Illinois State Water Survey Division
SURFACE WATER SECTION

SWS Contract Report 471

SEDIMENT TRANSPORT AND WATER QUALITY CHARACTERISTICS OF TWO STREAMS IN KANE COUNTY

by J. Rodger Adams, Raman K. Raman, and Edward Delisio

Prepared for the
Illinois Department of Energy and Natural Resources

Champaign, Illinois

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2204 Griffith Drive
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SEDIMENT TRANSPORT AND WATER QUALITY CHARACTERISTICS OF TWO STREAMS IN KANE COUNTY

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INTRODUCTION

Erosion, transport, and deposition of sediment by flowing water are natural processes. However, human activities such as agricultural practices can increase the rate of these processes or the area susceptible to erosion or deposition. Instream transport of suspended and dissolved materials can also be changed by large, long-term construction programs. Thus there was a need to obtain background data on area streams and prepare a monitoring program for the construction and postconstruction periods for the Superconducting Super Collider (SSC) to be located in northeastern Illinois.

Sediment has been recognized as the number-one pollutant in Illinois streams, rivers, and lakes. The Illinois State Water Plan Task Force (1984) named erosion and sediment control foremost among ten critical issues concerning the water resources of the state. The task force identified a need for a rational plan and consistent funding of data collection and research in the areas of streamflow, water quality, and suspended sediment transport. After approximately ten years of suspended sediment data collection by the U.S. Geological Survey (USGS) and four years by the Illinois State Water Survey (ISWS), widely varying funding levels became a factor in the development of a stream sediment monitoring program (Bhowmik and Adams, 1985) for the State Water Plan Task Force. At the present time, the Water Survey benchmark network includes 18 suspended sediment stations, or 28% of the 64 stations recommended in the proposed monitoring program.

In Kane County and vicinity, instream sediment data were available for only a few stations, and none covered more than two years (Bhowmik et al., 1986). Thus two sites at established USGS streamflow gaging stations were selected for preconstruction background data collection. This report presents the water quality and suspended sediment data collected from March 1987 through November 1988 for Ferson Creek near St. Charles and for Blackberry Creek near Yorkville.

Acknowledgements

Administrative guidance was provided by Richard G. Semonin, Chief, Illinois State Water Survey; and Michael L. Terstriep, Head, Surface Water Section.

Support for the project came from the Illinois Department of Energy and Natural Resources. Krishan P. Singh, Assistant Head, ISWS Surface Water Section, was project coordinator. John W. Brother and Linda Riggin prepared the illustrations, Laurie McCarthy edited the report, and Kathleen J. Brown typed and formatted it.

Site Description

Figure 1 shows the portion of northeastern Illinois surrounding the proposed SSC site. The broken lines represent watershed boundaries. The majority of the area within the ring is in the Fox River watershed, with small areas in the watersheds of the Kishwaukee and DuPage Rivers. Numbered triangles identify USGS streamgaging stations, and the round dots identify sites for sediment and water quality monitoring stations proposed for a comprehensive study of the suspended and dissolved loads of streams in the SSC vicinity.

The stream network in the SSC area and the two data collection sites finally installed are shown in figure 2. The USGS gaging station on Ferson Creek near St. Charles is at the Randall Road bridge, which is 2.2 miles upstream from the mouth of Ferson Creek. Streamflow data are available for 1960 to the present for the 51.7-square mile drainage area. The average discharge for the 26-year period is 41.1 cubic feet per second (cfs). The USGS gaging station on Blackberry Creek near Yorkville is at the Illinois Route 47 bridge, which is 3.3 miles upstream from the mouth of Blackberry Creek. Streamflow data are available from 1960 to the present for the 70.2-square mile drainage area. The average discharge for 27 years is 52.8 cfs. Both streams flow into the Fox River. Discharges for the dates on which samples were collected were obtained from the USGS.

An ISCO pumped sequential sampler was installed at each site. The one on Blackberry Creek was attached to the Illinois Route 47 bridge rail on the downstream side of the bridge. The Randall Road bridge over Ferson Creek is too high and exposed, so another site was selected for the ISCO installation. A suitable site was found 3.5 miles upstream of Randall Road at Bolcum Road, where the drainage area is 46.4 square miles.

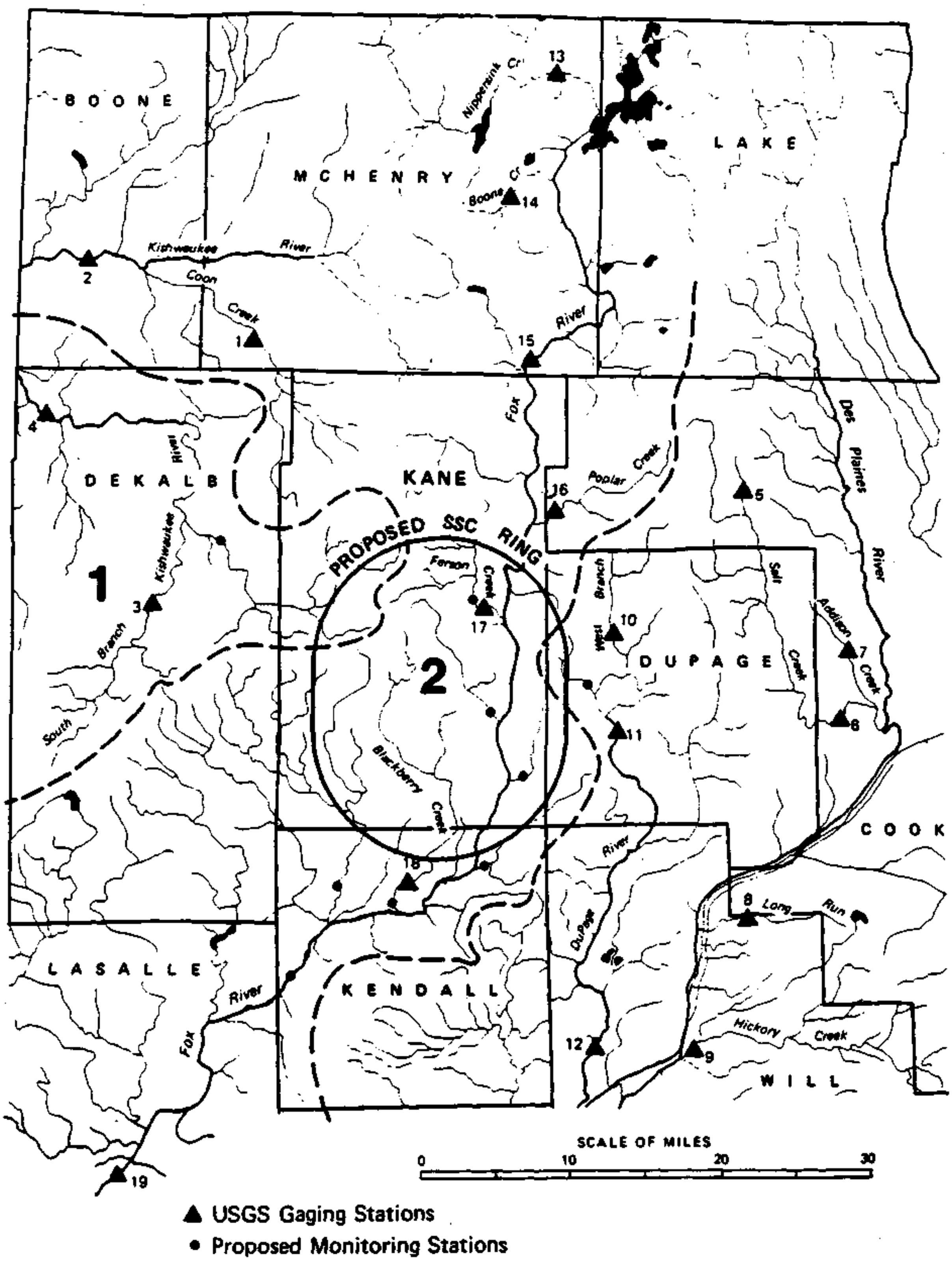

Figure 1. General location of proposed Superconducting Super Collider

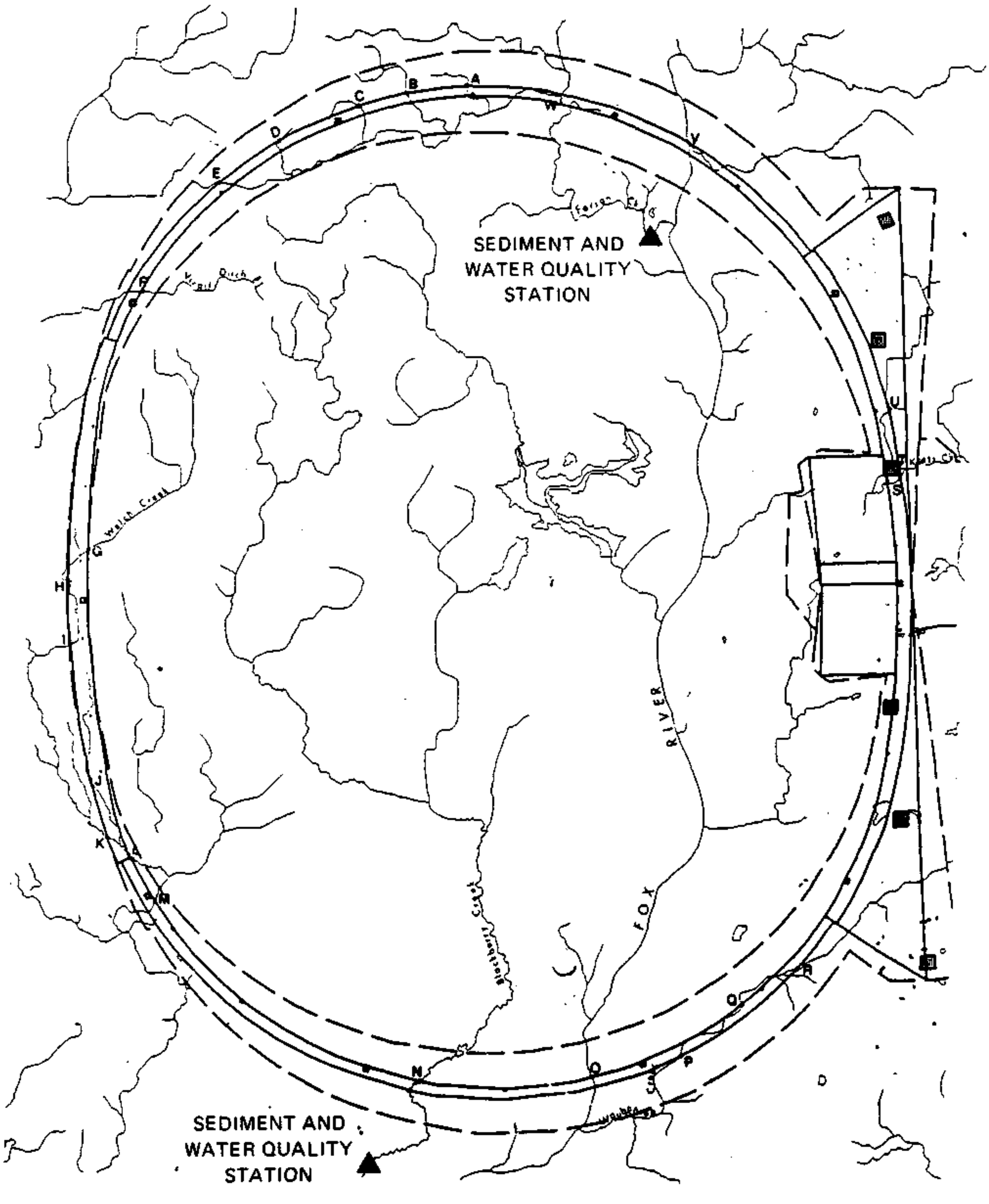

Figure 2. Location of suspended sediment and water quality sampling stations

SAMPLE COLLECTION METHODS AND SCHEDULE

Sample collection was done manually using a DH-59 depth-integrating sampler. The field person collected a sample at each site on his regular, twice-monthly schedule from March 1987 through November 1988. Samples were collected less frequently during winter months when the streams were ice-covered. Background and event sediment concentration samples were collected at each site with an automatic water sampler, which would assure a continuous sediment concentration record through both high- and low-flow conditions. Surface water quality samples were collected manually every two weeks.

