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BABINE LAKE MONITORING
- June 19-22, 1990 -

REGIONAL DATA REPORT: DR 92-10

by

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1.0 INTRODUCTION

Noranda Mines Limited started operation of Bell Mine on the Newman Peninsula area of Babine Lake in 1972 (Figure 1). The mine stopped operations in 1982 and resumed in 1985. A previous report was produced in 1985 to address the mine discharges during the close-out period (Godin et al., 1985). The present report is intended to address the state of the environment in Babine Lake in light of a report sponsored by the company in 1988 (Hatfield, 1989). Various major sub-basins of the lake close to the mine were surveyed, supplementing information provided by the company. Work included examination of benthic invertebrates, surface sediment chemistry, and sediment cores. In addition, sediment sequential extractions and sediment bioassays were performed (Table 1).

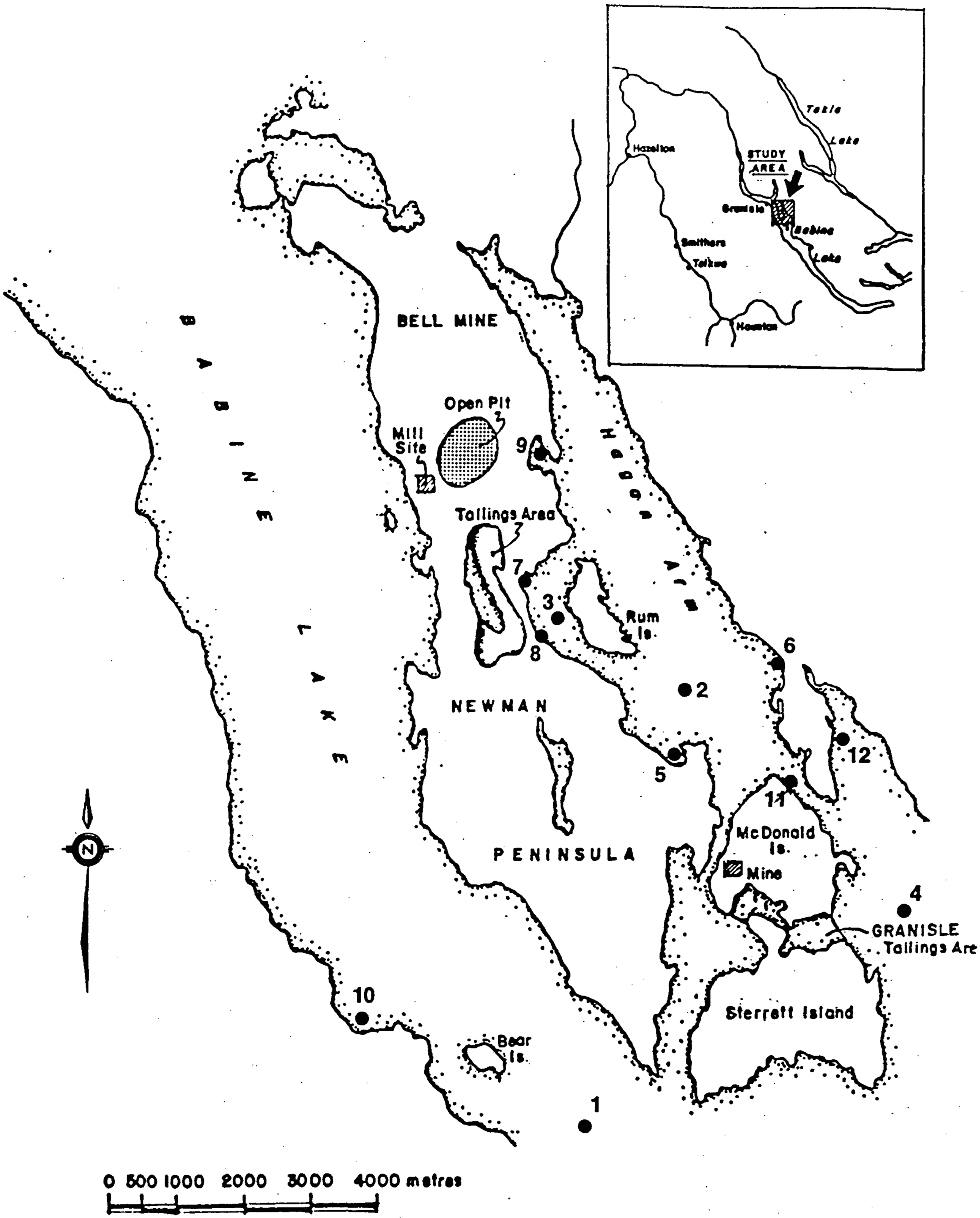


FIGURE 1: LOCATION OF SAMPLING STATIONS ON BABINE LAKE

2.0 SITE DESCRIPTION

Sample stations were established on Babine Lake to evaluate a number of parameters with respect to possible influence from the mine. Station locations, depths, and assessments carried out are presented in Table 1.

TABLE 1: SITE DESCRIPTION AND ASSESSMENTS

Station	Location	Water Depth	Assessments
1	Babine Lake Main Arm	103 m	Core, surface sediment, water profile, zooplankton, sediment bioassay, water chemistry
2	Hagan Arm	98 m	Core, surface sediment, water profile, zooplankton, sediment bioassay, water chemistry, sequential extraction
3	Rum Bay	75 m	Core, water profile, surface sediment, zooplankton, sediment bioassay, water chemistry, sequential extraction
4	Granisle Bay	20 m	Core, water profile, surface sediment, zooplankton, sediment bioassay, water chemistry
5	Little Bay, S. Hagan Arm	8 m	Surface sediment, benthic invertebrates
6	North Bay, N. Hagan Arm	8 m	Surface sediment, benthic invertebrates
7	Small Bay, N. Rum Bay	8 m	Surface sediment, benthic invertebrates
8	Tailings Pond S. Rum Bay	8 m	Surface sediment, benthic invertebrates
9	Wolverine Bay	9 m	Surface sediment, benthic invertebrates, sediment bioassay
10	Babine Main Arm, near shore	8 m	Surface sediment, benthic invertebrates, sediment bioassay
11	Granisle Bay, near AMD	8 m	Surface sediment, benthic invertebrates, sediment bioassay, sequential extraction
12	Granisle North Bay	8 m	Surface sediment, benthic invertebrates, sediment bioassay

3.0 MATERIALS AND METHODS

The site was visited June 19 to 22, 1990. Water profile data and surface sediment, sediment core, water chemistry, zooplankton, and bioassay samples were taken at four main stations in Babine Main Arm, Hagan Arm, Rum Bay, and Granisle Bay. Surface sediment, benthic invertebrate, and sediment bioassay samples were collected from eight other stations (Table 1).

3.1 Water Chemistry

Lake profiles were performed at several stations using a Hydrolab digital 4041 indicator unit and a 4021 Sonde unit. Conductivity, temperature, and pH were recorded.

Water quality analysis included alkalinity, total and dissolved organic carbon, total and dissolved inorganic carbon, total residues, non-filterable residues, sulphate, and metals. Samples were taken from the surface, near the bottom, and at two intermediate depths at four sites using Van Dorn bottles. The samples were packed with ice until analysis. Dissolved metal samples were filtered the same day through a 0.45 micron cellulose nitrate membrane filter. Total and dissolved metals were preserved with 0.5 ml nitric acid per 100 ml. All samples were collected in clean polyethylene bottles. The bottles for metal analysis were previously acid washed. Hardness was determined from the dissolved metal sample.

Inductively Coupled Argon Plasma (ICAP) Emission Spectroscopy was used for the total and dissolved metal analysis and gave a reading of twenty-eight metals. Cadmium, copper, and lead samples were re-analysed with the graphite furnace when results were less than twice the detection limit of the ICAP procedure. Analytical procedures were in accordance with the Environment Canada, Pacific Region, Laboratory Manual (Anon., 1979).

3.2 Sediment Collection

Lake bottom metal profiles were obtained by lowering a Phleger corer into the sediments. After corer penetration of about 35 - 40 cm, visual examination of the transparent core liner showed no evident disturbance of the top sediment with no turbidity above the sediment-water interface. Sediment was extruded and fractioned at every centimetre based on a modification of the close-interval fractionator described by Fast and Wetzel (1974). Sediment fractions were pushed above a Plexiglas plate by a plastic rod fitted with a rubber bung. The extruded sediment was cut off and contained by a sliding plastic ring and deposited into a sampling bag. The plate and ring were rinsed in water prior to each section.

Sediment was also collected from the benthic invertebrate sample sites using a ponar dredge. The top one centimetre of sediment was scooped with an acid-washed cut bottle, and a subsequent sample of approximately the same thickness was taken from immediately below. The samples were transferred into kraft bags and kept cool until analysed. Core samples were air dried, sieved to <150 μm, digested with aqua regia, and analysed for heavy metals using ICAP. Surface sediments were sieved to <63 μm.

3.3 Sequential Extraction

Sediment sequential extraction was performed at Stations 2, 3, and 11 to evaluate the potential mobility of metals in the sediment. A sample from Babine Main Arm was also collected but the analysis could not be performed due to lack of material. The methodology was based on that of Tessier et al. (1979). Samples were air dried, sieved to <63 μm, and rolled to homogenise. The samples were weighed into 50 ml centrifuge tubes and subjected to a sequential leaching procedure designed to partition trace metals into the following fractions:

1) F(a): Exchangeable metals. Sediment sample is extracted with 1M $MgCl_2$ initially at pH 7 at room temperature for one hour on a wrist action shaker.

2) F(b): Metals bound to carbonates or specifically adsorbed. The residue from (a) is leached with 1M sodium acetate adjusted to pH 5 with acetic acid at room temperature for five hours on a wrist action shaker.

3) F(c): Metals bound to Fe-Mn oxides. The residue from (b) is extracted at 96°C for six hours with 0.04M $NH_4OH.HCl$ in 25% (vol/vol) acetic acid.

4) F(d): Metals bound to organic matter and sulphides. The residue from (c) is extracted at 85°C for five hours with 0.02M HNO_3 and 30% H_2O_2 adjusted to pH 2 with HNO_3, and then at room temperature with 3.2M NH_4OAc in 20% (vol/vol) HNO_3 for 30 minutes on a wrist action shaker.

5) F(e): Residual metals. The original dried samples are weighed in Teflon digestion vessels and digested with HNO3 and HCl in a microwave oven, resulting in a total fraction (MT). The residual F(e) is calculated via

$$F(e) = MT - [F(a) + F(b) + F(c) + F(d)].$$

Analysis was performed via Inductively Coupled Argon Plasma (ICAP) Emission Spectroscopy. The internal laboratory reference material TATS-1 was used to evaluate the performance of the procedure.

