ENVIRONMENT CANADA

WATER QUALITY AND SEDIMENT ANALYSIS

FOR THE BUCK CREEK SYSTEM

ADJACENT TO THE EQUITY SILVER

NEAR HOUSTON B.

MAY 21 AND JUNE 19-2

P/EPS/RPR/88-01
GODIN, B.
WATER QUALITY AND SEDIME
ANALYSIS FOR THE BUCK
BNKO c. 2 mm SMITHERS

Regional Program Re

by

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RESUME

La direction de la Protection de l'Environnement a conduit un programme de surveillance, en mai et juin 1987, pour déterminer l'impact des effluents de la mine Equity Silver sur le lac Goosly. Une approche sédimentologique a été prise pour évaluer la réponse du lac au rejets de la mine. Une augmentation des sulphates et diminution de l'alcalinité ont été observées dans la qualité des eaux de fond. Un facteur de concentration de 3.5 pour le cadmium a été détecté dans les sédiments du lac Goosly. Les sédiments de l'étang à sédimentation étaient efficaces a retirer seulement le cuivre de l'effluent minier. Des études plus poussées sont nécessaire pour évaluer la signification biologique de concentrations élevées en métaux dans les sédiments de fond.

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1.0 INTRODUCTION

Equity Silver Mines is located approximately 33 km southeast of Houston B.C. (Figure 1). The mine began production in September 1980. In November 1981 it was determined that waste rock at the mine site was generating acid. The company constructed an acid mine drainage collection system and has treated the water since that time.

Environmental Protection undertook a sediment monitoring program to address the impact of the mining operation on Goosly Lake in the Buck Creek system. The sedimentological approach was used for this survey due to the acknowledged behavior of sediment as a metal sink and the use of sediment as a tachometer, recording metal input to the system through the years (Forstner, 1979; Hakanson, 1983; Schindler, 1987).

This survey describes the use of recent sediment collected by sediment traps (Hakanson 1976) and examines the possibility of utilising this approach as a monitoring tool.

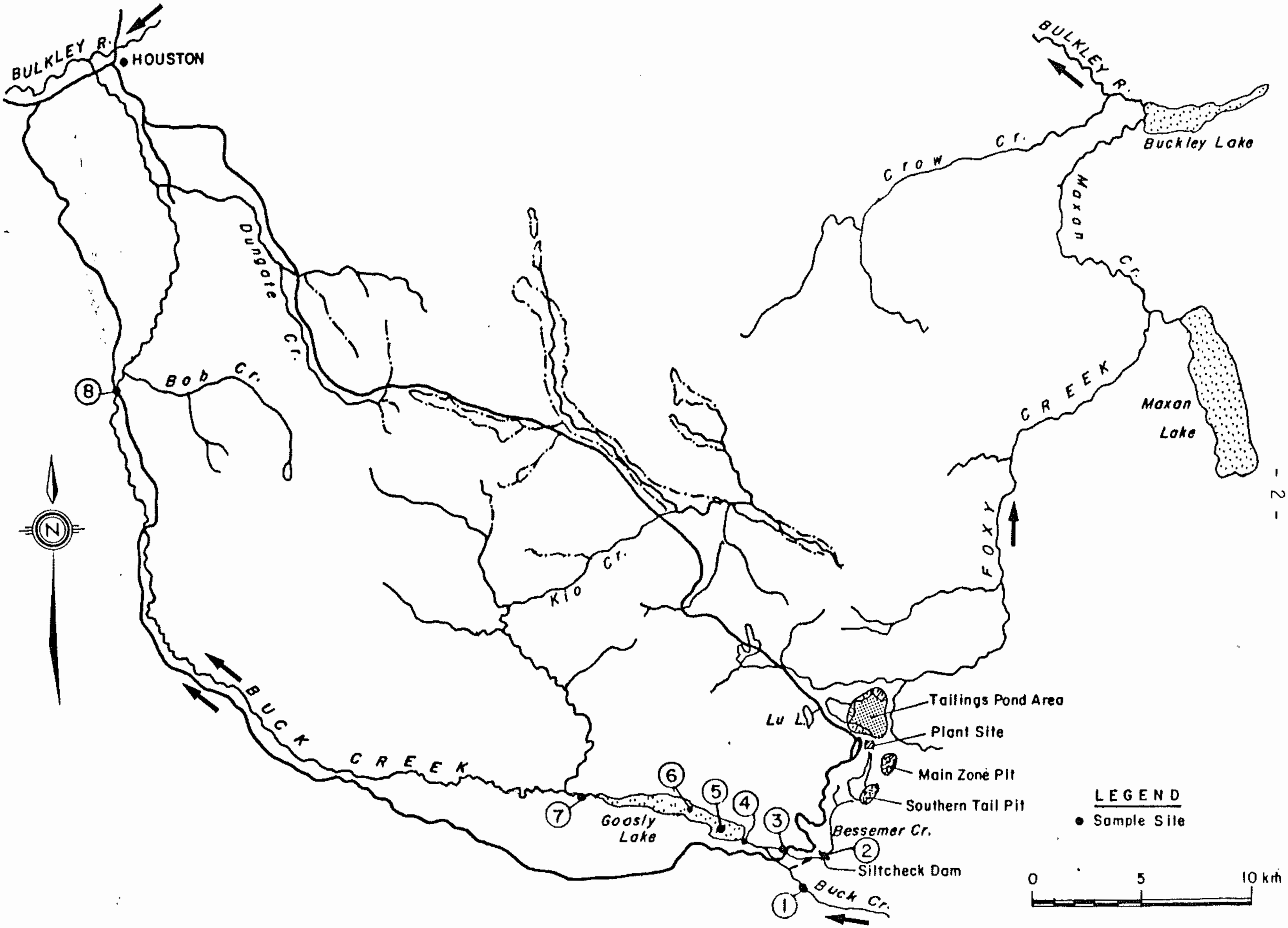


FIGURE I SAMPLING STATION LOCATIONS IN BUCK CREEK SYSTEM

2.0 DESCRIPTION OF THE STUDY AREA

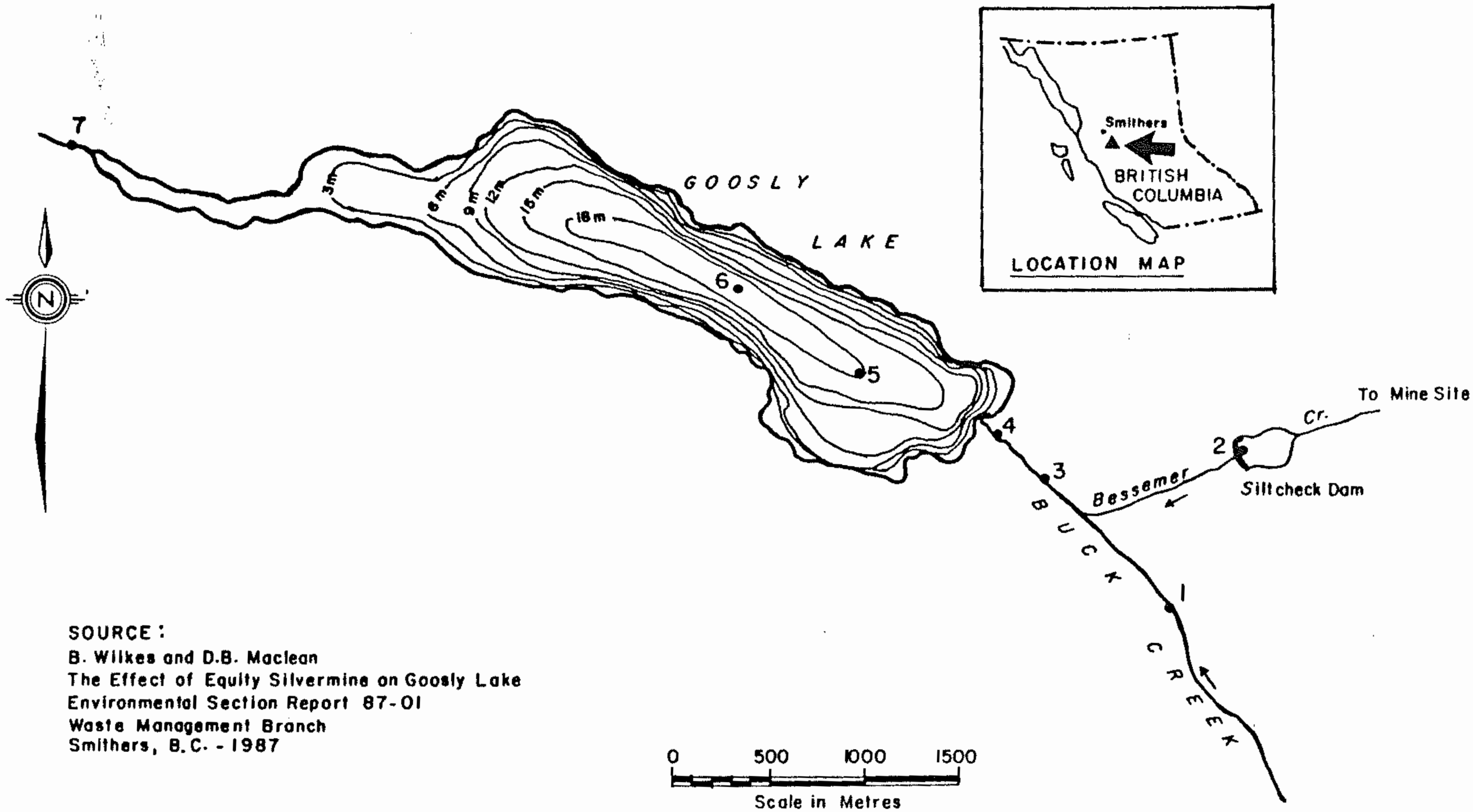
The Equity mine is situated at the headwaters of Foxy Creek, and of Bessemer Creek. The latter is a tributary to the Buck Creek. Buck Creek flows into Goosly Lake and continues until it joins the Bulkley River at Houston (Figure 1).

Eight stations were sampled during the 1987's survey; four in May 21, 1987, for water and the siltcheck dam sediments, and eight on June 19-20 1987 for sediment and water. The sample stations are described in Table 1 and shown in Figure 1 and 2 .

TABLE 1 - SAMPLE STATION DESCRIPTION

Station	Description
1	- Upstream from Bessemer Creek using Buck Creek Station corresponding to the Waste Management Branch Station # 0400765. - Water and sediment collected during June 1987
2	- Siltcheck dam (within settling pond) Equity mine's effluent to the Buck Creek System. - Water collected during May and June 1987, and sediments collected during May 1987.
3	- Downstream from Bessemer Creek, and 500 m upstream from station #4. - Water and sediments collected during June 1987.
4	- Downstream from Bessemer Creek and upstream of Goosly Lake, corresponding to the Waste Management Branch station # 0400766 - Water collected during May and June 1987, and sediments collected during June 1987.
5	- In Goosly Lake 800 metres from Buck Creek Inlet, 18 metres in depth. - Water collected during May and June 1987, and sediments collected on June 1987.

6	- In the middle of Goosly Lake, 18 metres in depth, corresponding to the Waste Management Branch station # 0700084 - Water collected during May and June 1987, and sediments collected during June 1987.
7	- In Buck Creek 100m downstream of Goosly Lake. - Water and sediments collected during June 1987
8	- In Buck Creek 12 km upstream of Houston - Water and sediments collected during June 1987



SOURCE:
B. Wilkes and D.B. Maclean
The Effect of Equity Silvermine on Goosly Lake
Environmental Section Report 87-01
Waste Management Branch
Smithers, B.C. - 1987

FIGURE 2 GOOSLY LAKE SAMPLING LOCATIONS - MAY 21 AND JUNE 19-20, 1987

3.0 MATERIAL AND METHODS

A) Water

Water samples were collected on two occasions. The first set of samples was collected on May 21, 1987 at four locations. A sample of acid mine drainage was also collected from the acid mine drainage collection pond on the same day. Only one grab sample was taken at each site.

The second sampling occurred on June 20, 1987. Five creek stations on Buck creek were collected in triplicate. A single grab sample was taken from the mine's siltcheck discharge as well as for the Goosly Lake samples. The lake samples were collected one metre from the surface and one metre from the bottom of the lake using a Van Dorn bottle. One blank sample was included in the sample set for quality control (see Table 3).

One lake profile was performed at the middle station on June 20, 1988, using a Hydrolab digital 4041 indicator unit and a 4021 sonde unit. Conductivity, temperature, and dissolved oxygen were recorded.

The following chemical parameters were analysed for the two surveys: Alkalinity, pH, nitrites, nitrates, total residues, filterable residues, and non filterable residues, and sulphates. In addition to the preceeding parameters the turbidity and true colour was analysed on May 21, sampling while ammonia, total nitrogen and total dissolved nitrogen were analysed on June 20 only. These parameters, labeled as immediates, were collected using one litre polyethylene bottles. These samples were kept cool until analysed. The organic carbon and inorganic carbon samples were collected in acid washed glass jars and preserved with a few drops of concentrated hydrochloric acid. The dissolved fraction of these two parameters were filtered within 24 hours of collection, using a 0.45 um cellulose nitrate filter.

Total metal samples were collected in a 100 ml acid washed polyethylene sample bottle and preserved with 0.5 ml of nitric acid. Dissolved metal samples were filtered the same day through a 0.45 um cellulose nitrate filter into a 100 ml polyethylene bottle and preserved with 0.5 ml of nitric acid. Total and dissolved metals were reanalysed by

Inductively Coupled Plasma (ICP) which gave a reading of twenty-six metals. The detection limit for trace metals analysed on ICP are as follows (in mg/l): Al <0.05; As <0.05; B <0.001; Ba <0.001; Be <0.001; Ca <0.1; Cd <0.002; Co <0.005; Cr <0.005; Cu <0.005; Fe <0.005; Mg <0.1; Mn <0.001; Mo <0.005; Na <0.1; Ni <0.02; P <0.05; Pb <0.02; Sb <0.05; Se <0.5; Si <0.1; Sn <0.01; Sr <0.01; Ti <0.002; V <0.005 and Zn <0.002. For cadmium and copper the samples were reanalysed with the graphite furnace and the values were below two times the detection limit on the ICP procedure. Hardness was determined from the dissolved metal sample. The graphite furnace detection limit for cadmium and copper was <0.0001 and <0.0005 mg/l respectively.

Those metals not included in the data tables that are equal or below the detection limit are: arsenic, boron, berellium, cobalt, molybdenum, nickel, antimony, titanium, and vanadium. Only strontium was not included in the samples collected on June 20, 1987, due to the large number of contaminations.

All the analysis were performed by the Environmental Protection laboratory in West Vancouver.

B) Sediments

Sediments from the siltcheck pond were collected using a small inflatable boat on May 19, 1987. The triplicate samples were collected using an Eckman dredge from the deepest part of the pond (4 m). The sample was subsampled by using an acrylic tube.

The lake sediments were collected using a sediment trap design by L. Hakanson (1976). This trap allows the collection of recently laid down sediment deposits. The trap consists of a Plexiglass pan with an outer height of 5 cm and a diametre of 45 cm. Four aluminum arms with lead weights were attached to the bottom to add stability and prevent the trap from tipping. Upon retreival a Plexiglass lid was lowered guided by a stainless steel cable fixed in the middle of the trap.

