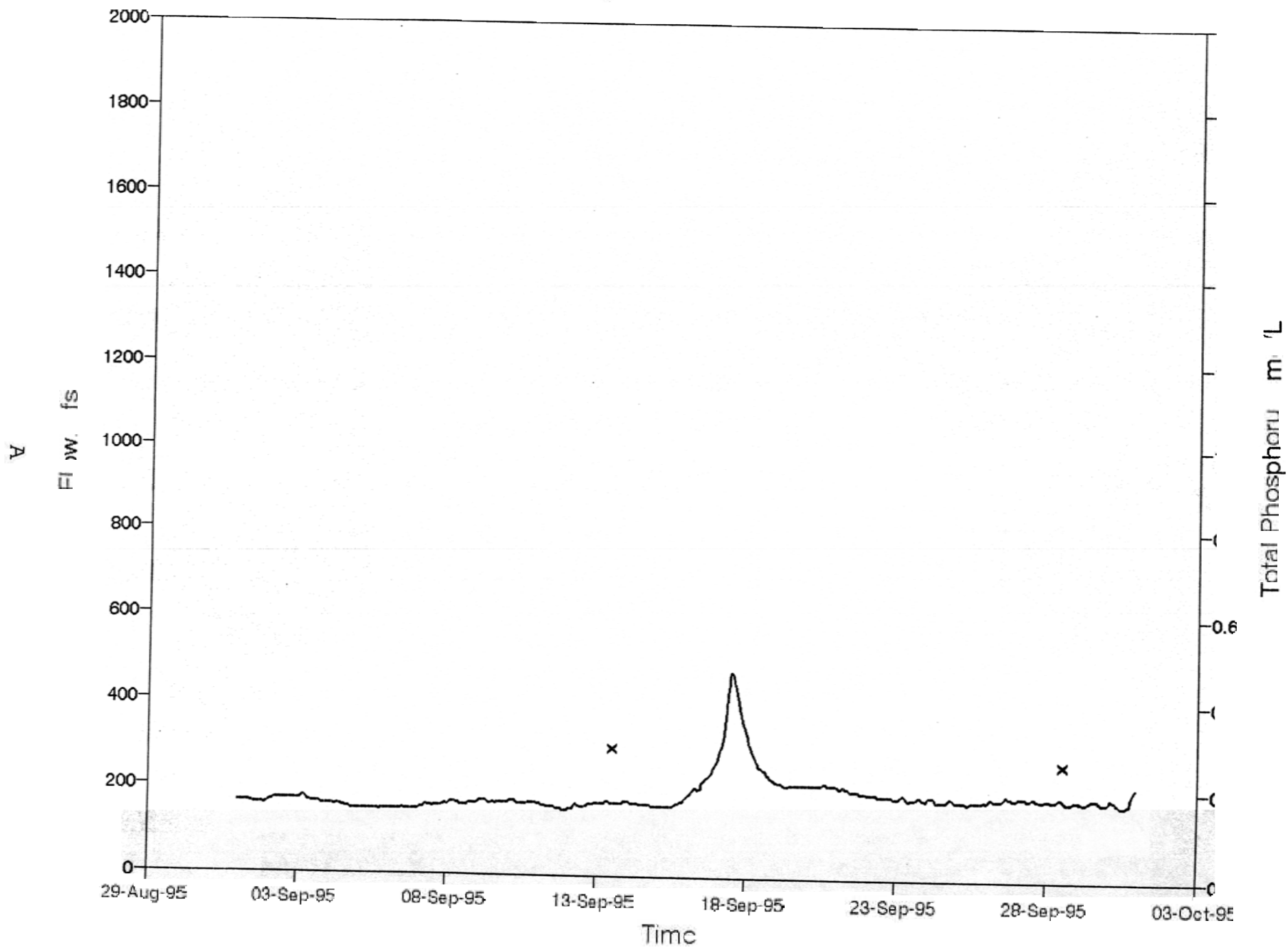




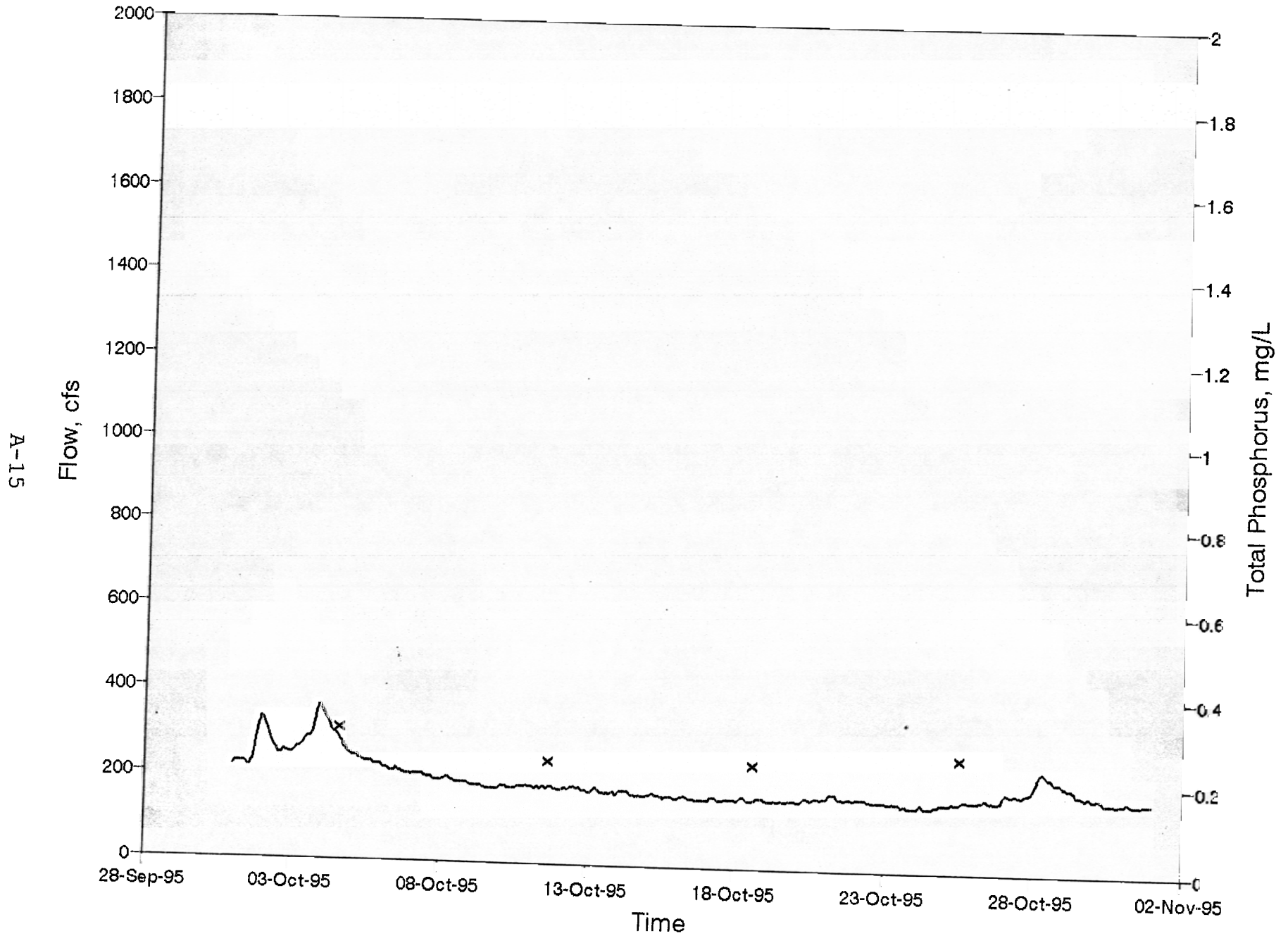
# Illinois River at Arkansas Highway 59 September 1996



# Illinois River at Oklahoma Highway 59 September 1995

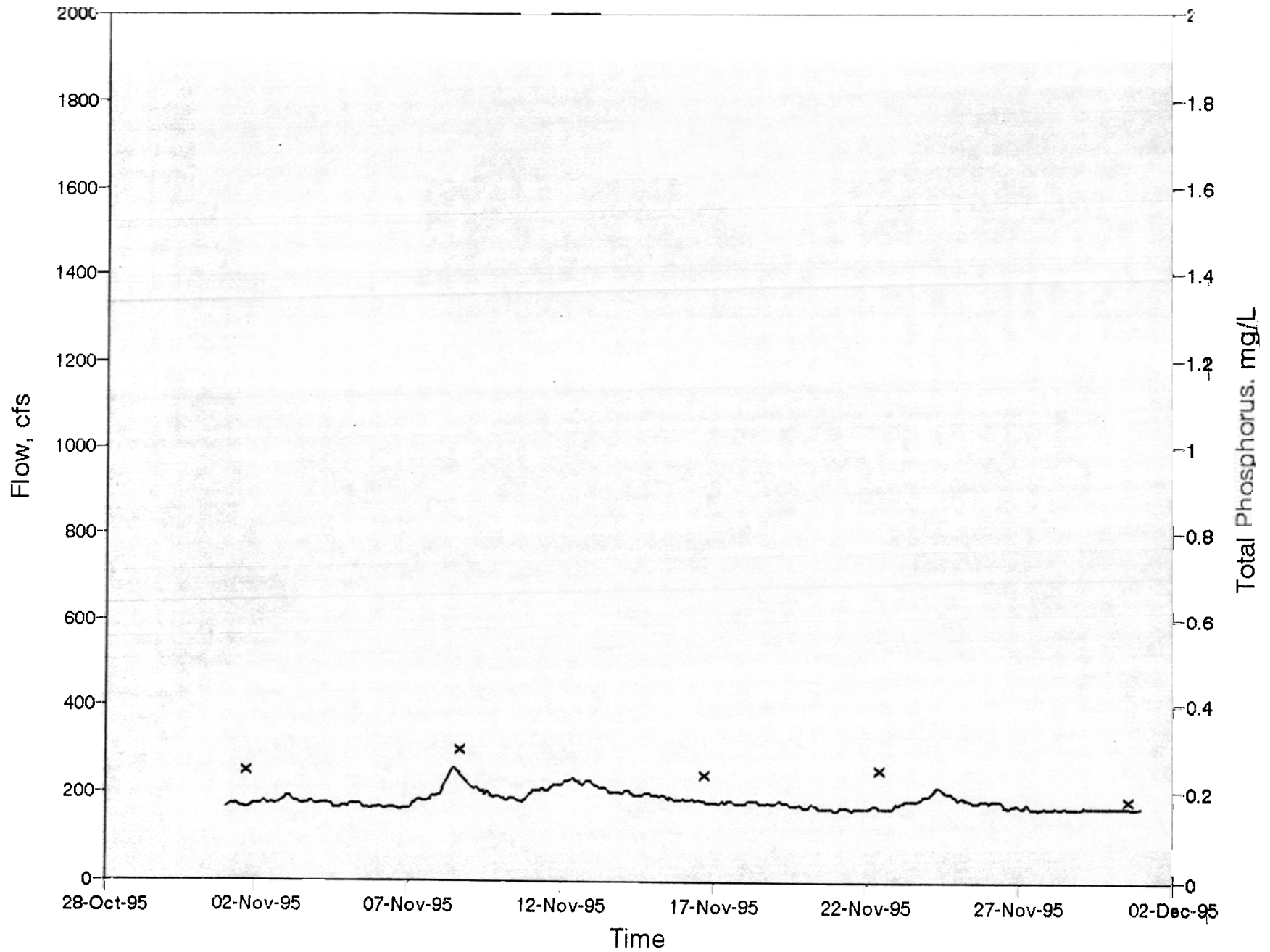


# Illinois River at Oklahoma Highway 59 October 1995



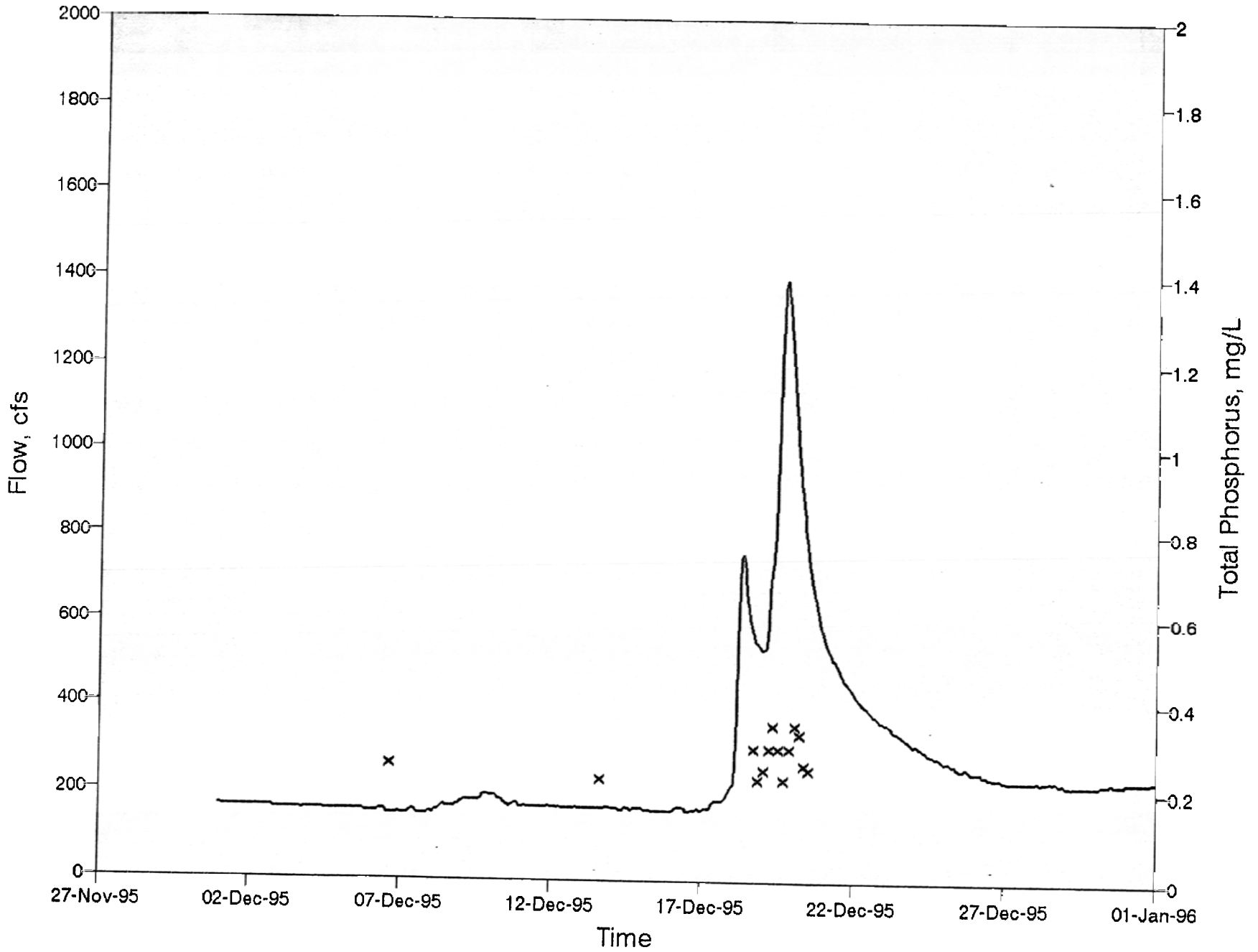
# Illinois River at Oklahoma Highway 59 November 1995

A-16

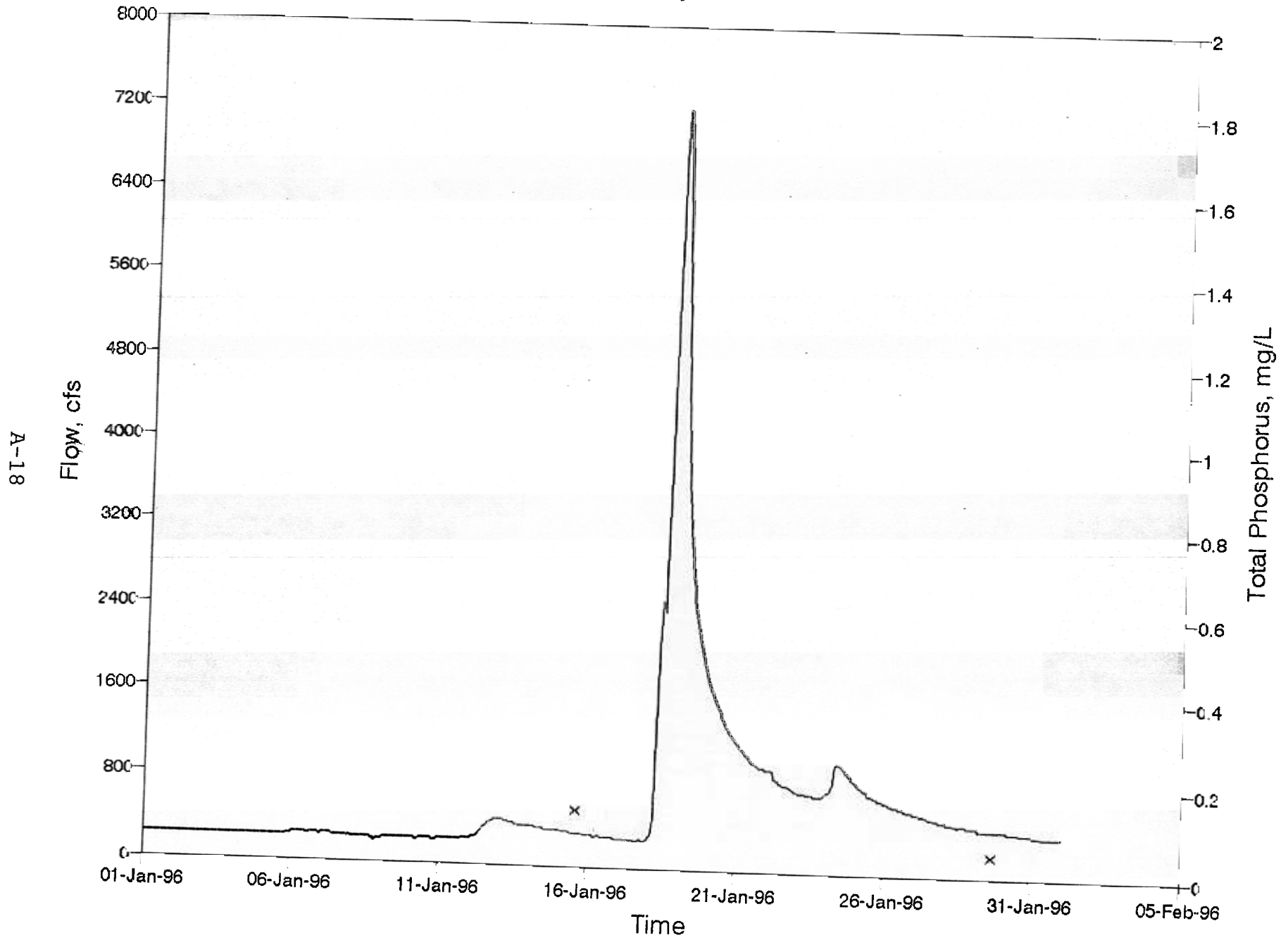


Illinois River at Oklahoma Highway 59  
December 1995

A-17

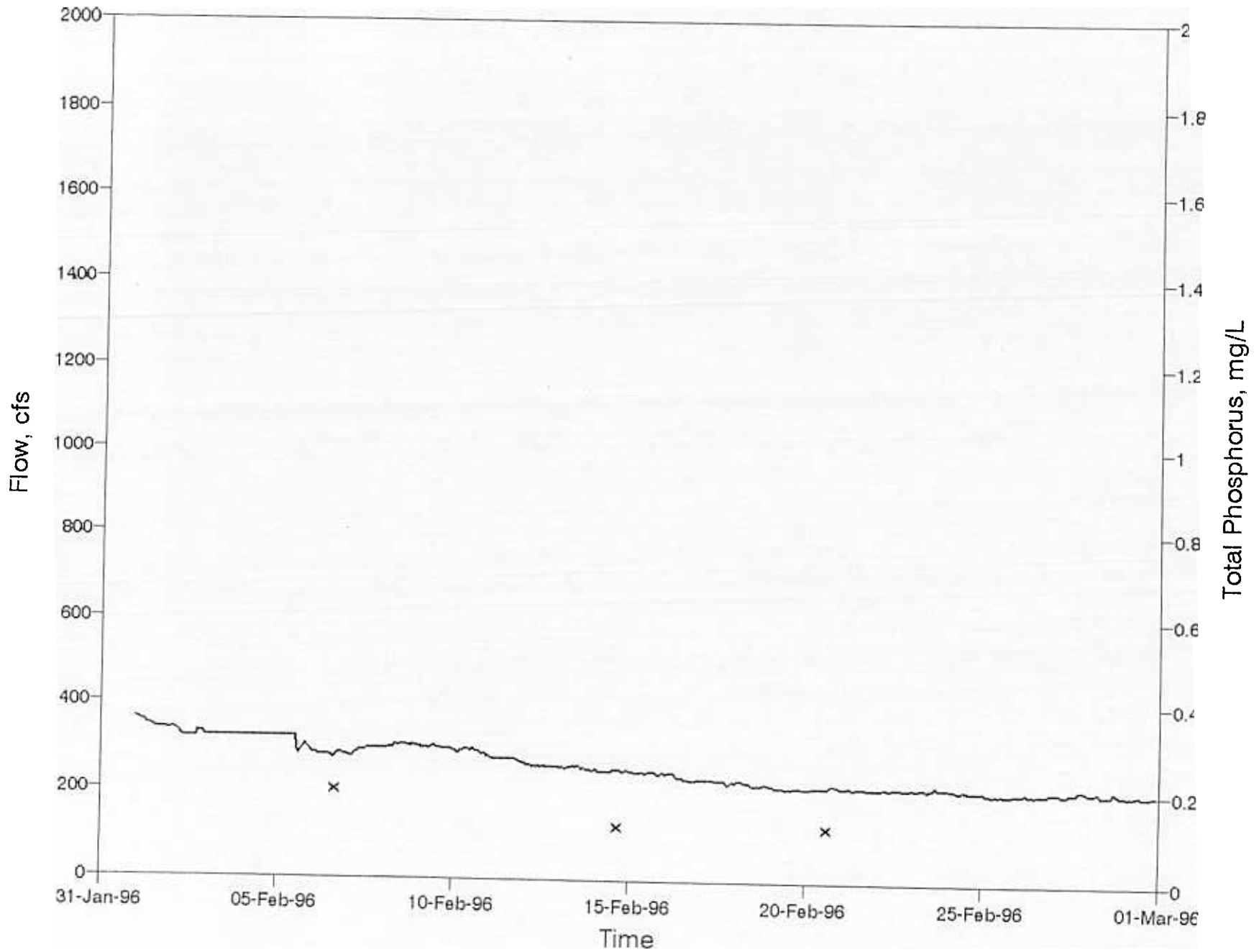


# Illinois River at Oklahoma Highway 59 January 1996

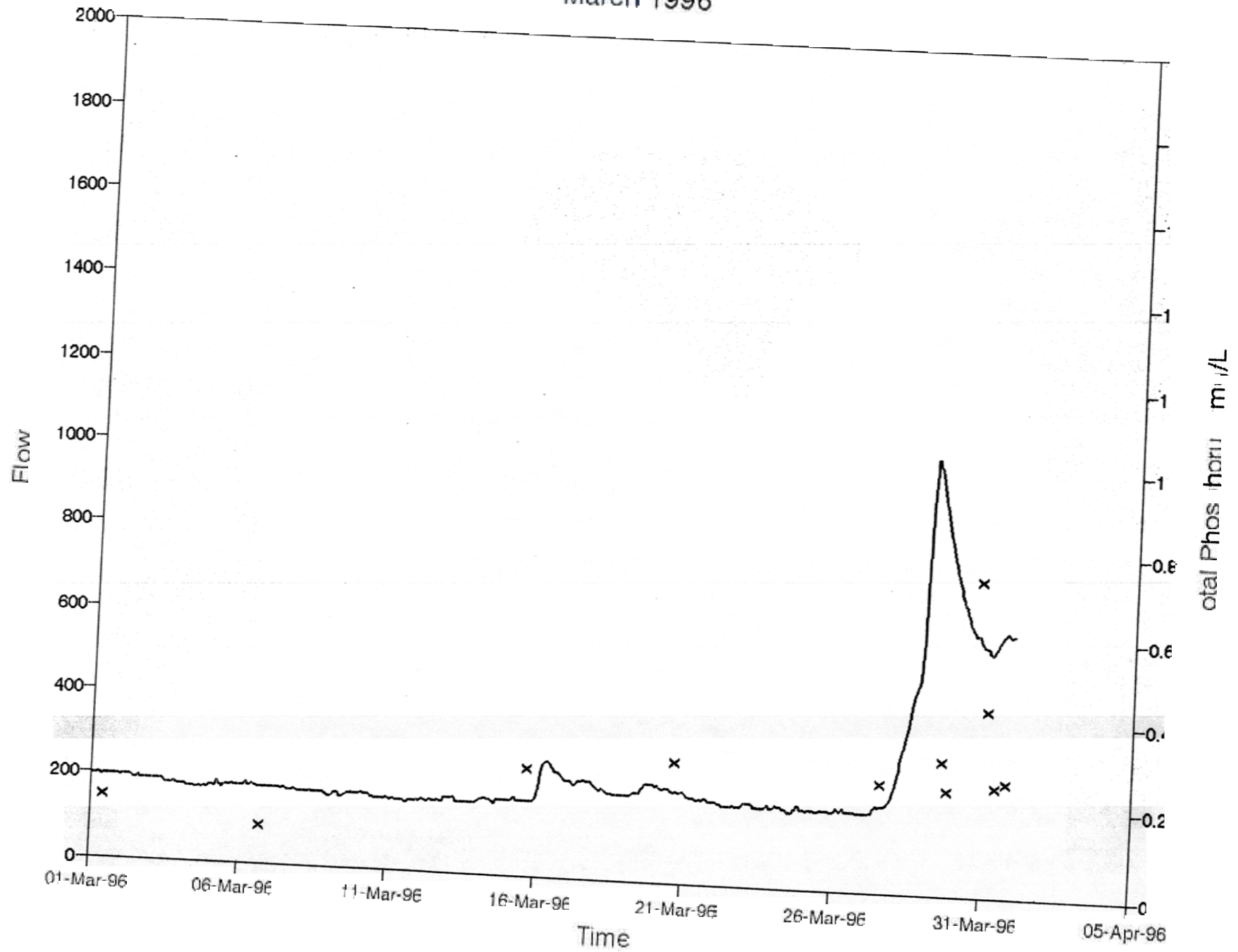


# Illinois River at Oklahoma Highway 59 February 1996

A-19



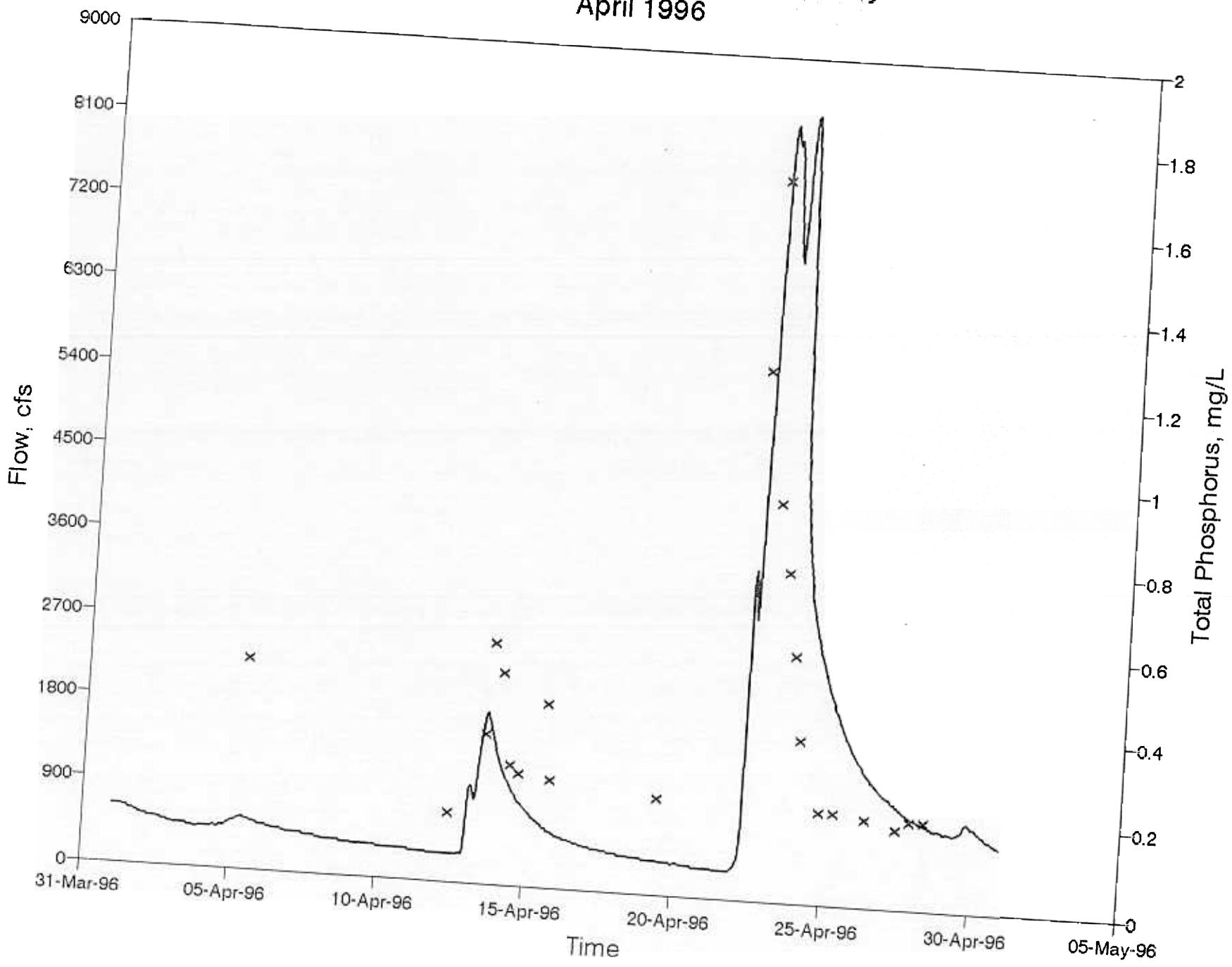
# Illinois River at Oklahoma Highway 59 March 1996





