WATER QUALITY STUDIES

OF THE

SPOKANE RIVER

BETWEEN

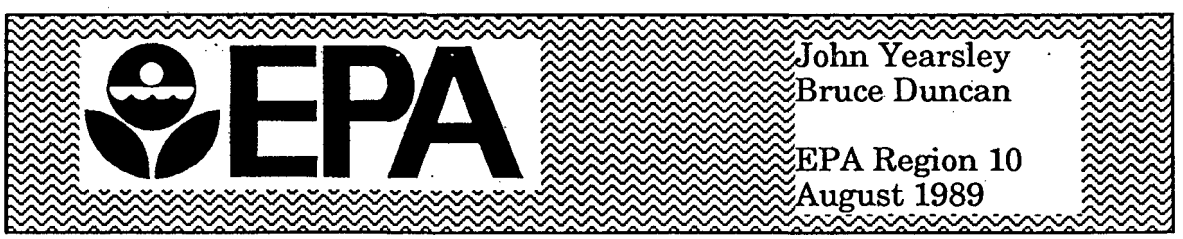
COEUR D'ALENE, IDAHO

AND

POST FALLS, IDAHO

1988

EPA 910/9-91-006



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EPA Region 10
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INTRODUCTION

During the period August 15-18, 1988 EPA Region 10 conducted a field study of water quality in the Spokane River between the outlet of Lake Coeur d'Alene and Post Falls Dam (Figure 1). The primary purpose of this field study was to assess water quality in the Spokane River during a period of low river flow and elevated water temperature. In addition, there is a need for data to support the mathematical model of dissolved oxygen (DO) in the reach of the Spokane River between its outlet from Lake Coeur d'Alene and the Post Falls Dam. A model of the dissolved oxygen budget of this reach of the river has been used to develop permit limitations for the City of Coeur d'Alene under EPA's National Pollution Discharge Elimination System Permit (NPDES) program. It will also be used to evaluate the impact of additional discharges to this segment, including the proposed discharge by the City of Hayden Lake.

The reach of the river between the outlet of Lake Coeur d'Alene and Post Falls Dam presently receives the discharge from the waste treatment plant of the City of Coeur d'Alene. Coeur d'Alene has submitted plans to increase the discharge from this treatment plant. The City of Hayden Lake is also considering locating the outfall from their treatment plant in this reach of the river. Results from previous studies of water quality by the EPA (Yearsley, 1980) and the USGS (Seitz and Jones, 1982) have shown that under certain hydrologic conditions dissolved oxygen in the river decreases downstream from the treatment plant discharge. Furthermore, the results of mathematical modelling (Yearsley, 1987) indicate that the proposed increases in discharge of oxygen demanding material could lead to conditions for which the water quality standards of the State of Idaho would be exceeded. Other water quality issues which have been identified in the Spokane River basin are heavy metals toxicity and excess nutrient loadings. The heavy metals toxicity is associated with mining activities on the Coeur d'Alene River, which discharges into Lake Coeur d'Alene. Excess nutrients in the Spokane River have been identified as the cause of accelerated rates of eutrophication in Long Lake, in

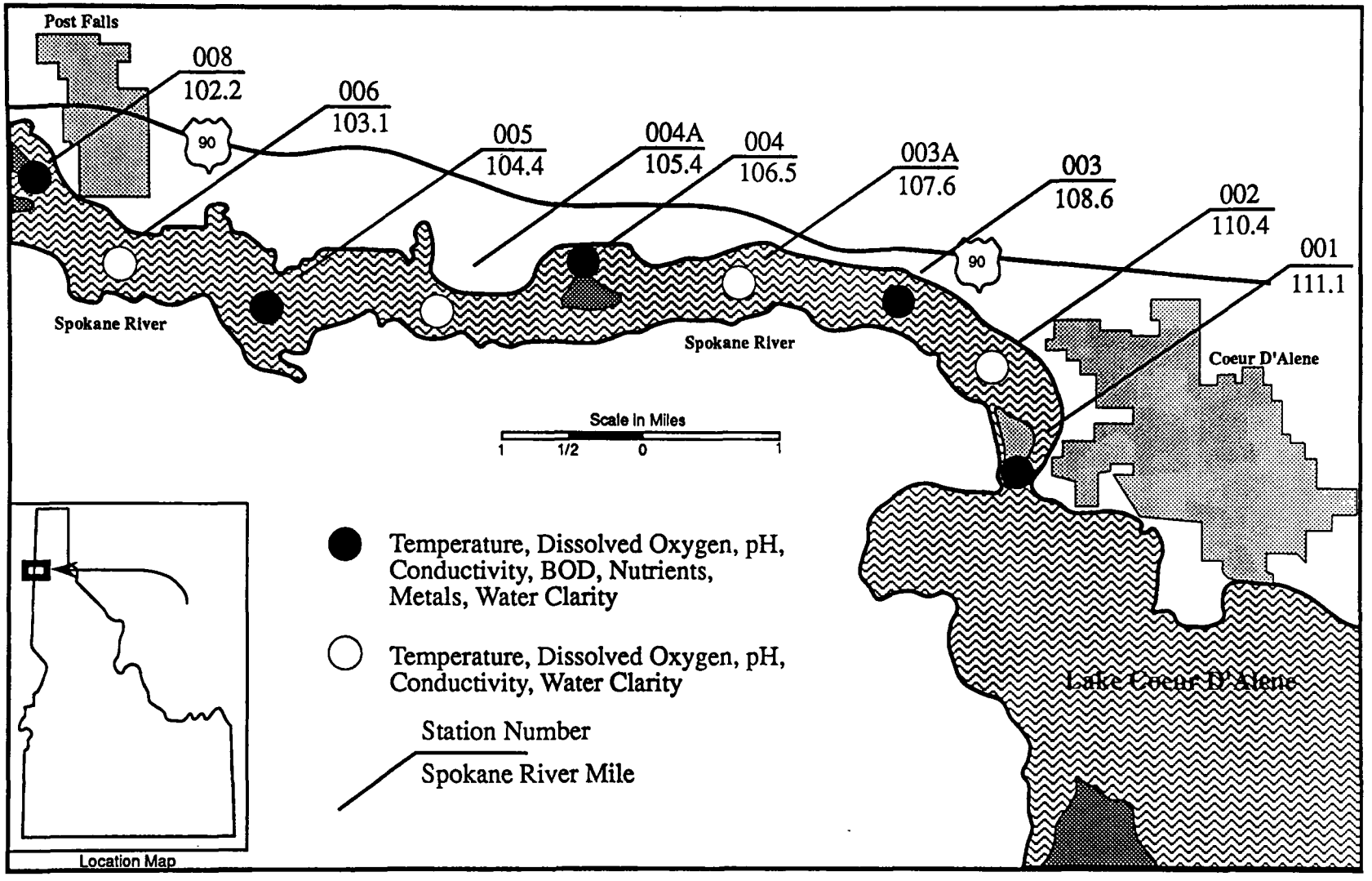

Figure 1. Location map for the field study of the Spokane River, August 16-18, 1988 showing water quality sampling stations

the State of Washington. The Spokane River, which receives effluent from a number of municipal and industrial sources, discharges to Long Lake several miles downstream from Post Falls.

FIELD STUDIES

In support of the objectives of assessing water quality , the field study program included measurements of water quality constituents and parameters in both the receiving waters and in effluent of municipalities presently discharging or considering discharge to the segment of the Spokane River between Lake Coeur d'Alene and Post Falls Dam. Table 1 shows the survey dates and the type of information collected. Data collected during the survey, including in situ and laboratory measurements, are given in Appendix A.

Receiving Waters

Data collected in the receiving waters included both observations made in the field and measurements from samples shipped to the EPA Regional Laboratory at Manchester, Washington. Temperature, DO, conductivity and pH measurements made in the field with a Hydrolab Model 4000 Calibration procedures for the Hydrolab Model 4000 were done in conformance with the manufacturers recommendations. The receiving water monitoring program was designed so that data could be used to characterize the distribution of water quality in both space and time. *In situ* measurements of temperature, DO, conductivity and pH were made at several depths; in the right, middle and left one-thirds of the river at each of the locations shown in Figure 1. This spatial sampling schedule was followed once in the morning and once in the afternoon each day during the period of August 16-18, 1988.

Samples for the laboratory analysis of biological oxygen demand (BOD), nutrients, and heavy metals were obtained at each of the locations shown Figure 1 by make a composite from samples taken at several depths and at the right, middle and left sections of the station. The samples of this type were collected during the morning only. The samples were stored in polyethylene containers, packed in ice and shipped daily, via air freight, to the Regional Laboratory at Manchester, Washington. Methods used for measurements made in the laboratory follow procedures described in EPA (1983).

Table 1. Sampling activities for Spokane River field study, August 16-18, 1989

Medium	Parameters	Spatial Distribution	Sampling Frequency
Receiving water	Temperature, DO, pH, conductivity, Secchi disk	Vertical profiles at 1/4, 1/2 and 3/4 of the river width	Twice daily August 16-18, 1989
	BOD (5-, 10, 15- and 20-day)	Composite from surface, mid-depth and bottom at 1/4, 1/2 and 3/4 of river width	Once daily August 16-18, 1989
	Total Metals As		
	Total Recoverable Metals Cd,Cr,Cu,Fe,Pb, Hg,Zn		
	Nutrients Total P Ammonia N NO_2+NO_3-N Kjeldahl N		
Point source	Temperature, DO, pH, conductivity	Twenty-four hour composite	Once daily August 15-18, 1989
	BOD (5-, 10, 15- and 20-day)	Twenty-four hour composite	Once daily August 16-18, 1989
	Total Metals As		
	Total Recoverable Metals Cd,Cr,Cu,Fe,Pb, Hg,Zn		
	Nutrients Total P Ammonia N NO_2+NO_3-N Kjeldahl N		
	Suspended Solids		

Locations of receiving water sampling stations for which laboratory analyses were performed are shown in Figure 1.

Point Sources

Samples from the municipal treatment facilities in Hayden Lake and Coeur d'Alene were obtained from 24-hour composites of the each treatment plants effluent . For those samples analyzed at the Regional Laboratory, handling and measurement procedures were the same as for the receiving water samples as described above. Flow measurements were obtained from measurement devices maintained at each facility.

RESULTS

Receiving Waters

For purposes of analyzing the results, the receiving water data (Appendix A) were aggregated in terms of time and depth-averages. The averaging method used to aggregate the data is described in Appendix B.

River Flow and River Surface Elevation

River flow was not measured as part of the EPA Region 10 study. However, the U.S. Geological Survey maintains a stream gage just below Post Falls Dam. Provisional records from this station and observations of river surface elevation were made available by Mr. Stuart Gutenberg of the USGS in Sand Point , Idaho. Data for the month of August are presented in Table 2.

Water Temperature

Average, maximum and minimum water temperatures measured during the field studies are shown in Figure 2. Averages are by station, across days. Maxima and minima are the highest and lowest temperature, respectively, measured at each station during three-day study. The distribution of water temperature during this field study was similar to that found during the field study of August 16-17, 1979 (Yearsley, 1980). Average temperatures ranged from 21.4 ^{o}C to 22.9 ^{o}C. For those segments of the river with water depths less than approximately seven meters, temperatures were nearly uniform from top to bottom and from left bank to right bank. In those segments for which water depth was greater than seven meters (Station 6 , 8 and Post Falls Dam), there was a thermocline from a depth of seven meters to the bottom. Vertical profiles of temperatures at a station with depth less than seven meters (Station 5) and greater than seven meters (Station 6) are shown in Figure 3.

Table 2. Daily discharge in the Spokane River near Post Falls and gage height in Lake Coeur d'Alene during August 1989 (preliminary information from the USGS).

Day	Discharge (cfs)	Gage Height (feet)
1	684	2127.82
2	729	2127.80
3	545	2127.82
4	431	2127.83
5	463	2127.82
6	494	2127.83
7	476	2127.80
8	470	2127.81
9	393	2127.81
10	344	2127.81
11	338	2127.80
12	334	2127.81
13	348	2127.82
14	346	2127.82
15	337	2127.82
16	338	2127.79
17	357	2127.80
18	350	2127.81
19	346	2127.79
20	344	2127.79
21	346	2127.78
22	344	2127.78
23	340	2127.78
24	338	2127.79
25	340	2127.78
26	336	2127.75
27	327	2127.75
28	318	2127.76
29	319	2127.77
30	329	2127.75
31	359	2127.72

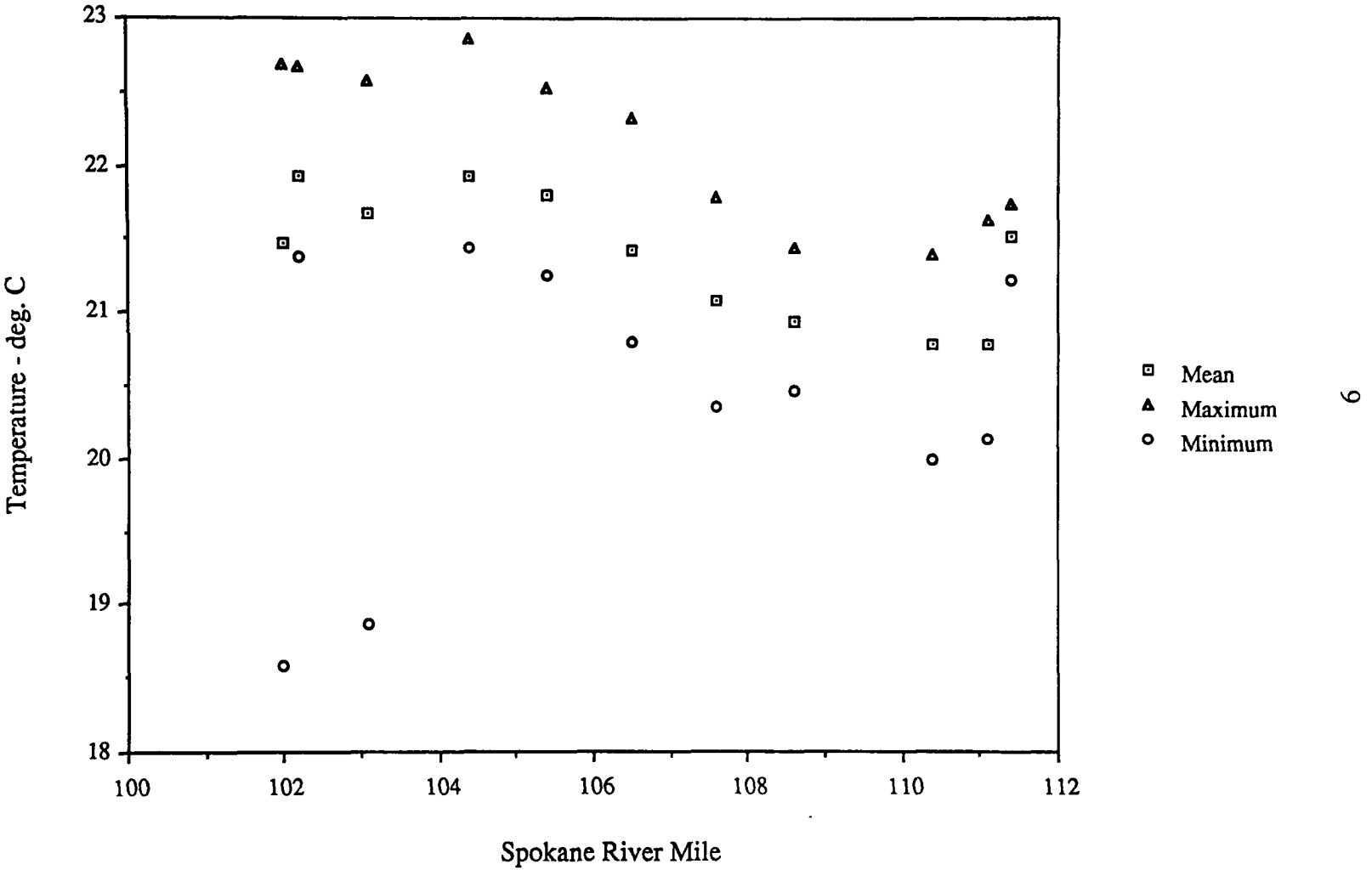

Figure 2. Mean, maximum and minimum temperature in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

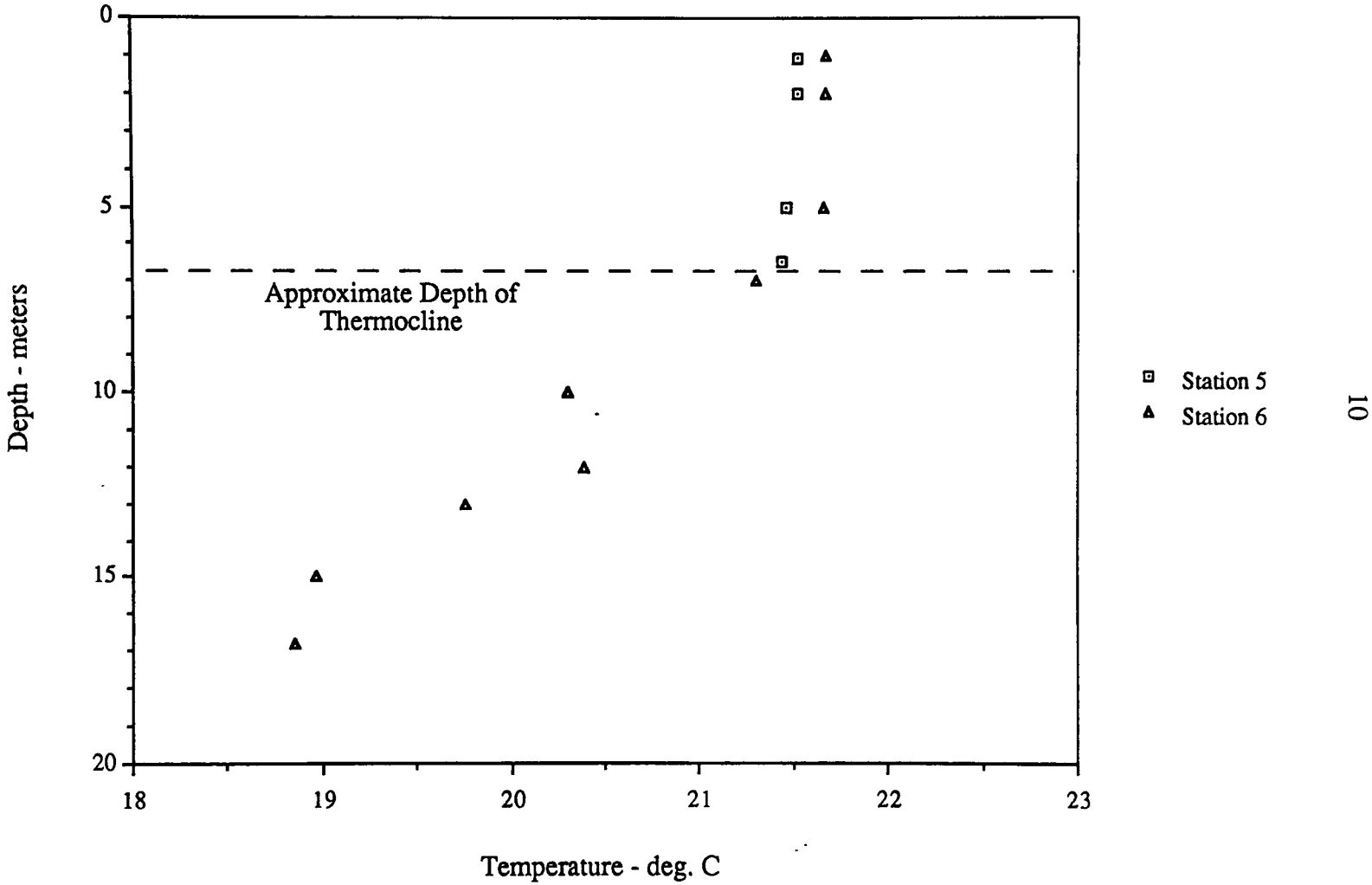

Figure 3. Vertical profiles of temperature at Stations 5 and 6 on August 18, 1988.