Background and event sediment concentration samples were collected using an ISCO automated water sampler installed in a security shelter permanently mounted on the bridge rail. Shelters for the ISCO samplers were installed on Blackberry Creek at Illinois Route 47 near Yorkville on March 25, 1987, and on Ferson Creek at Bolcum Road near St. Charles on March 24, 1988. The shelters were fabricated from 55-gallon drums with locking tops. They were anchored to the bridge rail with steel brackets and concrete anchor bolts. The drum holds the sampler and a 12-volt battery. When sampling, water is pumped up to the sampler through 1/4-inch vinyl tubing that passes through a hole in the bottom of the drum. The ISCO model 1680 samplers are fully programmable and were set to an 8-hour sampling frequency, regardless of the flow conditions. The samplers operated as long as the water remained free of ice. Each sampler contains a tray that holds 28 sample bottles, and when using an 8-hour sample interval (three samples per day), the bottles were changed once each week. The filled trays were returned to the Water Survey laboratories in Champaign, logged in, and prepared for shipment to the Survey's Water Quality Section in Peoria for sediment concentration analysis. Field measurements of dissolved oxygen (DO), temperature, pH, and conductivity were also determined at each weekly trip to the sites.

Water quality samples were collected at each of the two sites every two weeks. At high flows, a US DH-59 sampler was used to collect the sample following the standard procedures given by Guy and Norman (1970). At low flows, a grab sample was taken while wading in the water, or a dip sampler was used from the bridge. This sampler was fabricated from a 6-inch section of PVC pipe with a 3-1/2-inch diameter and an end cap that holds a pint-sized sample bottle. When this assembly is submerged, the bottle is held in place by two galvanized springs stretched across the diameter of the pipe.

Each water quality sample included one liter preserved with HNO3, one liter preserved with H_2SO_4, and one liter that was refrigerated. After collection, the samples were packed in ice and sent for analysis to the Water Survey's Water Quality Section in Peoria. Field measurements of temperature, dissolved oxygen, conductivity, and pH were also noted at this time. Dissolved oxygen measurements were taken following the modified Winkler method as outlined by the American Public Health Association et al. (1985). Conductivity and pH measurements were taken using a Lakewood Instruments model PCD pH/conductivity meter, which was calibrated to a known standard solution before each measurement.

SUSPENDED SEDIMENT DATA

Two types of samples make up the suspended sediment concentration data: 1) depth-integrated samples collected during a site visit and 2) point-integrated samples collected at timed intervals by the ISCO pumped samplers. As described above, more than one sample per day was occasionally analyzed for suspended sediment concentration during runoff events. Several cross-sectional measurements were made, in which depth-integrated samples were collected at a series of verticals across the river width. All of the suspended sediment concentration data are given in appendix tables A1 and A2; including the date and time of sample collection. On Blackberry Creek suspended sediment concentrations ranged from 6 to 1,100 milligrams per liter (mg/L). On Ferson Creek suspended sediment concentrations ranged from 10 to 552 mg/L.

The daily discharge for the period of monitoring was obtained from the USGS. All data after October 1, 1988, are provisional and subject to revision. The daily discharge and the daily concentration are used to calculate the daily sediment load in tons per day by means of the equation:

$$Q_s = 0.0027\, C_s\, Q_w \qquad (1)$$

When there are several concentrations on one day, the average concentration is used to calculate the daily load. The daily discharges and suspended sediment loads are also given in appendix tables Al and A2. Daily sediment loads range from 1 to 210 tons for Blackberry Creek and from 0.35 to 53.8 tons for Ferson Creek. The loads are plotted as functions of the discharges in figures 3 and 4 for Blackberry and Ferson Creeks, respectively. Also shown on these graphs are the power-type regression lines for suspended sediment loads as a function of discharge. The regression equations are:

$$Q_s = 0.296\, Q_w^{0.959} \text{ for Blackberry Creek} \qquad (2)$$

$$Q_s = 0.335\, Q_w^{0.884} \text{ for Ferson Creek} \qquad (3)$$

The correlation coefficients are 0.733 for Blackberry Creek and 0.787 for Ferson Creek.

For stations with weekly and event concentration and discharge data, the total suspended sediment load can be obtained in two ways. One method uses a proportion of the time between each pair of data points and assumes that the same load can be applied to the period dividing the time between the preceding and the following point at the midpoint. This works well if the data are evenly spaced or if there is little variation in load with time. However, serious errors can be made with sparse data and rapidly varying discharge, concentration, and load. The second method uses the regression equation for daily sediment load derived from the measured values and the daily discharges obtained from the USGS to estimate the load for each day. The individual daily loads may not be well estimated, but the