3.4 Sediment Bioassay

The *Chironomus tentans* emergence test was used on eight sediment samples, including three samples used for sequential extraction, to indicate toxic effects. Sediments were placed in the test container and covered by a screen to retain adults. The 3 cm deep sediment layer was covered by 15 cm of gently aerated water. At the start of the test, larvae were added to the test containers. A food mixture of Cerophyl, fish food, and distilled water was given to the larvae at the start of the test and again on Day 8, 14, and 18. Adults start to emerge after 20 days. The test was continued for another 5 days to count all emerging adults and to observe any delayed development.

3.5 Benthic Invertebrates

Benthic invertebrates were collected using a Ponar dredge sampling a surface area of 529 cm^2. All benthic invertebrates for Babine Lake surveys were collected at a depth of eight metres to facilitate comparisons with a Hatfield Consultants report (1989). The sample was field sieved through a 350 μm mesh screen. The insects were preserved with Kahle's solution (15 parts ethyl alcohol, 30 parts deionized water, 6 parts 40% buffered formalin, and one part glacial acetic acid). Rose bengal was added to help in sorting the biota. A single grab sample was taken at all sites except for the Babine Main Arm station where four replicates were collected.

Diversity indices were calculated from the bottom fauna data using the Shannon-Weiner diversity index described by Pielou (1975) and modified as follows:

$$\text{Species Diversity } (H') = -\sum_{i=1}^{g} (P_i \log_{10} P_i)$$

Where $P_i = n_i/N$

n_i = total number of individuals in the i^{th} genus

N = total number of individuals identified to genus level

g = total number of genera

The use of individuals identified to genus level instead of to species level results in slightly lower diversity index values.

The diversity of the benthic invertebrate community depends on the number of species and the evenness with which the individuals are apportioned among them. The method of measuring evenness is described by Pielou (1975) and is given by:

$$\text{Evenness } (J') = \frac{H'}{\log g}$$

Where H' = the species diversity

g = the number of genera

The diversity of benthic invertebrates also depends on the species richness (Boyle et al., 1990). Margalef's formula is used to calculate this index:

$$\text{Species Richness } (D) = \frac{S - I}{\ln (I)}$$

where S = total number of species in the community

I = total number of individuals in the community

4.0 RESULTS

4.1 Water Chemistry

Metal concentration results are presented in Table 2, general parameters are in Table 3, and temperature/conductivity profiles are in Table 4.

Non-filterable residues were less than 5 mg/L in all samples, and total residues ranged between 60 and 80 mg/L. Metal values were correspondingly low. Dissolved aluminum, antimony, arsenic, beryllium, boron, dissolved cadmium, dissolved chromium, cobalt, dissolved manganese, molybdenum, nickel, phosphorus, potassium, selenium, silver, tin, titanium, vanadium, and zinc were all near or below their detection limit in all samples except zinc at the surface at Station 4 (0.033 mg/L). Barium (0.020 - 0.028 mg/L), calcium (11.1 - 13.1 mg/L), magnesium (2.6 - 3.2 mg/L), (silicon 1.65 - 1.80 mg/L), sodium (2.0 - 2.3 mg/L), and strontium (0.080 - 0.095 mg/L) values were similar at all stations and depths. Total cadmium and total chromium had sporadic elevated values at various depths and stations. Iron (0.184 mg/L) and total manganese (0.003 mg/L) were highest at Babine Main (Station 1). Copper (0.0157 mg/L) was elevated in Hagan Arm samples (Station 2). Total aluminum (0.39 mg/L) and lead (0.0070 mg/L) were also greatest at Babine Main and Hagan Arm, but concentrations declined with depth.

Waters had low alkalinity (37-39 mg/L) and hardness (37.6 - 45.9 mg/L). Carbon values were normally 6 - 8 mg/L. Sulphate was lowest in Babine Main samples (4.7 - 4.9 mg/L), highest in Rum Bay samples (9.5 - 12.2 mg/L), and concentrations tended to increase with depth.

The temperature conductivity profile showed that the thermocline was very close to the surface in Babine Lake, between 1 and 3 metres for all four sub-basins. The conductivity was very low with values between 12.9 to 17.5 μmhos/cm. The hypolimnion in Rum Bay and Hagan Arm had the highest conductivity levels. The waters were alkaline and pH was within a narrow range of values (7.5 to 7.9).

TABLE 2:

WATER QUALITY - BABINE LAKE
June 19-22, 1990

Station Number	Depth M	TOTICP AG MG/L	DISICP AG MG/L	TOTICP AL MG/L	DISICP AL MG/L	TOTICP AS MG/L	DISICP AS MG/L	TOTICP B MG/L	DISICP B MG/L	TOTICP BA MG/L	DISICP BA MG/L	TOTICP BE MG/L	DISICP BE MG/L	TOTICP CA MG/L	DISICP CA MG/L
	Surface	<0.01	<0.01	0.39	<0.05	<0.05	<0.05	0.03	<0.01	0.021	0.019	<0.001	<0.001	11.7	10.8
1	1	<0.01	<0.01	0.32	0.07	<0.05	<0.05	0.03	<0.01	0.025	0.019	<0.001	<0.001	11.5	10.8
	4	<0.01	<0.01	0.25	<0.05	<0.05	<0.05	0.02	0.01	0.021	0.019	<0.001	<0.001	11.4	10.8
	105	<0.01	<0.01	0.26	<0.05	<0.05	<0.05	0.02	0.01	0.020	0.019	<0.001	<0.001	12.5	10.7
	Surface	<0.01	<0.01	0.16	<0.05	<0.05	<0.05	0.02	0.01	0.021	0.019	<0.001	<0.001	12.3	12.0
2	8	<0.01	<0.01	0.16	<0.05	<0.05	<0.05	0.02	<0.01	0.020	0.020	<0.001	<0.001	12.9	12.4
	11	<0.01	<0.01	0.14	<0.05	<0.05	<0.05	0.01	0.02	0.020	0.020	<0.001	<0.001	12.6	12.9
	95	<0.01	<0.01	0.11	<0.05	<0.05	<0.05	0.01	<0.01	0.020	0.020	<0.001	<0.001	12.6	12.5
	Surface	<0.01	<0.01	0.14	<0.05	<0.05	<0.05	0.01	<0.01	0.022	0.020	<0.001	<0.001	12.3	12.3
3	5	<0.01	<0.01	0.09	<0.05	<0.05	<0.05	<0.01	<0.01	0.023	0.020	<0.001	<0.001	12.4	12.3
	8	<0.01	<0.01	0.06	<0.05	<0.05	<0.05	<0.01	<0.01	0.021	0.020	<0.001	<0.001	12.4	12.4
	70	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	0.023	0.020	<0.001	<0.001	13.1	13.1
	Surface	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	0.01	0.01	0.021	0.019	<0.001	<0.001	11.7	11.4
4	1	<0.01	<0.01	0.06	<0.05	<0.05	<0.05	0.01	<0.01	0.023	0.018	<0.001	<0.001	11.5	11.0
	4	<0.01	<0.01	0.06	<0.05	<0.05	<0.05	0.02	<0.01	0.028	0.018	<0.001	<0.001	11.7	11.2
	18	<0.01	<0.01	0.07	<0.05	<0.05	<0.05	0.02	<0.01	0.020	0.018	<0.001	<0.001	11.1	11.0
Blank		<0.01	<0.01	0.46	<0.05	<0.05	<0.05	0.04	<0.01	0.001	<0.001	<0.001	<0.001	1.1	<0.1
Blank		<0.01	<0.01	0.11	<0.05	<0.05	<0.05	<0.01	<0.01	0.002	<0.001	<0.001	<0.001	0.1	<0.1

TABLE 2 (Cont.):

WATER QUALITY - BABINE LAKE
June 19-22, 1990

Station Number	Depth M	TOTICP CD MG/L	TOTGF CD MG/L	DISICP CD MG/L	DISGF CD MG/L	TOTICP CO MG/L	DISICP CO 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 K MG/L	DISICP K MG/L
	Surface	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	<0.005	0.0049	<0.005	0.0038	0.104	0.012	<2	<2
1	1	<0.005	0.0009	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	<0.005	0.0048	<0.005	0.0036	0.184	0.013	<2	<2
	4	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	0.011	<0.005	0.005	0.0073	<0.005	0.0034	0.057	0.010	<2	<2
	105	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	0.010	0.0030	<0.005	0.0033	0.068	0.012	<2	<2
	Surface	<0.005	0.0005	<0.005	0.0001	<0.005	<0.005	0.006	<0.005	0.017	0.0116	0.007	0.0096	0.077	0.009	<2	<2
2	8	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.006	<0.005	0.012	0.0157	0.010	0.0091	0.026	<0.005	<2	<2
	11	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	0.010	0.0118	0.010	0.0114	0.018	0.006	<2	<2
	95	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.007	<0.005	0.012	0.0100	0.010	0.0091	0.035	<0.005	<2	<2
	Surface	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	0.012	0.0117	0.009	0.0093	0.036	0.007	<2	<2
3	5	<0.005	0.0003	<0.005	0.0001	<0.005	<0.005	<0.005	<0.005	0.012	0.0117	0.010	0.0088	0.031	0.009	<2	<2
	8	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	0.008	0.0096	0.009	0.0089	0.046	0.009	<2	<2
	70	<0.005	<0.0001	<0.005	0.0001	<0.005	<0.005	<0.005	<0.005	0.010	0.0110	0.010	0.0104	0.016	<0.005	<2	<2
	Surface	<0.005	0.0016	<0.005	<0.0001	<0.005	<0.005	0.012	<0.005	0.008	0.0073	0.007	0.0065	0.028	0.010	<2	<2
4	1	<0.005	0.0003	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	0.005	0.0064	<0.005	0.0056	0.103	0.016	<2	<2
	4	<0.005	0.0003	<0.005	<0.0001	<0.005	<0.005	0.006	<0.005	0.010	0.0110	0.007	0.0080	0.055	0.011	<2	<2
	18	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.008	<0.005	0.008	---	<0.005	0.0044	0.029	0.009	<2	<2
Blank		<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.006	<0.005	<0.005	<0.0006	<0.005	0.0007	0.026	0.006	<2	<2
Blank		<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.008	<0.005	<0.005	<0.0006	<0.005	<0.0005	0.022	<0.005	<2	<2

TABLE 2 (Cont.):

