ENVIRONMENTAL SERVICES BRANCH
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC AND YUKON REGION

LITERATURE REVIEW AND DATA SUMMARY OF STUDIES RELATED TO BELL MINE, BABINE LAKE

Regional Program Report 84-10

By

Kalyan Basu

April 1984

ABSTRACT

This report summarizes available information on selected chemical and physical parameters of Babine Lake.

The information has been reviewed in order to understand long term effects of a possible permanent copper mine tailings pond supernatant discharge into Hagan Arm of Babine Lake. For this reason, emphasis was given to Hagan Arm and the immediate effluent discharge area.

The section on water chemistry deals with background levels of heavy metals and salts, effects of chelating complexes within the lake and the monitoring program of the supernatant discharge by Bell mine into Hagan Arm. Water chemistry parameters from both Bell mine and EPS are analyzed and evaluated.

Physical parameters such as temperature stratification, light intensity and secchi depth characteristics are considered within the context of lake circulation and mixing of the lake waters.

Studies on sediment analysis and acid leaching capability of mineralized rocks are summerized in view of the potential environmental change resulting from anticipated increases in logging and mining activities in the Babine Lake watershed.

RÉSUMÉ

Ce rapport résume l'information disponible sur une sélection de paramètres chimiques et physiques du lac Babine.

L'information a été pasée en revue de facon à comprendre les effets à long terme d'un éventuel déversement permanent de liquide surnageant provenant d'un étang de tailings d'une mine de cuivre; ce déversement se ferait dans le bras Hagan du lac Babine. Pour cette raison, l'emphase a été mise sur le bras Hagan et sur la zone immediate de déversement de l'effluent.

La section sur la chimie de l'eau traite des niveaux de bruit de fond pour les métaux lourds et les sels, des effets des complexes chilatants à l'intérieur du lac et du programme de surveillance du déversement dans le bras Hagan de liquide surnageant provenant de la mine Bell. Les paramètres chimiques de l'eau obtenus de la mine Bell et du SPE sont analysés et évalués.

Les paramètres physiques telsque les caractéristiques de stratification de température, d'intensité lumineuse et de profondeur de Secchi sont examinés dans le contexte de la circulation du lac et du mélange des eaux du lac.

Des études sur l'analyse de sédiments et sur le pouvoir acidifiant de lessivage des rockes minéralisées sont résumées par rapport au changement environemental potentiel résultant des augmentations anticipées dans les activités d'exploitation minière et forestière dans le bassin hydrographique du lac Babine.

ACKNOWLEDGEMENT

I would like to express my thanks to Margaret Ross for her constructive comments in the preparation of this report. The assistance of Lillian Pearson in the drafting of Maps and Figures and Pam Wakeman in the word processing is greatly appreciated.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

SUMMARY

The existing Babine Lake data on selected chemical and physical parameters have been reviewed in order to assess the effects of a permanent discharge from the Bell mine into the Hagan Arm of Babine Lake.

The information on water chemistry data includes pre-operational chemical surveys of Babine Lake conducted on September 1971 and July 1972 by Beak Consultants for Bell Mine. The data from these studies indicate high dissolved oxygen concentration, neutral pH and low suspended solids, hardness, turbidity, COD, BOD and TOC values. The concentration of selected heavy metals was also very low. The mine started operating in October 1972. Results are presented from a resource impact study by EPS in 1974 and from monitoring programs by the Babine Lake Watershed Change Steering Committee during the spring and fall of 1973 through to 1976. No significant changes were observed in either nutrient, major ion or most heavy metal concentrations during the three year study. However, mean copper concentrations on selected dates in 1974 and 1975 had increased in the northern basin closer to the open pit copper mine operations as compared to south basin stations. A water sampling program was conducted by Bell mine in 1983 in order to determine the effect of effluent in the receiving area. In some stations, conductivity and sulphate value increased with depth. This trend was not observed at all stations because the data was not available from deeper water (below 50 m). Dissolved copper values did not always increase with depth.

Conductivity profiles recorded with a Hydro Lab instrument by the Waste Management Branch in January 1983 showed that the conductivity values of effluent was 1600 umho/cm and the average conductivity of the receiving water was only 94 umho/cm indicating much dilution of the effluent took place. Studies on complexing capacity indicate that Babine Lake water is high in dissolved organic matter which complexes with ionic copper or other heavy metals to ameliorate toxicity (Chau, et al, 1974).

Physical parameters show that Babine Lake is a dimictic lake and characteristically ice-covered for four months in the winter. The annual mean residence time of this lake is approximately twenty years and almost no inflow takes place during the winter (Carmack and Farmer, 1982). Temperature in Babine Lake decreases rapidly in mid-August. Isothermal conditions occur in early November. By the end of December, the mixed layer retreats to the surface of the lake and the thermal structure remains unchanged until early April when the solar radiation warms the water beneath the ice causing convecting mixing layer that progressively deepens (Farmer and Carmack, 1981).

The vertical and horizontal thermal structure was measured in 1972 and 1973 using bathythermograph (Farmer, et al, 1976). Data from these studies permitted recognition of epilimnion, metalimnion and hypolimnion depth, mean temperature and volumes of these layers; nature of convecting warming in different parts of the lake and regions of upwelling.

Temperature depth profiles for the 1974-1975 season from the Babine Lake Watershed Change Steering Committee monitoring program showed a stable thermocline in the northern basin by early June whereas in the main lake, spring overturn with complete mixing took place in July. In 1973, the Babine Lake Watershed Change Steering Committee reported that due to greater wind protection, a stable stratification and greatly reduced mixed layer was observed in the Hagan Arm region. Light intensity and secchi depth characteristics from this report indicate an increase of light extintion-coefficient from north to south of the lake and secchi depths in the Hagan Arm region were fairly constant throughout the open water period.

Babine Lake sediments were analyzed for selected chemical components in view of potential enviornmental change resulting from logging and mining activities in the Babine Lake watershed. Average concentration of all measured chemical constituents of bottom sediments except zinc were highest in the north region of the lake (north of Fulton River). Highest

values of total phosphorous and organic carbon were observed in surface sediments (0-4.5 cm). Particularly high copper concentrations were observed in surface layer of Hagan Arm area where there were two active copper mine sites.