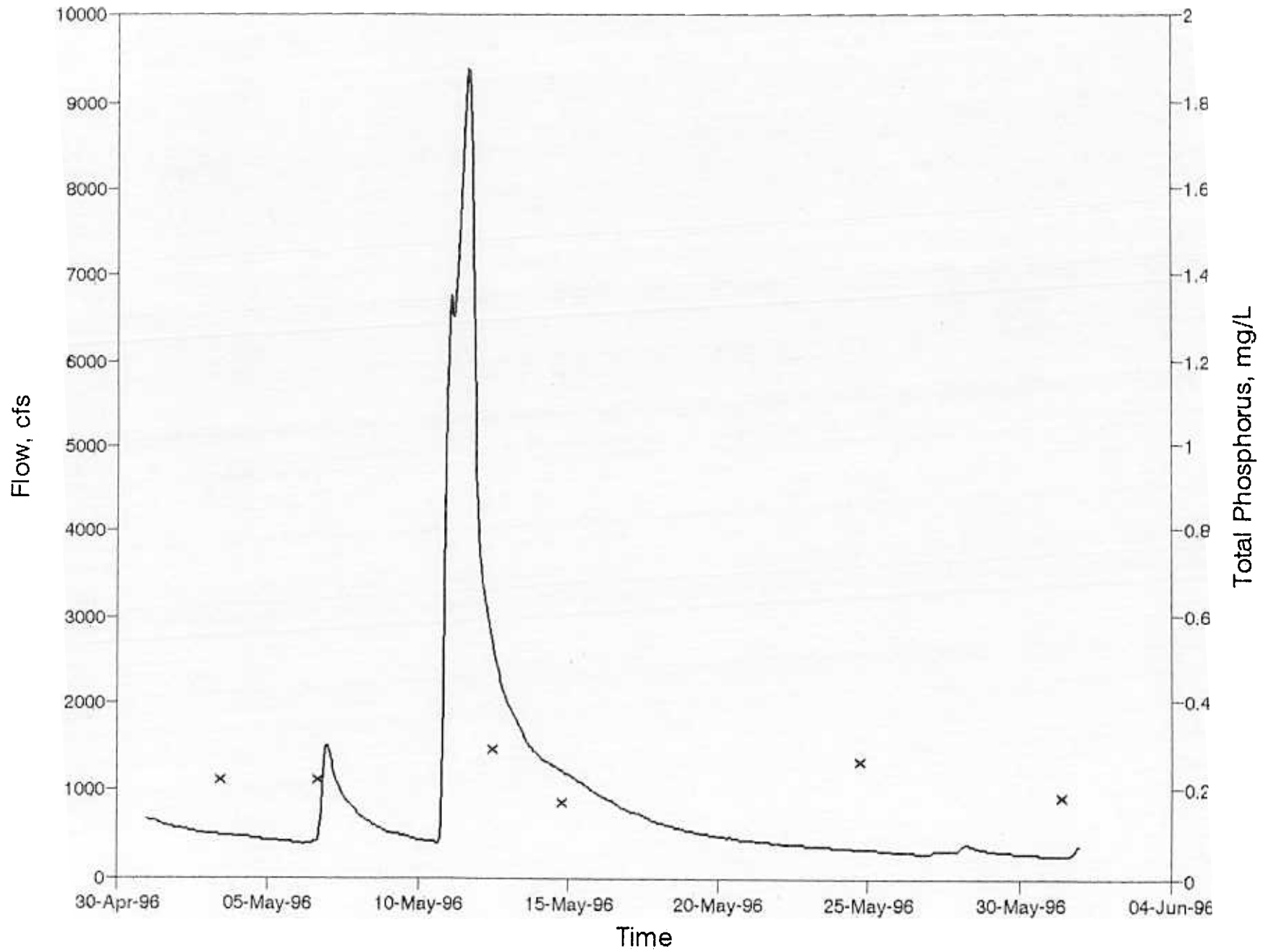
# Illinois River at Oklahoma Highway 59 April 1996

A-21



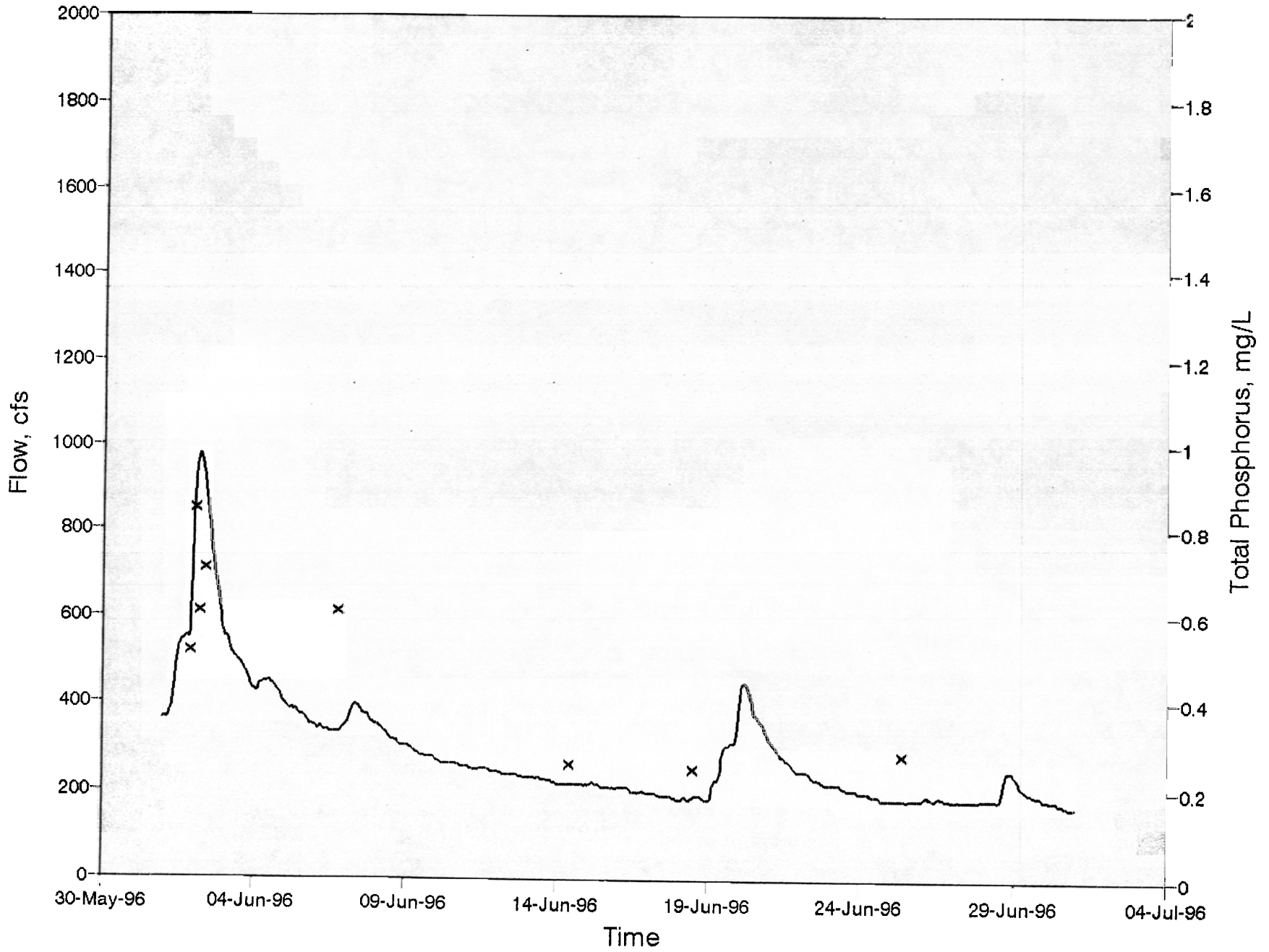
# Illinois River at Oklahoma Highway 59 May 1996

A-22



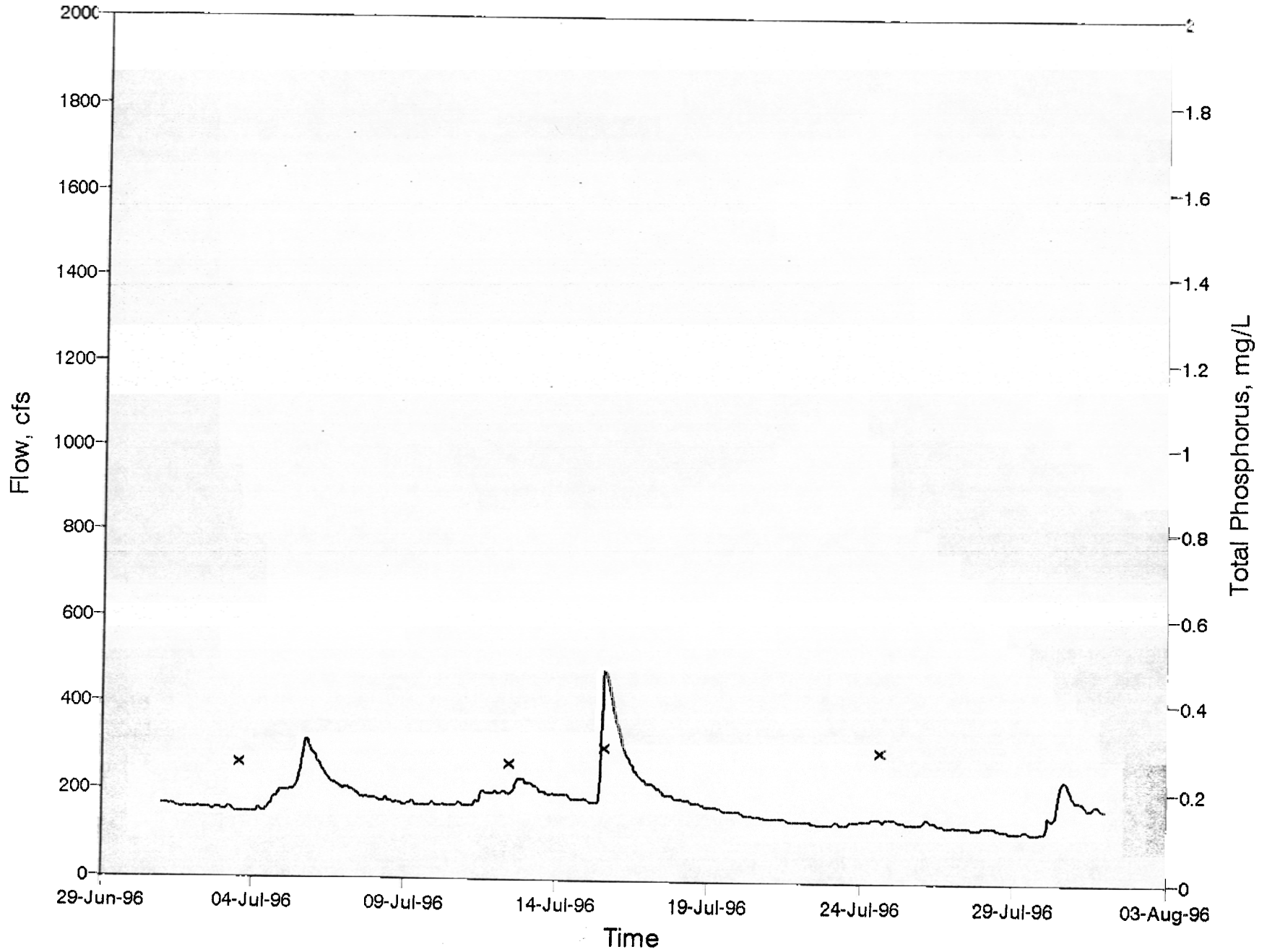
# Illinois River at Oklahoma Highway 59 June 1996

A-23

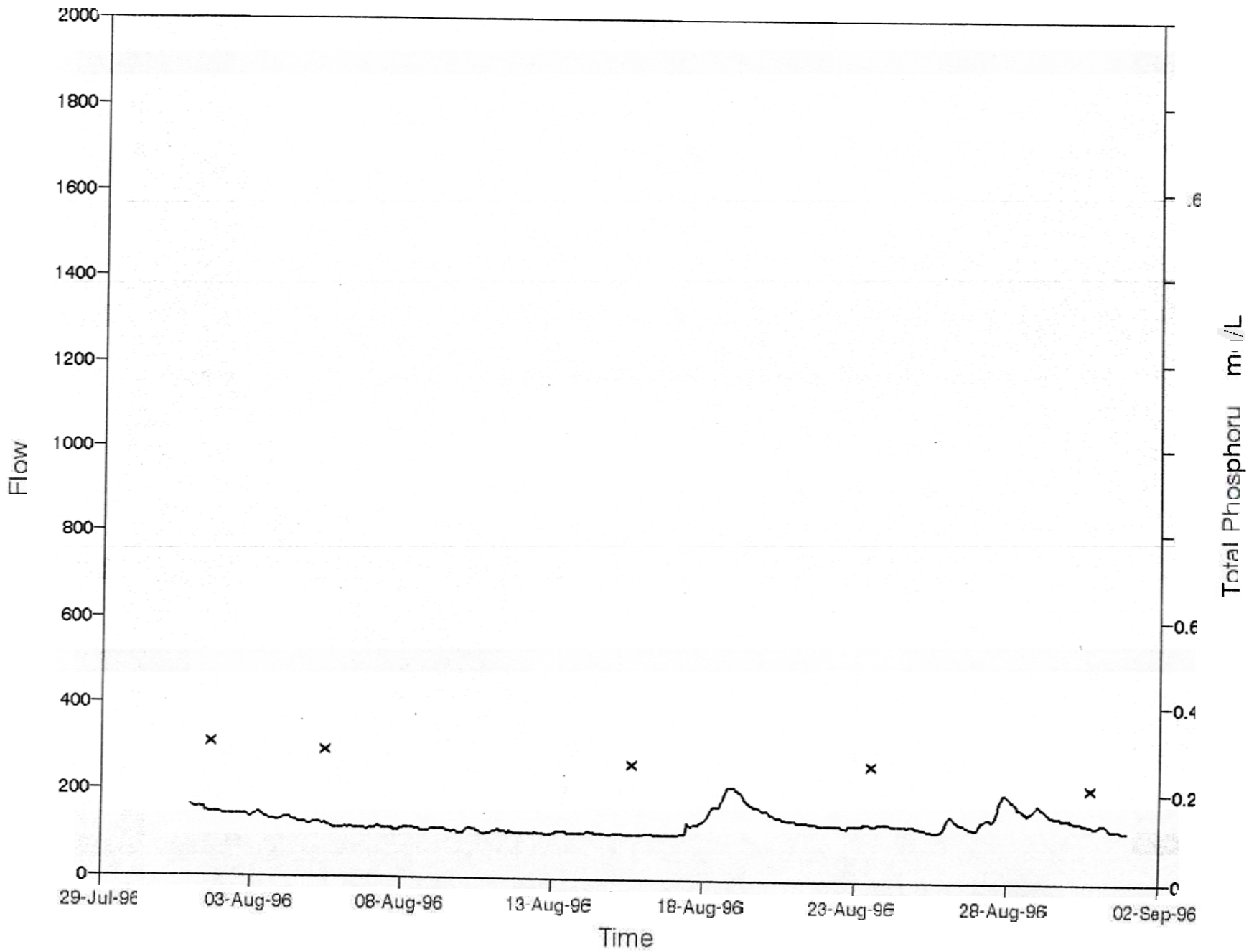


Illinois River at Oklahoma Highway 59  
July 1996

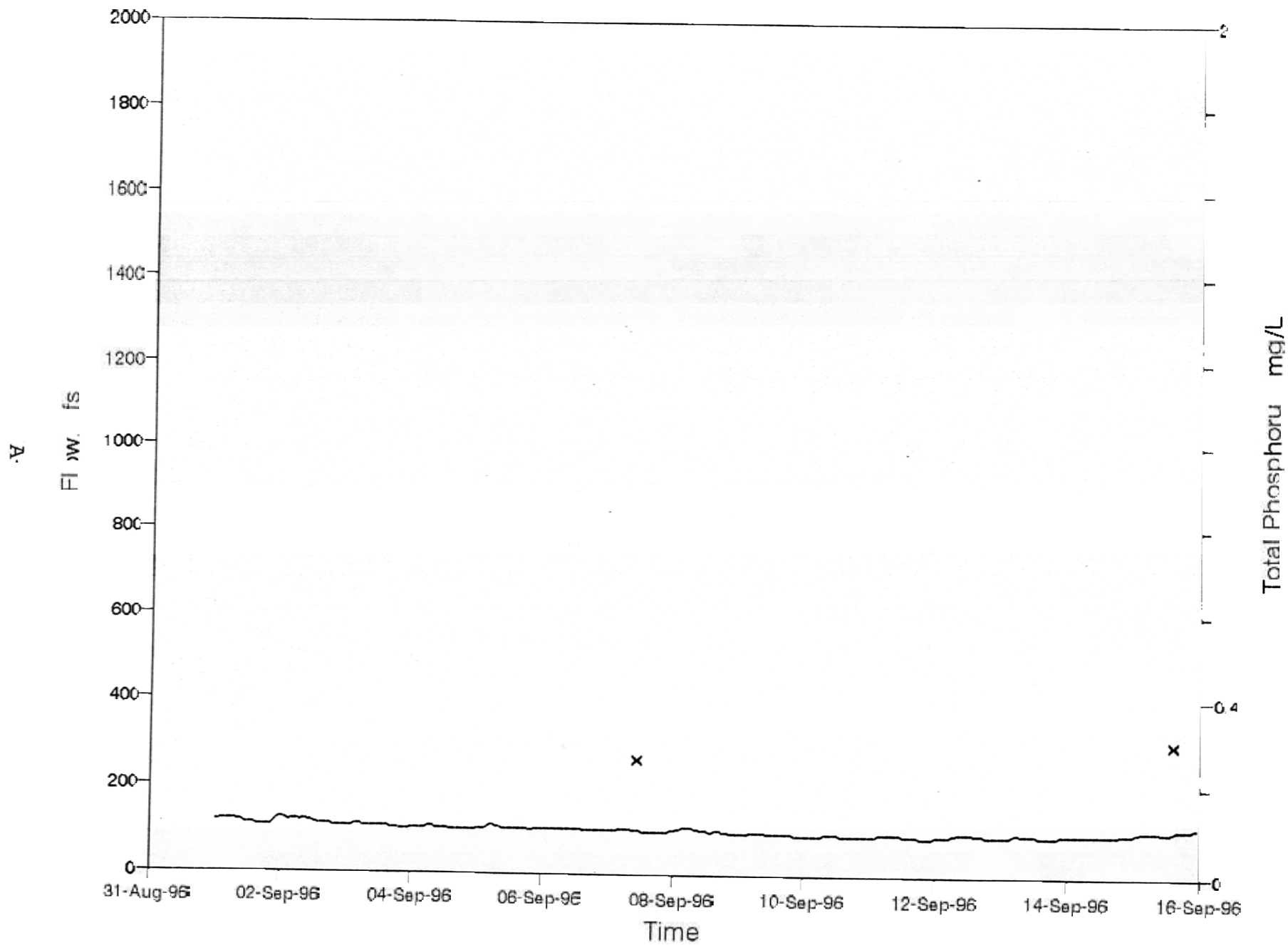
A-24



Illinois River at Oklahoma Highway 59  
August 1996



Illinois River at Oklahoma Highway 59  
September 1996



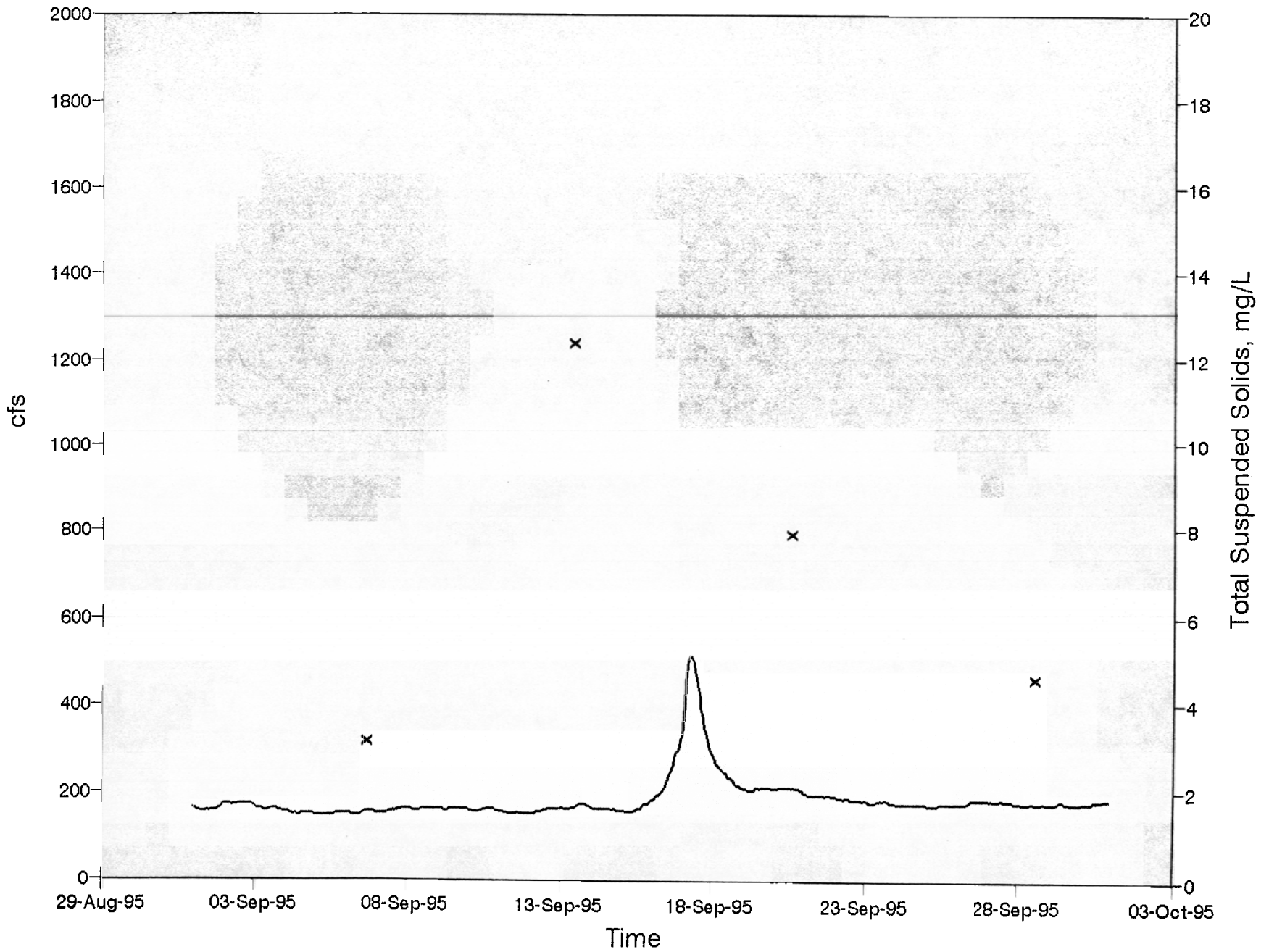
**Pollution Load and Effects of Arkansas and  
Lake Frances on the Illinois River**