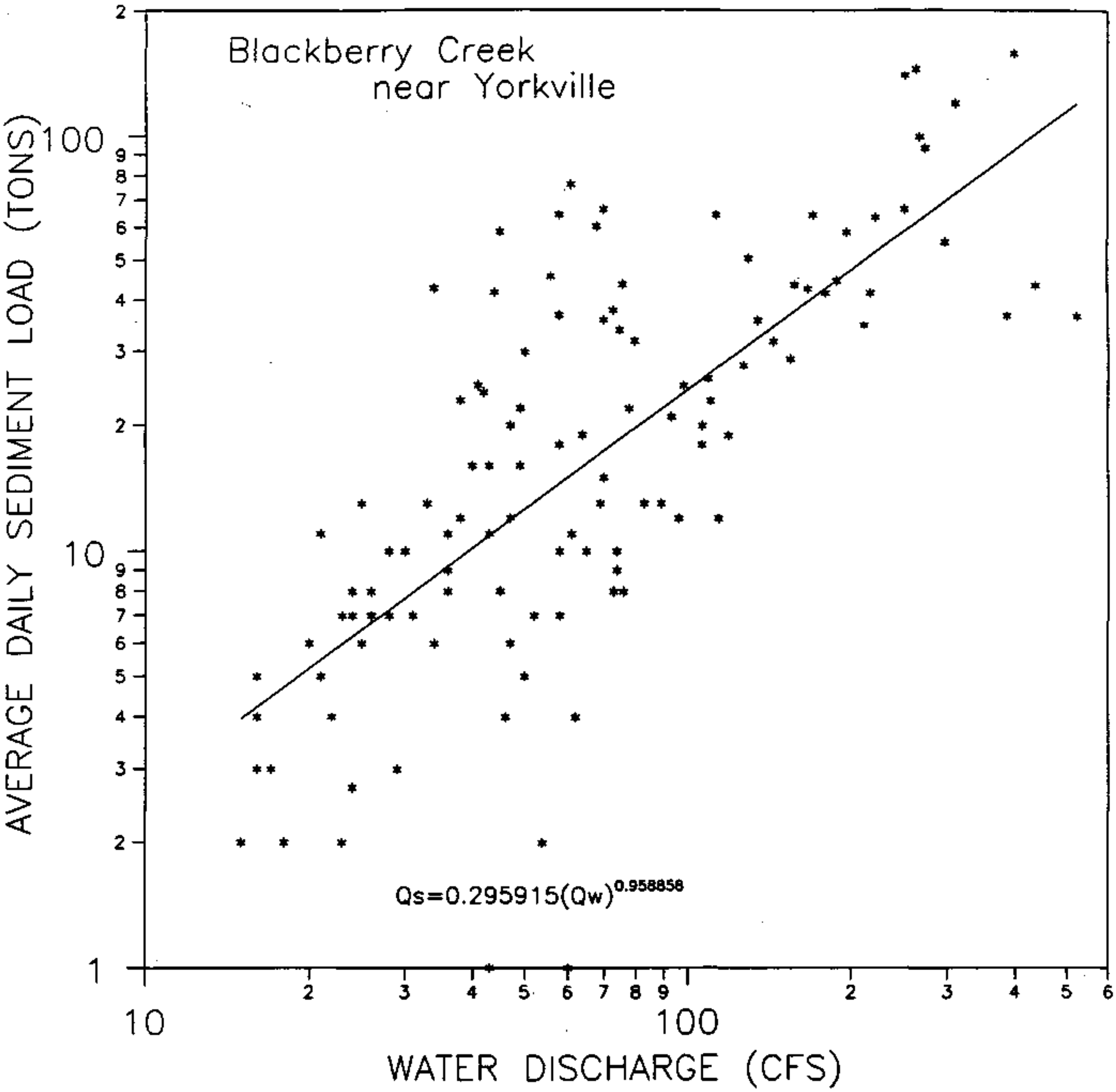

Figure 3. Suspended sediment load versus discharge for Blackberry Creek

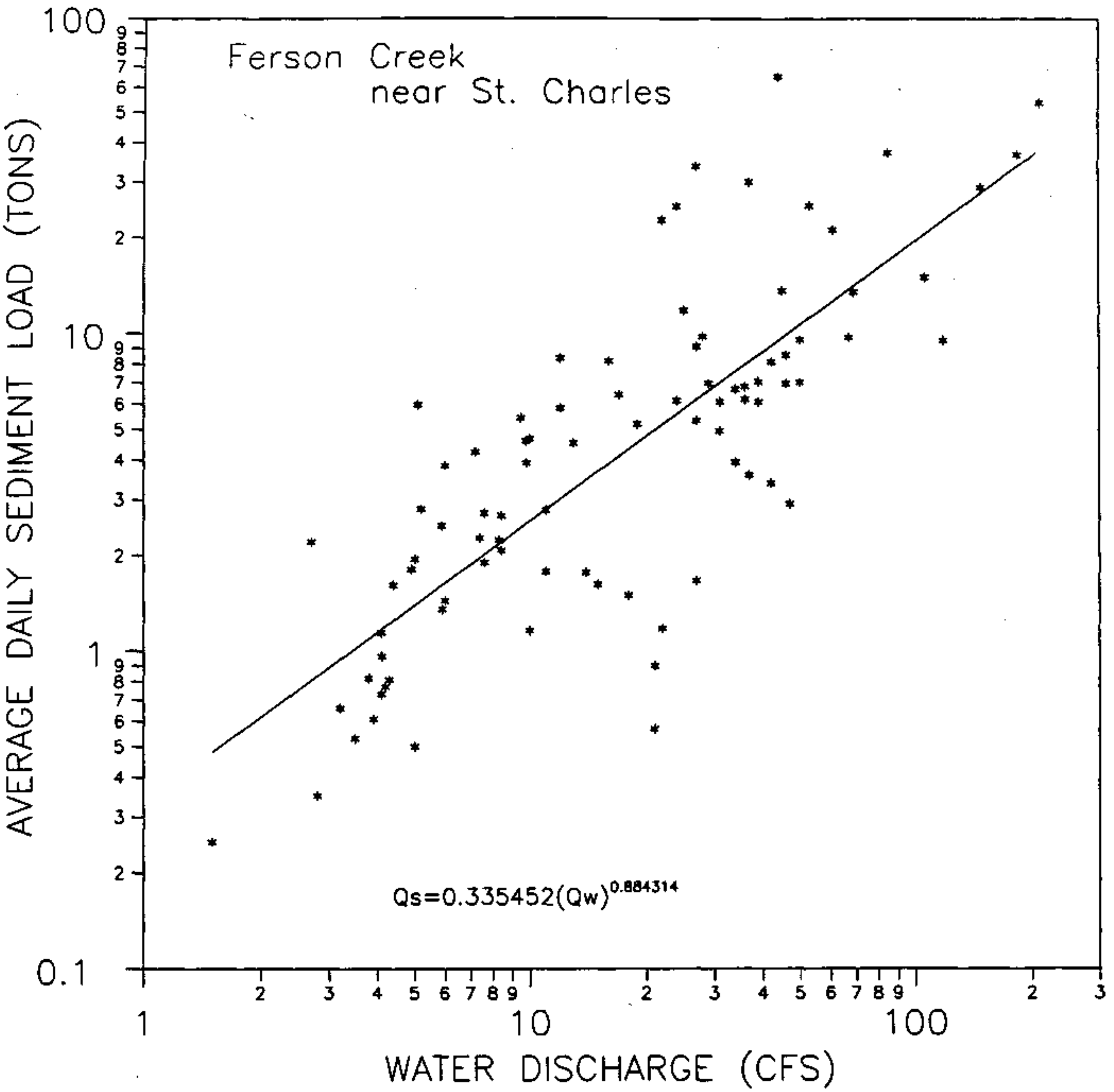

Figure 4. Suspended sediment load versus discharge for Ferson Creek

monthly and annual loads will be much closer. A factor can be applied to the annual loads to correct for the underestimation inherent in the log-log regression (Ferguson, 1986). This method was chosen because some winter periods have no measured concentrations or only one concentration per month.

The monthly average water discharge in cubic feet per second and the total suspended sediment load in tons are given for the study period for both streams in table 1. The monthly average discharges are compared with the period of record averages for Blackberry and Ferson Creeks in figures 5 and 6, respectively. Note that the average discharge for water year (WY) 1988 is above average for Blackberry Creek and average for Ferson Creek. The high discharges in the winter balanced the drought in the spring and summer months of 1988.

Weekly suspended sediment monitoring was conducted for two years on Ferson Creek in WY 1981 and 1982 (Bhowmik et al., 1986). For the years 1981 and 1982 the average discharges were 43.3 and 39.4 cfs, and the computed annual sediment loads were 5,500 and 5,220 tons, respectively. In WY 1988 discharge was 41.3 cfs and sediment load was 3,159 tons. WY 1988 was unusual in that most of the water flow occurred in the winter and spring, while the summer months were much below average. Also note that Blackberry Creek has a considerably higher sediment concentration and load than Ferson Creek.

Sediment yields per unit of drainage area allow some comparison with the calculated erosion rates. For WY 1988 the sediment carried by Blackberry Creek was equal to 83.5 tons per square mile (tons/sq mi), or 0.13 tons per acre. The sediment carried by Ferson Creek was equal to 61.1 tons/sq mi, or 0.095 tons per acre. Using the regional equation proposed by Bhowmik et al. (1986), the average annual sediment loads are 6,345 tons for 51.7 square miles (Ferson Creek) and 8,180 tons for 70.2 square miles (Blackberry Creek). The instream sediment loads can be compared with the soil erosion potential for the area as given by the Soil Conservation Service (1984). Some 83% of the SSC area has an annual erosion potential of 5 tons per acre, or 3,520 tons/sq mi. The differences seem extreme, but the erosion potential is based on individual fields, not on large areas. All sediment yield equations show a decrease in sediment per unit area with increasing drainage area. For instance, the average annual load equation used here gives a rate of 240 tons per year/sq mi for an area of 1 square mile. If the area is 1 acre (not a valid use of the equation because it was developed for areas over 10 square miles), the calculated annual yield is 720 tons/sq mi. But for a drainage area of 100 square miles, the calculated annual yield is only 110 tons/sq mi.

Table 1. Monthly Average Water Discharges and Suspended Sediment Loads

		Blackberry Creek		*Ferson Creek*	
Year	*Month*	$Q_{u'}$ *cfs*	$Q_{s'}$ *tons*	$Q_{u'}$ *cfs*	$Q_{s'}$ *tons*
1987	Apr	42.9	324	41.0	264
1987	May	59.0	453	25.6	181
1987	Jun	37.5	286	13.1	96
1987	Jul	27.8	221	7.7	62
1987	Aug	171.6	1241	141.4	758
1987	Sep	130.8	937	44.4	286
1987	Oct	58.1	451	21.5	157
1987	Nov	75.5	557	51.3	320
1987	Dec	170.9	1264	110.3	659
1988	Jan	115.2	864	105.7	431
1988	Feb	96.0	679	65.8	388
1988	Mar	74.0	568	52.7	343
1988	Apr	104.8	763	76.6	459
1988	May	41.1	323	24.7	177
1988	Jun	20.5	161	8.9	69
1988	Jul	12.4	102	6.1	50
1988	Aug	8.9	74	9.1	70
1988	Sep	6.6	54	4.2	36
1988	Oct	11.7	96	6.7	55
1988	Nov	34.0	259	31.8	210
1988	Dec	21.9	176	17.7	131