The trap was set on May 20, 1987 and retreived on June, 19 1987. Two sites were choosen for comparison basis. One set (six traps per set) was located in the middle of the lake at a depth of 18 metres while a second set was lowered about 700 to 800 metres from Buck Creek inlet, at a depth of 18 metres. Echosounding transects were performed prior to the lowering of the trap to make sure that the bottom was relatively flat. Only four traps were successfully retreived from the original set at each site. Traps with a very small amount of sediment resulting from disturbance upon retreival were discarded (evidence of dragging, improper fitting of the lid or cable tangling).

Buck Creek sediments were collected in quadruplicate at each site June 20, 1987. The sediments were collected using a clean acrylic tube (4.6 cm I.D.), pushed into the streambed approximately 6-8 cm deep. Sediments at station 7 on Buck Creek, immediately below Goosly lake, were sampled using a syringe probe following the methodology described by Derksen (1986). The samples were tranferred into Kraft soil sample envelopes, contained in a Whirl pac bag, and kept cool until analyzed.

Analysis were performed on the small fraction size (<150 um) and analysed, after digestion with aqua regia, with Inductively Coupled Plasma (ICP). The Buck Creek sediments were however reanalysed using a smaller fraction size (<63 um). The sediment were ignited at 550^0 C in muffle furnace and the loss of weight was reported as volatile residues while the remaining residues were reported as fixed residues. The total nitrogen was determined by autoclaving the sediments with potassium persulphate in a basic environment, the process converts all form of nitrogen into nitrate. The results are obtained with a colorimetric method.

C) Quality Control

The labatory personnel performed regular quality control on all water, biota and sediment analysis. After every tenth sample the laboratory runs a blank sample. After every 40 samples a reagent blank sample is evaluated as well as a reference material. A reevaluation of the samples were performed if measurements were outside of the reference material specified range. All acids used for field preservation and laboratory digestions were "Baher Instra-Analysed" for trace metal analysis.

D) Statistics

Means and standard deviations were calculated for all replicated samples. The coefficient of variation was given only for the Goosly Lake sediments (Table 8). Student's t-tests were used for comparisons between stations. The comparisons, for graphical purposes, were performed by the one way ANOVA and using the Tukey's harmonic significant difference multiple comparison plot. The significant difference was established when the probability was <0.05. A paired comparison was used to show the differences between the metal analysis on the <63 um and the <150 um sediment fraction size.

4.0 RESULTS AND DISCUSSION

A) Water

The water quality results can be found in Table 2.

1 - May 21, 1987

a - Water Quality Criteria

No Water Quality Objectives have yet been developed for Foxy Creek, Buck Creek or Goosly Lake. Comparisons can be made of the water quality results to the possible impact of the Equity mine discharge, in using the values developed by the Canadian Council of Resources and Environment Ministers (CCREM), as a reference, to point out parameters of concern.

The copper guideline calls for 2 ug/l total copper when the hardness is below 120 mg/l. In the present situation the level was exceeded at all the stations sampled especially at station 5 (17 m), where the level was 6.6 ug/l. The dissolved fractions were also above 2 ug/l ranging from 3 ug/l to 4.1 ug/l. The CCREM guideline for aluminum is 0.1 mg/l for waters with pH above 6.5 and dissolved organic carbon above 2 mg/l. The receiving water concentrations were all above this level (0.21 to 0.40 mg/l). The dissolved aluminum at station 4 was also above the total level with a value of 0.13 mg/l. The cadmium, chromium, lead, and zinc levels were all below the CCREM guidelines for the protection of aquatic life.

b-Goosly Lake

The survey was preformed shortly after the spring breakup. The comparison of the water quality in Goosly Lake from the surface measurements versus the bottom levels showed a higher concentration of the total metals in the bottom waters of station 5. This effect can be seen for all the metals except for those which were lower than the detection limit.

A comparison of the station 6 with a previous survey (Wilkes 1987), performed in May, 1984 (station 070084), showed few differences. The sulphate levels have clearly increased since May 1984. In both surveys the concentrations were higher in the bottom of the lake. The increase of

Table 2

Water quality for Buck creek system
May 21, 1987

Station	TOTICP AL MG/L	DISICP AL MG/L	TOTICP CA MG/L	DISICP CA MG/L	TOTICP CD MG/L	DISICP CD MG/L	TOTICP CR MG/L	DISICP CR MG/L	TOTICP CU MG/L	TOTGF CU MG/L	DISICP CU MG/L	DISGF CU MG/L	TOTICP FE MG/L	DISICP FE MG/L	TOTICP MG MG/L	DISICP MG MG/L	TOTICP MN MG/L	DISICP MN MG/L
2 surf.	0.90	0.07	243.0	227.0	0.003	0.002	<.005	<.005	0.028	--	0.019	--	0.687	0.048	58.1	60.2	0.455	0.409
2 (1m)	2.09	0.11	130.0	125.0	0.003	<.002	<.005	<.005	0.041	--	0.020	--	1.520	0.082	30.7	29.9	0.223	0.193
4	0.40	0.13	16.3	15.8	<.002	<.002	<.005	<.005	<.005	0.0035	<.005	0.0032	0.522	0.245	4.5	4.5	0.038	0.031
5 (1m)	0.21	0.06	16.8	15.8	<.002	<.002	<.005	<.005	<.005	0.0037	<.005	0.0030	0.317	0.136	4.9	4.6	0.099	0.065
5 (17m)	0.28	0.08	17.3	15.4	<.002	<.002	<.005	<.005	0.008	0.0066	0.006	0.0041	0.374	0.147	5.0	4.5	0.105	0.069
6 (1m)	0.24	<.05	17.8	16.9	<.002	<.002	<.005	<.005	<.005	0.0040	<.005	0.0031	0.399	0.133	5.0	5.0	0.096	0.061
6 (17m)	0.27	<.05	17.4	16.0	<.002	<.002	<.005	<.005	<.005	0.0040	<.005	0.0032	0.448	0.149	4.9	5.0	0.113	0.087
AND	356	--	295	--	1.26	--	0.15	--	89.5	--	--	--	683	--	327	--	80.5	--

Water quality for Buck creek system
May 21, 1987

Station	TOTICP NA MG/L	DISICP NA MG/L	TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	DISICP PB MG/L	TOTICP SI MG/L	DISICP SI MG/L	TOTICP SN MG/L	DISICP SN MG/L	TOTICP SR MG/L	DISICP SR MG/L	TOTICP TI MG/L	DISICP TI MG/L	TOTICP ZN MG/L	DISICP ZN MG/L	DISICP HC MG/L	DISICP HT MG/L
2 surf.	23.2	25.5	0.15	0.11	0.03	<.02	4.2	2.9	<.01	<.01	2.390	2.190	0.021	<.002	0.124	0.096	816	820
2 (1m)	12.8	11.2	0.15	0.09	0.04	<.02	6.5	3.1	<.01	<.01	1.410	1.280	0.066	<.002	0.068	0.040	434	436
4	3.2	2.3	0.07	0.07	<.02	<.02	5.1	4.5	<.01	<.01	0.196	0.191	0.012	<.002	0.004	0.004	57.7	59.1
5 (1m)	4.6	2.7	0.05	0.06	<.02	<.02	4.3	3.7	<.01	<.01	0.224	0.209	0.006	<.002	0.007	0.004	58.2	59.2
5 (17m)	4.7	2.8	<.05	0.06	<.02	<.02	4.5	3.6	<.01	<.01	0.230	0.203	0.009	0.002	0.017	0.010	57.1	58.2
6 (1m)	4.4	4.9	<.05	<.05	<.02	<.02	4.5	3.9	<.01	<.01	0.234	0.218	0.009	<.002	0.003	0.004	62.9	63.6
6 (17m)	4.2	3.7	<.05	<.05	<.02	<.02	4.3	3.8	<.01	<.01	0.225	0.218	0.008	<.002	0.007	0.005	60.2	61.1
AND	17	--	24.7	--	<.2	--	28	--	<.1	--	3.110	--	0.030	--	89.9	--	--	--

Table 2 (cont.)

Water quality for Buck creek system
May 21, 1987

Station Number	ALK MG/L	PH REL.U.	NO2 MG/L	NO2/3 MG/L	TR MG/L	FR MG/L	NFR MG/L	SO4 MG/L	TURB FTU	TC REL.U.	TEMP. Deg. C
2 surf.	24.5	7.5	0.010	2.580	1430	1418	12	780	4.3	30	6.5
2 (1m)	24.0	7.5	<.005	0.491	775	770	25	450	5.3	50	4.7
4	26.0	7.2	<.005	0.063	148	146	<5	38	2.3	70	6
5 (1m)	35.9	7.3	<.005	0.009	137	137	<5	39	1.8	60	7.5
5 (17m)	35.9	7.4	<.005	0.042	138	131	6	35	1.8	60	5.8
6 (1m)	35.4	7.3	<.005	0.025	137	131	6	34	1.8	60	7.5
6 (17m)	35.4	7.4	<.005	0.045	144	138	<5	44	2.3	60	5.7

the sulphate level was already apparent in Wilkes data (1987) and is verified by this data. It seems that the rate of removal of the sulphates in the lake is exceeded by the input rate coming from the mine. The alkalinity in earlier surveys showed differences between the top and bottom of the lake and were also higher than what was found in this survey (38.2 and 40.7 mg/l in May 1984; 35.4 mg/l on May 1987). A closer look at the alkalinity trend is needed since a reduction of the buffering capacity would have significant effect on Goosly Lake.

2 - June 20, 1987

a - Water Quality Criteria

The water quality data for June 20, 1987 can be found in Table 3. The lake profile data for station 6 is reported in Table 4.

TABLE 4

GOOSLY LAKE CONDUCTIVITY PROFILE (Station 6) June 19, 1987

DEPTH METERS	TEMP. DEG. C	SPECIFIC COND. UMHOS/CM
0.0	15.9	145
1.0	14.1	149
3.0	12.8	153
5.0	10.7	158
7.0	7.7	170
9.0	6.5	176
11.0	6.1	178
15.0	5.5	180
17.0	5.5	181

Table 3

Water quality for Buck creek system
June 20, 1987

Station		TOTICP AL MG/L	DISICP AL MG/L	TOTICP CA MG/L	DISICP CA MG/L	TOTICP CD MG/L	TOTGF CD MG/L	DISICP CD MG/L	DISGF CD MG/L	TOTICP CR MG/L	DISICP CR MG/L	TOTICP CU MG/L	TOTGF CU MG/L	DISICP CU MG/L	DISGF CU MG/L	TOTICP FE MG/L	DISICP FE MG/L	TOTICP MG MG/L	DISICP MG MG/L
	Repl.1	0.20	<.05	12.1	11.4	0.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0017	<.005	0.0010	0.528	0.328	3.6	3.6
1	Repl.2	0.18	0.05	12.3	11.7	0.003	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0015	<.005	0.0007	0.522	0.339	3.6	3.6
	Repl.3	0.13	0.05	11.5	11.5	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0033	<.005	0.0011	0.471	0.323	3.5	3.5
	Average	0.17	0.05	12.0	11.5	0.003	---	---	---	---	---	---	0.0022	---	0.0009	0.507	0.330	3.6	3.6
	S.D.	0.04	0.00	0.4	0.2	0.001	---	---	---	---	---	---	0.0010	---	0.0002	0.031	0.008	0.1	0.1
2		0.55	0.11	85.2	91.9	<.002	0.0007	0.003	0.0005	<.005	<.005	0.017	xxx	0.023	xxx	0.557	0.075	16.7	16.6
	Repl.1	0.17	0.05	22.4	21.5	0.005	xxx	<.002	<.0001	0.008	<.005	0.010	0.0022	<.005	0.0013	0.660	0.431	5.6	5.6
3	Repl.2	0.16	<.05	20.9	20.7	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0022	<.005	0.0015	0.626	0.407	5.4	5.2
	Repl.3	0.15	<.05	21.6	21.1	<.002	<.0001	<.002	<.0001	<.005	<.005	0.006	0.0028	<.005	0.0018	0.654	0.411	5.7	5.2
	Average	0.16	--	21.6	21.1	---	---	---	---	---	---	0.008	0.0024	---	0.0015	0.647	0.416	5.6	5.3
	S.D.	0.01	--	0.8	0.4	---	---	---	---	---	---	0.003	0.0003	---	0.0003	0.018	0.013	0.2	0.2
	Repl.1	0.14	<.05	20.5	20.7	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0025	<.005	0.0014	0.996	0.608	5.4	5.2
4	Repl.2	0.16	<.05	19.8	19.8	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0036	<.005	0.0013	0.962	0.589	5.2	5.2
	Repl.3	0.15	<.05	19.0	19.0	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0032	<.005	0.0016	0.923	0.646	5.1	5.3
	Average	0.15	--	19.8	19.8	---	---	---	---	---	---	---	0.0031	---	0.0014	0.960	0.614	5.2	5.2
	S.D.	0.01	--	0.8	0.9	---	---	---	---	---	---	---	0.0006	---	0.0002	0.037	0.029	0.2	0.1
5 (1m)		0.08	<.05	18.2	17.8	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0069	<.005	0.0084*	0.265	0.124	4.8	4.6
5 (17m)		0.98	<.05	20.0	18.2	<.002	<.0001	<.002	<.0001	<.005	<.005	0.007	0.0040	<.005	0.0025	1.720	0.184	5.2	4.7
6 (1m)		<.05	<.05	16.7	16.5	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0032	<.005	0.0028	0.194	0.107	4.5	4.4
6 (17m)		0.19	<.05	19.6	17.7	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0031	<.005	0.0018	0.469	0.180	5.0	4.8
	Repl.1	0.05	<.05	17.6	17.1	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0034	<.005	0.0029	0.237	0.122	4.6	4.5
7	Repl.2	0.07	<.05	17.4	17.4	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0029	<.005	0.0022	0.235	0.127	4.6	4.5
	Repl.3	0.06	0.05	17.1	17.1	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	0.0026	<.005	0.0019	0.207	0.123	4.5	4.5
	Average	0.06	--	17.4	17.2	---	---	---	---	---	---	---	0.0030	---	0.0023	0.226	0.124	4.6	4.5
	S.D.	0.01	--	0.3	0.2	---	---	---	---	---	---	---	0.0004	---	0.0005	0.017	0.003	0.1	0.0
	Repl.1	0.31	<.05	11.4	8.8	0.003	0.0001	<.002	<.0001	0.112	<.005	0.007	0.0020	<.005	0.0012	0.637	0.170	3.9	3.5
8	Repl.2	0.34	<.05	10.4	9.8	<.002	<.0001	<.002	0.0002*	<.005	<.005	<.005	0.0032	<.005	0.0044*	0.519	0.192	3.7	3.6
	Repl.3	0.26	<.05	10.4	10.0	<.002	<.0001	<.002	0.0002*	<.005	<.005	<.005	0.0039	<.005	0.0055*	0.434	0.176	3.7	3.5
	Average	0.30	--	10.7	9.5	---	---	---	---	---	---	---	0.0030	---	---	0.530	0.179	3.8	3.5
	S.D.	0.04	--	0.6	0.6	---	---	---	---	---	---	---	0.0010	---	---	0.102	0.011	0.1	0.1
Blank		<.05	<.05	<.1	<.1	<.002	<.0001	<.002	<.0001	<.005	<.005	<.005	<.0005	<.005	<.0005	0.026	<.005	<.1	<.1

* contamination suspected

xxx analysis not performed

Table 3 (cont.)

