Chemistry and hydrology in Swamp Creek, 1983. 1984

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CHEMISTRY AND HYDROLOGY
IN SWAMP CREEK, 1983

Prepared for

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1. INTRODUCTION

A one-year study of the aquatic biology, chemistry (water and sediment) and hydrology of Swamp Creek downstream from County Trunk Highway M was initiated by Ecological Analysts, Inc. (EA) in January 1983. The study was performed in the vicinity of the site proposed to receive the water discharge from the Crandon Project. Major components of the study included water and sediment chemistry, fish tissue analysis, particle size analysis, winter dissolved oxygen (DO) survey, summer diel (day/night) DO survey, current velocity, stream discharge, fisheries, and benthic macroinvertebrates. The frequency at which these components were examined is summarized below:

Task	Frequency During 1983
Regular water chemistry	Monthly; January through December
Intensive water chemistry	Quarterly; February, May, August, November
Tissue chemistry	Analysis of 15 fish collected during 1982-1983
Sediment chemistry	May
Particle size analysis	May
Winter DO survey	January through April
Summer diel DO survey	July through September
Current velocity	Monthly; March through December
Stream discharge	Monthly; February through December
Fisheries	April
Benthic macroinvertebrates	Quarterly; February, May, August, November

The chemistry and hydrology data obtained during the studies are presented and discussed in this report. The aquatic biology data are presented in a separate report. The specific objectives of the chemistry and hydrology studies were:

1. Establish existing water quality conditions in Swamp Creek at one station upstream and one downstream of the proposed location of the water discharge from the proposed mine/mill complex;

2. Establish existing sediment chemistry conditions at a station downstream of the proposed discharge site;

3. Document existing levels of selected metals in tissues of three species of fish in Swamp Creek;
4. Determine DO concentrations at several stations in Swamp Creek during the winter (January through April);
5. Determine diel fluctuations in DO and related parameters during the summer at one station upstream of the proposed water discharge and one station in the vicinity of the proposed water discharge;
6. Collect discharge data that will expand the data base for a gaging station in the vicinity of the proposed water discharge; and
7. Establish the relationship between discharge readings from the USGS gaging station at County Trunk Highway M and the gaging station (SG 24) located upstream from Squaw Creek in the vicinity of the proposed water discharge.

2. METHODS

2.1 CHEMISTRY

2.1.1 Sampling Stations and Frequency

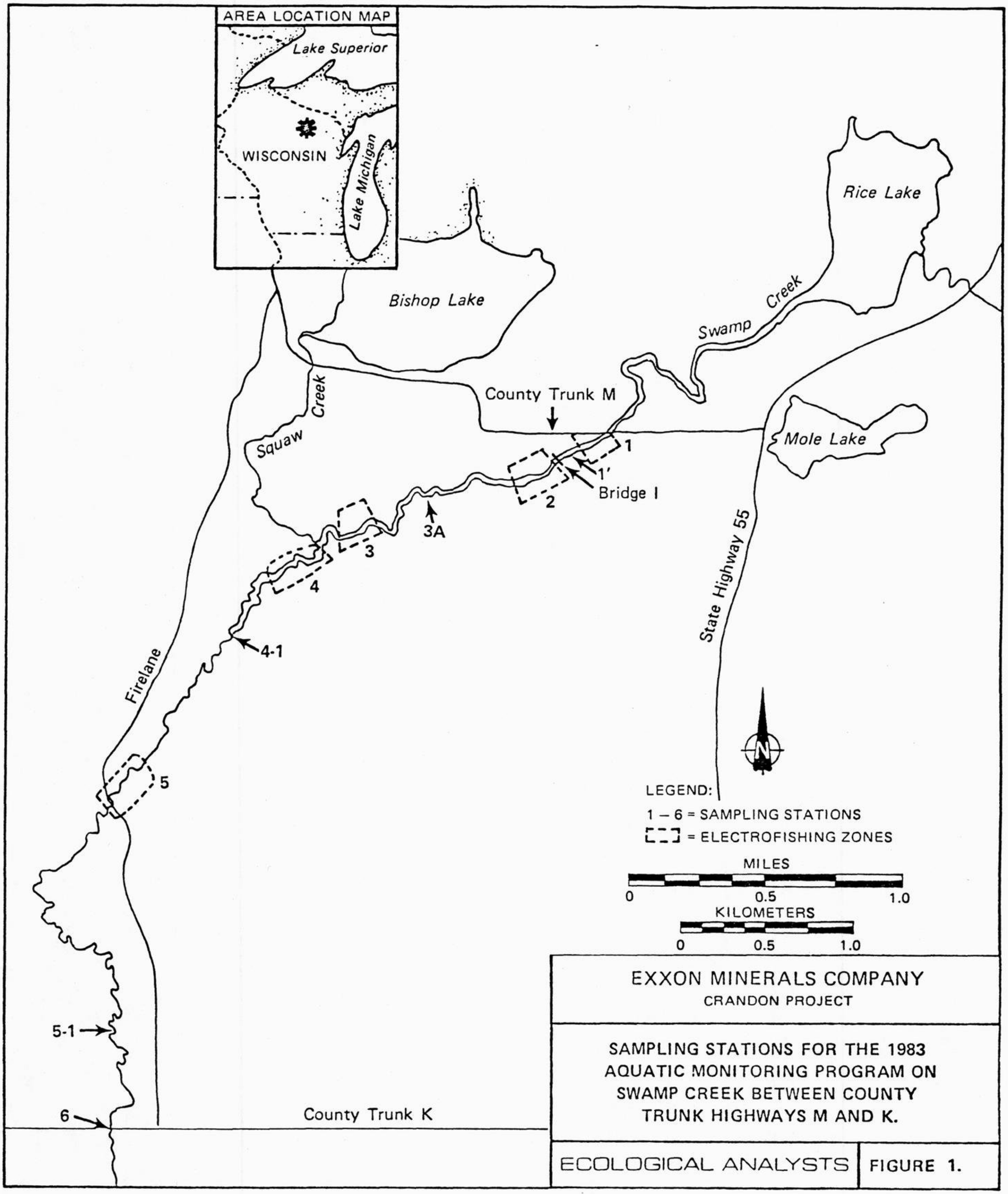
Four primary sampling stations were chosen (Figure 1) based on their relationship to the proposed location of the water discharge from the mine/mill site and the results of a habitat inventory (Ecological Analysts 1983a):

1. Station 1 was located at the County Trunk Highway M bridge upstream of the location proposed for the water discharge;
2. Station 3 was located approximately 2 km (1.2 mi) downstream of County Trunk Highway M in the vicinity of the location proposed for the water discharge, at the point where a staff gage (SG 24) was installed;
3. Station 4 was located approximately 750 m (2,500 ft) downstream of Station 3 and 50 m (164 ft) downstream of the mouth of Squaw Creek; and
4. Station 5 was located at a bridge on a firelane approximately 4.9 km (3 mi) downstream of County Trunk Highway M.

In addition to these primary stations, DO concentrations were measured during the winter at County Trunk Highway K (Station 6), at locations between Stations 4 and 5 (Station 4-1) and between Stations 5 and 6 (Station 5-1), and at the mouth of Squaw Creek (Figure 1). Water samples were collected on a monthly and seasonal schedule at Stations 1 and 4 and from January through April at Station 5 (Table 1). Parameters that were measured are itemized in Table 1. At Station 5, the full list of parameters was measured in January and February, while only iron, zinc, hardness, temperature, pH, DO, specific conductance, and total alkalinity were measured in March and April. Duplicate water samples were collected except for the following parameters: cadmium, barium, lead, mercury, selenium, and silver. Samples for these six metals were collected in triplicate. In May, duplicate samples of each available sediment type (silt and sand) were collected at Station 4.

2.1.2 Sample Collection and Handling Procedures

Before being transported to the field, each sample bottle was cleaned according to procedures described in Chapter IV of EA's Quality Control Manual for Analytical Chemistry (Ecological Analysts 1981). These methods are consistent with those described by U.S. EPA (1979). To prevent contamination, the appropriate preservatives (e.g., HNO_3, H_2SO_4, NaOH, H_3PO_4) were added to the sample bottles in the laboratory.



EXXON MINERALS COMPANY
CRANDON PROJECT

SAMPLING STATIONS FOR THE 1983 AQUATIC MONITORING PROGRAM ON SWAMP CREEK BETWEEN COUNTY TRUNK HIGHWAYS M AND K.

ECOLOGICAL ANALYSTS

FIGURE 1.

TABLE 1 FREQUENCY OF COLLECTION, METHOD OF PRESERVATION, AND HOLDING TIME ASSOCIATED WITH EACH OF THE WATER, FISH TISSUE AND BOTTOM SEDIMENT CHEMICAL PARAMETERS MONITORED IN SWAMP CREEK

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Parameter	Preservative	Holding Time(a)	Frequency of Collection		Sediment Analysis	Fish Tissue
			Seasonal	Monthly		
Total alkalinity	NA(b)	in field	X	X		
Specific conductance	NA	in field	X	X		
pH	NA	in field	X	X		
Temperature	NA	in field	X	X		
Dissolved oxygen	NA	in field	X	X		
Color, true	4C	24 hours	X			
Total hardness	4C, HNO_3	6 months	X			
Total dissolved solids	4C	7 days	X			
Total suspended solids	4C	7 days	X			
Nitrogen, ammonia	4C, H_2SO_4	24 hours	X			
Nitrogen, nitrate	4C	24 hours	X			
Nitrogen, nitrite	4C	48 hours	X			
Nitrogen, organic	4C, H_2SO_4	24 hours	X			
Total phosphorus	4C, H_2SO_4	24 hours	X			
Dissolved orthophosphate	4C, Filter	24 hours	X			
Phenol	4C, H_3PO_4, $CuSO_4$	24 hours	X		X	
Chloride	None	7 days	X	X		

(a) Water samples only.
(b) Not applicable.
(c) Analyses performed in triplicate.

TABLE 1 (Cont.) Page 2 of 2

Parameter	Preservative	Holding Time[(a)]	Frequency of Collection		Sediment Analysis	Fish Tissue
			Seasonal	Monthly		
Sulfur, total	4C	7 days	X	X	X	
Sulfate	4C	7 days	X	X	X	
Total cyanide	4C, NaOH	24 hours	X	X		
Biochemical oxygen demand	4C	24 hours	X			
Chemical oxygen demand	H_2SO_4	7 days	X			
Arsenic	HNO_3	6 months	X		X	X
Cadmium(c)	HNO_3	6 months	X	X	X	X
Chromium III	4C	48 hours	X			
Chromium VI	4C	48 hours	X			
Chromium, total	HNO_3	6 months			X	X
Barium(c)	HNO_3	6 months	X	X		
Copper	HNO_3	6 months	X	X	X	X
Iron	HNO_3	6 months	X	X	X	
Lead(c)	HNO_3	6 months	X	X	X	X
Fluoride	None	7 days	X	X		
Manganese	HNO_3	6 months	X		X	
Mercury(c)	HNO_3	13 days	X	X	X	X
Selenium(c)	HNO_3	6 months	X	X		
Silver(c)	HNO_3	6 months	X	X		
Zinc	HNO_3	6 months	X	X	X	X
Sediment size	NA	NA			X	

Samples were collected near midstream at each station using a plastic Kemmerer sampler. Samples analyzed for phenols were collected in glass bottles; all other samples were collected in plastic "poly" bottles. Samples that required refrigeration were placed in insulated shipping containers and immediately packed in ice and shipped to the laboratory. A Chain-of-Custody Record was completed at the time of sample collection and accompanied the samples to the laboratory. Samples for orthophosphate were filtered in the field and samples for total dissolved solids were filtered in the laboratory; no other samples were filtered.

Upon arrival in EA's laboratory, the samples in each shipping container were compared with the Chain-of-Custody Record and the samples were logged-in according to the procedure described in EA's Quality Control Manual for Analytical Chemistry (Ecological Analysts 1981). Those samples with 24-hr holding times were analyzed on the day of receipt; others were stored as appropriate. Holding times for all parameters were met throughout the study.

Sediment samples were collected using a Ponar sampler. Each Ponar sample was carefully emptied onto a plastic-covered pan. Sediment was taken from the center of the sample with a clean plastic cup and transferred to precleaned glass jars. These jars were shipped and handled in a manner identical to that described above for the water samples.