WATER QUALITY - BABINE LAKE
June 19-22, 1990

Station Number	Depth M	TOTICP MG MG/L	DISICP MG MG/L	TOTICP MN MG/L	DISICP MN MG/L	TOTICP MO MG/L	DISICP MO MG/L	TOTICP NA MG/L	DISICP NA MG/L	TOTICP NI MG/L	DISICP NI MG/L	TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	TOTGF PB MG/L	DISICP PB MG/L	DISGF PB MG/L
	Surface	2.7	2.7	0.003	<0.001	<0.01	<0.01	2.0	2.2	<0.02	<0.02	<0.1	<0.1	<0.05	0.0058	<0.05	0.0011
1	1	2.6	2.6	0.003	<0.001	<0.01	<0.01	2.1	2.1	<0.02	<0.02	<0.1	<0.1	<0.05	0.0025	<0.05	<0.0005
	4	2.7	2.6	0.001	<0.001	<0.01	<0.01	2.1	2.1	<0.02	<0.02	<0.1	<0.1	<0.05	0.0022	<0.05	<0.0005
	105	3.0	2.6	0.003	<0.001	<0.01	<0.01	2.3	2.1	<0.02	<0.02	<0.1	<0.1	<0.05	0.0016	<0.05	0.0008
	Surface	2.9	3.0	0.002	<0.001	<0.01	<0.01	2.3	2.2	<0.02	<0.02	0.1	<0.1	<0.05	0.0036	<0.05	0.0007
2	8	3.1	3.1	0.002	<0.001	<0.01	<0.01	2.2	2.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0070	<0.05	0.0007
	11	3.0	3.2	0.001	<0.001	<0.01	<0.01	2.3	2.4	<0.02	<0.02	<0.1	<0.1	<0.05	0.0019	<0.05	0.0014
	95	3.0	3.1	0.002	<0.001	<0.01	<0.01	2.2	2.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0014	<0.05	0.0009
	Surface	3.0	3.1	0.002	<0.001	<0.01	<0.01	2.2	2.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0023	<0.05	0.0007
3	5	3.0	3.0	0.002	<0.001	<0.01	<0.01	2.2	2.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0025	<0.05	0.0005
	8	3.0	3.1	0.002	<0.001	<0.01	<0.01	2.2	2.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0013	<0.05	0.0009
	70	3.2	3.2	0.002	<0.001	<0.01	<0.01	2.3	2.4	<0.02	<0.02	<0.1	<0.1	<0.05	0.0009	<0.05	<0.0005
	Surface	2.8	2.8	<0.001	<0.001	<0.01	<0.01	2.2	2.2	<0.02	<0.02	<0.1	<0.1	<0.05	0.0020	<0.05	0.0010
4	1	2.8	2.7	0.002	0.001	<0.01	<0.01	2.1	2.1	<0.02	<0.02	<0.1	<0.1	<0.05	0.0014	<0.05	0.0010
	4	2.9	2.8	0.002	<0.001	<0.01	<0.01	2.2	2.2	<0.02	<0.02	<0.1	<0.1	<0.05	0.0013	<0.05	0.0014
	18	2.8	2.7	0.002	<0.001	<0.01	<0.01	2.1	2.2	0.06	<0.02	<0.1	<0.1	<0.05	0.0010	<0.05	0.0009
Blank		<0.1	<0.1	<0.001	<0.001	<0.01	<0.01	<0.1	<0.1	<0.02	<0.02	<0.1	<0.1	<0.05	0.0015	<0.05	<0.0005
Blank		<0.1	<0.1	<0.001	<0.001	<0.01	<0.01	<0.1	<0.1	<0.02	<0.02	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005

TABLE 2 (Cont.):

WATER QUALITY - BABINE LAKE
June 19-22, 1990

Station Number	Depth M	TOTICP SB MG/L	DISICP SB MG/L	TOTICP SE MG/L	DISICP SE 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 V MG/L	DISICP V MG/L	TOTICP ZN MG/L	DISICP ZN MG/L
	Surface	<0.05	<0.05	<0.05	<0.05	1.72	1.49	<0.05	<0.05	0.083	0.076	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
1	1	<0.05	<0.05	<0.05	<0.05	1.69	1.47	<0.05	<0.05	0.081	0.074	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	4	<0.05	<0.05	<0.05	<0.05	1.75	1.49	<0.05	<0.05	0.080	0.075	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	105	<0.05	<0.05	<0.05	<0.05	1.74	1.55	<0.05	<0.05	0.093	0.074	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	Surface	<0.05	<0.05	<0.05	<0.05	1.69	1.46	<0.05	<0.05	0.091	0.088	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
2	8	<0.05	<0.05	<0.05	0.05	1.76	1.57	<0.05	<0.05	0.094	0.092	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	11	<0.05	<0.05	<0.05	<0.05	1.72	1.61	<0.05	<0.05	0.095	0.096	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	95	<0.05	<0.05	<0.05	<0.05	1.75	1.56	<0.05	<0.05	0.093	0.095	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	Surface	<0.05	<0.05	<0.05	<0.05	1.69	1.47	<0.05	<0.05	0.089	0.093	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
3	5	<0.05	<0.05	<0.05	<0.05	1.71	1.52	<0.05	<0.05	0.089	0.092	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	8	<0.05	<0.05	<0.05	<0.05	1.71	1.55	<0.05	<0.05	0.089	0.092	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	70	<0.05	<0.05	<0.05	<0.05	1.80	1.62	<0.05	<0.05	0.095	0.099	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	Surface	<0.05	<0.05	<0.05	<0.05	1.65	1.44	<0.05	<0.05	0.083	0.084	<0.002	<0.002	<0.01	<0.01	0.033	<0.002
4	1	<0.05	<0.05	<0.05	<0.05	1.66	1.41	<0.05	<0.05	0.080	0.080	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	4	<0.05	<0.05	<0.05	<0.05	1.66	1.43	<0.05	<0.05	0.084	0.084	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	18	<0.05	<0.05	<0.05	<0.05	1.72	1.52	<0.05	<0.05	0.082	0.084	<0.002	<0.002	<0.01	<0.01	0.005	<0.002
Blank		<0.05	<0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	0.013	<0.001	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
Blank		<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.001	<0.001	<0.002	<0.002	<0.01	<0.01	0.005	<0.002

TABLE 3:

WATER QUALITY - BABINE LAKE
June 19-22, 1990

Station Number	Depth M	ALK MG/L	DISICP HC MG/L	DISICP HT MG/L	TOC MG/L	DOC MG/L	TIC MG/L	DIC MG/L	SO4 MG/L	NFR MG/L	TR MG/L
	Surface	37	38.0	38.1	8	8	8	7	4.7	<5	70
1	1	37	37.8	38.2	8	8	8	6	4.9	<5	60
	4	37	37.7	37.7	8	8	8	6	4.9	<5	60
	105	38	37.6	37.6	8	7	9	8	4.8	<5	60
	Surface	38	42.1	42.1	8	7	8	8	9.1	<5	70
2	8	37	43.6	43.8	8	8	8	7	9.6	<5	80
	11	38	45.4	45.5	7	6	1	<1	10.3	<5	80
	95	38	44.0	44.1	7	6	2	3	10.1	<5	70
	Surface	39	43.3	43.5	8	8	8	5	9.6	<5	70
3	5	37	43.2	43.4	7	8	8	8	9.6	<5	70
	8	39	43.6	43.8	7	7	8	6	9.5	<5	70
	70	38	45.9	45.9	8	7	9	6	12.2	<5	70
	Surface	38	40.2	40.1	7	8	8	5	6.7	<5	70
4	1	38	38.5	38.2	8	7	8	6	6.5	<5	80
	4	38	39.5	39.2	8	7	8	5	7.9	<5	80
	18	38	38.7	38.2	8	7	8	8	6.0	<5	70
Blank		2.8	<0.4	<0.4	<1	<1	<1	<1	0.9	<5	<10
Blank		<1	<0.4	<0.4	1	<1	<1	<1	1.1	<5	10

TABLE 4: TEMPERATURE-CONDUCTIVITY PROFILES - BABINE LAKE - June 19-22, 1990

Station 1: Babine Main Arm

Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
1	15.6	8.5	7.9
2	14.3	6.9	7.8
3	14.4	6.6	7.9
4	14.5	6.1	7.8
5	14.1	6.1	7.8
6	14.1	6.1	7.9
7	14.1	6.1	7.9
10	14.1	6.0	7.8
20	14.3	5.2	7.8
30	14.0	5.1	7.8
40	13.8	4.4	7.8
50	13.8	4.1	7.8
75	13.5	3.7	7.8
90	12.9	3.7	7.7
100	12.9	3.6	7.7

Station 2: Hagan Arm

Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
0	15.8	10.4	7.8
1	15.6	10.0	7.9
2	15.6	9.8	7.9
3	15.7	9.6	7.9
4	15.4	9.4	7.9
5	15.8	9.1	7.9
6	15.5	8.9	7.9
7	15.7	8.4	7.9
8	15.4	8.0	7.8
9	15.5	7.7	7.8
10	15.1	6.4	7.8
11	15.5	6.1	7.7
15	16.9	4.7	7.7
20	17.0	4.3	7.7
30	17.4	3.9	7.7
50	17.5	3.9	7.7
70	17.5	3.6	7.7
90	17.1	3.6	7.5
95	17.1	3.7	7.5

TABLE 4 (Cont.): TEMPERATURE-CONDUCTIVITY PROFILES - BABINE LAKE - June 19-22, 1990

Station 3: Rum Bay

Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
0	16.1	10.5	7.9
1	15.5	10.4	7.9
2	15.6	10.2	7.9
3	15.8	9.0	7.9
4	15.9	8.6	7.8
5	15.7	8.4	7.8
6	15.7	8.1	7.8
7	16.2	7.6	7.7
8	16.0	7.1	7.7
9	16.0	7.0	7.7
10	16.1	6.7	7.7
15	16.8	5.0	7.7
20	16.9	4.6	7.7
30	17.4	4.1	7.6
50	17.4	3.9	7.6
70	17.1	3.7	7.7
72	17.1	3.7	7.7
73	17.1	3.7	7.7

Station 4: Granisle Bay

Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
0	14.5	14.5	7.9
1	14.3	14.0	7.9
2	14.1	12.3	7.9
3	14.8	9.4	7.9
4	15.2	8.9	7.9
5	15.4	8.1	7.8
6	15.0	7.0	7.8
10	15.1	5.0	7.8
15	15.1	4.8	7.8
18	14.8	4.7	7.8

4.2 Sediment Quality

Surface sediment quality results are presented in Table 5, sediment core profiles are in Table 6. Copper and manganese core profiles are displayed in Figures 2 and 3.

Antimony, cobalt, and tin were below their detection limit in all surface sediment samples. Arsenic, cadmium, molybdenum, lead, and silver were near or below their detection limit except for isolated higher values in the top layer of sediments at a few sites, especially Rum Bay. Copper concentrations tended to be much higher in the top centimetre sample, the maximum value was 1410 $\mu g/g$ from Granisle Bay near an acid mine seepage (Station 11). Mercury concentrations ranged from 0.040 to 0.186 $\mu g/g$, tending to be highest at the deep water sites. Zinc values ranged from 181 $\mu g/g$ to 776 $\mu g/g$, and tended to be higher in the top sediment layer. Other metal values tended to be those typical in the sediments of the area, though elevated levels were common in sediments from the deep water sites (Stations 1, 2, 3, and 4), and Station 10 on the Babine Main Arm. Sediments collected near the acid mine drainage and the tailings pond (Stations 8, 9, and 11) were not anomalous except for copper as mentioned above.