Mineralized rocks surrounding Babine Lake were studied for their acid leaching potential. Results of the study indicate that these rocks are not extremely easy to acidify and therefore do not consitute an obvious leaching hazard.

1. INTRODUCTION

When Bell mine is operating, discharges to the tailings pond are recycled and reused in the mill so there is no need for a direct discharge to the environment. However, during a shutdown, water levels in the tailings pond increase and threaten the stability of the tailings dams. Therefore, during a period of temporary shutdown, a limited approval was granted to Maclearn Forest Products - Bell Mine to discharge approximately 1,000,000 m^3 of tailings pond supernatant to Hagan Arm in Babine Lake from October 18, 1982 to April 30, 1983. The mine was granted only a limited approval rather than a permit for a permanent discharge because the shutdown was only expected to be temporary and Babine Lake is an important salmon fishery resource area; also, the effects of a permanent discharge were unknown.

In order to assess the effects of a permanent discharge from the Bell Mine on Babine Lake, a waste management plan and an environmental assessment report was submitted by Maclearen Forest Product Inc., Babine Mining Division Bell Mine to the Waste Management Branch on August, 1983. The purpose of this report was to summarize existing lake data, along with those submitted by Bell Mine, in order to understand long term effects of a permanent discharge of Bell Mine supernatant into Hagan Arm of Babine Lake.

Information on Water Chemistry, Physical Parameters, Sediment Analysis and acid leaching potential of mineralized rocks is presented for Babine Lake with emphasis on Hagan Arm and the immediate effluent discharge area.

2. WATER CHEMISTRY

The section on water chemistry includes a literature review and summary of the existing lake data with emphasis on:

1. Background levels of heavy metals and salts in Babine Lake.
2. Quality of tailings supernatant discharge by Bell Mine into the Hagan Arm of Babine Lake.
3. Effects of chelating complexes within the lake.

2.1 Background Chemical Data

Noranda mine (Bell Copper Division) began construction on site in 1970 and the first ore was extracted in October 1972. The ore was first concentrated in a mill on site and then the copper was extracted by a flotation process that used sodium cyanide as an iron dispersant (Smith, 1972).

The tailings from Bell Mine were deposited in Workburn Lake area. There was no direct discharge into Babine Lake; therefore, no contamination of Babine Lake from an effluent discharge was expected. Water from the tailings impoundment was recirculated and used in the milling process.

Noranda Mine Limited retained Beak Consultant Limited to conduct pre-operational chemical surveys in September 1971 and July 1972 (Figure 1). Following is a summary of water quality data for Babine Lake from this study (Tables 2, 3). Dissolved oxygen conentrations were high, three of the oil and grease samples in September were high, pH was neutral; suspended solids, turbidity and hardness values were all low. In addition, COD, BOD and TOC values were generally low. The concentrations of selected metals except iron, were very low. Iron has a very low toxicity (Beak Consultants, 1972) and is expected to be present in easily detectable quantities. There was one copper concentration recorded in September, 1971 at Station 11, east of Newman Peninsula that was high.