2.1.3 Sample and Data Analysis

Five white sucker (Catastomus commersoni), four northern pike (Esox lucius), and six rock bass (Ambloplites rupestris) collected by electrofishing during 1982 and 1983 were wrapped in aluminum foil immediately upon collection, labeled, and frozen for later analysis of arsenic, cadmium, chromium, copper, lead, mercury, and zinc.

During the winter DO survey, temperature measurements were made in situ at each station. Dissolved oxygen concentrations were either measured concurrently using the YSI 54A DO meter or were determined 1-2 hours after collection using samples that were "fixed" immediately upon collection using appropriate Winkler reagents.

The summer diel survey consisted of measuring temperature, pH, DO, alkalinity, and carbon dioxide at Stations 1 and 3 at 3-hour intervals over a 24-hour period. Temperature was measured in situ. Duplicate DO samples were collected each interval at each station, "fixed" immediately upon collection, and analyzed within one hour of collection. Duplicate 500-ml samples were collected each interval at each station for analysis of pH and alkalinity, which was accomplished within one hour of collection. Single 250-ml samples were collected each interval at each station and shipped overnight to EA's central chemistry laboratory for carbon dioxide analysis.

Water samples were analyzed for 40 parameters, sediment samples for 12 parameters, and fish tissue samples for 7 metals (Table 1). During the winter DO survey, only DO and temperature were measured. During the diel survey, temperature, DO, alkalinity, pH, and carbon dioxide were measured.

Water temperature, DO, pH, specific conductance, and alkalinity were measured in the field. A YSI Model 33 conductivity meter was used to measure specific conductance. Dissolved oxygen was measured using modified Winkler titrations. The pH was measured using either an Orion Model 399a pH meter or an Orion Model 501 pH meter, which were both calibrated each trip against standard solutions according to the manufacturer's specifications. Temperature was measured using either a mercury thermometer, the temperature mode of the conductivity meter, or a Whitney Model T-10C temperature meter. When the pH mode of the conductivity meter was used to measure temperature, its accuracy was checked against a mercury thermometer. The Whitney Model T-10C was calibrated in EA's central calibration lab and periodically checked against a mercury thermometer. Total alkalinity was determined titrimeterically using the pH mode of one of the Orion pH meters according to the procedures specified by EPA (1979) or APHA et al. (1976). All remaining parameters were measured in EA's laboratory according to EPA (1979) or APHA et al. (1976). The specific procedure used and the associated detection limit (the smallest concentration detectable with reasonable certainty, usually calculated as two times the standard deviation of replicated blanks) are presented in Table 2. The detection limits presented in Table 2 are those that typically can be achieved. However, parameter-specific limits were calculated during the analysis of each set of monthly samples. As a result, the less-than values reported in the tabular summaries (e.g., Tables 3 and 4) later in this report represent the detection limits achievable on the particular date in question. There is no "standard" method for measuring total sulfur. In this study, total sulfur was defined as the sum of sulfide and sulfate. To assure that all sulfate was measured, especially in the sediment samples, the sulfate portion of the total sulfur analysis was preceded by a vigorous acid digestion. The sulfate values reported in Table 3 refer to those measured by Method 375.2 (EPA 1979), not those obtained by the acid digestion phase of the total sulfur analysis. Concentrations in sediment samples were reported on a dry weight basis.

No commonly accepted (i.e., standard) procedures exist for incorporating less-than values (i.e., values below the detection limit) into the calculation of annual averages. In this study, mean values were not calculated if 50 percent or more of the monthly values consisted of less-than values or if the detection limit was variable. In situations where less-than values were used to calculate annual means, these values were considered to be equivalent to their respective level of detection for averaging purposes. For example, <1 μg/liter would be considered as 1 μg/liter for calculation of the mean.

Tissue analysis of the fish collected from Swamp Creek was based on muscle fillets with the skin attached. In the laboratory, tissue samples to be analyzed for mercury were prepared for subsequent analysis according to the procedures described by EPA (1980). For metals other than mercury, tissue samples were digested as described by FDA (1976), whereas preparation and homogenization of the samples followed techniques developed by EPA (1980). Subsequent analysis of all the metals followed the procedures presented in Table 2.

TABLE 2 METHODS USED TO DETERMINE PHYSICAL AND CHEMICAL WATER QUALITY PARAMETERS IN WATER AND SEDIMENT SAMPLES FROM SWAMP CREEK

Parameter	Detection Limit (mg/l)	Method	U.S. EPA 1979 Method Number
Temperature	NA[(a)]	Thermometric	170.0
Color, true	NA	Spectrophotometric	110.3
Total dissolved solids	10	Gravimetric (180 C)	160.1
Total suspended solids	1	Gravimetric (103 C)	160.2
Dissolved oxygen	NA	Membrane electrode	360.1
Total alkalinity	0.1	Titrimetric	310.1
pH	NA	Electrometric	150.1
Total hardness	2	Automated EDTA	130.1
Total phosphorus	0.05	Ascorbic acid	365.2, 365.4
Dissolved orthophosphate	0.01	Ascorbic acid	365.1, 365.2
Ammonia nitrogen	0.02	Potentiometric, automated phenate	350.1, 350.3
		Potentiometric, ion selective electrode	350.3
Nitrate nitrogen	0.01	Automated cadmium reduction	353.2
Nitrite nitrogen	0.01	Automated colorimetric	354.1
Organic nitrogen	0.05	Kjeldahl minus ammonia	351.2
Iron	0.03	Atomic absorption	236.1
Chemical oxygen demand	10	Automated colorimetric	410.4
Biochemical oxygen demand	1	5 day + 20 C	405.1
Copper	0.001	Atomic absorption	220.2
Zinc	0.001	Atomic absorption	289.2
Mercury	0.0002	Atomic absorption	245.1
Lead	0.001	Atomic absorption	239.2
Chromium, hexavalent	0.004	Atomic absorption	218.4
Manganese	0.002	Atomic absorption	243.2
Chloride	1	Automated ferricyanide	325.2
Sulfate	3	Automated methyl thymol blue	375.2
Total cyanide	0.01	Automated colorimetric	335.3
Phenol	0.01	Colorimetric automated with 4-AAP distillation	420.2
Sulfur, total	1	Sum of sulfide + sulfate (acid cooked)	--(b)
Arsenic	0.002	Atomic absorption	206.2
Cadmium	0.0001	Atomic absorption	213.2
Chromium, trivalent	0.004	Atomic absorption	218.2
Chromium, total	0.001	Atomic absorption	218.2
Barium	0.005	Atomic absorption	208.2
Fluoride	0.1	Potentiometric, ion-specific electrode	340.2
Selenium	0.001	Atomic absorption	270.2
Silver	0.0002	Atomic absorption	272.2
Aluminum	0.003	Atomic absorption	202.2
Cobalt	0.002	Atomic absorption	219.2
Molybdenum	0.001	Atomic absorption	246.2
Nickel	0.005	Atomic absorption	249.2
Sediment size	NA	Mechanical, U.S. standard sieves; hyrodometric	D422-63(c)
Carbon dioxide	0.1	Nomographic determination	407A(d)

(a) NA = Not applicable.
(b) No U.S. EPA method available.
(c) Method number according to ASTM (1981).
(d) Method number according to APHA et al. (1976).

2.1.4 Quality Assurance and Quality Control

To ensure proper quality control, all phases of the water, fish tissue, and sediment chemistry program, from preparation of the sample bottles to final reporting and validation of the data, were conducted in accordance with the procedures described in EA's Quality Control Manual. All chemistry data contained in this report were reviewed by the quality assurance coordinator at EA's central analytical laboratory. EA's project manager also reviewed all analytical data. Discrepancies between replicate data were resolved by checking appropriate quality control records or by rerunning the samples, if necessary.

2.2 HYDROLOGY

2.2.1 Current Velocity

Current velocity was measured monthly from March through December along a transect at Station 1. Current velocity was also measured along a transect at Station 4 in March, April, June, July, September, and October. Measurements were made at the 1/4, 1/2, and 3/4 points (as estimated visually) along each transect with a Marsh-McBirney Model 201 flow meter. In depths greater than 0.76 m (2.5 ft), measurements were taken at 0.8 and 0.2 depth (0.8 and 0.2 times the distance from the surface to the bottom) below the surface. In waters less than 0.76 m deep, measurements were recorded from 0.6 depth.

2.2.2 Stream Discharge

Monthly discharge measurements were taken at Station 3, adjacent to the staff gage, according to standard procedures (USGS 1969). A permanent fixed point was established at each end of a transect established just upstream of the staff gage and perpendicular to the stream's flow. A line marked in 0.38 m (1.25 ft) and 0.76 m (2.5 ft) intervals was stretched across the stream. Depth and current velocity were measured every 0.76 m (2.5 ft) along the line. Additional measurements were taken at 0.38-m (1.25-ft) intervals at the deeper points along the transect in order to keep the flow rate in any one segment to <10 percent of the total flow rate and the number of vertical sections between 25 and 30 as recommended by both USGS (1969) and Linsley et al. (1975). The velocity measurements were made with a Marsh-McBirney Model 201 flow meter. In water less than 0.76 m (2.5 ft) deep, a single velocity measurement was taken at 0.6 depth. In depths greater than 0.76 m (2.5 ft), measurements were made at 0.2 and 0.8 depths below the surface. In 1982, it was observed that the velocities at 0.8 depth were reduced because of aquatic macrophyte beds that had developed along the transect during the summer (Ecological Analysts 1983b). Thus, from July through September, when macrophyte growth was at its peak, a reading was also taken at 0.6 depth, wherever total depth was greater than 0.76 m (2.5 ft). These velocity measurements were then used to determine stream discharge (m^3/sec [cubic meter per second]) by multiplying the cross-sectional area of each 0.76 m (2.5 ft) segment by the mean stream velocity for that segment and summing the resultant values. Field observations indicated that when flow rates were high (>80 cfs) and/or gage readings exceeded 0.61 m (2 ft), some water bypassed the gage by flowing through the wetland that bordered the eastern side of the stream.

The discharge values were used to develop a rating curve for staff gage 24 according to standard procedures (i.e., plotting water levels [gage heights] versus discharge values on double log paper, USGS, 1969). The rating curve, in conjunction with weekly gage measurements provided by Exxon Minerals Company, was used to prepare a hydrograph depicting seasonal variations in stream discharge. A similar hydrograph was prepared using data collected by the USGS at the continuous recording gaging station at County Trunk Highway M.

Quarterly discharge measurements were collected at Station 4 using procedures identical to those described above. However, because only four data points were available, no discharge rating curve was developed for Station 4.

3. RESULTS

3.1 CHEMISTRY

3.1.1 Water Chemistry

The results of the water chemistry sampling are presented in Tables 3 and 4. To facilitate discussion, the results have been grouped into three major categories: general water quality, nutrients, and metals. Because the results for January through March at Station 1 were presented in last year's report (Ecological Analysts 1983b), they are not discussed in this section. Also, because of the limited data, the results for Station 5 are presented separately.

3.1.1.1 Stations 1 and 4

General Water Quality

Temperature, alkalinity, pH, specific conductance, dissolved oxygen, true color, total hardness, total and suspended solids, COD, BOD, chloride, sulfate, total sulfur, total cyanide, phenol, and fluoride are included in the general water quality group. The results of sampling during the year indicate that Swamp Creek is a moderately hard (64-115 mg/l), adequately buffered stream, with pH values in the neutral range (6.6-7.9)(Tables 3 and 4).