**Appendix B**

**TSS Concentration & Flow vs Time  
for Arkansas and Oklahoma**

# Illinois River at Arkansas Highway 59

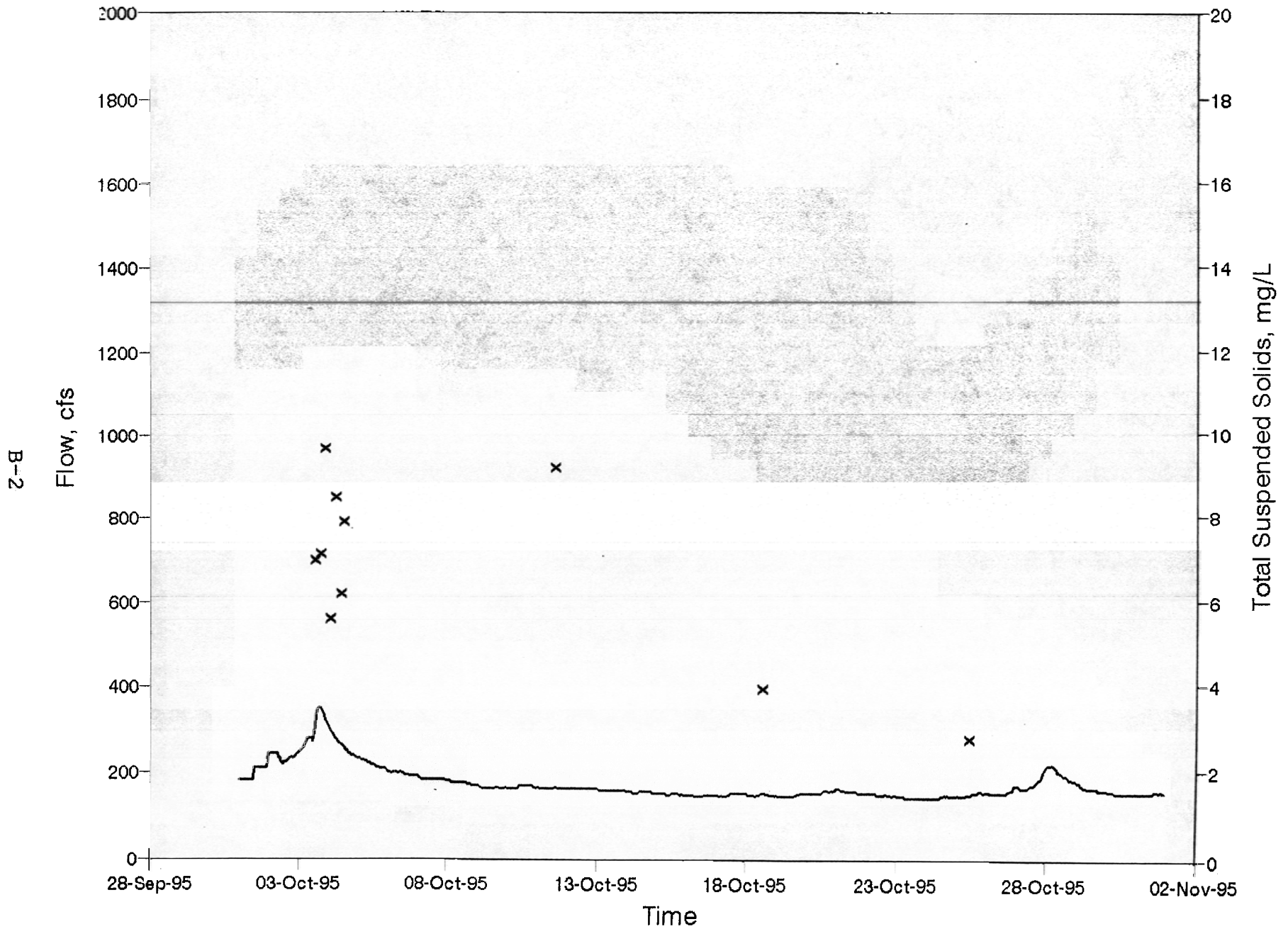
September 1995





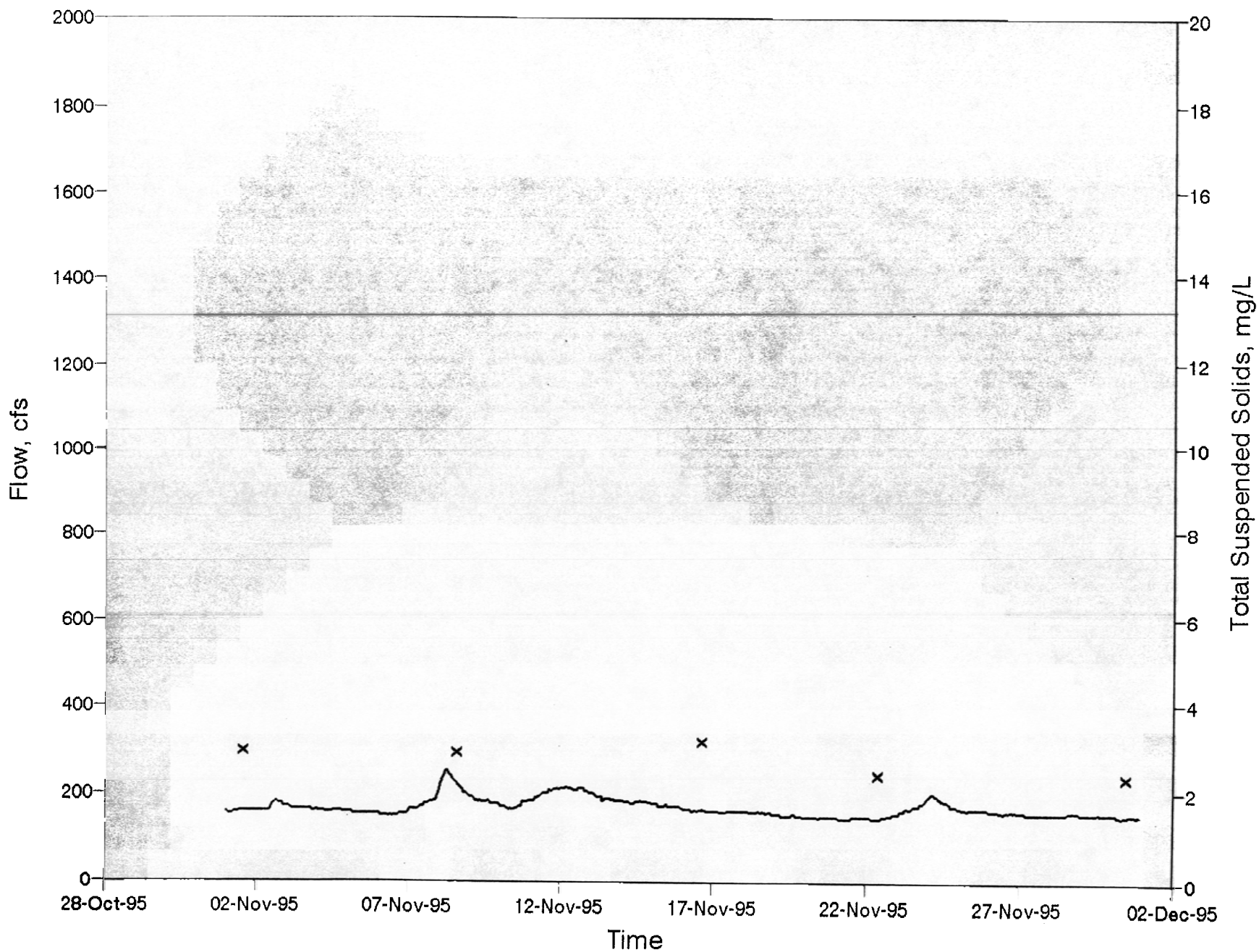
# Illinois River at Arkansas Highway 59

October 1995



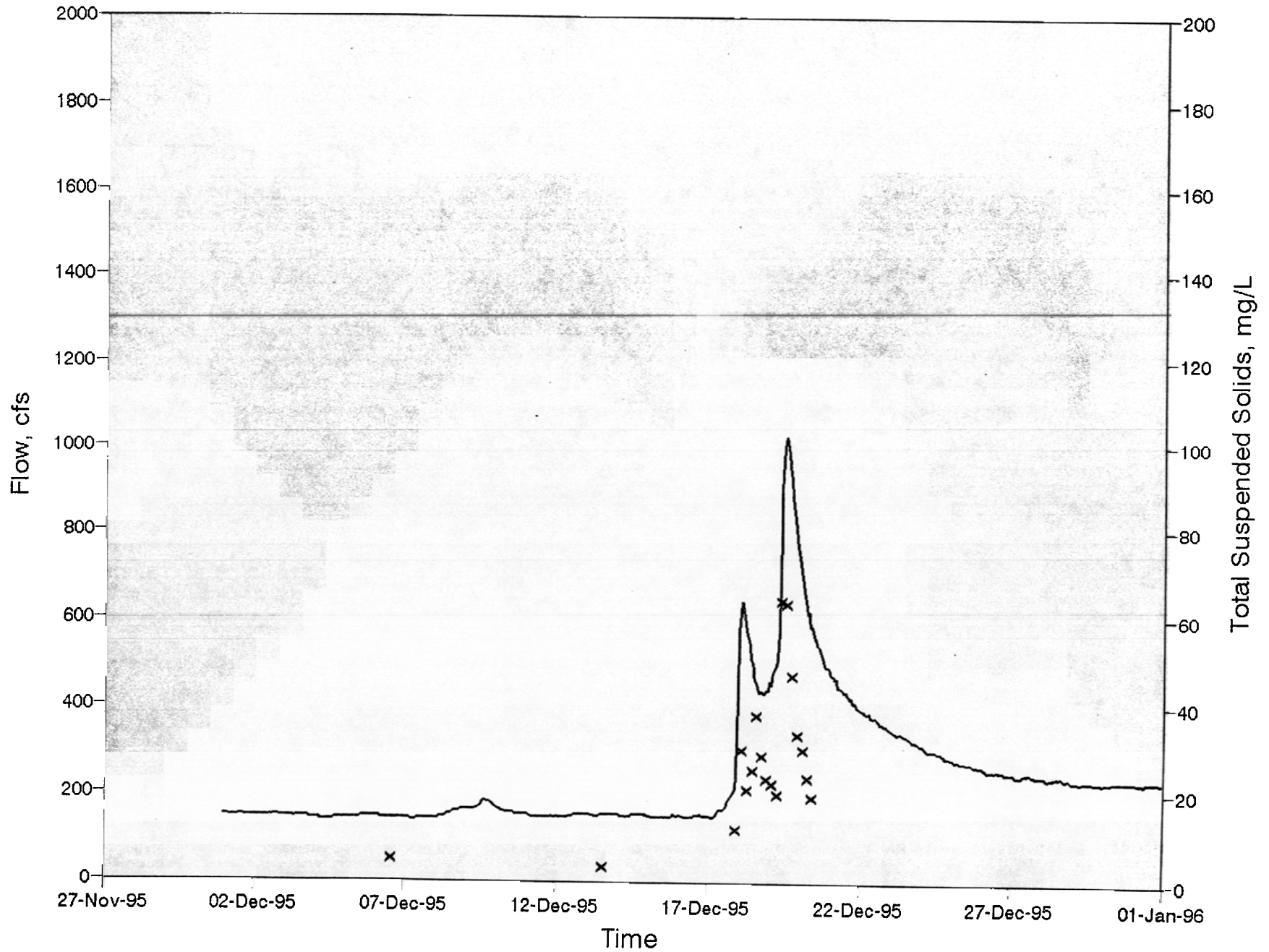
# Illinois River at Arkansas Highway 59

November 1995



# Illinois River at Arkansas Highway 59

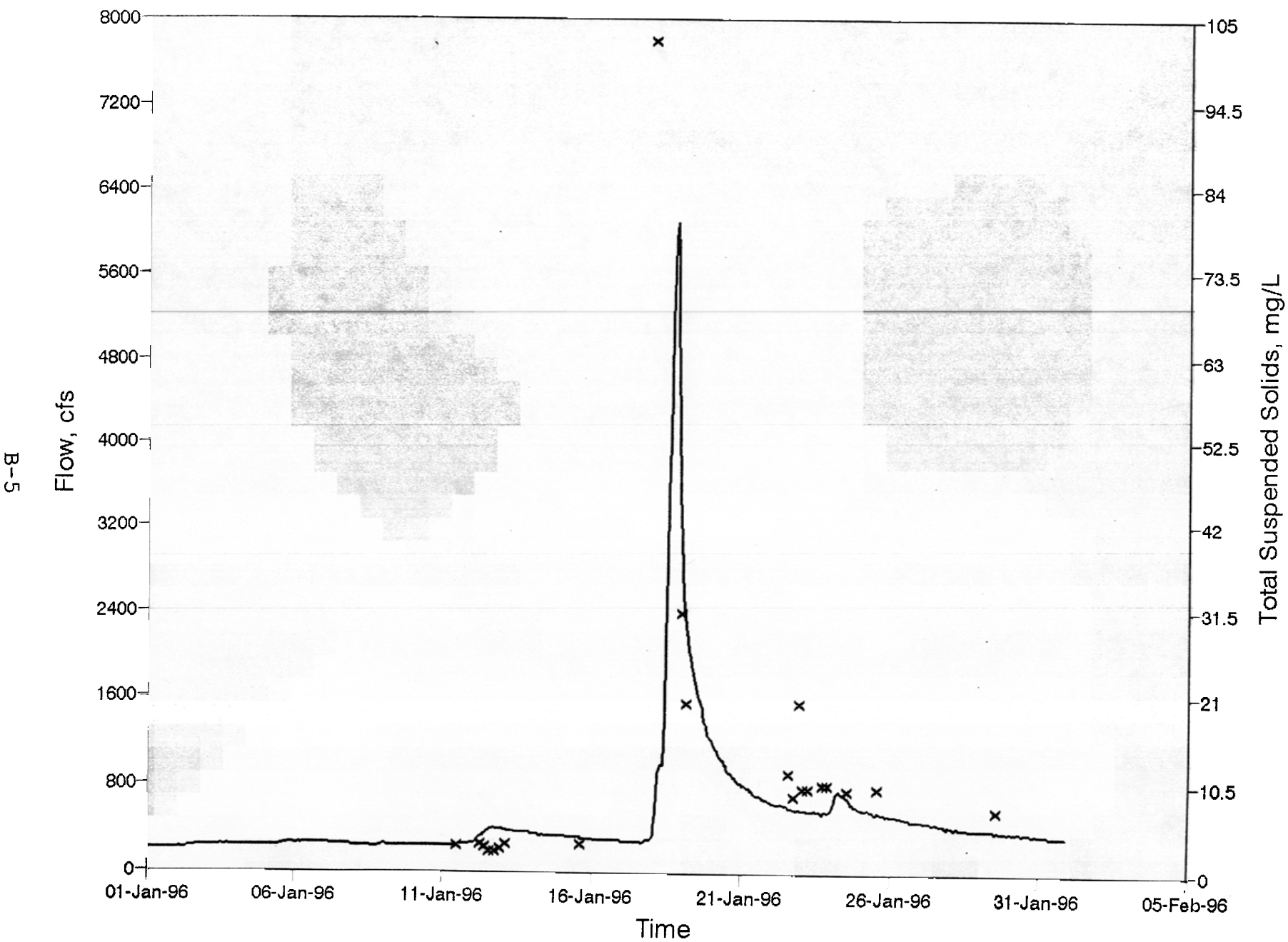
December 1995



B-4

# Illinois River at Arkansas Highway 59

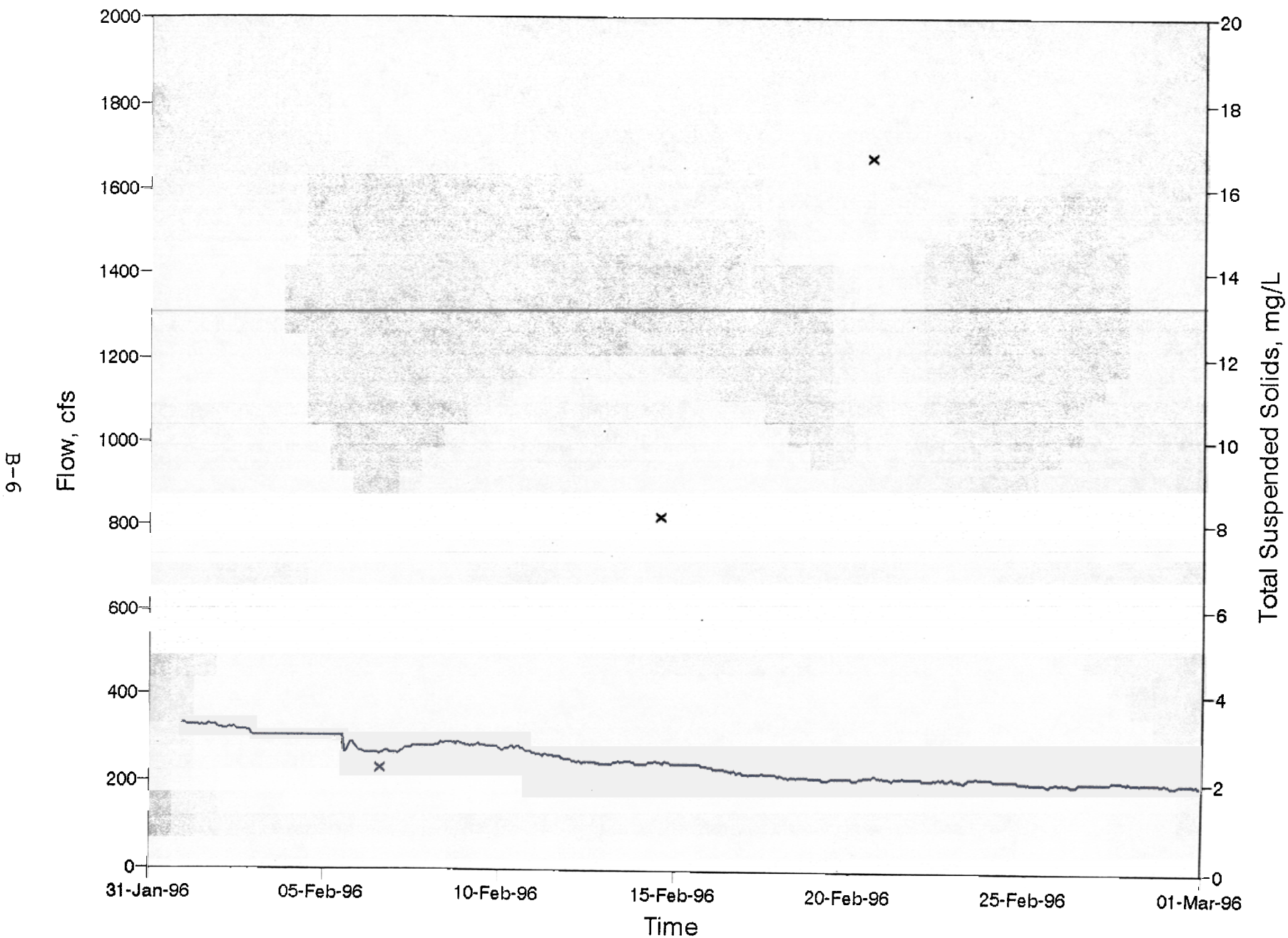
January 1996





# Illinois River at Arkansas Highway 59

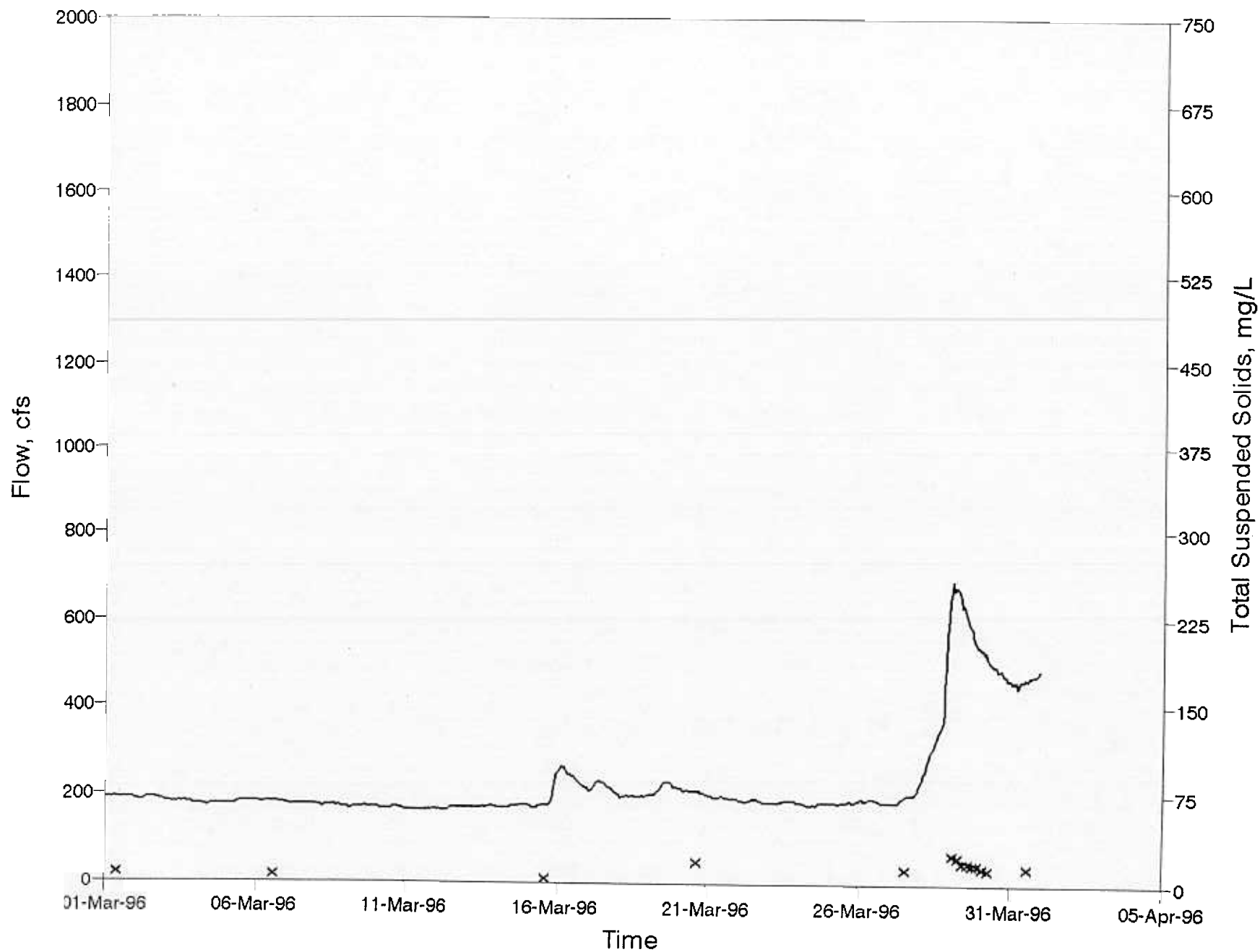
February 1996



# Illinois River at Arkansas Highway 59

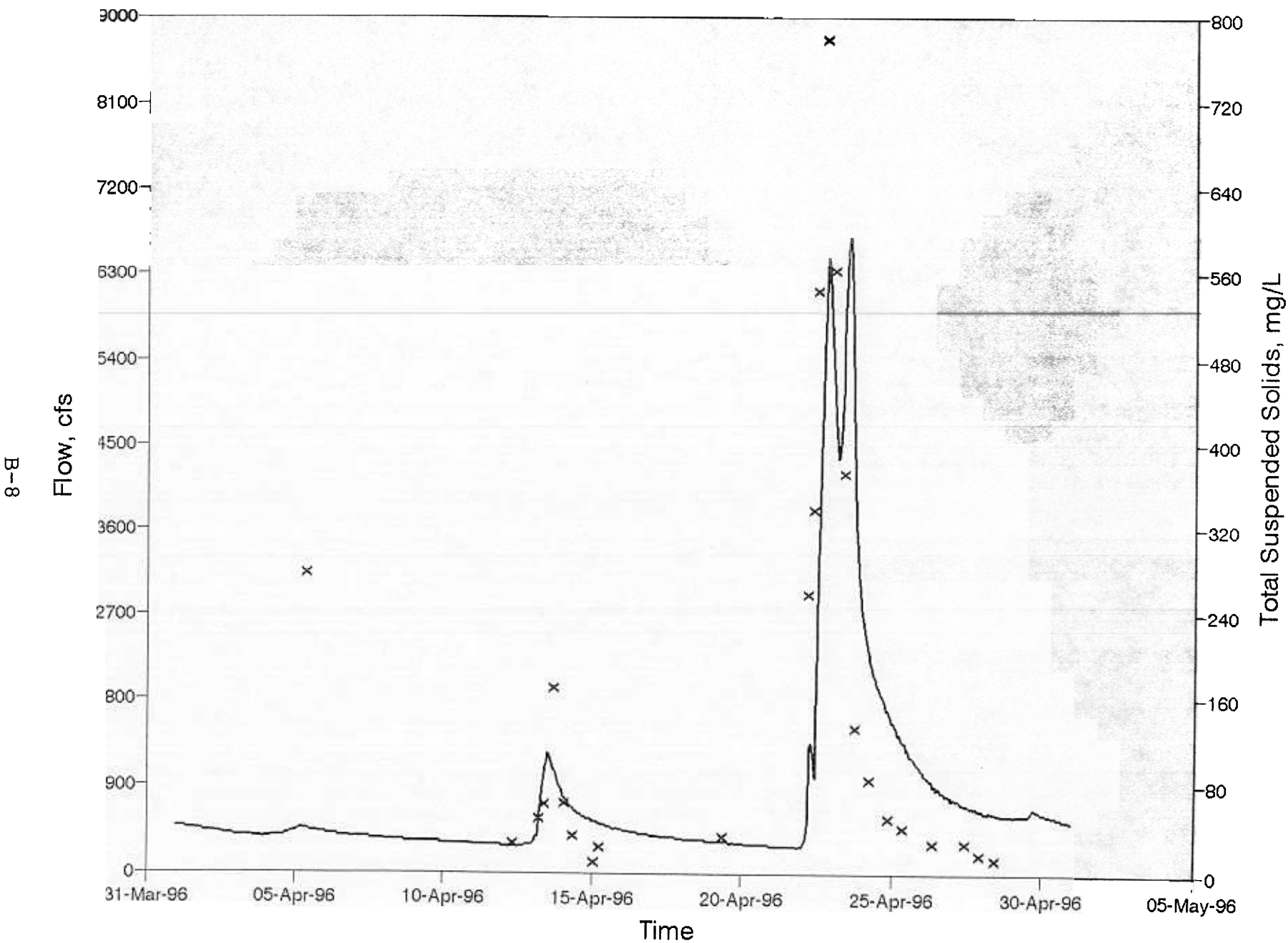
March 1996

B-7



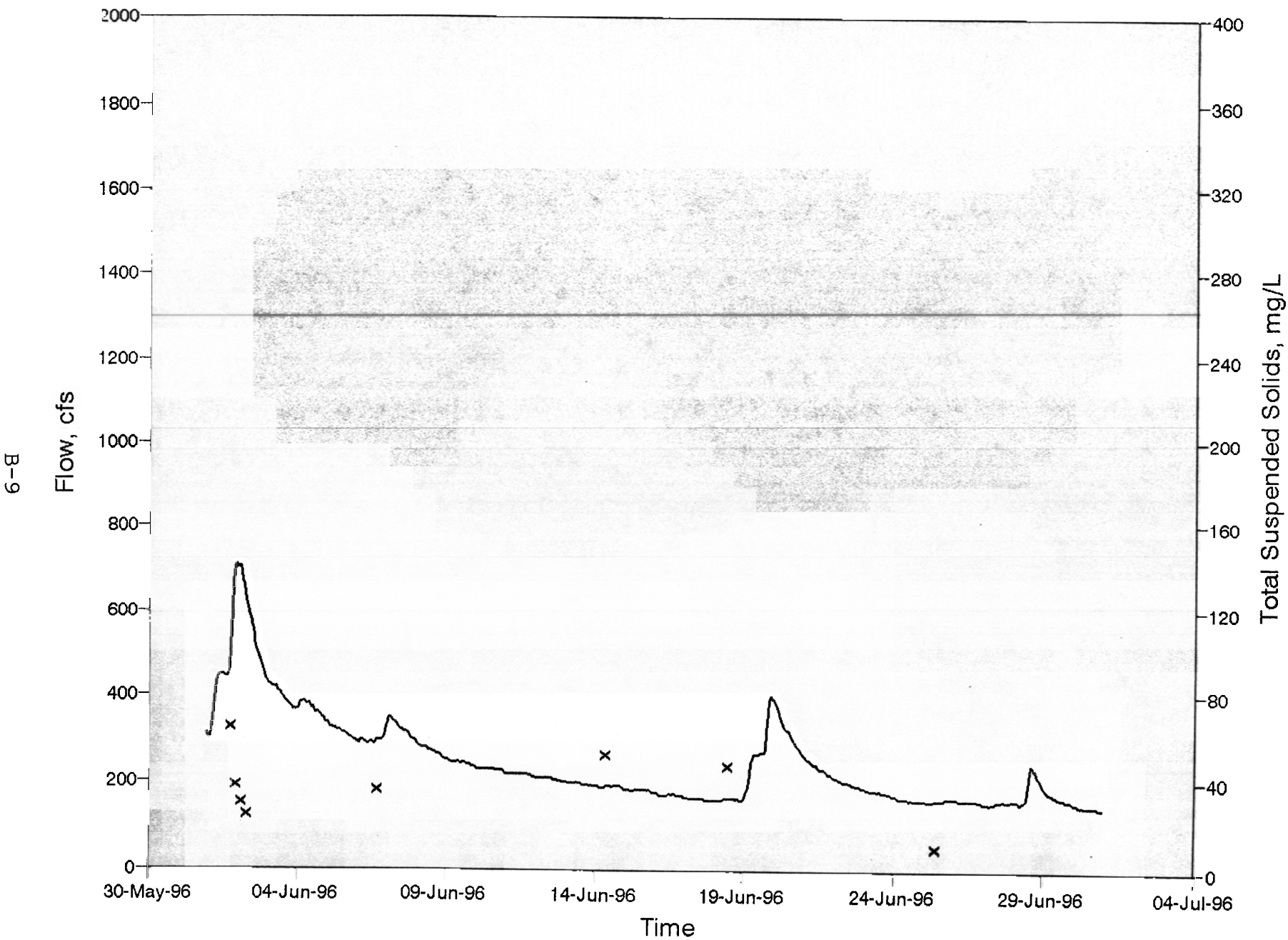
# Illinois River at Arkansas Highway 59

April 1996



# Illinois River at Arkansas Highway 59

June 1996

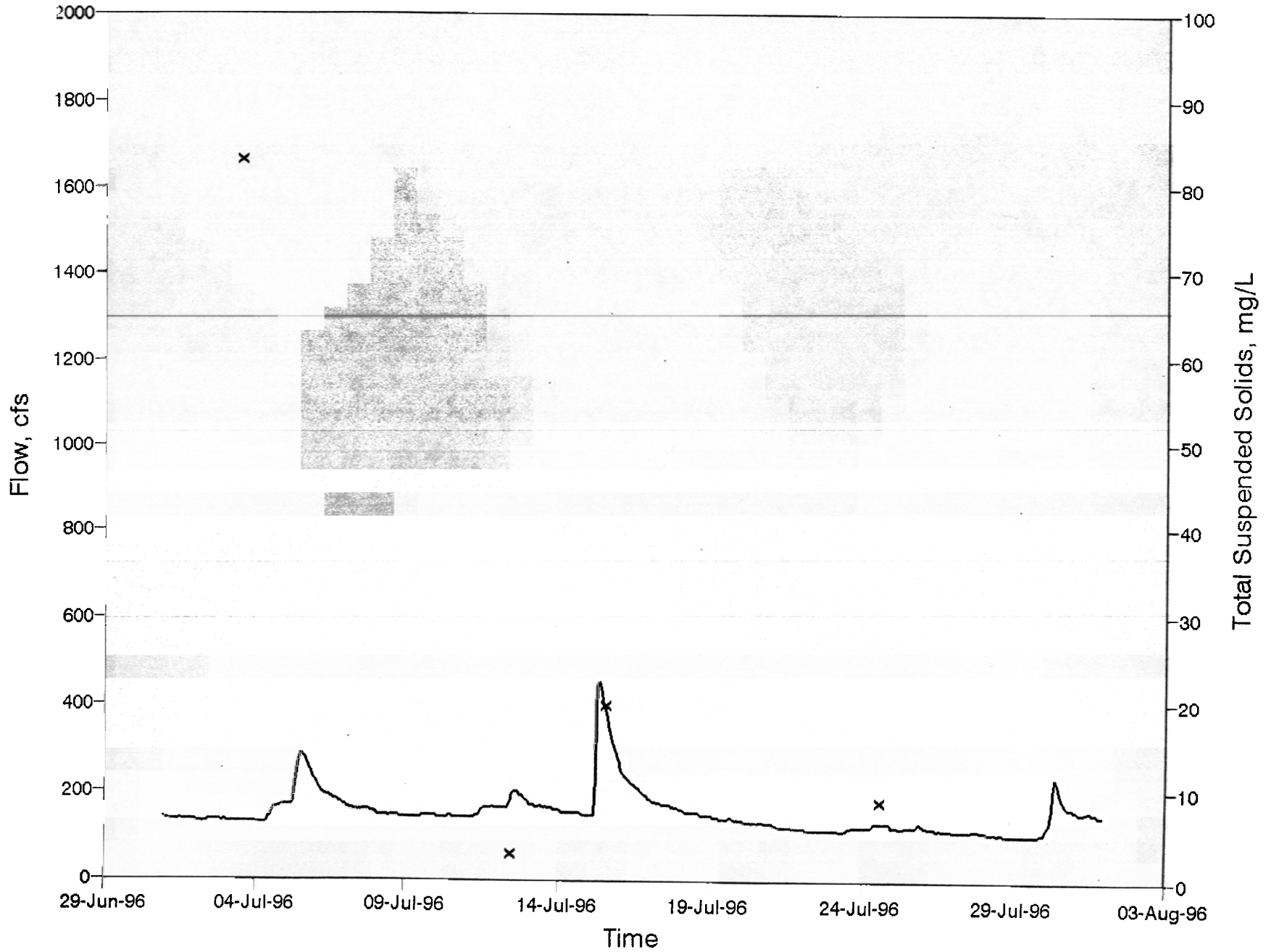




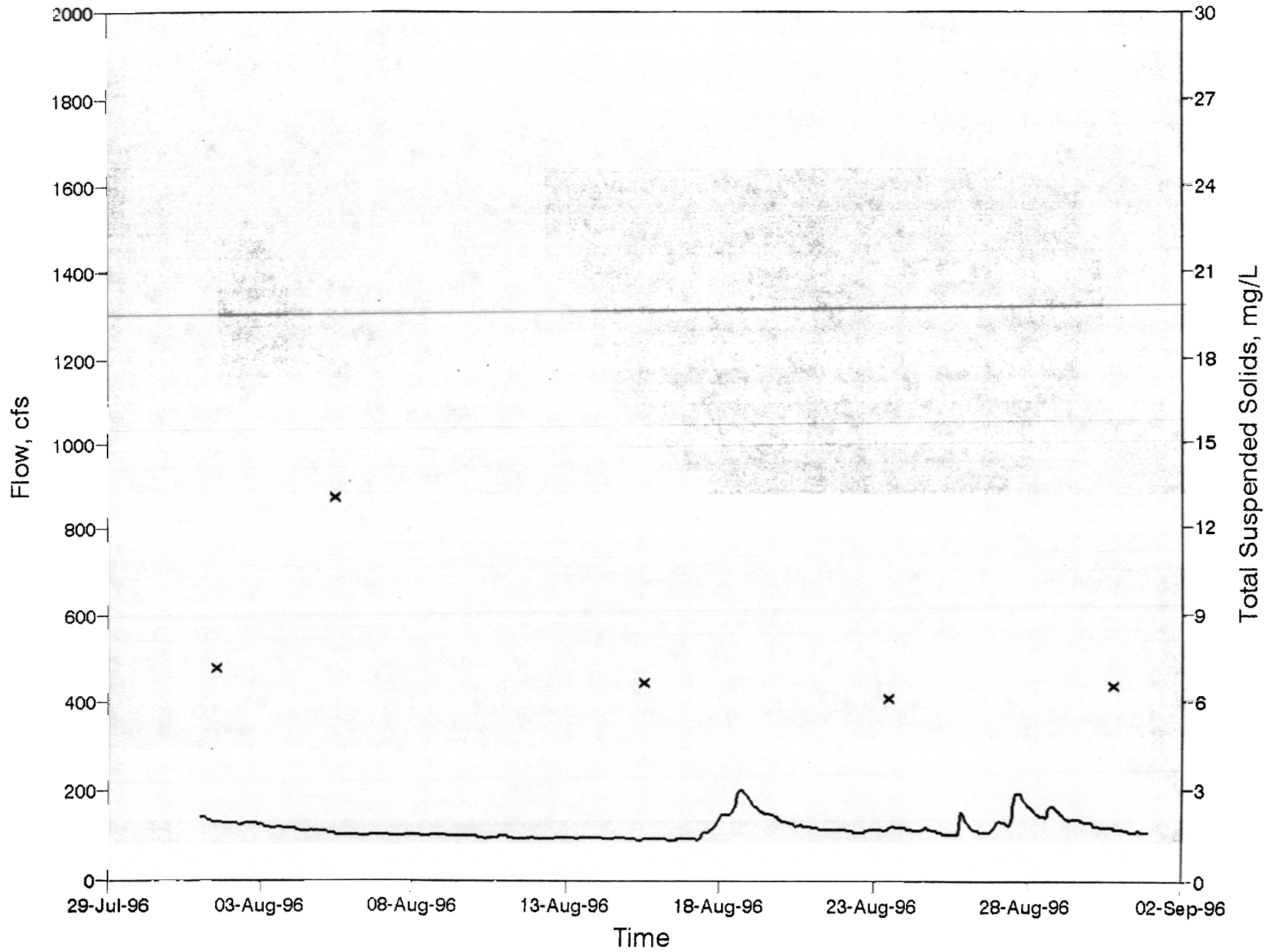
# Illinois River at Arkansas Highway 59

July 1996

B-10



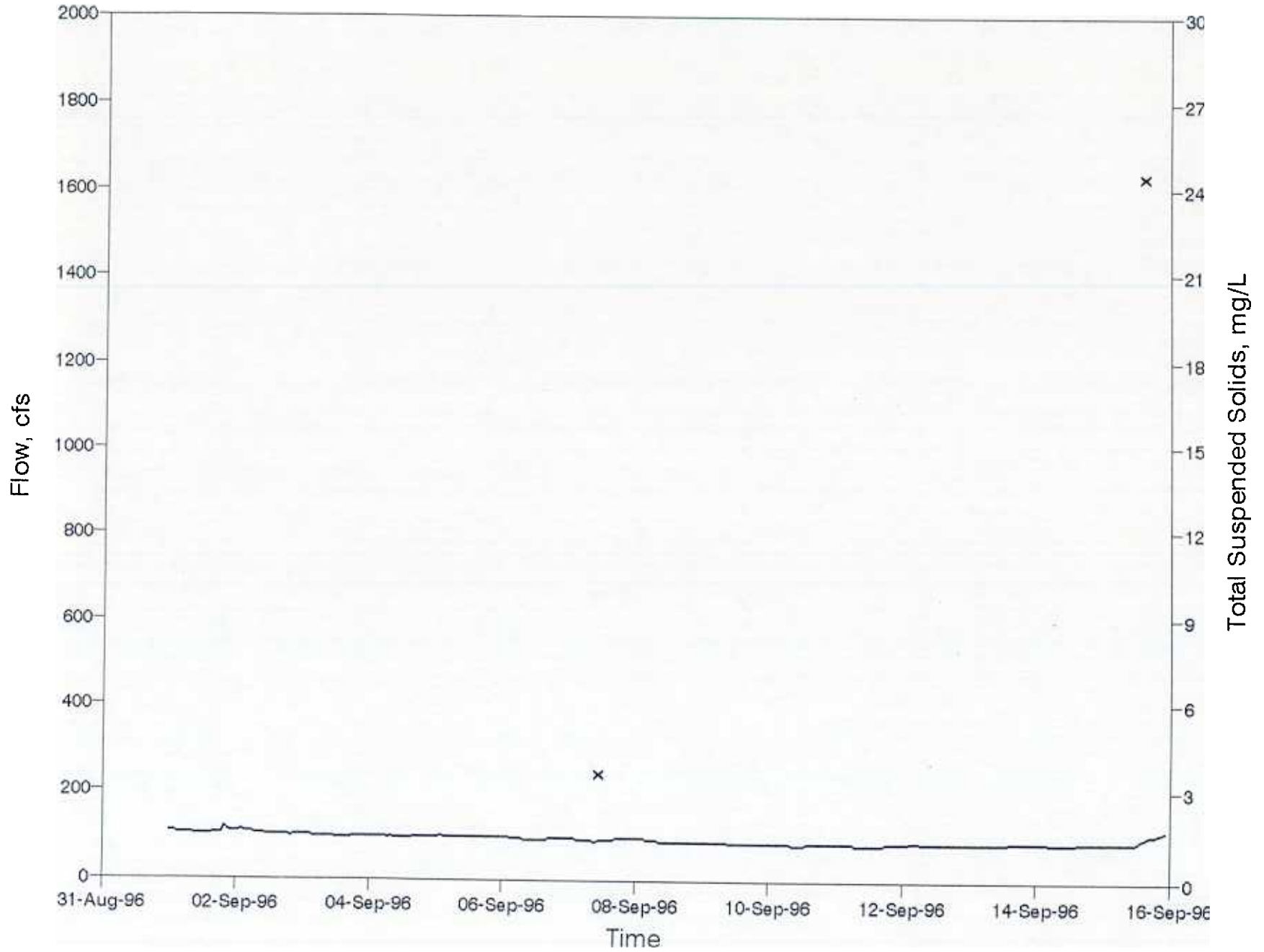
Illinois River at Arkansas Highway 59  
August 1996