The enrichment of copper in Hagan Arm and Rum Bay far exceeds the rate at which such a phenomenon might occur in the Babine Main Arm (Figure 2). This seems to reflect the mine discharges to Rum Bay. Manganese levels show a strong diagenesis effect, but the surface sediments of Rum Bay have a reduced concentration (Figure 3). It is not possible to determine the nature of this effect since no information on the sedimentation rate is available at the moment. This reduction could be due to the loss of manganese to surface water because of anoxic conditions or it could be a reflection of the December 1989 tailings spill.

Profiles for cadmium, chromium, lead, mercury, silicon, and zinc did not decline with depth to any great extent.

TABLE 5:

SEDIMENT QUALITY - BABINE LAKE (<63 um)
June 19, 1990

Lake Area	Station Number (depth)	SEDICP AG UG/G	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	SEDHG HG UG/G	SEDICP K UG/G	SEDICP MG UG/G
	1 (0-1 cm)	<2	21400	20	270	1	7400	<0.8	<20	23.9	276	39700	0.140	2100	5000
Babine Main Arm	1 (1-2 cm)	<2	27400	<8	1090	1	9060	3.8	<20	31.3	113	40800	0.120	3200	5340
	10 (0-1 cm)	<2	25300	<8	208	1	15600	<0.8	<20	16.0	74.5	63000	0.040	1800	8460
	10 (1-2 cm)	<2	28100	<8	172	1	16200	<0.8	<20	17.0	50.8	48500	0.041	2000	9190
	2 (0-1 cm)	<2	30400	<8	307	1	7550	<0.8	<20	33.5	525	33200	0.186	3400	6170
	2 (1-2 cm)	<2	29500	<8	357	1	7450	<0.8	<20	33.7	83.3	20100	0.120	3100	4740
Hagan Arm	5 (0-1 cm)	<2	14500	<8	174	1	8520	<0.8	<20	21.0	296	18800	0.092	2000	4600
	5 (1-2 cm)	<2	14200	<8	161	1	6690	<0.9	<20	20.5	39.0	16900	0.051	2000	4530
	6 (0-1 cm)	<2	20500	<8	159	1	6330	<0.8	<20	27.0	143	29800	0.091	2100	4890
	6 (1-2 cm)	<2	23600	<8	224	1	6250	<0.8	<20	31.9	36.5	22400	0.130	2400	4990
	3 (0-1 cm)	23	12000	356	6150	1	18300	7.4	<20	18.7	52.8	135000	0.045	2600	3280
	3 (1-2 cm)	<2	33700	<8	636	1	5490	<0.8	<20	39.6	84.6	54100	0.100	3800	5090
	7 (0-1 cm)	<2	23800	<8	225	1	7820	<0.8	<20	32.8	163	23100	0.060	2700	7330
Rum Bay	7 (1-2 cm)	<2	23000	<8	211	1	9260	<0.8	<20	33.8	45.8	27200	0.048	2500	8420
	8 (0-1 cm)	<2	19000	<8	207	1	11600	1.0	<20	27.8	324	26500	0.081	2700	6490
	8 (1-2 cm)	<2	19400	<8	219	1	11200	<0.8	<20	29.1	63.0	21400	0.065	2600	5950
	9 (0-1 cm)	<2	21900	<8	220	1	6280	<0.8	<20	28.9	380	27700	0.070	2900	4660
	9 (1-2 cm)	<2	20500	<8	224	1	5570	<0.8	<20	29.3	29.7	21400	0.069	2300	4300
	4 (0-1 cm)	<2	20800	110	541	1	8040	<0.8	<20	22.9	447	113000	0.094	1800	4970
	4 (1-2 cm)	<2	34200	<8	350	1	6160	1.0	<20	40.4	62.3	33000	0.110	3500	6360
Granisle Bay	11 (0-1 cm)	<2	40000	<8	284	1	2870	0.9	<20	39.0	1410	43400	0.055	1800	3910
	11 (1-2 cm)	<2	18100	<8	192	1	4900	<0.8	<20	25.3	47.4	20100	0.068	2000	4280
	12 (0-1 cm)	<2	26300	<8	286	1	7150	<0.8	<20	31.5	203	39000	0.100	2700	5430
	12 (1-2 cm)	<2	27100	<8	285	1	7260	1.0	<20	35.7	46.2	28100	0.094	2500	5540

TABLE 5 (Cont.):

SEDIMENT QUALITY - BABINE LAKE (<63 um)
June 19, 1990

Lake Area	Station Number (depth)	SEDICP MN UG/G	SEDICP MO UG/G	SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SB 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
	1 (0-1 cm)	9360	<2	380	27	1400	20	<8	2970	<8	71.5	294	63	318	893000	107000
Babine	1 (1-2 cm)	8360	8	480	30	1200	<8	<8	2170	<8	83.3	355	67	776	889000	111000
Main																
Arm	10 (0-1 cm)	1120	<2	320	10	2080	10	<8	3320	<8	95.3	1840	110	184	859000	141000
	10 (1-2 cm)	718	<2	450	20	1500	10	<8	2930	<8	92.6	2060	120	196	871000	129000
	2 (0-1 cm)	721	<2	540	33	1600	20	<8	2650	<8	70.7	291	73	556	---	---
	2 (1-2 cm)	366	<2	550	28	870	<8	<8	2550	<8	69.2	271	70	234	852000	148000
Hagen	5 (0-1 cm)	255	4	850	48	1400	20	<8	1890	<8	59.1	564	44	288	799000	201000
Arm	5 (1-2 cm)	164	<2	490	24	950	10	<8	1960	<8	45.2	617	46	267	---	---
	6 (0-1 cm)	621	<2	340	26	1200	<8	<8	1840	<8	53.6	679	58	484	902000	97600
	6 (1-2 cm)	260	<2	330	28	800	8	<8	1950	<8	54.0	712	68	201	919000	805500
	3 (0-1 cm)	125000	27	310	41	6620	<8	<8	2110	<8	157.0	119	22	261	850000	150000
	3 (1-2 cm)	3150	<2	830	56	4370	10	<8	2710	<8	52.8	314	90	335	846000	154000
	7 (0-1 cm)	397	<2	560	37	990	10	<8	1480	<8	58.1	621	65	299	867000	133000
Rum	7 (1-2 cm)	390	<2	780	39	960	10	<8	1320	<8	61.8	708	71	282	859000	141000
Bay																
	8 (0-1 cm)	505	4	360	32	1200	10	<8	1450	<8	69.0	349	51	295	742000	258000
	8 (1-2 cm)	308	<2	400	33	870	<8	<8	1330	<8	66.9	380	52	305	726000	274000
	9 (0-1 cm)	859	<2	600	37	1200	10	<8	1850	<8	58.8	392	54	307	868000	132000
	9 (1-2 cm)	243	<2	350	31	740	10	<8	1820	<8	46.6	488	55	181	918000	81700
	4 (0-1 cm)	5260	<2	310	36	6220	17	<8	1700	<8	85.3	246	71	340	853000	147000
	4 (1-2 cm)	409	<2	470	41	1000	<8	<8	1050	<8	61.3	566	98	275	892000	108000
Granisle																
Bay	11 (0-1 cm)	237	<2	390	26	2330	<8	<8	1220	<8	43.0	503	53	252	831000	169000
	11 (1-2 cm)	241	2	270	33	690	<8	<8	911	<8	46.3	553	63	229	877000	123000
	12 (0-1 cm)	812	2	400	35	1500	10	<8	985	<8	61.7	567	73	333	850000	150000
	12 (1-2 cm)	323	2	410	36	820	<8	10	1010	<8	57.7	676	85	304	856000	144000

TABLE 6:

SEDIMENT CORE PROFILE - BABINE LAKE (<150 um)
June 19, 1990

Station	Depth CM	AG UG/G	AL UG/G	AS UG/G	BA UG/G	BE UG/G	CA UG/G	CD UG/G	CO UG/G	CR UG/G	CU UG/G	FE UG/G	HG UG/G	K UG/G	MG UG/G
Stn 1	2	<2	28700	76	405	1	6890	<0.8	<20	34.7	87.0	54577	0.120	2900	5660
Babine	3	<2	32500	28	344	1	6330	<0.8	<20	36.8	54.0	42435	0.096	3200	6410
Main	4	<2	29400	<8	305	1	6120	<0.8	<20	35.0	60.7	48500	0.078	2700	6270
Arm	5	<2	36500	<8	413	1	6710	<0.8	<20	40.6	66.5	46600	0.083	4000	6670
	6	<2	34800	10	327	1	6610	<0.8	<20	37.5	65.1	57000	0.084	3700	6890
	7	<2	36200	<8	487	1	7070	0.9	<20	39.8	73.5	39400	0.079	3700	6740
	8	<2	35500	<8	473	1	6800	<0.8	<20	39.5	65.8	41200	0.085	3700	6880
	9	<2	29600	11	311	1	6310	<0.8	<20	32.3	56.3	76200	0.067	3100	5600
	10	<2	33500	<8	378	1	6550	1.0	<20	36.3	63.1	48400	0.085	3600	6600
	11	<2	28400	<8	362	1	6460	<0.8	<20	33.3	65.6	36200	0.079	2500	6280
	15	<2	38400	<8	473	1	6880	<0.8	<20	40.9	65.9	43600	0.086	4300	7280
	20	<2	31600	<8	394	1	6680	<0.8	<20	35.8	64.5	45400	0.092	2900	7410
	25	<2	28900	<8	308	1	6350	<0.8	<20	31.3	62.2	62700	0.086	2600	6760
Stn 2	2	<2	30000	<8	191	1	6640	<0.8	20	34.1	685	44300	0.160	3700	6050
Hagen	3	<2	26400	<8	161	1	7170	0.9	<20	32.8	202	24300	0.130	2700	4740
Arm	4	<2	29000	<8	193	1	6960	<0.8	<20	35.8	112	23100	0.100	2900	5000
	5	<2	34200	<8	222	1	7580	1.0	<20	41.0	107	25100	0.130	3800	5260
	6	<2	27200	<8	180	1	6980	<0.8	<20	34.5	95.7	22300	0.110	2600	4650
	7	<2	25400	<8	175	1	7310	<0.8	<20	34.0	97.7	23000	0.110	2100	4790
	8	<2	25700	<8	169	1	7380	<0.8	<20	33.5	83.5	22800	0.130	2200	4640
	9	<2	31000	<8	227	1	7370	<0.8	<20	38.9	219	24700	0.120	2800	5000
	10	<2	26200	<8	222	1	7090	<0.8	<20	35.6	85.0	23600	0.120	2200	4690
	11	<2	29300	<8	246	1	7160	<0.8	<20	37.8	83.6	27300	0.130	2600	5440
	12	<2	31300	<8	263	1	7130	<0.8	<20	38.6	75.5	28800	0.120	2800	5580
	17	<2	34800	<8	224	1	7640	1.0	<20	43.0	84.1	28200	0.130	3400	5620
	22	<2	35300	<8	404	1	8180	<0.8	<20	44.6	97.0	31100	0.185	3300	6240
	27	<2	28600	<8	319	1	7810	1.0	<20	41.6	99.9	30400	0.140	2600	5970
Stn 3	2	7	27600	<8	1160	1	9720	<0.8	<20	22.5	440	35100	0.160	3200	5220
Rum	3	4	18300	16	1860	1	10300	<0.8	<20	17.7	96.3	120000	0.079	2500	3590
Bay	4	<2	27400	42	813	1	8210	<0.8	<20	30.3	79.2	99000	0.096	3000	4510
	5	<2	40100	<8	456	1	5810	<0.8	<20	44.6	96.7	60100	0.130	4500	6040
	6	<2	42800	<8	435	2	5890	<0.8	<20	49.2	109	51700	0.150	4900	6500
	7	<2	39200	<8	359	2	6060	<0.8	<20	49.4	114	44300	0.140	4300	6630
	8	<2	44900	<8	466	2	6430	<0.8	<20	54.6	114	58900	0.120	5100	7060
	9	<2	46100	<8	412	2	6390	1.0	<20	55.9	119	48000	0.120	5400	7350
	10	<2	47100	<8	383	2	5750	<0.8	<20	56.8	103	46000	0.110	5500	7670
	11	<2	48500	<8	376	2	5950	1.0	<20	59.2	110	48600	0.120	5600	7920
	12	<2	43700	<8	369	2	5880	1.0	<20	51.4	114	48800	0.120	5000	7360
	17	<2	46500	<8	376	2	6220	1.0	<20	54.3	128	45500	0.110	5800	7970
	22	<2	49100	<8	405	2	5990	<0.8	<20	51.9	120	44800	0.096	6500	8820
Stn 4	2	<2	27800	100	454	1	7640	<0.8	<20	28.7	366	105000	0.085	3000	5350
Granisle	3	<2	29400	29	370	1	6760	<0.8	<20	32.5	108	71100	0.088	3100	5460
Bay	4	<2	36700	<8	315	1	6430	0.9	<20	44.1	69.1	44500	0.095	4200	6430
	5	<2	33300	<8	276	1	6080	1.0	<20	40.5	69.3	36300	0.094	3300	6310
	6	<2	34200	<8	300	1	6170	<0.8	<20	41.4	66.9	34700	0.100	3400	6680
	7	<2	39100	<8	306	1	6350	<0.8	<20	44.7	67.0	36600	0.110	4200	7000
	8	<2	34700	<8	312	1	5930	<0.8	<20	40.8	67.0	36500	0.100	3300	6530
	9	<2	32100	<8	237	1	5900	38.0	<20	40.6	66.8	38400	0.226	3100	6360
	10	<2	32800	<8	267	1	5910	<0.8	<20	40.9	66.0	33300	0.097	3100	6410
	11	<2	38200	<8	283	1	6200	<0.8	<20	44.1	66.9	33800	0.100	4100	6600
	12	<2	27400	<8	209	1	6120	<0.8	<20	35.9	67.5	31200	0.099	2300	5900
	17	<2	34100	<8	332	1	6300	<0.8	<20	41.7	69.8	37900	0.120	3400	6410
	22	<2	27700	<8	283	1	6130	<0.8	<20	36.2	66.4	45200	0.110	2500	6440
	27	<2	22000	<8	295	1	5680	<0.8	<20	31.9	67.3	33700	0.100	2000	6310