Temperature followed normal seasonal patterns with annual maxima (26.5-27.0 C) occurring in August and annual minima (0 C) in December, January, and February (Tables 3 and 4). The pH values were consistently near 7 and no seasonal pattern was apparent. Alkalinity values were variable (41-105 mg/liter) but generally were between 70 and 100 mg/liter. No seasonal pattern was apparent; however, lowest values typically occurred during periods of high flow rates (e.g., March, April, May, and October). Dissolved oxygen values varied from 5.4 to 12.2 mg/liter. Average DO concentrations were similiar at Stations 1 and 4. Except during January and February, percent saturation values at Stations 1 and 4 were between 66 and 133 percent. Supersaturated conditions occurred at both stations in July and August, apparently as a result of photosynthetic activity. In January and February, percent saturation values were between 37 and 44 percent at both stations (Tables 3 and 4). Specific conductance averages were similar at both stations. The reason for the atypically low value in December at Station 1 is unknown. True color values in Swamp Creek ranged from 35 to 95 with the values being much lower during the winter than during the other seasons. Total hardness averages and ranges were nearly identical at the two stations. As with alkalinity, total hardness values were typically lowest during periods with high flow rates. Total dissolved solids (TDS) values were between 88 and 149 mg/liter with no seasonal trends apparent. Total suspended solids were low, $\leq$7 mg/liter, at both stations indicating minimal turbidity and sedimentation in Swamp Creek. The high flow rates in May did not increase suspended solid levels. Phenols were also low, always $\leq$0.03 mg/liter, and typically $\leq$0.01 mg/liter. Chloride concentrations were consistently between 2.1 and 4.6 mg/liter at both stations. Sulfate concentrations were low

TABLE 3 RESULTS OF WATER QUALITY SAMPLING AT STATION 1 ON SWAMP CREEK IN 1983

Parameter (Units)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average(a)	Range(a)
Temperature (C)	0	0	1	6	13.2	23.1	26.5	27.0	11.1	8.1	2.6	0	13.1	0-27.0
pH (units)	7.1	7.3	7.1	6.7	7.6	6.6	7.4	7.6	7.2	7.1	7.1	7.2	7.2	6.6-7.6
Total alkalinity (mg/l)	108	102	88	41	73	89	98	95	89	64	92	93	82	41-98
Dissolved oxygen (mg/l)	6.4	5.4	10.3	12.2	10.1	6.7	9.4	9.0	7.5	8.0	11.5	9.7	9.3	6.7-12.2
Specific conductance (µmhos/cm)	196	194	172	172	157	174	218	197	158	143	196	98	168	98-218
True color (units)	--(b)	29	--	--	80	--	--	95	--	--	73	--	83	73-95
Total hardness (mg/l)	105	116	87	64	74	90	107	92	89	69	101	97	87	64-107
Total dissolved solids (mg/l)	--	150	--	--	149	--	--	123	--	--	130	--	134	123-149
Total suspended solids (mg/l)	--	1	--	--	4	--	--	7	--	--	7	--	6	4-7
Ammonia, N (mg/l)	--	0.11	--	--	0.03	--	--	0.03	--	--	0.16	--	0.07	0.03-0.16
Nitrate, N (mg/l)	--	0.15	--	--	0.02	--	--	0.06	--	--	0.11	--	0.06	0.02-0.11
Nitrite, N (mg/l)	--	<0.01	--	--	<0.01	--	--	<0.01	--	--	<0.01	--	<0.01	<0.01
Organic nitrogen, N (mg/l)	--	0.19	--	--	0.3	--	--	0.8	--	--	0.93	--	0.68	0.3-0.93
Total phosphorus, P (mg/l)	--	<0.2	--	--	<0.1	--	--	0.36	--	--	0.31	--	0.26	<0.1-0.36
Dissolved orthophosphate, P (mg/l)	--	0.02	--	--	<0.01	--	--	<0.01	--	--	<0.01	--	<0.01	<0.01
Total phenol (mg/l)	--	<0.02	--	--	<0.01	--	--	<0.01	--	--	0.03	--	NC(c)	<0.01-0.03
Chloride (mg/l)	3.1	3.1	3.2	2.3	2.3	2.5	3.3	2.4	4.6	2.9	3.8	2.9	3.0	2.3-4.6
Total sulfur, S (mg/l)	1.7	<1.7	5.2	3.3	3	3	1.7	1.7	2	3	1.3	3	2.4	1.3-3.3
Sulfate(d) (mg/l)	6	<5	7	9	10	6	6	5	4	7	5	6	6	4-10
Total cyanide (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BOD, 5-day (mg/l)	--	1.0	--	--	1.4	--	--	1.7	--	--	1.6	--	1.6	1.4-1.7
COD (mg/l)	--	35	--	--	30	--	--	36	--	--	102	--	56	30-102
Fluoride (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	0.15	<0.1	NC	<0.1-0.15
Arsenic (mg/l)	<2	<1	<2	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	<1-<2
Barium (µg/l)	15	7	15	7.5	7	6	15	14	20	15	7	17	12	6-20
Cadmium (µg/l)	<0.1	0.3	1.4	1.5	0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.2	NC	<0.1-1.5
Chromium^{+3} (µg/l)	<1	<1	<3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium^{+6} (µg/l)	<1	<1	<4	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Copper (µg/l)	<1	5.9	8	11	2.6	2	7	3.5	8	3.9	5.1	3	5.1	2-11
Iron (mg/l)	0.2	0.21	0.21	0.2	0.25	0.47	0.33	0.35	0.52	0.27	0.13	0.25	0.31	0.13-0.52
Lead (µg/l)	<1	3.4	5	1.4	<1	<1	2	2	1.3	1	<1	<1	1.3	<1-2
Manganese (µg/l)	35	37.1	35	94	36	61	56	69	57	34	30	63	56	30-94
Mercury (µg/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2-0.2
Selenium (µg/l)	1.1	<1	<1	<1	<2	<1	<2	5	<2	3	<2	<1	NC	<1-5
Silver (µg/l)	<1	0.1	<0.2	1.0	<0.2	<0.2	<0.2	<0.2	<0.3	<0.2	<0.2	0.1	NC	0.1-1.0
Zinc (µg/l)	2.3	29	42	5.3	7.9	0.7	7.0	6.8	3.8	4.0	9.1	11	6.2	0.7-11
Aluminum (µg/l)	6.2	33	26	43	28	8	26	8	15	30	22	35	24	8-43
Cobalt (µg/l)	2.1	<1	<1	5.7	4	<1	6	11	<2	<2	<2	<2	NC	<1-11
Molybdenum (µg/l)	<1	3.0	2.4	1.8	<1	<1	2	<1	<1	4	<1	<1	NC	<1-4
Nickel (µg/l)	1	<2	<1	9.8	1.5	6	<1	19	7.8	10	13	13	9.0	<1-19

(a) Average and range calculated using data for April through December only.
(b) Dash indicates no data collected.
(c) Not calculated because most values were less than the detection limit and/or the detection limit was variable.
(d) Sulfate measured by EPA Method 375.2.

TABLE 4 RESULTS OF WATER QUALITY SAMPLING AT STATION 4 ON SWAMP CREEK IN 1983

Parameter (Units)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average	Range
Temperature (C)	0	0.5	1	8	13.8	23.5	26.0	26.5	10.9	7.8	2.6	0	10.1	0-26.5
pH (units)	7.1	7.2	7.2	7.5	7.5	6.6	7.8	7.9	7.1	7.1	7.1	7.3	7.3	6.6-7.9
Total alkalinity (mg/l)	105	102	91	65	67	82	99	96	83	64	85	86	85	64-105
Dissolved oxygen (mg/l)	6.1	5.4	10.3	11.3	9.9	7.5	10.9	9.5	7.7	8.6	11.5	10.1	9.1	5.4-11.5
Specific conductance (µmhos/cm)	203	194	--(a)	147	149	168	216	198	153	136	181	157	173	136-216
True color (units)	--	35	--	--	92	--	--	93	--	--	85	--	76	35-93
Total hardness (mg/l)	106	115	82	64	72	81	107	93	85	68	93	92	88	64-115
Total dissolved solids (mg/l)	--	121	--	--	121	--	--	109	--	--	88	--	110	88-121
Total suspended solids (mg/l)	--	1	--	--	5	--	--	6	--	--	3	--	4	1-6
Ammonia, N (mg/l)	--	0.07	--	--	0.02	--	--	0.03	--	--	0.15	--	0.07	0.02-0.15
Nitrate, N (mg/l)	--	0.26	--	--	0.05	--	--	0.07	--	--	0.09	--	0.12	0.05-0.26
Nitrite, N (mg/l)	--	<0.01	--	--	<0.01	--	--	<0.01	--	--	<0.01	--	<0.01	<0.01
Organic nitrogen, N (mg/l)	--	0.27	--	--	0.3	--	--	0.7	--	--	1.41	--	0.67	0.27-1.41
Total phosphorus, P (mg/l)	--	<0.2	--	--	<0.1	--	--	0.33	--	--	0.36	--	NC(b)	<0.1-0.36
Dissolved orthophosphate, P (mg/l)	--	<0.01	--	--	<0.01	--	--	<0.01	--	--	<0.01	--	<0.01	<0.01
Total phenol (mg/l)	--	0.03	--	--	<0.01	--	--	<0.01	--	--	0.03	--	NC	<0.01-0.03
Chloride (mg/l)	3.4	3.2	2.8	2.1	2.2	2.3	3.4	2.5	4.4	3.3	2.9	2.6	2.9	2.1-4.4
Total sulfur, S (mg/l)	1.7	<1.7	4.7	3.3	3	2	1.7	1.7	2	2	1.1	2	2.2	<1.7-4.7
Sulfate(c) (mg/l)	5	<5	7	9	10	6	6	5	5	6	5	5	6	<5-10
Total cyanide (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BOD, 5-day (mg/l)	--	1.0	--	--	<1	--	--	1.1	--	--	1.5	--	1.2	<1-1.5
COD (mg/l)	--	39	--	--	28	--	--	52	--	--	96	--	54	28-96
Fluoride (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	NC	<0.1-0.1
Arsenic (mg/l)	2.1	1.0	<2	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	<1-2.1
Barium (µg/l)	13	5	11	9	7	6	14	10	16	14	7	17	11	5-17
Cadmium (µg/l)	<0.1	0.3	0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.7	<0.1	<0.1	0.1	NC	<0.1-0.7
Chromium^{+3} (µg/l)	<1	<1	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1	NC	<1-<2
Chromium^{+6} (µg/l)	<1	<1	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1	NC	<1-<2
Copper (µg/l)	1.6	5.2	3	<1	<1	<1	3	2.1	5	2.8	3.2	1	2.5	<1-5.2
Iron (mg/l)	0.2	0.27	0.28	0.2	0.25	0.54	0.27	0.37	0.40	0.27	0.16	0.22	0.29	0.2-0.54
Lead (µg/l)	<1	2.8	3	1.0	<1	<1	1	3	1.8	<1	<1	<1	NC	<1-3
Manganese (µg/l)	39	41.5	35	27	35	69	24	47	47	33	61	49	42	24-69
Mercury (µg/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2-0.2
Selenium (µg/l)	<1	<1	<1	<1	<2	<1	<2	5	<2	3	<2	<1	NC	<1-5
Silver (µg/l)	<1	<0.1	<0.2	1.1	<0.2	<0.2	<0.2	<0.2	<0.3	<0.2	<0.2	<0.1	NC	<0.1-1.1
Zinc (µg/l)	2.4	10	10	1.5	3.3	0.9	5.1	12.7	5.7	12.9	8.5	9	6.8	0.9-12.9
Aluminum (µg/l)	15.6	29	28	49	36	24	28	12	16	29	49	27	29	12-49
Cobalt (µg/l)	2.1	<1	<1	2.0	3	<1	6	11	<2	<2	<2	<2	NC	<1-11
Molybdenum (µg/l)	<1	4.0	2.7	1.4	<1	<1	2	<1	<1	3	<1	<1	NC	<1-4.0
Nickel (µg/l)	<1	<2	<1	10.8	<1	2	<1	22	4.3	9	11	7	6.0	<1-22

(a) Dash indicates no data collected.
(b) Not calculated because most values were less than the detection limit and/or the detection limit was variable.
(c) Sulfate measured by EPA Method 375.2.

(≤10 mg/liter) and consistent (range of 4-10 mg/liter). Of the two components of total sulfur, one (sulfide) was always below its detection limit (0.7 mg/liter). As a result, the total sulfur values presented in Tables 3 and 4 are based solely on the concentration of sulfate found in the acidified sample.

Total cyanide concentrations were below the limit of detection (0.01 mg/liter) at both stations throughout the year. Biological oxygen demand concentrations were also low throughout the year, and were always <2 mg/liter. Chemical oxygen demand concentrations were consistent (28-52 mg/liter) until the fall sampling when they increased for unknown reasons to 96-102 mg/liter. Fluoride concentrations were consistently ≤0.1 mg/liter throughout the year. The values for all the general water quality parameters measured in Swamp Creek during the year were within the ranges reported for streams in northern Wisconsin (USGS 1978, 1979, 1980, 1981, 1982, and 1983).