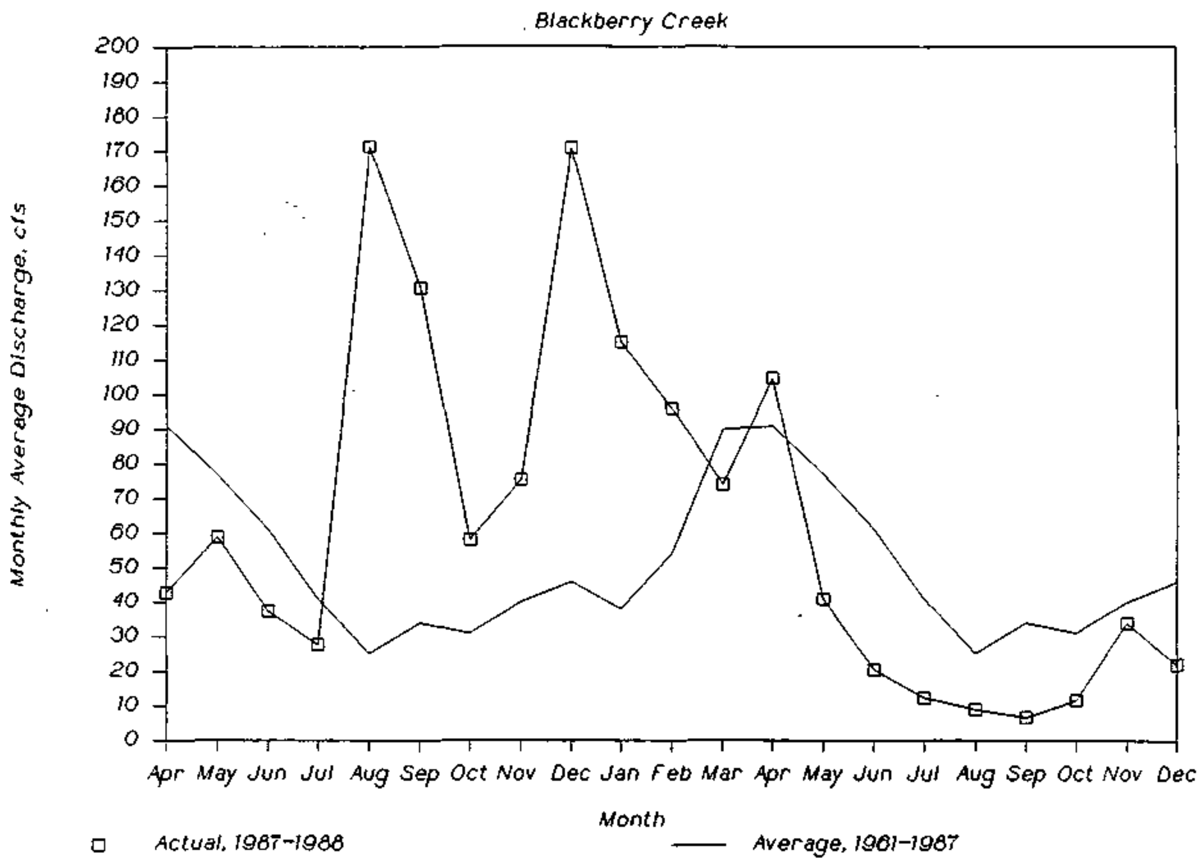

Figure 5. Monthly discharges for Blackberry Creek

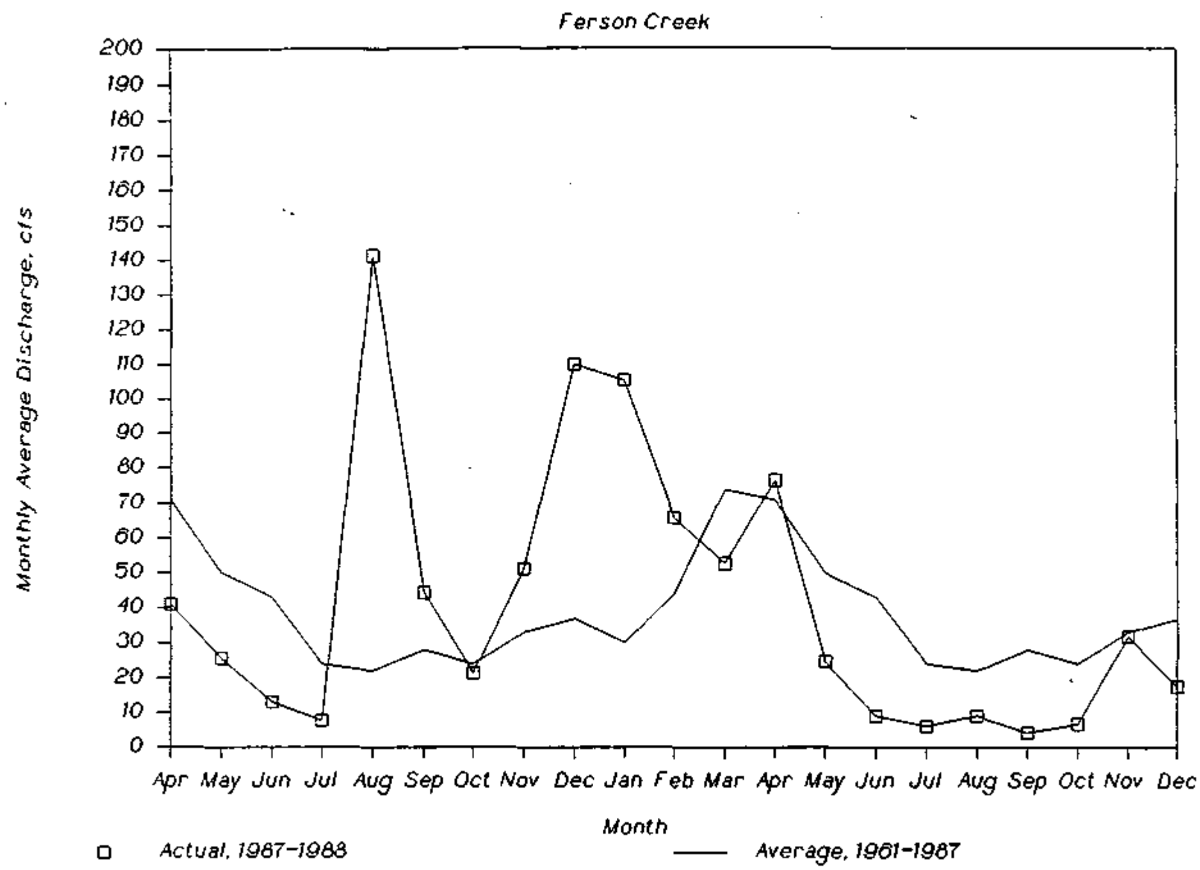

Figure 6. Monthly discharges for Ferson Creek

WATER QUALITY DATA FOR BLACKBERRY AND FERSON CREEKS

Water quality monitoring and sampling of Blackberry Creek and Ferson Creek were conducted approximately every two weeks starting on March 20, 1987. The goal was to develop information concerning the general water quality characteristics of the surface water resources in the region proposed for the Superconducting Super Collider in Illinois. The field sampling continued until November 11, 1988.

During each visit to the sampling sites, temperature and dissolved oxygen were measured in the field. Dissolved oxygen concentrations were determined by the modified Winkler method as outlined by the American Public Health Association et al. (1985). Samples were collected, stored in ice, and shipped to the Water Survey laboratory in Peoria. The samples were refrigerated upon receipt and processed soon thereafter. Standard methods for the examination of water and wastewater were used in all the analyses for water quality parameters (American Public Health Association et al., 1985). Laboratory determinations were made for conductivity, turbidity, pH, alkalinity, chloride, sulfate, hardness, total phosphate-P, total dissolved phosphate-P, total Kjeldahl-N, ammonia-N, nitrate-N, total dissolved solids, suspended solids, volatile suspended solids, barium, cadmium, chromium, copper, iron, lead, manganese, nickel, silver, and zinc.

Summaries of water quality data, including number of samples, mean, range, and standard deviation for Blackberry and Ferson Creeks, are shown respectively in tables 2 and 3. Complete water quality data for these two water courses are shown in appendix tables B1 and B2.

The water quality characteristics of Blackberry and Ferson Creeks are typical of northern Illinois streams, well buffered with high alkalinity, hardness, conductivity, and dissolved solids. For purposes of comparison, mean values of water quality characteristics of other small streams tributary to the Fox Chain of Lakes in northern Illinois are shown in table 4. These streams also have high alkalinity, hardness, conductivity, and dissolved solids. Total and suspended solids in all these streams are also comparable.

The ambient observed temperatures in Blackberry and Ferson Creeks ranged from a minimum of about 1.5°C to a maximum of about 30°C with mean values of about 15°C (tables 2 and 3). As there are no heated effluent discharges into these streams, temperatures vary in these water courses with seasonal changes and other natural phenomena. The mean dissolved oxygen values in these two streams were found to be well above the desirable levels of 6 mg/L for gamefish populations. Barring one observation for DO in Blackberry Creek, dissolved oxygen values for the two streams met the Illinois Pollution Control Board's (IPCB) standards

Table 2. Summary of Water Quality Characteristics of Blackberry Creek

Parameters	*Number of samples*	*Mean*	*Maximum value*	*Minimum value*	*Standard deviation*
Temperature, °C	41	15.1	30.0	1.5	8.06
Dissolved oxygen	36	9.3	13.4	4.9	2.15
Conductivity, lmho/cm at 25°C	42	837	1138	485	149.61
Turbidity, NTU	42	22	139	5	22.67
pH, units	42		8.62	7.85	
Alkalinity	42	276	320	159	31.50
Chloride	42	44	64	29	8.24
Sulfate	42	81	146	51	15.66
Hardness	42	386	496	226	47.65
Total phosphate-P	42	0.12	0.48	0.03	0.10
Total dissolved phosphate-P	42	0.05	0.2	0.01	0.03
Kjeldahl nitrogen-N	42	0.86	1.87	0.24	0.36
Ammonia-N(T)	42	0.16	0.4	0.01	0.10
Nitrate-N (dissolved)	42	3.10	7.25	0.93	1.54
Total solids	42	531	659	369	55.23
Gooch suspended solids	42	29	225	2	39.47
Suspended volatile solids	42	7	33	0	6.67
Barium (T)	42	0.06	0.1	0.02	0.02
Cadmium (T)	42	0.001	0.01	0	0.00
Chromium (T)	42	0.00	0.04	0	0.01
Copper (T)	42	0.00	0.01	0	0.00
Iron(T)	42	0.91	5.08	0.21	0.95
Lead(T)	42	0.02	0.1	0.01	0.01
Manganese (T)	42	0.10	0.32	0.03	0.05
Nickel (T)	42	0.02	0.05	0	0.01
Silver (T)	42	0.000	0.005	0	0.00
Zinc(T)	42	0.03	0.22	0	0.04

Notes: Concentrations are expressed in mg/L except where indicated.
T = total

Table 3. Summary of Water Quality Characteristics of Ferson Creek

Parameters	*Number of samples*	*Mean*	*Maximum value*	*Minimum value*	*Standard deviation*
Temperature, °C	41	14.8	29.7	1.4	7.92
Dissolved oxygen	35	9.5	14.1	5.6	2.22
Conductivity, lmho/cm at 25°C	42	860	1149	563	138.81
Turbidity, NTU	42	23	167	4	27.12
pH, units	42		8.40	7.81	
Alkalinity	42	293	349	218	23.89
Chloride	42	64	471	37	64.33
Sulfate	42	68	97	44	10.14
Hardness	42	389	443	276	32.15
Total phosphate-P	42	0.10	0.3	0.03	0.06
Total dissolved phosphate-P	42	0.05	0.16	0.01	0.03
Kjeldahl nitrogen-N	42	0.90	2.82	0.24	0.43
Ammonia-N(T)	42	0.18	1.09	0.01	0.17
Nitrate-N (Dissolved)	42	2.85	5.57	0.65	1.26
Total solids	42	516	635	5.14	89.01
Gooch suspended solids	42	23	79	3	19.95
Suspended volatile solids	42	6	38	0	6.72
Barium (T)	42	0.06	0.12	0.01	0.02
Cadmium (T)	42	0.000	0.01	0	0.00
Chromium (T)	42	0.00	0.03	0	0.01
Copper (T)	42	0.00	0.02	0	0.01
Iron(T)	42	0.79	2.94	0.18	0.64
Lead(T)	42	0.02	0.04	0.01	0.01
Manganese (T)	42	0.10	0.25	0.05	0.05
Nickel (T)	42	0.02	0.04	0	0.01
Silver (T)	42	0.000	0	0	0.00
Zinc(T)	42	0.03	0.31	0	0.05

Notes: Concentrations are expressed in mg/L except where indicated.
T = total

Table 4. Summary of Water Quality Characteristics of Other Small Streams in Northern Illinois

Parameters	*Lily Lake Drain*	*Nippersink Creek*	*Sequoit Creek*	*Squaw Creek*
Dissolved oxygen	8.9	10.0	8.2	10.1
Turbidity (FTU)	8.4	11.1	15.9	10.4
pH, units	7.93-8.62	7.89-8.70	7.82-8.47	7.98-8.75
Alkalinity	257	234	210	201
Chloride	12	30	60	36
Sulfate	61	59	71	81
Hardness	336	313	261	289
Total phosphate-P	0.10	0.25	1.27	0.83
Dissolved orthophosphate-P	0.05	0.16	1.09	0.67
Nitrate-N (Dissolved)	0.63	1.54	1.03	0.92
Kjeldahl nitrogen-N	1.29	1.14	3.46	2.49
Ammonia-N (total)	0.43	0.29	2.16	1.11
Total solids	443	451	488	449
Total dissolved solids	414	409	442	423
Suspended solids	29	43	49	27
Total iron	0.78	1.61	1.64	0.66

Note: Concentrations are expressed as mg/L except where indicated.

(IPCB, 1982). General-use water quality standards applicable to Blackberry and Ferson Creeks are shown in appendix C. All pH values observed for the streams met the standards.

The mean total phosphate-P values for the two creeks are twice the concentrations suggested by the IPCB. The rules and regulations state that phosphorus as P shall not exceed 0.05 mg/L in any reservoir or lake with a surface area of 8.1 hectares (20 acres) or more, or in any stream at the point where it enters any such reservoir or lake (appendix C). As these two streams are not tributary to any lake or reservoir, the phosphorus standard per se is not applicable. Even otherwise, phosphorus concentrations in Illinois streams are invariably higher than the stipulated standard. The dissolved phosphorus constitutes about 40 to 50% of the total phosphorus. Streams receiving municipal waste discharges tend to exhibit values of dissolved phosphorus equal to about 80% of the total phosphorus.

The mean values for ammonia-N, nitrate-N, and organic nitrogen observed in these streams are typical of most Illinois streams. All the observed values for ammonia-N were within the stipulated stream standards. This was true for chlorides, sulfates, and dissolved solids also.

The mean heavy metals concentrations investigated in this study were all below the stipulated standards. Even the maximum observed concentrations for all the metals except iron were within the standards. Iron concentrations exceeded the limit 26% of the time in Blackberry Creek and 29% of the time in Ferson Creek. Concentrations of iron in Illinois surface waters have generally been found to be high.

SUMMARY

The proposed construction of the SSC raised concern about the impact of construction activities on the sediment loads and water quality of surface streams. Two monitoring sites were established at existing USGS streamgaging stations to collect suspended sediment and water quality samples for almost two years.

Blackberry and Ferson Creeks were found to be typical of northern Illinois streams: well buffered, high in alkalinity, hardness, and mineral content. Turbidity in these streams is moderate. About 70 to 80% of the suspended sediments are inorganic in nature. The dissolved phosphorus constitutes about 40 to 50% of the total phosphorus. The dissolved oxygen concentrations in the streams were much higher than the desired level of 6.0 mg/L. Concentrations of heavy metals such as arsenic, barium, and cadmium were all less than the stipulated standards with the exception of iron. Concentrations of iron exceeded the standards in about 30% of the total observations. In general, the physical and chemical quality characteristics of waters in these two streams are excellent. They meet or exceed the state standards in all but two parameters evaluated, namely total phosphorus and iron.