The lowest temperature observed at depth during the study was 18.6 °C at Post Falls Dam Data collected in the State of Idaho's Volunteer Monitoring Program (Appendix C) show that temperature of the water surface was 19 °C between May 25, 1988 and June 25, 1988. This implies that the water at depth with temperatures of less than 19 °C had been there for at least five to six weeks.

Dissolved Oxygen

Daily cross-sectional averages of concentrations and saturation levels for dissolved oxygen, measured at each station during the field study, are shown Figure 4. Stations 1-5 show a consistent increase in the average concentration from morning to afternoon. These stations are all fairly shallow and well-mixed from top to bottom. Water transparency, as measured by Secchi disk, were generally in the range of 3.0 to 4.0 meters at these stations. . Assuming that the depth of active photosynthesis is given by 1.7*Secchi depth, Stations 1-5 are shallow enough that the cross-sectional average is affected by photosynthetic activity. Stations 6, 8 and Post Falls Dam show a consistent increase from morning to afternoon for cross-sectional averages only for the top five meters. The total cross-sectional average at these three stations is controlled by the extremely low values of DO occurring at depth. Photosynthesis has a much smaller role in the DO at depth. As a result, the deeper stations have less diurnal variability in depth-averaged value of DO than do the shallow stations.

When the flow in the Spokane River is low, vertical mixing is reduced and, as described above, a thermocline develops at those locations for which water depth is greater than approximately seven meters. The vertical distribution of DO is also affected by the reduced mixing and at DO also decreases rapidly at depths greater than approximately seven meters. Vertical profiles of DO at a shallow station (Station 5) and a deep station (Station 6) are compared in Figure 5.

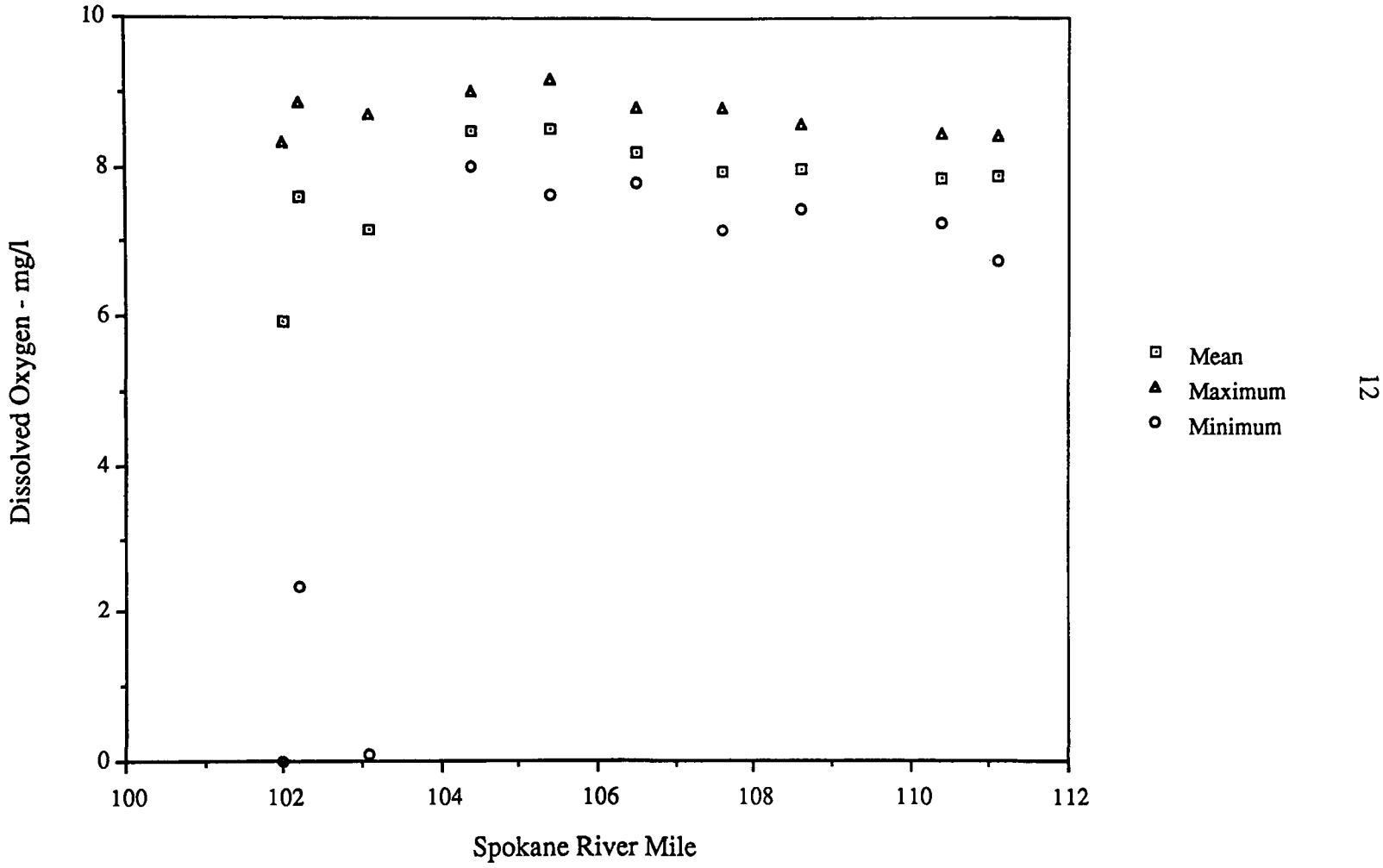

Figure 4. Mean, maximum and minimum dissolved oxygen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

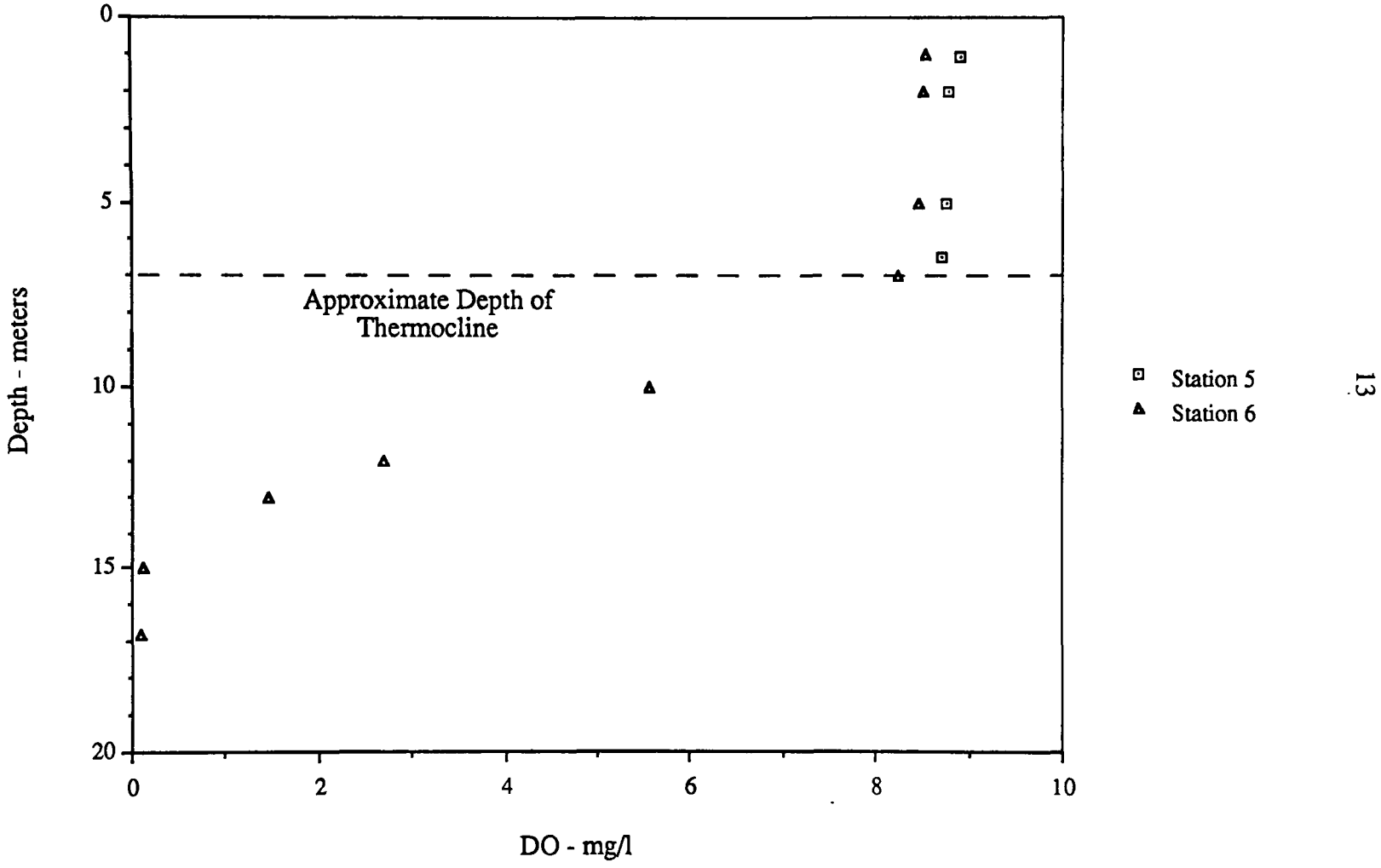

Figure 5. Vertical profiles of dissolved oxygen (DO) at Stations 5 and 6 on August 18, 1988.

Conductivity and pH

Conductivity and pH were measured both in the field with the Hydrolab Survey Model 4000 and in the laboratory. Cross-sectional averages of the conductivity measured in the field for the three-day sampling period are given in Figure 6.

Average pH increases monotonically downstream from the outlet of Lake Coeur d'Alene, as shown in Figure 7.

Nutrients

Concentrations of total phosphorus, nitrate+nitrite-nitrogen, Kjeldahl nitrogen and total ammonia-nitrogen, averaged over the three-day period of the field study, are shown in Figures 8 through 11. Average total phosphorus were below the detection level (0.01 mg/l) at the outlet of Lake Coeur d'Alene. Average total phosphorus increased to 0.055 mg/l at the first river sampling station downstream from the STP. As shown in Figure 8, the average concentration of total phosphorus decreased in a downstream direction after the initial pulse was introduced by the STP. Possible sinks for total phosphorus include uptake by attached algae and macrophytes and uptake by planktonic algae which eventually settle to the bottom of the river. No data were collected during this survey for testing either of these hypotheses.

Nitrate+nitrite-nitrogen in the Spokane River was below the level of detection (0.01 mg/l) throughout the field study (Fig. 9). Both Kjeldahl nitrogen and total ammonia-nitrogen were greater at the station just downstream from the discharge of the STP, as shown in Figures 10 and 11. However, Kjeldahl nitrogen and ammonia-nitrogen decreased downstream after the initial increase. Volatilization, nitrification, and algal uptake are potential sinks for ammonia. When nitrification occurs, the loss in ammonia-nitrogen should be accompanied by an increase in nitrate-nitrogen. The measurements of nitrate+nitrite-nitrogen made in this study do not show an increase in nitrate+nitrite-nitrogen corresponding to the decrease in ammonia-nitrogen. Insufficient information was available to determine the importance of volatilization or algal uptake to the nitrogen budget.

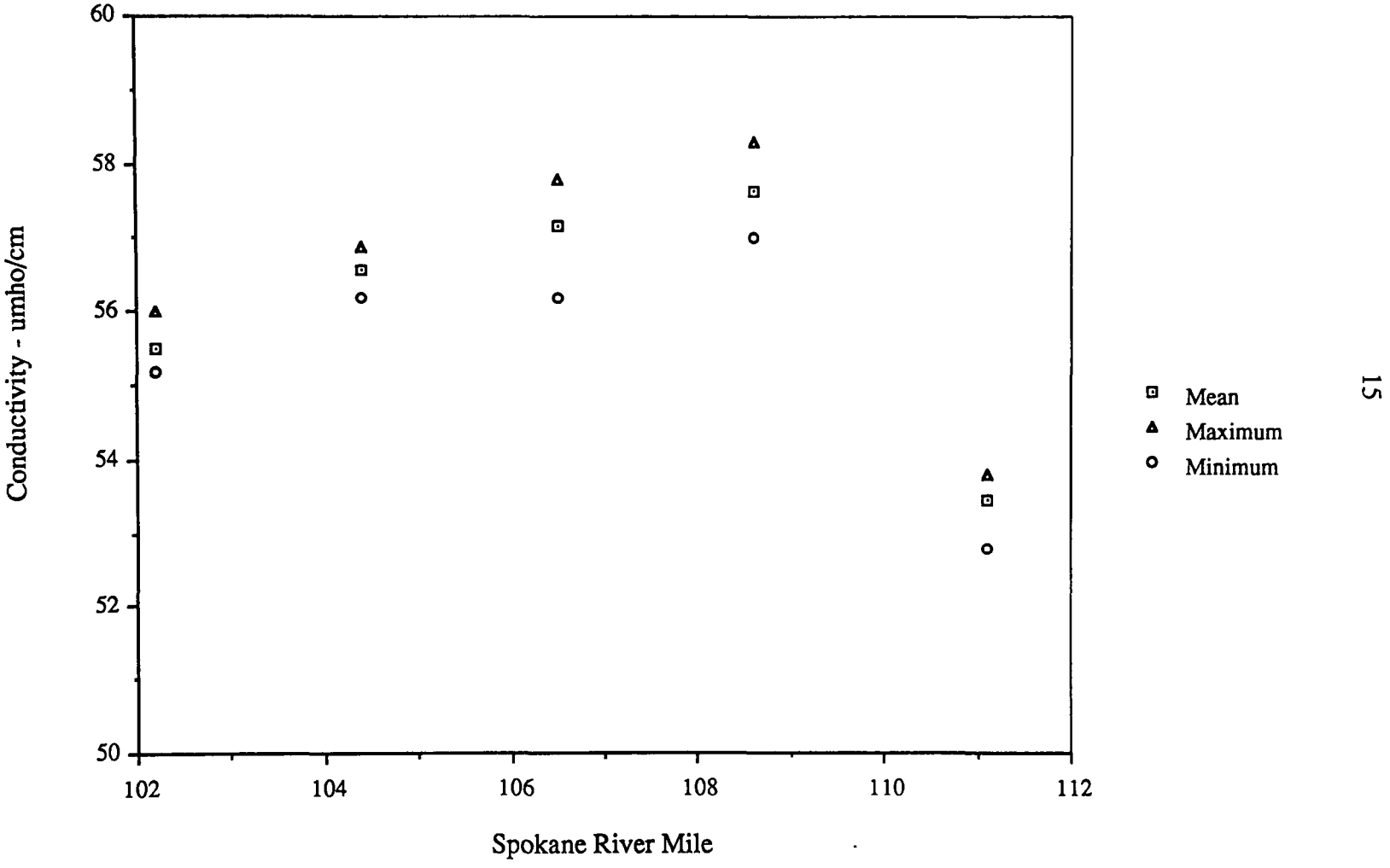

Figure 6. Mean, maximum and minimum conductivity in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field of study of August 16-18, 1988.

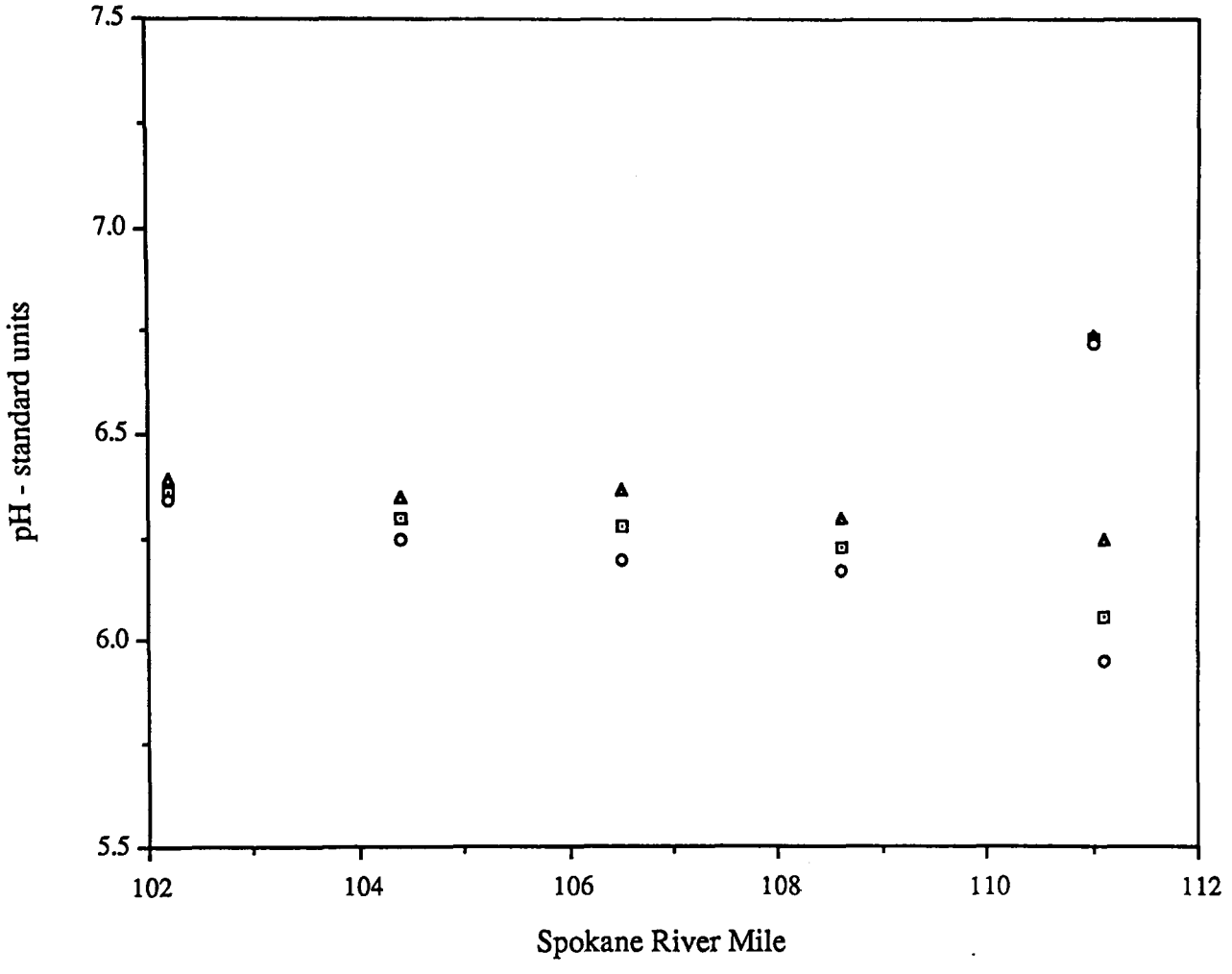

Figure 7. Mean, maximum and minimum pH in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