Nutrients

This group includes the various forms of nitrogen and phosphorus. Total phosphorus concentrations ranged from <0.1 to 0.36 mg/liter and orthophosphate concentrations were consistently below the limit of detection: 0.01 mg/liter (Tables 3 and 4). Nitrate and ammonia nitrogen concentrations were noticeably higher when water temperatures were cold (i.e., in the fall and winter). Organic nitrogen levels were higher in the summer and fall than in the winter and spring.

In February, at the request of the Wisconsin DNR (WDNR), a second set of ammonia, organic nitrogen, nitrate, and total phosphorus samples were collected concurrently with the regular samples. The sulfuric acid preservative (kept in sealed ampoules until collection) was added to these samples in the field, rather than using the regular procedure which calls for the preservative to be added to each sample bottle in the laboratory before collection. As summarized below, no differences in the results obtained from the two collection procedures were apparent for any of the four parameters.

Parameter (mg/l)	Preservative Added In	Station 1	Station 3	Station 4	Station 5
Ammonia (N)	Lab	0.11	0.08	0.07	0.07
	Field	0.06	0.09	0.06	0.08
Nitrate (N)	Lab	0.15	0.27	0.26	0.22
	Field	0.16	0.27	0.26	0.23
Organic N	Lab	0.19	0.42	0.27	0.31
	Field	0.24	0.31	0.30	0.29
Total P	Lab	<0.2	<0.2	<0.2	<0.2
	Field	<0.2	<0.2	<0.2	<0.2

Metals

This group includes aluminum, barium, cadmium, chromium, cobalt, copper, iron, lead, mercury, manganese, molydenum, nickel, silver, zinc, and for the purposes of this report, arsenic and selenium. With the exception of aluminum, barium, iron, manganese, and zinc, concentrations of all the other metals were near or below their respective levels of detection (Tables 3 and 4). Aluminum concentrations were between 8 and 49 µg/liter, with most values between 15 and 30 µg/liter. Barium concentrations were consistently between 5 and 20 µg/liter at both stations, the identical range shown at Stations 1 and 3 last year (Ecological Analysts 1983b). Iron was present in much higher concentrations than any of the other metals in Swamp Creek. Iron concentrations varied from 130 to 540 µg/liter, with values between 200 and 400 µg/liter being typical. Values at the two stations were similar. Manganese concentrations varied from 24 to 94 µg/liter, but generally were between 30 and 70 µg/liter. Concentrations were generally comparable at the two stations. Zinc concentrations were generally <10 µg/liter at both stations but higher values were measured occasionally. No pattern was apparent with regard to these higher values. With few exceptions, arsenic, selenium, chromium (both +3 and +6), mercury, and silver were consistently below their respective levels of detection. Similarly, cadmium concentrations were below detectable limits on most dates. Exceptions were in March and April when values of 1.4 and 1.5 µg/liter, respectively, of cadmium were measured at Station 1, and in September when 0.7 µg/liter was measured at Station 4. The elevated levels at Station 1 coincided with high flow rates caused by spring rains and snowmelt. Cobalt, lead, molybdenum, and nickel concentrations were low, generally being below detectable levels approximately 50 percent of the time. Copper concentrations were low, but detectable, on all dates. The average value at Station 1 (5.1 µg/liter) was twice as high as that at Station 4 (2.5 µg/liter).

3.1.1.2 Station 5

Results of sampling at Station 5 in January through April are presented in Table 5. Although data are limited, it is apparent that the concentrations of most, if not all, parameters measured at Station 5 are comparable to the concentrations measured at Stations 1 and 4 (Tables 3 and 4). For the January through April period, iron concentrations at Station 5 were approximately twice as high as those measured at Stations 1 or 4. However, the data are too limited to predict whether this difference would have been shown over the course of the entire year.

3.1.2 Sediment Chemistry

Of the 12 chemical parameters measured in the sediment, iron, manganese, sulfate, and total sulfur were present in relatively high concentrations (Table 6). Iron and manganese concentrations were also relatively high in the water samples (see Section 3.1.1.1). For certain parameters, the concentration varied depending on substrate. The concentrations of sulfate, iron, lead, manganese, zinc, and copper were higher in silt than in sand, whereas the reverse was true only for total sulfur. The other five parameters exhibited no pattern relative to substrate. High metal

TABLE 5 RESULTS OF WATER QUALITY SAMPLING AT STATION 5 ON SWAMP CREEK IN 1983

Parameter (Units)	JAN	FEB	MAR	APR	Average	Range
Temperature (C)	0	0.5	1	6	1.9	0-6
pH (units)	6.9	7.1	7.2	--(a)	7.1	6.9-7.2
Total alkalinity (mg/l)	96	97	85	--	93	85-97
Dissolved oxygen (mg/l)	4.5	4.4	10.5	11.5	7.7	4.4-11.5
Specific conductance (µmhos/cm)	104	198	154	154	153	104-198
True color (units)	--	51	--	--	NA(b)	NA
Total hardness (mg/l)	99	112	78	64	88	64-112
Total dissolved solids (mg/l)	--	133	--	--	NA	NA
Total suspended solids (mg/l)	--	1	--	--	NA	NA
Ammonia, N (mg/l)	--	0.07	--	--	NA	NA
Nitrate, N (mg/l)	--	0.22	--	--	NA	NA
Nitrite, N (mg/l)	--	<0.01	--	--	NA	NA
Organic nitrogen, N (mg/l)	--	0.31	--	--	NA	NA
Total phosphorus, P (mg/l)	--	<0.2	--	--	NA	NA
Dissolved orthophosphate, P (mg/l)	--	<0.01	--	--	NA	NA
Total phenol (mg/l)	--	0.03	--	--	NA	NA
Chloride (mg/l)	3.0	3.1	--	--	3.1	3.0-3.1
Total sulfur, S (mg/l)	1.7	<1.7	--	--	NC(c)	<1.7-1.7
Sulfate(d) (mg/l)	5	<5	--	--	NC	<5-5
Total cyanide (mg/l)	<0.01	<0.01	--	--	NC	<0.01
BOD, 5-day (mg/l)	--	1.0	--	--	NA	NA
COD (mg/l)	--	46	--	--	NA	NA
Fluoride (mg/l)	<0.1	<0.1	--	--	<0.1	<0.1
Arsenic (mg/l)	<2	<1	--	--	NC	<1-<2
Barium (µg/l)	15	7	--	--	11	7-15
Cadmium (µg/l)	<0.1	0.4	--	--	NC	<0.1-0.4
Chromium^{+3} (µg/l)	<1	<1	--	--	<1	<1
Chromium^{+6} (µg/l)	<1	<1	--	--	<1	<1
Copper (µg/l)	1.2	6.7	--	--	4.0	1.2-6.7
Iron (mg/l)	0.6	0.37	0.33	0.35	0.41	0.33-0.6
Lead (µg/l)	<1	3.1	--	--	NC	<1-3.1
Manganese (µg/l)	47	41.2	--	--	44.1	41.2-47
Mercury (µg/l)	<0.2	<0.2	--	--	<0.2	<0.2
Selenium (µg/l)	<1	<1	--	--	<1	<1
Silver (µg/l)	<1	<0.1	--	--	NC	<0.1-<1
Zinc (µg/l)	3.7	6	8	2.7	5.1	2.7-8
Aluminum (µg/l)	20.5	28	--	--	24.3	20.5-28
Cobalt (µg/l)	2.2	<1	--	--	NC	<1-2.2
Molybdenum (µg/l)	1	2.5	--	--	1.8	1-2.5
Nickel (µg/l)	<1	<2	--	--	NC	<1-<2

(a) Dash indicates no data collected.
(b) Not applicable.
(c) Not calculated because most values were less than the detection limit and/or the detection limit was variable.
(d) Sulfate measured by EPA Method 375.2.

TABLE 6 RESULTS OF CHEMICAL ANALYSIS OF SEDIMENT SAMPLES COLLECTED AT STATION 4 ON SWAMP CREEK IN MAY 1983

Parameter (mg/kg)[(a)]	Silt-A[(b)]	Silt-B[(b)]	Sand-A	Sand-B
Sulfate	2,070	1,260	1,100	1,090
Total sulfur	1,400	1,440	10,100	13,500
Arsenic	8.0	6.9	6.6	5.3
Cadmium	9.4	8.5	8.4	7.6
Total Chromium	22.2	12.6	10.3	10.5
Copper	9.8	8.5	4.2	4.6
Iron	8,210	7,090	4,120	4,510
Lead	12.8	8.5	5.1	4.6
Manganese	867	433	168	227
Mercury	0.19	0.16	0.14	0.13
Zinc	45.5	36.9	19.2	19.5
Phenol	1.9	1.0	1.7	5.2
Total Residue (%)	16.84	25.36	43.39	40.38

(a) Dry weight.

(b) A and B = Replicate samples taken from separate Ponar grabs.

concentrations in the silt fraction are typical because the small size of the particles making up the silt fraction provides proportionally greater surface area compared to the sand.

3.1.3 Particle Size Analysis

No coarse materials (>2.83 mm) were present in either the sand or silt substrates (Table 7). Fine to coarse sand (0.125-≤2.83 mm) dominated both substrates, composing 63.1 and 78.6 percent in the silt and sand substrates, respectively. The percentage of fine materials (<0.125 mm) in the samples was 36.8 and 21.4 percent for the silt and sand substrates, respectively. Within the silt substrate, these fine materials were composed of 14.8 percent very fine sand, 15.5 percent silt, and 6.5 percent clay. Comparatively, the sand samples contained 11.7 percent very fine sand, 5.7 percent silt, and 4.0 percent clay. Thus, the silt sample contained twice as much silt and clay (22 percent combined) as did the sand sample (9.7 percent combined).

3.1.4 Fish Tissue Analysis

Table 8 summarizes the results from the 15 fish tissue samples that were analyzed. Concentrations of all parameters except total chromium were low with few trends apparent regarding species or age. Arsenic concentrations were consistently <1 mg/kg and no species-specific differences were apparent. Cadmium concentrations were always ≤0.2 mg/kg and were <0.1 mg/kg in the majority of samples. Total chromium concentrations were high, ranging from 19.4 to 222 mg/kg. Mean concentrations for northern pike (72.5 mg/kg) and rock bass (101.6 mg/kg) were similar, while those for white sucker (50.4 mg/kg) were lower. Mean concentrations of copper in northern pike (4.40 mg/kg) and rock bass were similar (4.87 mg/kg), but were noticeably higher in white sucker (13.00 mg/kg). Lead concentrations in white sucker and rock bass tissues were comparable, whereas mean concentrations in northern pike were somewhat higher. Mercury concentrations were low in all three species, but mean concentrations in rock bass were approximately double those in the other two species. Mean zinc concentrations were comparable among the three species (Table 8).

3.1.5 Winter Dissolved Oxygen Survey

Because of mild winter weather conditions, particularly in terms of temperature, portions of Swamp Creek and Squaw Creek remained open much of the winter. Ice-out occurred in late March so the stream had little ice cover during the March sampling and no ice cover in April. The results of the winter DO survey reflect the amount of ice cover on the stream. In January and February, when the stream was almost entirely ice-covered, DO concentrations ranged from 4 to 6 mg/liter in Swamp Creek (Table 9). Dissolved oxygen concentrations were highest at those stations closest to Rice Lake (i.e., Stations 1 and 3) and decreased steadily in a downstream direction (Table 9). However, even at the station farthest downstream, DO concentrations were not low enough to be stressful to aquatic organisms. Dissolved oxygen concentrations in Squaw Creek in January and February were approximately double those at the downstream stations in Swamp Creek.