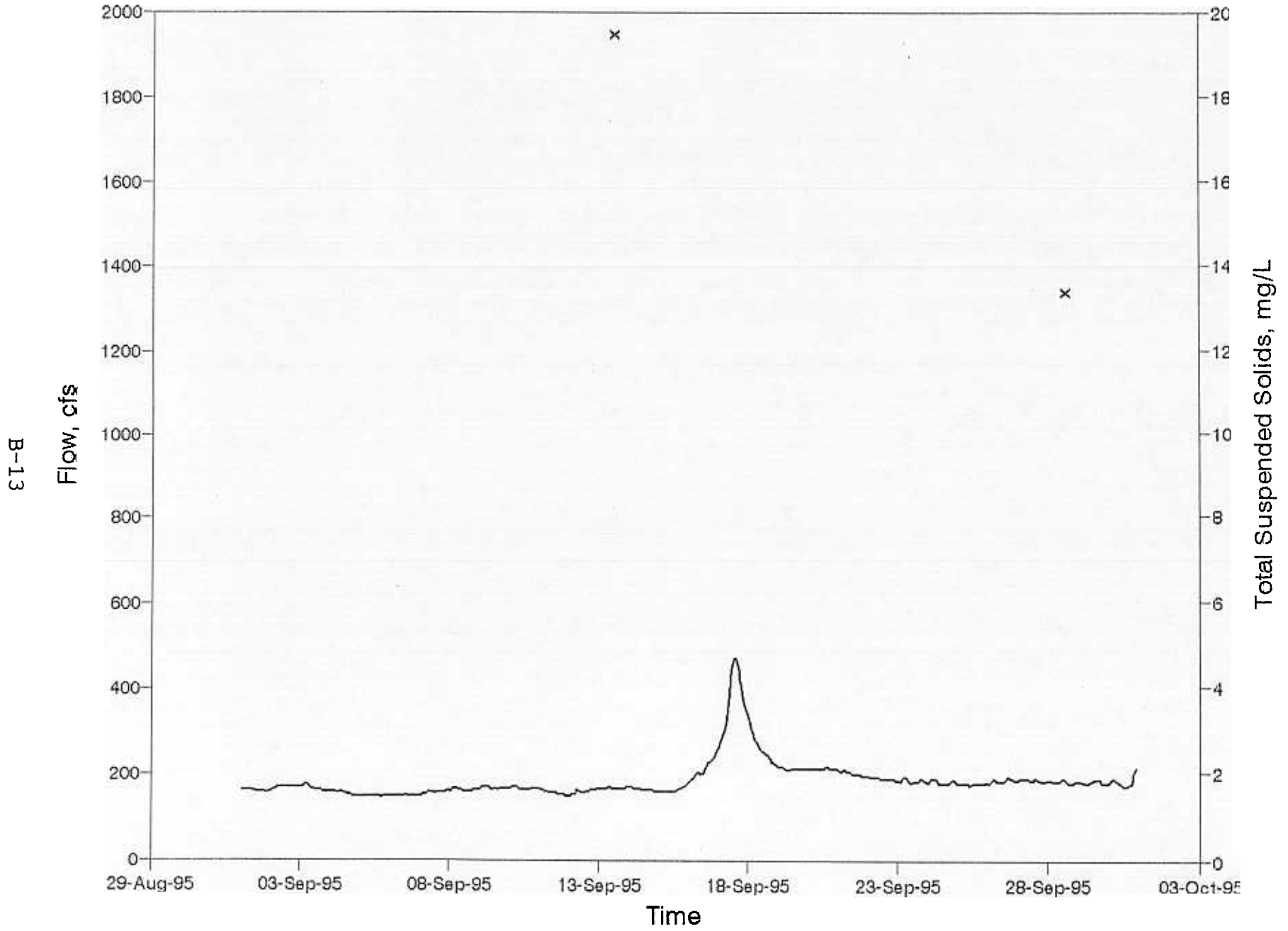
B-11

# Illinois River at Arkansas Highway 59 September 1996

B-12

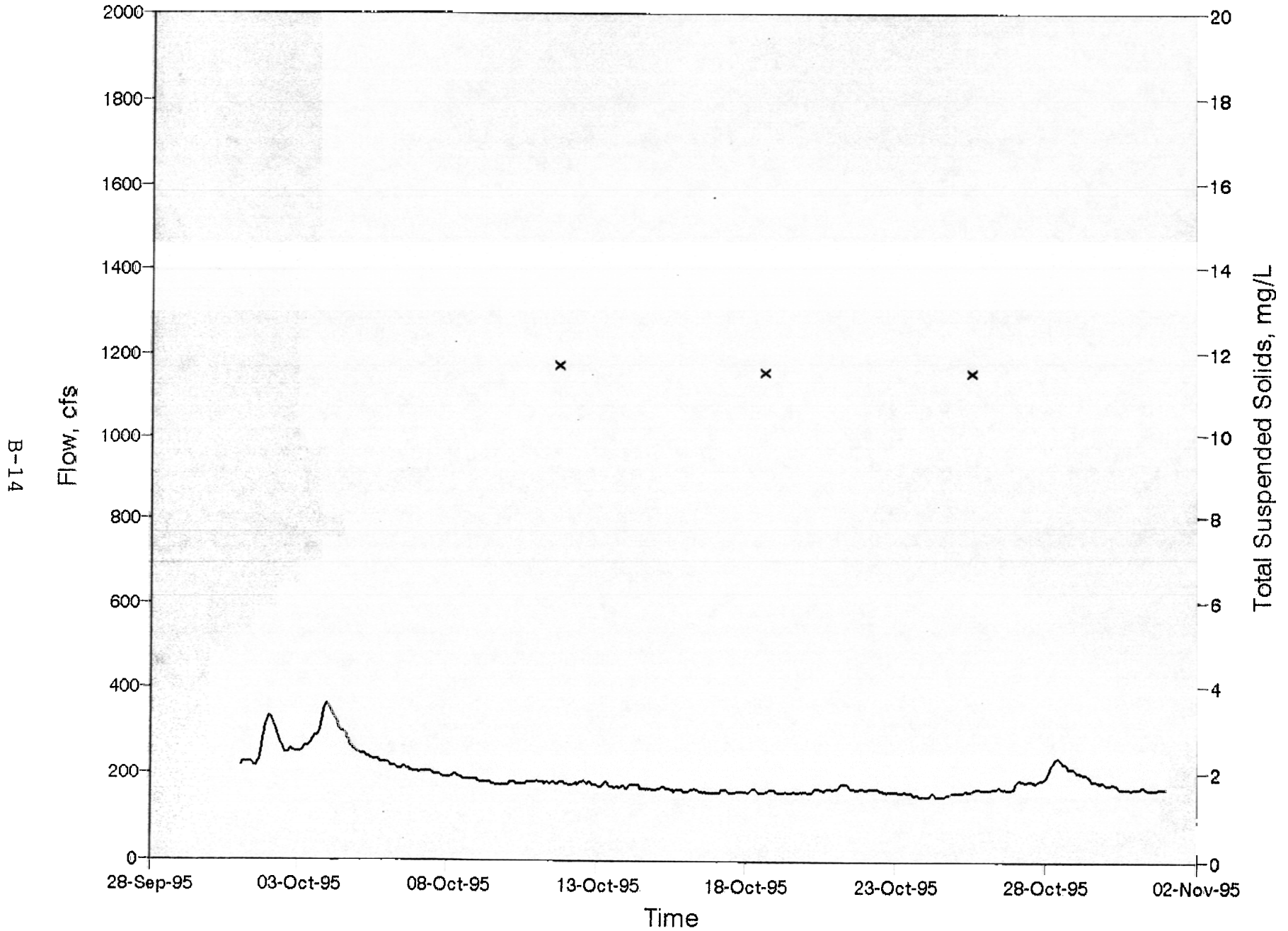


# Illinois River at Oklahoma Highway 59 September 1995

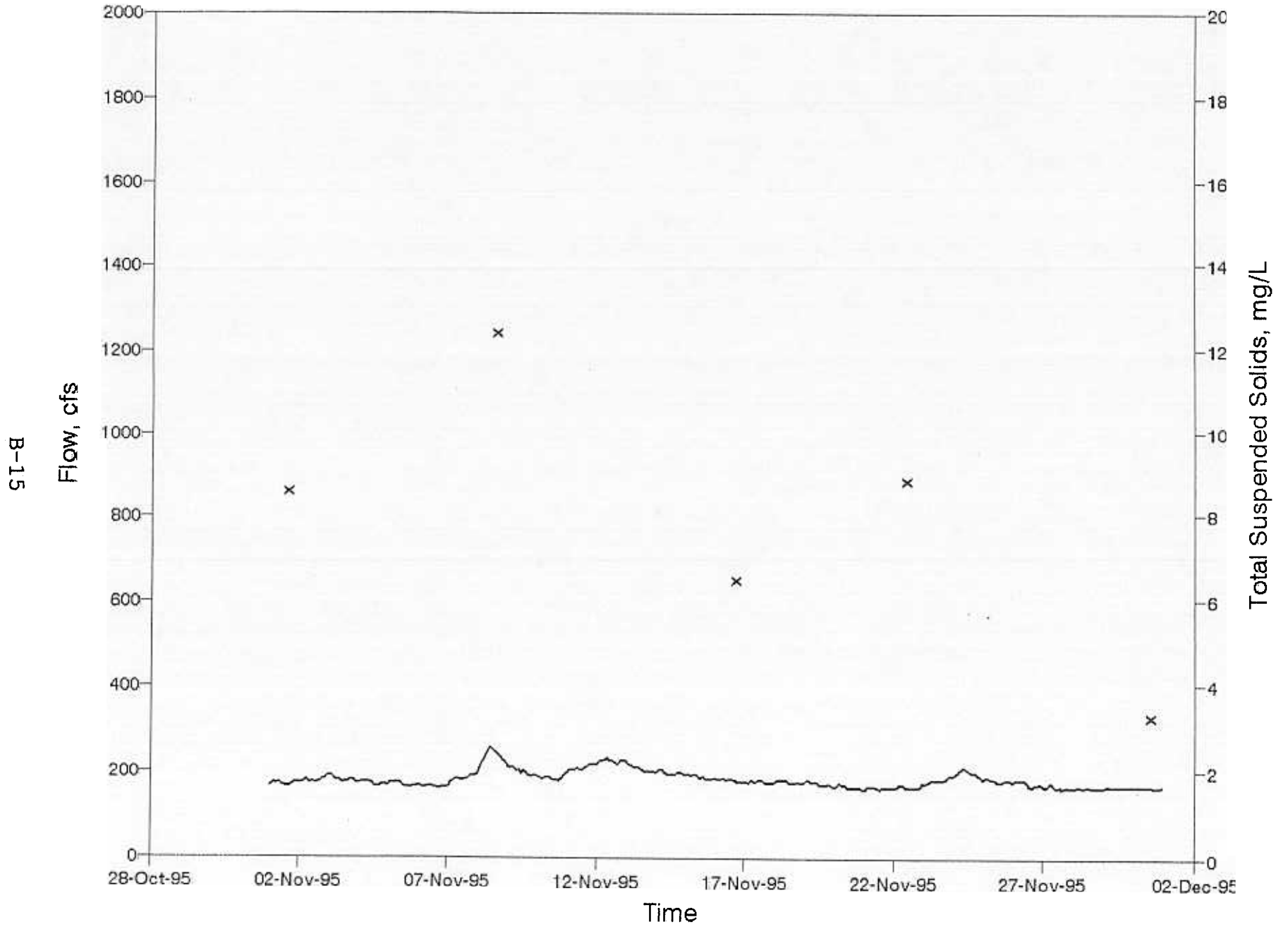


# Illinois River at Oklahoma Highway 59

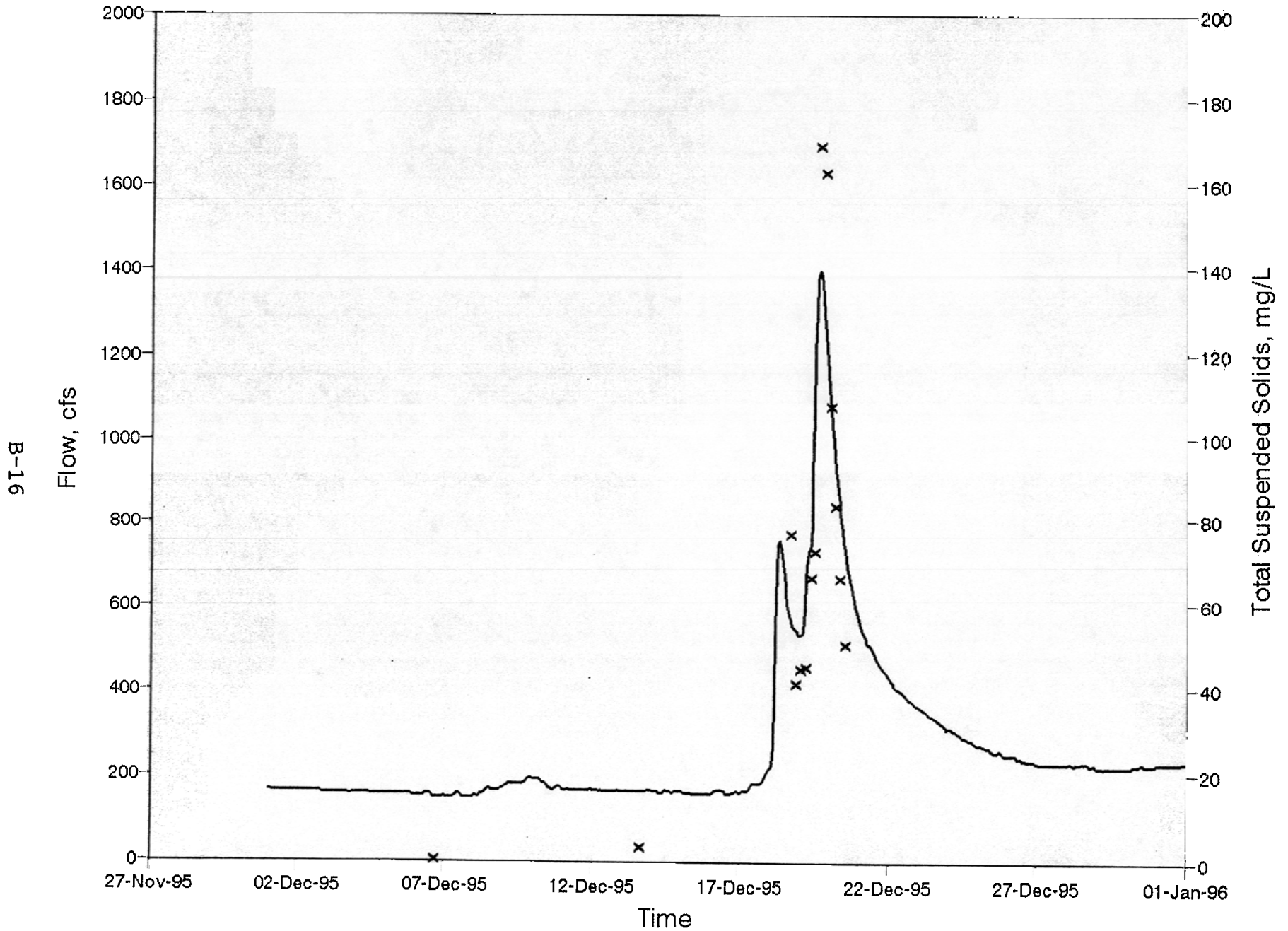
October 1995



# Illinois River at Oklahoma Highway 59 November 1995

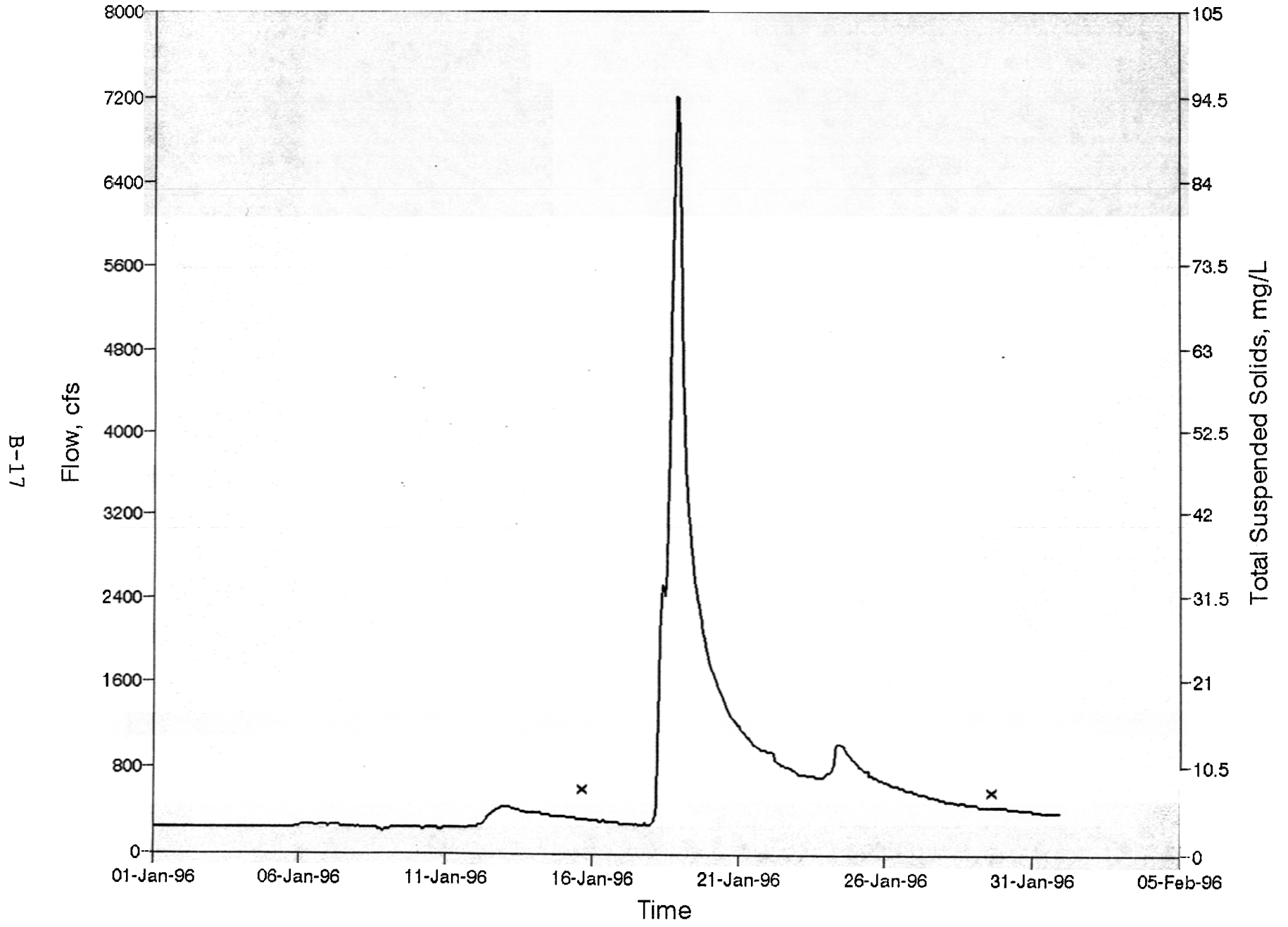


# Illinois River at Oklahoma Highway 59 December 1995



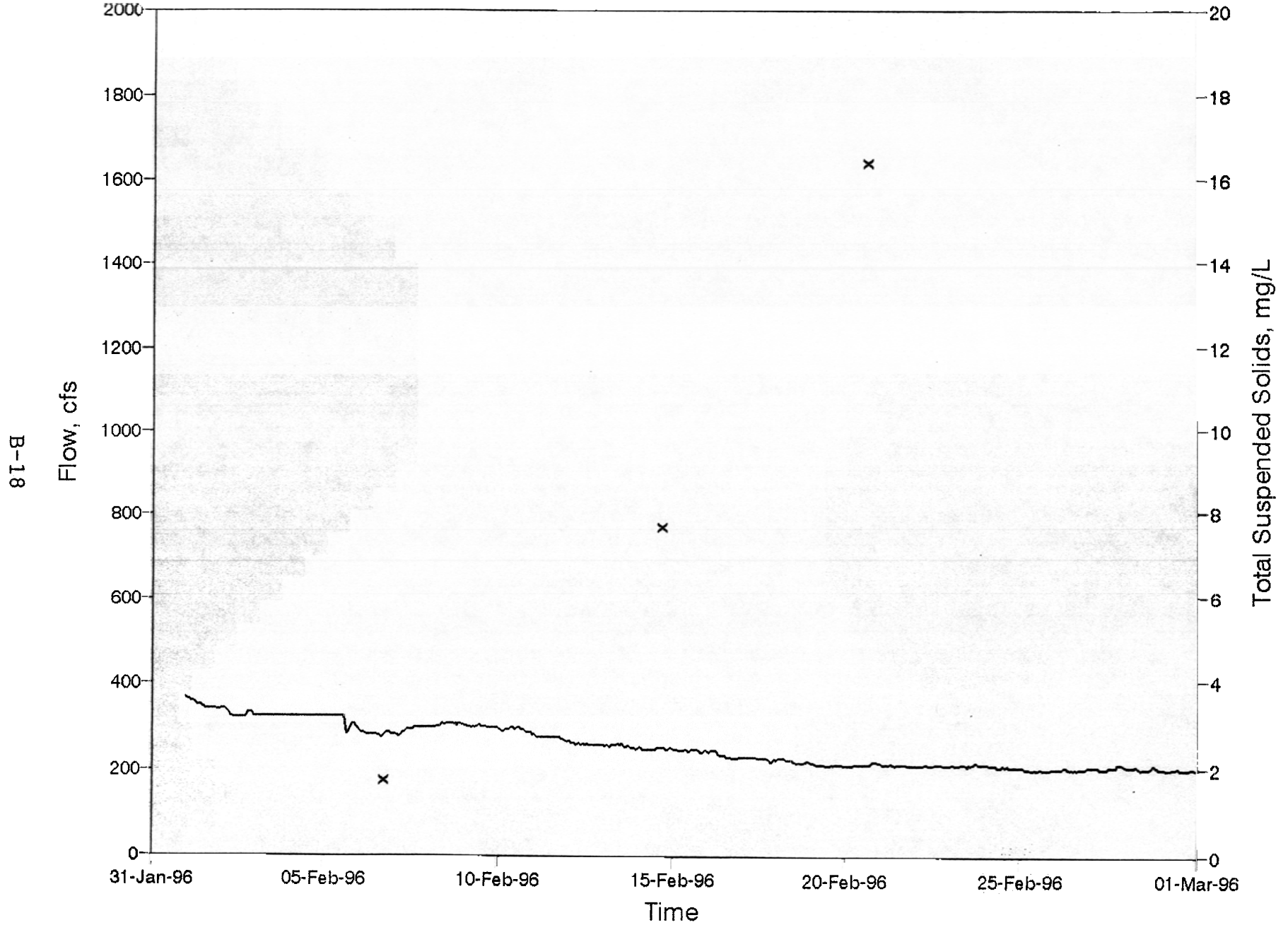


# Illinois River at Oklahoma Highway 59 January 1996

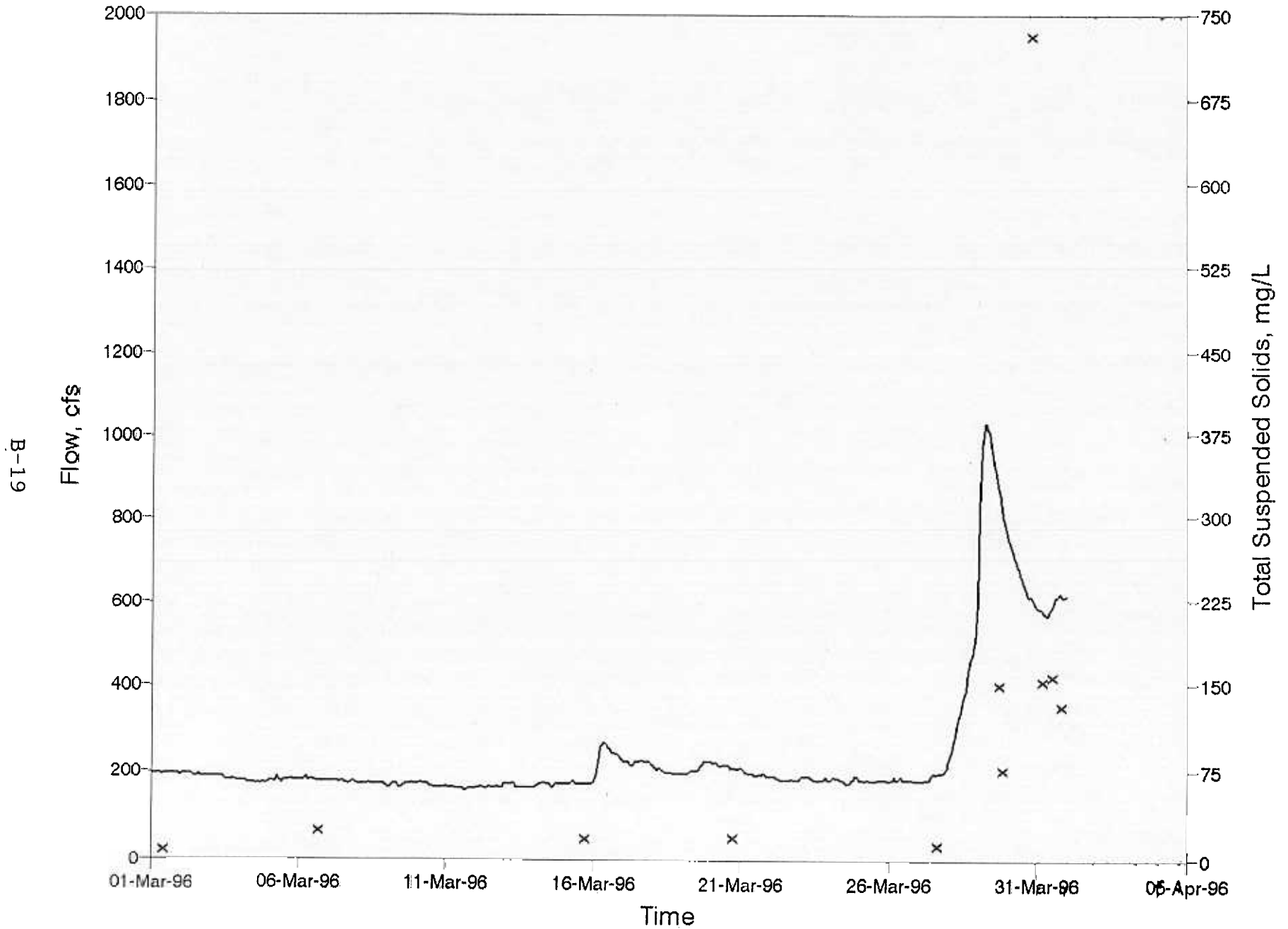




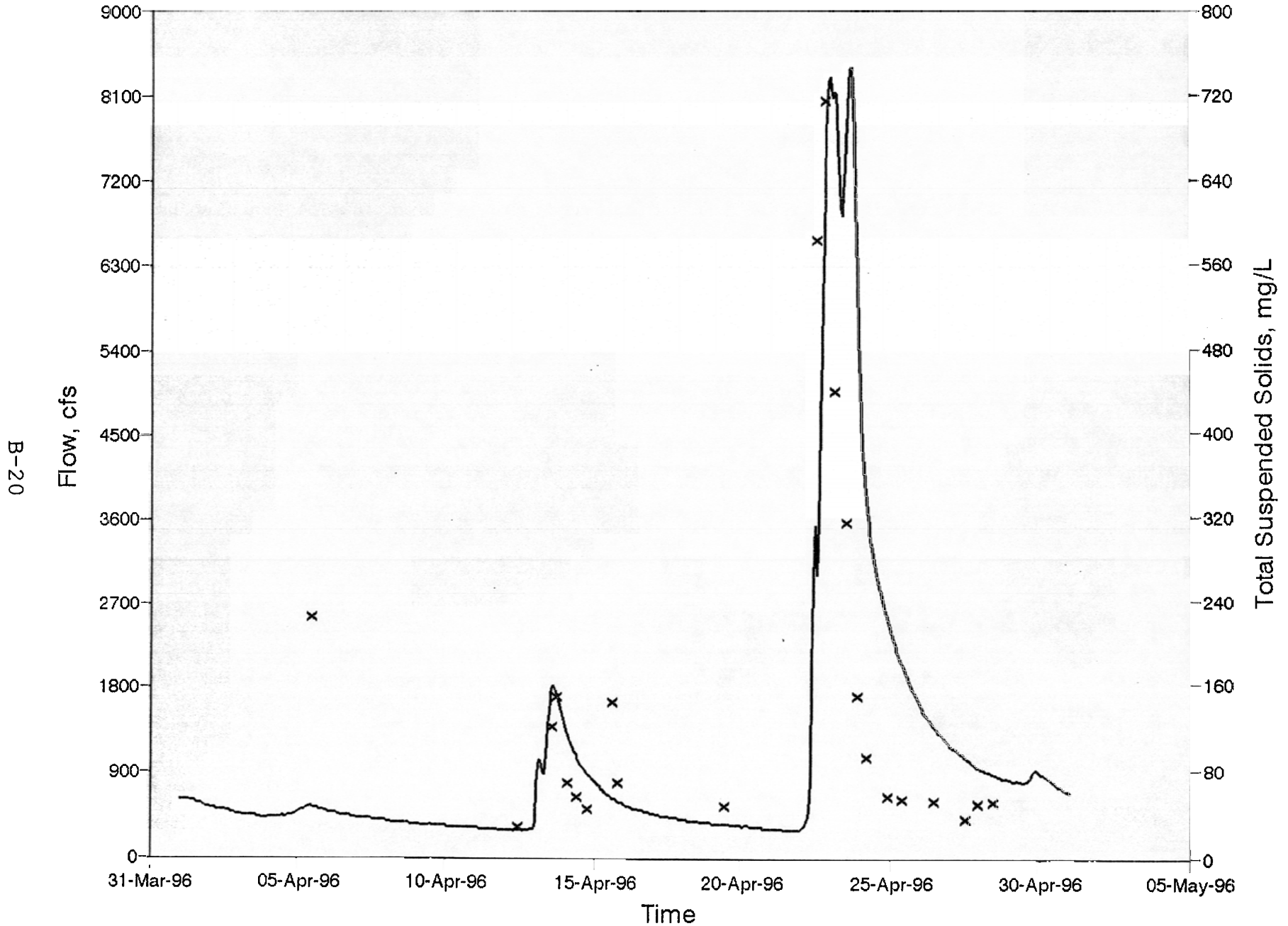
# Illinois River at Oklahoma Highway 59 February 1996



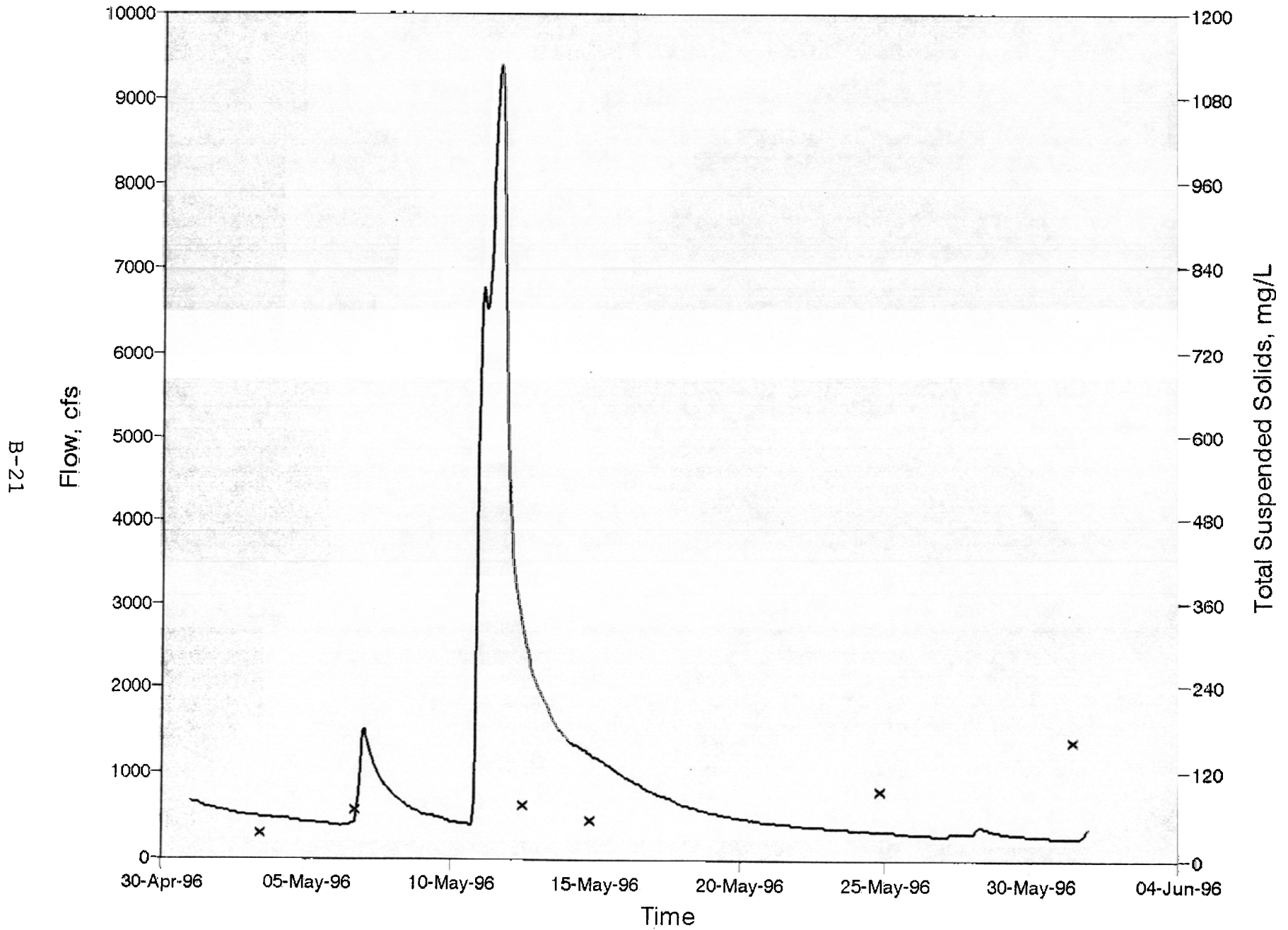
# Illinois River at Oklahoma Highway 59 March 1996



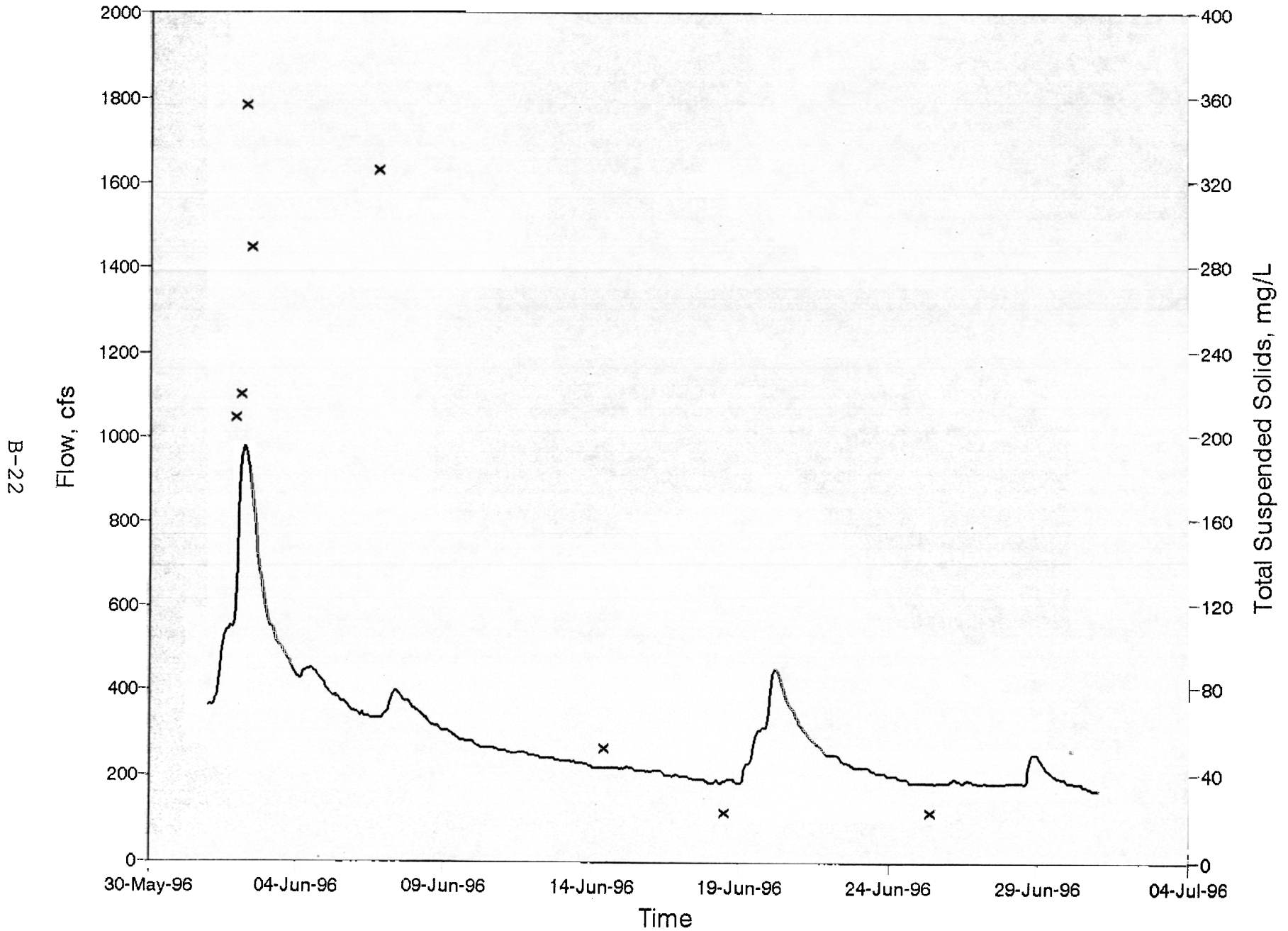
# Illinois River at Oklahoma Highway 59 April 1996



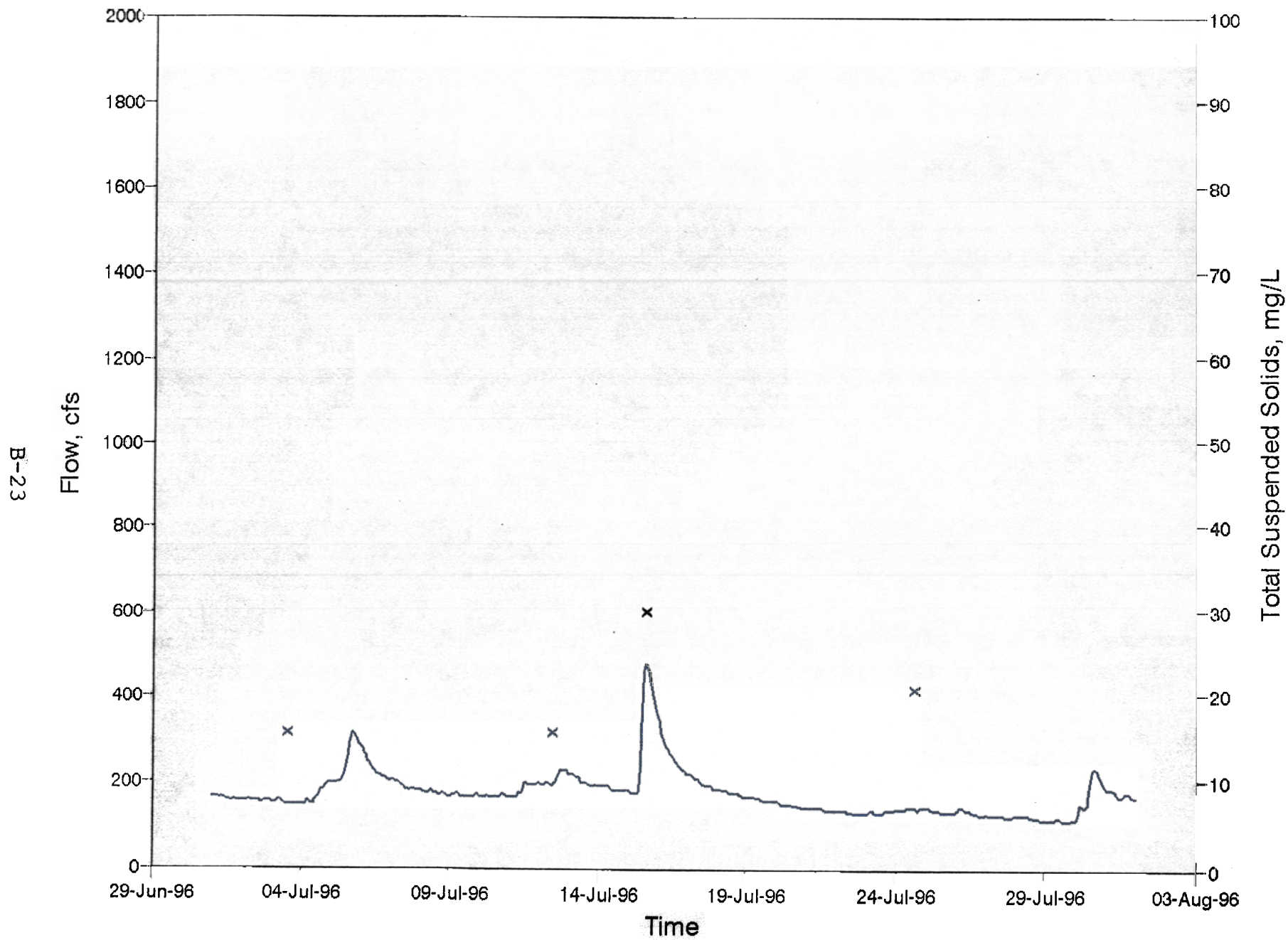
# Illinois River at Oklahoma Highway 59 May 1996