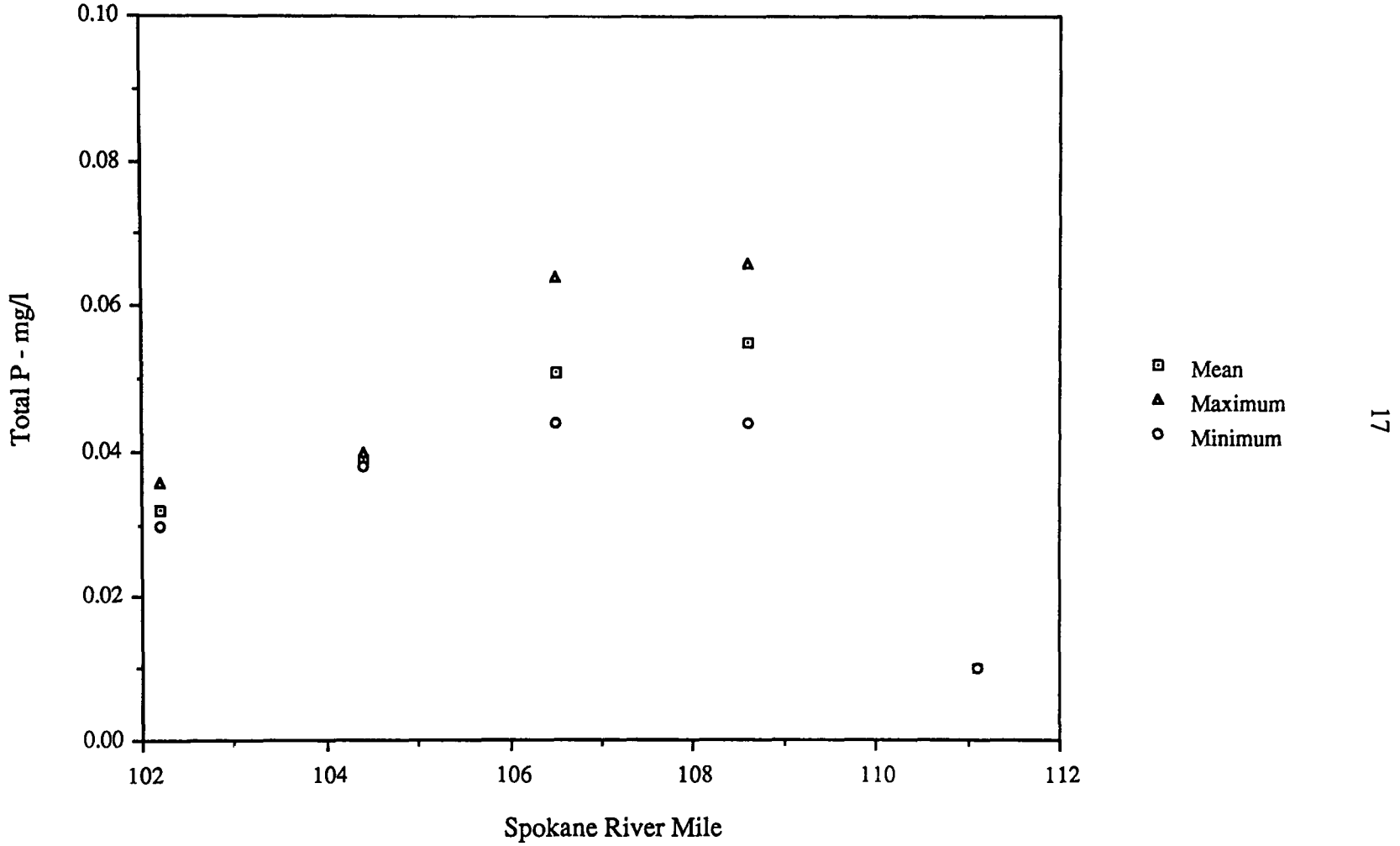

Figure 8. Mean, maximum and minimum total phosphorus in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

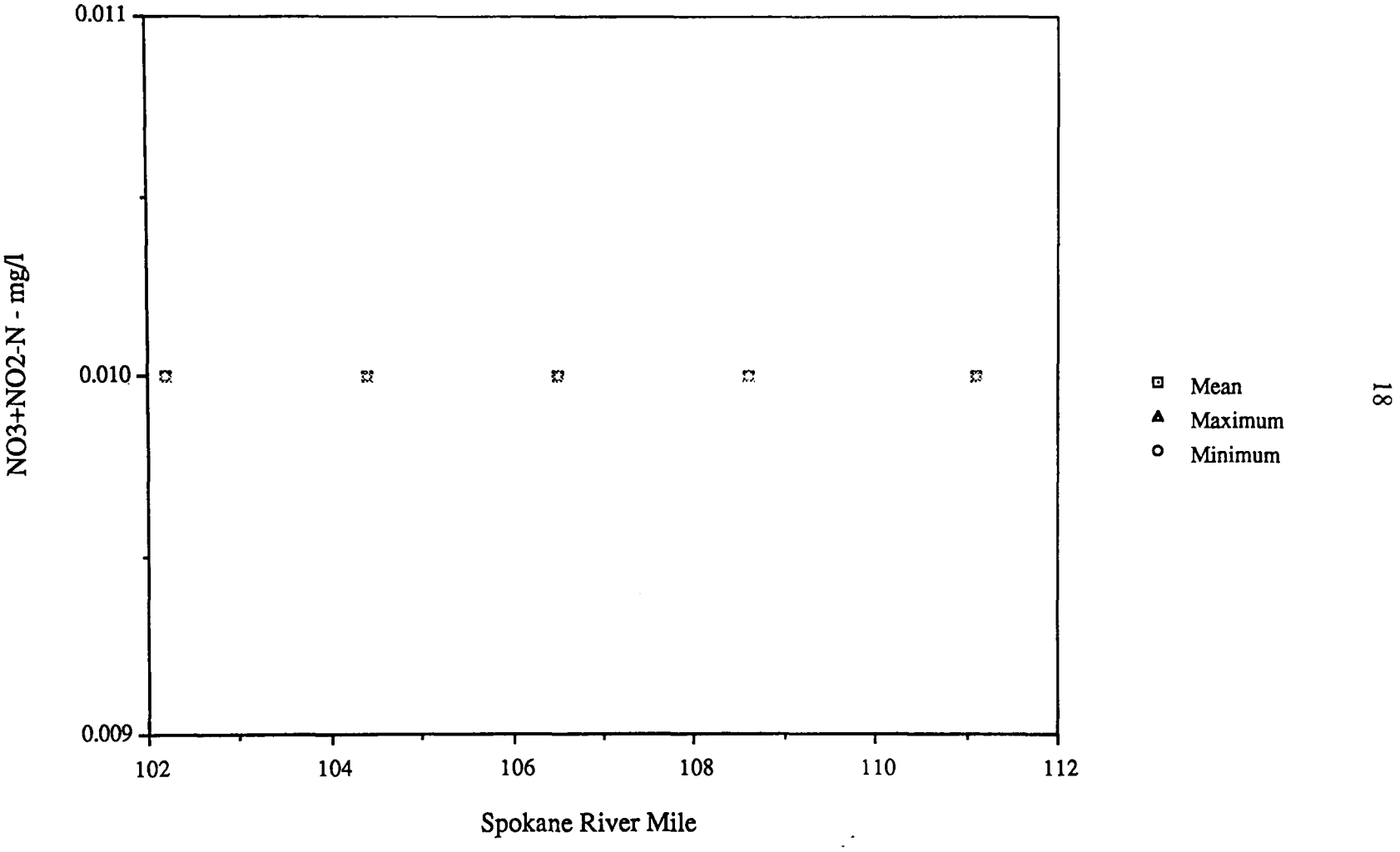

Figure 9. Mean, maximum and minimum NO2+NO3-Nitrogen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

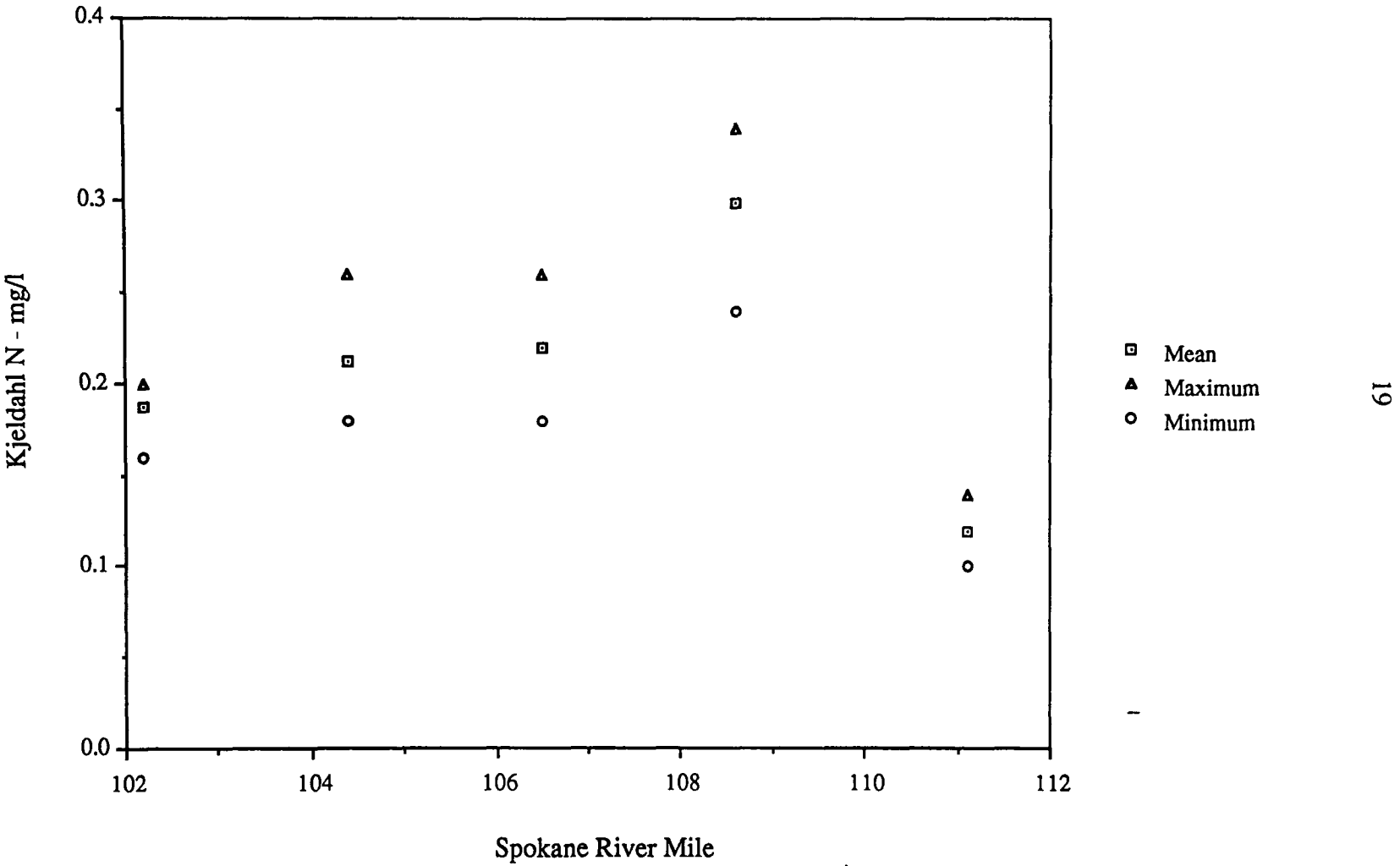

Figure 10. Mean, maximum and minimum Kjeldahl Nitrogen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

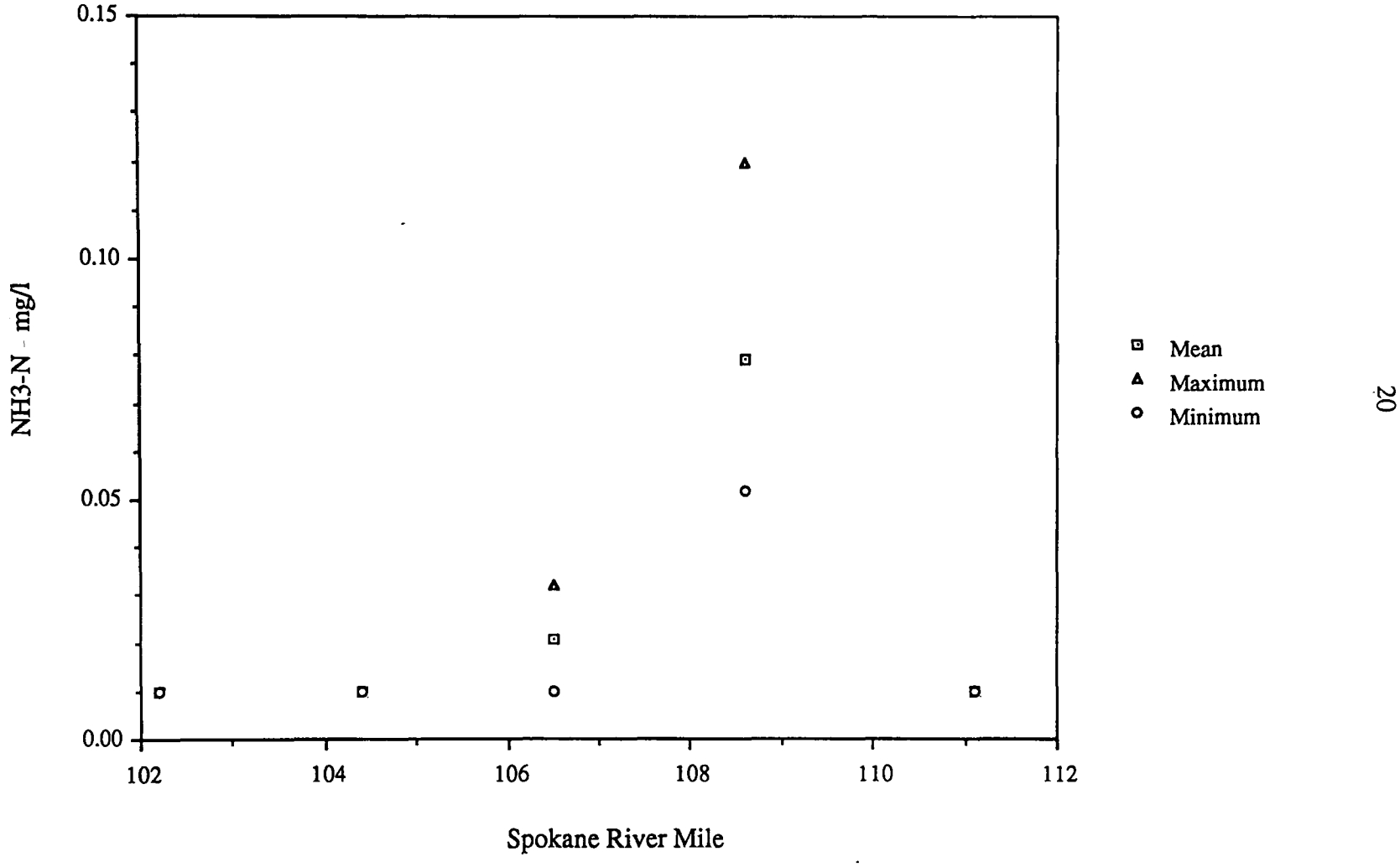

Figure 11. Mean, maximum and minimum NH3 Nitrogen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

Biological Oxygen Demand (BOD)

Ultimate BOD, L_{ult}, and rates of deoxygenation, K_1, were determined from standard, uninhibited 5-, 10-,15-,20- and 60-day BOD measurements from samples obtained on each of the three days during the field study. The parameters L_{ult} and K1 were estimated by minimizing the squared difference between the observations and the equation for BOD:

$$L = L_{ult}e^{-K_1 t} \quad (1)$$

where,

L = the BOD at any time, t, mg/l

L_{ult} = the ultimate BOD, mg/l

t = time, days

K_1 = the deoxygenation rate constant, $days^{-1}$.

The simplex method for minimizing a nonlinear function (Nelder and Mead, 1964) was used to find the minimum. The mean, maximum and minimum ultimate BOD for the receiving water stations are shown in Figure 12, the estimated values of the deoxygenation rates, K_1, are shown in Table 3.

Table 3. Mean, maximum and minimum of the estimated deoxygenation rate, K_1, in the Spokane River during the field study of August 16-18, 1988.