TABLE 7 SEDIMENT SIZE DISTRIBUTION OF THE SILT AND SAND SUBSTRATES COLLECTED AT STATION 4 ON SWAMP CREEK (Data are percent [by weight] and represent the mean of two samples)

Particle Size (mm)	Substrate Silt	 Sand
>2.83 (gravel, rubble)	0	0
0.125 to ≤2.83 (fine to coarse sand)	63.1	78.6
0.074 to ≤0.125 (very fine sand)	14.8	11.7
0.004 to ≤0.074 (silt)	15.5	5.7
<0.004 (clay)	6.5	4.0

TABLE 8 RESULTS OF CHEMICAL ANALYSIS OF FISH TISSUE SAMPLES COLLECTED DURING 1982-1983 IN SWAMP CREEK

Parameter (mg/kg)[a]	Northern Pike				Mean	Rock Bass						Mean	White Sucker					Mean
Age (years)	3+	1+	2+	2+		6+	4+	6+	5+	6+	4+		2+	2+	3+	3+	3+	
Arsenic	0.46	<0.34	0.60	0.82	<0.55	0.87	0.85	<0.37	<0.32	<0.68	<0.60	<0.61	0.40	0.66	0.40	0.56	0.66	0.54
Cadmium	0.15	0.08	0.09	0.08	0.10	0.10	0.17	0.18	0.11	0.17	0.20	0.15	0.07	0.09	0.07	0.07	0.06	0.07
Total chromium	63.2	19.4	27.5	180.0	72.5	66.5	113.8	75.5	50.4	222.0	81.6	101.6	29.9	113.0	41.6	22.9	44.7	50.4
Copper	5.02	3.55	2.01	7.04	4.40	4.43	5.94	7.18	5.04	6.15	6.47	5.87	3.59	12.29	32.8	6.05	10.24	13.00
Lead	3.96	1.27	1.55	4.75	2.88	2.79	<1.70	1.66	<0.97	<1.37	<1.09	<1.60	<0.73	1.50	1.34	0.83	3.45	<1.57
Mercury	1.37	0.93	1.03	1.64	1.24	2.89	3.57	1.10	1.07	2.56	1.99	2.20	0.86	0.94	0.87	1.53	<0.42	<0.92
Zinc	83.7	42.2	52.4	106.0	71.1	66.5	66.2	52.5	69.7	59.8	72.6	64.5	64.5	89.3	85.9	61.8	77.4	75.8

(a) Dry weight.

TABLE 9 RESULTS OF DISSOLVED OXYGEN/TEMPERATURE SURVEYS CONDUCTED MONTHLY JANUARY THROUGH APRIL 1983 AT SEVEN STATIONS ON SWAMP CREEK AND ONE ON SQUAW CREEK (The stations on Swamp Creek are arranged upstream to downstream)

	DO Concentration (mg/l)				Temperature (C)			
Station	JAN	FEB	MAR	APR	JAN	FEB	MAR	APR
1	6.4	5.4	10.3	12.2	0	0	1.0	6.0
3	6.2	5.7	10.9	NM(a)	0	0	1.0	NM
4	6.1	5.4	10.3	11.3	0	0.5	1.0	8.0
4-1	4.5	5.1	10.7	NM	0	0.5	1.0	NM
5	4.5	4.4	10.5	11.5	0	0.5	1.0	6.0
5-1	4.5	4.1	10.0	NM	0	0.5	1.0	NM
6	4.1	4.1	10.1	NM	0	0.5	1.0	NM
Squaw Creek	9.8	8.1	8.9	10.2	0	1.0	1.0	7.0

(a) NM = not measured.

The lack of ice cover in March resulted in DO concentrations being uniform throughout the reach of Swamp Creek that was sampled (Table 9). The DO concentrations in Swamp Creek in March represented saturation levels of 70-76 percent. The DO concentration in Squaw Creek (8.9 mg/liter) in January was comparable to the concentrations found in January and February. In April, no samples were collected downstream of Station 5 because no reduction in DO concentrations was expected subsequent to ice out. The high concentrations (11.3-12.2 mg/liter) measured at Stations 1, 4, and 5 confirm this (Table 9). These concentrations represent saturation levels of 92-98 percent.

3.1.6 Summer Diel Dissolved Oxygen Survey

The summer diel DO survey revealed major diel fluctuations in DO concentrations, temperature, pH, and carbon dioxide in July and August, whereas these parameters varied only minimally in September (Table 10). In July, pH, temperature, and DO at both Stations 1 and 3 achieved their respective minimum values during the night and maximum values during the day, while carbon dioxide values followed the reverse trend (Figures 2 and 3). Alkalinity values showed no diel fluctuations. For each parameter, the same pattern was apparent at both stations. Moreover, the absolute values measured at the two stations were similiar. The only differences were that pH values were noticeably higher at Station 3 than at Station 1, and that maximum and minimum DO concentrations were slightly higher at Station 3 compared to Station 1. As discussed later, these differences can be explained by the large numbers of aquatic macrophytes present at Station 3.

The diel patterns observed in July were equally apparent in August. Temperature, DO, and pH peaked during mid to late afternoon, while maximium carbon dioxide values occurred around midnight (Table 10). As in July, no diel fluctuations were apparent in the August alkalinity values. Similarly, the higher pH and DO values observed in July at Station 3 compared to Station 1 were again apparent in August.

In September, water temperatures were 12-17 C cooler than in July or August, and although some diel fluctuations were observed, the magnitude of these fluctuations was reduced considerably (Table 10). In September, daytime temperatures were approximately 2 C warmer than at night, and daytime DO concentrations were only about 1 mg/liter higher than at night. Carbon dioxide and pH values during the night were slightly lower than during the day. As in the preceding months, no diel fluctuations in alkalinity were apparent. The higher DO and pH values at Station 3 in July and August were not in evidence in September.

3.2 HYDROLOGY

3.2.1 Velocity Transects

Velocity measurements were taken along the quarter points on 10 dates at Station 1 and six dates at Station 4 (Table 11). Velocities at Station 1 were consistent, with 27 of 37 measurements (73 percent) ranging from 0.12 to 0.22 m/sec (0.40 and 0.71 ft per second). Higher velocities occurred on 9 May, 20 September, and 17 October, whereas lower velocities

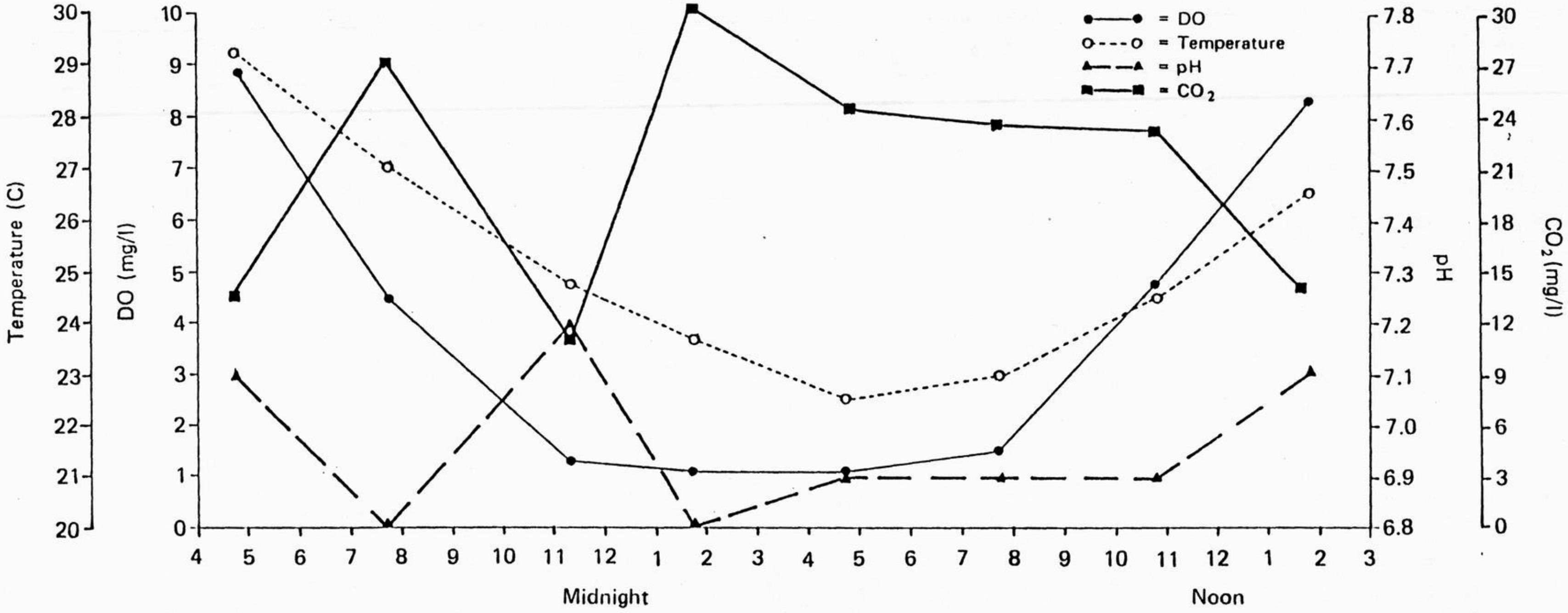
TABLE 10 RESULTS OF DIEL SAMPLING CONDUCTED 19 AND 20 JULY, 15-16 AUGUST, AND 20-21 SEPTEMBER 1983 AT TWO STATIONS ON SWAMP CREEK Page 1 of 2

	July		August		September	
	Station		Station		Station	
	1	3	1	3	1	3
Time	1645	1645	1710	1710	1650	1650
pH (units)	7.1	7.8	7.4	7.9	7.7	7.6
Temperature (C)	29.2	29.0	26.0	25.5	11.9	11.8
Alkalinity(a) (mg/l)	99	97	96	95	96	95
DO(a) (mg/l)	8.9	10.7	8.8	9.8	7.1	7.5
CO_2 (mg/l)	13.7	2.7	7.0	2.2	4.4	5.5
Time	1945	1945	2010	2010	2064	2064
pH (units)	6.8	7.2	7.1	7.2	7.4	7.3
Temperature (C)	27.0	28.0	25.0	25.0	11.4	11.4
Alkalinity (mg/l)	97	95	95	95	94	91
DO (mg/l)	4.5	8.1	5.9	7.1	6.4	7.0
CO_2 (mg/l)	27.4	10.6	14.0	10.9	8.7	10.7
Time	2315	2315	2310	2310	2250	2250
pH (units)	7.2	6.9	6.6	6.8	7.5	7.8
Temperature (C)	24.8	27.0	23.5	24.0	10.9	10.9
Alkalinity (mg/l)	99	101	91	91	97	96
DO (mg/l)	1.3	4.9	2.5	4.5	6.3	6.5
CO_2 (mg/l)	11.6	22.8	43.2	26.6	7.2	3.6
Time	0145	0145	0200	0200	0150	0150
pH (units)	6.8	6.9	7.0	7.0	7.3	7.5
Temperature (C)	23.7	26.0	22.5	23.5	10.6	10.3
Alkalinity (mg/l)	101	99	96	95	94	93
DO (mg/l)	1.1	2.9	1.5	3.1	6.4	6.1
CO_2 (mg/l)	30.2	22.6	18.4	17.7	11.2	7.0
Time	0445	0445	0510	0510	0500	0500
pH (units)	6.9	7.1	7.1	7.3	7.1	7.2
Temperature (C)	22.5	22.5	22.0	22.0	10.2	10.0
Alkalinity (mg/l)	101	100	96	97	93	92
DO (mg/l)	1.1	2.0	1.3	2.1	6.3	6.3
CO_2 (mg/l)	24.4	15.1	14.7	9.3	17.7	14.0
Time	0745	0745	0805	0805	0800	0800
pH (units)	6.9	7.0	7.1	7.1	7.5	7.6
Temperature (C)	23.0	23.0	22.0	21.5	9.6	9.5
Alkalinity (mg/l)	100	100	97	97	95	97
DO (mg/l)	1.5	2.4	1.5	2.7	6.3	6.3
CO_2 (mg/l)	23.9	18.8	14.9	14.8	7.3	5.9

(a) Data are mean of two replicates.

TABLE 10 (Cont.)