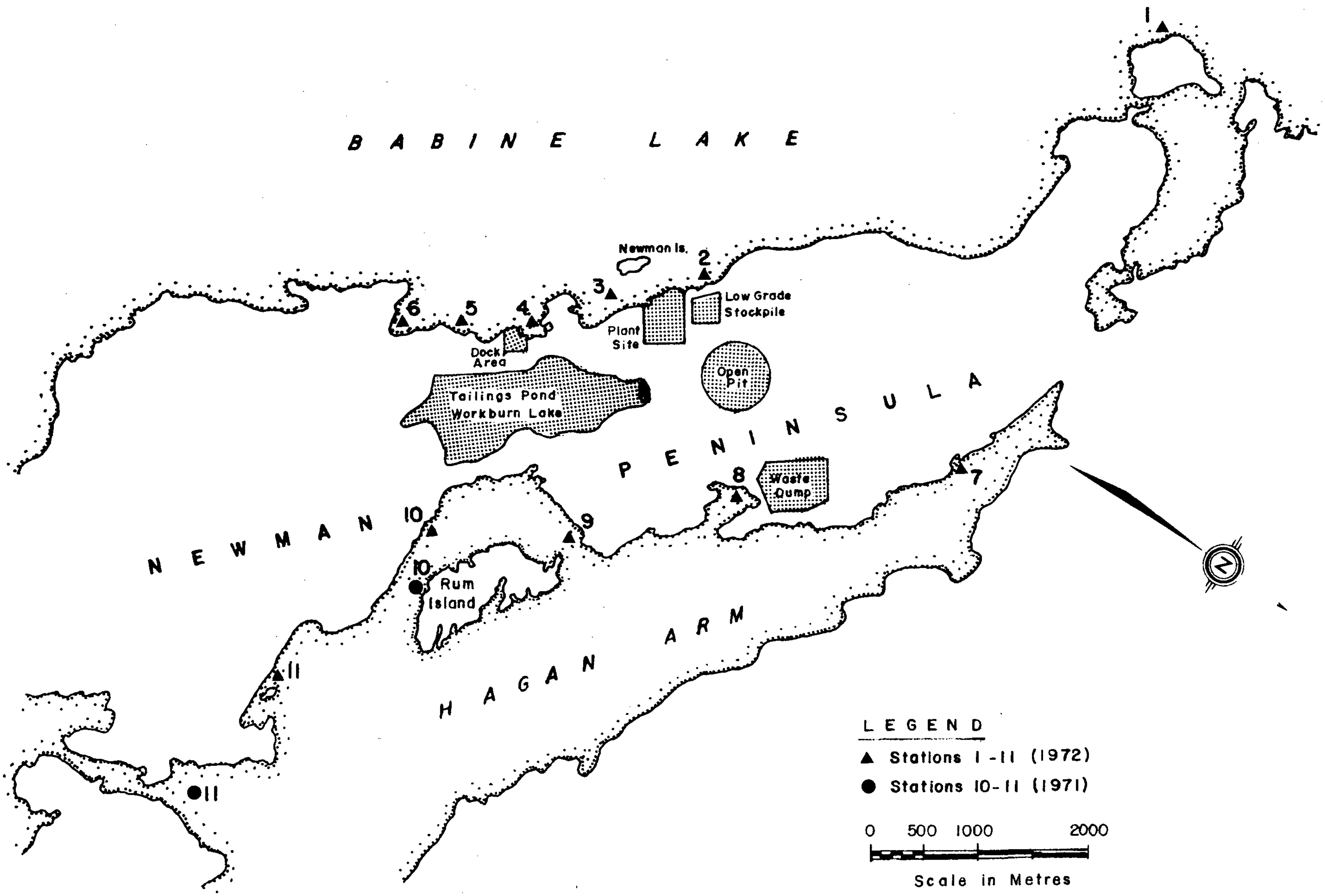


FIGURE 1 STATIONS FROM PRE-OPERATIONAL WATER QUALITY SURVEYS CONDUCTED BY BEAK CONSULTANTS, September 1971 and July 1972

TABLE 1 SUMMARY OF WATER QUALITY DATA FOR BABINE LAKE FROM BEAK CONSULTANTS PRE-OPERATIONAL SURVEYS IN SEPTEMBER 1971 AND JULY 1972*

	STATION	WEST OF NEWMAN PENINSULA			EAST OF NEWMAN PENINSULA		
	NO.	1	2	3	8	10	11
Temperature	Sept./71	12.2	12.2	12.2	12.2	12.2	12.2
(°C)	July /72	14.2	13.5	13.8	15.1	12.7	12.1
Dissolved Oxygen	Sept./71	9.4	9.4	9.4	9.4	9.5	9.6
(mg/l)	July /72	9.3	9.2	9.3	8.9	9.3	9.5
pH	Sept./71	7.5	7.5	7.4	7.6	7.6	7.6
(log units)	July /72	7.4	7.9	7.9	7.5	7.5	7.8
Total Hardness	Sept./71	35	36	36	36	36	36
(ppm as $CaCO_3$)	July /72	33	35	35	33	35	32
Turbidity	Sept./71	0.7	0.8	0.7	0.6	0.4	0.7
(JTU)	July /72	0.7	0.9	0.7	0.5	0.6	0.8
COD	Sept./71	10	14	12	17	24	42
(ppm)	July /72	28	19	20	21	20	21
Total Solids	Sept./71	73	63	63	58	65	61
(ppm)	July /72	51	47	51	37	47	44
Total Organic Carbon	Sept./71	8	7	9	8	9	8
(ppm)	July /72	12	10	10	9	20	9
Cyanide	Sept./71	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
(ppm)	July /72	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Oil and Grease	Sept./71	5.8	4.3	20.3	7.8	25.5	22.1
(ppm)	July /72	1.3	< 1.0	1.8	1.8	1.7	2.3
Sulfate	Sept./71	3.5	3.7	4.8	4.1	4.5	4.4
(ppm)	July /72	2.0	4.0	2.3	3.7	3.3	2.5
Sulfide	Sept./71	0.06	0.05	0.05	0.05	0.06	0.05
(ppm)	July /72	0.05	0.05	0.05	0.05	0.05	0.05

*EACH VALUE REPRESENTS THE AVERAGE OF THE DATA FROM THE THREE DEPTHS, SURFACE, MID, AND BOTTOM AT EACH STATION

TABLE 2 SUMMARY OF CHEMICAL ANALYSES FOR SELECTED METALS IN BABINE LAKE FROM BEAK CONSULTANTS PRE-OPERATIONAL SURVEYS DURING SEPTEMBER 14-16, 1971 AND JULY 13-14, 1972*

	STATION	WEST OF NEWMAN PENINSULA			EAST OF NEWMAN PENINSULA		
	NO.	1	2	3	8	10	11
Arsenic	Sept./71	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
(ppm)	July./72	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	Sept./71	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
(ppm)	July./72	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Copper	Sept./71	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.13
(ppm)	July./72	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Iron	Sept./71	0.2	0.3	0.4	0.4	0.4	0.4
(ppm)	July./72	0.19	0.04	0.03	0.03	0.03	0.18
Lead	Sept./71	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
(ppm)	July./72	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
Mercury	Sept./71	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
(ppb)	July./72	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Molybdenum	Sept./71	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
(ppm)	July./72	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Nickel	Sept./71	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
(ppm)	July./72	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	Sept./71	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
(ppm)	July./72	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Silver	Sept./71	-	-	< 0.05	-	-	-
(ppm)	July /72	< 0.005	< 0.005	< 0.005	-	< 0.005	-

*EACH VALUE REPRESENTS THE AVERAGE OF THE TOTAL CONCENTRATION FOR THE SURFACE, MID AND BOTTOM WATER AT EACH STATION

In 1972, EPS reported on the water quality of some sites in Babine Lake adjacent to the mine site (Kussat, et al, 1972). Station N2 was located in the general area of the present discharge site (Figure 2). The concentrations of dissovled metal obtained at Station N1 and N2 (Table 3) reflect lake conditions before any effluent was discharged into Babine Lake from Bell Mine and can serve as baseline data for future surveys.

Hallam (1975) in an EPS resource impact study reported that all water chemistry parameters were considered to be in the normal range in the vicinity of Noranda Bell Mine. Sample stations are depicted in Figure 3 and water chemistry parameters are listed in Tables 4 and 5.

As part of the Babine Lake watershed change program, Stockner and Shortreed (MS 1974) conducted a limnogical study of Babine Lake in 1973 (Figure 4). Chemical parameters (Table 6) for this study indicate that there is little spatial or temporal variation in phosphate and nitrate concentrations. Silicate concentrations were lowest in June in all zones compared to July and September. Total alkalinity showed little variation in 1973; however, zone 2 values were lower than the rest of the lake. Zonal variations of conductivity were not significant.