Spokane River Mile	Deoxygenation Rate, K_1, $days^{-1}$		
	Mean	Maximum	Minimum
111.1	0.05	0.06	0.04
108.6	0.05	0.05	0.05
106.5	0.08	0.13	0.06
104.4	0.09	0.14	0.06
102.2	0.08	0.10	0.06

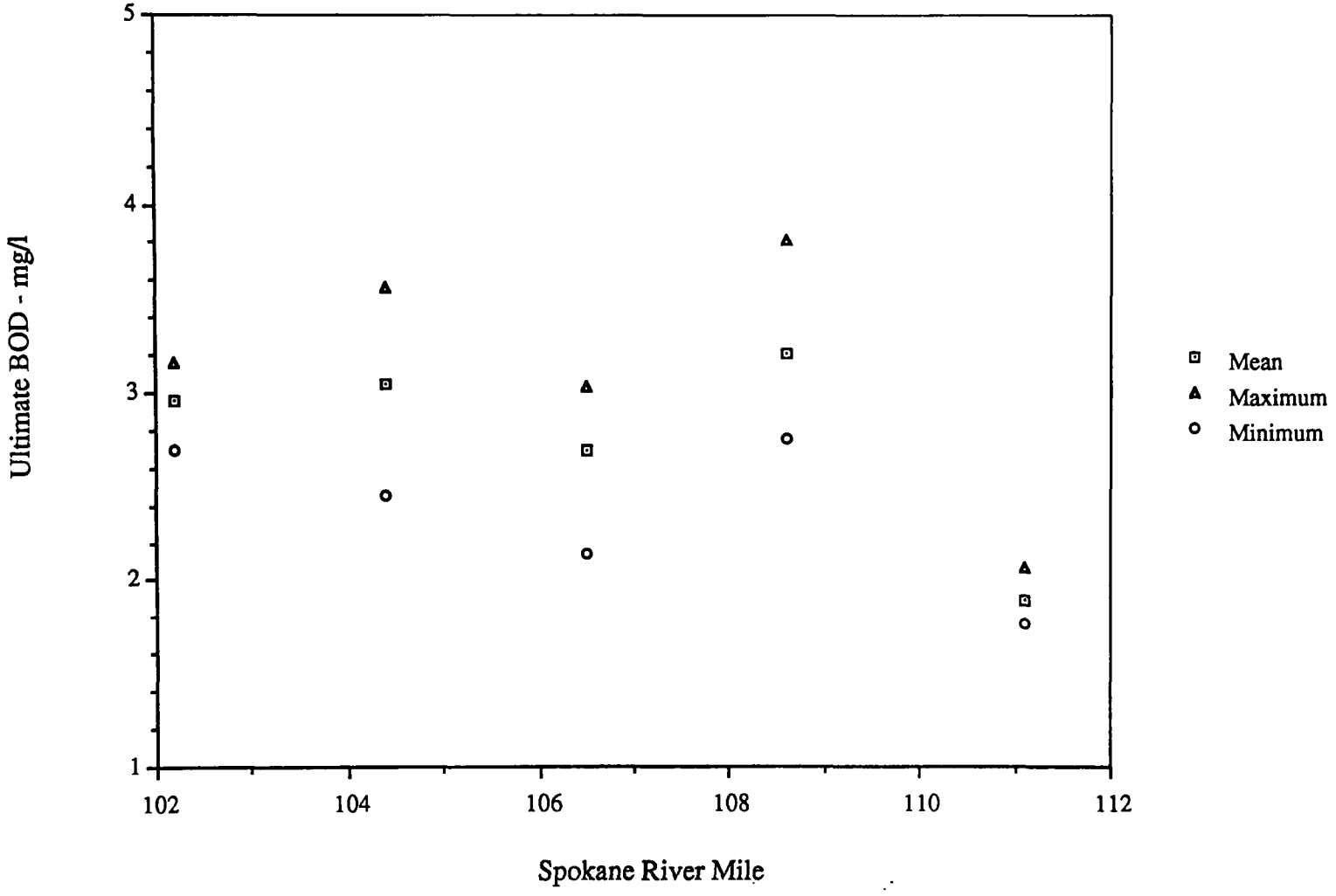

Figure 12. Mean, maximum and minimum ultimate BOD in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

Alkalinity and Hardness

Mean, maximum and minimum of observed alkalinity and hardness in the Spokane River during the field study are shown in Figures 13 and 14, respectively. Both hardness and alkalinity increase downstream implying a continuous inflow along the entire reach. Groundwater inflow (Drost and Seitz, 1978) represents a potential source.

Metals

Average concentrations of total arsenic, total recoverable cadmium, total recoverable copper, total recoverable chromium,total recoverable iron, total recoverable lead, total mercury, and total recoverable zinc are shown in Figures 15 through 22.

Point Sources

Water samples from the Coeur d'Alene STP, composited over a 24-hour period, were collected on August 16, 17, 18, and 19, 1989. The average, maximum and minimum for measurements of flow rates, nutrients, metals, BOD and conductivity are given in Table 4. Average flow of the STP on each of these days was obtained from the flow-measuring device operated by the STP. Loadings were estimated as the product of the average flow times the measured concentration of the composited sample. The loadings estimated in this way are also given in Table 4.

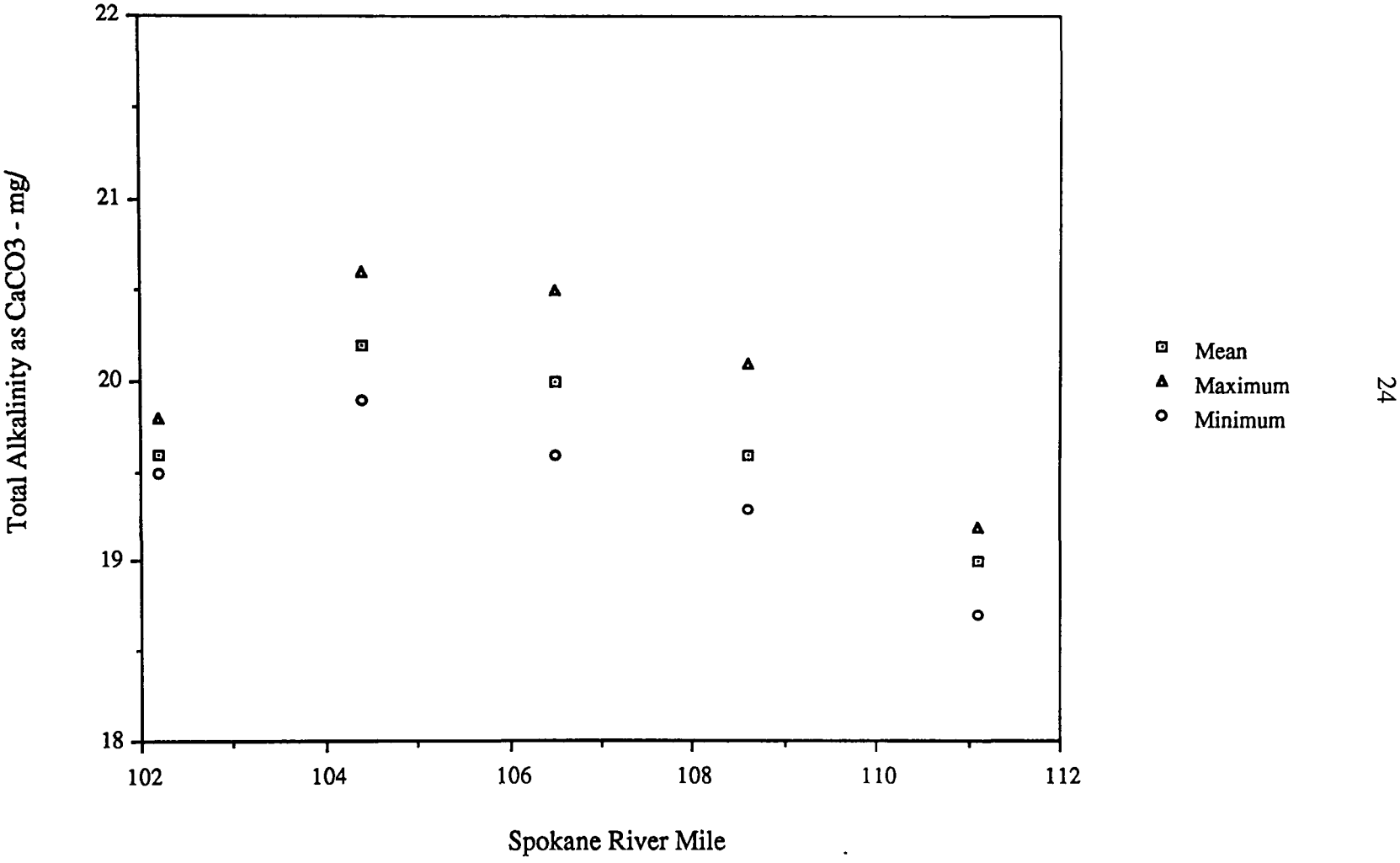

Figure 13. Mean, maximum and minimum alkalinity in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

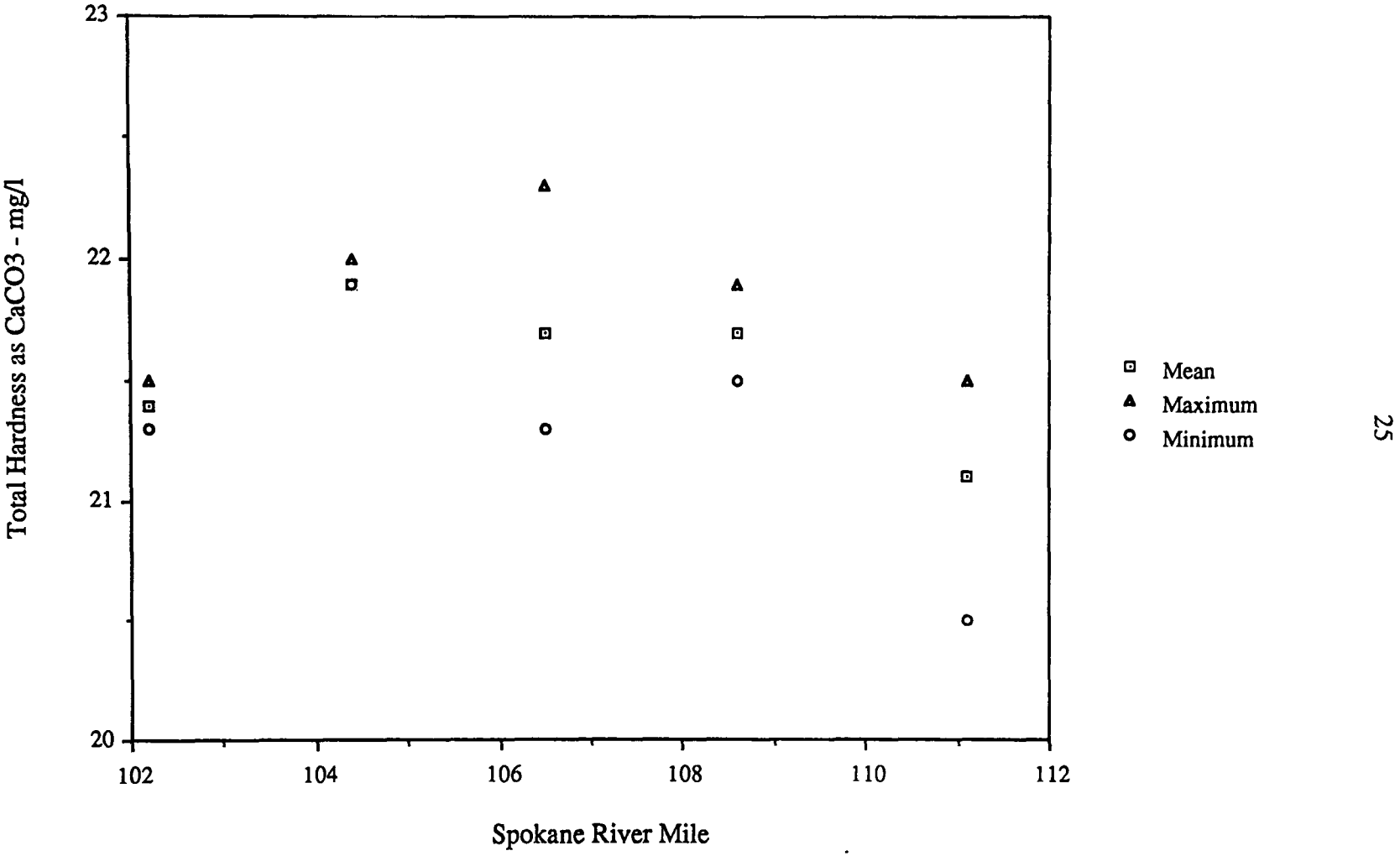

Figure 14. Mean, maximum and minimum hardness in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

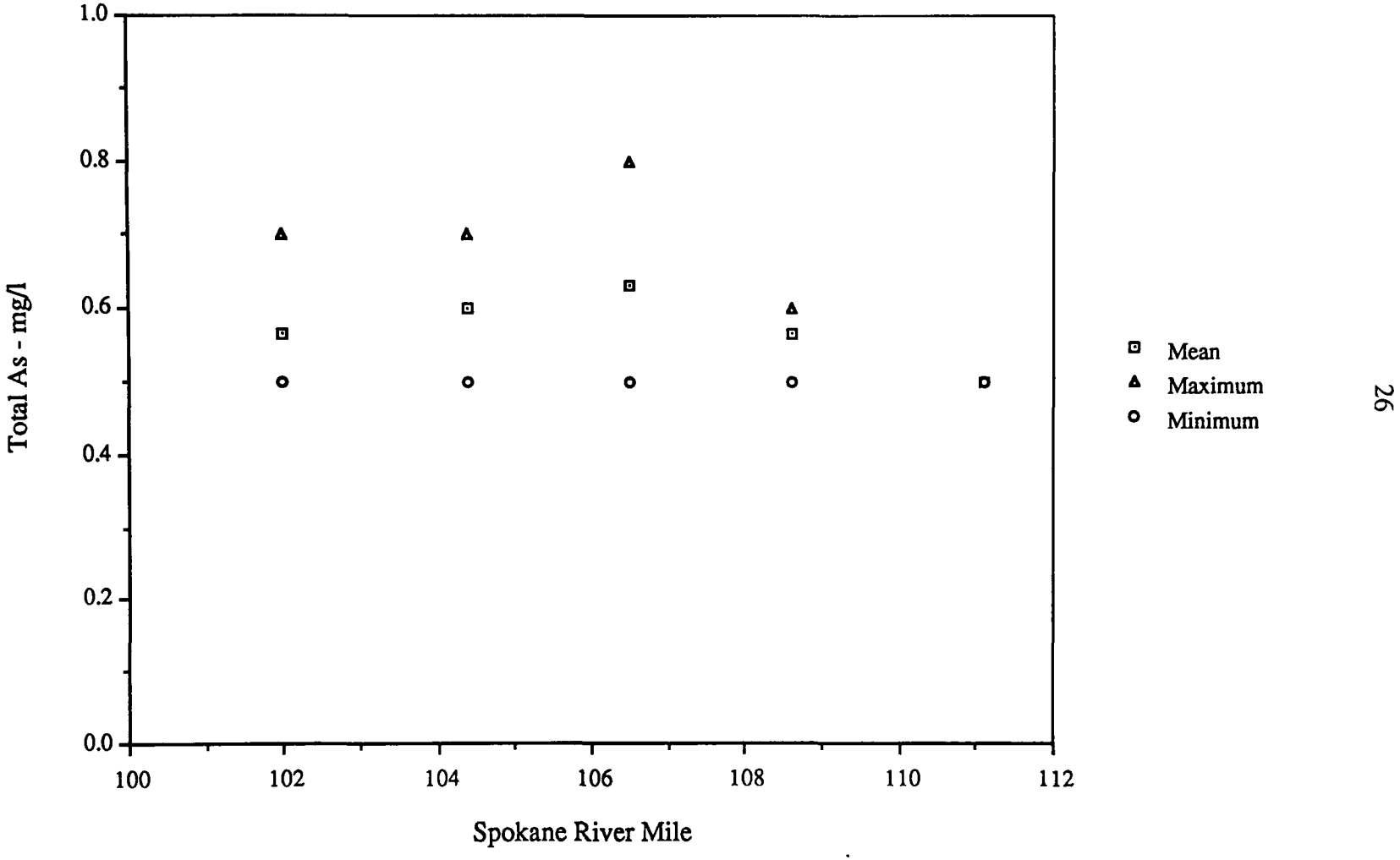

Figure 15. Mean, maximum and minimum total arsenic in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

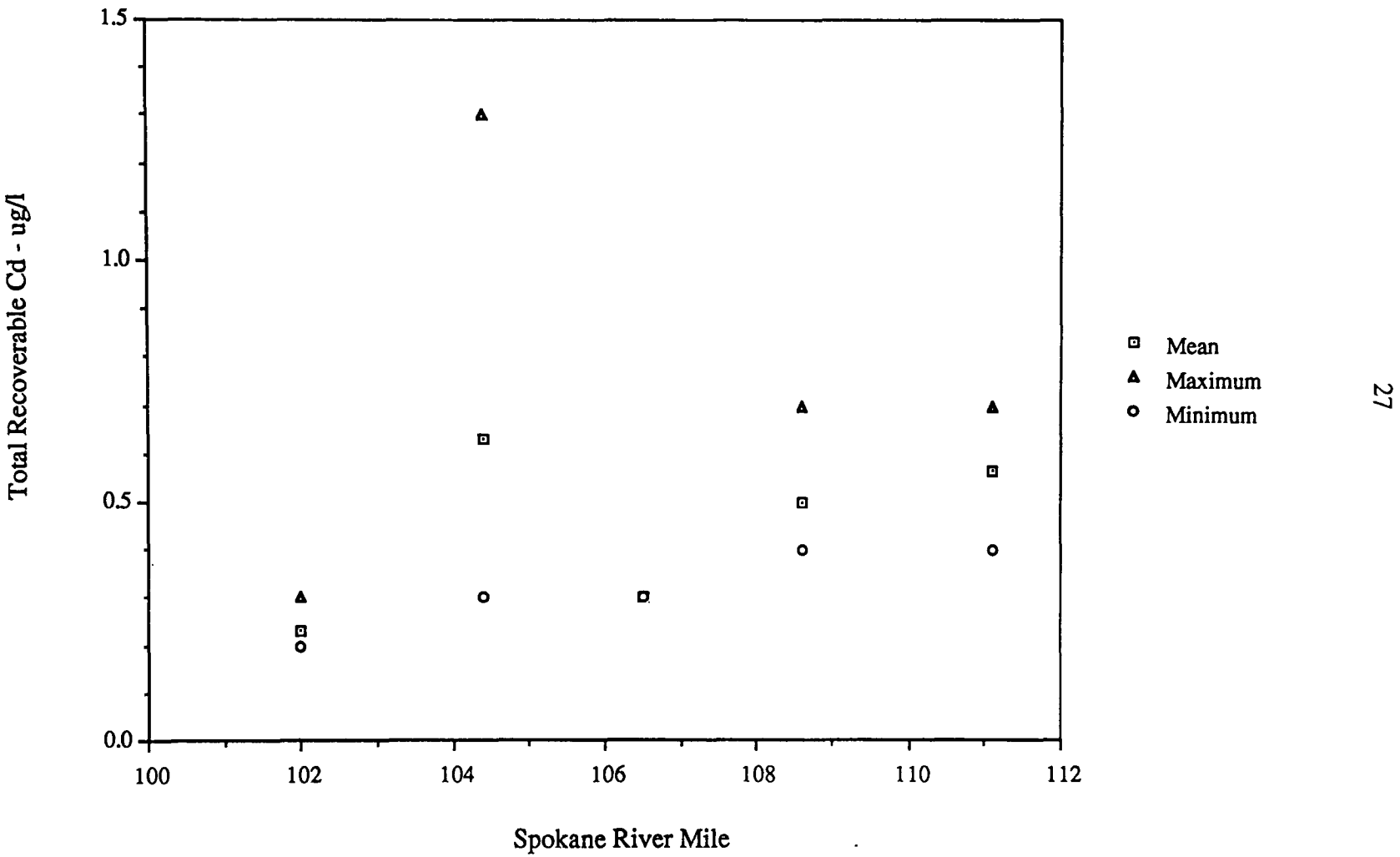

Figure 16. Mean, maximum and minimum total recoverable cadmium in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