TABLE 6 (Cont.):

SEDIMENT CORE PROFILE - BABINE LAKE (<150 um)
June 19, 1990

Station	Depth CM	MN UG/G	MO UG/G	NA UG/G	NI UG/G	P UG/G	PB UG/G	SB UG/G	SI UG/G	SN UG/G	SR UG/G	TI UG/G	V UG/G	ZN UG/G
Stn 1	2	7127	<2	470	48	2260	<8	<8	3180	<8	60.0	367	81	384
Babine	3	1735	<2	530	37	1600	<8	<8	3380	<8	57.2	414	93	189
Main	4	2200	<2	480	39	1970	18	<8	3600	<8	53.3	346	86	556
Arm	5	2080	<2	620	37	1600	19	<8	2590	<8	64.0	477	98	326
	6	1940	<2	590	40	1200	10	<8	2460	<8	60.6	471	94	481
	7	1840	<2	520	38	1200	9	<8	2230	<8	68.2	441	100	365
	8	1940	<2	540	33	1100	10	<8	2580	<8	65.2	467	91	335
	9	3228	<2	520	35	3875	10	<8	3550	<8	53.5	467	100	447
	10	2280	<2	540	42	2520	<8	<8	2830	<8	60.5	485	91	491
	11	1670	<2	460	31	1100	<8	<8	2420	<8	57.6	321	82	393
	15	1590	<2	610	36	1000	10	<8	2110	<8	68.0	480	99	337
	20	1500	<2	430	39	1000	10	<8	2400	<8	59.5	379	87	497
	25	2170	<2	450	41	1400	18	<8	3320	<8	54.4	330	90	450
Stn 2	2	1240	<2	670	34	1850	42	<8	2490	<8	57.7	354	75	1340
Hagen	3	509	<2	940	39	1100	28	<8	2370	<8	58.5	242	65	916
Arm	4	374	<2	930	61	920	17	<8	2670	<8	58.7	244	75	906
	5	368	<2	790	36	1000	10	<8	2250	<8	62.9	304	82	590
	6	315	<2	1319	71	920	20	<8	2880	<8	55.3	217	69	573
	7	328	<2	610	33	940	9	<8	3400	<8	55.4	188	73	1080
	8	309	<2	920	55	950	<8	<8	3310	<8	56.9	179	71	967
	9	330	<2	430	32	920	17	<8	2920	<8	59.9	221	80	154
	10	299	<2	320	32	870	10	<8	3180	<8	55.7	184	73	559
	11	333	<2	380	39	950	10	<8	3310	<8	58.8	223	84	742
	12	375	<2	697	44	2100	10	<8	3520	<8	59.0	187	81	854
	17	328	<2	590	38	910	10	<8	2730	<8	61.1	210	88	983
	22	361	<2	540	41	880	17	<8	2600	<8	72.0	196	91	244
	27	373	<2	410	47	920	20	<8	2840	<8	65.9	177	98	614
Stn 3	2	21500	10	1300	72	1740	<8	<8	2280	<8	88.4	191	65	705
Rum	3	44500	<2	2620	96	8070	<8	<8	2970	<8	104	165	48	552
Bay	4	93000	<2	430	35	6810	10	<8	2710	<8	80.1	218	79	624
	5	5180	<2	1200	64	4980	<8	<8	2350	<8	57.7	278	99	936
	6	2390	<2	690	59	3750	<8	<8	2270	<8	60.5	297	110	624
	7	1710	<2	550	49	2240	10	<8	2600	<8	58.3	234	110	695
	8	2630	<2	620	51	6440	17	<8	2870	<8	66.4	276	120	455
	9	1510	<2	640	63	2310	10	<8	2990	<8	66.2	265	130	496
	10	1220	<2	620	54	1600	20	<8	3150	<8	63.6	257	120	578
	11	1080	<2	650	57	1300	21	<8	3110	<8	64.6	228	120	564
	12	1440	<2	610	61	3000	20	<8	3270	<8	60.7	239	110	500
	17	967	<2	670	69	1300	10	<8	3070	<8	67.1	250	130	576
	22	839	<2	730	55	890	<8	<8	3090	<8	71.2	231	120	318
Stn 4	2	3530	<2	630	38	5820	20	<8	1450	<8	79.4	373	83	817
Granisle	3	1390	<2	550	36	5720	<8	<8	1170	<8	67.0	488	90	1080
Bay	4	696	<2	620	42	4290	10	<8	1020	<8	62.3	691	110	633
	5	513	<2	470	40	2170	<8	<8	1040	<8	57.0	507	100	686
	6	441	<2	460	38	1300	<8	<8	1160	<8	58.6	527	100	501
	7	472	<2	570	41	1200	<8	<8	1110	<8	62.6	586	110	550
	8	502	<2	460	50	1740	8	<8	1100	<8	58.6	437	99	474
	9	403	<2	820	42	1100	10	<8	1140	<8	53.8	395	97	579
	10	386	<2	440	42	980	<8	<8	1080	<8	54.4	384	98	515
	11	391	<2	590	46	1100	10	<8	1080	<8	60.9	564	110	595
	12	386	<2	430	41	1100	<8	<8	1150	<8	50.8	336	97	564
	17	574	<2	490	44	2570	<8	<8	1050	<8	60.1	482	100	405
	22	836	<2	360	48	3230	<8	<8	1160	<8	54.6	401	96	366
	27	423	<2	220	41	1000	<8	<8	1290	<8	50.3	246	84	155