# Illinois River at Oklahoma Highway 59 June 1996

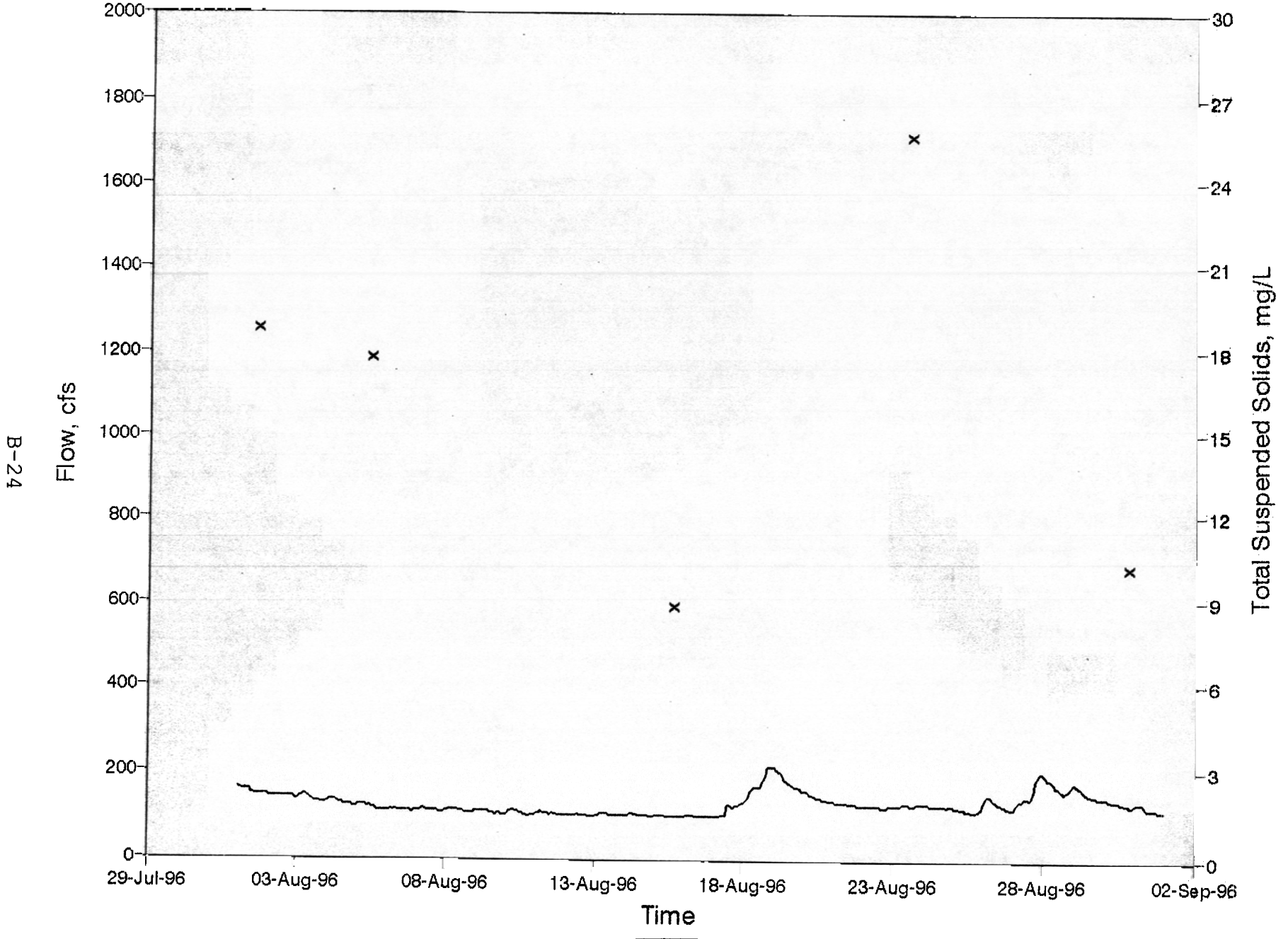


# Illinois River at Oklahoma Highway 59 July 1996

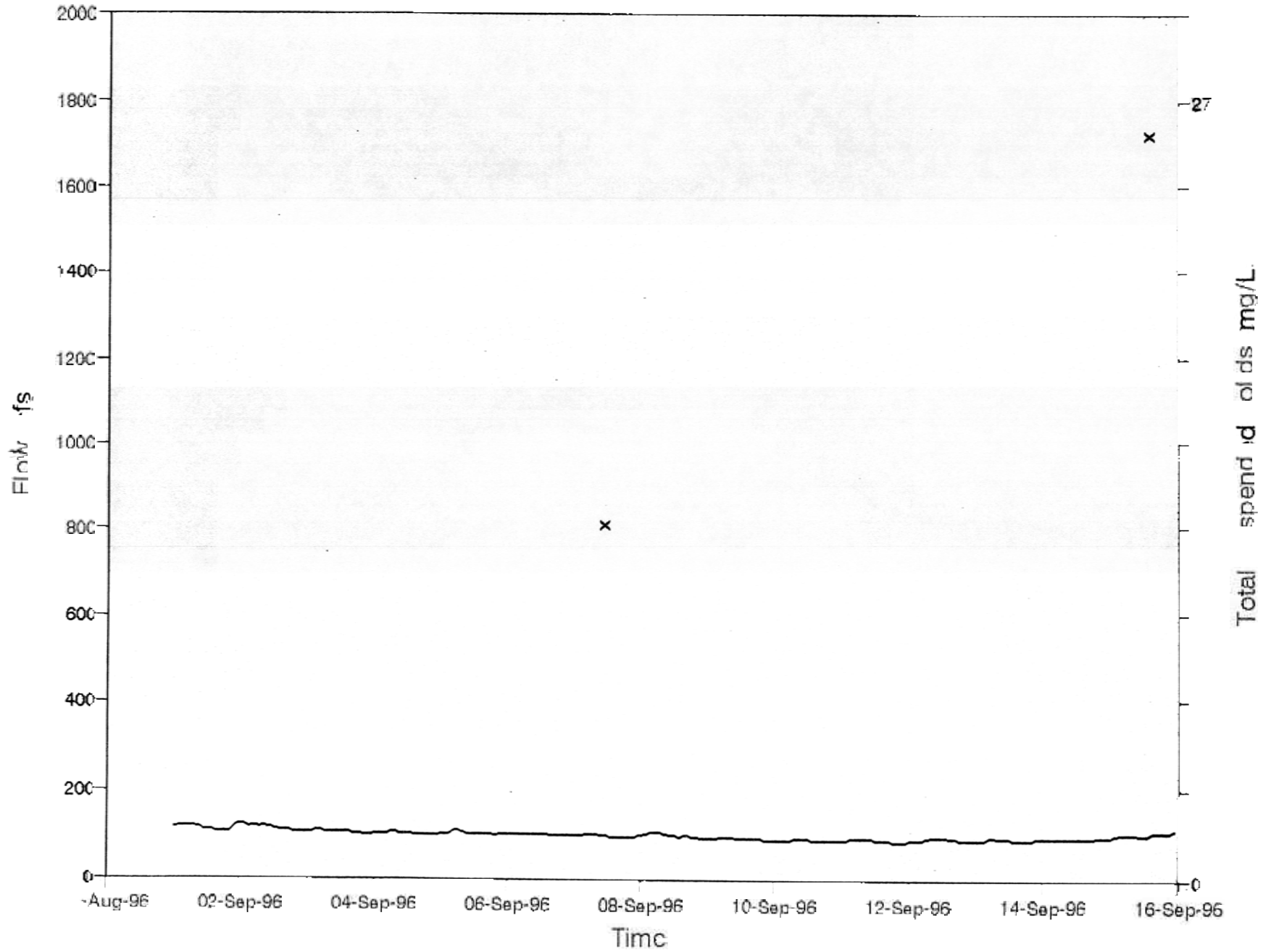




# Illinois River at Oklahoma Highway 59 August 1996

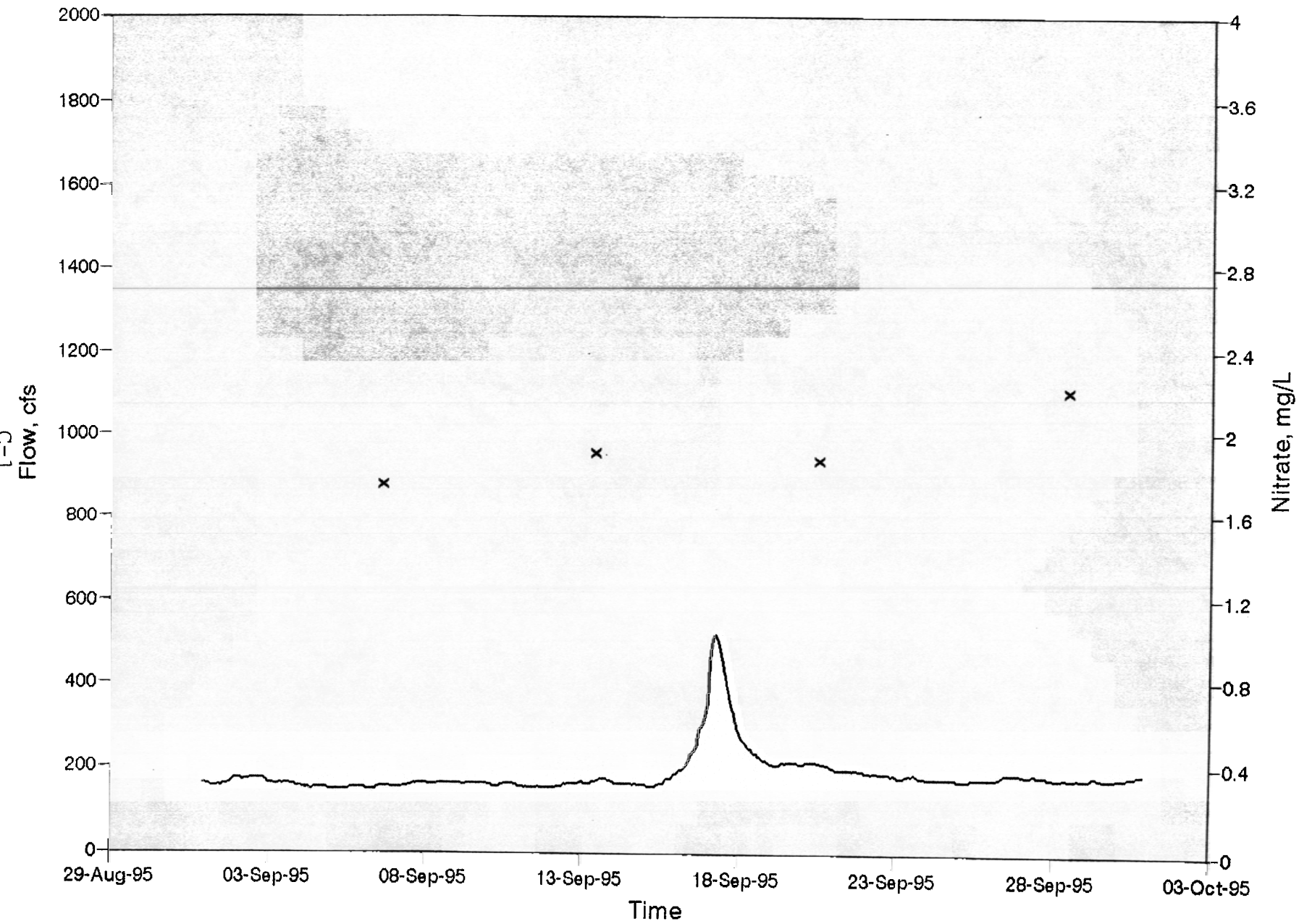


# Illinois River at Oklahoma Highway 59 September 1996

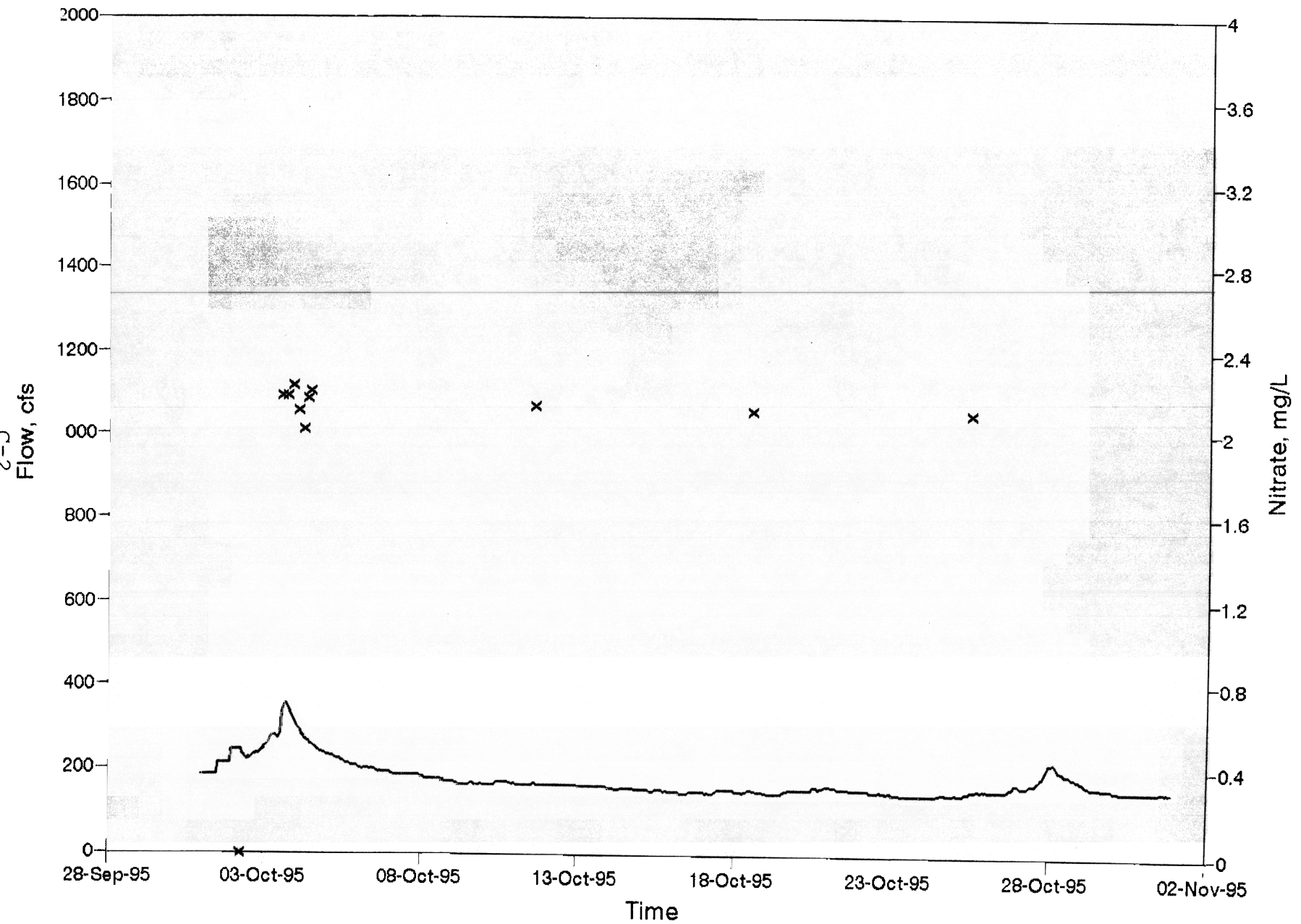




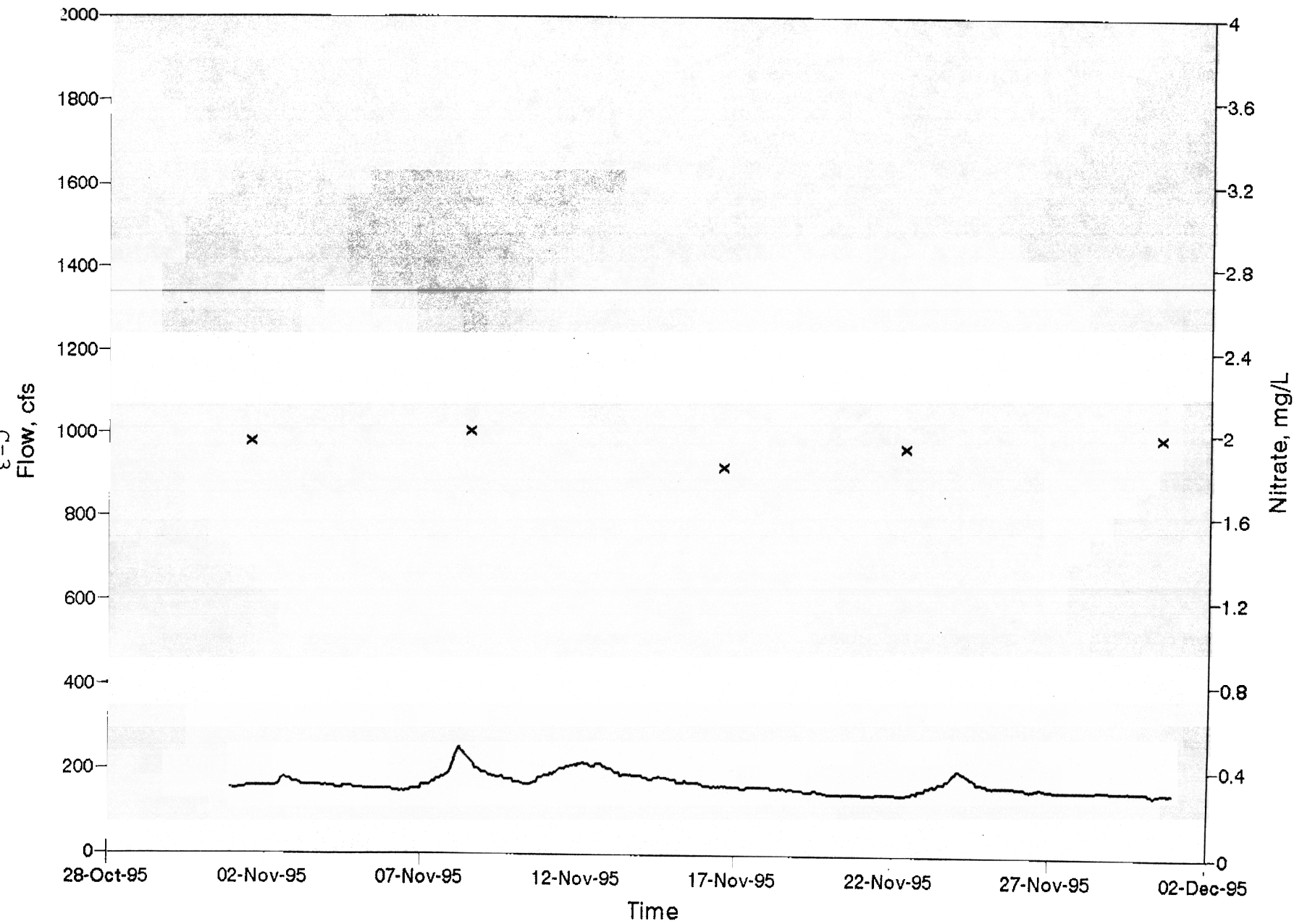
# Illinois River at Arkansas Highway 59 September 1995



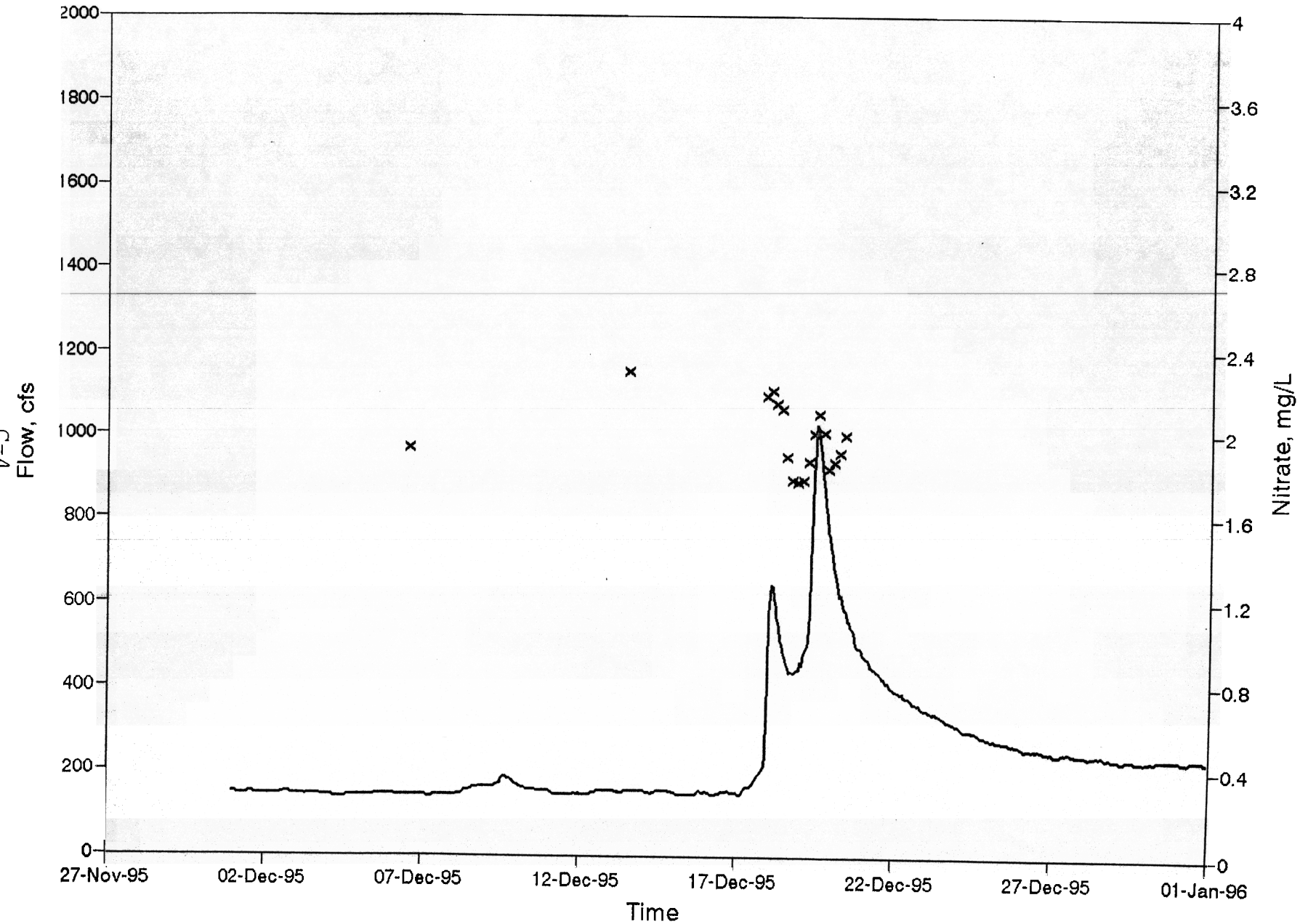
# Illinois River at Arkansas Highway 59 October 1995



# Illinois River at Arkansas Highway 59 November 1995

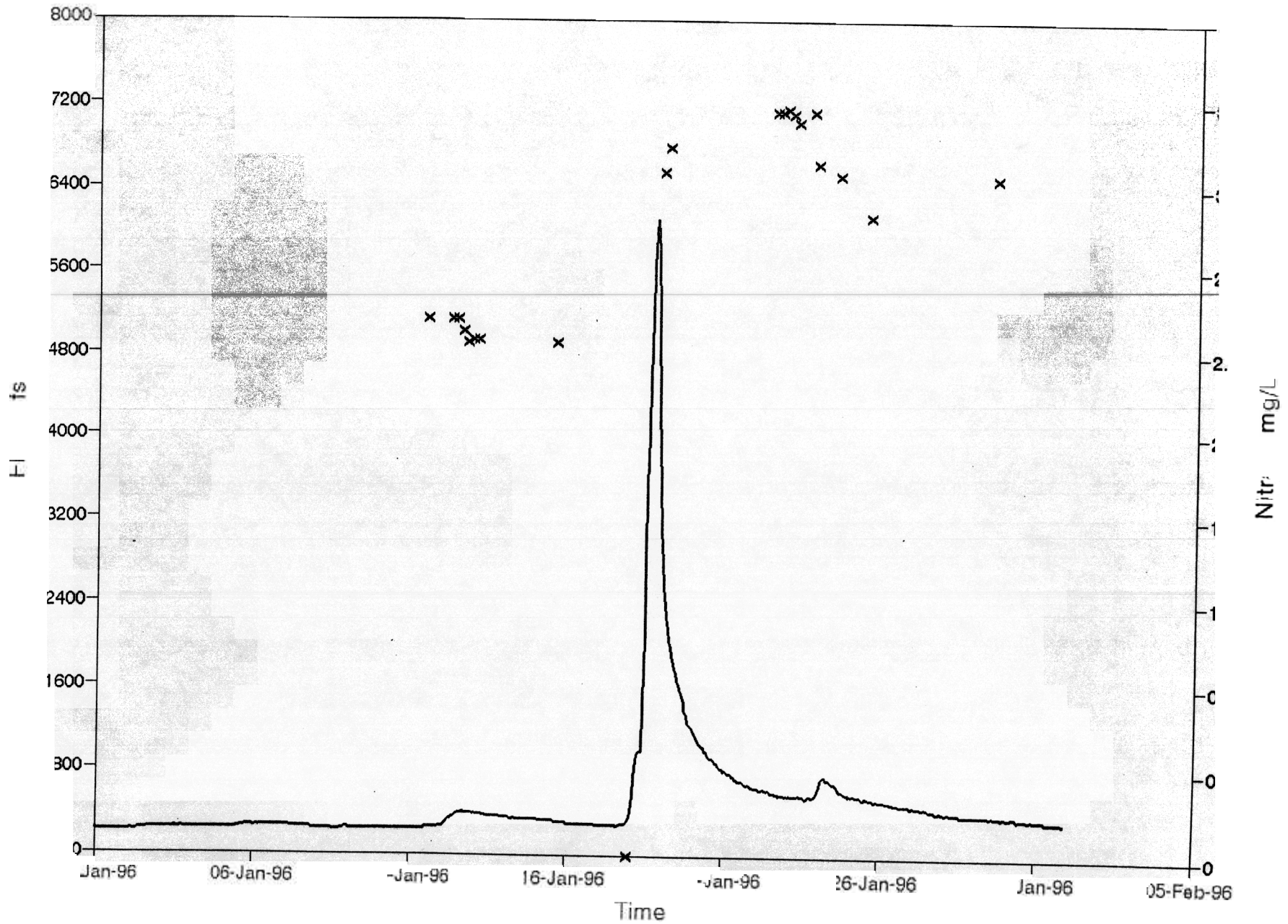


# Illinois River at Arkansas Highway 59 December 1995

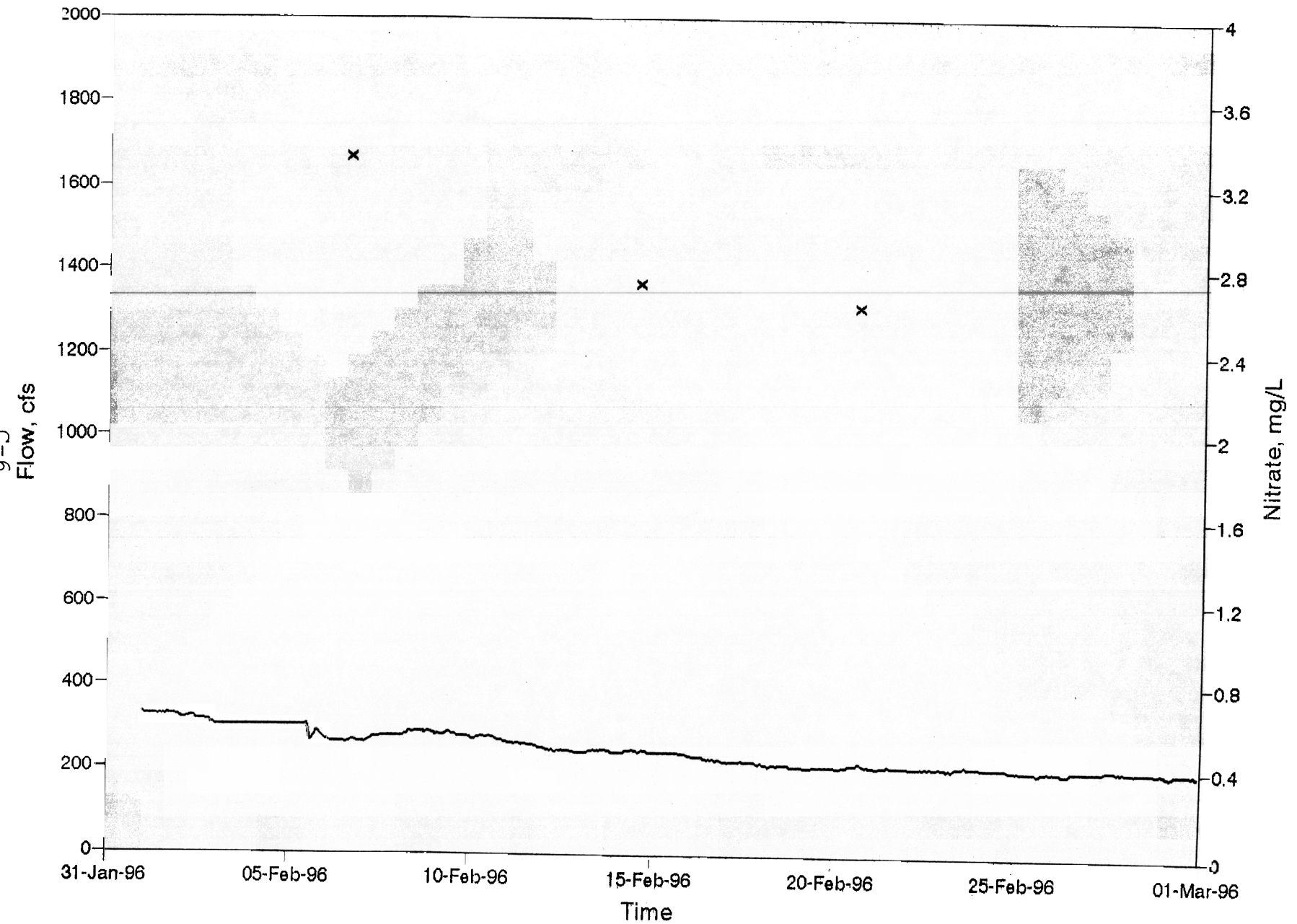




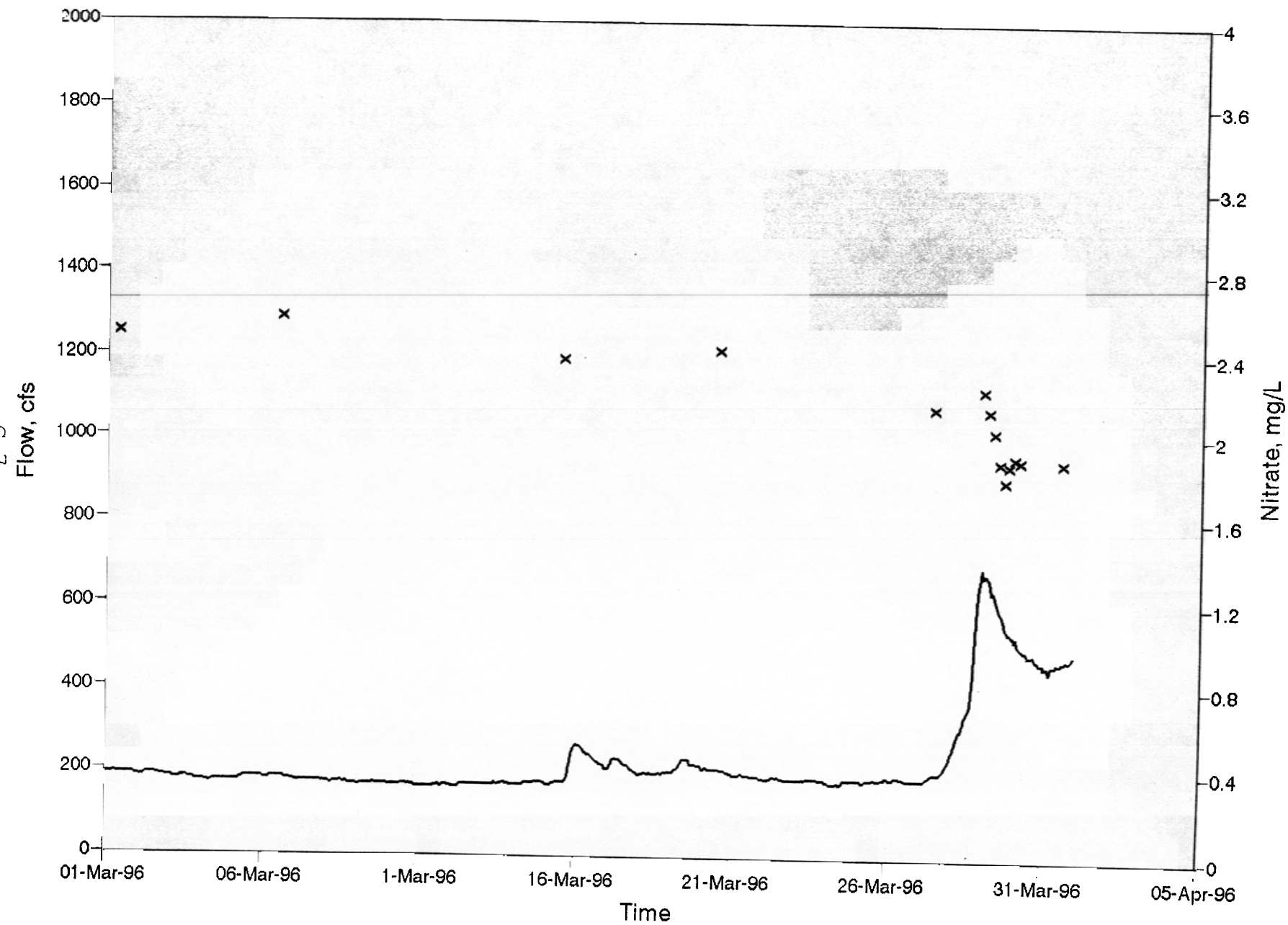
# Illinois River at Arkansas Highway 59 January 1996



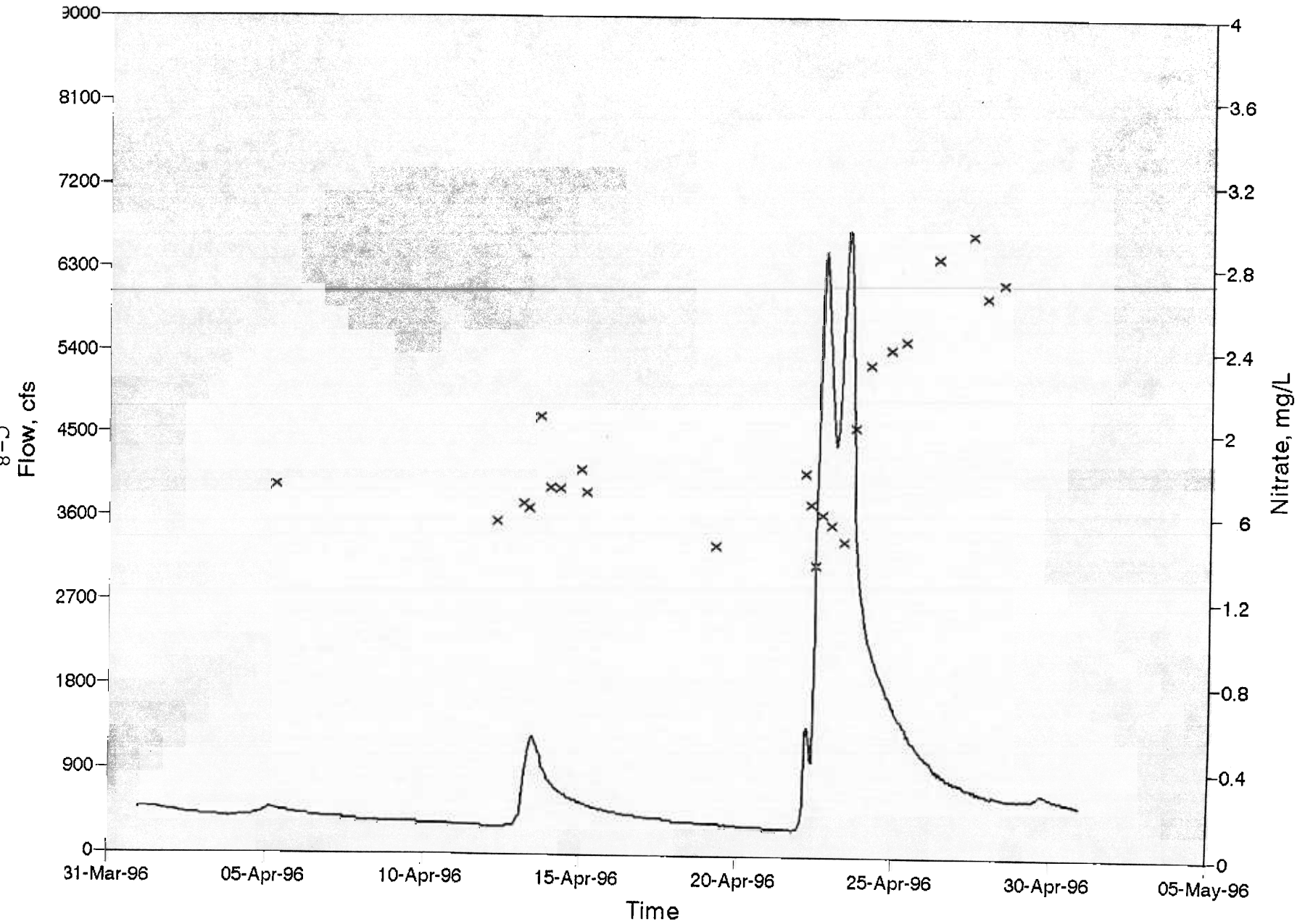
# Illinois River at Arkansas Highway 59 February 1996