Water quality for Buck creek system
June 20, 1987

Station		TOTICP MN MG/L	DISICP MN MG/L	TOTICP NA MG/L	DISICP NA MG/L	TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	DISICP PB MG/L	TOTICP SI MG/L	DISICP SI MG/L	TOTICP SN MG/L	DISICP SN MG/L	TOTICP ZN MG/L	DISICP ZN MG/L	DISICP HC MG/L	DISICP HT MG/L
	Repl.1	0.037	0.029	2.6	2.5	0.08	<.05	0.02	<.02	5.2	4.7	<.01	<.01	<.002	0.005*	43.3	44.3
1	Repl.2	0.037	0.030	2.7	2.5	0.06	<.05	0.02	<.02	5.3	4.6	0.01	0.02	0.003	<.002	43.8	45.0
	Repl.3	0.034	0.029	2.8	2.5	<.05	<.05	<.02	<.02	5.0	4.4	<.01	<.01	<.002	<.002	42.9	44.0
	Average	0.036	0.029	2.7	2.5	0.07	--	0.02	--	5.2	4.6	--	--	---	---	43.3	44.4
	S.D.	0.002	0.001	0.1	0.0	0.01	--	0.00	--	0.2	0.2	--	--	---	---	0.5	0.5
2		0.125	0.122	8.5	7.2	0.10	<.05	<.02	<.02	4.8	3.8	<.01	<.01	0.038	0.033	307.0	311.0
	Repl.1	0.077	0.071	4.1	3.8	0.08	0.08	0.06	<.02	5.4	4.5	<.01	<.01	0.005	0.003	76.6	78.2
3	Repl.2	0.071	0.067	4.1	3.7	0.07	0.12	<.02	<.02	5.1	4.2	<.01	<.01	0.003	0.002	73.0	74.5
	Repl.3	0.074	0.068	4.7	3.6	<.05	0.07	0.02	<.02	5.4	4.3	0.02	<.01	0.004	<.002	74.3	75.7
	Average	0.074	0.069	4.3	3.7	0.08	0.09	0.04	--	5.3	4.3	--	--	0.004	0.003	74.6	76.1
	S.D.	0.003	0.002	0.3	0.1	0.01	0.03	0.03	--	0.2	0.2	--	--	0.001	0.001	1.8	1.9
	Repl.1	0.094	0.089	4.2	3.5	<.05	0.05	<.02	0.02	5.2	4.4	<.01	<.01	<.002	<.002	73.2	74.9
4	Repl.2	0.090	0.085	4.1	3.4	0.10	<.05	<.02	<.02	5.1	4.4	<.01	<.01	<.002	0.002*	70.9	72.5
	Repl.3	0.086	0.082	4.2	3.5	0.06	<.05	<.02	<.02	5.0	4.4	<.01	<.01	0.002	0.003*	69.1	70.8
	Average	0.090	0.085	4.2	3.5	0.08	--	--	--	5.1	4.4	--	--	---	---	71.1	72.7
	S.D.	0.004	0.004	0.1	0.1	0.03	--	--	--	0.1	0.0	--	--	---	---	2.1	2.1
5 (1m)		0.022	0.002	4.5	3.5	0.08	<.05	<.02	<.02	4.2	3.3	0.06	<.01	<.002	<.002	63.2	63.9
5 (17m)		0.307	0.174	4.9	4.0	0.20	0.07	<.02	0.02	6.8	3.4	0.05	0.02	0.007	<.002	64.6	65.8
6 (1m)		0.016	0.001	4.6	3.5	<.05	<.05	<.02	<.02	4.0	3.4	<.01	<.01	<.002	<.002	59.9	60.5
6 (17m)		0.267	0.190	4.4	3.8	0.09	<.05	<.02	<.02	4.7	3.7	<.01	<.01	0.010	0.008	65.1	66.3
	Repl.1	0.031	0.010	4.5	3.8	<.05	0.06	<.02	0.02	3.9	3.1	<.01	<.01	<.002	<.002	61.1	61.9
7	Repl.2	0.031	0.010	4.4	3.8	<.05	<.05	<.02	<.02	3.9	3.2	<.01	<.01	<.002	<.002	62.0	62.7
	Repl.3	0.030	0.010	4.4	3.7	0.06	<.05	<.02	<.02	3.8	3.2	<.01	<.01	<.002	<.002	61.2	62.0
	Average	0.031	0.010	4.4	3.8	--	--	--	--	3.9	3.2	--	--	---	---	61.4	62.2
	S.D.	0.001	0.000	0.1	0.1	--	--	--	--	0.1	0.1	--	--	---	---	0.5	0.4
	Repl.1	0.298	0.016	3.3	2.7	0.16	<.05	0.02	0.02	7.7	5.9	0.07	<.01	0.010	<.002	36.4	36.9
8	Repl.2	0.045	0.019	3.6	2.8	0.10	<.05	<.02	<.02	7.6	6.0	0.03	<.01	<.002	0.005*	39.3	40.1
	Repl.3	0.029	0.019	3.5	2.8	0.11	0.12	<.02	<.02	7.3	5.7	0.05	<.01	<.002	<.002	38.5	40.2
	Average	0.124	0.018	3.5	2.8	0.12	--	--	--	7.5	5.9	0.05	--	---	---	38.4	39.1
	S.D.	0.151	0.002	0.2	0.1	0.03	--	--	--	0.2	0.2	0.02	--	---	---	1.7	1.9
Blank		<.001	<.001	<.1	<.1	0.06	0.09	<.02	<.02	<.1	<.1	0.07	0.01	<.002	<.002	0.4	0.5

* Contamination suspected

Table 3 (cont.)

Water quality for Buck creek system
June 20, 1987

Station		ALK MG/L	PH REL.U.	TIC MG/L	DIC MG/L	TOC MG/L	DOC MG/L	NH3 MG/L	NO2 MG/L	NO2/3 MG/L	TN MG/L	TDN MG/L	TR MG/L	NFR MG/L	SO4 MG/L
	Repl.1	42.3	6.9	11	10	14	9	0.049	<.005	<.005	0.33	0.28	93	<5	5
1	Repl.2	42.3	6.9	11	11	14	7	0.042	<.005	<.005	0.32	0.30	98	<5	5
	Repl.3	42.3	6.9	11	11	14	9	0.051	<.005	<.005	0.33	0.28	95	<5	5
	Average	42.3	6.9	11	11	14	8	0.047	---	---	0.33	0.29	95	-	5
	S.D.	0.0	---	0	1	0	1	0.005	---	---	0.01	0.01	3	-	0
2		47.4	7.4	12	12	8	4	0.067	<.005	1.140	1.40	1.40	465	7	200
	Repl.1	42.3	7.0	11	10	11	7	0.046	<.005	0.060	0.36	0.32	144	<5	34
3	Repl.2	42.3	7.0	10	11	11	7	0.042	<.005	0.062	0.36	0.33	146	<5	38
	Repl.3	42.3	7.0	10	10	11	7	0.042	<.005	0.062	0.38	0.33	142	<5	37
	Average	42.3	7.0	10	10	11	7	0.043	---	0.061	0.37	0.33	144	-	36
	S.D.	0.0	---	1	1	0	0	0.002	---	0.001	0.01	0.01	2	-	2
	Repl.1	43.3	6.9	10	10	13	9	0.044	<.005	0.015	0.36	0.31	135	<5	31
4	Repl.2	43.3	6.9	11	10	13	8	0.045	<.005	0.012	0.36	0.32	141	<5	32
	Repl.3	43.3	7.0	10	10	13	7	0.046	<.005	0.012	0.35	0.31	139	6	29
	Average	43.3	6.9	10	10	13	8	0.045	---	0.013	0.36	0.31	138	-	31
	S.D.	0.0	---	1	0	0	1	0.001	---	0.002	0.01	0.01	3	-	2
5 (1m)		32.0	7.0	8	8	12	10	0.054	<.005	<.005	0.41	0.33	127	<5	30
5 (17m)		32.0	6.5	9	9	12	10	0.059	<.005	0.030	0.46	0.37	136	<5	29
6 (1m)		30.9	7.0	8	8	13	11	0.055	<.005	<.005	0.46	0.34	122	<5	34
6 (17m)		32.0	6.7	8	9	14	10	0.047	<.005	0.037	1.00	0.39	137	7	37
	Repl.1	30.9	7.0	8	8	13	10	0.051	<.005	<.005	0.39	0.34	124	<5	33
7	Repl.2	32.0	7.0	8	8	13	11	0.050	<.005	<.005	0.39	0.34	129	<5	34
	Repl.3	30.9	7.0	8	8	14	11	0.050	<.005	<.005	0.40	0.33	129	<5	33
	Average	31.3	7.0	8	8	13	11	0.050	---	---	0.39	0.34	127	-	33
	S.D.	0.6	---	0	0	1	1	0.001	---	---	0.01	0.01	3	-	1
	Repl.1	32.5	7.1	8	7	6	4	0.043	<.005	<.005	0.27	0.24	85	6	12
8	Repl.2	33.5	7.1	9	9	6	4	0.043	<.005	<.005	0.26	0.23	92	<5	11
	Repl.3	33.0	7.2	8	8	8	4	0.069	<.005	<.005	0.26	0.22	88	<5	11
	Average	33.0	7.1	8	8	7	4	0.052	---	---	0.26	0.23	88	-	11
	S.D.	0.5	---	1	1	1	0	0.015	---	---	0.01	0.01	4	-	1
Blank		-	-	<1	<1	<1	<1	0.043	<.005	<.005	<.02	<.02	-	-	-

The comparison of the receiving water with the CCREM guidelines shows exceedance at different areas of the system for five metals. The aluminum levels were all above the guideline of 0.1 mg/l, while the dissolved fraction were near or below the detection limit of 0.05 mg/l. The knowledge of speciation for this metal would be important to differentiate the effect of erosion and a potential toxicant especially since at station 5 (17m), the level was 0.98 ug/l and pH 6.5. The chromium level of one of the replicate was 0.112 mg/l at station 8. The cause of this result is unknown. The copper levels showed high variability in the replicates and at the control station, this reflects the nature of the mineralisation in the area. The iron levels were also all above the CCREM of 0.3 mg/l but their wide distribution shows the influence of the system on that metal. The marshes may contribute to the introduction of dissolved iron in the system. No graphite furnace analysis for lead was performed to better confirm the distribution of the metal at levels lower than 20 ug/l. It is therefore difficult to compare the water with the CCREM guidelines where the criterin developed is 1 ug/l for waters with hardness below 60 mg/l.

b- Buck Creek

There was no significant differences between the the various stations for total aluminum except at station 8 where the levels were elevated. This particular increase in Buck Flats may be due to the erosion occuring in this riffle area as the dissolved fraction does not exceed the detection limit.

The level of calcium increased immediately downstream of the effluent discharge. At station 8, the level dropped back to background levels.

Cadmium concentrations at station 2 were 0.7 ug/l total and 0.5 ug/l dissolved cadmium. All the other concentrations were at or below the detection limit of 0.1 ug/l.

One of the replicate at station 8 for total chromium was completely different from the other two. The reason for this might be explained by the erosion occuring at that station.

Copper concentrations showed a very high variability at the upstream station. Due to this variability, no significant differences in the copper concentrations were found in downstream stations.

There was an increase of manganese in the downstream stations after the effluent discharge. Increased concentrations were in the lake water surface and increased towards the bottom of the water column. The increase of manganese in Buck Flats (station 8) may be due to the erosion or contamination of a replicate.

The effect of zinc after the effluent input was only shown at station 3.

c - Goosly Lake

The comparison of Goosly Lake June survey with the May 1987 survey revealed an increase of metal levels at depth for aluminum, iron, manganese, and also in the hardness. Magnesium, calcium, and sodium changed from the previous survey. There was a decrease with depth for copper. The alkalinity, pH and sulphates also decreased. However, in comparison with a previous survey performed on June 2, 1986, the sulphate levels were higher and alkalinity and pH were lower at depth in June 1987.

The conductivity profile conducted at station 6 on June 19, 1987 indicated a thermocline situated between 5 and 7 meters. The water conductivity increased with depth from 145 to 181 umhos/cm. The greatest increase in conductivity also occurred between 5 and 7 metres in depth.

B) SEDIMENTS

1 - Goosly Lake

a - Station Differences

The results are presented in Table 5, statistical analysis plots can be seen in Figure 3a to 3e, and the statistical station separation on Table 6.

No significant differences could be found between station 5 and 6, for the following metals: barium, beryllium, calcium, cobalt, iron,

Table 5

Goosly lake sediments
June 19, 1987

Station		SEDICP AL UG/G	SEDICP AS UG/G	SEDICP BA UG/G	SEDICP BE UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDICP CO UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDICP MG UG/G	SEDICP MN UG/G	SEDICP MO UG/G
5	Repl.1	30300	<8	582	0.7	9640	3.0	29.6	39.2	107.0	70500	7740	1780	22.9
	Repl.2	30000	<9	560	0.7	9390	3.0	28.9	40.1	105.0	69700	7530	1900	17.8
	Repl.3	27100	<8	576	0.6	12000	1.5	25.2	41.3	94.3	73500	7410	1560	17.4
	Repl.4	29600	<8	556	0.7	12200	2.5	27.6	40.4	110.0	71400	7940	1680	13.3
	AVERAGE	29250	---	569	0.7	10808	2.5	27.8	40.3	104.1	71275	7655	1730	17.9
	S.D.	1462	---	12	0.0	1498	0.7	1.9	0.9	6.8	1638	234	145	3.9
6	Repl.1	33800	<9	576	0.7	9840	4.5	30.9	39.4	127.0	69100	8320	1910	15.5
	Repl.2	33100	<10	563	0.6	9300	4.6	25.0	36.0	128.0	65900	8280	3090	14.0
	Repl.3	35900	<8	538	0.7	10600	5.0	30.3	37.9	134.0	64500	8800	1800	14.9
	Repl.4	34200	<8	587	0.7	9970	4.3	30.8	38.5	124.0	72200	8240	1820	21.1
	AVERAGE	34250	---	566	0.7	9928	4.6	29.3	38.0	128.3	67925	8410	2155	16.4
	S.D.	1190	---	21	0.0	534	0.3	2.8	1.4	4.2	3439	262	625	3.2