FIGURE 2: BABINE LAKE SEDIMENT PROFILE - COPPER - June 1990

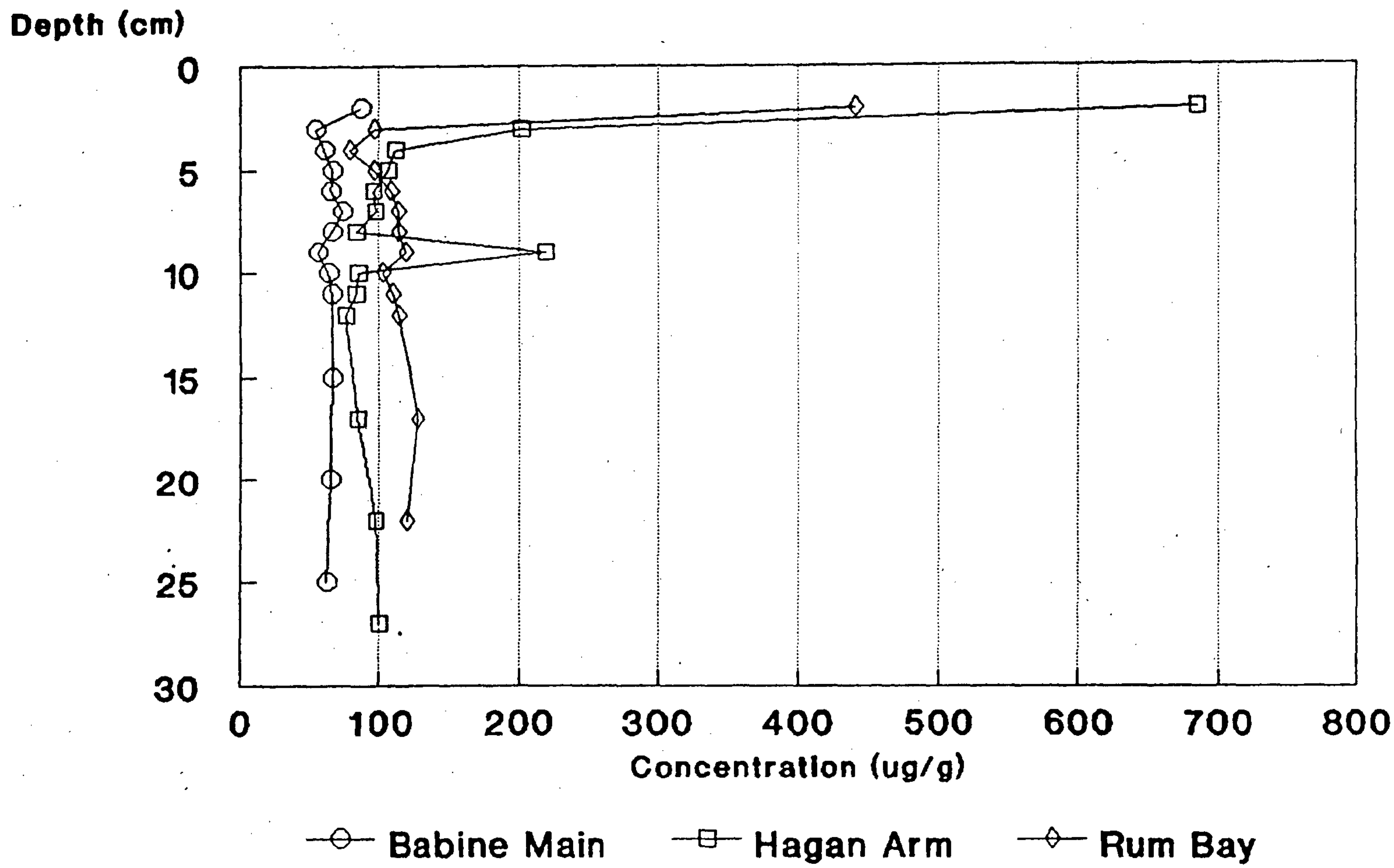
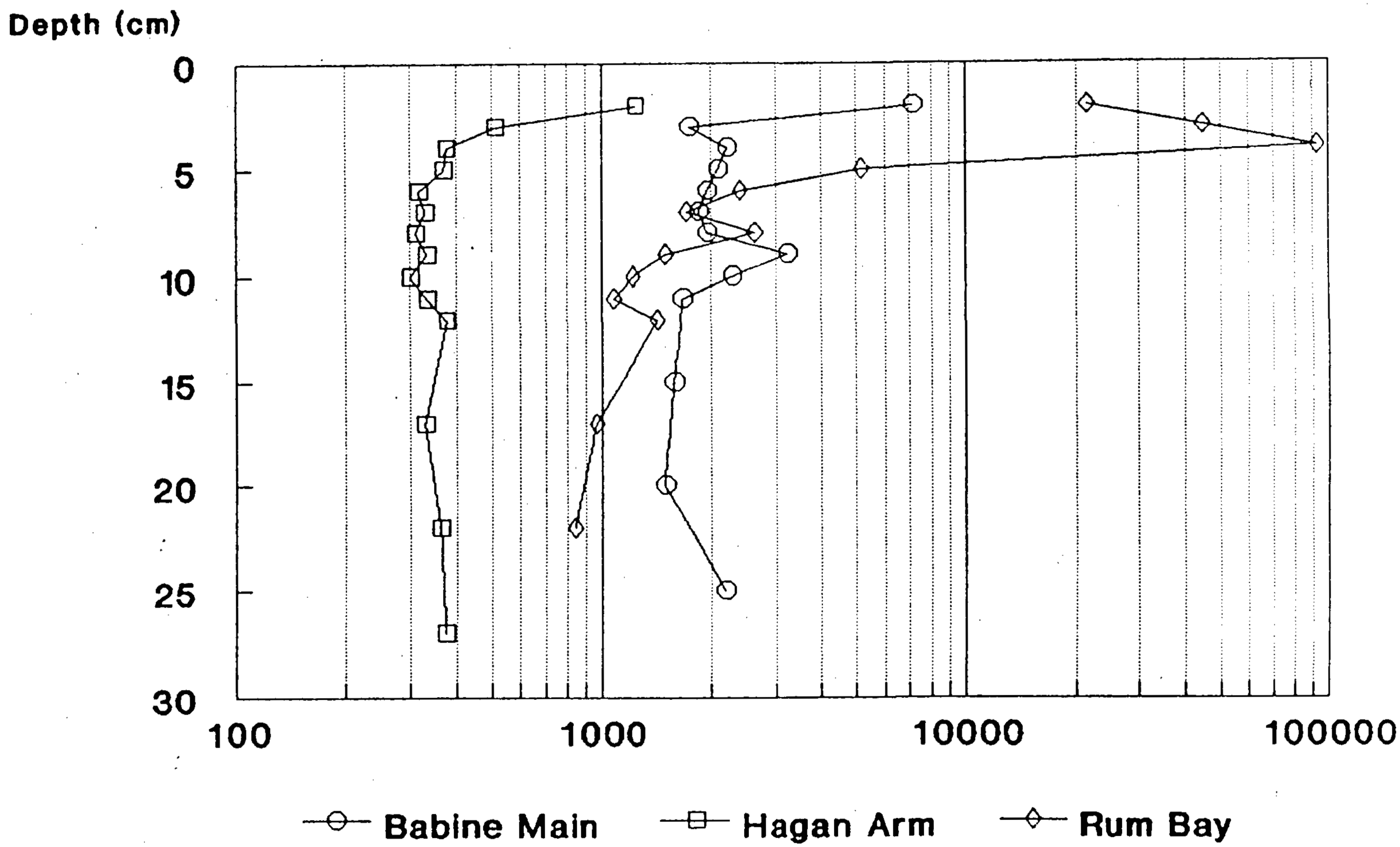


FIGURE 3: BABINE LAKE SEDIMENT PROFILE - MANGANESE - June 1990



4.3 Sequential Extraction and Sediment Bioassays

Sequential extraction results are given in Tables 7 to 9. Selected metal results are shown in Figures 4 to 7. Bioassay results are in Table 10.

Sequential extraction gives an indication of the biological availability of a metal. The amount present in the exchangeable and carbonate fractions is considered more easily taken up by organisms. Low arsenic, cadmium, and lead levels occurred in the exchangeable or carbonate fractions of sediment from the three sites tested (Stations 2, 3, and 11 in Hagan Arm, Rum Bay, and Granisle Bay, respectively).

The three sediment samples evaluated by sequential extractions to determine the bioavailability of heavy metals present were also tested for chronic effects with the Chironomus tentans emergence test. It was found that Rum Bay and Hagan Arm samples showed delayed fly emergence toxicity while the sample from Granisle Bay (Station 11) showed acute toxicity. At Station 11, high levels of exchangeable aluminum (450 $\mu g/g$), copper (111 $\mu g/g$), and zinc (90.3 $\mu g/g$) may have been responsible for this effect. The Hagan Arm sample had less mobile aluminum and copper (Al, 3 $\mu g/g$; Cu, 2.8 $\mu g/g$) but more reactive zinc (196 $\mu g/g$).

It is difficult to determine the reasons for the chronic toxicity in the Rum Bay sample. None of aluminum, copper, arsenic, cadmium, copper, lead, or zinc were above the detection limit in the exchangeable fraction and these metals were not particularly high in the carbonate fraction either. On the other hand, total metals that were high in this sample but not in the other two include silver (23 $\mu g/g$), arsenic (356 $\mu g/g$), and cadmium (7.4 $\mu g/g$).

Five other samples were analysed for fly emergence. Only the sample from Station 1 showed some chronic toxicity. Unfortunately not enough material was available to perform a sequential extraction. It could be inferred from the surface sediment quality that the elements arsenic, copper, and zinc could be involved in the toxicity. It is impossible to tell if aluminum would have participated in such an effect.

TABLE 7: SEQUENTIAL EXTRACTION - STATION 2, HAGAN ARM - JUNE 20, 1990 (98 metres deep)

Metals (µg/g)	Exchange-able	Carbonates	Fe+Mn Oxide	Organic & Sulphides	Residual	Total
Ag	<0.4	<0.4	<0.4	<0.4	<2	<2
Al	3	25	990	3630	25800	30400
As	<2	<2	2	5	<1	<8
Ba	56.2	22.6	46.4	22.1	160	307
Be	<0.04	0.04	0.53	0.1	0.33	1
Ca	4940	469	320	400	1420	7550
Cd	0.4	<0.2	<0.2	<0.2	<0.4	<0.8
Co	<4	<4	<4	<4	<20	<20
Cr	0.5	0.2	2.4	7.76	22.6	33.5
Cu	2.8	18.6	46.7	259	198	525
Fe	<2	18	6620	4080	22500	33200
K	100	<80	<80	<80	3300	3400
Mn	155	70.4	126	36	334	721
Mo	<0.4	<0.4	0.6	3	NIL	<2
Ni	1	1	3	4	24	33
P	<4	20	200	1110	270	1600
Pb	<2	<2	<2	4.5	<15.5	20
Sb	<2	<2	<2	<2	<8	<8
Sn	<2	<2	<2	<2	<8	<8
Sr	33	4.47	4.32	3.6	25.3	70.7
Ti	<0.08	<0.08	<0.08	147	144	291
V	<0.4	<0.4	9.4	9.8	53.8	73
Zn	196	83.9	90.4	28.4	157	556

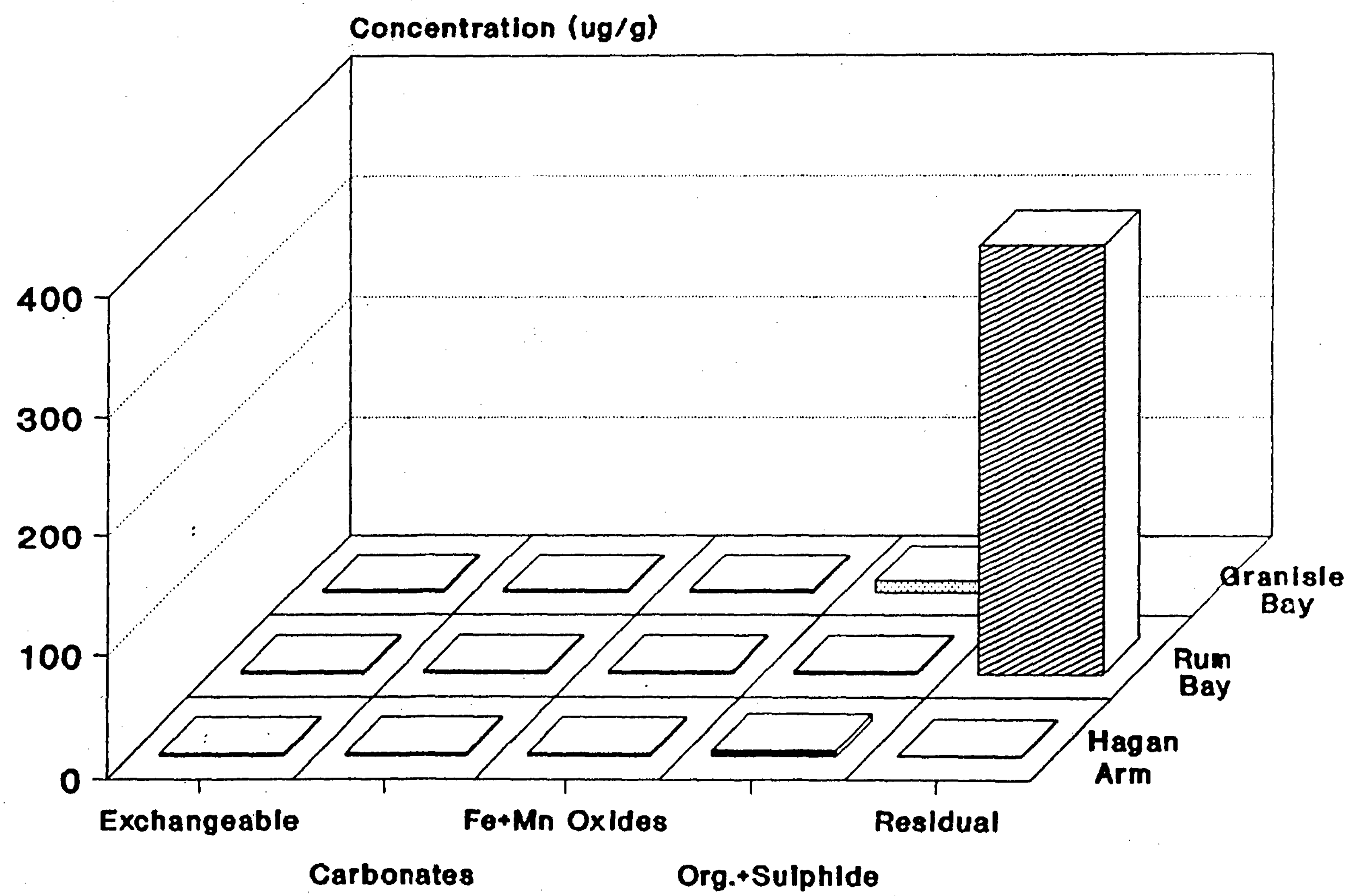
TABLE 8: SEQUENTIAL EXTRACTION - STATION 3, RUM BAY - JUNE 20, 1990 (75 metres deep)