# Illinois River at Arkansas Highway 59 March 1996

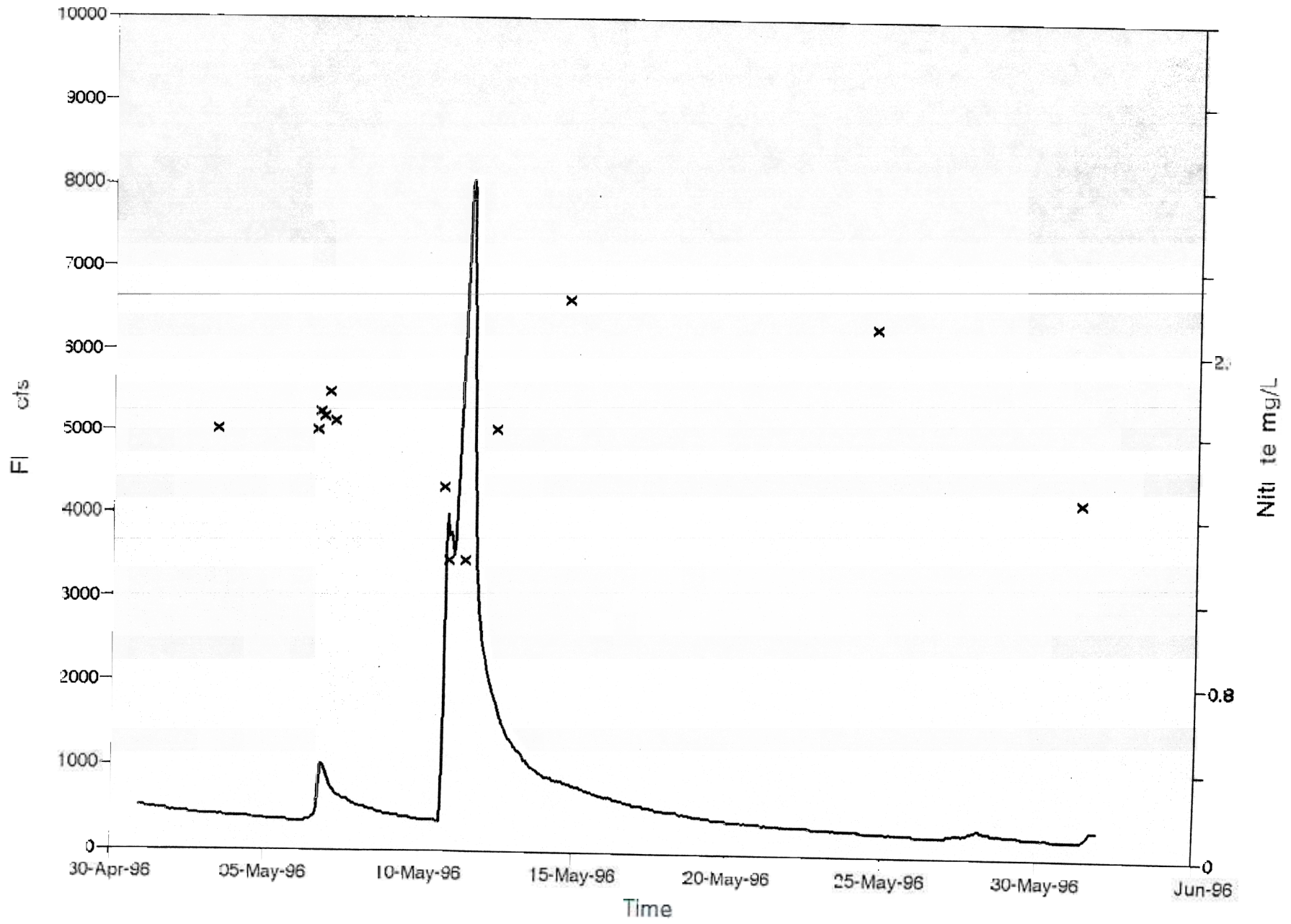


# Illinois River at Arkansas Highway 59 April 1996

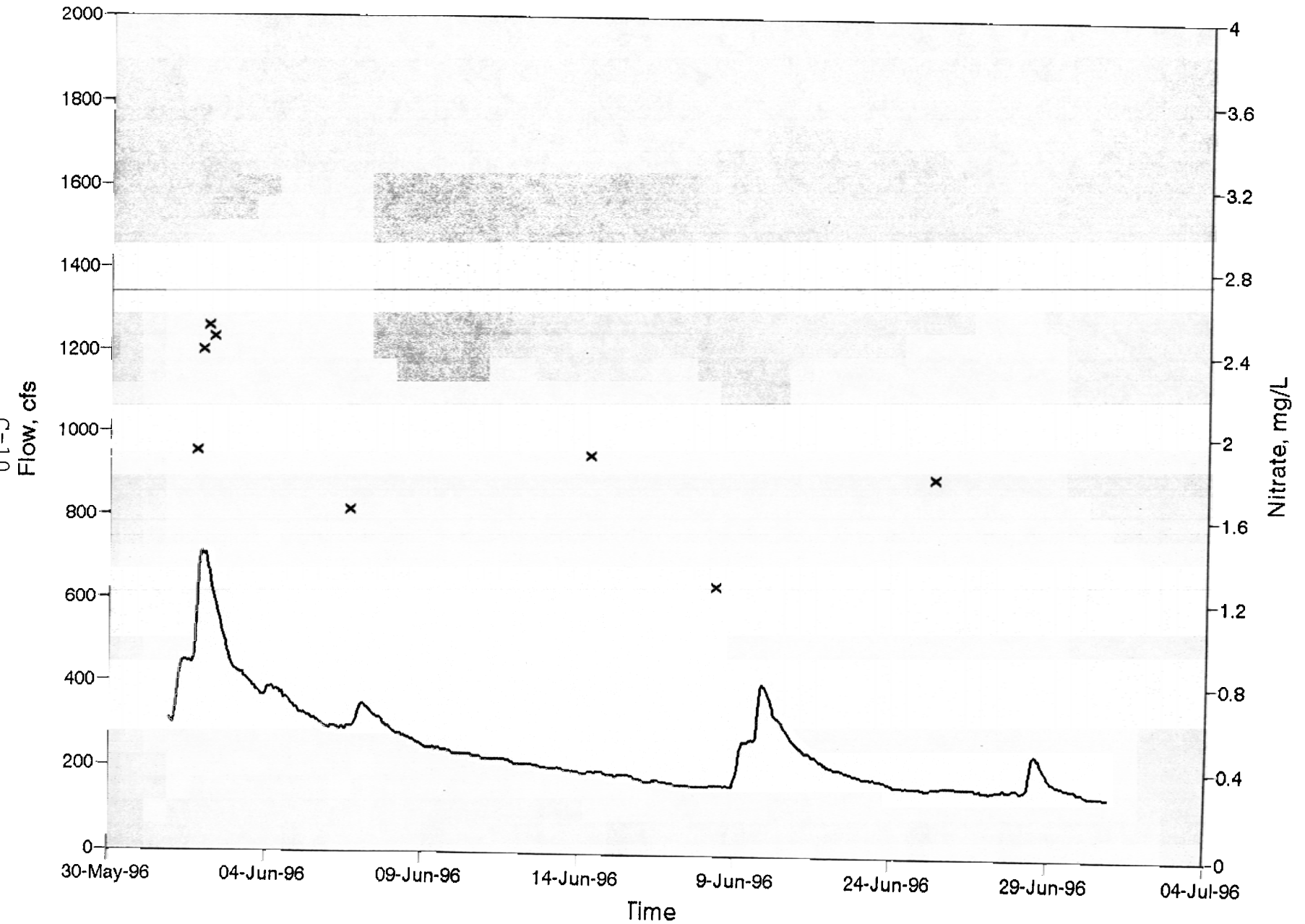




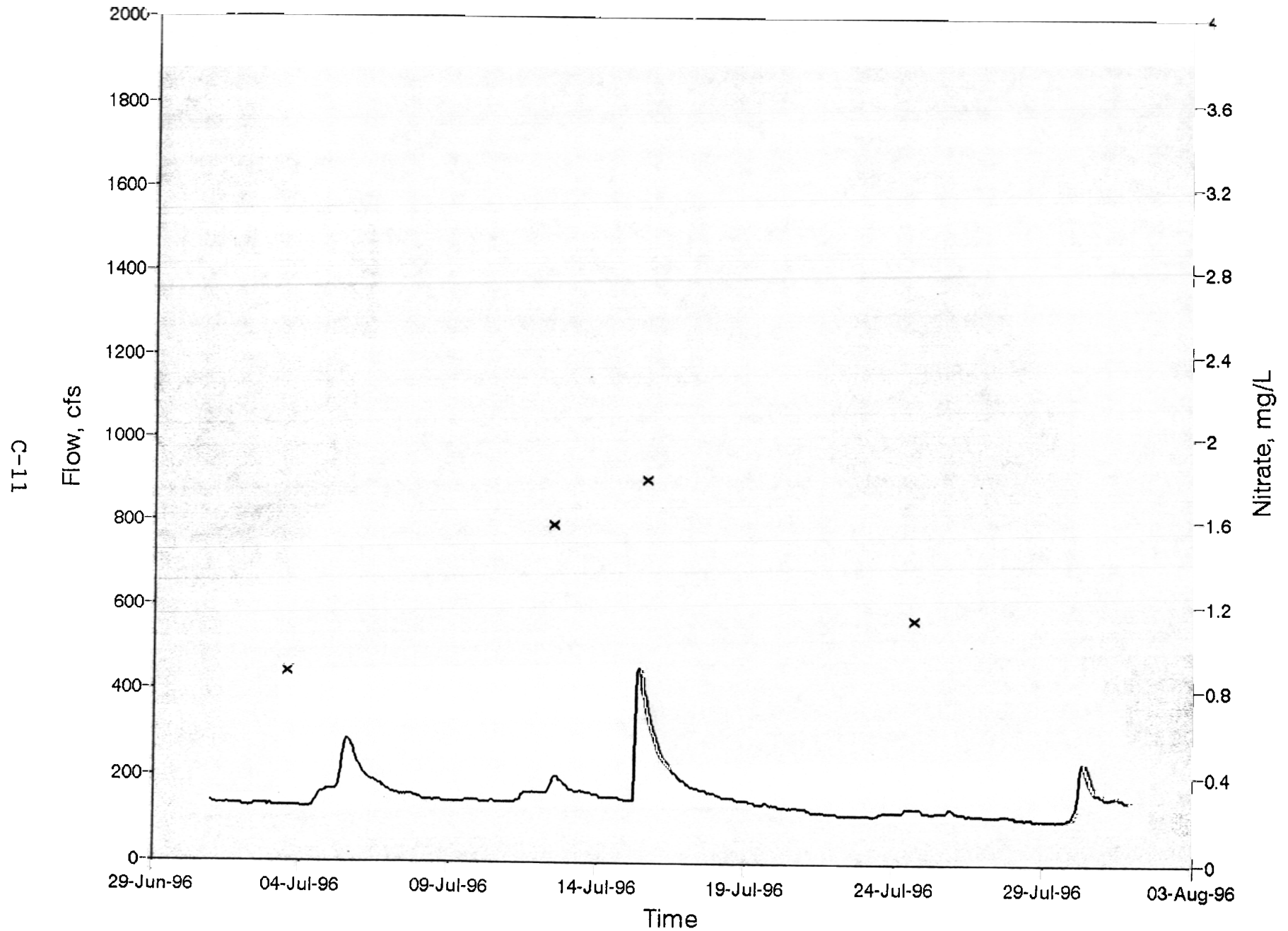
# Illinois River at Arkansas Highway 59 May 996



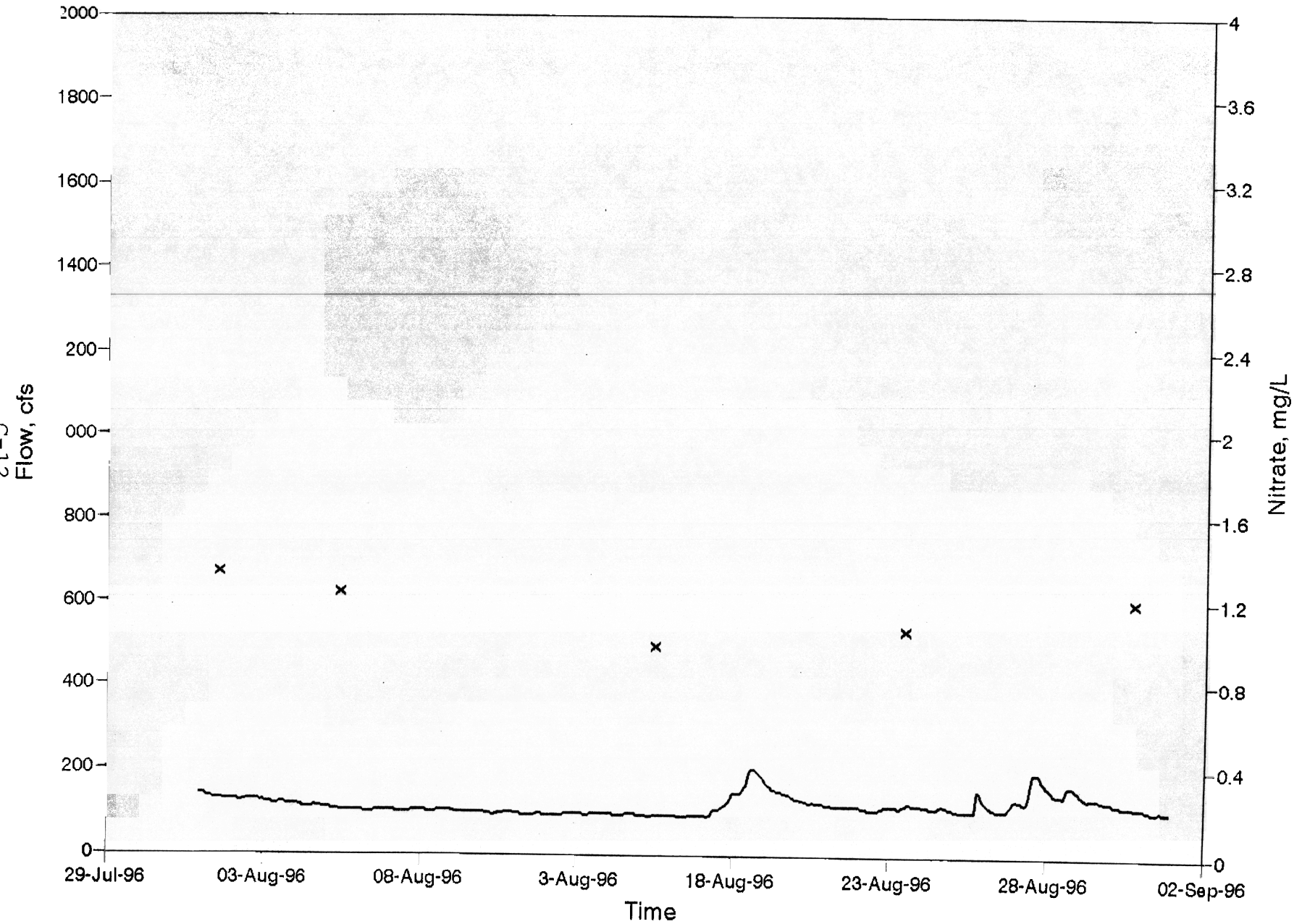
# Illinois River at Arkansas Highway 59 June 1996



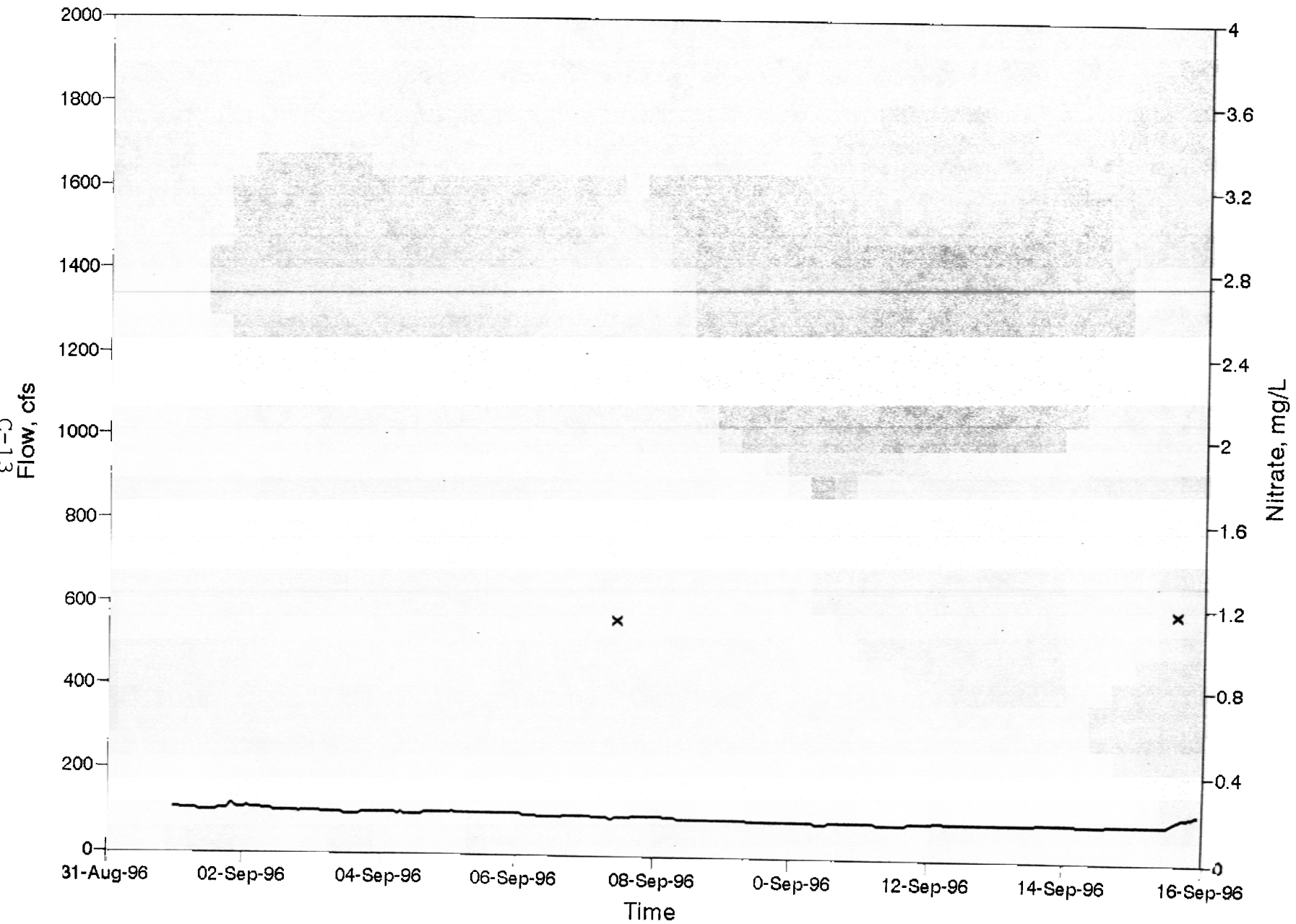
Illinois River at Arkansas Highway 59  
July 1996