The Babine Lake Watershed Change Steering Committee sampled during the spring and fall of 1974 through to 1976 (Stockner and Shortreed, 1976, 1978) (Figures 5 and 6). No significant changes were observed in nutrient, major ion or most heavy metal concentrations during the three year study (Tables 7-22). However copper concentrations had increased in 1975 at some stations.

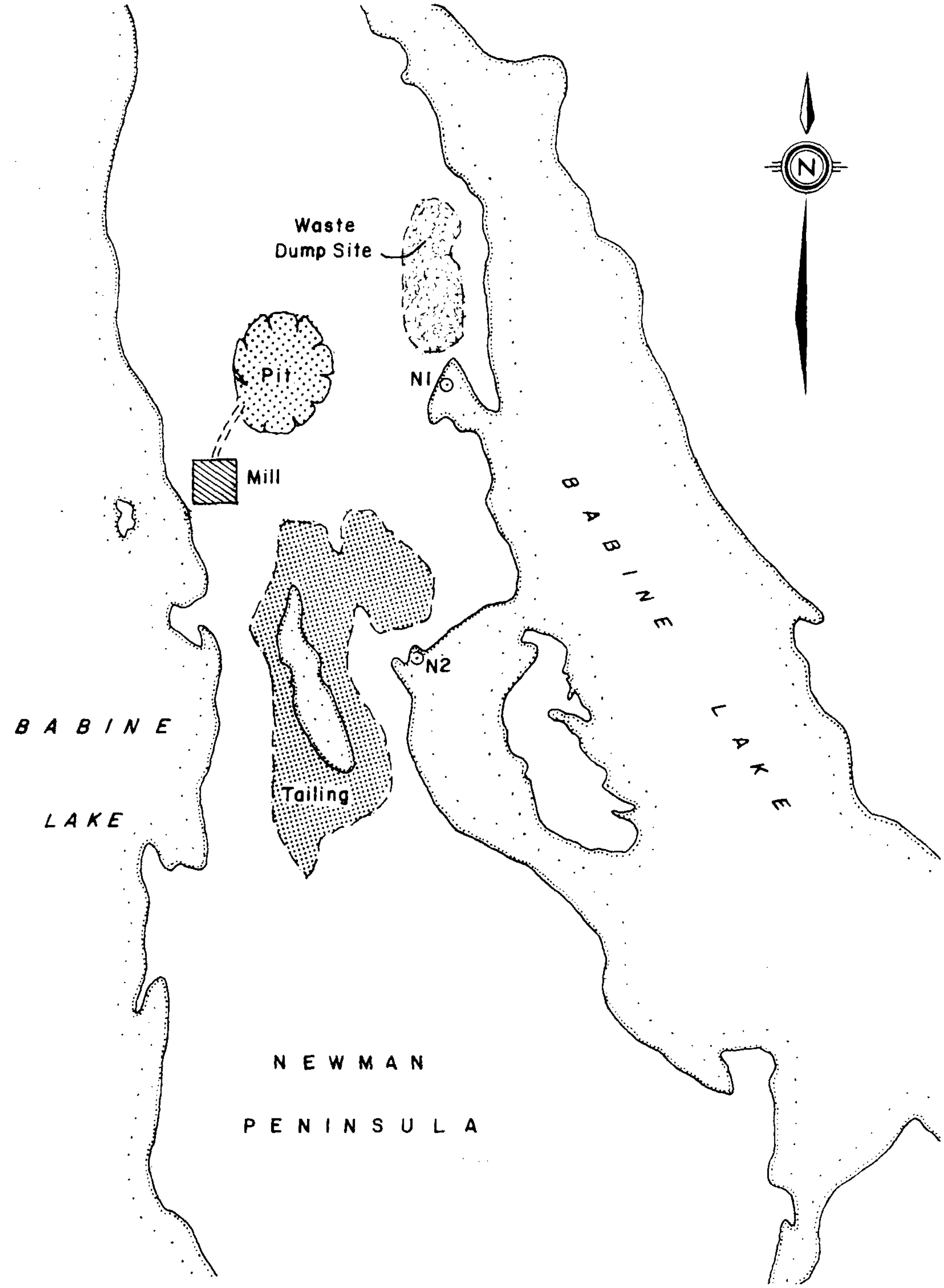


FIGURE 2 BELL COPPER MINE SITE AND EPS SAMPLING LOCATIONS (1972)

TABLE 3 RESULTS OF MAY 21 AND AUGUST 23, 1972 WATER ANALYSES, NORANDA BELL

SITE		DEPTH (m)	SECCHI (feet)	pH	T.R. (mg/l)	Cu (mg/l)	Fe (mg/l)	Zn (mg/l)	JTU
MAY 21/72									
N1	Surface	0	14 (Bottom)	8.0	72.8	< 0.01	< 0.05	< 0.01	1.5
	Centre	1.5		8.0	81.6	< 0.01	< 0.05	< 0.01	1.0
	Bottom	3		8.1	75.9	< 0.01	< 0.05	< 0.01	1.5
N2	Surface	0	19 (Bottom)	7.9	74.1	< 0.01	< 0.05	< 0.01	< 1.0
	Centre	2.5		7.9	64.4	< 0.01	< 0.05	< 0.01	1.5
	Bottom	5		8.0	79.0	< 0.01	0.39	< 0.01	3.5
AUGUST 23/72									
N1	Surface	0		6.8	51	< 0.01	< 0.03	< 0.01	0.45
	Centre			6.8	2				0.68
	Bottom								
N2	Surface	0		6.8	19	< 0.01	< 0.03	< 0.01	0.6
	Centre								
	Bottom			7.1	105				1.7