Goosly lake sediments
June 19, 1987

Station		SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SN UG/G	SEDICP SR UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G	SFR MG/KG	SVR MG/KG	TN MG/KG
5	Repl.1	540	30	3960	63	870	10	179	736	117	255	858000	142000	5700
	Repl.2	360	32	3650	61	890	9	174	792	118	243	860000	140000	5300
	Repl.3	280	32	3520	59	790	9	217	746	119	230	857000	143000	5000
	Repl.4	340	33	3600	64	820	8	226	749	118	247	850000	150000	6400
	AVERAGE	380	32	3683	62	843	9	199	756	118	244	856250	143750	5600
	S.D.	112	1	193	2	46	1	26	25	1	10	4349	4349	606
6	Repl.1	430	33	3850	76	860	10	194	694	117	306	839000	161000	8150
	Repl.2	760	32	3720	68	1410	5	189	679	110	308	-----	-----	-----
	Repl.3	480	34	3460	98	1080	7	208	677	111	326	841000	159000	6900
	Repl.4	420	33	3900	72	950	9	200	702	116	298	-----	-----	-----
	AVERAGE	523	33	3733	79	1075	8	198	688	114	310	840000	160000	7525
	S.D.	160	1	197	13	241	2	8	12	4	12	1414	1414	884