# Illinois River at Arkansas Highway 59 August 1996

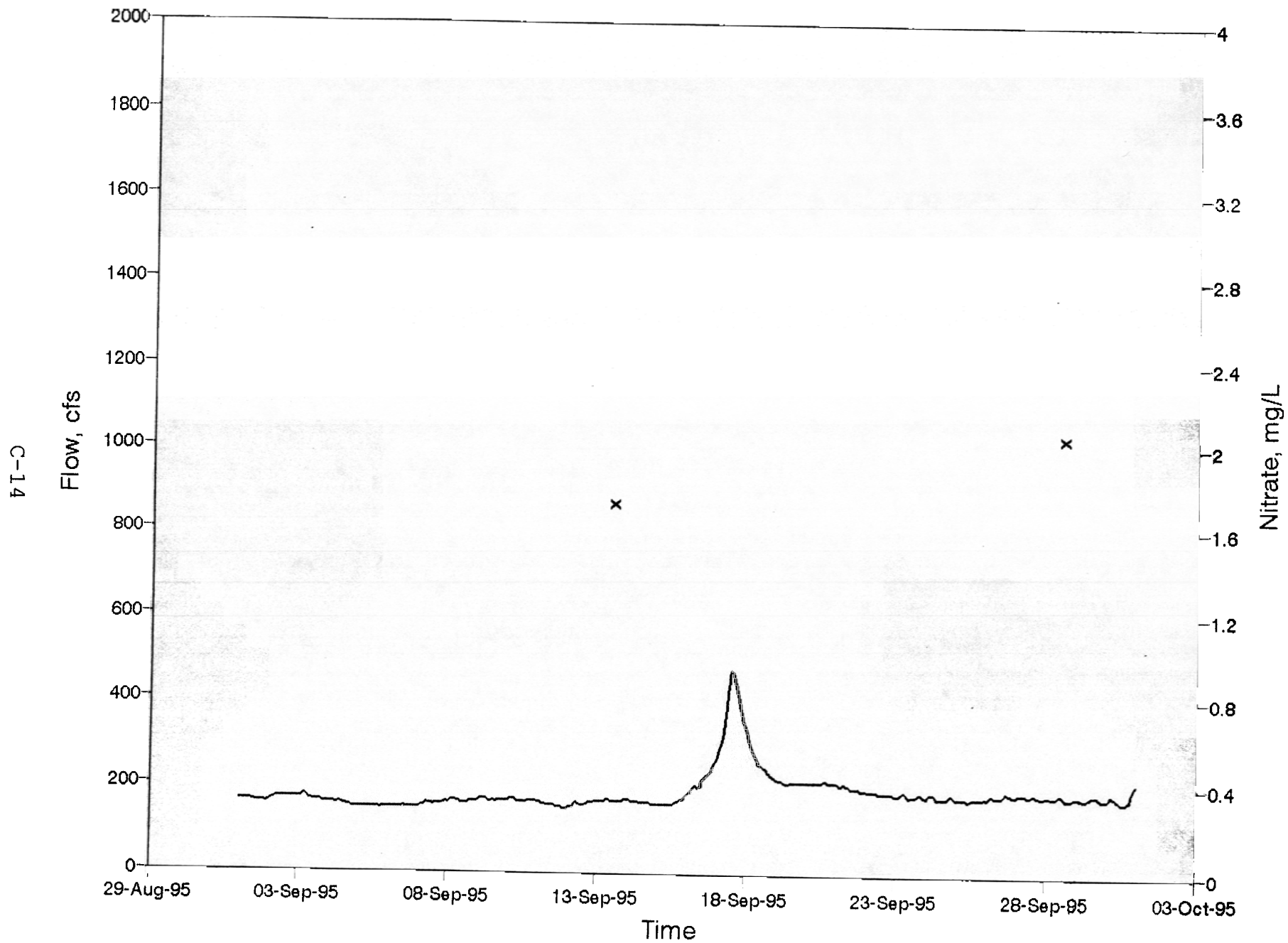


# Illinois River at Arkansas Highway 59 September 1996



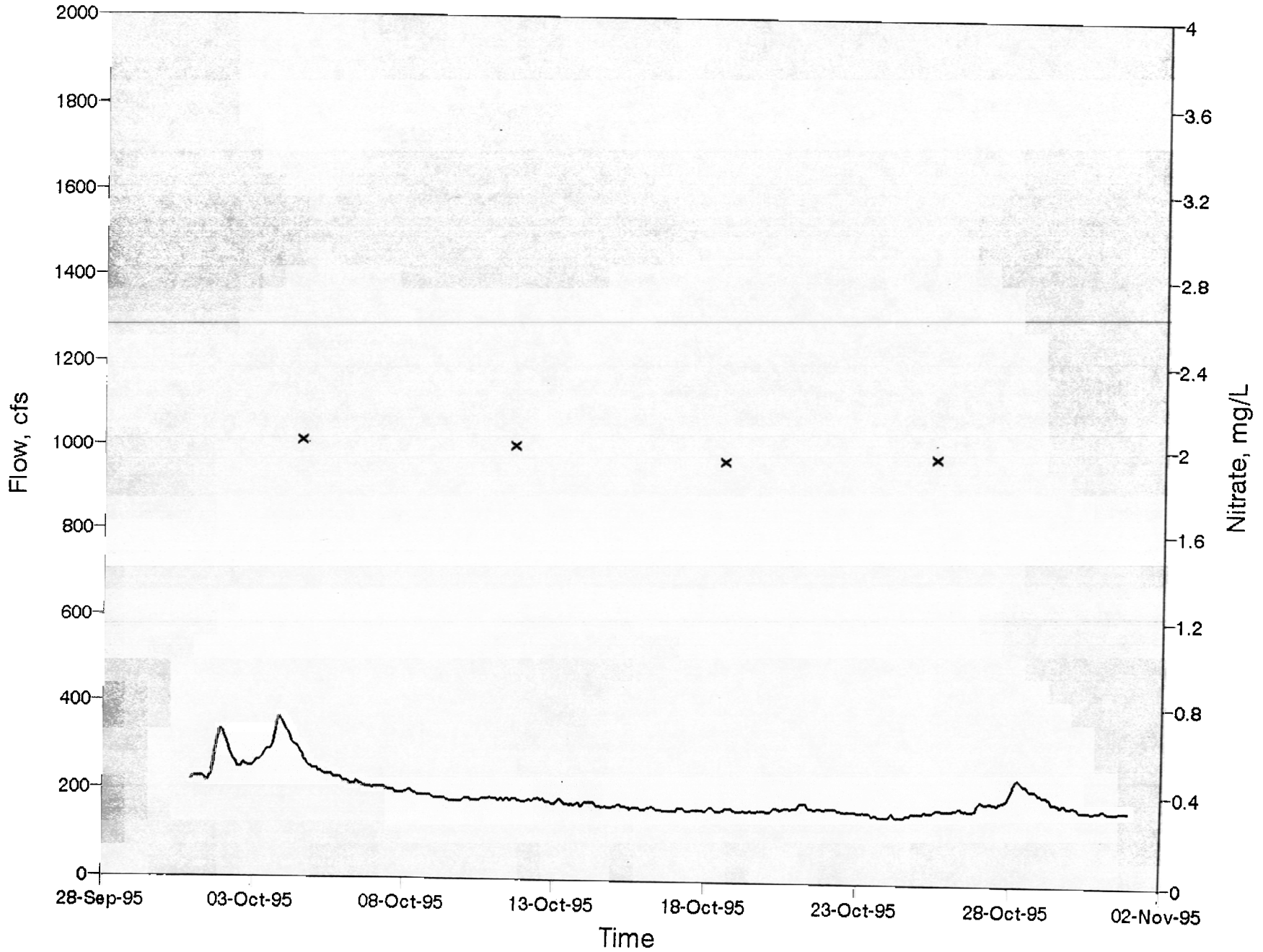


# Illinois River at Oklahoma Highway 59 September 1995



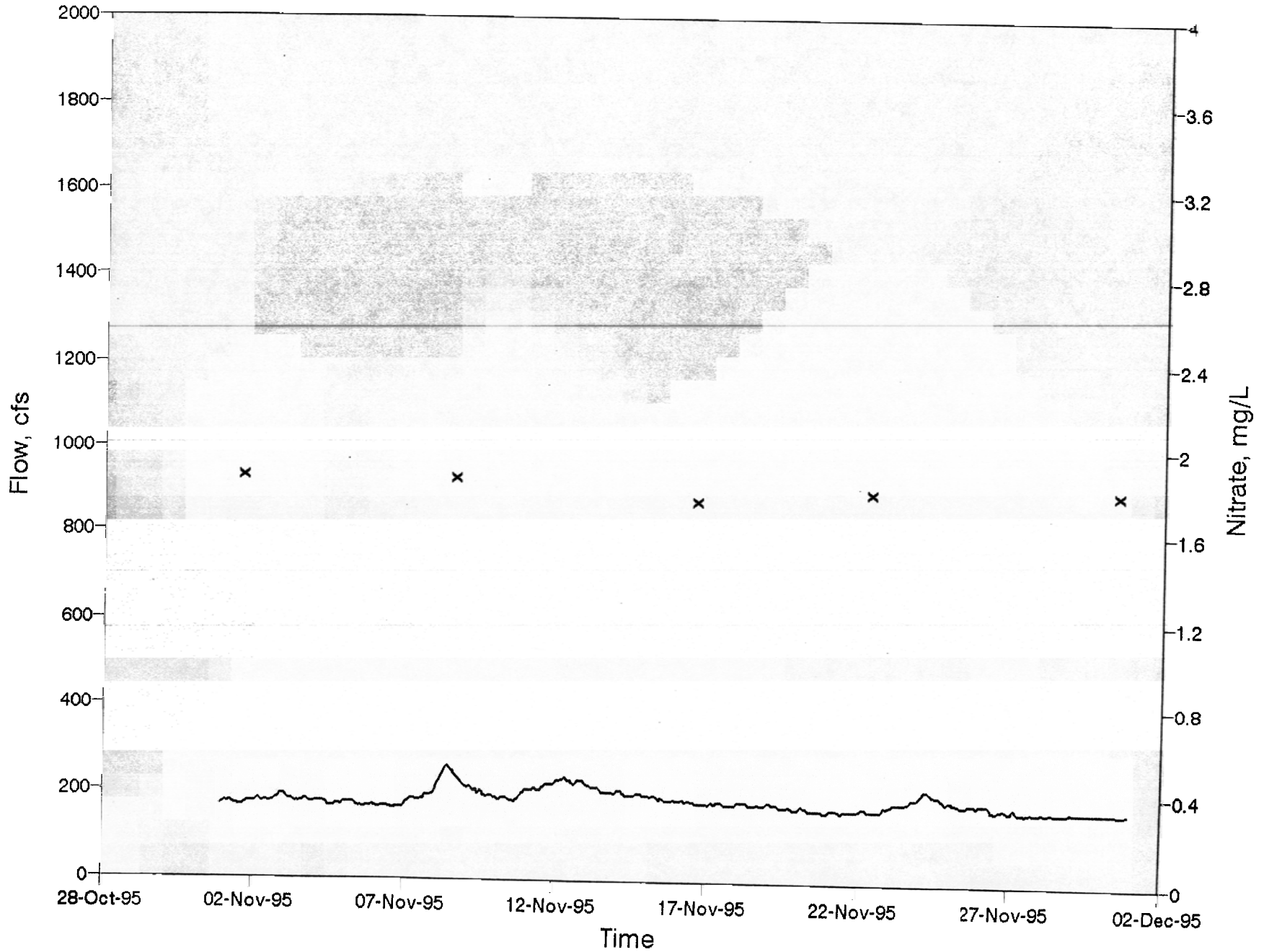
# Illinois River at Oklahoma Highway 59

October 1995



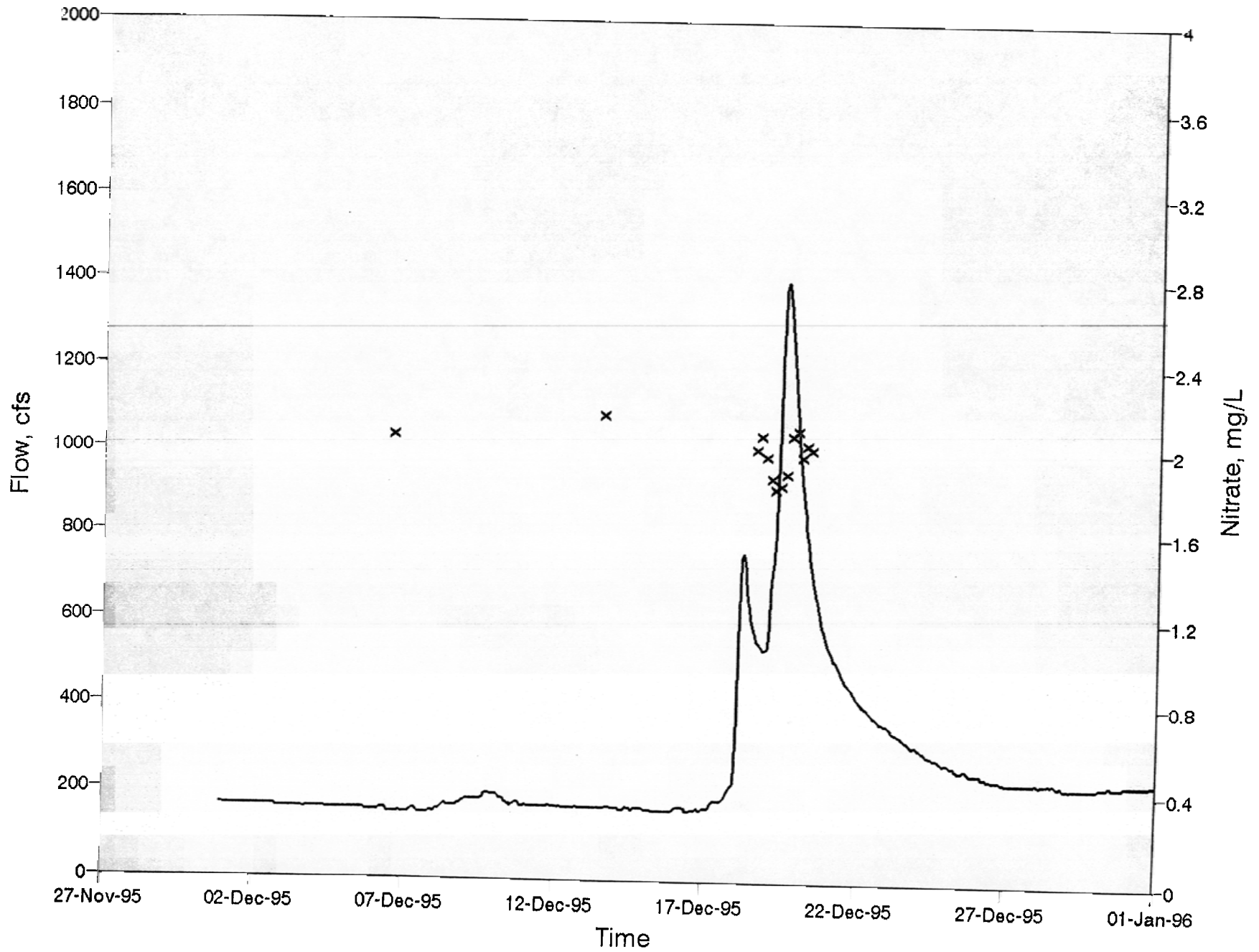
# Illinois River at Oklahoma Highway 59

November 1995



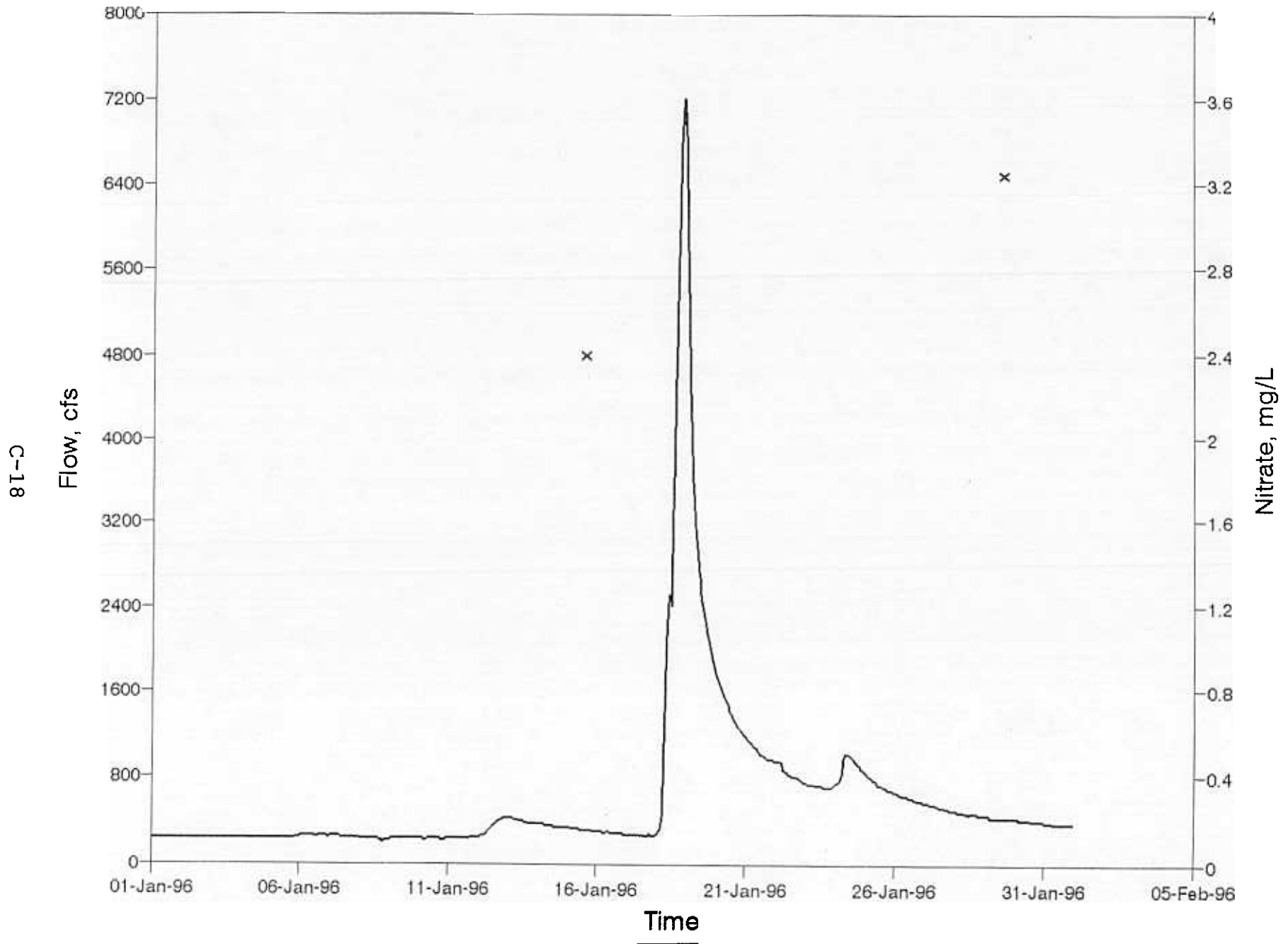


# Illinois River at Oklahoma Highway 59 December 1995

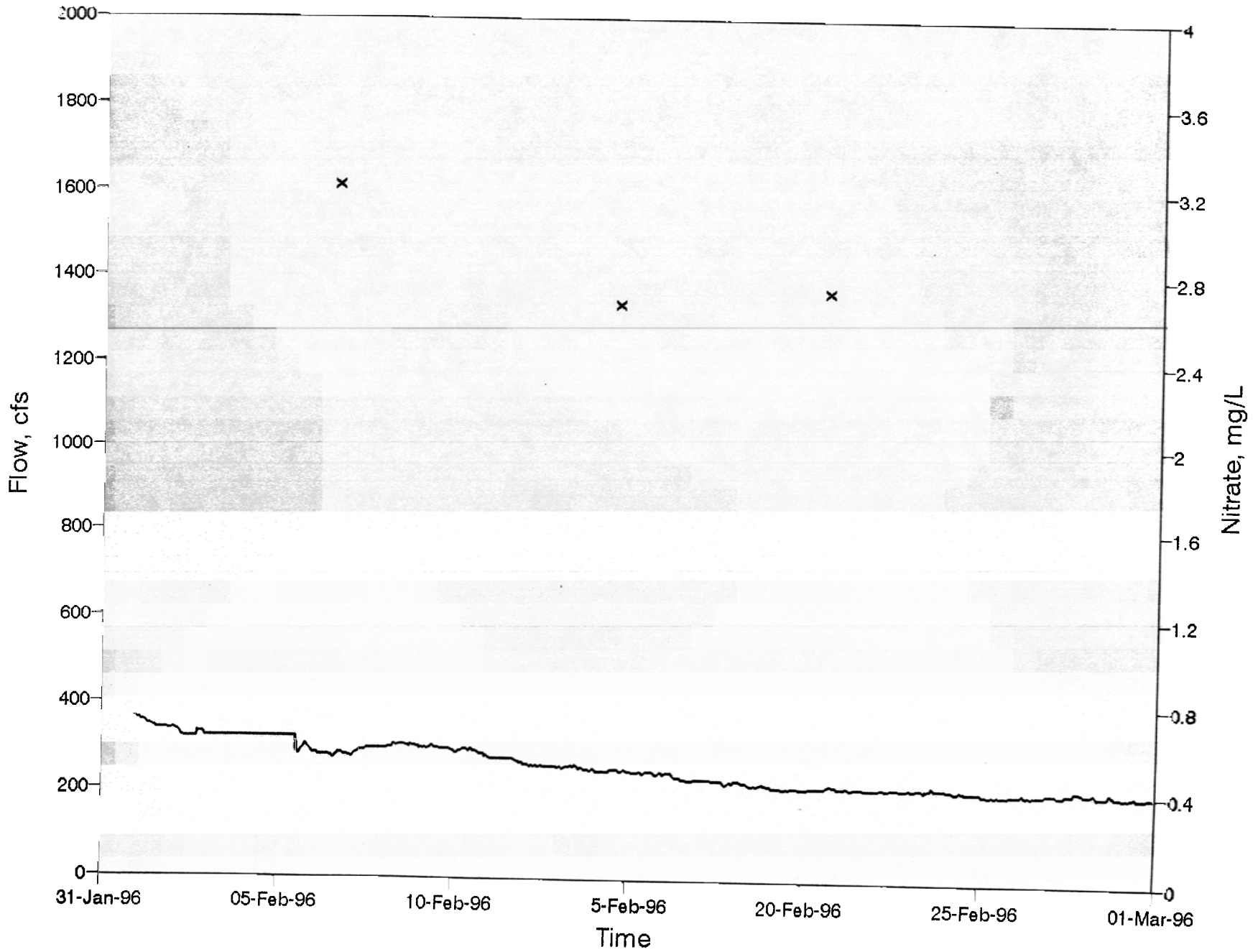


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Illinois River at Oklahoma Highway 59  
January 1996

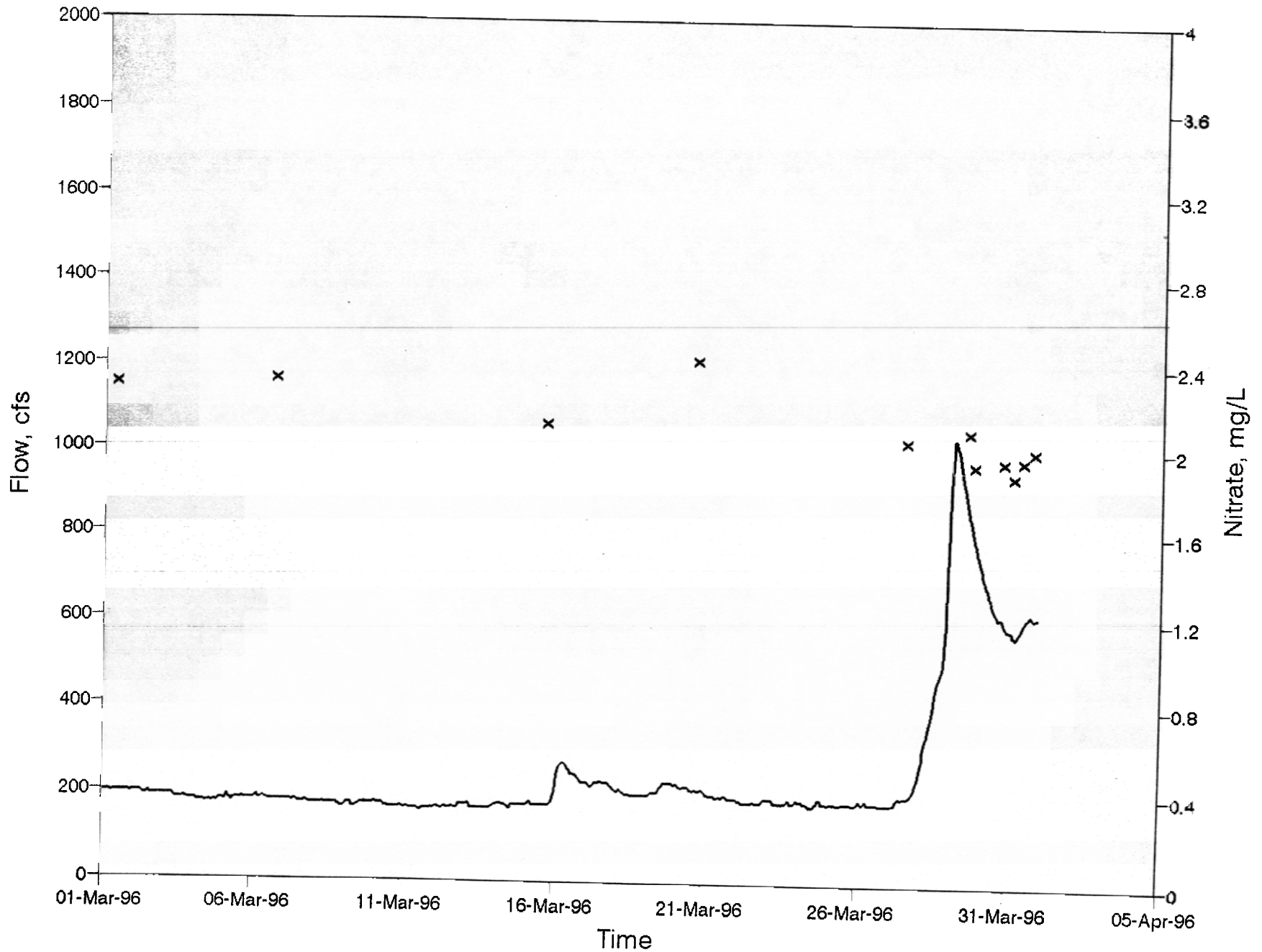