Suspended sediment concentration and loads were also in the range expected for this part of Illinois. Blackberry Creek has a sediment yield about 30% higher than Ferson Creek. Maximum concentrations were about 500 mg/L, and the maximum daily suspended sediment loads were 158 tons per day for Blackberry Creek and 65 tons per day for Ferson Creek.

Thus the ambient conditions of these streams are typical of others in the area, all of which are in generally good condition. Since the streams in Kane County have low suspended sediment concentrations and good water quality, any construction project, especially of a scale approaching that of the proposed SSC tunnel, should take measures to prevent sediment and pollutants from entering the creeks and streams.

Appendix Table A1. Suspended Sediment Concentration Data for Blackberry Creek

Date	*Time*	*Conc.*	*Aug. conc.*	*USGS Q*	*Load*	*Daily avg. load*
04/01/87	1419	42	42	24	3	3
06/02/87	1600	188	221	50	25	30
06/02/87	2400	254	221	50	34	30
06/03/87	800	270	240	58	42	37
06/03/87	1600	210	240	58	33	37
06/04/87	2400	168	168	49	22	22
06/05/87	800	230	230	41	25	25
06/09/87	1150	108	108	26	8	8
06/11/87	2400	190	190	25	13	13
06/12/87	800	356	357	70	67	67
06/12/87	1600	424	357	70	80	67
06/12/87	2400	290	357	70	55	67
06/13/87	800	334	334	68	61	61
06/14/87	2400	158	158	47	20	20
06/16/87	1215	146	146	33	13	13
06/20/87	1600	165	229	38	17	23
06/20/87	2400	292	229	38	30	23
06/21/87	800	418	418	58	65	65
06/24/87	800	132	132	28	10	10
06/25/87	1114	208	208	42	24	24
06/27/87	800	128	121	30	10	10
06/27/87	2400	113	121	30	9	10
06/30/87	1600	123	123	24	8	8
07/01/87	1315	53	107	23	3	7
07/01/87	800	160	107	23	10	7
07/08/87	1910	33	33	18	2	2
07/10/87	800	94	94	36	9	9
07/11/87	1600	72	215	113	22	65
07/11/87	2400	358	215	113	109	65
07/12/87	800	478	466	61	79	77
07/12/87	1600	574	466	61	94	77
07/12/87	2400	346	466	61	57	77
07/13/87	800	488	488	45	59	59
07/15/87	1531	70	70	34	6	6
07/16/87	800	101	79	31	8	7
07/16/87	1600	78	79	31	7	7
07/16/87	2400	57	79	31	5	7
07/17/87	800	99	99	26	7	7
07/18/87	800	113	113	24	7	7
07/20/87	800	92	93	21	5	5
07/20/87	1600	103	93	21	6	5

Appendix Table A1. (Continued)

Date	*Time*	*Conc.*	*Avg. conc.*	*USGS Q*	*Load*	*Daily avg. load*
07/20/87	2400	84	93	21	5	5
07/22/87	1745	29	29	23	2	2
07/29/87	1120	61	61	22	4	4
07/31/87	2400	119	119	24	8	8
08/01/87	800	112	83	25	8	6
08/01/87	1600	53	83	25	4	6
08/05/87	1201	64	64	17	3	3
08/06/87	1600	65	65	16	3	3
08/07/87	800	96	95	16	4	4
08/07/87	2400	94	95	16	4	4
08/09/87	2400	119	119	20	6	6
08/12/87	1649	50	50	15	2	2
08/13/87	1600	43	124	16	2	5
08/13/87	2400	204	124	16	9	5
08/14/87	800	182	308	56	27	46
08/14/87	1600	314	308	56	47	46
08/14/87	2400	428	308	56	65	46
08/15/87	800	302	205	253	206	140
08/15/87	1600	196	205	253	134	140
08/15/87	2400	118	205	253	80	140
08/16/87	800	76	38	440	90	44
08/16/87	1600	60	38	440	71	44
08/16/87	1651	36	38	440	43	44
08/16/87	1653	38	38	440	45	44
08/16/87	1655	38	38	440	45	44
08/16/87	1656	38	38	440	45	44
08/16/87	1657	32	38	440	38	44
08/16/87	1659	32	38	440	38	44
08/16/87	1702	30	38	440	36	44
08/16/87	1705	31	38	440	37	44
08/16/87	1706	29	38	440	34	44
08/16/87	1709	28	38	440	33	44
08/16/87	1710	33	38	440	39	44
08/16/87	1713	31	38	440	37	44
08/16/87	1733	31	38	440	37	44
08/17/87	1600	86	70	300	69	56
08/17/87	2400	53	70	300	43	56
08/18/87	800	39	36	389	41	37
08/18/87	1600	29	36	389	30	37
08/18/87	2400	39	36	389	41	37
08/19/87	1651	88	88	189	45	45

Appendix Table A1. (Continued)

Date	*Time*	*Conc.*	*Avg. conc.*	*USGS Q*	*Load*	*Daily avg. load*
08/24/87	800	224	213	76	46	44
08/24/87	1600	196	213	76	40	44
08/24/87	2400	218	213	76	45	44
08/25/87	800	180	194	73	35	38
08/25/87	1600	208	194	73	41	38
08/26/87	800	294	203	265	210	145
08/26/87	1600	216	203	265	154	145
08/26/87	2400	100	203	265	71	145
08/31/87	800	77	141	171	35	65
08/31/87	1600	148	141	171	68	65
08/31/87	2400	198	141	171	91	65
09/01/87	800	146	146	130	51	51
09/02/87	1740	87	87	109	26	26
09/07/87	800	164	190	70	31	36
09/07/87	1600	192	190	70	36	36
09/07/87	2400	214	190	70	40	36
09/10/87	1620	69	69	61	11	11
09/11/87	800	122	118	58	19	18
09/11/87	1600	114	118	58	18	18
09/16/87	1138	66	66	58	10	10
09/17/87	800	202	142	313	170	120
09/17/87	2400	82	142	313	69	120
09/19/87	1600	26	26	524	37	37
09/21/87	800	104	104	158	44	44
09/22/87	2400	98	98	135	36	36
09/23/87	1545	60	60	119	19	19
09/30/87	1500	40	40	76	8	8
10/07/87	1530	24	24	62	4	4
10/14/87	1701	14	14	54	2	2
10/21/87	1608	6	6	60	1	1
11/04/87	1600	44	39	114	14	12
11/04/87	2400	34	39	114	10	12
11/05/87	800	55	45	96	14	12
11/05/87	1600	42	45	96	11	12
11/05/87	2400	37	45	96	10	12
11/06/87	800	30	47	74	6	9
11/06/87	1600	76	47	74	15	9
11/06/87	2400	35	47	74	7	9
11/24/87	1212	7	7	43	1	1
11/28/87	2400	148	148	80	32	32
11/29/87	800	164	138	269	119	100

Appendix Table A1. (Continued)

Date	Time	Conc.	Aug. conc.	USGS Q	Load	Daily avg. load
11/29/87	1600	166	138	269	120	100
11/29/87	2400	84	138	269	61	100
11/30/87	800	98	107	223	59	64
11/30/87	1600	129	107	223	77	64
11/30/87	2400	94	107	223	56	64
12/01/87	800	80	70	155	33	29
12/01/87	1600	78	70	155	33	29
12/01/87	2400	53	70	155	22	29
12/02/87	800	133	82	127	45	28
12/02/87	1600	58	82	127	20	28
12/02/87	2400	56	82	127	19	28
12/11/87	1524	37	86	180	18	42
12/11/87	1600	156	86	180	76	42
12/11/87	2400	66	86	180	32	42
12/12/87	800	95	83	144	37	32
12/12/87	1600	54	83	144	21	32
12/12/87	2400	100	83	144	39	32
12/13/87	800	58	58	119	19	19
12/20/87	800	62	61	212	35	35
12/20/87	1600	59	61	212	34	35
12/24/87	1600	127	112	197	67	59
12/24/87	2400	97	112	197	51	59
12/25/87	800	150	127	275	111	94
12/25/87	1600	108	127	275	80	94
12/25/87	2400	124	127	275	92	94
03/24/88	800	63	60	83	14	13
03/24/88	1600	42	60	83	9	13
03/24/88	2400	74	60	83	17	13
03/25/88	800	52	56	89	12	13
03/25/88	1600	42	56	89	10	13
03/25/88	2400	74	56	89	18	13
03/28/88	1600	32	41	73	6	8
03/28/88	2400	50	41	73	10	8
03/29/88	800	72	78	110	21	23
03/29/88	1600	76	78	110	23	23
03/29/88	2400	85	78	110	25	23
03/30/88	800	92	95	167	41	43
03/30/88	1205	87	95	167	39	43
03/30/88	2400	106	95	167	48	43
04/02/88	2400	63	63	106	18	18
04/03/88	800	70	70	106	20	20

Appendix Table A1. (Continued)

Date	*Time*	*Conc.*	*Avg. conc.*	*USGS Q*	*Load*	*Daily avg. load*
04/06/88	2400	72	72	218	42	42
04/07/88	1145	138	146	401	149	158
04/07/88	1147	124	146	401	134	158
04/07/88	1149	134	146	401	145	158
04/07/88	1150	140	146	401	151	158
04/07/88	1151	140	146	401	151	158
04/07/88	1153	136	146	401	147	158
04/07/88	1155	144	146	401	155	158
04/07/88	1156	140	146	401	151	158
04/07/88	1157	151	146	401	163	158
04/07/88	1159	150	146	401	162	158
04/07/88	1200	154	146	401	166	158
04/07/88	1201	160	146	401	173	158
04/07/88	1202	150	146	401	162	158
04/07/88	1203	158	146	401	171	158
04/07/88	1205	148	146	401	160	158
04/07/88	1206	160	146	401	173	158
04/07/88	1207	130	146	401	140	158
04/07/88	1209	154	146	401	166	158
04/07/88	1217	153	146	401	165	158
04/07/88	1600	197	146	401	213	158
04/07/88	2400	110	146	401	119	158
04/08/88	800	98	98	252	67	67
04/12/88	2400	95	95	98	25	25
04/13/88	800	85	85	93	21	21
04/16/88	800	51	49	74	10	10
04/16/88	1600	47	49	74	9	10
04/18/88	1225	78	78	70	15	15
04/24/88	2400	72	68	69	13	13
04/24/88	800	63	68	69	12	13
04/25/88	2400	58	58	65	10	10
04/29/88	2400	47	47	58	7	7
05/02/88	1600	48	48	52	7	7
05/03/88	1200	38	38	50	5	5
05/05/88	800	45	45	47	6	6
05/06/88	2400	31	31	46	4	4
05/11/88	2400	97	97	47	12	12
05/13/88	1600	70	70	45	8	8
05/18/88	1235	85	85	36	8	8
05/23/88	1600	105	118	36	10	11
05/23/88	2400	130	118	36	13	11

Appendix Table A1. (Concluded)