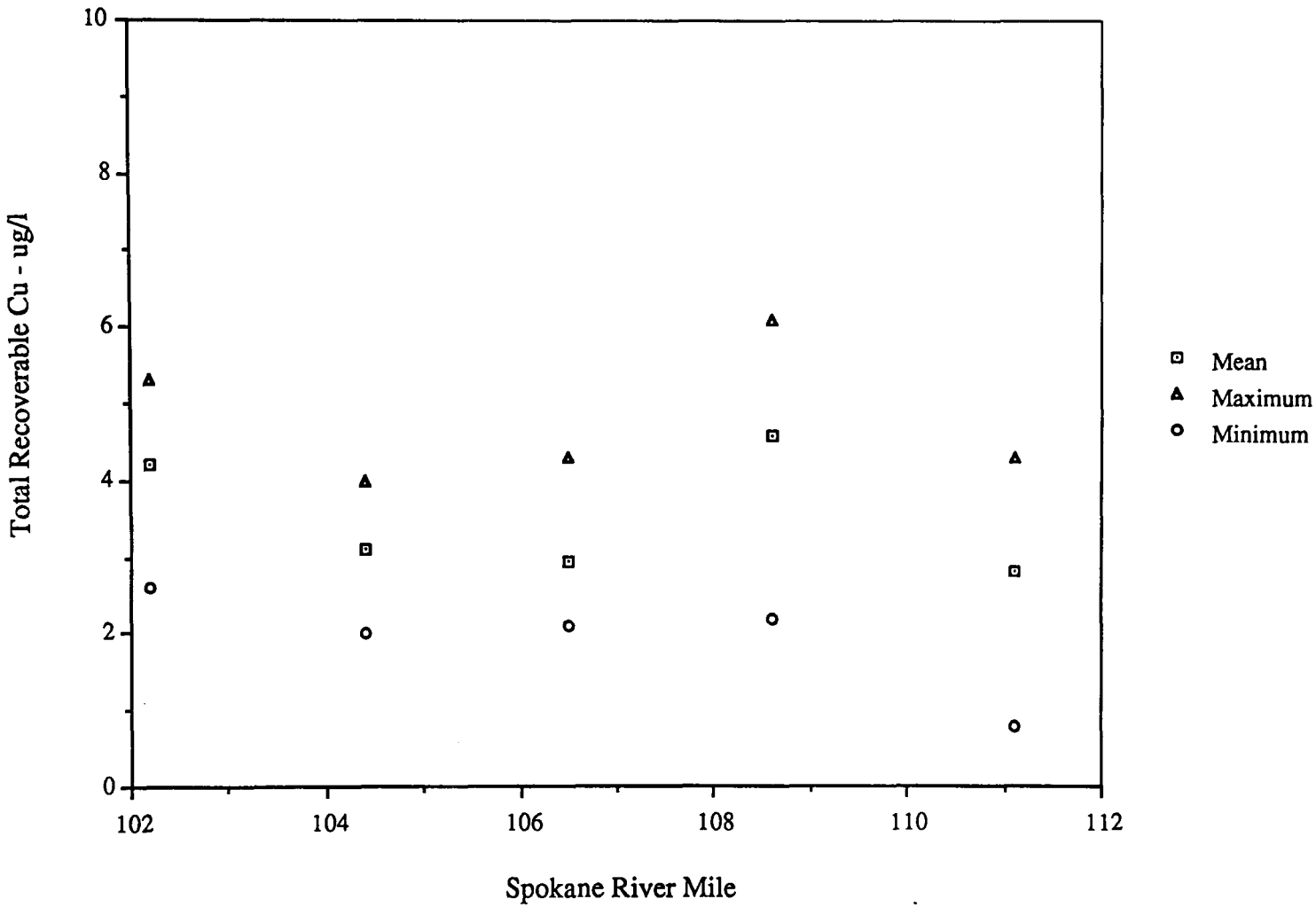

Figure 17. Mean, maximum and minimum total recoverable copper in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

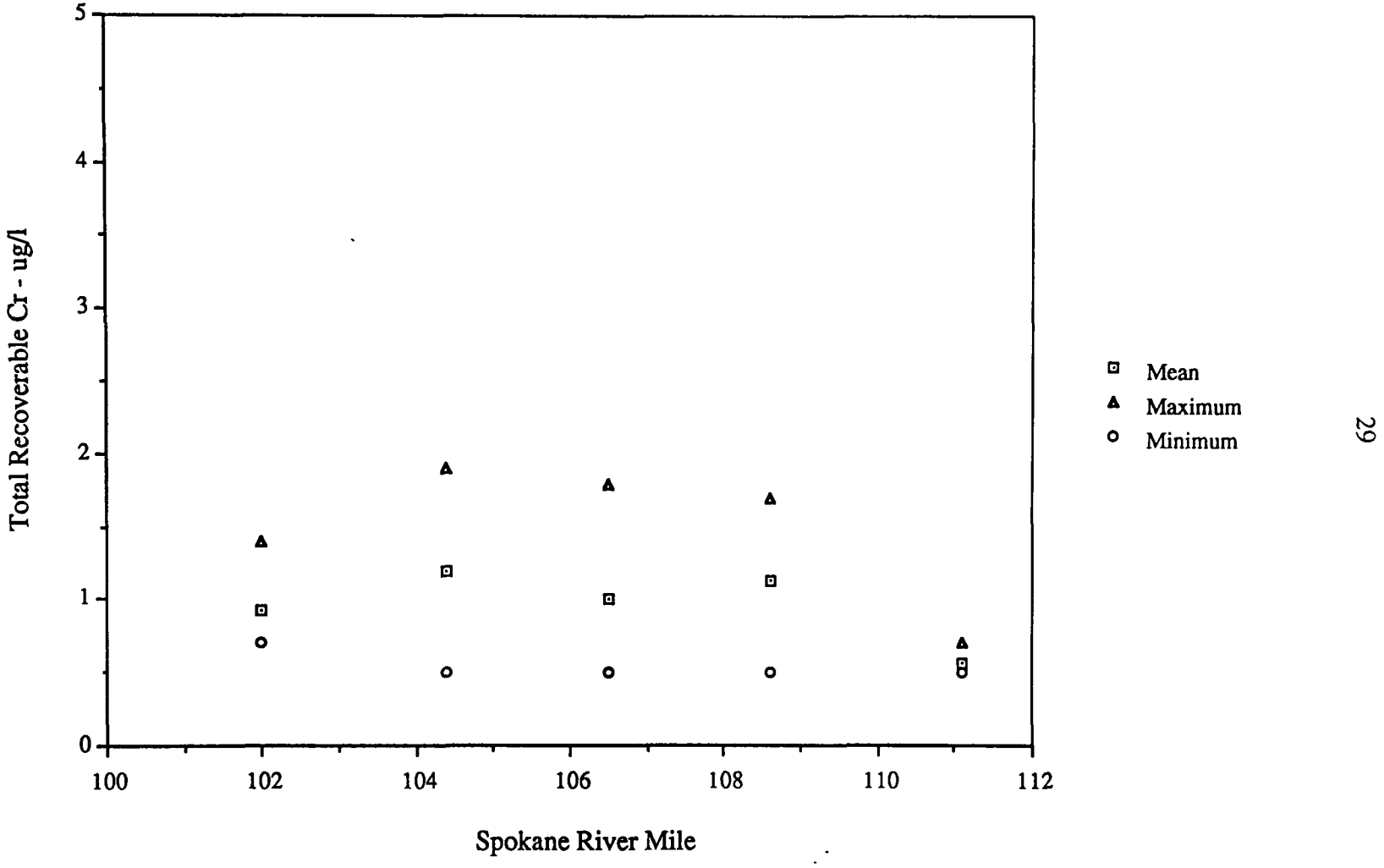

Figure 18. Mean, maximum and minimum total recoverable chromium in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

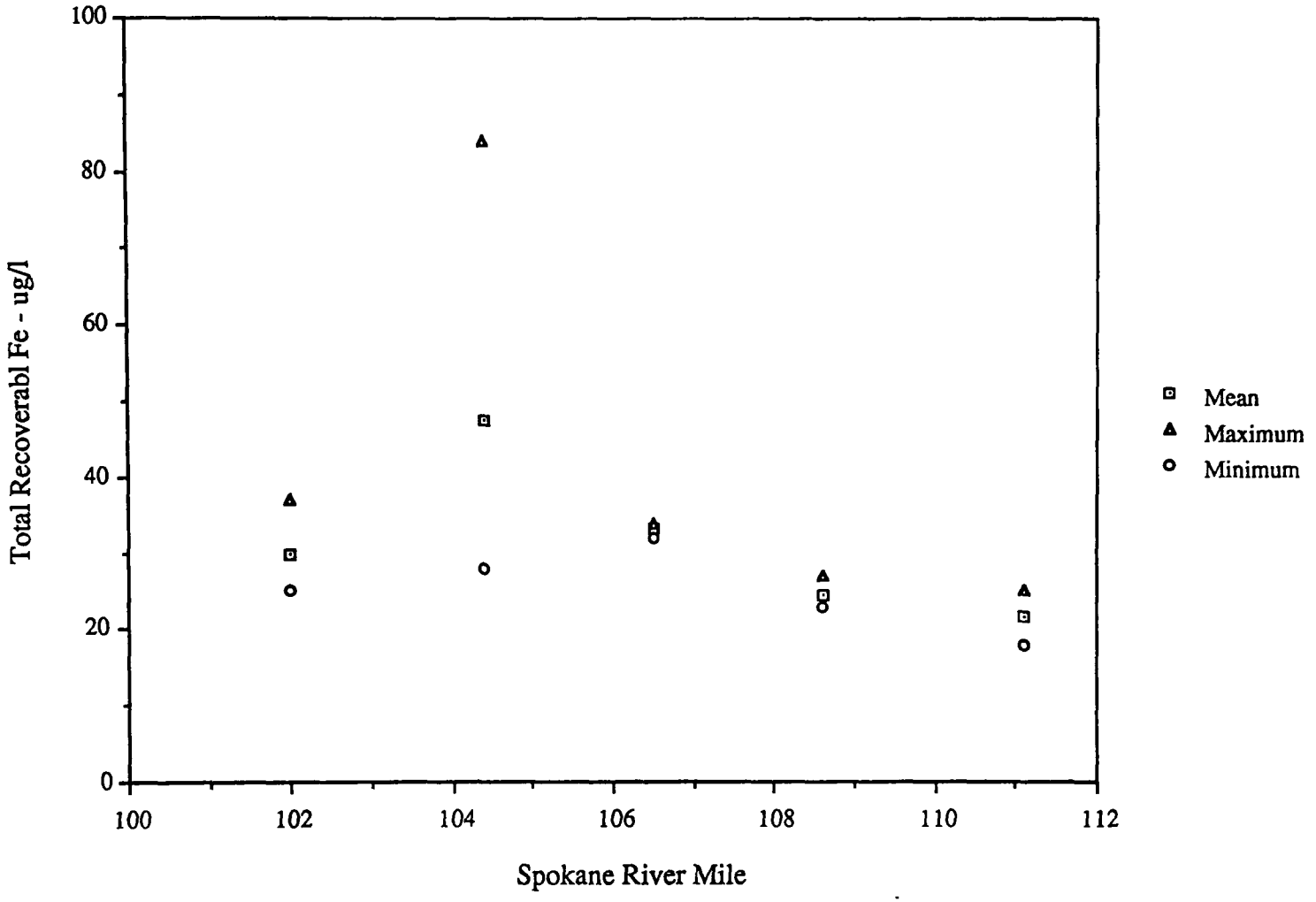

Figure 19. Mean, maximum and minimum total recoverable iron in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

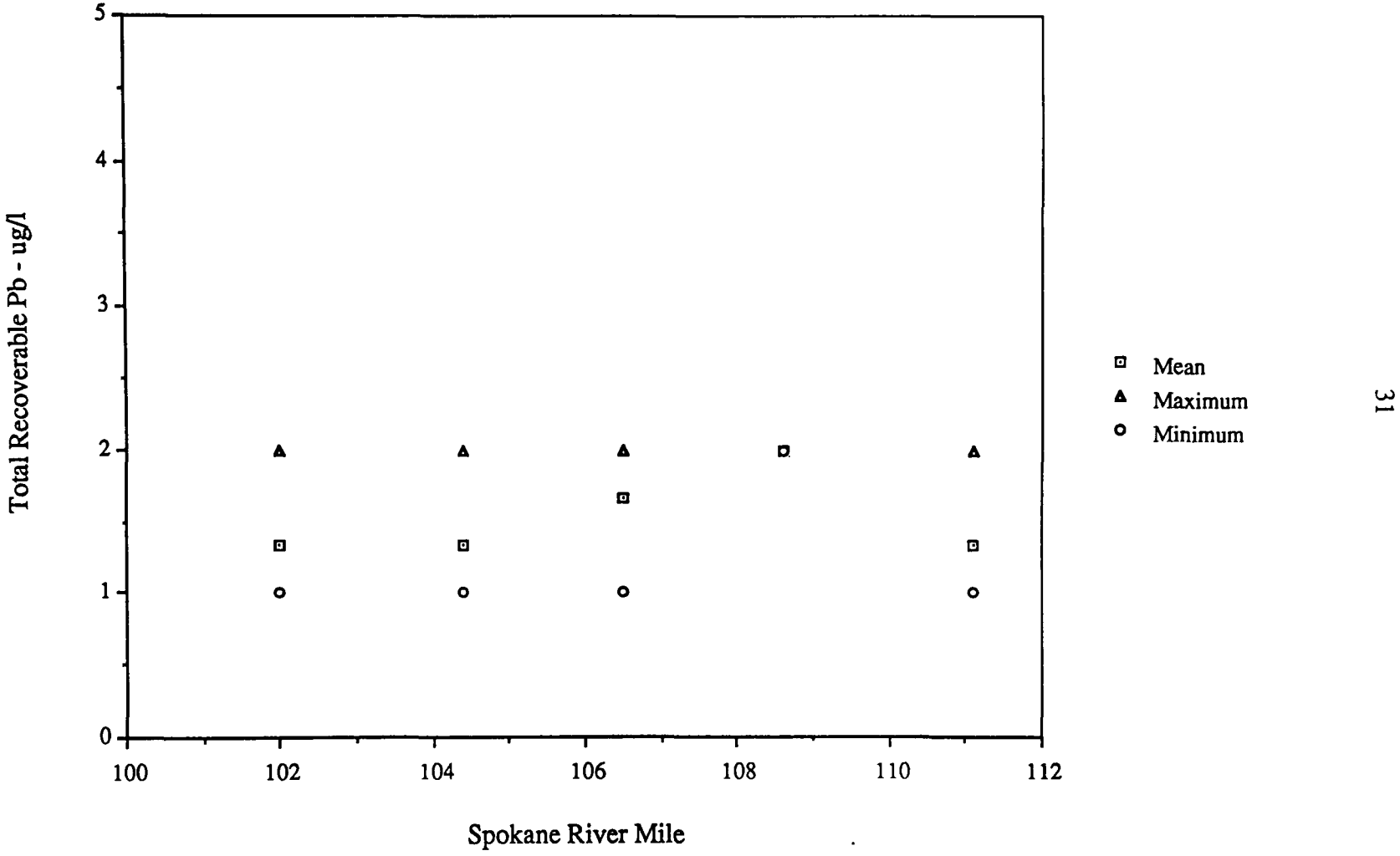

Figure 20. Mean, maximum and minimum total recoverable lead in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

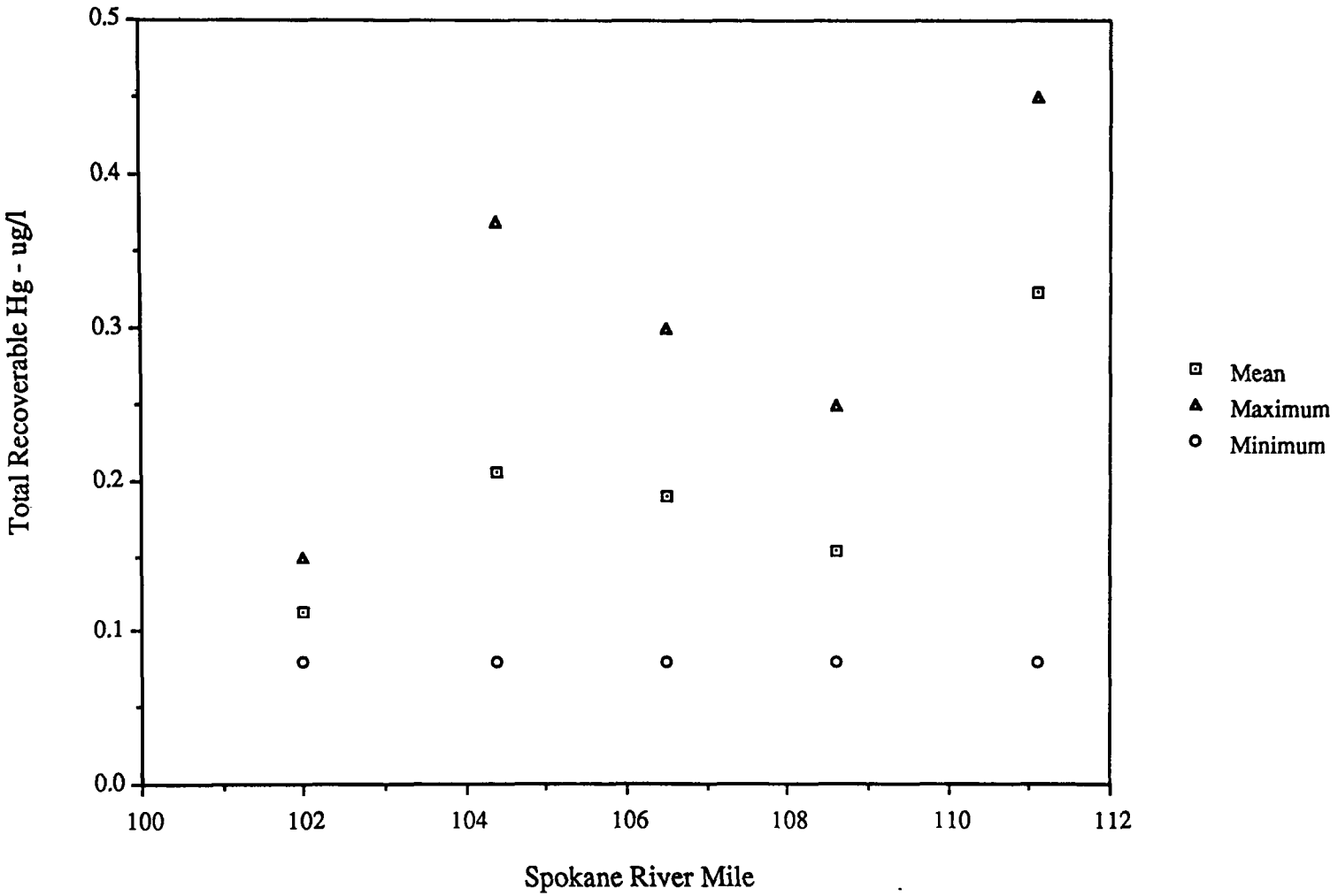

Figure 21. Mean, maximum and minimum total recoverable mercury in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