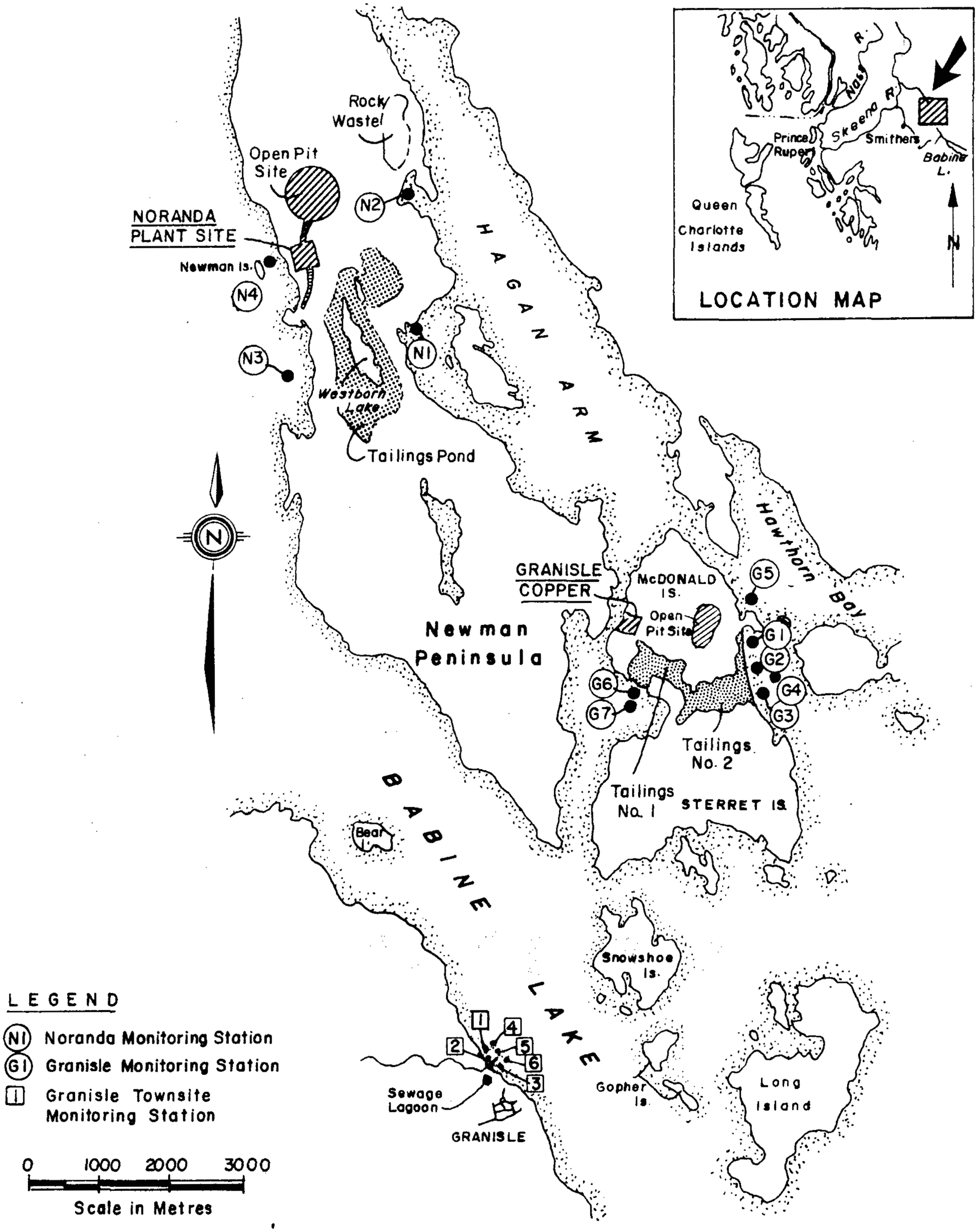


FIGURE 3 EPS MINE MONITORING STATIONS (1974)

TABLE 4 A YEARLY SUMMARY OF NORANDA BELL MONITORING RESULTS FOR TOTAL METAL, PH, AND SO$_4$

STATION	DEPTH	Cd ±0.01 ppm	Cu ±0.01 ppm	Fe ±0.03 ppm	Pb ±0.02 ppm	Zn ±0.01 ppm	SO$_4$ ±5 ppm	pH ±.1 ppm
				MAY 29/1974				
N1	Top	< 0.01	0.01	0.11	< 0.02	0.04		7.0
	Bottom	< 0.01	0.02	0.38	< 0.02	0.06		6.9
N2	Top	< 0.01	< 0.01	0.33	< 0.02	0.08		7.1
	Bottom	< 0.01	< 0.01	0.63	< 0.02	0.07		7.0
N3	Top	< 0.01	< 0.01	0.20	< 0.02	0.06		7.1
	Bottom	< 0.01	< 0.01	0.52	< 0.02	0.07		7.1
N4	Top	< 0.01	0.01	0.32	< 0.02	0.06		7.0
	Mid	< 0.01	0.01	0.49	< 0.02	0.07		7.0
	Bottom	< 0.01	< 0.01	1.2	< 0.02	0.05		7.0
				JULY 20/1974				
N1	Top	< .01	< 0.01	.20	< 0.02	.03	< 5	7.0
	Mid	< .01	0.02	.20	< 0.02	.04	< 5	
	Bottom	< .01	0.01	.11	< 0.02	.02	< 5	7.0
N2	Top	< .01	0.01	.13	< 0.02	.04	< 5	7.5
	Mid	< .01	0.02	.22	< 0.02	.04		
	Bottom	< .01	0.01	.14	< 0.02	.04	< 5	7.0
N3	Top	< .01	0.02	.05	< 0.02	.02	< 5	7.0
	Mid	< .01	0.9	.30	< 0.02	.02	< 5	7.0
	Bottom	< .01	0.01	.13	< 0.02	.02	< 5	7.0
N4	Top	< .01	0.01	.33	< 0.02	.02	11	7.0
	Mid	< .01	0.02	.30	< 0.02	.02	< 5	7.5
	Bottom	< .01	0.01	.08	< 0.02	.01	< 5	7.5
				OCTOBER 19/1974				
N1	Top	< .03	.02	.10	< .02	< .01	5	6.9
	Bottom	< .03	.02	.08	< .02	< .01	5	7.0
N2	Top	< .03	.02	.10	< .02	< .01	6	6.9
	Bottom	< .03	.02	.08	< .02	< .01	6	6.9
N3	Top	< .03	.01	.15	< .02	< .01	< 5	7.0
	Bottom	< .03	.01	.10	< .02	< .01	< 5	6.9
N4	Top	< .03	.01	.11	< .02	.02	7	6.8
	Bottom	< .03	.02	.08	< .02	< .01	6	6.8