# Illinois River at Oklahoma Highway 59 February 1996

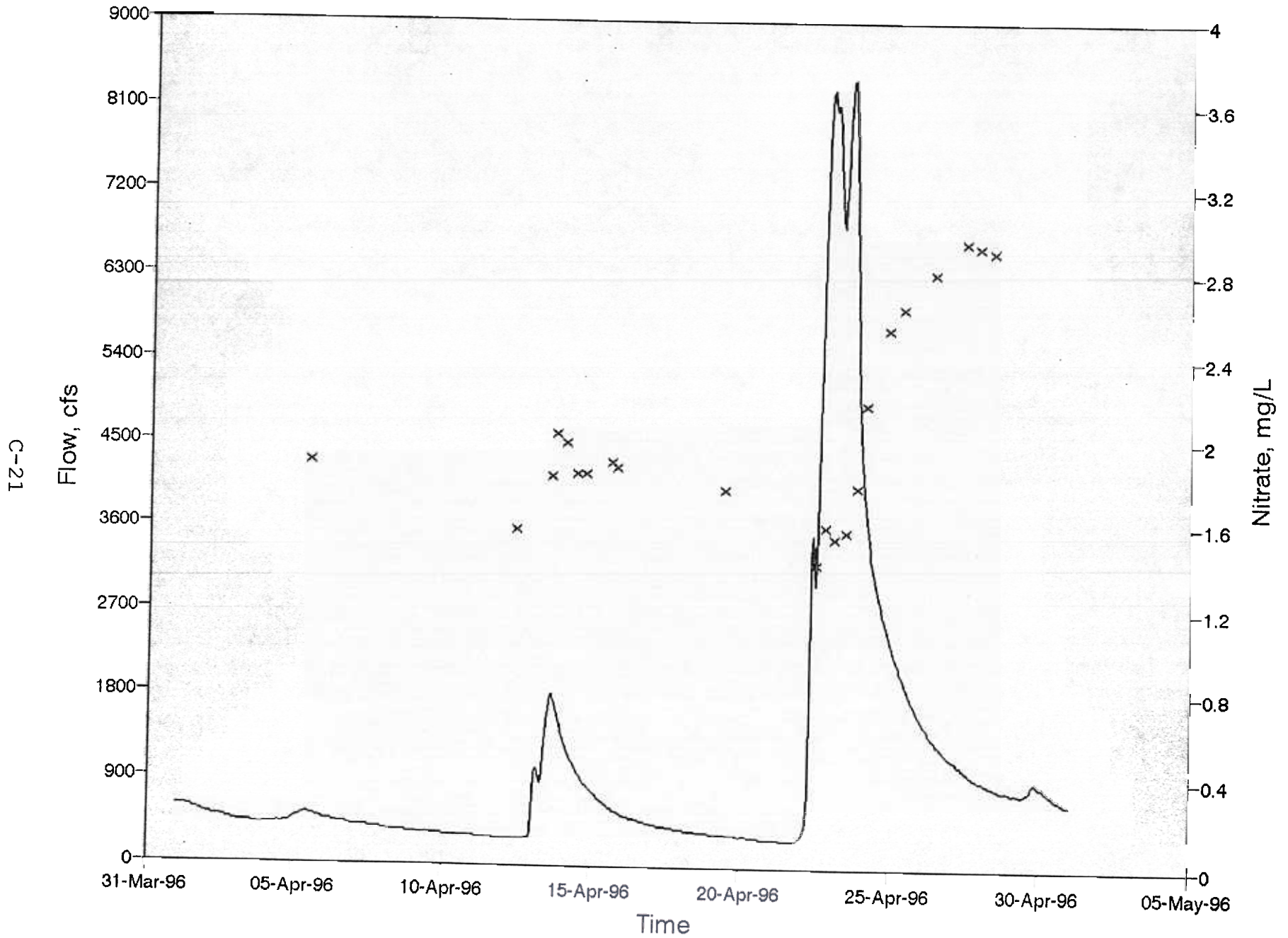


# Illinois River at Oklahoma Highway 59

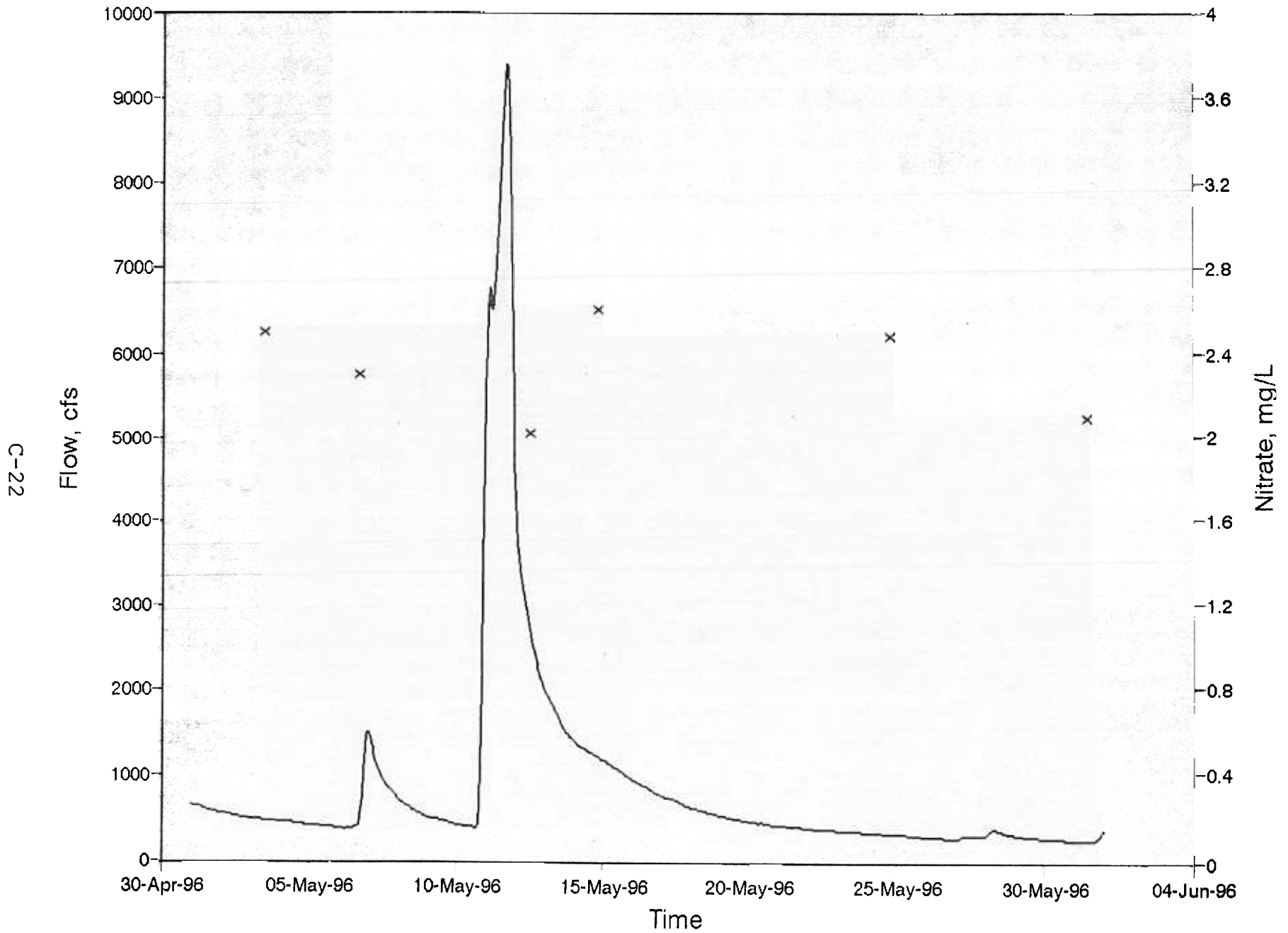
March 1996



# Illinois River at Oklahoma Highway 59 April 1996



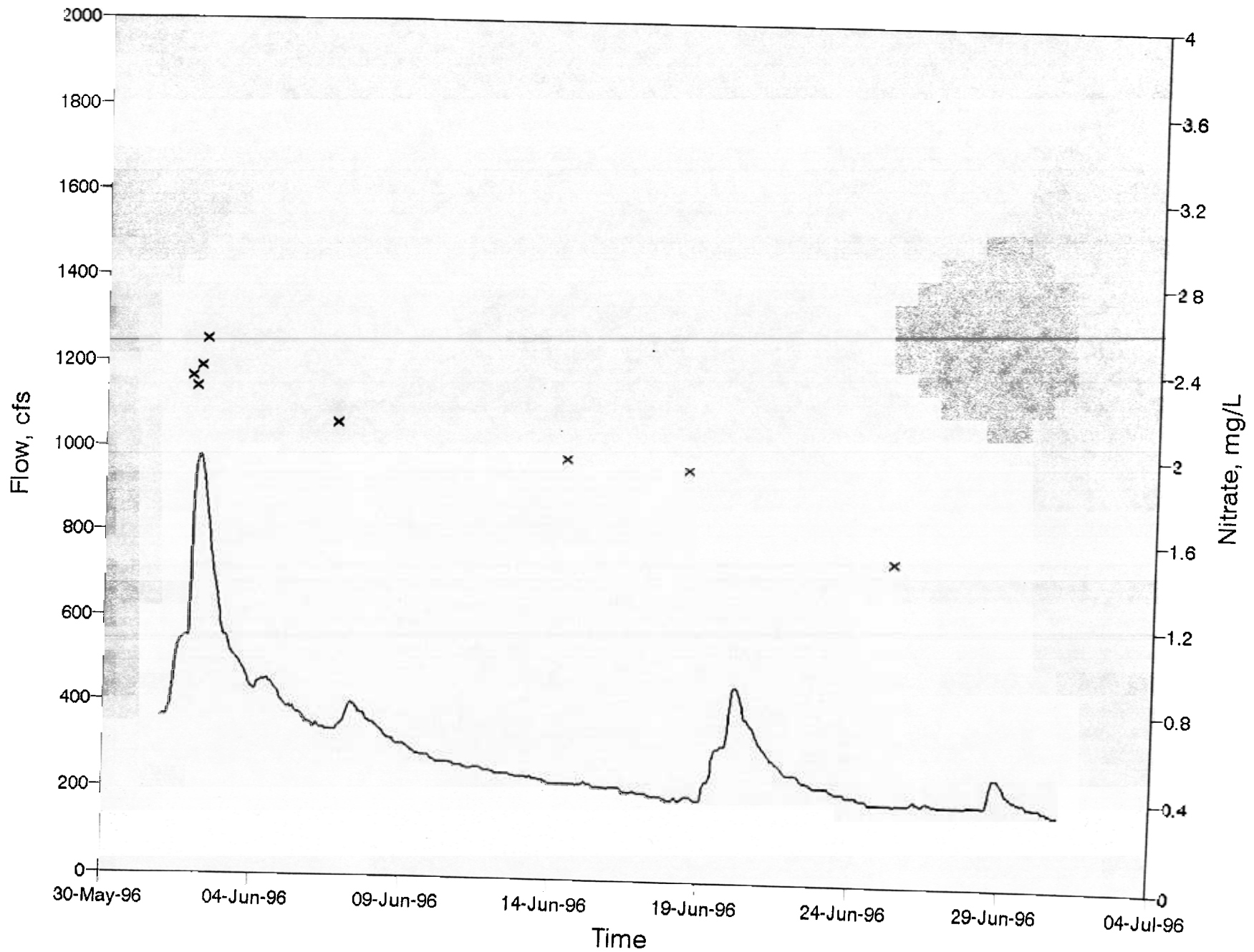
Illinois River at Oklahoma Highway 59  
May 1996





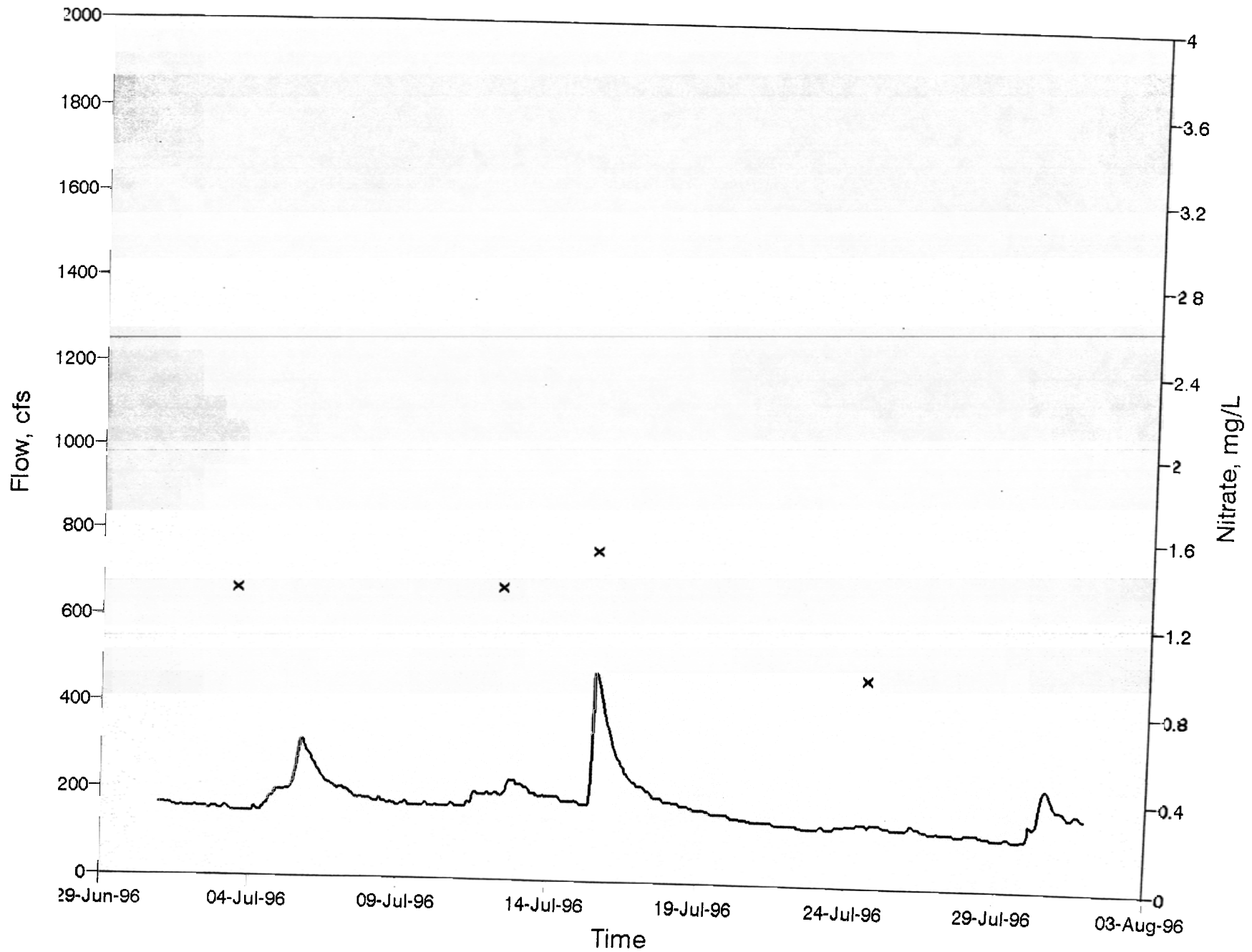
# Illinois River at Oklahoma Highway 59

June 1996



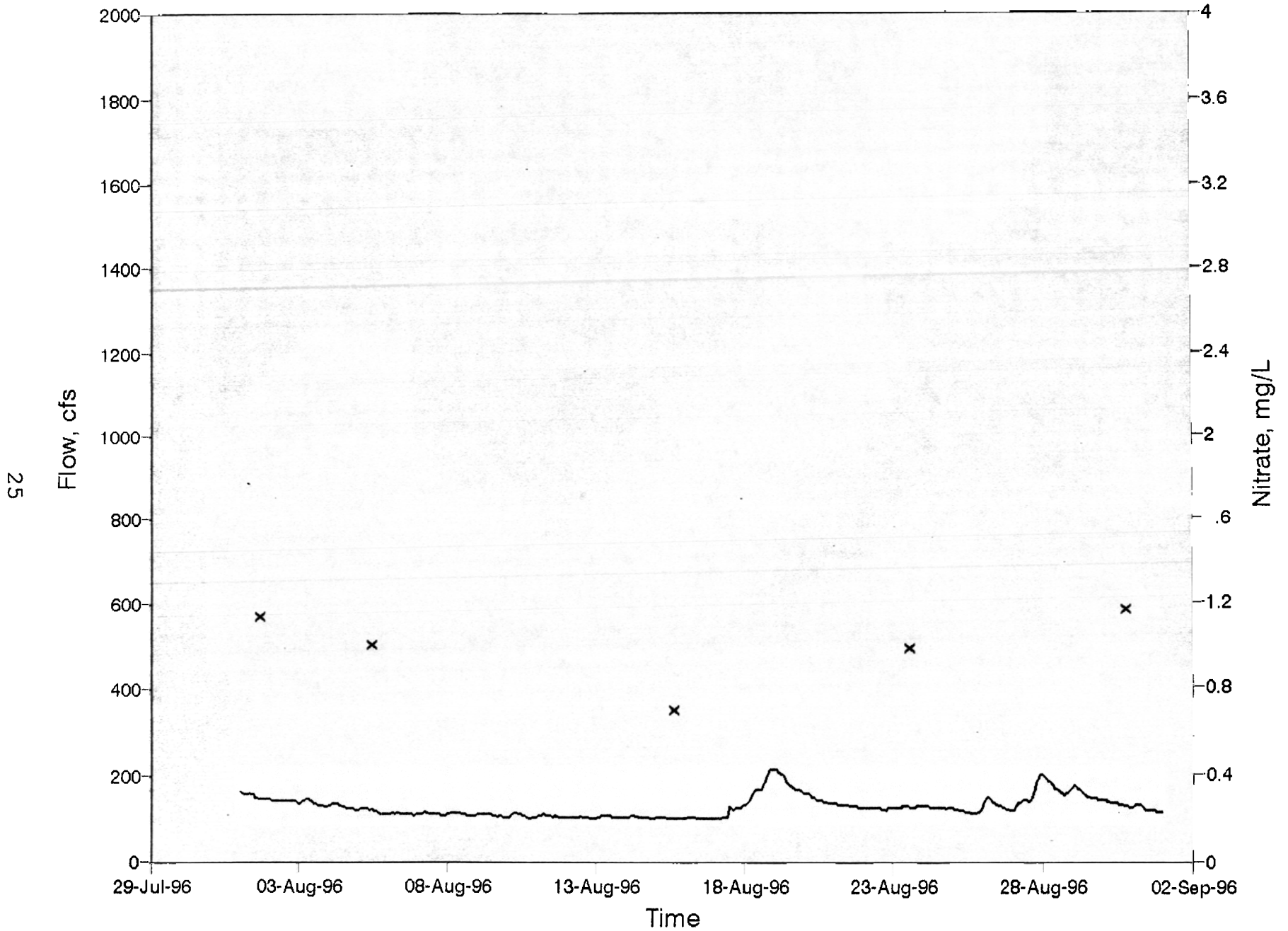
# Illinois River at Oklahoma Highway 59

## July 1996





# Illinois River at Oklahoma Highway 59 August 1996



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# Illinois River at Oklahoma Highway 59 September 1996