	July		August		September	
	Station		Station		Station	
	1	3	1	3	1	3
Time	1045	1045	1105	1105	1100	1100
pH (units)	6.9	7.2	7.2	7.4	7.4	7.4
Temperature (C)	24.5	25.0	23.5	23.2	9.7	9.7
Alkalinity (mg/l)	100	100	97	97	93	93
DO (mg/l)	4.7	6.4	4.2	6.4	6.7	7.1
CO_2 (mg/l)	23.4	11.5	11.6	7.2	9.0	9.1
Time	1345	1345	1420	1420	1400	1400
pH (units)	7.1	7.6	7.5	7.9	7.2	7.2
Temperature (C)	26.5	26.0	26.0	26.0	11.1	11.0
Alkalinity (mg/l)	97	98	95	96	89	89
DO (mg/l)	8.3	9.7	8.1	10.1	7.5	7.7
CO_2 (mg/l)	14.1	4.4	5.5	2.1	13.2	13.2



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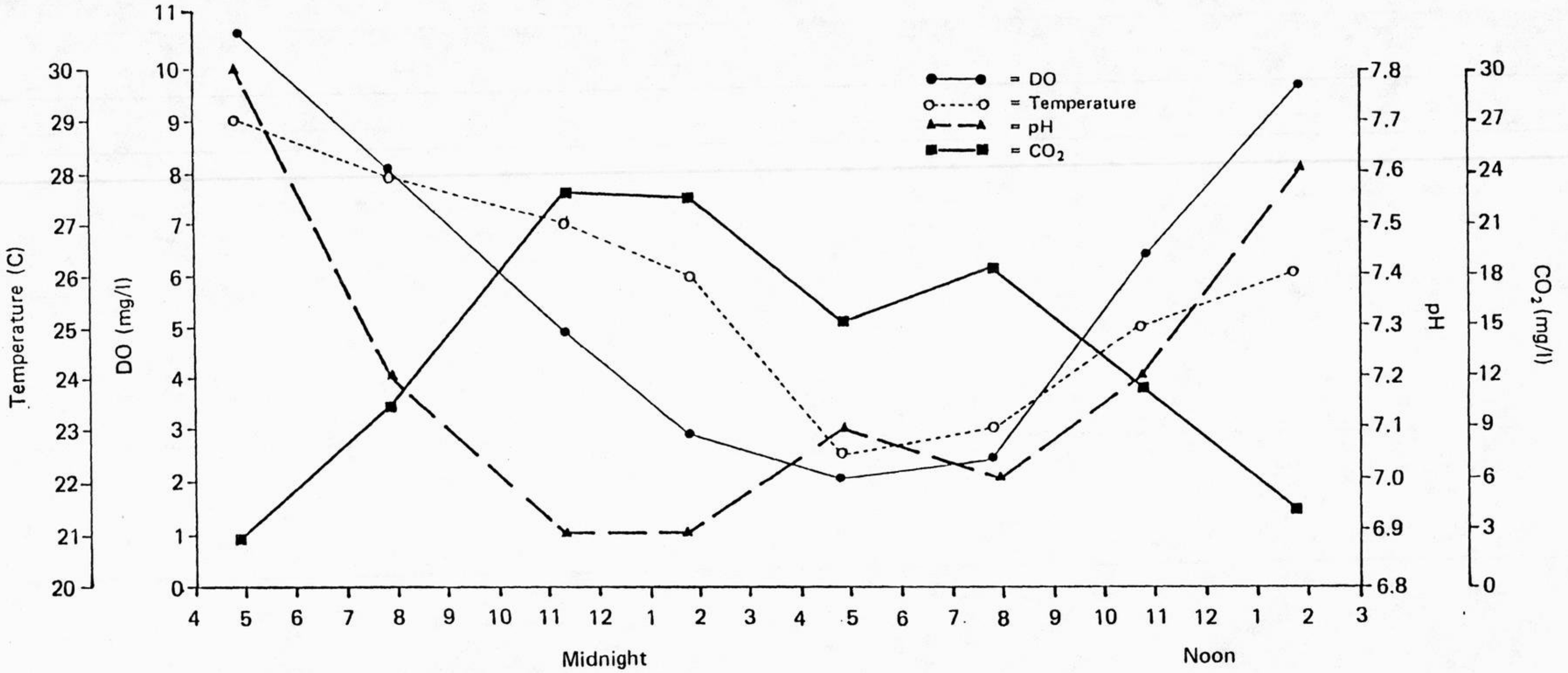
RESULTS OF DIEL SAMPLING AT STATION 1 IN SWAMP CREEK ON 19 – 20 JULY 1983.

ECOLOGICAL ANALYSTS

FIGURE 2.



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RESULTS OF DIEL SAMPLING AT STATION 3 IN SWAMP CREEK ON 19 – 20 JULY 1983.

ECOLOGICAL ANALYSTS	**FIGURE 3.**

TABLE 11 A SUMMARY OF VELOCITY MEASUREMENTS (fps) MADE AT STATIONS 1 AND 4

	Quarter Point			Mid-Point			Three-Quarter Point			
	Depth(a)			Depth			Depth			Discharge(b) (cfs)
Date	0.8	0.6	0.2	0.8	0.6	0.2	0.8	0.6	0.2	
STATION 1										
23 MAR		0.60			0.60			0.40		47
20 APR	0.55		0.55	0.68		0.71		0.50		63
9 MAY		0.90		0.75		0.80		0.60		82
20 JUN		0.55			0.70			0.50		58
19 JUL		0.45			0.70			0.60		38
15 AUG		0.70			0.45			0.35		39
20 SEP		0.46		0.92	0.82	0.85		0.73		55
17 OCT	0.62		0.62	0.75		0.78		0.65		82
15 NOV		0.55			0.68			0.70		44
5 DEC		0.45			0.49			0.41		NA(c)
STATION 4										
23 MAR		1.10			1.10			0.80		NA
20 APR		1.40			1.10			0.1	0.2	NA
20 JUN		1.00			1.15			0.80		NA
19 JUL		0.50			0.50			0.40		NA
20 SEP		0.58			0.47			0.59		NA
17 OCT		0.65			0.63			0.55		NA

(a) Multiple of total depth as measured from the surface down.
(b) Values based on USGS provisional data.
(c) Not available.

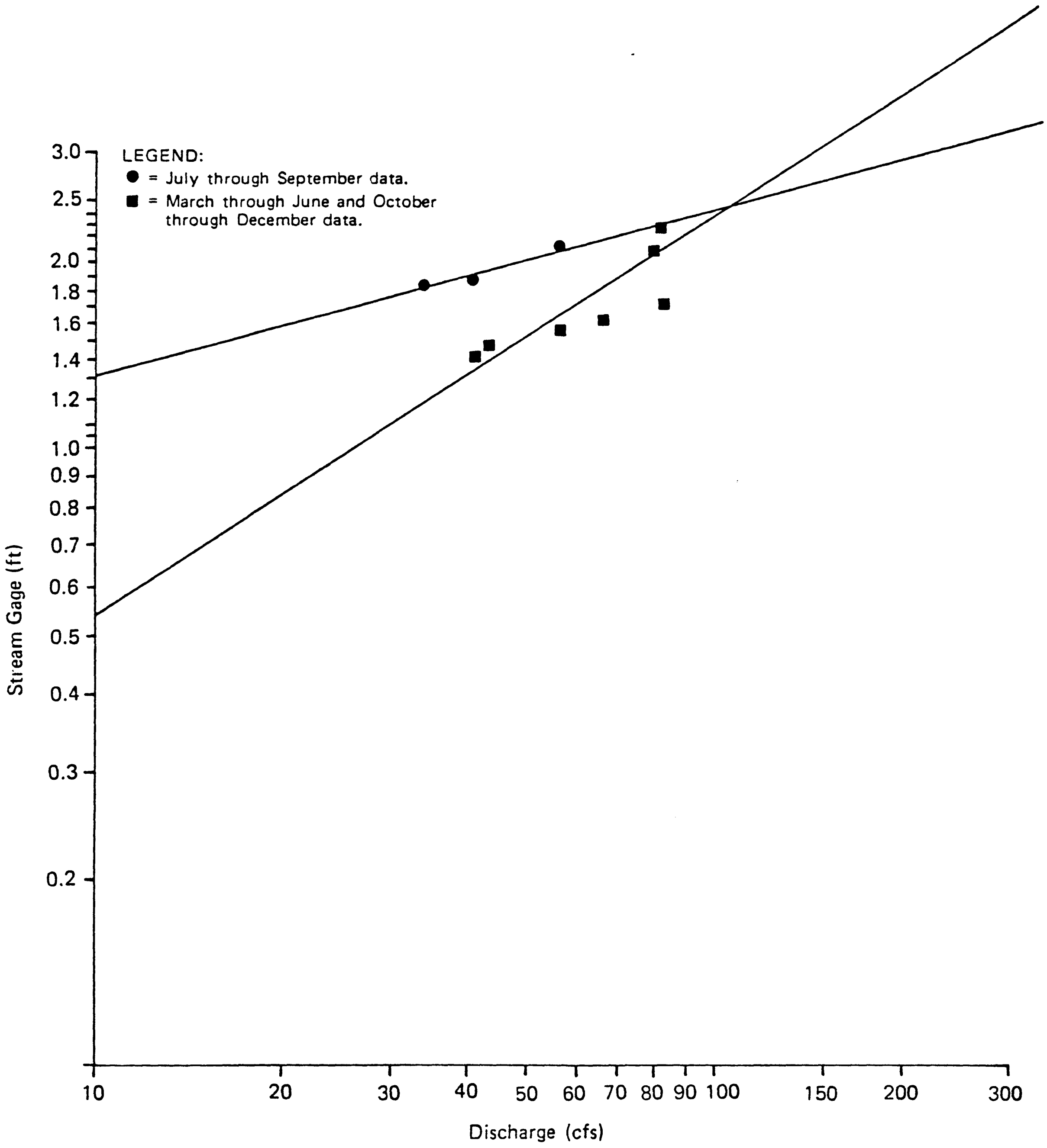
occurred on 15 August. There was a general relationship between flow rates and velocities; however, it was neither exact nor consistent. Velocities at Station 4 were more variable than at Station 1, ranging from 0.03 to 0.43 m/sec (0.1-1.40 ft per second). This variability was related to the fact that at Station 4 the stream is quite broad (18-20 m, 60-65 feet) and shallow (typically 50-70 cm [1.7-2.3 ft]) with numerous "chutes" present.

3.2.2 Discharge Measurements

Discharge measurements were made at Station 3 on 11 dates during the 1983 program. Data collected on 16 February were not used because the measured flow rate was much different than was expected (i.e., predicted) for the respective gage height. This apparently erroneous value was probably the result of the ice on the stream shifting the staff gage. When the 10 remaining points were plotted (Figure 4), it became apparent that because of extensive macrophyte growth in the stream, two different rating curves were applicable. The equation of the "no macrophyte curve" is Q (flow rate) = $29.7715(\text{gage ht})^{1.3725}$ and the equation for the "macrophyte curve" is Q = $5.4576(\text{ht})^{3.095}$. The fit for the "no macrophyte curve" (R = 0.95) was better than for the "macrophyte curve" (R = 0.83). The "no macrophyte curve" was applicable during those months of the year when macrophyte growth was minimal (i.e., January through mid-June and November and December). The "macrophyte curve" applied during July through September when macrophyte growth was maximal. The datum point for October fit the "macrophyte curve" even though macrophyte abundance was greatly reduced at Station 3 in October. However, it is possible that macrophyte growth was still substantial in other portions of Swamp Creek, thereby affecting the gage reading at SG 24. These results indicate that October was a transitional month in Swamp Creek in 1983 with macrophyte growth at an intermediate stage. The curves developed for SG 24 were used in conjunction with weekly gage readings supplied by Exxon Minerals Company to compute weekly discharge measurements for the year (Table 12). These data were then used to develop a hydrograph (Figure 5) which graphically depicts the annual flow rate cycle at SG 24.

Discharge measurements were made seasonally at Station 4 with the following results:

Date	Flow (cfs)
17 February	65.2
9 May	107.9
16 August	40.9
14 November	67.6



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RATING CURVES FOR
STREAM GAGE 24.