TABLE 5 A YEARLY SUMMARY OF NORANDA BELL MONITORING RESULTS FOR RESIDUES, TURBIDITY AND CONDUCTIVITY

STATION	DEPTH	Turb. FTU's	Cond. umko/cm	Total Res. ±2.5 mg/l	Filt. Res. ±2.5 mg/l	Non. Filt. Res. ±2.5 mg/l
MAY 29/1974						
N1	Top	1.8	100	56	51	5.0
	Bottom	1.5	94	59	59	< 2.5
N2	Top	2.0	94	55	50	5.0
	Bottom	2.1	92	62	58	4.0
N3	Top	2.0	89	58	53	5.0
	Bottom	2.0	89	52	44	8.0
N4	Top	1.5	90	51	47	4.0
	Mid	1.8	89	54	48	6.0
	Bottom	1.9	91	67	67	< 2.5
JULY 20/1974						
N1	Top	0.8	94	68	68	< 2.5
	Bottom	1.3	93	71	71	< 2.5
N2	Top	1.2	94	69	69	< 2.5
	Bottom	1.3	94	72	72	< 2.5
N3	Top	1.3	90	67	64	3.1
	Mid	1.6	90	-	-	-
	Bottom	0.8	90	75	72	3.5
N4	Top	1.4	89	64	61	3.2
	Mid	1.2	90	68	65	2.9
	Bottom	1.3	90	72	70	2.7
OCTOBER 19/1974						
N1	Top	0.6	68	70	70	< 3
	Bottom	0.6	66	69	69	< 3
N2	Top	0.6	67	72	72	< 3
	Bottom	0.6	67	69	69	< 3
N3	Top	0.6	64	65	65	< 3
	Bottom	0.6	64	68	68	< 3
N4	Top	0.6	64	65	65	< 3
	Bottom	0.6	64	68	68	< 3

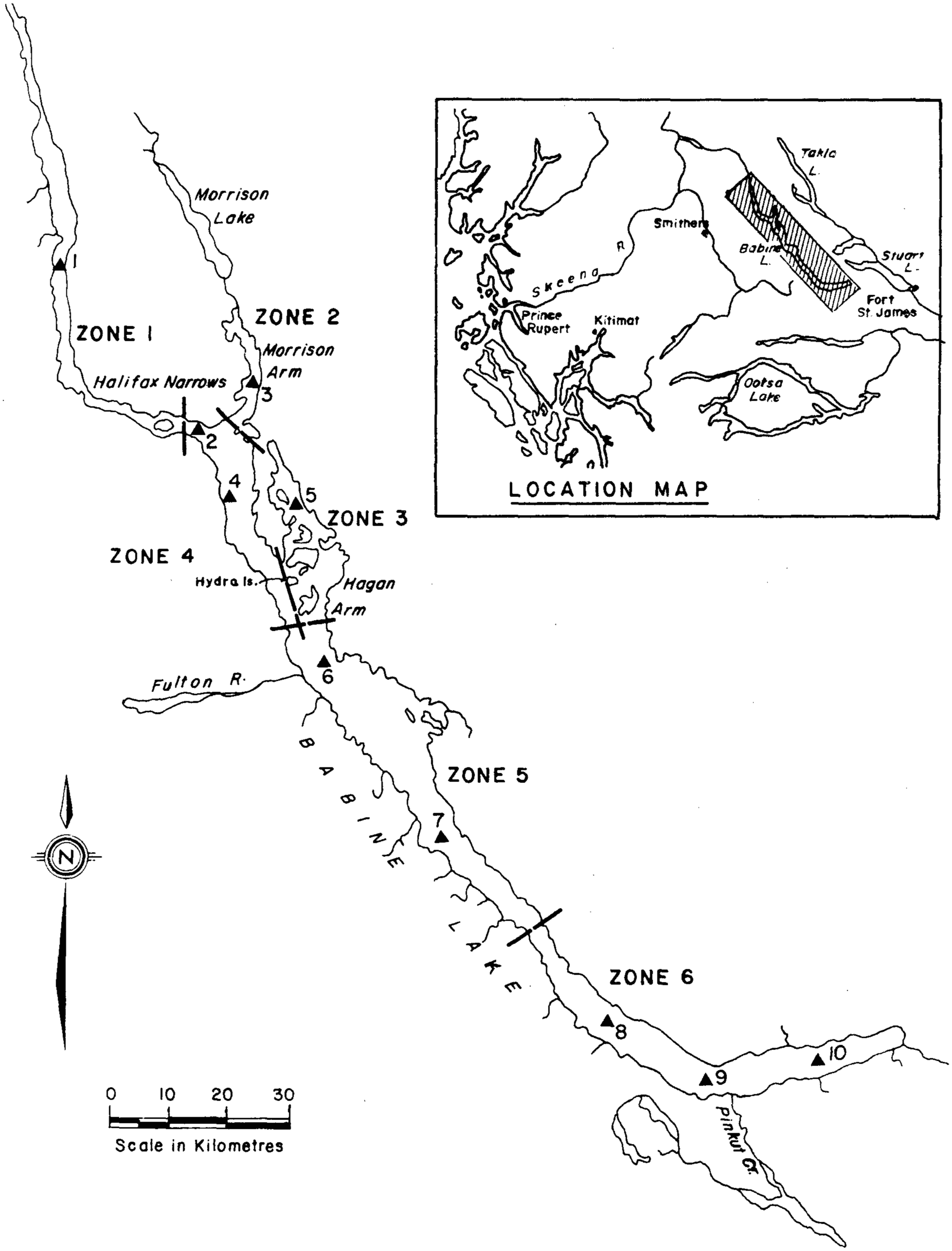


FIGURE 4 SAMPLING LOCATIONS FOR BABINE LAKE WATERSHED CHANGE PROGRAM (1973)