Metals (μg/g)	Exchange-able	Carbonates	Fe+Mn Oxide	Organic & Sulphides	Residual	Total
Ag	<0.5	<0.5	5.4	6.9	10.7	23
Al	<2	5.2	269	891	10800	12000
As	<2	<2	<2	<2	356	356
Ba	4	63.4	1210	1890	2980	6150
Be	<0.05	<0.05	0.2	0.1	<0.6	0.9
Ca	6200	2260	2500	1470	5870	18300
Cd	<0.2	<0.2	2.1	2.2	3.1	7.4
Co	<5	<5	<5	<5	<20	<20
Cr	0.4	<0.2	<0.2	<0.2	18.3	18.7
Cu	<0.2	<0.2	9.19	15.6	28	52.8
Fe	<2	22	12200	17700	105000	135000
K	<90	400	400	<90	1800	2600
Mn	1.6	73.5	2.7	4	>83500	>83600
Mo	<0.5	<0.5	<0.5	<0.5	27	27
Ni	<0.9	<0.9	9.1	5	26.9	41
P	<5	20	190	1240	5170	6620
Pb	<2	<2	<2	<2	<8	<8
Sb	<2	<2	<2	<2	<8	<8
Sn	<2	<2	<2	<2	<8	<8
Sr	39.8	40.1	44.4	9.06	60.6	194
Ti	<0.09	<0.09	<0.09	<0.09	119	119
V	<0.5	<0.5	<0.5	<0.5	22	22
Zn	<0.09	7.64	78.9	39.9	135	261

TABLE 9: SEQUENTIAL EXTRACTION - STATION 11, GRANISLE BAY - JUNE 21, 1990 (8 metres deep)

Metals (μg/g)	Exchange-able	Carbonates	Fe+Mn Oxide	Organic & Sulphides	Residual	Total
Ag	<0.4	<0.4	<0.4	<0.4	<2	<2
Al	450	1960	6530	5790	25300	40000
As	<2	<2	<2	9.5	NIL	<8
Ba	11.5	5.68	14.5	72.3	180	284
Be	0.06	0.1	0.63	0.1	0.11	1
Ca	557	73	150	860	1230	2870
Cd	0.4	<0.2	<0.2	<0.2	<0.5	0.9
Co	<4	<4	<4	<4	<20	<20
Cr	0.2	1.1	7.63	5.51	24.8	39
Cu	111	108	36.1	860	<365	1410
Fe	134	233	10600	7980	24500	43400
K	<80	<80	<80	<80	1800	1800
Mn	21.8	1.9	20.5	27.6	165	237
Mo	<0.4	<0.4	0.9	3	NIL	<2
Ni	2	<0.8	2	2	20	26
P	7	10	260	1930	123	2330
Pb	<2	<2	<2	2	<6	<8
Sb	<2	<2	<2	<2	<8	<8
Sn	<2	<2	<2	<2	<8	<8
Sr	4.39	1	2.7	10.3	24.6	43
Ti	<0.08	<0.08	<0.08	31.3	472	503
V	<0.4	<0.4	4.3	5.3	43.4	53
Zn	90.3	14	28.1	15	105	252