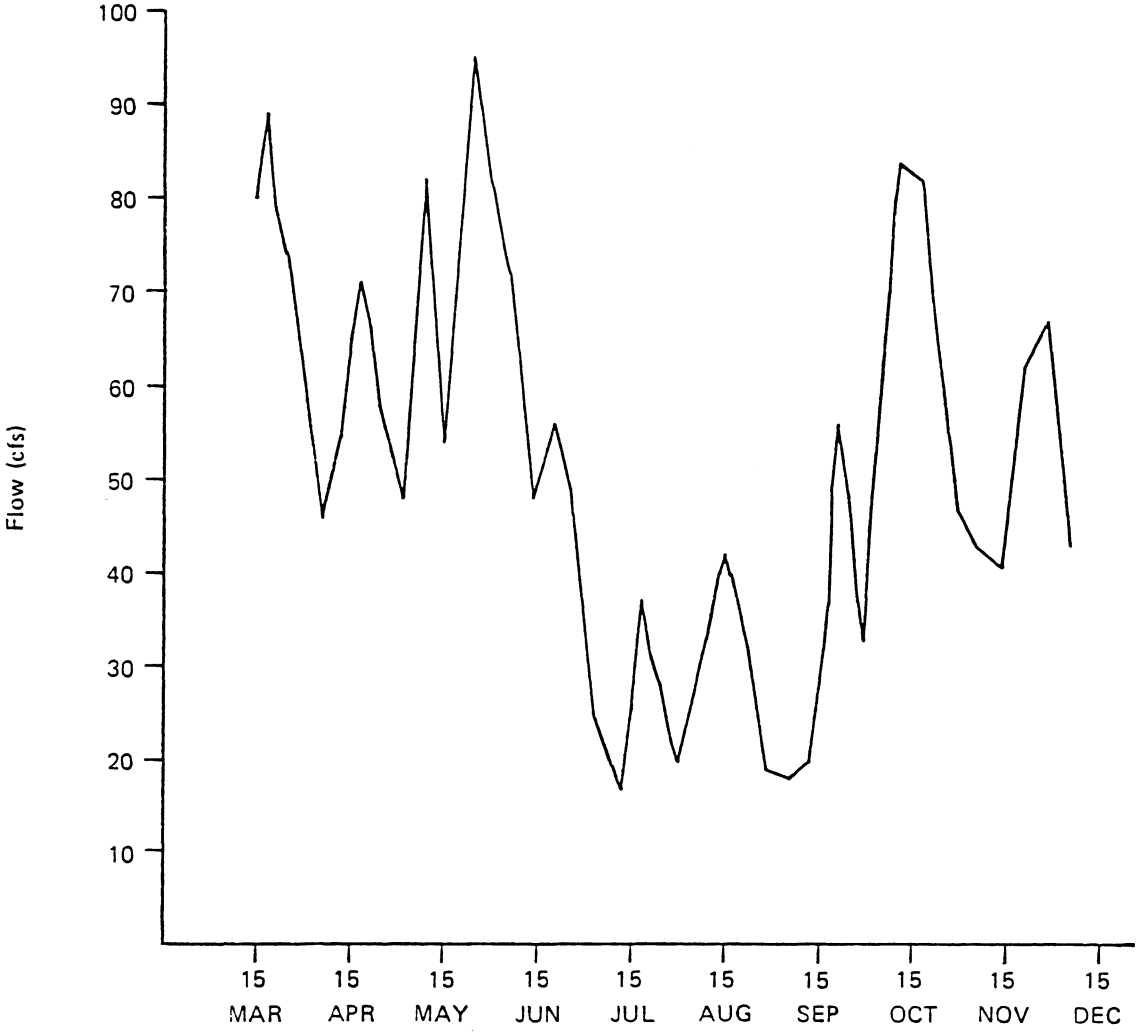
ECOLOGICAL ANALYSTS

FIGURE 4.

TABLE 12 SUMMARY OF READINGS FROM STREAM GAGE SG 24, 15 MARCH - 5 DECEMBER 1983

Date (1983)	Gage Reading (ft)	Measured Discharge (cfs)	Computed Discharge (cfs)[a]
15 MAR	2.06	--	80
21 MAR	2.22	--	89
23 MAR	2.09	79	--
28 MAR	1.94	--	74
5 APR	1.38	--	46
11 APR	1.57	--	55
18 APR	1.88	--	71
21 APR	1.60	66	--
25 APR	1.63	--	58
2 MAY	1.41	--	48
9 MAY	1.71	82	--
16 MAY	1.55	--	54
23 MAY	2.33	--	95
31 MAY	2.09	--	82
6 JUN	1.91	--	72
14 JUN	1.41	--	48
20 JUN	1.56	56	--
28 JUN	1.43	--	49
5 JUL	1.63	--	25
11 JUL	1.43	--	17
18 JUL	1.85	--	37
19 JUL	1.84	34	--
25 JUL	1.64	--	25
1 AUG	1.53	--	20
8 AUG	1.78	--	33
15 AUG	1.93	--	42
16 AUG	1.86	40	--
22 AUG	1.77	--	32
29 AUG	1.50	--	19
6 SEP	1.48	--	18
13 SEP	1.53	--	20
19 SEP	1.85	--	37
20 SEP	2.12	56	--
26 SEP	1.78	--	33
4 OCT	1.58	--	56
10 OCT	2.13	--	84
17 OCT	2.27	82	--
31 OCT	1.40	--	47
7 NOV	1.31	--	43
14 NOV	1.41	41	--
21 NOV	1.68	--	61
29 NOV	1.80	--	67
5 DEC	1.47	43	--

(a) Computed according to the formulas $Q = 5.4576(\text{gage ht})^{3.095}$ for July through September and $Q = 29.7715(\text{gage ht})^{1.3725}$ for the remainder of the year.



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HYDROGRAPH OF SWAMP CREEK
FLOWS MEASURED AT STREAM
GAGE 24 FROM 15 MARCH THROUGH
5 DECEMBER 1983

ECOLOGICAL ANALYSTS | FIGURE 5

4. DISCUSSION

4.1 CHEMISTRY

4.1.1 Water Chemistry

The 1982-1983 water chemistry report prepared by EA for Swamp Creek (Ecological Analysts 1983b) included a discussion of water quality in Swamp Creek, which incorporated all water quality data available for Swamp Creek. Last year's studies by EA and the earlier studies by other investigators (USGS 1978, 1979, 1980, 1981; Section 2.4 of the EIR [Exxon Minerals Company 1982]) collectively demonstrated that (1) Swamp Creek is a moderately hard stream with pH values in the neutral range, (2) with the exception of a few dates, it generally contains DO concentrations sufficient to support a diverse aquatic community, and (3) concentrations of most metals are low, generally near or below their respective levels of detection, with the exception of aluminum, iron, manganese, and zinc. The 1983 results at Stations 1, 4, and 5 (Tables 3, 4, and 5) confirm these earlier observations. Mean values measured during the 1982-1983 program are compared with those measured during 1983 in Table 13. To provide a valid comparison between the 1982-1983 and 1983 programs, the means presented in Table 13 for Station 1 were calculated for non-overlapping periods--April 1982 through March 1983 for the 1982-1983 program, and April through January 1983 for the 1983 program. Examination of the data reveals few annual differences. At Station 1, the only parameters that were notably different between years were temperature and manganese (Table 13). The higher mean temperature in 1983 was primarily the result of the high temperatures (23-27 C) measured during June through August. The mean concentration (54 μg/liter) of manganese at Station 1 in 1983 was higher than the maximum concentration (40 μg/liter) measured there in 1982-1983, suggesting that the observed difference was real. However, the reason for this difference is unknown. The high mean concentration of zinc at Station 1 in 1982-1983 was attributable to a few very high values, rather than to consistently higher values. Thus, zinc concentrations were actually comparable both years.

Station 4 was not sampled during the 1982-1983 program. However, Station 3, located approximately 750 m (2,500 ft) upstream of Station 4, was sampled. Mean values calculated for 1982-1983 for Station 3 were comparable to those measured during the present study (Table 13). Even though these two stations are located about 750 m apart, agreement between Stations 3 and 4 was even better than between 1982-1983 and 1983 results for Station 1. The differences in temperature and manganese observed between the two study years at Station 1 was also apparent in comparing the annual means for Stations 3 and 4. However, the difference in each of these two parameters was less pronounced between Stations 3 and 4. Because Station 4 is located downstream of Squaw Creek, this similarity of results suggests either that Squaw Creek has little effect on the water quality of Swamp Creek or that the water quality (chemistry) of Squaw Creek is similar to that of Swamp Creek.

TABLE 13 COMPARISON OF AVERAGE CONCENTRATIONS FOR 40 PARAMETERS MEASURED IN SWAMP CREEK AT STATION 1 IN 1982-1983 AND 1983, STATION 3 IN 1982-1983, AND STATION 4 IN 1983

Parameter (units)	Station 1		Station 3	Station 4
	1982-1983	1983	1982-1983	1983
Temperature (C)	8.8	13.1	8.7	10.1
pH (units)	6.9	7.2	7.1	7.3
Total alkalinity (mg/l)	87	82	85	85
Dissolved oxygen (mg/l)	7.8	9.3	8.7	9.1
Specific conductance (umhos/cm)	178	168	175	173
True color (units)	71	83	73	76
Total hardness (mg/l)	94	87	93	88
Total dissolved solids (mg/l)	139	134	128	110
Total suspended solids (mg/l)	3.4	6	6.1	4
Ammonia, N (mg/l)	0.05	0.07	0.05	0.07
Nitrate, N (mg/l)	0.10	0.06	0.14	0.12
Nitrite, N (mg/l)	<0.01	<0.01	<0.01	<0.01
Organic nitrogen, N (mg/l)	0.41	0.68	0.52	0.67
Total phosphorus, P (mg/l)	0.22	0.26	0.28	NC(a)
Dissolved orthophosphate, P (mg/l)	0.04	<0.01	0.03	<0.01
Total phenol (mg/l)	0.05	NC	0.03	NC
Chloride (mg/l)	2.9	3.0	2.8	2.9
Total sulfur, S (mg/l)	2.0	2.4	1.9	2.2
Sulfate (mg/l)	5.2	6	5.1	6
Total cyanide (mg/l)	<0.01	<0.01	<0.01	<0.01
BOD, 5-day (mg/l)	1.8	1.6	1.7	1.2
COD (mg/l)	35	56	38	54
Fluoride (mg/l)	NC	NC	NC	NC
Arsenic (μg/l)	NC	<2	NC	<2
Barium (μg/l)	11	12	11	11
Cadmium (μg/l)	0.2	NC	NC	NC
Chromium^{+3} (μg/l)	NC	<1	NC	NC
Chromium^{+6} (μg/l)	NC	<1	NC	NC
Copper (μg/l)	6.0	5.1	3.9	2.5
Iron (μg/l)	250	310	283	290
Lead (μg/l)	2	1.3	1	NC
Manganese (μg/l)	32	56	29	42
Mercury (μg/l)	<0.2	<0.2	<0.2	<0.2
Selenium (μg/l)	NC	NC	NC	NC
Silver (μg/l)	NC	NC	NC	NC
Zinc (μg/l)	12.2	6.2	11	6.8
Aluminum (μg/l)	35	24	40	29
Cobalt (μg/l)	NC	NC	NC	NC
Molybdenum (μg/l)	NC	NC	1.3	NC
Nickel (μg/l)	NC	9.0	NC	6.0

(a) Not calculated because most values were less than the detection limit and/or the detection limit was variable.

4.1.2 Sediment Chemistry

Sediment samples have not been collected at Station 4 previously, so a direct comparison with previous results is not possible; however, samples were collected in May of 1982 at Station 3, approximately 750 m (2,500 ft) upstream of Station 4. In addition, samples from Station 4 were split with the WDNR. The data reported in this study for Station 4 agreed well with the values reported by WDNR (Table 14). Cadmium was the only parameter in which there was a noticeable difference. However, for all parameters, values reported by both EA and WDNR at Station 4 in 1983 were higher than those reported at Station 3 in 1982 (Table 14). Sulfate, total sulfur, arsenic, cadmium, and phenol concentrations in 1983 at Station 4 were generally one to two orders of magnitude higher than those reported at Station 3 in 1982 (Table 14). Manganese and zinc concentrations were 2-5 times higher in 1983 than in 1982, regardless of substrate. Chromium, iron, and lead concentrations in the sand substrate were 3-6 times higher at Station 4 (1983) than at Station 3 (1982), whereas in the silt samples, concentrations of these parameters exhibited no difference. Copper and mercury concentrations at Station 4 (1983) were approximately double those at Station 3 (1982), regardless of substrate. The reasons for the observed differences are unclear. Possible explanations are that Station 4 is more of a depositional area than is Station 3 or that sediments with higher metal concentrations from Squaw Creek are being deposited at Station 4. The levels observed at Station 4, although elevated compared to those found at Station 3, are comparable to those found in Swamp Creek upstream of Rice Lake (see Section 2.4 of the EIR [Exxon Minerals Company 1982]).