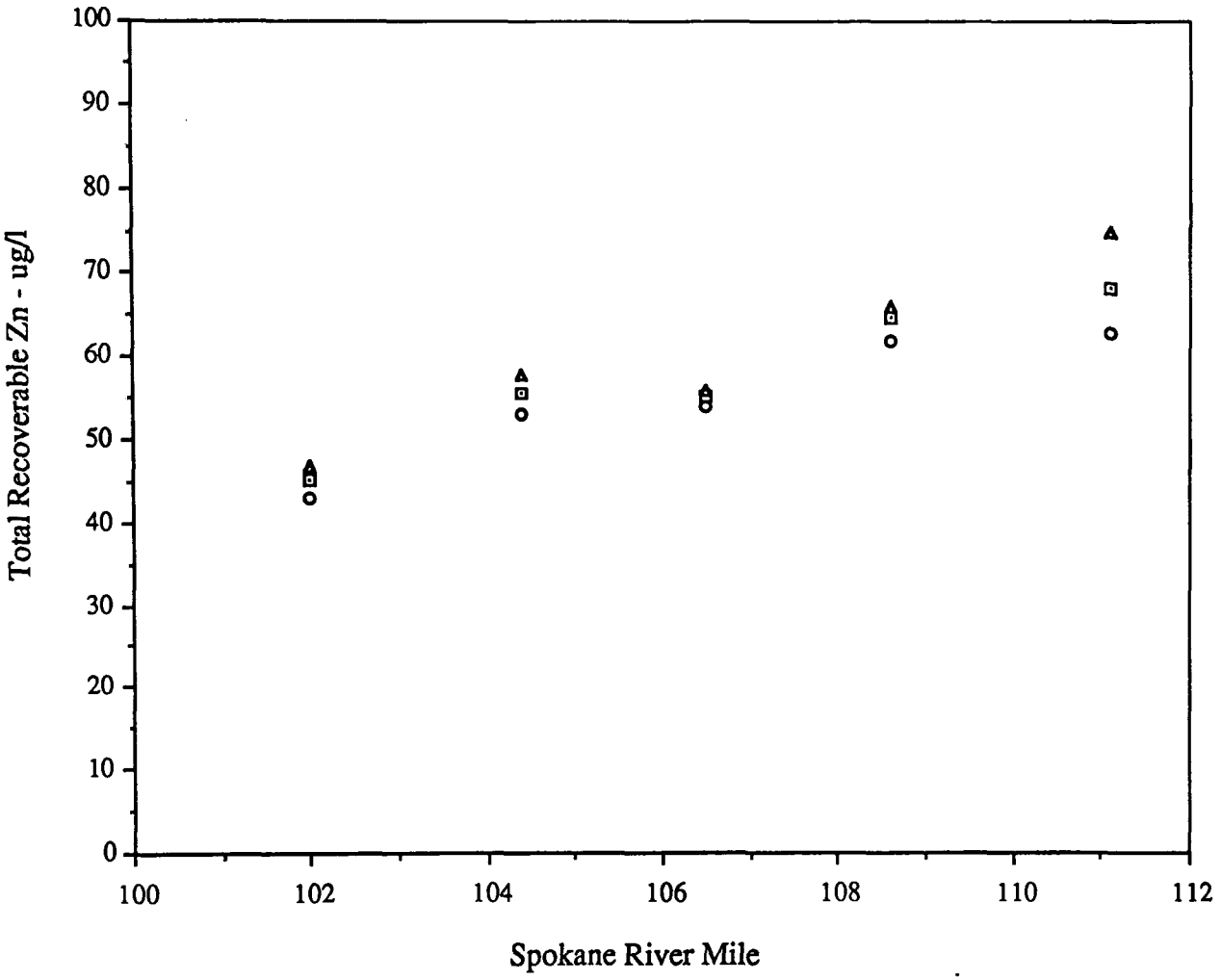

Figure 22. Mean, maximum and minimum total recoverable zinc in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

Table 4. Mean, maximum and minimum values of water quality characteristics of the effluent of City of Coeur d'Alene's STP during the field study of August 16-18, 1988. Loadings for BOD, nutrients and metals are also shown.

Parameter	Parameter Value			Loading
	Mean	Maximum	Minimum	Pounds/Day
Flow - cfs	4.24	4.45	4.09	---
Deoxygenation Rate, K_1 - $days^{-1}$	0.07	0.08	0.06	---
pH - standard units	6.7	6.7	6.7	---
Conductivity - µmho/cm	674	677	672	---
Alkalinity as $CaCO_3$ - mg/l	197	202	193	---
Hardness as $CaCO_3$ - mg/l	71	110	32	---
NH_3-Nitrogen - mg/l	15.8	16.6	14.7	360
NO_2+NO_3-Nitrogen - mg/l	1.2	1.6	0.8	28.1
Kjeldahl Nitrogen - mg/l	22.3	23.0	21.5	510
Total Phosphorus - mg/l	7.0	7.2	6.8	160
Total As - µg/l	1.5	1.8	1.4	0.04
Total Recoverable Cd - µg/l	0.70	1.0	0.5	0.02
Total Recoverable Cu - µg/l	5.9	14.4	1.6	0.10
Total Recoverable Cr - µg/l	3.5	4.0	3.1	0.08
Total Recoverable Pb - µg/l	5.3	7.0	4.0	0.10
Total Recoverable Hg - µg/l	0.11	0.17	0.08	0.003
Total Recoverable Zn - µg/l	31	51	0	0.71

CONCLUSIONS

The results of the field study conducted during the period August 16-18, 1988 were were similar to those of earlier studies (Yearsley, 1980) in a number of ways. Major conclusions derived from the results include:

- Dissolved oxygen was low at those locations in the river where a thermocline had formed. The depth of the thermocline was generally at a depth of approximately seven meters and was observed in two segments of the river. One of these segments was near Ford Rock (Spokane River Mile 104.4) and the other was in the forebay of Post Falls Dam (Spokane River Mile 102.2).
- The City of Coeur d'Alene's STP contributes a significant load of phosphorus to the Spokane River. Upstream from the STP discharge the observed concentration of total phosphorus was below the detection limit of 0.01 mg/l. The mean value of observed total phosphorus downstream from the STP was 0.055 mg/l. The estimated average loading of total phosphorus from the STP was 160 pounds/day during this period.
- In addition, the results of the August 16-18, 1988 field study showed that the City of Coeur d'Alene' STP contributed significantly to the BOD loading and to the loading of nitrogen, primarily in the form or organic nitrogen and ammonia.

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APPENDIX A

Measurements of Water Quality in the Receiving Waters and from Point Sources in the Spokane River between Coeur d'Alene and Post Falls, Idaho

In situ measurements of water quality in the Spokane River between Coeur d'Alene and Post Falls, Idaho during the period August 16-18, 1988 are given in Table A-1. Station locations can be obtained from Figure 1. Laboratory measurements of various water quality characteristics from both receiving waters and point sources are given in Table A-2. The key relating laboratory sample numbers and station location is given in Table A-3.