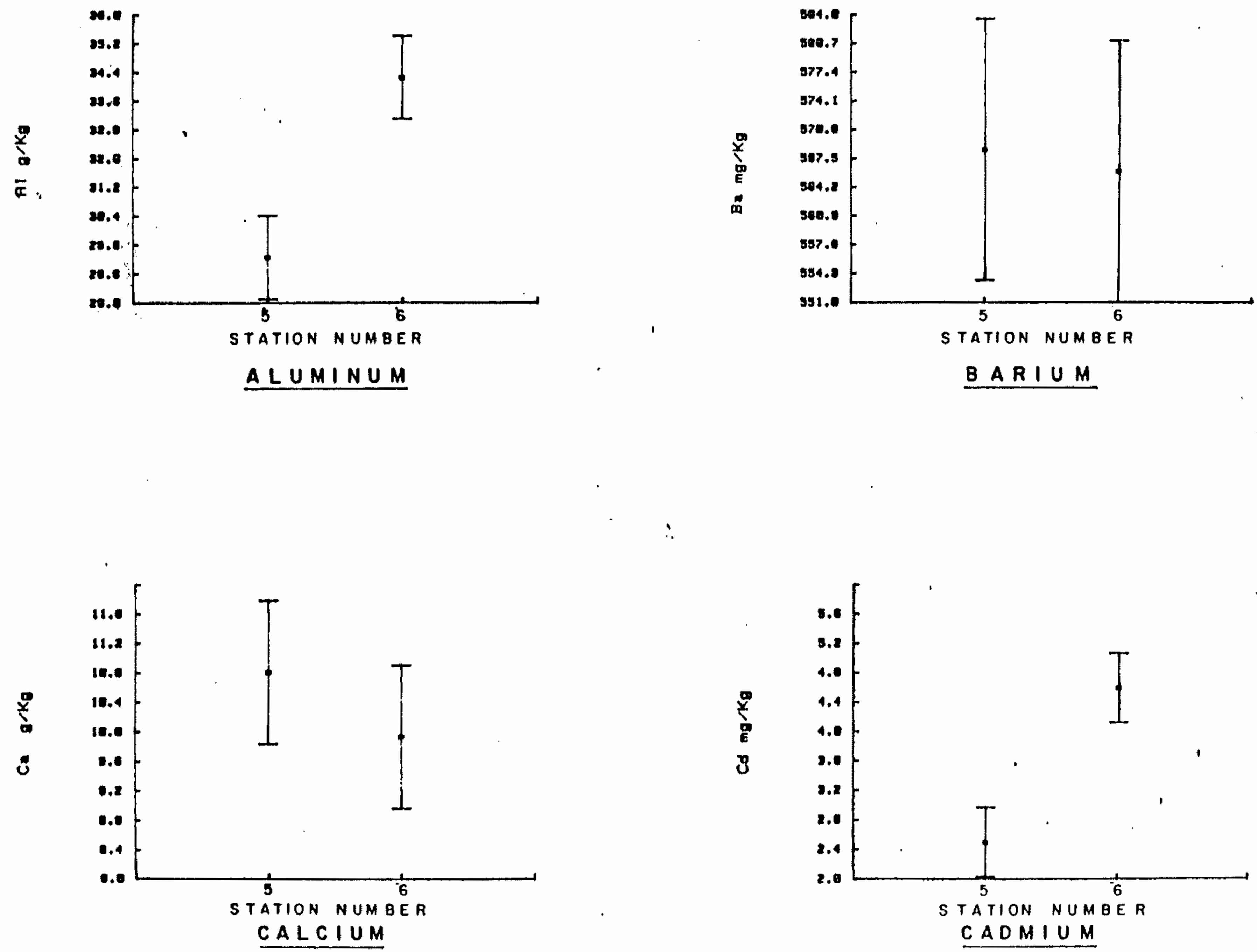


FIGURE 3a TUKEY'S MULTIPLE COMPARISON FOR GOOSLY LAKE SEDIMENTS - JUNE 19, 1987

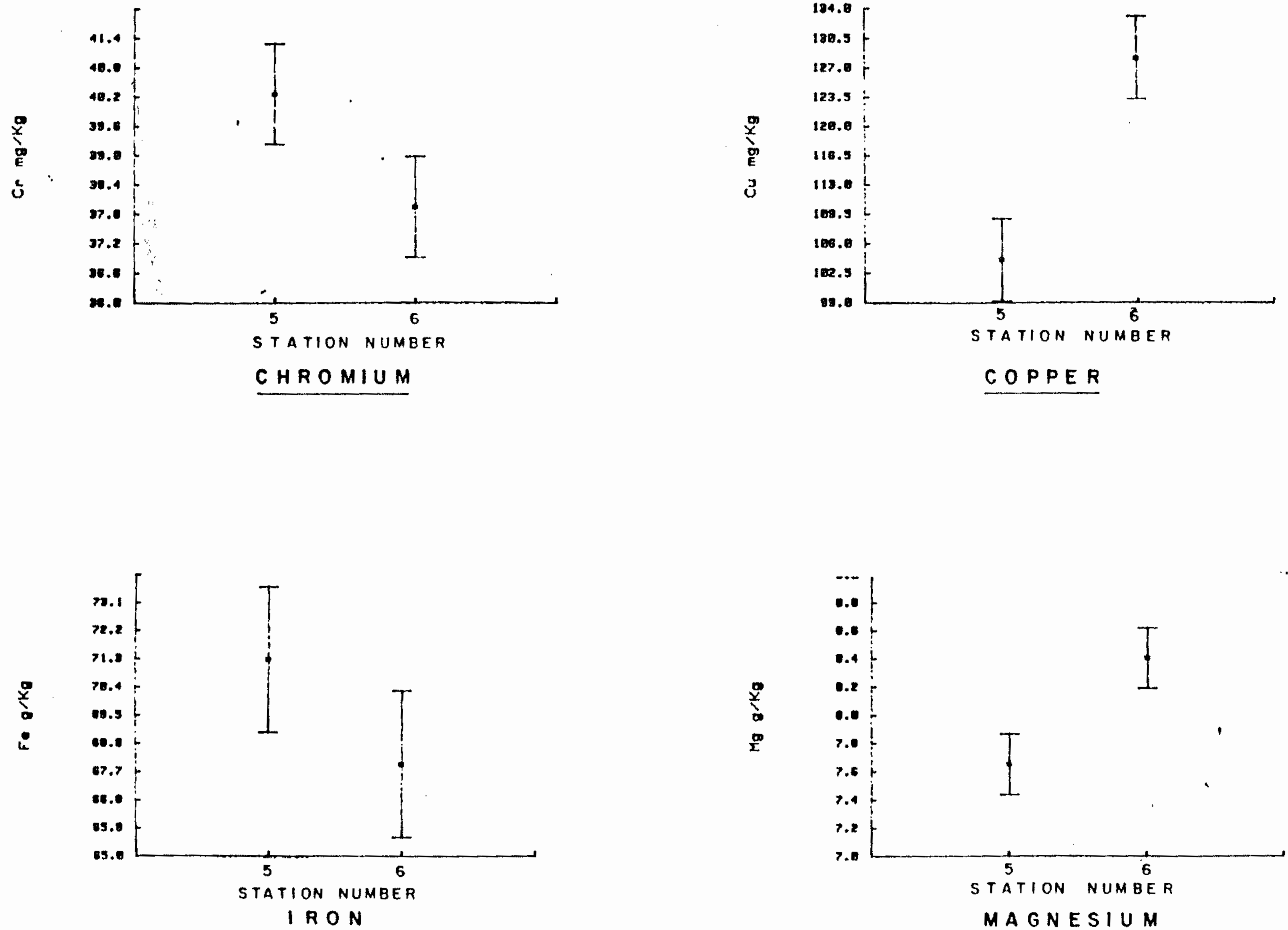


FIGURE 3b TUKEY'S MULTIPLE COMPARISON FOR GOOSLY LAKE SEDIMENTS - JUNE 19, 1987

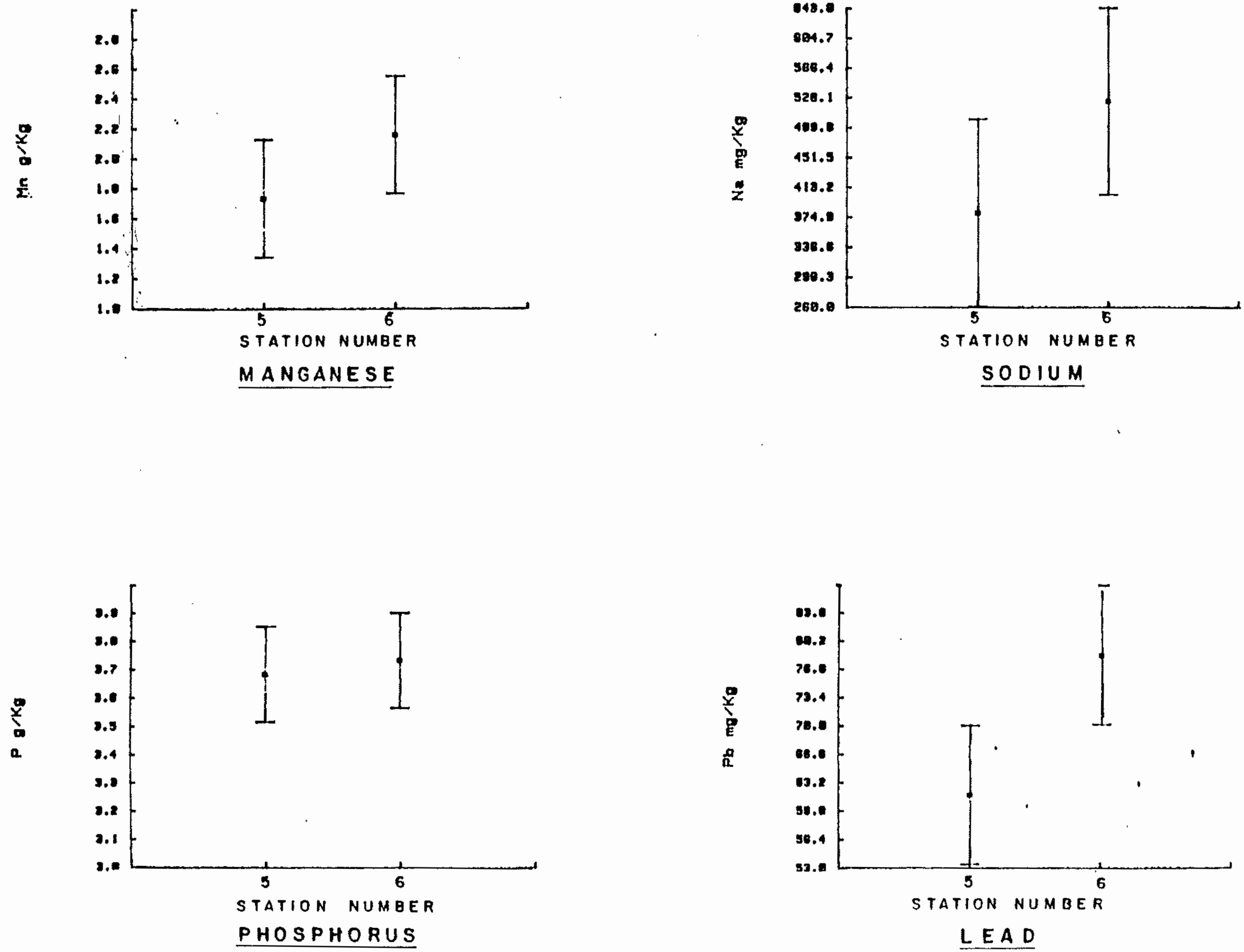


FIGURE 3c TUKEY'S MULTIPLE COMPARISON FOR GOOSLY LAKE SEDIMENTS - JUNE 19, 1987

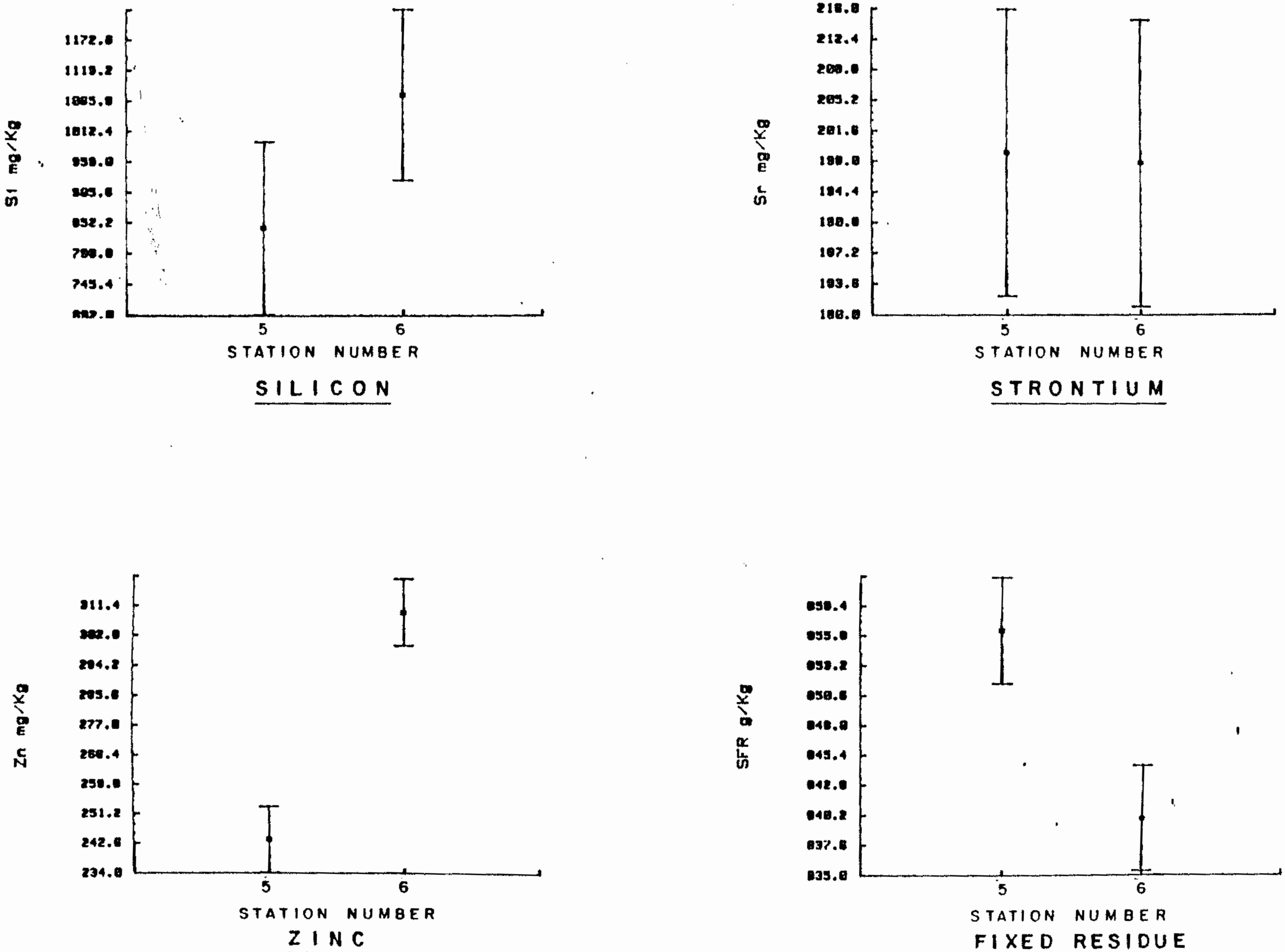
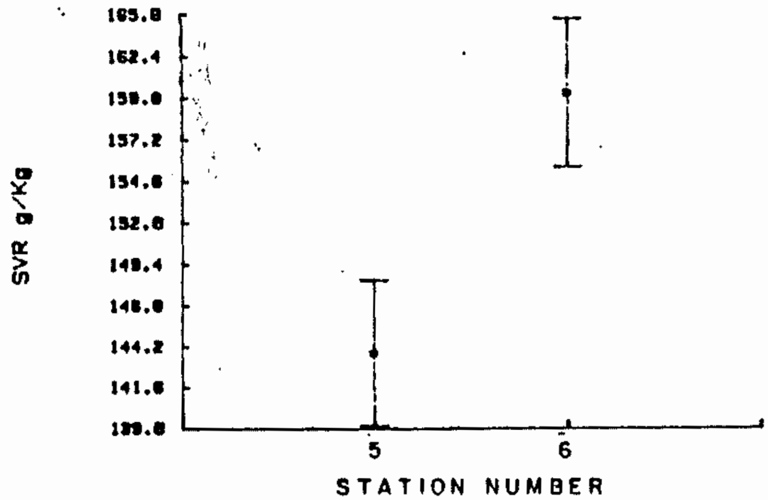
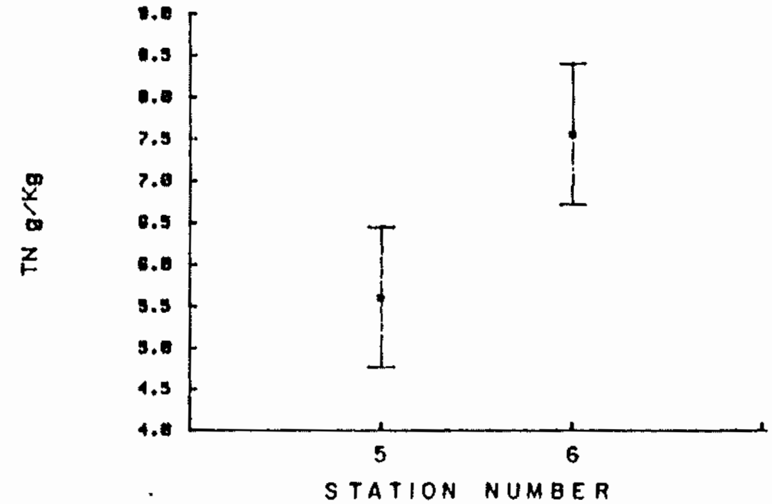


FIGURE 36 TUKEY'S MULTIPLE COMP SC FO 3OC Y KE SEDIMENTS - JUNE 19 1987



VOLATILE RESIDUES



TOTAL NITROGEN

FIGURE 3e TUKEY'S MULTIPLE COMPARISON FOR GOOSLY LAKE SEDIMENTS - JUNE 19, 1987

Table 6

Goosly Lake - Statistical Station Seperations
June 19, 1987

Parameter	Station	Seperation	Parameter	Station	Seperation
Aluminum	6	a	Sodium	6	a
	5	b		5	a
Barium	5	a	Phosphorus	6	a
	6	a		5	a
Calcium	5	a	Lead	6	a
	6	a		5	b
Cadmium	6	a	Silicon	6	a
	5	b		5	a
Chromium	5	a	Strontium	5	a
	6	b		6	a
Copper	6	a	Zinc	6	a
	5	b		5	b
Iron	5	a	SFR	5	a
	6	a		6	b
Magnesium	6	a	SVR	6	a
	5	b		5	b
Manganese	6	a	TN	6	a
	5	a		5	b

Note : The stations are ranked by the highest mean. The seperation is determined by the overlapping confidence intervals.

manganese, molybdenum, sodium, nickel, phosphorus, silicon, tin, titanium, strontium and vanadium.

The metal content of the sediments was greatest at station 5 for chromium as well as for fixed residue which may be from the influence of Buck Creek. Station 6 was significantly greater than station 5 for the following parameters: aluminum, cadmium, copper, magnesium, lead, zinc, total nitrogen and volatile residue.

b - Siltcheck

The results from the siltcheck station can be seen in Table 7.

No significant differences could be detected between the siltcheck sediments and stations 5 and 6, for the following metals: aluminum, beryllium, calcium, cadmium, cobalt, iron, sodium, nickel, phosphorus, silicon, strontium, titanium and vanadium. Barium, manganese, molybdenum, tin and volatile residues concentrations were significantly lower than the two lake stations. The siltcheck was higher than the two lake stations for copper and fixed residues. The siltcheck sediments were equal to station 6 concentrations but higher than station 5 for lead, zinc and total nitrogen.

The number of replicates of the siltcheck sediments was 3 and the lake samples was 4. The confidence limits are very sensitive to the number of replicates and a small sample size tends to increase the confidence interval. The difference in the number of samples between the siltcheck sediments and the lake sediments explains the reason why aluminum, cadmium and chromium are equal, when lake stations are compared together, differences occurs. An increased sampling of the sediments in the siltcheck would help us to better determine differences for these metals.

It appears that, except for removal of copper and fixed residues, the siltcheck site does not precipitate the heavy metals as well as Goosly Lake. It is well known that the organic materials have a high affinity to heavy metals and an increase of organics might improve the water quality coming from the siltcheck dam, however, it might also increase the

Table 7

Siltcheck dam sediments
May 21,1987

	SEDICP AL UG/G	SEDICP AS UG/G	SEDICP BA UG/G	SEDICP BE UG/G	SEDICP CA UG/G	SEDICP CO UG/G	SEDICP CD UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDICP MG UG/G	SEDICP MN UG/G	SEDICP MO UG/G
Repl.1	23300	83	434	0.8	8460	18.4	2.0	37.1	430	54200	7020	618	<.9
Repl.2	26800	196	436	0.9	8670	25.4	1.6	39.8	588	60200	7350	635	<.8
Repl.3	28000	94	432	0.9	8540	26.6	2.4	39.2	542	54200	7470	723	<.8
Average	26033	124	434	0.9	8557	23.5	2.0	38.7	520	56200	7280	659	--
S.D.	2442	62	2	0.1	106	4.4	0.4	1.4	81	3464	233	56	--

Siltcheck dam sediments
May 21, 1987

	SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SN UG/G	SEDICP SR UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G	SFR MG/KG	SVR MG/KG	TN MG/KG
Repl.1	370	42	2950	157	1280	<2	133	800	102	492	964000	36300	690
Repl.2	640	39	2950	142	1580	2	160	802	103	426	951000	49000	1100
Repl.3	610	40	2800	143	1260	<2	156	860	106	422	953000	46900	1100
Average	540	40	2900	147	1373	--	150	821	104	447	956000	44067	963
S.D.	148	2	87	8	179	--	15	34	2	39	7000	6808	237

availability of cadmium to aquatic organisms.

c - Ecological Risk Assessment

The following evaluation is heavily based on the sedimentological approach from Lars Hakanson (1980) developed in Sweden. This approach concerns only limnic systems and should be used as a crude model to evaluate the state of the environment.

REQUIREMENTS

Recent sediments were collected to compare them to preindustrial levels. The surface layer of the lake sediments provide the most valuable information; it will give the most recent accumulation of heavy metal, greatest interaction with surface water and benthic invertebrates, and also the greatest possibility of remobilisation.

The two approaches to obtain recent sediments relies on sediment traps and cores. For the cores the usual criteria is to subsample the core thin layers (< 1 cm). This approach was used by Hakanson, (1983), Davidson, (1985), Aggett, (1985), Johnson, (1986), Cornwell,(1986) and many other researchers. In our situation we choose to use sediment traps which allow the collection of large amounts of recent sediment. The construction of the traps were made according to the design of Hakanson (1976).

The location of the trap is important in order to obtain undisturbed sediment from the bottom of the lake. The sediment trap should be located in an area of accumulation. This analysis was performed prior to the survey with a bathymetric map provided by B. Wilkes (1987). The slope at different depths was calculated. The slope between the depth of 15 metres and 18 metres was 0.4 % while from 18 metres to the centre (23 metres) the slope was 3%. With this small slope the traps would be within depths in which resuspension was minimal. The slope between 3 and 6 metres was 15%; from 6 to 9 metres, it was 12% as well as between 9 and 12 metres.

Another approach taken was to evaluate the area of accumulation using a formula developed by L. Hakanson (1982). The formula described below shows the relationship between the erosion and transportation area versus the accumulation zones. The interest of this approach is that from easily obtainable limnological data, an appreciation of station location is possible. The formula is expressed as follows:

$$a_{E+T}=100-a_{A}=52.0[(\sqrt{a}/D_{max})-0.2](D_{max}/3*D)*\log(60.6D/\sqrt{a})+19.3$$

where a_{E+T} = The percentage of erosion and transportation

a_A = The percentage of accumulation

a = The area of the lake (Goosly Lake= 2.41 km^2)

D = Mean depth (Goosly Lake = 10.3 m)

D_{max} = Maximum depth (Goosly Lake = 23 m)

The percentage of accumulation area for Goosly Lake is approximately 68%, as derived from the formula. It was found using a bathymetric map produced by B. Wilkes that 52% of the bottom surface area lies below 9 metres (30 feet). This means that the location of the trap below this level would result in the collection of new material.

The sediment samples collected were almost liquid which reveals the very high water content. Further to this observation the settling of the sediments in imhoff cones did not indicated the presence of sands .

The replicability of the samples were good, as per the coefficient of variability (Table 8). This adds confidence in the result obtained by the traps as been representative of the bottom floor. However the sedimentological approach suggest that the samples (at least 5) should be evenly distributed over the accumulation area of the lake or any sub-basin, to make a proper estimate of the parameters mean values. The even distribution of the traps was not performed because the evaluation of the quality of the data was more important in this first trial.

Unfortunately the background levels were not addressed in details. Fragmentary data provided by Wilkes (1987) will however be utilised in a later section. The utilisation of a preindustrial reference

Table 8

Coefficient of variation (%) for Goosly lake sediments

Parameter	Station 5	Station 6
Aluminum	4.99	3.47
Barium	2.2	3.73
Calcium	13.88	5.34
Cadmium	28.4	6.3
Chromium	2.16	3.79
Copper	6.56	3.27
Iron	2.3	5.06
Magnesium	3	3.09
Manganese	8.09	29
Sodium	29.46	30.72
Phosphorus	5.16	5.36
Lead	3.6	17.07
Silicon	5.43	22.41
Strontium	13.23	4.14
Zinc	4.28	3.82
Fixed residues	0.51	0.17
Volatile residues	0.3	0.88
Total nitrogen	10.89	11.69

level, as established by Bowen (1966), provides useful information which can be adequate for the present approach. These levels are (ug/g dry solids): As = 15, Cd = 1.0, Cr = 90, Cu = 50, Hg = 0.25, Pb = 70, Zn = 175. This problem of background levels directly related to Goosly Lake will be addressed in future surveys.

CONTAMINATION FACTOR AND DEGREE OF SEDIMENT CONTAMINATION

The contamination factor is defined as the mean content of the substance in the lake divided by the preindustrial reference value for that substance (Hakanson 1980). The overall average for Goosly Lake (station 5 and 6) was: for arsenic below the detection limit (<8 ug/l), 3.5 ug/g Cd, 39.1 ug/g Cr, 116.2 ug/g Cu, 70.1 ug/g Pb, and 276.6 ug/g Zn. The contamination factor for Goosly Lake was:

As	0.3
Cd	3.5
Cr	0.4
Cu	2.3
Pb	1.0
Zn	1.6

The higher the contamination factor (Cf^i) the higher the contamination. The following description indicates the relative contamination of each substance into the lake.

Cf^i <1	low contamination
$1 < Cf^i < 3$	moderate contamination
$3 < Cf^i < 6$	considerable contamination
6	very high contamination

The degree of contamination is the sum of all contamination factors. For Goosly Lake this sum was 9.1. Since only six substances were used instead of the eight proposed by Hakanson, the following terminology to describe the degree of contamination (Dc) has been used :

Dc <6	low contamination
6 < Dc < 12	moderate contamination
12 < Dc < 24	considerable contamination
Dc > 24	very high contamination

SEDIMENTOLOGICAL TOXICOLOGICAL FACTORS (St^i)

The toxicity factor is included here to take into consideration the different toxicity of a substance to the environment. The toxicity of a metal is seen to be inversely proportional to the abundance of this element in the nature. The sequence in nature, taken from relative abundance in rocks, soils, fresh water, plants, and animals, showed the following: Zn < Cu < Pb < Cr < As < Cd < Hg (Hakanson, 1980).

The presence of these metals in sediments also depend on the ability of the element to sink to the bottom of the lake. By taking into account the toxicity, the sink effect of the various substances and by normalizing the data with a square root of the value to account for different order of magnitude, the sedimentological toxicological factor (St^i) for the six substances are the following (Hakanson, 1980):

Cd	30
As	10
Pb	5
Cu	5
Cr	2
Zn	1

The sedimentological toxicological factors and the lake sensitivity are used in developing the lake toxic response.