Date	*Time*	*Conc.*	*Aug. conc.*	*USGS Q*	*Load*	*Daily avg. load*
05/24/88	800	108	122	49	14	16
05/24/88	2400	136	122	49	18	16
05/27/88	1600	112	112	64	19	19
07/19/88	1230	89	89	28	7	7
10/18/88	800	362	354	44	43	42
10/18/88	1600	386	354	44	46	42
10/18/88	2400	314	354	44	37	42
10/19/88	800	184	102	24	12	7
10/19/88	1200	19	102	24	1	7
11/04/88	2400	201	201	21	11	11
11/05/88	800	235	138	43	27	16
11/05/88	1600	129	138	43	15	16
11/05/88	2400	49	138	43	6	16
11/06/88	800	37	37	29	3	3
11/09/88	800	30	74	22	2	4
11/09/88	2400	117	74	22	7	4
11/10/88	1600	113	113	38	12	12
11/11/88	800	94	94	43	11	11
11/14/88	2400	146	146	40	16	16
11/15/88	800	130	466	34	12	43
11/15/88	1600	169	466	34	15	43
11/15/88	2400	1100	466	34	101	43
11/16/88	800	159	168	75	32	34
11/16/88	1600	200	168	75	40	34
11/16/88	2400	144	168	75	29	34
11/17/88	800	112	106	78	24	22
11/17/88	1600	99	106	78	21	22

Appendix Table A2. Suspended Sediment Concentration Data for Ferson Creek

Date	*Time*	*Conc.*	*Avg. conc.*	*USGS Q*	*Load*	*Daily avg. load*
04/01/87	1720	23	23	27	1.67	1.67
06/16/87	1315	94	94	11	2.78	2.78
06/25/87	1010	93	93	7.6	1.90	1.90
07/01/87	1204	92	92	8.4	2.08	2.08
07/14/87	1419	70	70	4.3	0.81	0.81
07/22/87	1615	37	37	5	0.50	0.50
07/29/87	1013	552	552	44	65.40	65.40
08/05/87	1200	89	89	6	1.44	1.44
08/12/87	1445	68	68	4.2	0.77	0.77
08/16/87	1901	71	74.2	184	35.18	36.76
08/16/87	1903	73	74.2	184	36.17	36.76
08/16/87	1905	74	74.2	184	36.67	36.76
08/16/87	1907	79	74.2	184	39.14	36.76
08/16/87	1908	74	74.2	184	36.67	36.76
08/16/87	1911	74	74.2	184	36.67	36.76
08/16/87	1911	74	74.2	184	36.67	36.76
08/16/87	1913	73	74.2	184	36.17	36.76
08/16/87	1914	75	74.2	184	37.16	36.76
08/16/87	1919	75	74.2	184	37.16	36.76
08/16/87	1920	75	74.2	184	37.16	36.76
08/16/87	1922	73	74.2	184	36.17	36.76
08/19/87	1530	53	53	106	15.13	15.13
08/25/87	1520	56	56	46	6.94	6.94
09/02/87	1550	54	54	67	9.74	9.74
09/10/87	1434	36	36	37	3.59	3.59
09/16/87	1010	59	59	31	4.93	4.93
09/23/87	1410	58	58	39	6.09	6.09
09/30/87	1335	64	64	36	6.20	6.20
10/07/87	1415	16	16	21	0.90	0.90
10/14/87	1530	31	31	18	1.50	1.50
10/21/87	1440	20	20	22	1.18	1.18
11/24/87	1325	10	10	21	0.57	0.57
12/11/87	1346	30	30	118	9.53	9.53
03/30/88	1340	65	72.8	148	25.90	29.01
03/30/88	1352	77	72.8	148	30.69	29.01
03/30/88	1354	75	72.8	148	29.89	29.01
03/30/88	1355	68	72.8	148	27.10	29.01
03/30/88	1356	84	72.8	148	33.48	29.01
03/30/88	1358	73	72.8	148	29.09	29.01
03/30/88	1400	78	72.8	148	31.09	29.01

Appendix Table A2. (Continued)

Date	*Time*	*Conc.*	*Aug. conc.*	*USGS Q*	*Load*	*Daily avg. load*
03/30/88	1401	82	72.8	148	32.68	29.01
03/30/88	1403	75	72.8	148	29.89	29.01
03/30/88	1404	80	72.8	148	31.88	29.01
03/24/88	1600	42	72.8	34	3.85	6.67
03/24/88	2400	74	72.8	34	6.78	6.67
03/25/88	800	52	52	50	7.00	7.00
04/07/88	1428	98	94.7	211	55.68	53.79
04/07/88	1429	78	94.7	211	44.32	53.79
04/07/88	1430	48	94.7	211	27.27	53.79
04/07/88	1432	176	94.7	211	100.00	53.79
04/07/88	1433	95	94.7	211	53.98	53.79
04/07/88	1434	94	94.7	211	53.41	53.79
04/07/88	1435	79	94.7	211	44.89	53.79
04/07/88	1436	87	94.7	211	49.43	53.79
04/07/88	1437	89	94.7	211	50.57	53.79
04/07/88	1438	100	94.7	211	56.82	53.79
04/07/88	1440	95	94.7	211	53.98	53.79
04/07/88	1441	97	94.7	211	55.11	53.79
04/18/88	1400	69	69	46	8.55	8.55
04/19/88	2400	72	72	42	8.14	8.14
04/21/88	2400	30	30	42	3.39	3.39
04/23/88	800	130	130	61	21.35	21.35
04/25/88	2400	71	71	50	9.56	9.56
04/28/88	2400	23	23	47	2.91	2.91
05/01/88	800	67	67	39	7.04	7.04
05/02/88	2400	70	70	36	6.79	6.79
05/03/88	1325	43	43	34	3.94	3.94
05/05/88	2400	73	73	31	6.09	6.09
05/07/88	2400	89	89	29	6.95	6.95
05/12/88	1600	73	73	27	5.31	5.31
05/16/88	2400	125	125	27	9.09	9.09
05/18/88	1355	95	95	24	6.14	6.14
05/23/88	800	108	101.3	19	5.53	5.18
05/23/88	1600	82	101.3	19	4.20	5.18
05/23/88	2400	114	101.3	19	5.83	5.18
05/24/88	800	176	176	25	11.85	11.85
05/29/88	800	190	190	16	8.19	8.19
06/01/88	800	212	212	9.5	5.42	5.42
06/02/88	800	174	174	9.8	4.59	4.59
06/04/88	2400	148	148	9.8	3.91	3.91
06/08/88	2400	100	100	8.3	2.24	2.24

Appendix Table A2. (Continued)

Date	*Time*	*Conc.*	*Avg. conc.*	*USGS Q*	*Load*	*Daily avg. load*
06/12/88	800	114	114	7.4	2.27	2.27
06/18/88	1600	85	85	5.9	1.35	1.35
06/21/88	1400	286	303.6	37	28.50	30.25
06/21/88	1420	326	303.6	37	32.48	30.25
06/21/88	1424	336	303.6	37	33.48	30.25
06/21/88	1426	354	303.6	37	35.27	30.25
06/21/88	1428	216	303.6	37	21.52	30.25
06/23/88	1600	180	180	12	5.82	5.82
06/25/88	800	133	133	7.6	2.72	2.72
06/28/88	800	137	137	4.9	1.81	1.81
07/16/88	2400	304	304	2.7	2.21	2.21
07/18/88	1600	570	466	27	41.44	33.88
07/18/88	2400	362	466	27	26.32	33.88
07/19/88	1345	54	129.5	28	4.07	9.76
07/19/88	1600	205	129.5	28	15.46	9.76
07/21/88	800	218	218	7.2	4.23	4.23
07/26/88	800	145	145	5	1.95	1.95
08/07/88	1600	63	63	1.5	0.25	0.25
08/09/88	800	404	387	22	23.93	22.93
08/09/88	1600	370	387	22	21.92	22.93
08/10/88	2400	392	392	24	25.33	25.33
08/13/88	800	140	140	17	6.41	6.41
08/17/88	800	200	200	5.2	2.80	2.80
08/18/88	2400	434	434	5.1	5.96	5.96
08/19/88	800	259	259	12	8.37	8.37
08/20/88	1600	173	173	10	4.66	4.66
08/22/88	1600	118	118	8.4	2.67	2.67
08/24/88	800	156	156	5.9	2.48	2.48
09/15/88	2400	136	136	4.4	1.61	1.61
09/19/88	800	80	80	3.8	0.82	0.82
09/20/88	2400	103	103	4.1	1.14	1.14
09/21/88	2400	87	87	4.1	0.96	0.96
09/24/88	800	66	66	4.1	0.73	0.73
09/26/88	2400	58	58	3.9	0.61	0.61
09/29/88	2400	56	56	3.5	0.53	0.53
10/10/88	800	77	77	3.2	0.66	0.66
10/16/88	800	47	47	2.8	0.35	0.35
10/17/88	2400	237	237	6	3.83	3.83
10/19/88	800	81	47	14	3.05	1.77
10/19/88	1330	13	47	14	0.49	1.77
10/20/88	2400	60	60	11	1.78	1.78

Appendix Table A2. (Concluded)

Date	*Time*	*Conc.*	*Aug. conc.*	*USGS Q*	*Load*	*Daily avg. load*
10/22/88	1600	43	43	10	1.16	1.16
10/24/88	800	40	40	15	1.62	1.62
11/09/88	2400	129	129	13	4.52	4.52
11/10/88	800	178	178	53	25.40	25.40
11/13/88	800	113	113	45	13.69	13.69
11/13/88	1600	123	113	45	14.90	13.69
11/13/88	2400	103	113	45	12.48	13.69
11/16/88	800	276	163.7	85	63.17	37.46
11/16/88	1600	113	163.7	85	25.86	37.46
11/16/88	2400	102	163.7	85	23.35	37.46
11/17/88	800	76	73	69	14.12	13.56
11/17/88	1600	70	73	69	13.01	13.56

Appendix Table B1. Water Quality Characteristics of Blackberry Creek, 1987- 1988

Parameter	*3/20/87*	*4/1/87*	*4/14/87*	*4/28/87*	*5/14/87*	*5/28/87*	*6/9/87*	*6/25/87*	*7/8/87*	*7/22/87*
Temperature, °C		7.2	11.7	17.4	20.9	23.0	20.0	22.0	27.5	28.6
Dissolved oxygen		12.5	8.3	9.7	8.2	6.8	7.6	6.6	6.5	7.1
Conductivity, mho/cm at 25°C	766	767	778	783	755	750	786	628	793	813
Turbidity, NTU	7	6	11	33	23	71	51	36	12	14
pH, units	8.40	8.41	8.11	8.40	8.20	8.09	8.25	8.13	8.34	8.42
Alkalinity	291	296	299	296	275	280	299	246	302	293
Chloride	53	51	46	48	45	42	30	30	45	39
Sulfate	84	54	51	82	82	72	83	95	104	90
Hardness	397	390	390	402	385	391	416	312	402	371
Total phosphate-P	0.03	0.04	0.08	0.11	0.10	0.25	0.21	0.45	0.08	0.12
Total dissolved phosphate-P	0.02	0.01	0.02	0.02	0.02	0.04	0.08	0.10	0.06	0.06
Kjeldahl nitrogen-N	0.63	0.83	0.87	1.00	1.38	1.25	0.77	1.66	0.88	1.06
Ammonia-N(T)	0.02	0.07	0.08	0.08	0.36	0.13	0.09	0.20	0.13	0.16
Nitrate-N (Dissolved)	2.49	2.39	2.54	5.87	5.17	7.25	4.93	3.61	2.48	1.70
Total solids	512	482	492	562	576	630	640	659	612	496
Gooch suspended solids	9	3	9	47	29	108	70	225	17	40
Suspended volatile solids	6	1	3	15	3	22	15	33	6	3
Barium (T)	0.06	0.03	0.05	0.03	0.04	0.04	0.06	0.08	0.08	0.07
Cadmium (T)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (T)	0.01	<0.01	0.04	0.01	0.01	0.02	0.02	0.01	<0.01	<0.01
Copper (T)	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01
Iron(T)	0.26	0.22	0.50	1.62	0.90	3.20	2.53	2.53	0.43	0.50
Lead(T)	0.03	0.02	0.03	0.01	0.02	0.03	0.01	0.04	0.03	0.02
Manganese (T)	0.09	0.07	0.15	0.14	0.10	0.18	0.14	0.32	0.03	0.05
Nickel (T)	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.05	0.02	0.01
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	0.05	0.05	<0.01	0.05	0.11	0.02	0.02	0.04	0.03	0.03

Note: Concentrations are expressed as mg/L except where indicated and (T) = total.