TABLE 6 SEASONAL VARIATION OF SELECTED CHEMICAL PARAMETERS (After Smith and Davidson, MS 1974)

STATION NO. AND LOCATION	DATE 1973	TPO$_4$ g.m^{-3}	PO4 g.m^{-3}	NO$_2$-NO$_3$ g.m^{-3}	SiO$_2$ g.m^{-3}	COND.	T. Alk. g.m^{-3} CaCO$_3$
10 (zone 6)	5/6	<.01	<.02	.05	2.0	91.4	37.5
	18/7	.01	<.02	.07	3.9	78.0	-
	30/9	.01	.02	.07	3.6	97.3	-
	x	<.01	.02	.06	3.2	88.9	37.5
9 (zone 6)	6/6	<.01	<.02	.06	2.0	86.8	34.3
	18/7	.01	<.02	.07	3.9	86.0	-
	30/9	.01	<.02	.07	3.6	84.8	-
	x	.01	<.02	.07	3.2	85.9	34.3
8 (zone 6)	6/6	<.01	<.02	.05	1.9	91.7	36.4
	18/7	.02	<.02	.08	3.8	79.0	-
	30/9	<.01	<.02	.06	3.2	65.9	-
	x	.01	<.02	.06	3.0	78.9	36.4
7 (zone 5)	6/6	<.01	<.02	.05	1.9	91.8	36.7
	18/7	.016	<.02	.07	3.8	77.0	-
	30/9	.016	<.02	.07	3.9	85.0	-
	x	.014	<.02	.06	3.2	84.6	36.7
4 (zone 4)	6/6	<.01	<.02	.05	1.9	92.0	36.2
	18/7	.012	<.02	.08	3.8	82.0	-
	30/9	<.01	<.02	.07	4.1	72.3	-
	x	.01	<.02	.07	3.3	82.1	36.2
3 (zone 2)	6/6	.034	<.02	.03	2.0	74.7	30.8
	13/7	<.01	<.02	.08	3.7	78.0	-
	30/9	<.01	<.02	.06	4.1	100.3	-
	x	.018	<.02	.06	3.3	84.3	30.8
1 (zone 1)	6/6	-	-	-	-	-	-
	13/7	-	-	-	-	-	-
	1/10	<.01	<.02	.07	4.3	119.5	-
	x	<.01	<.02	.07	4.3	119.5	-

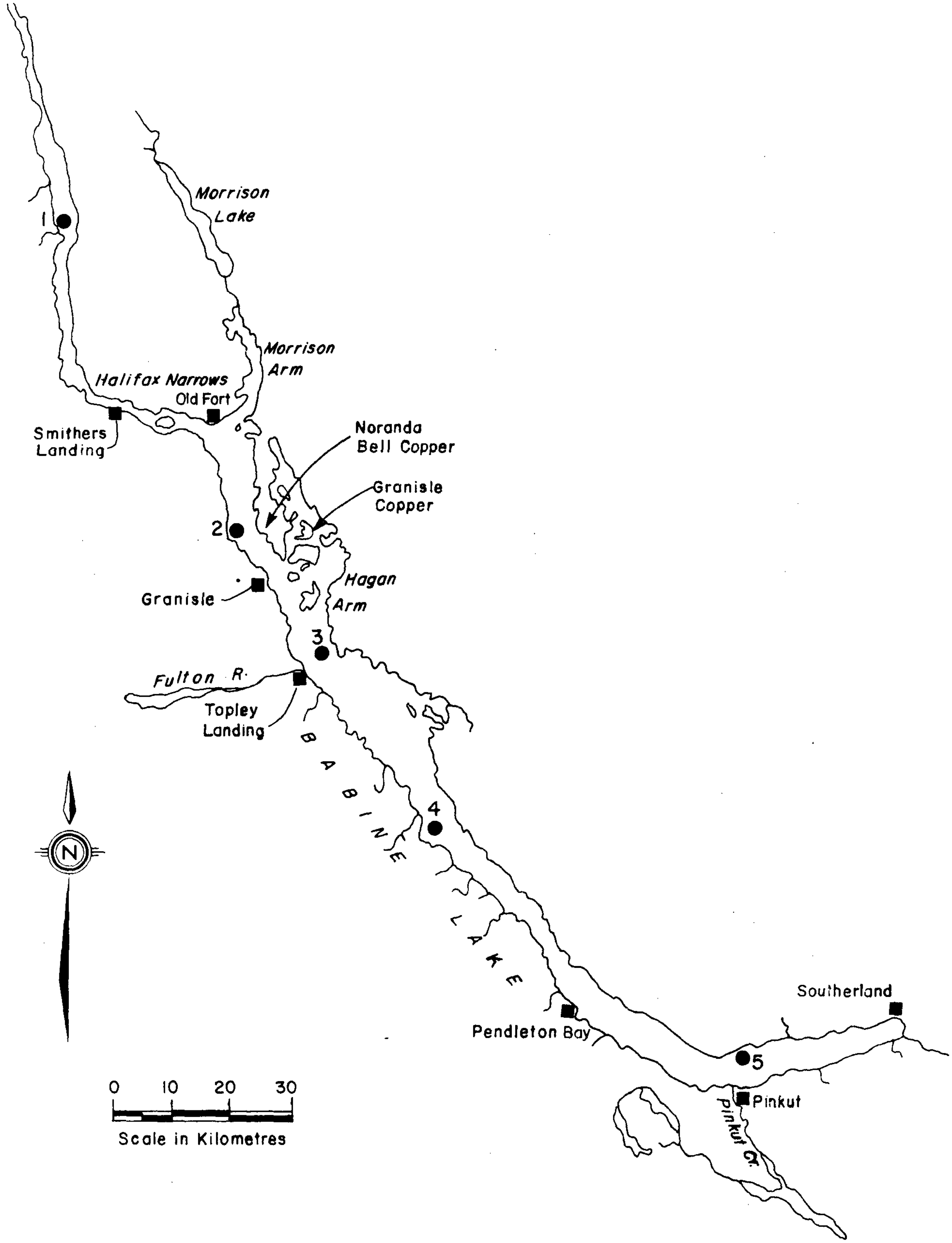


FIGURE 5 SAMPLING STATIONS FOR BABINE LAKE WATERSHED CHANGE PROGRAM (1974 - 1976)