LAKE SENSITIVITY

The sensitivity of toxic substances varies from lake to lake and the appreciation of this sensitivity may be utilised to evaluate the risk of the release of these toxic subtances to the environment. The trophic status of a lake can be determined from the sediment by using the loss on ignition (IG) and the nitrogen content. A bioproduction level (BPI) can be determined as the N-content on the regression line for IG=10% (Hakanson 1984). The toxic response of all metals, except for arsenic which show a special pattern in water and sediment, appear to be related to the degree of bioproduction (Hakanson 1980), i.e. the negative effects tend to increase with decreasing bioproduction. The toxic response value (Tr^i) has been related to an intermediate bioproduction (BPI) value of 5 which is characteristic for moderately eutrophic lakes. This value (BPI = 5.0) is looked upon as a reference value for the evaluation of the toxic response as the lake bioproduction index changes. The normative factor chosen is therefore $\sqrt{5}/\sqrt{BPI}$ (Hakanson, 1980). Based on this principle and the previously discussed sedimentological toxic factor, the toxic response (Tr^i) for all the metals except for arsenic is expected to be:

Substance	St^i	Norm	Tr^i
Cd	30	$\sqrt{5}/\sqrt{BPI}$	$30*\sqrt{5}/\sqrt{BPI}$
As	10	-	10
Pb	5	$\sqrt{5}/\sqrt{BPI}$	$5*\sqrt{5}/\sqrt{BPI}$
Cu	5	$\sqrt{5}/\sqrt{BPI}$	$5*\sqrt{5}/\sqrt{BPI}$
Cr	2	$\sqrt{5}/\sqrt{BPI}$	$2*\sqrt{5}/\sqrt{BPI}$
Zn	1	$\sqrt{5}/\sqrt{BPI}$	$1*\sqrt{5}/\sqrt{BPI}$

Extra analysis were performed on the Goosly Lake sediments in order to provide a better appreciation of the organic fraction of the sediments. These samples were submitted at the same time as the other replicates and represent two samples from station 6 and one from station 5. The following table gives the result of these analysis:

TABLE 9 SEDIMENT TOTAL NITROGEN AND VOLATILE RESIDUE

Replicate	TN mg/Kg	SVR mg/Kg	SFR mg/Kg
Repl.1	7200	164,000	836,000
Repl.2	6900	171,000	829,000
Repl.3	5800	149,000	851,000

The regression of the nitrogen content to the loss on ignition of organic contents for all of Goosly Lake data (N= 9) was: N= 0.0543 IG - 3.46. From this regression the bioproduction index (BPI) in Goosly lake was 1.97.

RISK FACTOR AND RISK INDEX

The risk factor (Er^i) of a certain toxic chemical is equal to the contamination factor multiplied to the toxic response of that substance.

Substance :	Tr^i		Cf^i	=	Er^i
Zn	1.59	*	1.58	=	2.52
Cr	3.18	*	0.4	=	1.28
Cu	7.97	*	2.32	=	18.48
Pb	7.97	*	1.0	=	7.97
As	10.00	*	0.3	=	3.00
Cd	47.79	*	3.5	=	167.28

The relative evaluation of the risk factor can be appreciate as following:

$Er^i < 40$	low potential ecological risk
$40 < Er^i < 80$	moderate potential ecological risk
$80 < Er^i < 160$	considerable potential ecological risk
$160 < Er^i < 320$	high potential ecological risk
$Er^i > 320$	very high ecological risk

The potential ecological risk index (RI) can be appreciate in the same way as the degree of contamination by adding all the risk factors. This risk index for Goosly Lake was 200.5. This following terminology for the six parameters used allows an appreciation of the potential ecological risk for Goosly Lake.

RI < 115	low ecological risk for the lake
115 < RI < 230	moderate ecological risk for the lake
230 < RI < 460	considerable ecological risk for the lake
RI > 460	very high ecological risk for the lake

GOOSLY LAKE ASSESSMENT IN LIGHT OF THE RISK INDEX

It should be stressed that the above evaluation is basically a tool to diagnose lakes and sub-basins for water pollution control purposes. There are few methodological refinements that can be obtain from future sampling surveys. The use of preindustrial metal levels in the sediments determined from the area and taking into consideration the specific geological features should help to evaluate the contamination factor with better accuracy. Metal concentrations in lake sediments determined for British Columbia (McKean, C.J.P. 1985 quoted in Wilkes 1987) showed, on the dry weight basis, that the average level from 202 lakes was: 40.4 ug/g As; 1 ug/g; 36 ug/g Cr; 42 ug/g Cu; 42 ug/g Pb; and 90 ug/g Zn. These reference levels are usually lower than the one derived from sedimentary rocks except for cadmium where the level is the same and arsenic which is about 2.5 times higher. There was no range of metal concentration with these data to express the variability of the B.C. sediments. One sediment sample collection in Goosly Lake from a core by Wilkes, 10 to 20 cm below the sediment surface was used here for comparison purposes. The contamination factor (Cf^{i}) for the metals calculated with these reference numbers are:

Parameter	Provincial Mean Cf^i	Er^i	Goosly Lake Sediment (Wilkes 1987) Cf^i	Er^i
As	0.12	1.25	0.21	2.16
Cd	3.5	167.28	>3.5	>167.28
Cr	1.08	3.43	1.5	4.77
Cu	2.76	21.99	2.15	17.13
Pb	1.66	13.23	2.5	19.92
Zn	3.07	4.88	2.6	4.21

This potential risk index sum of 212.06 for Goosly Lake using the provincial mean and 215.47 using Goosly Lake data. These levels are not increased significantly from the previous risk value of 200.5.

A greater distribution of the sampling over the whole area of accumulation of the lake would help to get a better mean value for the toxic substances and also for the evaluation of the bioproduction index. This should be addressed in the next survey as well as the determination of the site specific sediment reference levels. The analysis of silver and mercury in the sediments should be performed. These refinements may change substantially the risk index for Goosly Lake but are unlikely to reclassify the lake to a lower ecological risk.

The main effect of the cadmium on the ecological risk is obvious. Cadmium threshold for some zooplankton populations (CCREM, 1987) is at the detection limit in water samples however the level found in the sediments for this metal is above the detection limit. Different groups of zooplankton populations have different sensitivity to cadmium releases. Amongst the most sensitives are the cladocerans followed by calanoids copepods and with cyclopoid copepods the most resistant (Laurence and Holoka 1987).

The zooplankton collected from May 1983 to September 1985 (Wilkes 1987) showed that the dominant species are copepods and more specifically the cyclopoids. However, no baseline surveys were performed on the lake prior to the operation and it is not possible for the moment to determine the pre-mining zooplankton community structure in Goosly Lake.

The contamination factors (Cf^i) for Goosly Lake showed the introduction of heavy metals to the system. The toxic reponse (Tr^i) indicates the sensitivity of the lake to further cadmium input.

Information on the bioavailability of cadmium in Goosly Lake should be generated. There is presently no data that would indicate whether the cadmium (and other heavy metals) would become more available from the sediments with time. Several approaches can be taken to assess the impact of heavy metal accumulation in the lake sediments to the aquatic environment. Sediment fractioning should give an appreciation of the metal mobility into the environment. Reproduction tests with Daphnia magna on a sediment elutriation may give an insight on the effect the bottom sediments may have on the zooplankton populations. Benthic invertebrates, due to their close relationship with the sediments, should be good indicators of the metal influence on the biota. Metal concentrations in fish tissues in Gooly Lake should give an estimate of the metal bioavailability to the aquatic resource.

2 - BUCK CREEK SEDIMENT

a - Sediment Fraction Size

The collection of sediments was not uniform for all the stations visited. At station 7 the syringe method was used (Derksen 1985), while the other sediments were collected using the plastic corer. The analysis showed an anomaly at station 7 where the metal content in the sediments were often higher than the upstream or downstream stations. This discrepency was suspected to be generated by the selectivity of the sediment fraction size using the syringe method where only fine sediments are collected (largest opening 2.0mm). In order to avoid a size fraction effect, the sediments were reanalysed on the fraction size less than 63 um. This procedure has been found to be the most appropriate method to described the concentration of heavy metals in sediments (Hakanson 1983). The sediments analysed using the <150 um fraction size are presented in Table 10 and the sediments reanalysed with the fraction size less than 63 um are presented in Table 11.

Table 10

Buck creek sediments (<150 um)
June 20, 1987

Station		SEDICP AL UG/G	SEDICP AS UG/G	SEDICP BA UG/G	SEDICP BE UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDICP CO UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDICP MG UG/G	SEDICP MN UG/G	SEDICP MO UG/G
	Repl.1	12900	<8	215	0.2	6710	1.0	18.1	43.7	20.3	36100	5790	876	10.2
1	Repl.2	13400	<8	253	0.2	7270	<.3	12.1	42.6	22.7	34300	5830	1730	7.7
	Repl.3	13200	<8	237	0.3	7380	0.4	15.6	45.8	21.4	37200	5910	1130	6.0
	Repl.4	13500	<8	212	0.2	6290	1.0	14.6	46.0	20.1	36600	5940	424	6.4
	Average	13250	---	229	0.2	6913	0.8	15.1	44.5	21.1	36050	5868	1040	7.6
	S.D.	265	---	19	0.0	508	0.3	2.5	1.7	1.2	1250	69	545	1.9
	Repl.1	17400	<8	252	0.3	7400	2.8	22.9	56.0	63.7	52000	6910	1390	10.4
3	Repl.2	14100	<8	202	0.2	7720	2.0	19.1	64.7	52.2	46900	6430	902	8.7
	Repl.3	14500	<8	190	0.2	7340	2.0	14.8	49.6	56.9	39200	6390	986	6.3
	Repl.4	13700	<8	186	0.3	7920	1.6	18.7	67.5	52.5	48300	6490	984	10.4
	Average	14925	---	208	0.3	7595	2.1	18.9	59.5	56.3	46600	6555	1066	9.0
	S.D.	1682	---	30	0.1	273	0.5	3.3	8.2	5.4	5382	240	220	1.9
	Repl.1	14900	<8	218	0.3	7290	1.3	17.5	38.6	37.9	38800	6680	448	11.1
4	Repl.2	14200	<8	222	0.3	7760	0.3	11.1	38.9	35.7	41000	6170	701	9.7
	Repl.3	13500	<8	190	0.3	8190	<.3	16.3	45.6	33.2	42400	6480	643	11.9
	Repl.4	14700	<9	192	0.2	7590	1.9	19.0	41.7	39.0	37800	6250	691	7.6
	Average	14325	---	206	0.3	7708	1.2	16.0	41.2	36.5	40000	6395	621	10.1
	S.D.	624	---	17	0.0	376	0.8	3.4	3.2	2.6	2085	231	118	1.9
	Repl.1	16500	<8	243	0.5	9680	2.1	17.8	73.1	38.7	33000	8580	608	6.4
7	Repl.2	16700	<9	228	0.5	9670	1.5	13.3	96.6	37.3	37600	8330	541	6.3
	Repl.3	17400	<8	254	0.6	10100	1.2	14.1	78.7	43.6	37000	8240	531	8.7
	Repl.4	25100	<20	335	0.7	13100	2.2	25.0	88.0	85.0	42700	9380	998	15.0
	Average	18925	---	265	0.6	10638	1.8	17.6	84.1	51.2	37575	8633	670	9.1
	S.D.	4135	---	48	0.1	1654	0.5	5.3	10.4	22.7	3980	519	222	4.1
	Repl.1	15300	<8	275	0.4	6910	2.2	21.8	40.8	23.5	32500	6980	916	5.8
8	Repl.2	12300	<8	232	0.2	6460	2.2	18.6	44.7	18.0	38000	6920	858	5.9
	Repl.3	15400	<8	282	0.3	6660	1.9	17.4	36.9	23.1	31300	7060	899	5.1
	Repl.4	15300	<8	283	0.3	6620	1.7	15.1	38.0	22.4	31100	6920	874	3.3
	Average	14575	---	268	0.3	6663	2.0	18.2	40.1	21.8	33225	6970	887	5.0
	S.D.	1517	---	24	0.1	186	0.2	2.8	3.5	2.5	3243	66	26	1.2

Table 10 (cont.)

Buck creek sediments (<150 um)
June 20, 1987

Station		SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SN UG/G	SEDICP SR UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G	SFR MG/KG	SVR MG/KG
	Repl.1	300	26	1700	21	470	8	79.8	1150	108.0	89.0	968000	32100
1	Repl.2	250	28	1600	15	550	8	96.0	1020	94.4	85.9	956000	44500
	Repl.3	260	28	1710	19	440	7	88.3	1140	107.0	89.4	960000	40000
	Repl.4	300	26	1700	22	400	12	75.6	1240	117.0	108.0	966000	33900
	Average	278	27	1678	19	465	9	84.9	1138	106.6	93.1	962500	37625
	S.D.	26	1	52	3	64	2	9.1	90	9.3	10.1	5508	5695
	Repl.1	350	33	2130	37	540	7	110.0	1310	155.0	170.0	951000	48900
3	Repl.2	350	32	2460	32	270	9	94.2	1480	158.0	143.0	972000	28200
	Repl.3	350	30	2260	28	540	4	93.3	1110	123.0	142.0	971000	28800
	Repl.4	300	35	2380	30	500	9	91.7	1370	163.0	144.0	964000	36100
	Average	338	33	2308	32	463	7	97.3	1318	149.8	149.8	964500	35500
	S.D.	25	2	144	4	130	2	8.5	155	18.1	13.5	9678	9628
	Repl.1	330	26	2230	27	590	10	100.0	1020	98.1	140.0	954000	45900
4	Repl.2	280	26	2150	22	540	7	109.0	1030	99.8	154.0	951000	48700
	Repl.3	250	29	2290	25	540	10	103.0	1140	113.0	161.0	961000	39200
	Repl.4	350	27	2210	29	510	8	107.0	1090	102.0	151.0	958000	42100
	Average	303	27	2220	26	545	9	104.8	1070	103.2	151.5	956000	43975
	S.D.	46	1	58	3	33	2	4.0	56	6.7	8.7	4397	4177
	Repl.1	580	42	2640	23	380	15	130.0	2200	101.0	184.0	951000	49300
7	Repl.2	540	49	2530	19	360	13	114.0	2180	120.0	216.0	945000	54800
	Repl.3	460	46	2400	18	400	16	120.0	2220	120.0	190.0	924000	75600
	Repl.4	420	55	2620	40	1000	19	163.0	2080	143.0	344.0	---	---
	Average	500	48	2548	25	535	16	131.8	2170	121.0	233.5	940000	59900
	S.D.	73	5	109	10	310	3	21.9	62	17.2	75.0	14177	13872
	Repl.1	480	25	1430	28	400	10	108.0	1410	96.9	122.0	961000	38600
8	Repl.2	430	25	1530	28	410	9	83.8	1330	119.0	133.0	982000	18000
	Repl.3	500	22	1430	24	500	10	109.0	1290	91.5	123.0	961000	39100
	Repl.4	490	24	1380	22	480	9	111.0	1310	90.3	122.0	962000	38100
	Average	475	24	1443	26	448	10	103.0	1335	99.4	125.0	966500	33450
	S.D.	31	1	63	3	50	1	12.8	53	13.4	5.4	10344	10308