Appendix Table B1. (Continued)

Parameter	*8/5/87*	*8/16/87*	*9/2/87*	*9/16/87*	*9/30/87*	*10/14/87*	*11/4/87*	*11/19/87*	*12/11/87*	*12/22/87*
Temperature, °C	23.2	26.7	19.2	19.6	16.0	12.7	13.8	5.3	6.5	3.8
Dissolved oxygen	7.5	4.9		7.6	9.0	12.8	9.5	13.4		
Conductivity, mho/cm at 25°C	787	485	658	758	767	777	737	797	983	957
Turbidity, NTU	28	28	45	30	18	9	16	6	22	22
pH, units	8.30	7.85	8.20	8.20	8.39	8.31	8.20	8.30	8.02	7.99
Alkalinity	306	174	273	318	320	300	273	305	250	228
Chloride	42	42	29	35	34	40	37	41	35	46
Sulfate	92	78	74	82	77	86	67	79	67	60
Hardness	396	237	343	398	403	417	384	419	357	337
Total phosphate-P	0.14	0.30	0.24	0.14	0.11	0.03	0.10	0.04	0.14	0.15
Total dissolved phosphate-P	0.07	0.20	0.06	0.06	0.05	0.01	0.07	0.04	0.05	0.06
Kjeldahl nitrogen-N	0.97	1.87	1.22	0.55	0.53	0.60	1.13	0.74	0.78	0.83
Ammonia-N (T)	0.08	0.07	0.13	0.06	0.08	0.40	0.09	0.35	0.14	0.13
Nitrate-N (Dissolved)	1.72	3.63	3.77	2.59	1.99	2.90	4.68	3.29	5.96	5.88
Total solids	534	369	502	547	512	496	495	545	498	460
Gooch suspended solids	31	37	32	38	20	3	17	3	37	26
Suspended volatile solids	3	19	7	9	4	1	10	1	14	7
Barium (T)	0.09	0.08	0.08	0.10	0.09	0.07	0.08	0.06	0.06	0.08
Cadmium (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (T)	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper (T)	<0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron(T)	1.04	0.98	2.08	1.32	1.11	0.25	0.57	0.21	0.95	0.86
Lead(T)	0.02	0.02	0.03	0.04	0.02	0.02	0.03	0.03	0.02	0.02
Manganese (T)	0.11	0.07	0.12	0.10	0.07	0.04	0.07	0.05	0.06	0.05
Nickel (T)	0.03	0.02	0.02	0.01	0.02	0.01	<0.01	0.03	0.02	0.02
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	0.03	0.03	0.10	0.01	0.02	<0.01	0.04	<0.01	<0.01	<0.01

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B1. (Continued)

Parameter	*1/29/88*	*2/18/88*	*3/1/88*	*3/14/88*	*3/18/88*	*3/24/88*	*4/7/88*	*4/27/88*	*5/10/88*	*5/24/88*
Temperature, °C	2.1	1.5	7.6	1.8	7.0	11.2	9.8	7.8	14.3	17.0
Dissolved oxygen	12.5	11.9			12.8	10.9	9.3	12.0	10.1	8.4
Conductivity, mho/cm at 25°C	1031	1138	1047	1077	1076	1028	727	1077	1072	1008
Turbidity, NTU	19	19	14	8	11	21	139	5	11	41
pH, units	7.95	8.02	8.29	8.31	8.40	8.20	8.08	8.30	8.31	8.12
Alkalinity	270	275	271	279	283	271	159	289	287	262
Chloride	37	58	45	48	45	39	42	37	39	42
Sulfate	66	70	74	76	75	77	54	76	78	71
Hardness	388	379	456	385	397	377	226	389	401	364
Total phosphate-P	0.08	0.07	0.07	0.04	0.05	0.13	0.48	0.06	0.07	0.20
Total dissolved phosphate-P	0.03	0.04	0.03	0.02	0.02	0.02	0.13	0.01	0.03	0.04
Kjeldahl nitrogen-N	0.77	0.42	0.68	0.52	0.44	0.85	1.72	0.61	0.24	1.34
Ammonia-N (T)	0.32	0.29	0.27	0.13	0.11	0.06	0.24	0.01	0.04	0.30
Nitrate-N (Dissolved)	4.52	4.18	3.66	3.80	3.44	2.76	5.04	3.40	3.03	2.93
Total solids	497	533	511	493	520	497	457	527	526	550
Gooch suspended solids	18	13	19	6	8	24	119	2	16	51
Suspended volatile solids	1	4	3	0	4	10	18	1	6	10
Barium (T)	0.07	0.05	0.08	0.05	0.06	0.04	0.04	0.04	0.04	0.04
Cadmium (T)	0.003	0.003	0.004	0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Chromium (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Iron(T)	0.59	0.51	0.50	0.29	0.29	0.74	5.08	0.27	0.53	1.69
Lead(T)	0.02	0.02	0.10	0.02	0.02	0.02	0.02	0.03	0.02	0.01
Manganese (T)	0.07	0.07	0.07	0.05	0.05	0.11	0.17	0.06	0.10	0.20
Nickel (T)	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.03
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	0.07	0.02	<0.01	<0.01	<0.01	0.02	0.05	0.03	0.02	0.02

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B1. (Continued)

Parameter	*6/9/88*	*6/27/88*	*7/12/88*	*8/4/88*	*8/16/88*	*8/30/88*	*9/15/88*	*9/21/88*	*10/5/88*	*10/14/88*
Temperature, °C	17.5	22.3	26.2	30.0	28.7	18.5	18.1	16.6	10.8	12.6
Dissolved oxygen	8.5	8.0	6.5	8.8	6.2	8.0	8.4	9.2	10.1	10.4
Conductivity, mho/cm at 25°C	1125	756	779	684	688	787	756	756	751	807
Turbidity, NTU	24	23	16	10	19	13	12	10	8	11
pH, units	8.39	8.31	8.21	8.62	8.12	8.21	8.20	8.21	8.25	8.25
Alkalinity	299	295	283	258	245	257	267	279	287	292
Chloride	47	46	53	33	54	53	59	55	50	56
Sulfate	81	85	87	87	74	85	90	92	88	94
Hardness	390	419	406	362	339	378	391	397	410	436
Total phosphate-P	0.11	0.13	0.11	0.13	0.13	0.09	0.08	0.08	0.06	0.07
Total dissolved phosphate-P	0.04	0.05	0.07	0.03	0.06	0.05	0.04	0.03	0.04	0.04
Kjeldahl nitrogen-N	0.99	0.77	0.51	1.31	0.95	0.69	0.66	0.60	0.62	0.53
Ammonia-N(T)	0.22	0.08	0.10	0.30	0.18	0.32	0.09	0.07	0.29	0.09
Nitrate-N (Dissolved)	2.94	1.33	1.35	1.82	1.43	1.41	0.93	1.03	1.31	1.23
Total solids	521	568	609	484	486	520	562	499	515	574
Gooch suspended solids	25	24	13	5	13	14	9	11	5	9
Suspended volatile solids	4	5	5	3	2	6	2	9	4	4
Barium (T)	0.04	0.03	0.06	0.05	0.08	0.02	0.03	0.06	0.07	0.05
Cadmium (T)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Chromium (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper (T)	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron(T)	0.94	0.83	0.52	0.23	0.75	0.48	0.37	0.34	0.28	0.41
Lead(T)	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Manganese (T)	0.13	0.12	0.07	0.08	0.13	0.08	0.07	0.06	0.06	0.08
Nickel (T)	0.03	0.03	0.02	0.01	0.01	0.02	0.04	0.02	0.03	0.02
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	0.03	0.01	<0.01	0.22	0.06	<0.01	<0.01	0.01	<0.01	0.01

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B1. (Concluded)

Parameter	*11/1/88*	*11/8/88*
Temperature, °C	5.7	7.4
Dissolved oxygen	11.6	12.0
Conductivity, mho/cm at 25°C	842	837
Turbidity, NTU	8	7
pH, units	8.2	8.19
Alkalinity	306	271
Chloride	64	48
Sulfate	105	146
Hardness	496	470
Total phosphate-P	0.05	0.06
Total dissolved phosphate-P	0.03	0.04
Kjeldahl nitrogen-N	0.63	0.78
Ammonia-N(T)	0.07	0.11
Nitrate-N (Dissolved)	1.30	2.38
Total solids	597	620
Gooch suspended solids	7	2
Suspended volatile solids	2	2
Barium (T)	0.08	0.07
Cadmium (T)	<0.003	<0.003
Chromium (T)	<0.01	<0.01
Copper (T)	<0.01	<0.01
Iron (T)	0.29	0.27
Lead (T)	0.03	0.03
Manganese (T)	0.08	0.07
Nickel (T)	<0.01	<0.01
Silver (T)	<0.005	<0.005
Zinc (T)	0.02	0.02

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B2. Water Quality Characteristics of Ferson Creek, 1987 - 1988

Parameter	*3/20/87*	*4/1/87*	*4/14/87*	*4/28/87*	*5/14/87*	*5/28/87*	*6/9/87*	*6/25/87*	*7/8/87*	*7/22/87*
Temperature, °C		6.8	10.8	17.7	19.9	22.9	20.6	22.3	27.2	26.2
Dissolved oxygen		12.4	10.0	12.3	10.7	7.0	7.8	5.8	8.5	6.7
Conductivity, mho/cm at 25°C	776	775	771	738	787	779	800	774	785	773
Turbidity, NTU	5	5	10	11	7	24	27	167	19	18
pH, units	8.29	8.39	8.15	8.40	8.30	8.10	8.18	8.10	8.31	8.18
Alkalinity	307	309	306	278	305	305	318	310	305	297
Chloride	47	54	50	46	52	47	471	41	57	64
Sulfate	70	45	44	70	74	69	78	75	80	83
Hardness	395	392	382	375	398	397	395	371	391	368
Total phosphate-P	0.05	0.03	0.05	0.05	0.07	0.11	0.14	0.16	0.12	0.15
Total dissolved phosphate-P	0.02	0.02	0.01	0.01	0.03	0.05	0.06	0.08	0.06	0.09
Kjeldahl nitrogen-N	0.67	0.76	0.80	0.71	0.77	0.71	0.80	1.58	0.96	0.88
Ammonia-N (T)	0.12	0.07	0.01	0.08	0.12	0.17	0.15	0.35	0.09	0.12
Nitrate-N (Dissolved)	3.59	2.82	2.24	5.38	2.94	4.86	3.32	2.39	1.44	0.65
Total solids	513	526	471	490	552	562	588	559	635	514
Gooch suspended solids	5	3	6	13	10	29	30	42	23	44
Suspended volatile solids	4	1	2	8	3	9	6	24	9	6
Barium (T)	0.05	0.03	0.04	0.03	0.03	0.02	0.01	0.07	0.11	0.08
Cadmium (T)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (T)	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.02	<0.01	<0.01
Copper (T)	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Iron(T)	0.19	0.18	0.34	0.34	0.31	1.05	1.09	0.79	0.90	0.72
Lead(T)	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.03
Manganese (T)	0.06	0.06	0.09	0.07	0.07	0.14	0.15	0.16	0.12	0.14
Nickel (T)	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.02	0.02
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	0.02	0.08	<0.01	0.02	0.01	0.01	0.03	0.06	0.03	0.03