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88	630	#1 Right	0.9	20.34	7.45	88.3	48	7.54	
08/16/88			2.8	20.37	8.07	95.7	48	7.79	
08/16/88	650	#1 Mid	0.3	20.14	8.16	96.3	48	7.45	3.0
08/16/88			2.0	20.17	8.09	95.6	48	7.66	
08/16/88	700	#1 Left	0.8	20.20	8.08	95.5	49	7.37	
08/16/88			2.4	20.22	7.93	93.8	49	7.59	
08/16/88	713	#2 Right	0.7	20.31	7.95	94.2	53	7.45	
08/16/88			3.2	20.35	7.88	93.4	52	7.53	
08/16/88	718	#2 Mid	0.7	20.39	7.92	94.0	51	7.55	4.0
08/16/88			2.8	20.31	7.91	93.7	49	7.41	
08/16/88	723	#2 Left	0.7	20.24	7.97	94.3	49	7.52	
08/16/88			2.1	19.99	7.88	92.8	50	7.29	
08/16/88	734	#3 Right	0.3	20.80	7.78	93.0	52	7.51	
08/16/88			2.6	20.86	7.60	91.0	53	7.20	
08/16/88	746	#3 Mid	0.9	20.94	7.84	94.0	53	7.21	3.8
08/16/88			3.3	20.97	7.77	93.2	53	7.24	
08/16/88	754	#3 Left	0.8	20.91	8.06	96.6	53	7.32	
08/16/88			2.4	20.90	7.96	95.4	53	7.04	
08/16/88	805	#3A Right	0.8	21.26	7.23	87.2	53	6.75	
08/16/88			2.8	21.30	7.18	86.7	53	7.11	
08/16/88	813	#3A Mid	0.9	21.27	7.68	92.7	54	7.29	3.5
08/16/88			3.1	21.24	7.87	94.9	53	7.28	
08/16/88	820	#3A Left	0.9	21.31	7.86	94.9	52	7.16	
08/16/88			3.1	21.16	7.87	94.7	53	7.25	
08/16/88	833	#4 Right	0.6	21.42	8.10	98.0	53	7.18	4.0
08/16/88			5.5	21.45	8.05	97.5	53	7.38	
08/16/88	842	#4 Mid	0.5	21.48	8.08	97.9	52	7.04	3.8
08/16/88			5.1	21.33	7.79	94.0	52	7.40	
08/16/88	851	#4 Left	0.8	21.50	7.97	96.6	53	7.01	
08/16/88			3.5	21.52	7.97	96.6	53	7.36	
08/16/88	905	#4A Right	0.7	21.72	8.61	104.8	53	7.07	
08/16/88			2.6	21.75	8.57	104.4	52	7.50	
08/16/88	906	#4A Mid	0.7	21.82	8.52	103.8	54	7.48	3.5
08/16/88			5.6	21.81	8.46	103.1	52	7.52	
08/16/88	910	#4A Left	0.9	21.82	8.51	103.7	52	7.38	3.3
08/16/88			6.5	21.78	8.32	101.4	52	7.47	
08/16/88	918	#5 Right	0.7	21.93	8.71	106.4	52	7.32	
08/16/88			5.9	21.88	8.40	102.5	52	7.57	
08/16/88	929	#5 Mid	0.8	21.92	8.72	106.5	52	7.52	
08/16/88			5.9	21.82	8.65	105.4	52	7.77	
08/16/88	935	#5 Left	0.9	21.95	8.73	106.7	52	7.46	3.6
08/16/88			5.0	21.90	8.73	106.6	52	7.84	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88	954	#6 Right	0.8	22.04	8.26	101.1	52	7.43	4.5
08/16/88			2.0	22.03	8.29	101.4	51	7.53	
08/16/88			5.0	21.91	8.15	99.5	52	7.50	
08/16/88			7.0	21.91	7.64	93.3	52	7.34	
08/16/88			7.7	21.81	7.09	86.4	51	7.13	
08/16/88	1001	#6 Mid	0.8	22.05	8.41	102.9	52	7.48	4.2
08/16/88			2.0	22.03	8.39	102.6	52	7.33	
08/16/88			5.0	21.98	8.33	101.9	52	7.64	
08/16/88			7.0	21.83	7.53	91.8	52	7.26	
08/16/88	1008	#6 Left	0.2	22.05	8.46	103.6	52	7.37	
08/16/88			2.0	22.04	8.39	102.7	52	7.52	
08/16/88			3.0	21.99	8.42	102.9	52	7.58	
08/16/88	1020	#8 Right	0.9	22.05	8.31	101.8	51	7.30	4.5
08/16/88			2.0	21.98	8.26	101.0	51	7.40	
08/16/88			5.0	21.90	8.18	99.9	51	7.53	
08/16/88			7.0	21.82	7.88	96.0	51	7.42	
08/16/88			8.9	21.48	4.46	54.0	51	6.85	
08/16/88	1030	#8 Mid	0.9	22.02	8.35	102.2	52	7.39	
08/16/88			2.0	22.05	8.35	102.2	52	7.44	
08/16/88	1035	#8 Left	0.9	22.08	8.46	103.6	51	7.46	
08/16/88	1044	P.F. Dam	0.8	22.06	8.18	100.2	52	7.44	
08/16/88			2.0	22.01	8.07	98.8	51	7.41	
08/16/88			5.0	21.89	7.82	95.5	52	7.26	
08/16/88			7.0	21.73	6.65	80.9	51	6.91	
08/16/88			10.0	21.12	3.13	37.6	51	6.63	
08/16/88			12.5	19.04	0.18	2.0	51	6.46	
08/16/88	1430	Lake Ent	1.1	21.74	7.56	92.1	49	7.21	
08/16/88			2.0	21.58	7.55	91.7	50	7.28	
08/16/88			5.0	21.23	7.62	91.9	49	7.36	
08/16/88	1437	#1 Right	1.0	21.34	8.29	100.1	49	7.56	
08/16/88			2.0	21.34	8.23	99.4	49	7.66	
08/16/88	1441	#1 Mid	1.0	21.42	8.16	98.7	49	7.48	
08/16/88			2.2	21.11	8.25	99.2	50	7.64	
08/16/88	1445	#1 Left	1.0	21.42	8.34	100.9	50	7.51	
08/16/88			3.3	21.03	8.42	101.2	50	7.68	
08/16/88	1452	#2 Right	1.0	21.33	8.09	97.7	59	7.22	
08/16/88			3.0	21.01	8.28	99.4	55	7.37	
08/16/88	1454	#2 Mid	1.0	21.16	8.27	99.5	51	7.44	
08/16/88			3.2	21.01	8.16	97.9	55	7.38	
08/16/88	1500	#2 Left	1.0	21.08	8.47	101.8	51	7.64	
08/16/88			2.0	21.01	8.40	100.8	51	7.67	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88	1506	#3 Right	1.0	21.45	8.33	100.9	54	7.21	
08/16/88			2.6	21.32	8.18	98.8	53	7.28	
08/16/88	1510	#3 Mid	1.0	21.37	8.34	100.8	53	7.28	
08/16/88			3.5	21.31	8.23	99.4	54	7.34	
08/16/88	1515	#3 Left	1.0	21.45	8.59	104.0	53	7.44	
08/16/88			2.2	21.38	8.28	100.1	53	7.36	
08/16/88	1520	#3A Right	1.0	21.79	8.00	97.4	53	7.11	
08/16/88			3.0	21.47	7.97	96.5	53	7.18	
08/16/88	1525	#3A Mid	1.0	21.79	8.33	101.5	53	7.27	
08/16/88			3.2	21.47	8.64	104.6	53	7.41	
08/16/88	1528	#3A Left	1.0	21.78	8.53	103.9	53	7.34	
08/16/88			2.5	21.49	8.80	106.5	53	7.34	
08/16/88	1536	#4 Right	1.0	22.14	8.46	103.8	53	7.27	
08/16/88			5.5	21.44	7.82	94.7	53	7.15	
08/16/88	1541	#4 Mid	1.0	22.19	8.60	105.6	54	7.36	
08/16/88			5.4	21.40	8.15	98.5	52	7.24	
08/16/88	1545	#4 Left	1.0	22.25	8.73	107.3	52	7.47	
08/16/88	1550	#4A Right	1.0	22.53	8.62	106.5	53	7.94	
08/16/88			1.7	22.21	8.64	106.1	53	7.95	
08/16/88	1557	#4A Mid	1.0	22.43	9.13	112.5	54	7.68	
08/16/88			6.7	21.80	7.63	93.0	53	7.37	
08/16/88	1603	#5 Right	1.0	22.86	8.82	109.6	53	7.57	
08/16/88			5.8	21.95	8.50	103.8	52	7.46	
08/16/88	1606	#5 Mid	1.0	22.78	8.73	108.3	53	7.68	
08/16/88			6.5	21.91	8.39	102.4	52	7.51	
08/16/88	1609	#5 Left	1.0	22.66	8.87	109.8	53	7.70	
08/16/88			3.1	22.10	8.81	108.0	52	7.72	
08/16/88	1615	#6 Right	1.0	22.57	8.71	107.7	52	7.61	
08/16/88			2.0	22.41	8.56	105.5	52	7.55	
08/16/88			5.0	22.02	8.44	103.3	51	7.39	
08/16/88			8.0	22.41	8.56	105.5	52	7.55	
08/16/88	1620	#6 Mid	1.0	22.50	8.71	107.5	53	7.59	
08/16/88			2.0	22.36	8.63	106.2	52	7.59	
08/16/88			5.0	22.05	8.46	103.6	52	7.61	
08/16/88			7.0	21.86	6.66	81.2	52	6.95	
08/16/88			10.0	21.09	4.43	53.3	52	6.69	
08/16/88			11.0	20.71	3.80	45.3	53	6.62	
08/16/88	1630	#6 Left	1.0	22.47	8.69	107.3	52	7.54	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88			2.0	22.33	8.59	105.7	52	7.63	
08/16/88			5.0	22.01	8.22	100.6	52	7.31	
08/16/88			8.9	21.46	4.64	56.2	53	6.78	
08/16/88	1645	#8 Right	1.0	22.67	8.52	105.5	51	7.47	
08/16/88			2.0	22.61	8.25	102.0	51	7.42	
08/16/88			5.0	22.07	8.30	101.6	51	7.40	
08/16/88			7.2	21.88	7.29	88.9	50	7.17	
08/16/88			10.0	21.45	2.35	28.5	52	6.54	
08/16/88	1650	#8 Mid	1.0	22.58	8.46	104.6	52	7.44	
08/16/88			2.0	22.46	8.36	103.1	52	7.41	
08/16/88	1656	#8 Left	1.0	22.47	8.67	106.9	52	7.71	
08/16/88	1700	P.F. Dam	1.0	22.68	8.20	101.6	53	7.44	
08/16/88			2.0	22.63	8.32	103.0	51	7.50	
08/16/88			5.0	22.03	8.19	100.3	51	7.44	
08/16/88			7.0	21.89	6.88	84.0	52	7.09	
08/16/88			10.0	21.06	2.13	25.6	52	6.56	
08/16/88			11.9	19.49	0.01	0.1	52	6.37	
08/17/88	630	#1 Right	1.0	20.59	7.93	94.5	49	7.47	3.4
08/17/88			2.8	20.53	7.88	93.7	48	7.44	
08/17/88	640	#1 Mid	1.0	20.60	7.81	93.1	49	7.41	
08/17/88			2.0	20.65	7.67	91.4	48	7.36	
08/17/88	646	#1 Left	1.0	20.63	7.53	89.7	48	7.30	
08/17/88			2.9	20.63	7.56	90.2	48	7.31	
08/17/88	656	#2 Right	1.0	20.85	7.88	94.3	58	7.30	
08/17/88			2.8	20.86	7.73	92.5	58	7.26	
08/17/88	700	#2 Mid	1.0	20.93	7.80	93.4	54	7.26	
08/17/88			2.9	20.66	7.89	94.1	54	7.44	
08/17/88	704	#2 Left	1.0	20.90	7.70	92.3	50	7.38	
08/17/88			2.2	20.75	7.83	93.6	50	7.46	
08/17/88	711	#3 Right	1.0	20.49	7.60	90.4	52	7.26	
08/17/88			3.0	20.47	7.46	88.7	52	7.23	
08/17/88	720	#3 Mid	1.0	20.54	7.88	93.7	52	7.34	4.1
08/17/88			3.7	20.56	7.75	92.2	52	7.29	
08/17/88	730	#3 Left	1.0	20.51	8.14	96.8	51	7.47	
08/17/88			2.6	20.48	7.89	93.7	51	7.41	
08/17/88	742	#3A Right	1.0	20.89	7.67	91.8	53	7.20	
08/17/88			3.3	20.80	7.72	92.3	53	7.20	
08/17/88	747	#3A Mid	1.0	20.94	7.50	89.9	53	7.15	
08/17/88			3.2	20.80	7.69	92.0	53	7.22	
08/17/88	750	#3A Left	1.0	20.93	7.53	90.2	53	7.15	
08/17/88			3.0	20.75	7.77	92.8	53	7.23	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	755	#4 Right	1.0	21.29	8.01	96.6	52	7.25	4.0
08/17/88			2.0	21.35	7.92	95.8	54	7.24	
08/17/88			5.0	21.32	7.92	95.6	53	7.23	
08/17/88	806	#4 Mid	1.0	21.36	8.05	97.2	53	7.27	3.9
08/17/88			2.0	21.37	7.96	96.2	53	7.15	
08/17/88			5.0	21.32	7.97	96.3	52	7.24	
08/17/88	814	#4 Left	1.0	21.32	8.24	99.5	52	7.32	
08/17/88			2.0	21.36	8.22	99.3	53	7.33	
08/17/88	823	#4A Right	1.0	21.42	8.71	105.4	52	7.47	
08/17/88			1.5	21.40	8.63	104.4	52	7.47	
08/17/88	827	#4A Mid	1.0	21.60	8.56	104.0	53	7.37	3.6
08/17/88			1.5	21.40	8.63	104.4	52	7.47	
08/17/88	831	#4A Left	1.0	21.63	8.52	103.5	53	7.34	
08/17/88			2.0	21.63	8.42	102.2	53	7.42	
08/17/88			5.0	21.63	8.39	101.9	53	7.45	
08/17/88			6.5	21.62	8.37	101.6	52	7.39	
08/17/88	840	#5 Right	1.0	21.73	8.44	102.7	52	7.38	3.5
08/17/88			2.0	21.78	8.30	101.0	53	7.34	
08/17/88			5.9	21.70	8.25	100.3	52	7.36	
08/17/88	847	#5 Mid	1.0	21.75	8.42	102.6	52	7.35	
08/17/88			2.0	21.78	8.38	102.1	53	7.38	
08/17/88			5.0	21.75	8.29	100.9	52	7.37	
08/17/88			6.1	21.72	8.25	100.4	52	7.35	
08/17/88	857	#5 Left	1.0	21.76	8.42	102.6	52	7.37	3.5
08/17/88			2.0	21.78	8.32	101.4	52	7.35	
08/17/88			5.0	21.72	8.33	101.4	52	7.40	
08/17/88			6.0	21.65	8.30	100.8	52	7.38	
08/17/88	905	#6 Right	1.0	21.81	8.20	100.0	52	7.38	3.7
08/17/88			2.0	21.83	8.17	99.6	52	7.38	
08/17/88			5.0	21.84	8.17	99.6	52	7.39	
08/17/88			7.0	21.83	8.10	98.8	52	7.38	
08/17/88			7.8	21.58	6.97	84.6	52	6.91	
08/17/88	915	#6 Mid	1.0	21.89	8.30	101.4	52	7.39	
08/17/88			2.0	21.89	8.23	100.5	52	7.43	
08/17/88			5.0	21.83	7.52	91.7	52	7.16	
08/17/88			7.0	21.79	7.54	91.8	52	7.11	
08/17/88			10.0	21.02	4.55	54.6	52	6.71	
08/17/88			12.8	19.87	1.81	21.2	52	6.47	
08/17/88	930	#6 Left	1.0	21.90	8.32	101.6	52	7.34	
08/17/88			2.0	21.90	8.28	101.0	52	7.41	
08/17/88			5.0	21.86	8.21	100.2	52	7.42	
08/17/88			7.5	21.83	7.86	95.8	52	7.23	
08/17/88			10.0	21.11	3.02	36.3	55	6.61	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	942	#8 Right	1.0	21.82	8.21	100.1	52	7.39	4.0
08/17/88			2.0	21.85	8.17	99.6	52	7.39	
08/17/88			5.0	21.83	8.02	97.7	52	7.38	
08/17/88			7.0	21.79	7.67	93.4	52	7.25	
08/17/88			10.0	21.38	2.79	33.7	51	6.60	
08/17/88	952	#8 Mid	1.0	21.88	8.22	100.3	52	7.20	
08/17/88			2.0	21.88	8.18	99.9	52	7.31	
08/17/88			5.0	21.85	8.17	99.6	51	7.35	
08/17/88			7.0	21.82	7.92	96.5	51	7.26	
08/17/88			8.0	21.75	6.94	84.5	51	6.96	
08/17/88	1002	#8 Left	1.0	21.78	8.30	101.1	52	7.37	
08/17/88	1008	P.F. Dam	1.0	21.91	7.94	97.0	52	7.26	
08/17/88			2.0	21.92	7.98	97.5	52	7.26	
08/17/88			5.0	21.88	7.79	95.0	52	7.21	
08/17/88			7.0	21.83	7.73	94.2	52	7.15	
08/17/88			10.0	21.19	1.63	19.6	52	6.54	
08/17/88			13.4	18.58	0.15	1.7	53	6.35	
08/17/88	1435	#1 Right	0.8	21.37	7.66	92.5	49	7.48	
08/17/88			2.8	21.34	7.59	91.7	49	7.35	
08/17/88	1440	#1 Mid	1.0	21.34	7.48	90.4	49	7.14	
08/17/88			2.8	21.32	7.43	89.8	49	7.18	
08/17/88	1445	#1 Left	1.0	21.63	6.77	82.2	49	8.20	
08/17/88			2.8	21.31	7.63	92.1	48	7.37	
08/17/88	1453	#2 Right	1.0	21.40	7.85	94.9	54	7.28	
08/17/88			2.5	21.14	7.82	94.1	52	7.33	
08/17/88	1458	#2 Mid	1.0	21.15	7.87	94.7	51	7.27	
08/17/88			3.0	21.13	7.92	95.2	51	7.36	
08/17/88	1502	#2 Left	1.0	21.19	8.02	96.6	51	7.44	
08/17/88			2.0	21.16	7.92	95.3	50	7.48	
08/17/88	1509	#3 Right	1.0	21.12	8.09	97.3	52	7.35	
08/17/88			2.6	21.05	8.18	98.3	52	7.46	
08/17/88	1512	#3 Mid	1.0	21.05	8.07	97.0	52	7.26	
08/17/88			3.1	21.00	8.18	98.2	53	7.43	
08/17/88	1516	#3 Left	1.0	21.04	8.43	101.3	52	7.46	
08/17/88			2.2	21.02	8.45	101.5	52	7.56	
08/17/88	1521	#3A Right	1.0	21.33	7.91	95.5	53	7.06	
08/17/88			3.0	21.09	7.92	95.2	53	7.22	
08/17/88	1528	#3A Mid	1.0	21.23	8.22	99.1	52	7.35	
08/17/88			2.8	20.99	8.47	101.7	53	7.64	
08/17/88	1532	#3A Left	1.0	21.15	8.73	105.1	52	7.36	
08/17/88			2.5	21.00	8.54	102.5	53	7.52	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	1541	#4 Right	1.0	22.33	8.54	105.0	54	7.34	3.8
08/17/88			4.8	21.30	8.17	98.6	53	7.57	
08/17/88	1545	#4 Mid	1.0	21.97	8.47	103.5	54	7.35	3.8
08/17/88			5.6	21.26	8.24	99.4	53	7.52	
08/17/88	1550	#4 Left	1.0	21.74	8.80	107.2	53	7.41	
08/17/88			3.0	21.58	8.58	104.1	53	7.48	
08/17/88	1555	#4A Right	1.0	22.26	9.08	111.6	53	7.69	
08/17/88			1.7	22.13	9.19	112.7	53	8.02	
08/17/88	1600	#4A Mid	1.0	22.30	8.93	109.9	53	7.64	3.8
08/17/88			2.0	22.07	8.88	108.7	53	7.66	
08/17/88			5.0	21.72	8.41	102.3	53	7.29	
08/17/88			7.1	21.67	8.17	99.4	52	7.25	
08/17/88	1610	#4A Left	1.0	22.37	8.85	109.0	53	7.61	
08/17/88			2.0	22.20	8.85	108.7	53	7.60	
08/17/88			5.0	21.72	8.31	101.1	53	7.52	
08/17/88	1617	#5 Right	1.0	22.47	8.91	109.9	53	7.66	
08/17/88			2.0	22.01	8.74	106.9	52	7.55	
08/17/88			5.0	21.85	8.19	99.9	53	7.47	
08/17/88	1623	#5 Mid	1.0	22.35	8.67	106.7	53	7.43	3.5
08/17/88			2.0	22.07	8.67	106.1	53	7.40	
08/17/88			5.7	21.81	8.10	98.7	52	7.50	
08/17/88	1629	#5 Left	1.0	22.44	9.04	111.4	53	7.70	
08/17/88			2.0	22.04	8.84	108.2	52	7.87	
08/17/88	1638	#6 Right	1.0	22.38	8.72	107.4	53	7.68	3.8
08/17/88			2.0	22.25	8.66	106.4	52	7.69	
08/17/88			5.0	21.93	8.37	102.2	52	7.77	
08/17/88			7.0	21.87	7.97	97.3	52	7.47	
08/17/88	1646	#6 Mid	1.0	22.50	8.43	104.1	52	7.47	
08/17/88			2.0	22.21	8.52	104.6	52	7.61	
08/17/88			5.0	21.95	8.35	102.0	52	7.60	
08/17/88			7.0	21.82	7.22	88.0	52	7.29	
08/17/88			10.0	21.14	4.40	52.9	53	6.71	
08/17/88			12.0	20.34	2.64	31.3	53	6.35	
08/17/88			15.6	18.90	0.08	1.0	54	6.39	
08/17/88	1700	#6 Left	1.0	22.56	8.45	104.5	52	7.52	
08/17/88			2.0	22.47	8.57	105.8	52	7.61	
08/17/88			5.0	21.94	8.46	103.4	52	7.45	
08/17/88			7.0	21.83	7.55	92.0	52	7.04	
08/17/88			10.0	21.13	2.97	35.8	53	6.48	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	1723	#8 Right	1.0	22.51	8.50	104.9	52	7.42	
08/17/88			2.0	22.14	8.38	102.7	52	7.55	
08/17/88			5.0	21.93	7.79	95.1	52	7.29	
08/17/88			7.0	21.87	7.59	92.6	52	7.20	
08/17/88			9.0	21.64	3.38	41.1	52	6.50	
08/17/88	1731	#8 Mid	1.0	22.51	8.41	103.8	52	7.41	
08/17/88			2.0	22.19	8.54	104.8	52	7.55	
08/17/88			5.0	21.96	7.55	92.3	51	7.25	
08/17/88	1738	#8 Left	1.0	22.60	8.88	109.8	52	7.64	
08/17/88	1740	P.F. Dam	1.0	22.16	8.03	98.5	53	7.30	
08/17/88			2.0	22.16	8.03	98.5	53	7.30	
08/17/88			5.0	21.92	7.65	93.4	52	7.40	
08/17/88			8.0	21.82	6.11	74.5	51	6.95	
08/17/88			10.0	21.45	3.88	47.0	51	6.57	
08/17/88			12.0	19.43	0.14	1.6	51	6.34	
08/18/88	630	#1 Right	1.1	20.27	8.04	95.1	49	7.75	
08/18/88			2.8	20.26	8.01	94.8	48	7.73	
08/18/88	637	#1 Mid	1.3	20.27	7.89	93.4	48	7.70	
08/18/88			2.0	20.33	7.73	91.6	49	7.52	
08/18/88	644	#1 Left	1.0	20.18	7.80	92.2	49	7.61	
08/18/88			2.6	20.20	7.64	90.3	48	7.52	
08/18/88	655	#2 Right	1.1	20.43	7.32	87.0	61	7.30	
08/18/88			3.1	20.39	7.28	86.3	61	7.22	
08/18/88	657	#2 Mid	1.1	20.41	7.38	87.6	55	7.36	
08/18/88			3.2	20.48	7.36	87.5	51	7.33	
08/18/88	700	#2 Left	1.1	20.16	7.70	91.0	49	7.42	
08/18/88			2.2	20.19	7.64	90.3	50	7.43	
08/18/88	706	#3 Right	1.1	20.67	7.75	92.4	55	7.37	
08/18/88			2.9	20.67	7.57	90.3	54	7.28	
08/18/88	714	#3 Mid	1.1	20.77	7.80	93.2	55	7.40	
08/18/88			3.5	20.79	7.68	91.9	54	7.38	
08/18/88	722	#3 Left	1.1	20.71	7.82	93.4	54	7.36	
08/18/88			2.4	20.70	7.72	92.2	54	7.28	
08/18/88	730	#3A Right	1.1	20.46	7.48	88.9	52	7.28	
08/18/88			3.0	20.50	7.36	87.5	52	7.47	
08/18/88	733	#3A Mid	1.1	20.47	7.94	94.4	52	7.34	
08/18/88			3.1	20.49	7.88	93.7	52	7.60	
08/18/88	736	#3A Left	1.1	20.43	7.94	94.3	53	7.32	
08/18/88			2.8	20.36	7.92	93.9	52	7.55	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	742	#4 Right	1.1	20.91	7.97	95.5	52	7.46	3.9
08/18/88			2.0	20.95	7.96	95.5	53	7.46	
08/18/88			5.1	20.93	7.98	95.7	53	7.47	
08/18/88	752	#4 Mid	1.1	20.91	8.17	97.8	53	7.44	4.0
08/18/88			2.4	20.93	8.09	97.0	53	7.44	
08/18/88			5.2	20.90	8.05	96.4	52	7.47	
08/18/88	758	#4 Left	1.1	20.99	8.16	97.9	53	7.39	
08/18/88	805	#4A Right	1.1	21.26	8.46	102.1	52	7.57	
08/18/88			1.8	21.26	8.42	101.6	52	7.51	
08/18/88	809	#4A Mid	1.1	21.48	8.32	100.8	53	7.50	
08/18/88			2.0	21.48	8.34	101.0	52	7.38	
08/18/88			5.9	21.41	8.42	101.9	51	7.61	
08/18/88	814	#4A Left	1.1	21.50	8.24	99.8	52	7.42	3.5
08/18/88			2.0	21.51	8.23	99.7	52	7.43	
08/18/88			5.2	21.50	8.21	99.5	52	7.49	
08/18/88	822	#5 Right	1.1	21.50	8.37	101.4	53	7.47	
08/18/88			2.0	21.54	8.32	100.9	53	7.47	
08/18/88			4.8	21.52	8.34	101.1	53	7.57	
08/18/88	828	#5 Mid	1.1	21.53	8.25	100.0	53	7.49	3.7
08/18/88			2.0	21.53	8.13	98.5	53	7.53	
08/18/88			5.0	21.47	8.10	98.1	52	7.55	
08/18/88			6.5	21.44	8.06	97.6	52	7.42	
08/18/88	834	#5 Left	1.0	21.56	8.34	101.2	53	7.52	
08/18/88			2.0	21.55	8.19	99.4	52	7.47	
08/18/88			5.0	21.47	8.17	98.9	52	7.55	
08/18/88	840	#6 Right	1.0	21.63	8.02	97.4	52	7.37	
08/18/88			2.0	21.66	7.97	96.9	52	7.41	
08/18/88			5.0	21.63	7.88	95.7	52	7.42	
08/18/88			6.2	21.62	7.75	94.1	53	7.31	
08/18/88	848	#6 Mid	1.0	21.67	7.91	96.1	52	7.34	3.8
08/18/88			2.0	21.67	7.88	95.8	52	7.42	
08/18/88			5.0	21.66	7.83	95.2	52	7.43	
08/18/88			7.0	21.30	7.63	92.1	52	6.73	
08/18/88			10.0	20.30	5.15	61.0	53	6.52	
08/18/88			12.0	20.39	2.50	29.7	55	6.38	
08/18/88			13.0	19.76	1.34	15.7	53	6.38	
08/18/88			15.0	18.96	0.11	1.3	54	6.37	
08/18/88			16.8	18.86	0.08	1.0	55	6.38	
08/18/88	900	#6 Left	1.0	21.64	7.99	97.1	52	7.30	
08/18/88			2.0	21.66	7.92	96.2	52	7.31	
08/18/88			5.0	21.64	7.81	94.9	52	7.37	
08/18/88			7.0	21.63	7.39	89.7	52	7.23	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	922	#8 Right	1.0	21.53	7.41	89.8	51	7.13	3.9
08/18/88			2.0	21.59	7.31	88.8	52	7.12	
08/18/88			5.0	21.56	7.52	91.2	51	7.25	
08/18/88			7.0	21.57	6.96	84.5	51	7.11	
08/18/88			8.7	21.56	7.16	86.8	51	7.16	
08/18/88	930	#8 Mid	1.0	21.69	7.68	93.4	52	7.24	
08/18/88			2.0	21.68	7.65	93.0	51	7.27	
08/18/88			4.4	21.60	8.05	97.8	51	7.41	
08/18/88	933	#8 Left	1.0	21.63	8.16	99.1	52	7.51	
08/18/88	940	P.F. Dam	1.0	21.70	7.34	89.3	51	7.10	
08/18/88			2.0	21.71	7.28	88.5	52	7.12	
08/18/88			5.0	21.64	7.19	87.4	52	7.18	
08/18/88			7.0	21.63	7.22	87.7	52	7.22	
08/18/88			10.0	21.56	6.28	76.1	53	6.80	
08/18/88	1448	#1 Right	1.0	21.03	8.07	97.0	49	7.43	
08/18/88			2.7	20.84	8.11	97.0	49	7.77	
08/18/88	1455	#1 Mid	1.0	20.91	7.96	95.4	49	7.53	
08/18/88			1.9	20.89	7.96	95.4	49	7.59	
08/18/88	1458	#1 Left	1.0	20.88	8.08	96.8	49	7.50	
08/18/88			2.6	20.75	8.05	96.1	49	7.56	
08/18/88	1507	#2 Right	1.0	21.08	7.93	95.4	53	7.27	
08/18/88			2.0	20.73	7.87	94.0	52	7.43	
08/18/88	1510	#2 Mid	1.0	20.80	7.87	94.1	50	7.27	
08/18/88			2.8	20.66	7.97	95.1	51	7.59	
08/18/88	1513	#2 Left	1.0	20.92	8.03	96.2	50	7.50	
08/18/88			2.2	20.77	7.99	95.5	51	7.59	
08/18/88	1521	#3 Right	1.0	21.11	7.91	95.1	54	7.34	
08/18/88			2.7	21.07	8.04	96.6	53	7.50	
08/18/88	1525	#3 Mid	1.0	21.07	7.84	94.2	53	7.23	
08/18/88			3.3	21.04	7.92	95.2	53	7.57	
08/18/88	1531	#3 Left	1.0	21.12	8.42	101.2	53	7.42	
08/18/88			1.5	21.15	8.47	102.0	53	7.54	
08/18/88	1537	#3A Right	1.0	21.10	7.55	90.8	52	7.12	
08/18/88			3.3	20.86	7.64	91.4	53	7.22	
08/18/88	1540	#3A Mid	1.0	21.10	8.00	96.2	53	7.16	
08/18/88			3.0	20.91	8.26	99.0	53	7.38	
08/18/88	1546	#3A Left	1.0	21.14	8.26	99.4	54	7.39	
08/18/88			2.8	20.92	8.75	104.9	53	7.85	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	% Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	1553	#4 Right	1.0	21.56	8.54	103.5	53	7.53	
08/18/88			2.0	21.41	8.47	102.5	52	7.65	
08/18/88			5.0	20.82	7.99	95.6	52	7.60	
08/18/88	1601	#4 Mid	1.0	21.53	8.40	101.8	53	7.59	3.9
08/18/88			2.0	21.45	8.39	101.5	53	7.62	
08/18/88			5.0	20.80	8.00	95.6	52	7.43	
08/18/88	1606	#4 Left	1.0	21.46	8.56	103.7	53	7.56	
08/18/88	1614	#4A Right	1.0	22.03	8.92	109.1	53	7.80	
08/18/88			2.0	21.80	8.94	109.0	53	7.94	
08/18/88	1617	#4A Mid	1.0	21.96	8.76	107.0	53	7.72	3.4
08/18/88			2.0	21.80	8.76	106.7	53	7.82	
08/18/88			5.0	21.48	8.34	101.0	53	7.48	
08/18/88			7.0	21.47	8.24	99.8	53	7.38	
08/18/88	1625	#4A Left	1.0	22.06	8.77	107.3	54	7.68	
08/18/88			2.0	21.99	8.71	106.5	53	7.81	
08/18/88			5.0	21.51	7.82	94.8	53	7.24	
08/18/88			6.2	21.50	7.84	95.0	53	7.20	
08/18/88	1634	#5 Right	1.0	21.92	8.87	108.3	53	7.99	3.7
08/18/88			4.2	21.62	8.33	101.2	53	7.55	
08/18/88	1637	#5 Mid	1.0	22.20	8.56	105.1	54	7.59	
08/18/88			2.0	21.85	8.56	104.4	53	7.68	
08/18/88			5.0	21.58	8.24	100.0	53	7.47	
08/18/88			7.0	21.51	8.01	97.0	53	7.26	
08/18/88	1645	#5 Left	1.0	22.31	8.55	105.2	53	7.77	
08/18/88			2.0	22.10	8.87	108.7	53	8.00	
08/18/88	1652	#6 Right	1.0	22.03	8.47	103.7	53	7.59	
08/18/88			2.0	21.99	8.44	103.2	53	7.65	
08/18/88			5.0	21.75	7.99	97.3	52	7.37	
08/18/88			6.1	21.70	7.79	94.7	52	7.21	
08/18/88	1659	#6 Mid	1.0	22.25	8.28	101.7	52	7.50	
08/18/88			2.0	22.25	8.27	101.6	53	7.58	
08/18/88			5.0	21.96	8.14	99.5	53	7.39	
08/18/88			7.0	21.70	7.83	95.3	52	7.20	
08/18/88			10.0	21.38	5.18	62.6	52	6.69	
08/18/88			13.4	19.93	1.38	16.2	52	6.30	
08/18/88	1708	#6 Left	1.0	22.32	8.24	101.4	52	7.45	3.7
08/18/88			2.0	22.30	8.21	101.0	53	7.48	
08/18/88			5.0	21.88	8.13	99.2	53	7.36	
08/18/88			7.0	21.71	7.80	94.9	52	7.17	
08/18/88			10.0	21.69	7.68	93.4	52	7.10	

Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	1724	#8 Right	1.0	22.14	7.96	97.6	53	7.34	
08/18/88			2.0	21.88	8.12	99.1	52	7.42	
08/18/88			5.0	21.73	7.56	92.0	52	7.15	
08/18/88			7.0	21.68	7.23	87.9	52	7.03	
08/18/88			8.5	21.64	7.16	86.9	52	6.97	
08/18/88	1732	#8 Mid	1.0	22.29	7.80	95.9	52	7.22	
08/18/88			2.0	22.18	7.85	96.3	53	7.26	
08/18/88			5.0	21.74	7.40	90.0	52	7.04	
08/18/88	1736	#8 Left	1.0	22.32	8.11	99.8	52	7.43	
08/18/88	1739	P.F. Dam	1.0	22.03	7.78	95.2	53	7.20	
08/18/88			2.0	21.91	8.10	98.9	53	7.38	
08/18/88			5.0	21.81	7.87	95.9	52	7.28	
08/18/88			7.0	21.74	7.43	90.5	52	7.09	
08/18/88			10.0	21.51	4.72	57.2	52	6.58	
08/18/88			12.5	19.43	0.11	1.3	51	6.25	

Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	BOD5 mg/L	BOD10 mg/L	BOD15 mg/L	BOD20 mg/L	BOD60 mg/L
340300					
340301	8.00	17.60	114.00	74.00	
340304	5.60	29.60	90.40	98.00	
340307	12.40	27.60	72.80	86.80	
340302					
340303	8.40	38.60	23.60	15.40	
340305	8.60	36.80	8.20	17.60	
340306	12.20	47.20	24.00	21.60	
340311	0.73	0.59	0.96	0.95	1.75
340316	0.42	0.89	0.82	1.15	1.92
340321	0.44	0.79	1.09	1.21	
340312	0.89	1.14	1.43	1.91	2.89
340317	0.79	1.12	1.40	1.84	2.66
340322	0.78	1.47	1.94	2.34	
340313	1.28	1.48	1.87	2.07	3.09
340318	0.98	1.30	1.64	1.90	2.88
340323	1.04	1.55	1.75	2.03	
340314	1.25	1.67	2.01	2.16	3.54
340319	0.92	1.39	1.78	2.03	3.05
340324	1.27	1.83	2.20	2.30	
340315	1.70	1.96	2.28	2.48	3.35
340320	1.13	1.22	1.76	1.85	2.98
340325	1.08	1.50	2.10	2.25	
340326					

Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	NH3-N Total mg/l	NO2NO3-N Total mg/l	Kjel-N Total mg/l	Phos Total mg/l
340300	0.01U	0.01U	0.04U	0.01U
340301	16.000	1.65	22.50	7.000
340304	16.600	0.80	23.00	7.200
340307	14.700	1.24	21.50	6.800
340302	0.01U	0.01U	0.04U	0.01U
340303	0.055	25.00	1.92	9.900
340305	0.055	26.00	2.06	10.200
340306	0.058	25.50	2.50	10.200
340311	0.01U	0.01U	0.10	0.01M
340316	0.01U	0.01U	0.14	0.010
340321	0.01U	0.01U	0.12	0.010
340312	0.066	0.01	0.32	0.056
340317	0.052	0.01M	0.24	0.044
340322	0.120	0.01	0.34	0.066
340313	0.032	0.01U	0.26	0.064
340318	0.020	0.01U	0.22	0.044
340323	0.01U	0.01U	0.18	0.044
340314	0.01U	0.01U	0.26	0.040
340319	0.01U	0.01U	0.20	0.038
340324	0.01U	0.01U	0.18	0.040
340315	0.01U	0.01U	0.20	0.030
340320	0.01U	0.01U	0.16	0.030
340325	0.01U	0.01U	0.20	0.036
340326	0.01U	0.01U	0.06	0.010

Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	Arsenic As-Total ug/l	Mercury Hg-Total ug/l	Cadmium Tot-Rec ug/l	Chromium Tot-Rec ug/l	Lead Tot-Rec ug/l	Iron Tot-Rec ug/l	Zinc Tot-Rec ug/l
340300	0.6	0.08U	0.1U	0.5U	1U	7U	5U
340301	1.4	0.17	0.6	3.3	5		
340304	1.8	0.08U	1.0	3.1	7	253	51
340307	1.4	0.08U	0.5	4.0	4	216	42
340302	0.5U	0.08U	0.1U	0.7	1U	7U	5U
340303	3.7	0.21	0.2	1.3	2	102	43
340305	4.4	0.08U	2.0	0.9	1	105	38
340306	3.9	0.08U	0.2	0.9	1	109	40
340311	0.5U	0.44	0.7	0.5U	1	25	75
340316	0.5	0.45	0.4	0.7	1	22	63
340321	0.5	0.08U	0.6	0.5U	2	18	67
340312	0.6	0.25	0.7	1.2	2	27	66
340317	0.5U	0.13	0.4	1.7	2	24	62
340322	0.6	0.08U	0.4	0.5U	2	23	66
340313	0.8	0.30	0.3	1.8	1	34	56
340318	0.5	0.19	0.3	0.7	2	32	54
340323	0.6	0.08U	0.3	0.5U	2	34	56
340314	0.6	0.17	0.3	0.5U	1	28	53
340319	0.5	0.37	0.3	1.2	1	30	58
340324	0.7	0.08U	1.3	1.9	2	84	56
340315	0.5U	0.11	0.2	0.7	1	25	43
340320	0.7	0.15	0.3	0.7	1	28	47
340325	0.5U	0.08U	0.2	1.4	2	37	46
340326	0.5U	0.08U	0.1U	0.5U	1U	7U	5U

Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	Cond@25C Meter umho/cm	pH LAB Meter Std Unts	Alk-Tot CaCO3 mg/l	Hard-Tot CaCO3 mg/l
340300	1.5	4.40	0.1U	1.0U
340301	672.0	6.74	193.0	
340304	674.0	6.72	202.0	103.0
340307	677.0	6.74	196.0	110.0
340302	1.7	4.20	0.6	1.0U
340303	538.0	6.80	60.4	
340305	538.0	6.80	62.0	105.0
340306	538.0	6.74	60.0	103.0
340311	53.8	6.25	18.7	20.5
340316	53.8	5.95	19.0	21.5
340321	52.8	5.97	19.2	21.4
340312	57.6	6.30	19.3	21.8
340317	57.0	6.22	19.3	21.5
340322	58.3	6.17	20.1	21.9
340313	57.5	6.37	19.6	21.3
340318	57.8	6.27	19.9	22.3
340323	56.2	6.20	20.5	21.6
340314	56.9	6.35	20.2	22.0
340319	56.2	6.25	20.6	21.9
340324	56.6	6.30	19.9	21.9
340315	56.0	6.35	19.8	21.3
340320	55.3	6.34	19.5	21.4
340325	55.2	6.39	19.5	21.5
340326	1.8	4.28	1.5	1.0

Table A-3. Index for location of laboratory samples for receiving waters and point sources during the field study of August 16-18, 1988.

EPA Lab#	Date	Time	Description	River mile
340300	88/08/16	0840	Coeur d'Alene STP effl blank	
340301	88/08/16	0845	Coeur d'Alene STP effl (G)	111.0
340304	88/08/17	0845	Coeur d'Alene STP effl (24)	111.0
340307	88/08/18	0940	Coeur d'Alene STP effl (24)	111.0
340302	88/08/16	0950	Hayden Lk STP effl blank	
340303	88/08/16	0955	Hayden Lk STP effl (G)	
340305	88/08/17	0930	Hayden Lk STP effl (24)	
340306	88/08/18	0835	Hayden Lk STP effl (24)	
340311	88/08/16	0630	Sta 1	111.1
340316	88/08/17	0630	Sta 1	111.1
340321	88/08/18	0630	Sta 1	111.1
340312	88/08/16	0740	Sta 3	108.6
340317	88/08/17	0715	Sta 3	108.6
340322	88/08/18	0710	Sta 3	108.6
340313	88/08/16	0835	Sta 4	106.5
340318	88/08/17	0800	Sta 4	106.5
340323	88/08/18	0745	Sta 4	106.5
340314	88/08/16	0920	Sta 5	104.4
340319	88/08/17	0845	Sta 5	104.4
340324	88/08/18	0820	Sta 5	104.4
340315	88/08/16	1020	Sta 8	102.0
340320	88/08/17	0945	Sta 8	102.0
340325	88/08/18	0920	Sta 8	102.0
340326	88/08/18		Transfer Blank	

APPENDIX B

Method for Estimating Cross-Sectional Averages of Water Quality

To compute the mean values by station for dissolved oxygen (DO) concentration, percent DO saturation, water temperature and conductivity, the receiving water data for these parameters were aggregated using areal average techniques. The data were depth-averaged for each section (right, middle, and and left) of each station.

Although DO, temperature, and conductivity were measured at increasing depths, these specific depths were not identical across sections or stations. Therefore, a method was sought that would produce estimates of parameter averages from the raw data. First, the river bed at each section was assumed to be 0.5 meters below the greatest depth where measurements were made (see Figs. B-1.1 and B-1.2). Next, simple linear equations (expressing parameter values as a function of water depth) were fit to each successive pair of measurements. Parameter values were assumed to be constant in the intervals between the surface and the first measurement and between the last measurement and the river bed (Fig. B-1.3). Parameter averages were then computed from the areas under the resulting line segments.

Assuming the section widths (right, middle, and left) were equal, the overall average for the station was computed by summing all of the areas, then dividing by the sum of the water depths. These data were further aggregated by summing over all the days on which measurements were made to obtain a station average of each parameter for the period of study. The results are presented as highly aggregated tranformations of the raw data.

APPENDIX C

Measurements obtained from the Citizens' Volunteer Monitoring Program

The State of Idaho's Department of Environmental Quality, working in cooperation with local volunteers, have implemented a sampling program in the Spokane River at three locations in the Spokane River between Coeur d'Alene and Post Falls, Idaho. Data obtained from this program is given in Tables C-1, C-2, and C-3.

Table C-1. Water quality measurements in the Spokane River at the Cedars Site (approximate R.M. 111.1) obtained in the Citizen's Volunteer Monitoring Program supported by the State of Idaho's Department of Environmental Quality.

CVMP 1988						DEQ DUPE	
CEDARS SITE							
DATE	5/25/88	6/27/88	7/19/88	8/23/88	9/27/88	9/27/88	10/18/88
TIME	1100	1100	930	1000	1000	1000	1000
MAXIMUM DEPTH (M)	2.75	2.75	2.75	2.6	2.5	2.5	
SECCHI DEPTH (M)	2.75	2.75	2.75	2.6	2.5	2.5	
TEMPERATURE (C)@ 1M DEPTH	13.3	20	21	20	16	16	
TEMPERATURE (C)@ 1M OFF BOTTOM	12.2	21	20	20	16	16	
DISSOLVED OXYGEN (MG/L)@ 1M	12	4	8	7	9	9	
DISSOLVED OXYGEN (MG/L)@ 1M OFF	12	4	8	8	7	7	
TOTAL AMMONIA (MG/L)	0.013	0.014	0.05	0.007	0.018	0.021	0.007
TOTAL NO2+NO3 (MG/L)	0.014	0.008	0.018	0.02	0.02	0.016	0.012
TOTAL KJELDAHL (MG/L)	0.11	0.13	0.05	0.09	0.12	0.11	0.13
TOTAL PHOSPHORUS (MG/L)	0.011	0.009	0.008	0.009	0.007	0.008	0.008
ORTHOPHOSPHORUS (MG/L)		0.001	0.001	0.002	0.002	0.002	0.001
SPECIFIC CONDUCTANCE (UMHOS)	52	45	48	51	51	53	54
CHLOROPHYLL a (UG/L)		1.1	1.1	1.7	1	1	0.7
ZINC (UG/L)	90	220	60	30	59		50

Table C-2. Water quality measurements in the Spokane River at Harbor Island (approximate R.M. 106.5) obtained in the Citizen's Volunteer Monitoring Program supported by the State of Idaho's Department of Environmental Quality.

SPOKANE RIVER CVMP 1988 HARBOR ISLAND						DEQ DUPE	
DATE	5/25/88	6/27/88	7/19/88	8/23/88	9/27/88	9/27/88	10/18/88
TIME	1300	1200	1100	1030	1140	1140	1000
MAXIMUM DEPTH (M)	5.75	5.75	5.75	5.8	5.8	5.8	
SECCHI DEPTH (M)	3.25	3.75	3.25	2.75	4.5	4.5	
TEMPERATURE (C)@ 1M DEPTH	13.3	20	21	21	15	15	
TEMPERATURE (C)@ 1M OFF BOTTOM	13.3	21	21	21	15	15	
DISSOLVED OXYGEN (MG/L)@ 1M	12	9	9	4	8	8	
DISSOLVED OXYGEN (MG/L)@ 1M OFI	12	9	6	8	9	9	
TOTAL AMMONIA (MG/L)	0.011	0.027	0.045	0.026	0.053	0.045	0.024
TOTAL NO2+NO3 (MG/L)	0.019	0.017	0.009	0.027	0.036	0.027	0.025
TOTAL KJELDAHL (MG/L)	0.14	0.13	0.12	0.19	0.17	0.14	0.13
TOTAL PHOSPHORUS (MG/L)	0.014	0.017	0.018	0.037	0.029	0.027	0.02
ORTHOPHOSPHORUS (MG/L)	0.001	0.007	0.003	0.022	0.017	0.018	0.013
SPECIFIC CONDUCTANCE (UMHOS)	50	46	50	55	53	53	56
CHLOROPHYLL a (UG/L)		1.6	1.7	6.5	0.8	1	0.6
ZINC (UG/L)	70	140	60	30	55		50
FECAL COLIFORM (#/100 ML)			10		10		

Table C-3. Water quality measurements in the Spokane River at Post Falls Bridge (approximate R.M. 101.8) obtained in the Citizen's Volunteer Monitoring Program supported by the State of Idaho's Department of Environmental Quality.

SPOKANE RIVER CVMP 1988 POST FALLS BRIDGE						DEQ DUPE	
DATE	5/25/88	6/27/88	7/19/88	8/23/88	9/27/88	9/27/88	10/18/88
TIME	1430	1200	1030	1115	1240	1240	
MAXIMUM DEPTH (M)	9	8.6	8.5	8.6	8.5	8.5	
SECCHI DEPTH (M)	3.25	3.5	2.75	4.75	4.75	4.75	
TEMPERATURE (C)@ 1M DEPTH	14	19.7	22.5	22	15	15	
TEMPERATURE (C)@ 1M OFF BOTTOM	13.4	21	21	22	15	15	
DISSOLVED OXYGEN (MG/L)@ 1M	13	5	9	10	8	8	
DISSOLVED OXYGEN (MG/L)@ 1M OFI	13	5	9	8	8	8	
TOTAL AMMONIA (MG/L)	0.013	0.019	0.028	0.01	0.035	0.038	0.024
TOTAL NO2+NO3 (MG/L)	0.017	0.021	0.003	0.016	0.033	0.034	0.018
TOTAL KJELDAHL (MG/L)	0.14	0.12	0.13	0.12	0.16	0.18	0.16
TOTAL PHOSPHORUS (MG/L)	0.014	0.016	0.017	0.028	0.027	0.027	0.023
ORTHOPHOSPHORUS (MG/L)		0.005	0.002	0.01	0.017	0.018	0.014
SPECIFIC CONDUCTANCE (UMHOS)	0.001	48	50	55	54	53	56
CHLOROPHYLL a (UG/L)	80	220	60	30	52	1	50
ZINC (UG/L)	70	140	60	30	55		50