Table 11

Buck creek sediments (<63 um)
June 20, 1987

Station		SEDICP AL UG/G	SEDICP AS UG/G	SEDICP BA UG/G	SEDICP BE UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDICP CO UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDICP MG UG/G	SEDICP MN UG/G	SEDICP MO UG/G
	Repl.1	16700	<8	297	0.7	8440	2.0	23.5	49.9	31.0	41300	7260	1150	<.8
1	Repl.2	17800	<9	300	0.7	8170	2.0	17.0	54.4	29.0	38800	6890	1980	<.9
	Repl.3	17800	<9	302	0.7	8150	1.0	12.0	53.9	28.7	40100	7230	1270	<.9
	Repl.4	18500	<8	279	0.8	7660	2.0	15.0	52.0	26.1	41500	7430	507	<.8
	Average	17700	---	295	0.7	8105	1.8	16.9	52.6	28.7	40425	7203	1227	---
	S.D.	744	---	11	0.0	325	0.5	4.9	2.0	2.0	1247	226	604	---
	Repl.1	19800	23	304	1.0	8680	1.9	17.0	47.7	68.0	51400	7320	1690	<.8
3	Repl.2	16500	29	252	0.8	8780	2.1	20.7	58.6	66.3	47100	7410	1230	<.9
	Repl.3	16300	10	243	0.8	8630	1.9	<.9	57.2	69.9	43100	6950	1310	<.9
	Repl.4	17900	<8	256	0.9	9230	2.4	30.4	55.5	69.0	48100	7880	1290	1.0
	Average	17625	21	264	0.9	8830	2.1	22.7	54.8	68.3	47425	7390	1380	---
	S.D.	1615	10	27	0.1	274	0.2	6.9	4.9	1.5	3419	383	209	---
	Repl.1	18200	<9	267	0.8	8700	2.2	14.0	44.0	48.2	46800	8090	527	<.9
4	Repl.2	18700	17	315	0.8	8990	1.9	15.0	45.1	47.9	49600	7580	810	<.8
	Repl.3	17300	<8	231	0.8	8560	2.1	22.6	44.5	42.1	46400	7950	642	<.8
	Repl.4	16600	<9	221	0.8	8690	2.0	9.9	48.2	43.9	43700	6890	774	<.9
	Average	17700	17	259	0.8	8735	2.1	15.4	45.5	45.5	46625	7628	688	---
	S.D.	935	---	43	0.0	182	0.1	5.3	1.9	3.0	2414	537	130	---
	Repl.1	14700	<8	218	0.7	9320	1.0	<.8	73.1	32.6	30200	7290	503	<.8
7	Repl.2	13900	<8	195	0.7	8410	1.0	1.0	89.2	30.9	33400	6970	426	<.8
	Repl.3	16300	<8	235	0.8	8960	1.9	4.0	73.9	39.1	32600	7310	401	<.8
	Repl.4	---	---	---	---	---	---	---	---	---	---	---	---	---
	Average	14967	---	216	0.7	8897	1.3	2.5	78.7	34.2	32067	7190	443	---
	S.D.	1222	---	20	0.1	458	0.5	2.1	9.1	4.3	1665	191	53	---
	Repl.1	16400	<8	321	0.8	8260	1.0	8.6	55.1	22.0	36300	6860	1080	<.8
8	Repl.2	---	---	---	---	---	---	---	---	---	---	---	---	---
	Repl.3	14900	<8	300	0.8	7740	1.0	11.0	50.5	21.0	34400	6600	1020	<.8
	Repl.4	15300	<8	309	0.8	7880	0.6	2.5	53.7	20.3	35000	6610	985	<.8
	Average	15533	---	310	0.8	7960	0.9	7.4	53.1	21.1	35233	6690	1028	---
	S.D.	777	---	11	0.0	269	0.2	4.4	2.4	0.9	971	147	48	---

Table 11

Buck creek sediments (<63 um)
June 20, 1987

Station		SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SN UG/G	SEDICP SR UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G
	Repl.1	<20	31	2040	29	1100	9	90.3	1140	106.0	106.0
1	Repl.2	<20	29	1800	19	1000	<2	104.0	1280	102.0	87.4
	Repl.3	<20	33	1920	22	980	<2	96.8	1250	106.0	91.7
	Repl.4	<20	32	2010	28	1000	3	84.4	1270	117.0	122.0
	Average	---	31	1943	25	1020	6	93.9	1235	107.8	101.8
	S.D.	---	2	108	5	54	4	8.4	65	6.4	15.7
	Repl.1	<20	35	2160	31	1100	<2	122.0	1190	121.0	167.0
3	Repl.2	<20	34	2390	37	930	10	107.0	1280	126.0	148.0
	Repl.3	<20	34	2290	40	890	2	102.0	1260	117.0	152.0
	Repl.4	<20	36	2490	40	920	<2	110.0	1330	129.0	148.0
	Average	---	35	2333	37	960	6	110.3	1265	123.3	153.8
	S.D.	---	1	141	4	95	6	8.5	58	5.3	9.0
	Repl.1	<20	32	2680	31	970	4	108.0	1210	106.0	157.0
4	Repl.2	<20	31	2500	30	890	<2	126.0	1220	107.0	168.0
	Repl.3	<20	32	2510	30	880	<2	108.0	1200	108.0	168.0
	Repl.4	<20	28	2370	53	850	<2	112.0	1200	102.0	156.0
	Average	---	31	2515	36	898	4	113.5	1208	105.8	162.3
	S.D.	---	2	127	11	51	---	8.5	10	2.6	6.7
	Repl.1	<20	39	2450	27	700	5	104.0	1830	84.3	155.0
7	Repl.2	<20	40	2270	150	750	10	87.2	1810	101.0	169.0
	Repl.3	<20	37	2210	33	780	<2	96.3	1850	101.0	160.0
	Repl.4	---	---	---	---	---	---	---	---	---	---
	Average	---	39	2310	70	743	8	95.8	1830	95.4	161.3
	S.D.	---	2	125	69	40	4	8.4	20	9.6	7.1
	Repl.1	<20	24	1600	23	800	<2	106.0	1580	103.0	124.0
8	Repl.2	---	---	---	---	---	---	---	---	---	---
	Repl.3	<20	25	1540	23	840	10	99.8	1470	96.8	121.0
	Repl.4	<20	23	1560	34	780	6	101.0	1510	98.8	124.0
	Average	---	24	1567	27	807	8	102.3	1520	99.5	123.0
	S.D.	---	1	31	6	31	3	3.3	56	3.2	1.7

A paired comparison between the two method were performed on the results to determine the effect of using different fraction size on the metal content. The metal content was significantly higher ($p < 0.05$) in the fraction size less than 63 um for all the metals except for chromium, lead, nickel, strontium, zinc and cadmium (Table 12).

b - Station Differences

The evaluation of differences in metal content at the various stations were performed by using the data generated by the small fraction size (<63um). The fixed residues, volatile residues and total nitrogen analysis were performed on the <150 um fraction size. A graphical statistical evaluation can be found in Figure 4a to 4e and the statistical separation on Table 13.

The aluminum concentration in the sediment did not increase significantly downstream of Bessemer Creek, but decreased at station 7 downstream of Goosly Lake.

The calcium level increased downstream of Bessemer Creek with a level similar to the control station at station 8. This increase is mainly due to the addition of lime to the mine effluent for water quality control purposes.

There was no significant increase of the cadmium content downstream of Bessemer Creek. The levels start to decrease downstream of Goosly Lake and are significantly lower than the control station at station 8. The cadmium level at the control station averaged 1.8 ug/kg. This may indicate that the upstream station contributes to the increase of the cadmium content in the sediments of Goosly Lake. The establishment of a baseline level for Goosly Lake is critical for the evaluation of the contamination factors.

The chromium and nickel concentrations in the sediments were significantly higher at station 7 than any other stations. The significance of these results are unknown.

Table 12: Paired Comparisons Between Buck Creek Sediment <150 um and <63 um

Obs	Variable	Mean	Std Error	T	PROB>|T|
18	Aluminium	2055.56	569.50	3.61	0.0032
	Calcium	819.44	204.28	4.01	0.0009
	Cadmium	0.06	0.23	0.27	0.7884
	Chromium	3.43	1.98	1.73	0.1016
	Copper	5.10	1.72	2.97	0.0086
	Iron	2594.44	899.56	2.89	0.0102
	Magnesium	507.78	237.27	2.14	0.0471
	Manganese	110.61	10.99	2.70	0.0152
	Nickel	1.17	1.05	1.11	0.2841
	Phosphorus	120.00	46.71	2.57	0.0199
	Lead	13.28	7.12	1.87	0.0795
	Silicon	430.56	27.11	15.88	0.0001
	Tin	-3.44	1.37	-2.52	0.0357
	Strontium	1.38	3.41	0.41	0.6899
	Zinc	-20.79	52.92	-0.39	0.6993