4.1.3 Fish Tissue Analysis

No other studies have been completed to determine the concentrations of metals in fish collected from Swamp Creek downstream of Rice Lake. However, studies have been conducted using fish collected in Rice Lake and in Swamp Creek upstream of Rice Lake. Quantitative comparisons are difficult, however, because muscle fillet was analyzed with the skin on in the previous study and the studies have only one species (white sucker) in common. Three white suckers collected upstream of Rice Lake (see Table F-5 in Appendix 2.5F of the EIR [Exxon Minerals Company 1982]) had tissue metal levels comparable to those reported for white suckers during the present study (Table 8), with the exception of cadmium concentrations which were distinctly lower in white suckers collected during the present study. Tissue levels determined in a sample comprised of 25 black bullheads (Table F-5 in Appendix 2.5F of the EIR [Exxon Minerals Company 1982]) generally were comparable to the levels recorded in the three species analyzed during the present study (Table 8). However, copper and mercury concentrations during the present study were approximately an order of magnitude higher than those reported for black bullheads from Rice Lake. Yellow perch collected from Little Sand Lake had arsenic, copper, lead, and mercury concentrations (see Table F-9 in Appendix 2.5F of the EIR [Exxon Minerals Company 1982]) comparable to those recorded in the three species analyzed during the present study (Table 8). Compared to the species tested during the present study, cadmium levels were generally higher and zinc levels generally lower in yellow perch. On a broader basis, the tissue levels of metals (except

TABLE 14 COMPARISON BETWEEN RESULTS OF SEDIMENT SAMPLES COLLECTED IN 1983 AT STATION 4 (split by EA and WDNR) WITH SAMPLES COLLECTED AT STATION 3 IN 1982

	Silt(b)			Sand(b)		
	1983 Station 4			1983 Station 4		
Parameter (mg/kg)(a)	EA	WDNR(c)	1982 Station 3	EA	WDNR(c)	1982 Station 3
Sulfate	1,665	--	101	1,095	--	45
Total sulfur	1,420	--	155	11,800	--	54
Arsenic	7.5	5.5	<0.2	5.9	2.6	6.1
Cadmium	8.9	<2	0.23	8.0	<2	0.07
Total chromium	17.4	20	10.7	10.4	13	2.1
Copper	9.1	8.2	4.0	4.4	4.1	2.2
Iron	7,650	9,100	5,075	4,315	5,350	1,755
Lead	10.7	13	6.0	4.9	10	1.7
Manganese	650	930	195	197	275	61
Mercury	0.17	0.10	0.07	0.13	0.04	<0.03
Zinc	41.2	--	18.5	19.3	--	6.7
Phenol	1.5	1.8	<0.07	3.5	<0.5	<0.04

(a) Dry weight.

(b) Each value is the mean of two replicates.

(c) Samples analyzed by the Wisconsin Hygiene Laboratory, Madison, Wisconsin. Data provided by Mr. Larry Maltbey, WDNR, 21 September 1983.

for total chromium) in Swamp Creek fishes are similiar to those seen in fishes collected from other areas (Giesy and Wiener 1977; Rehwoldt et al. 1978). Total chromium levels were much higher in the three species analyzed during the present study (Table 8) and were also higher than the values reported in fishes captured elsewhere in the Swamp Creek and Pickerel Creek drainages (Appendix 2.5F of the EIR [Exxon Minerals Company 1982]). These elevated levels may have been the result of the fish being wrapped in aluminium foil. This procedure was adopted before it was known whether tissue analysis would include both metals and organics.

4.1.4 Dissolved Oxygen Survey

Although a general decrease in DO concentrations was observed with increasing distance downstream of Rice Lake, concentrations during the January through April sampling period were not low enough to affect aquatic life adversely. During sample collection, open water areas were noted in Swamp Creek and particularly in Squaw Creek. These open areas, which would serve to re-aerate the stream, would not be expected during a typical winter. Thus, the upstream-downstream trend and the high DO concentrations observed may not be representative of typical wintertime DO conditions in Swamp Creek.

4.1.5 Diel Dissolved Oxygen Survey

The diel DO survey revealed major diel fluctuations in temperature, carbon dioxide, and DO (Table 10) during July and August, together with smaller fluctuations in pH. Diel fluctuations, which are caused by photosynthesis during the daylight hours and respiration at night, are typical of lakes and streams in which macrophytes are abundant (Hynes 1970; Hutchinson 1975). Hynes' description of the classic diel DO pattern--"high in the daytime, usually, highest in the late afternoons, and lowest at night, shortly before dawn"--provides an exact account of the pattern in Swamp Creek during July and August.

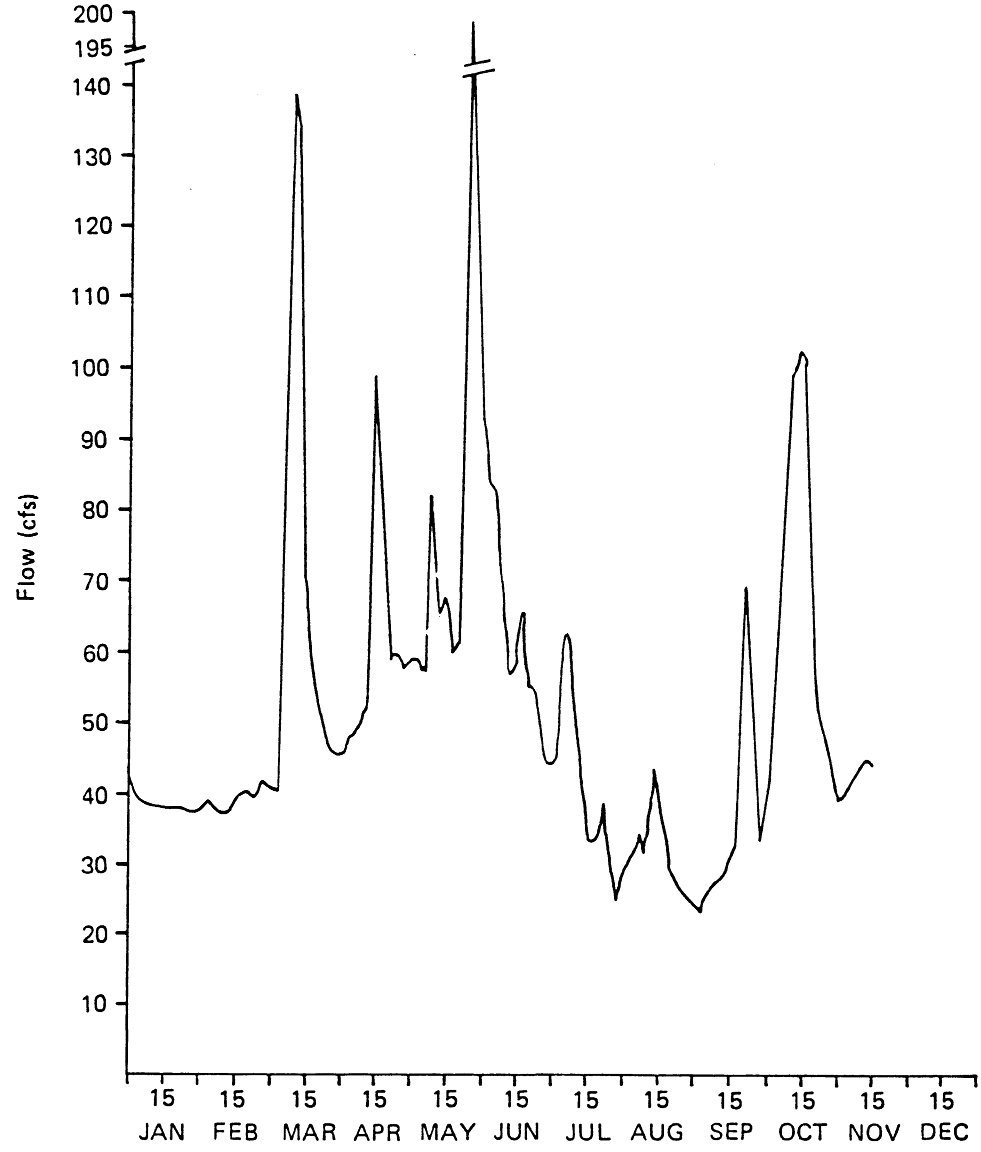
4.2 HYDROLOGY

The USGS maintains a staff gage at County Trunk Highway M, which corresponds with Station 1. Station 3, where the discharge measurements for this study were taken, is located approximately 2 km (1.2 mi) downstream of the USGS gaging station. Because there are no tributaries between the USGS station and Station 3, flows at the two stations should be comparable.

A comparison of the data from Station 3 (Table 12) and the USGS gage (George 1983; Table 15) shows that flow rates at these two gages were within 13 percent of one another on 10 of the 11 dates for which comparisons are possible. The reason for the large discrepancy on 23 March is unclear; however, the USGS gage is influenced by the backwaters from a beaver dam located approximately 335 m (1,100 ft) downstream of County Trunk Highway M. This beaver dam has caused USGS to take periodic (approximately every two weeks) instream measurements rather than relying on a rating curve (George, personal communication). Also, the USGS data are provisional, so the apparent discrepancy on 23 March may not actually exist. The USGS data when plotted in the form of a hydrograph (Figure 6)

TABLE 15 SUMMARY OF FLOW RATES (cfs) IN 1983 REPORTED BY USGS FOR THEIR GAGING STATION IN SWAMP CREEK AT COUNTY TRUNK HIGHWAY M (data are provisional)

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
1	44	38	41	45	59	94	44	29	24	41	39
2	40	38	41	47	59	90	46	28	23	47	39
3	39	39	40	48	59	84	46	31	23	55	39
4	38	39	45	48	58	85	55	35	23	61	39
5	38	39	56	48	56	86	62	36	24	63	39
6	38	38	70	48	57	81	63	35	26	66	40
7	38	38	97	48	61	76	61	33	27	71	40
8	38	37	117	49	74	71	56	32	28	92	40
9	38	37	139	50	82	68	57	30	27	98	43
10	38	37	134	52	77	64	54	34	28	92	47
11	38	37	124	53	69	60	48	42	28	87	48
12	38	37	108	54	64	57	44	44	28	103	45
13	38	37	94	58	62	54	41	43	28	115	43
14	38	37	80	80	66	53	36	41	28	114	43
15	38	38	71	101	68	58	33	39	29	102	44
16	38	40	64	104	66	67	31	36	31	92	45
17	38	40	61	92	63	68	29	35	32	85	--
18	38	40	57	80	59	66	33	35	34	76	--
19	38	39	55	70	59	62	38	32	36	67	--
20	38	39	53	63	61	58	42	30	55	61	--
21	38	39	52	59	62	55	40	29	69	56	--
22	38	40	50	59	81	56	37	27	70	51	--
23	38	39	47	60	161	56	34	24	60	50	--
24	38	39	46	60	199	53	31	26	47	49	--
25	38	41	45	58	194	50	28	25	37	47	--
26	37	42	45	58	162	46	26	25	34	46	--
27	37	42	45	57	125	44	24	25	33	43	--
28	37	42	45	59	101	43	27	24	33	42	--
29	37	--	45	58	94	41	28	22	34	41	--
30	38	--	45	58	92	40	30	23	36	41	--
31	38	--	45	--	95	--	29	24	--	40	--
Mean	38.2	38.9	66.4	60.8	85.3	62.9	40.4	31.4	34.5	67.5	--
Maximum	44	42	139	104	199	94	63	44	70	115	--
Minimum	37	37	40	45	56	40	24	22	23	40	--



EXXON MINERALS COMPANY
CRANDON PROJECT

HYDROGRAPH OF SWAMP CREEK FLOWS
MEASURED BY USGS AT COUNTY TRUNK
HIGHWAY M FROM JANUARY 1983
THROUGH 15 NOVEMBER 1983.
(DATA ARE PROVISIONAL.)

ECOLOGICAL ANALYSTS

FIGURE 6.

follow the same patterns that are evident in the hydrograph prepared from the data collected at SG 24 (Figure 5).

The rating curves developed from the 1983 data are similar to those developed from the 1982 data (Ecological Analysts 1983b). Minor differences are expected due to changes in channel morphometry and the difference in macrophyte development between the years. In both years, two curves were necessary to describe the relationship between gage height and stream flow--one applicable during the portion of the year when few macrophytes are present and one for the period when macrophytes are abundant.

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