FIGURE 4: SEQUENTIAL EXTRACTION - ARSENIC - June 1990



<u>FIGURE 5</u>: SEQUENTIAL EXTRACTION - CADMIUM - June 1990

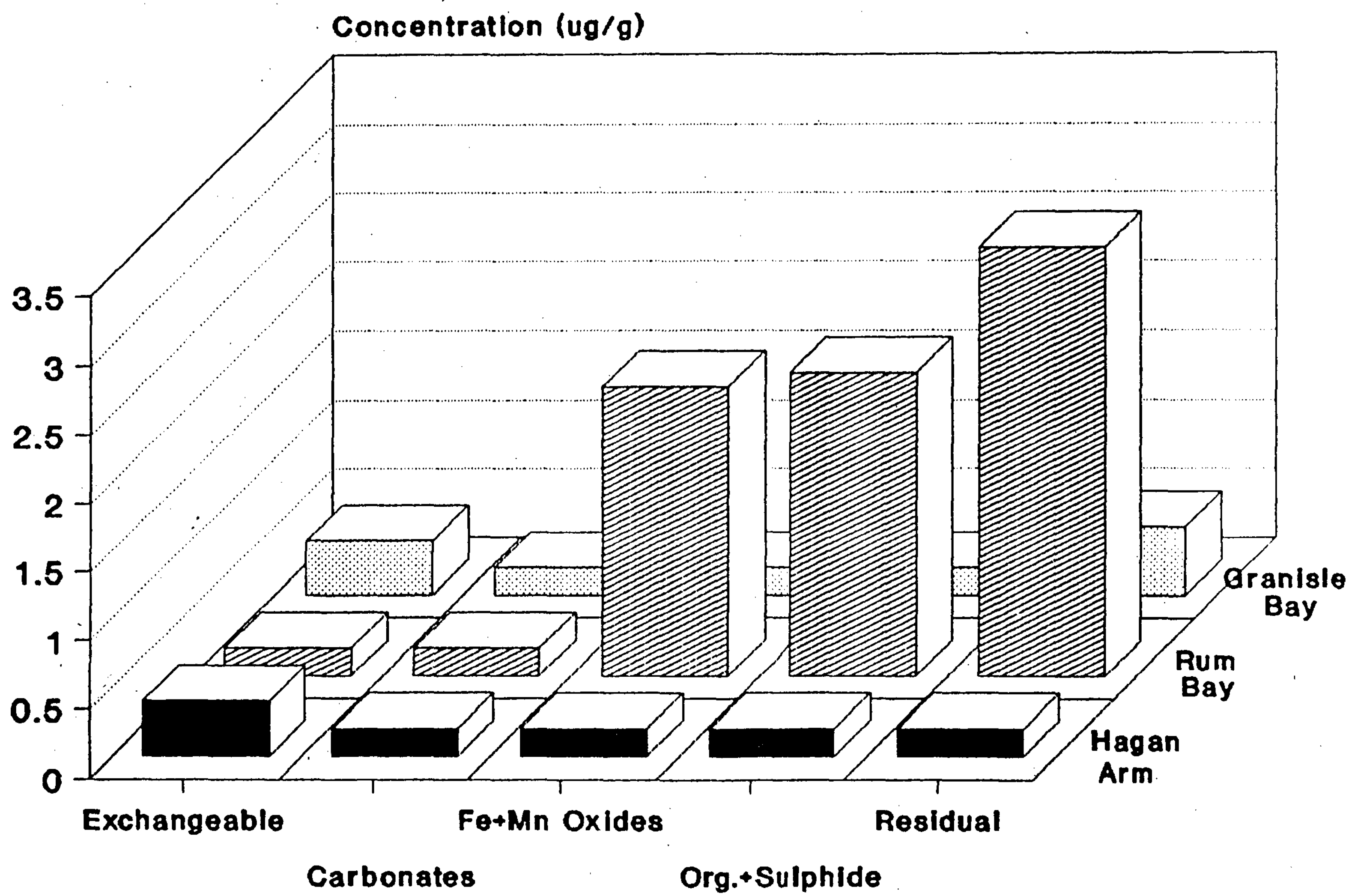


FIGURE 6: SEQUENTIAL EXTRACTION - COPPER - June 1990

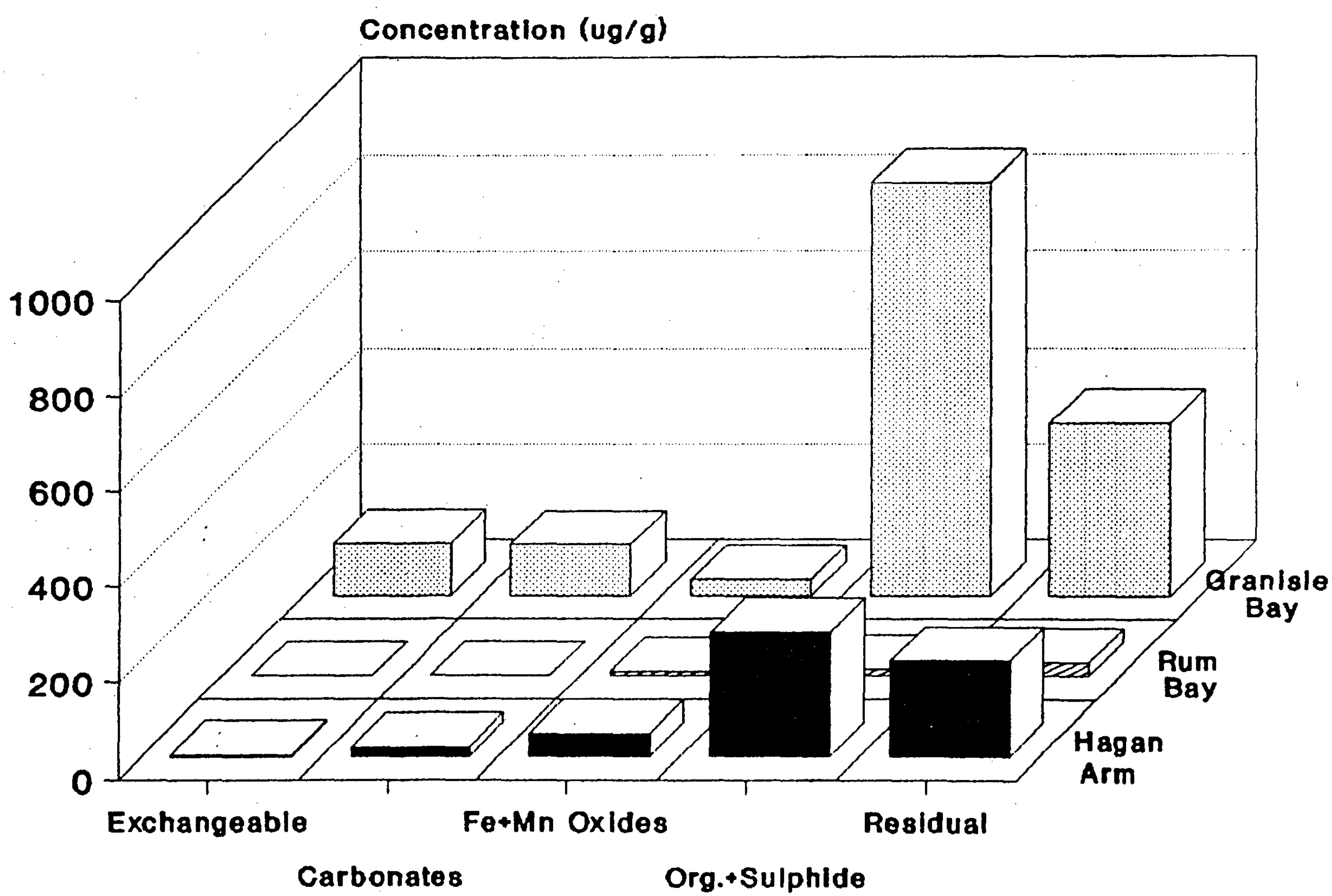


FIGURE 7: SEQUENTIAL EXTRACTION - ZINC - June 1990

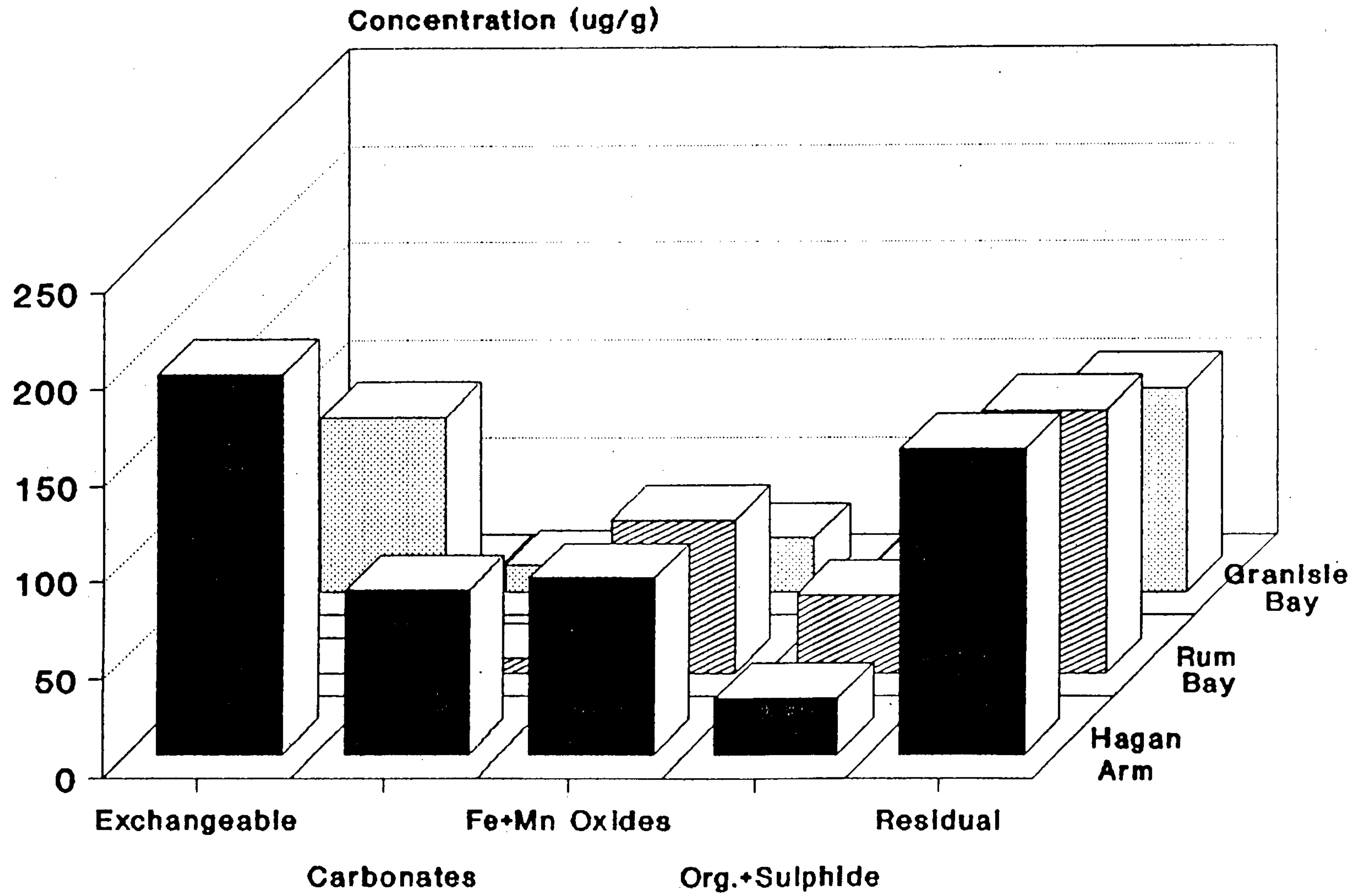


TABLE 10: Chironomus tentans SEDIMENT BIOASSAY RESULTS - BABINE LAKE - JUNE 19-22, 1990

STATION	RESULT
1	TOXIC
2	TOXIC
3	TOXIC
4	NON TOXIC
9	NON TOXIC
10	NON TOXIC
11	ACUTELY TOXIC
12	NON TOXIC

4.4 Benthic Invertebrates

The relative density of organisms (454 to 1172 organisms/m^2) did not show the same range of value from the previous study (Hatfield, 1989) where the density values varied from 19 to 2717 organisms/m^2 (Table 11).

The species list between the two studies differs substantially. Nine chironomidae, nine oligocheate, and three tricoptera species were identified only in the Hatfield study while five different chironomidae and one tricoptera species were identified in this study. Ephemeroptera, amphipoda, nematoda, lepidoptera, coelenterata, and coleoptera were identified only in the Hatfield study. This difference could be due to the sampling time since Hatfield performed their study in September while our study was performed June 19-22. Also, the selection of sampling sites influenced the species list since no sampling was performed on the east shore of Newman Peninsula. Benthic invertebrate samples were collected in triplicate by Hatfield while only one grab sample was analysed in our study. More replicates augments the chance of encountering a higher number of species. Other differences between the studies may have been due to different sampling time and mesh size.

Diversity indices were lower (0.73 to 1.15) in this survey compared to Hatfield (0.88 to 3.69). Evenness was more consistent with a range of 0.77 to 0.92, compared to 0.34 to 0.92 for the Hatfield survey. Richness in this study was higher with a range of value from 1.9 to 4.6 compared to 0.69 to 2.66.

TABLE 11: BENTHIC INVERTEBRATES - BABINE LAKE - JUNE 19-22, 1990

	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12
PLANKTONIC ORGANISMS								
Calanoida								
Diaptomidae juv.							2	
Epischura nevadensis		7					7	1
Calanoida, juv, unid.		1				1	20	
Cladocera								
Daphnia rosea	2		11	5	10	1		2
Daphnia ambigua								9
Bosmina longirostris		7	2	1	4		8	2
Eurycercus lamellatus	1							
(Allona sp.?) dam.	1							
EPIBENTHIC ORGANISMS								
Cyclopoida								
(Cyclops exilis?) (range)	2	3		1				3
Cyclopoida juv.	1						7	
Harpacticoida				1		3		
Trichoptera								
Triaenodes sp.					2			
Hydracarina								
Forelia sp.							1	
Neumania sp.	1		1					
Kerendowskia sp.	1	1						
Arrenurius sp.				1				
Unid. dam.							1	
BENTHIC ORGANISMS								
Megaloptera								
Sialis sp.				1				
Oligochaeta								
Tubificidae, juv.	1	1		2	6	1		1
Ostracoda	2							

TABLE 11 (Cont.): BENTHIC INVERTEBRATES - BABINE LAKE - JUNE 19-22, 1990

	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12
Diptera								
Ceratopogonidae								
Palpomyia sp.			1			1		1
Empididae pupae				2				
Chironomidae pupae	2		1	3	2	1		
Cladopelma sp.				1				
Phycoidella sp.				1				
Chironomus sp.				8				3
Phaenopsectra sp.	8							1
Procladius sp.	1			6	2	3		2
Micropsectra sp.						1		
Natarsia sp.						1		
Microtendipes sp.						1		1
Monodiamesa sp.	2	1			2			3
Rheotanytarsus sp.	2			3	4			9
Cardiocladius sp.	8	2	4					1
Polypedilum (Polypedilum) sp.			1	1				1
Eukiefferiella sp.	1			2				2
Constempelina sp.								4
Paracladius sp.	2							
Unid. dam.				1			1	
Bivalvia								
Pisidium (ferrugineum)				2		4		
Sphaerium (nitidum)	13	2	3	5		7		5
Gastropoda								
Valvata sincera		2		2				
TOTAL # OF ORGANISMS	25	32	42	51	24	27	62	47
DENSITY (#/m^2)	473	605	794	964	454	510	1172	888
NUMBER OF TAXA	12	8	8	18	8	10	20	18
DIVERSITY	0.95	0.82	0.73	1.12	0.72	0.87	1.00	1.15
EVENNESS	0.88	0.91	0.81	0.89	0.80	0.87	0.77	0.92
RICHNESS	3.4	2.1	1.9	4.3	2.2	2.7	4.6	4.4

5.0 CONCLUSIONS

The sediment analysis, as demonstrated by the surface and core profile, indicated that copper contamination could be detected in Rum Bay and Hagan Arm. However, copper concentrations from the exchangeable fraction of the sediment extraction were below the detection limit in the Rum Bay sample. Chronic toxic effects, expressed by the Chironomus tentans emergence test, were demonstrated for the deep sub-basins (Station 1, 2, and 3) as well as for Station 11 which is downstream of an AMD seepage to the lake. The benthic invertebrate species list was smaller than a previous survey conducted by Hatfield Consultants for Noranda. This may be a result of the reduced replication in our survey as well as a different sampling period and mesh size.

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