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B2. (Continued)

Parameter	*8/5/87*	*8/16/87*	*9/2/87*	*9/16/87*	*9/30/87*	*10/14/87*	*11/4/87*	*11/19/87*	*12/11/87*	*12/22/87*
Temperature, °C	22.1	24.7	18.6	18.6	15.3	11.5	13.1	5.6	6.3	4.2
Dissolved oxygen	6.7	5.6	8.0	7.4	8.9	11.1	8.8	12.2		
Conductivity, mho/cm at 25°C	808	563	702	763	805	838	796	817	980	989
Turbidity, NTU	59	57	25	25	11	6	11	7	17	14
pH, units	8.31	7.98	8.11	8.19	8.30	8.19	8.19	8.22	7.99	7.97
Alkalinity	313	218	297	318	349	323	313	318	259	258
Chloride	58	58	37	44	44	54	46	47	38	41
Sulfate	83	78	68	72	72	79	64	64	64	59
Hardness	390	276	357	381	415	431	416	420	363	361
Total phosphate-P	0.23	0.30	0.16	0.11	0.09	0.04	0.03	0.05	0.12	0.09
Total dissolved phosphate-P	0.10	0.16	0.08	0.05	0.05	0.01	0.03	0.02	0.05	0.04
Kjeldahl nitrogen-N	1.01	1.59	1.21	0.71	0.63	0.62	0.86	1.34	0.78	0.68
Ammonia-N (T)	0.15	0.17	0.18	0.16	0.09	0.20	0.19	0.16	0.14	0.11
Nitrate-N (Dissolved)	1.67	4.00	3.33	2.26	1.38	2.50	3.40	3.29	5.57	5.30
Total solids	560	461	497	522	527	551	5.14	536	504	463
Gooch suspended solids	62	78	64	25	12	6	11	3	33	19
Suspended volatile solids	5	38	12	5	1	0	8	3	18	8
Barium (T)	0.12	0.09	0.07	0.07	0.10	0.09	0.07	0.03	0.06	0.06
Cadmium (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (T)	0.01	<0.01	0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01
Copper (T)	0.02	0.02	0.02	0.02	0.01	0.01	0.01	<0.01	<0.01	<0.01
Iron(T)	2.26	1.29	2.94	1.07	0.56	0.28	0.45	0.21	0.69	0.58
Lead(T)	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02
Manganese (T)	0.20	0.13	0.09	0.09	0.08	0.05	0.08	0.05	0.06	0.05
Nickel (T)	0.02	0.02	0.02	0.02	0.01	0.01	<0.01	0.03	0.02	0.02
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	0.06	0.05	0.31	0.03	0.10	0.01	0.01	0.04	<0.01	<0.01

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B2. (Continued)

Parameter	*1/29/88*	*2/18/88*	*3/1/88*	*3/14/88*	*3/18/88*	*3/24/88*	*4/7/88*	*4/27/88*	*5/10/88*	*5/24/88*
Temperature,°C	2.1	2.2	6.1	1.4	5.9	10.6	11.1	7.2	13.2	17.1
Dissolved oxygen					14.1	13.0	10.0	11.8	9.8	8.7
Conductivity, mho/cm at 25°C	1062	1124	1007	1053	1056	1063	888	1068	1103	1097
Turbidity, NTU	14	14	17	8	11	13	65	4	6	21
pH, units	7.95	7.99	8.21	8.29	8.32	8.29	7.81	8.15	8.27	8.10
Alkalinity	286	286	267	282	278	283	228	283	287	279
Chloride	46	76	45	47	53	47	40	47	72	60
Sulfate	57	60	58	62	63	58	53	59	64	65
Hardness	382	403	358	370	384	364	372	371	372	380
Total phosphate-P	0.08	0.07	0.08	0.04	0.04	0.05	0.21	0.05	0.05	0.09
Total dissolved phosphate-P	0.03	0.04	0.04	0.01	0.01	0.01	0.08	0.02	0.03	0.06
Kjeldahl nitrogen-N	0.64	0.44	0.72	0.59	0.52	0.76	1.06	1.03	0.24	0.93
Ammonia-N (T)	0.26	0.26	0.17	0.22	0.03	0.09	0.16	0.01	0.04	0.34
Nitrate-N (Dissolved)	4.74	4.14	3.51	3.41	3.11	2.84	5.44	3.17	2.74	2.39
Total solids	510	534	494	474	499	509	480	499	515	512
Gooch suspended solids	8	9	22	6	7	12	79	6	10	19
Suspended volatile solids	1	4	4	0	4	6	7	2	5	5
Barium (T)	0.06	0.08	0.07	0.06	0.06	0.04	0.03	0.04	0.05	0.05
Cadmium (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.003	<0.003	<0.003	<0.003	<0.003
Chromium (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01
Iron(T)	0.40	0.30	0.61	0.23	0.24	0.79	2.47	0.19	0.25	0.49
Lead(T)	0.02	0.04	0.03	0.01	0.02	0.03	0.02	0.03	0.02	0.01
Manganese (T)	0.06	0.06	0.07	0.06	0.06	0.08	0.11	0.06	0.09	0.13
Nickel (T)	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.08	0.07	0.02	0.02

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B2. (Continued)

Parameter	*6/9/88*	*6/27/88*	*7/12/88*	*8/4/88*	*8/16/88*	*8/30/88*	*9/15/88*	*9/21/88*	*10/5/88*	*10/14/88*
Temperature, C	18.7	22.9	26.2	29.7	28.6	17.8	18.1	16.7	11.5	11.1
Dissolved oxygen	9.7	7.7	8.5	9.0	6.4	8.6	7.7	9.9	10.4	12.5
Conductivity, mho/cm at 25°C	1149	800	759	697	763	777	786	777	794	799
Turbidity, NTU	21	47	30	17	47	35	36	18	12	14
pH, units	8.31	8.19	8.28	8.37	8.20	8.24	8.19	8.29	8.29	8.15
Alkalinity	308	287	289	275	283	301	283	298	299	303
Chloride	58	66	58	70	59	60	69	66	67	62
Sulfate	69	65	69	66	69	74	70	68	72	74
Hardness	418	440	410	306	390	417	397	403	403	430
Total phosphate-P	0.10	0.18	0.11	0.13	0.24	0.12	0.13	0.12	0.10	0.10
Total dissolved phosphate-P	0.04	0.07	0.06	0.05	0.09	0.04	0.06	0.07	0.06	0.03
Kjeldahl nitrogen-N	1.51	0.84	0.64	1.19	2.82	0.73	1.58	0.84	0.64	0.52
Ammonia-N(T)	0.22	0.28	0.12	0.25	1.09	0.07	0.43	0.07	0.09	0.19
Nitrate-N (Dissolved)	3.05	2.24	1.46	1.14	1.86	1.89	1.85	1.58	1.60	1.45
Total solids	532	522	617	483	567	579	543	516	540	563
Gooch suspended solids	17	42	25	14	47	36	32	15	6	10
Suspended volatile solids	4	3	3		6 1 1	1 0	3	8		4 1
Barium (T)	0.04	0.03	0.06	0.04	0.06	0.04	0.07	0.04	0.04	0.04
Cadmium (T)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Chromium (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper (T)	<0.01	<0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Iron(T)	0.79	1.83	1.13	0.59	1.83	1.23	1.33	0.55	0.46	0.61
Lead(T)	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03
Manganese (T)	0.16	0.21	0.20	0.25	0.18	0.12	0.12	0.07	0.05	0.08
Nickel (T)	0.02	0.02	0.02	0.02	0.01	0.04	0.03	0.03	0.03	0.01
Silver (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc(T)	0.02	0.02	0.03	0.02	0.01	<0.01	0.01	0.01	<0.01	0.03

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

Appendix Table B2. (Concluded)

Parameter	*11/1/88*	*11/8/88*
Temperature, °C	6.0	7.3
Dissolved oxygen	12.0	12.5
Conductivity, mho/cm at 25°C	855	823
Turbidity, NTU	6	5
pH, units	8.15	8.19
Alkalinity	322	291
Chloride	56	64
Sulfate	86	97
Hardness	443	443
Total phosphate-P	0.06	0.08
Total dissolved phosphate-P	0.03	0.04
Kjeldahl nitrogen-N	0.68	0.75
Ammonia-N (T)	0.11	0.13
Nitrate-N (Dissolved)	1.82	1.88
Total solids	588	570
Gooch suspended solids	5	3
Suspended volatile solids	4	2
Barium (T)	0.07	0.10
Cadmium (T)	<0.003	<0.003
Chromium (T)	<0.01	<0.01
Copper (T)	<0.01	<0.01
Iron (T)	0.42	0.39
Lead (T)	0.03	0.02
Manganese (T)	0.08	0.08
Nickel (T)	<0.01	<0.01
Silver (T)	<0.005	<0.005
Zinc (T)	0.07	0.04

Note: Concentrations are expressed in mg/L except where indicated and (T) = total.

APPENDIX C. GENERAL-USE WATER QUALITY STANDARDS

- pH shall be within the range of 6.5 to 9.0 except for natural causes.

- Dissolved oxygen shall not be less than 6.0 mg/L during at least 16 hours of any 24-hour period, nor less than 5.0 mg/L at any time.

- Phosphorus as P shall not exceed 0.05 mg/L in any reservoir or lake with a surface area of 8.1 hectares (20 acres) or more, or in any stream at the point where it enters any such reservoirs or lakes.

- Ammonia nitrogen (as N) shall in no case exceed 15 mg/L. If ammonia nitrogen is less than 15 mg/L and greater than or equal to 1.5 mg/L, then unionized ammonia (as N) shall not exceed 0.04 mg/L. Ammonia nitrogen concentrations of less than 1.5 mg/L are lawful regardless of un-ionized ammonia concentration.

- The following levels of chemical constituents shall not be exceeded (concentrations in mg/L): dissolved solids, 1,000; chloride, 500; sulfate, 500; arsenic, 1.0; barium, 5.0; cadmium, 0.05; chromium, 0.05; copper, 0.02; iron, 1.0; lead, 0.1; manganese, 1.0; nickel, 1.0; silver, 0.005; and zinc, 1.0.

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