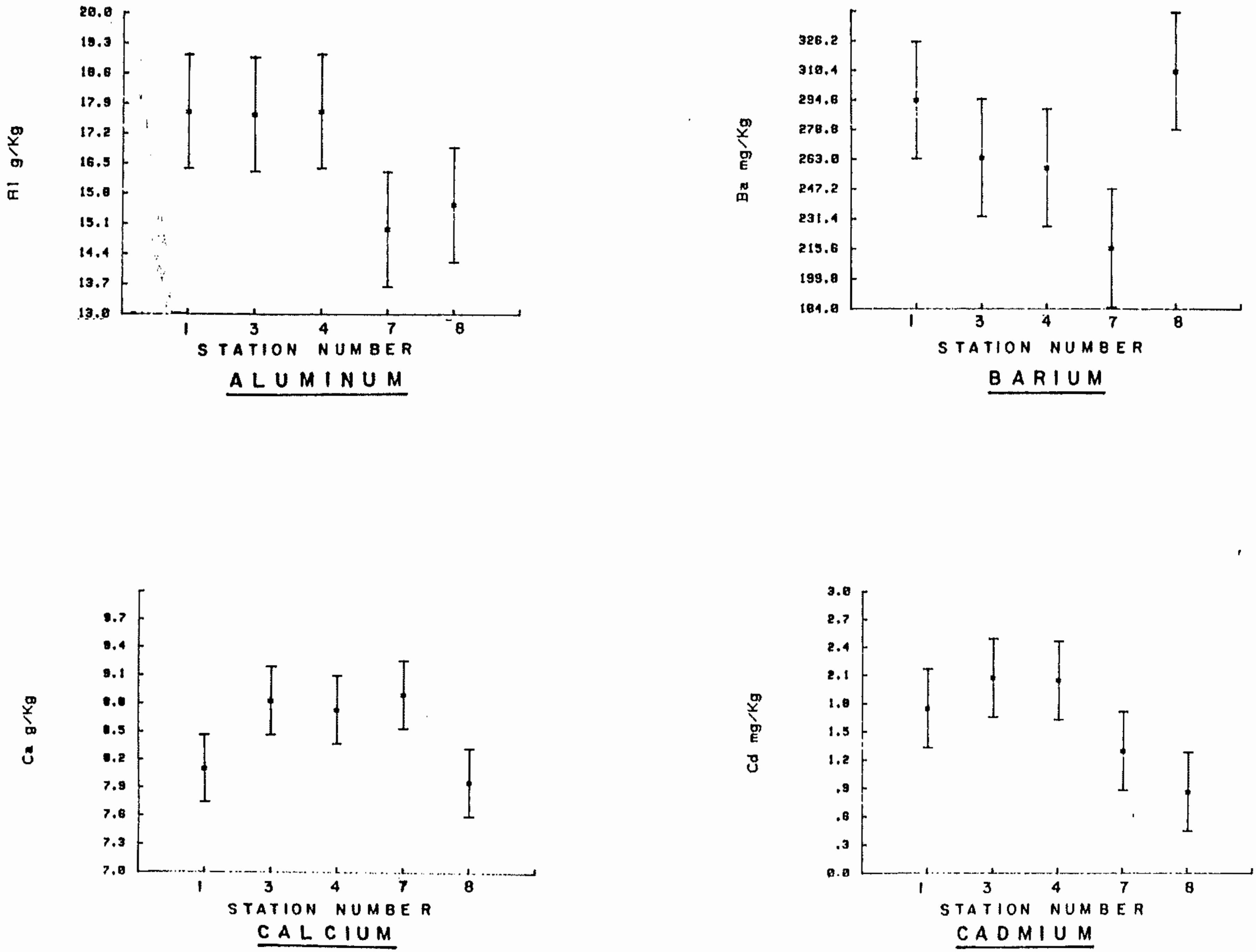


FIGURE 4a TUKEY'S MULTIPLE COMPARISON FOR BUCK CREEK SEDIMENTS - JUNE 20, 1987

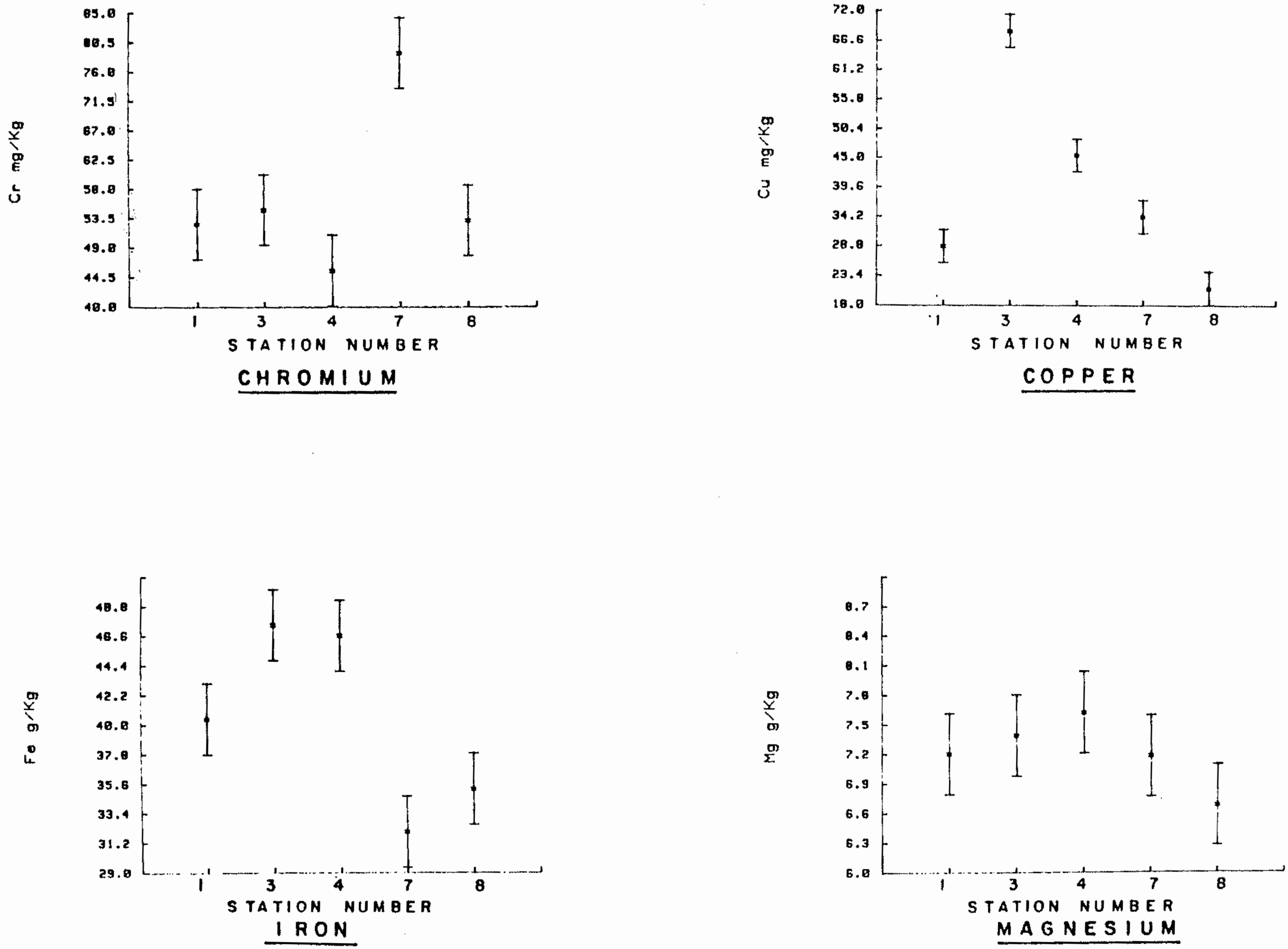


FIGURE 4b TUKEY'S MULTIPLE COMPARISON FOR BUCK CREEK SEDIMENT . . IE 19

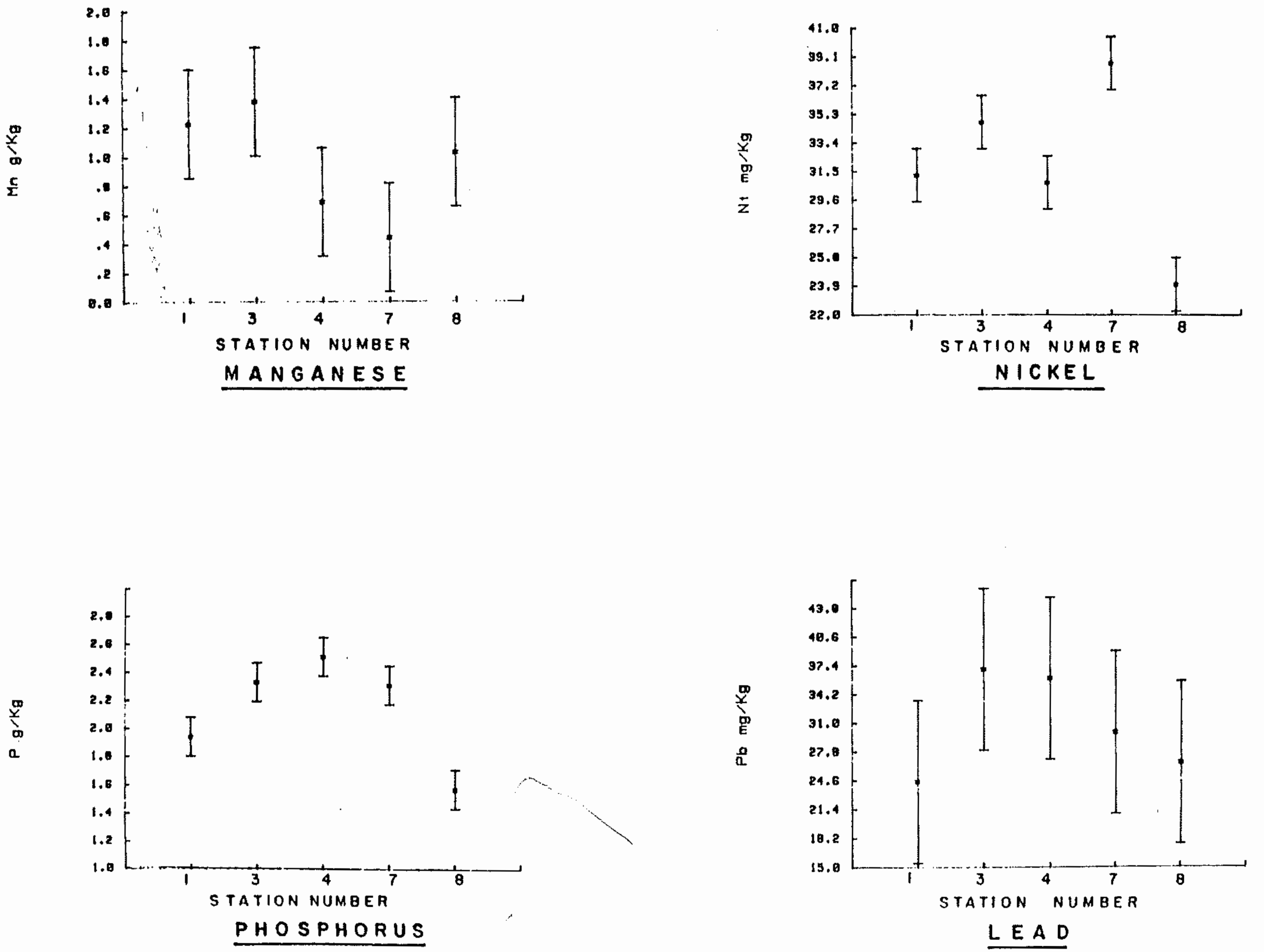


FIGURE 4c TUKEY'S MULTIPLE COMPARISON FOR BUCK CREEK SEDIMENTS - JUNE 20, 1987

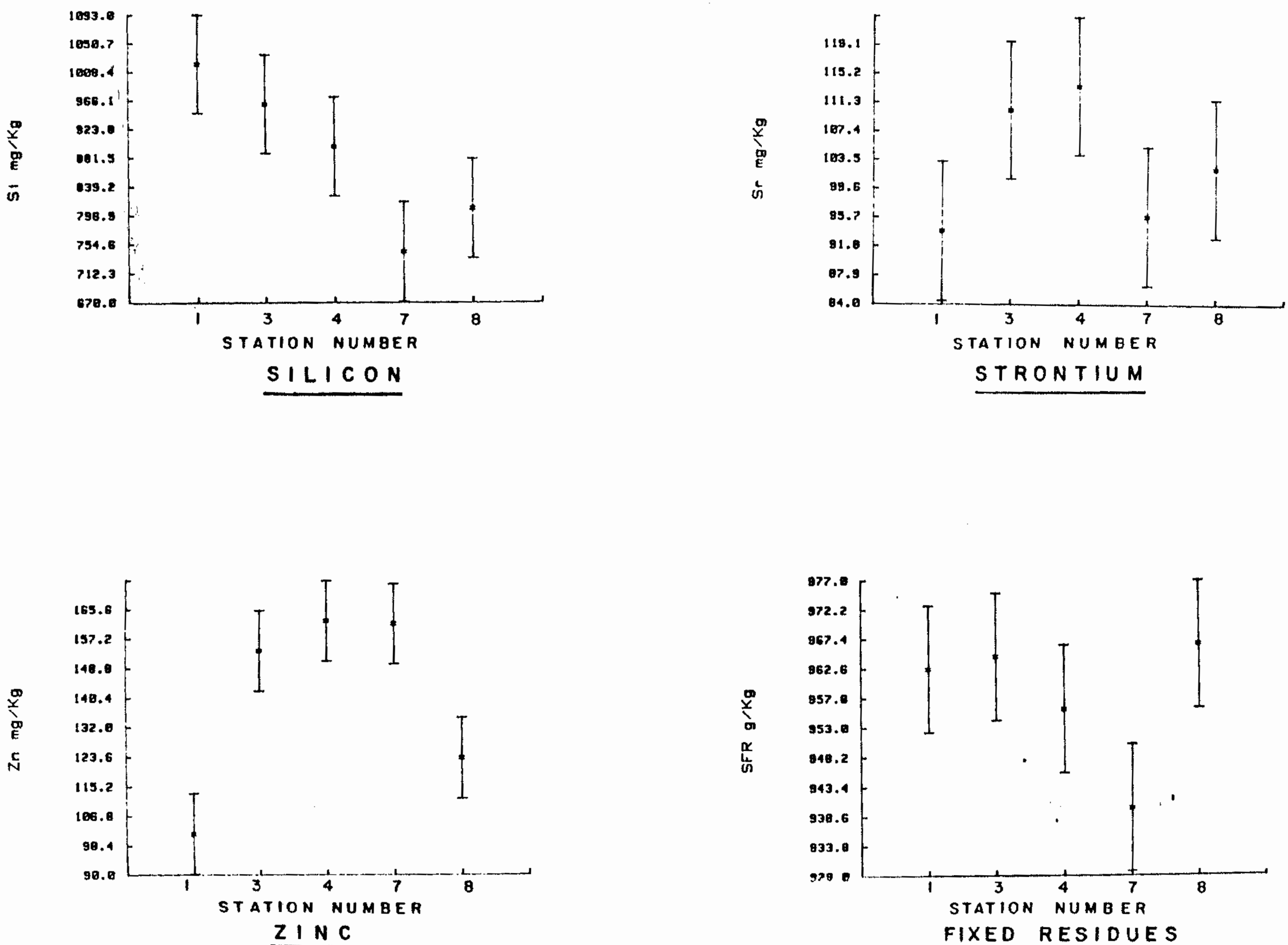
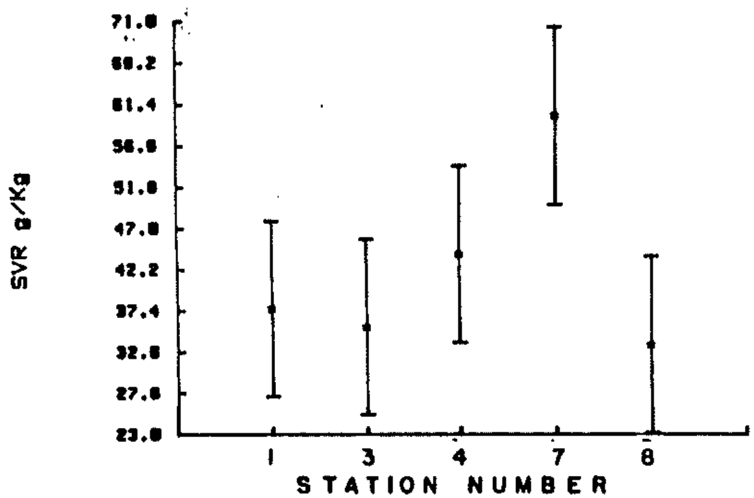
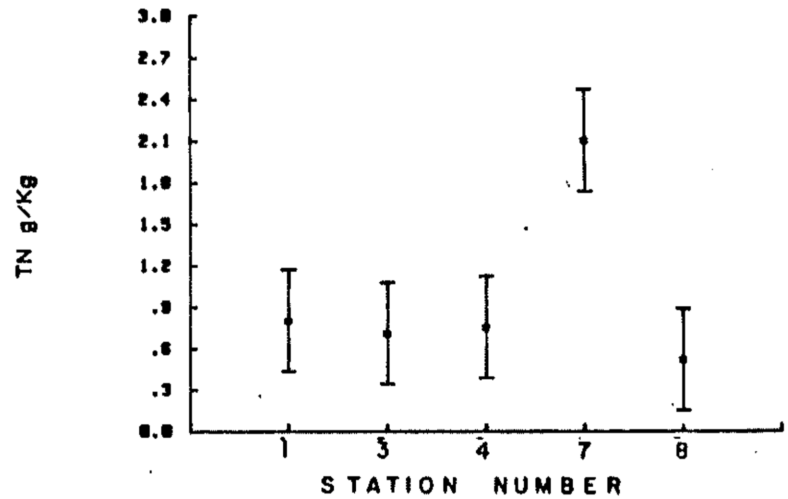


FIGURE 4a [illegible]UKEY'S MULTIPLE COMPARISON [illegible]OR [illegible]CK [illegible]RE[illegible] SE[illegible]ME[illegible]S [illegible]UN[illegible] 20, [illegible]987



VOLATILE RESIDUES



TOTAL NITROGEN

FIGURE 4e TUKEY'S MULTIPLE COMPARISON FOR BUCK CREEK SEDIMENTS - JUNE 20, 1987

Table 13

Buck Creek (< 63 um) - Statistical Station Separations
June 20, 1987

Parameter	Station	Separation	Parameter	Station	Separation	Parameter	Station	Separation
Aluminum	1	a	Iron	3	a	Silicon	1	a
	3	a		4	a		3	a
	4	a		1	b		4	b
	8	ab		8	bc		8	bc
	7	b		7	c		7	c
Barium	8	a	Magnesium	4	a	Strontium	4	a
	1	a		3	ab		3	ab
	3	ab		1	ab		8	ab
	4	ab		7	ab		7	ab
	7	b		8	b		1	b
Calcium	7	a	Manganese	3	a	Zinc	4	a
	3	a		1	a		7	a
	4	ab		8	ab		3	a
	1	bc		4	ab		8	b
	8	c		7	b		1	b
Cadmium	3	a	Nickel	7	a	SFR	8	a
	4	a		3	b		3	a
	1	a		1	bc		1	a
	7	ab		4	c		4	ab
	8	b		8	d		7	b
Chromium	7	a	Phosphorus	4	a	SVR	7	a
	3	b		3	a		4	ab
	8	b		7	a		1	b
	1	b		1	b		3	b
	4	b		8	c		8	b
Copper	3	a	Lead	3	a	TN	7	a
	4	b		4	a		1	b
	7	c		7	a		4	b
	1	c		8	a		3	b
	8	d		1	a		8	b

Note : The stations are ranked by the highest mean. The separation is determined by the overlapping confidence intervals.

The copper content was significantly increased downstream of Bessemer Creek and decreased significantly at each stations downstream where it was lower than the control station at station 8.

The iron, magnesium, phophorus and strontium sediment contents were increased downstream of Bessemer Creek but reduced downstream of Goosly Lake.

No significant differences were found in the Buck Creek sediments for lead due to the great variability of the results.

A significant increase of the zinc concentrations in the sediments downstream of Bessemer Creek was found with no decrease downstream of Goosly Lake. Station 8 was significantly lower than the station 3, 4 and 7.

The fixed residues level were significantly lower at station 7 after sedimentation in Goosly Lake, and increased to a similar level as the control station at station 8. The volatile residues content were higher downstream of Goosly Lake but decreased to a similar level at station 8. The same pattern was shown for the total nitrogen sediment content.

5.0 CONCLUSION

The water quality of Goosly Lake showed a steady increase in sulphate in the bottom of the lake and a tendency to have lower alkalinity compared to previous surveys. The buffering capacity is still high but the long-term implication of this decrease has still to be resolved.

The station in the deep part of the lake tends to accumulate higher metal values in the sediment for aluminum, cadmium, copper and zinc, when compared to the station closer to Buck Creek inlet. Based on pre-industrial sediment levels, province-wide average and preliminary baseline sediment in Goosly Lake, the contamination factor varies between 2.15 to 2.76 for copper; 1.0 to 2.5 for lead and 1.6 to 3.07 for zinc. The cadmium contamination factor was consistently 3.5 using three different sources of sediment reference material. The toxicity of cadmium is known to be an order of magnitude higher than the other metals and the next question is to address the bioavailability and toxicity of increased cadmium in Goosly Lake sediment. Following by positive response to the first question, the biological significance on Goosly Lake populations of such effect would have to be answered.

The siltcheck pond sediments were effective in removing only copper from the mine effluent. All the other metals were not significantly different from Goosly Lake.

Buck Creek sediments were highly variable. Metal analysis on different size fractions contributed to the variability. It is suggested that the fraction <63 um be used for the analysis of sediments. Only copper was significantly reduced downstream of the mine discharge.

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