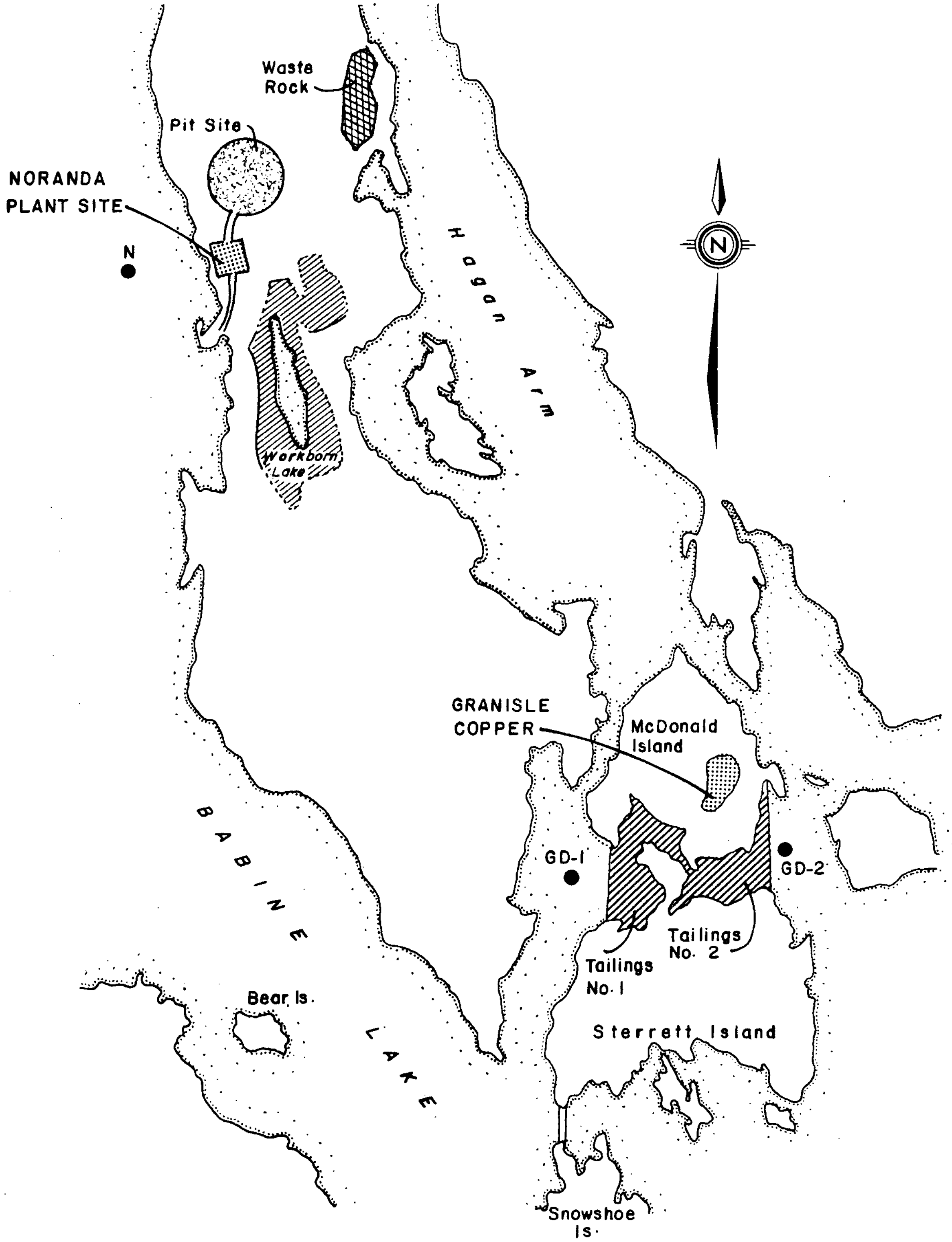


FIGURE 6 MINE MONITORING STATIONS FOR BABINE LAKE WATERSHED CHANGE PROGRAM (1974 - 1976)

TABLE 7 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - July 20 to 23, 1974

PARAMETERS*	STATIONS				
	1	2	3	4	5
pH	7.6	7.7	7.7	7.7	7.6
Total Alkal.$CaCO_3$($mg.l^{-1}$)	35.6	36.6	36.4	37.0	36.3
Nutrients ($mg.l^{-1}$)					
Total Org. C	6.5	6.0	4.3	3.0	5.3
Diss. P	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Total P	0.004	0.005	0.006	0.006	0.008
Diss. N(NO_3+NO_2)	0.07	0.07	0.08	0.09	0.09
Total Kjeldahl N	0.20	0.15	0.19	0.22	0.17
Total N	0.27	0.22	0.27	0.30	0.25
React. SiO_2	4.3	4.2	4.2	4.4	4.5
Diss. Na	1.9	2.0	1.8	1.9	1.9
Diss. K	0.6	0.6	0.6	0.6	0.6
Diss. Cl	0.5	0.6	0.6	0.6	0.6
Diss. SO_4	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total Res. (105C)	63	64	65	65	64
Filt. Res. (105C)	61	62	62	63	62
Spect. Cond. ($umho.cm^{-2}$)	76	78	76	79	79
Turbidity (F.T.U.)	0.8	0.7	0.5	0.5	0.5
Colour	28	23	25	23	23
Heavy Metals[a]($mg.l^{-1}$)					
Cd	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Cu	0.003	0.003	0.002	0.003	0.002
Fe	0.1	0.1	0.1	0.1	0.1
Pb	0.001	0.001	0.001	0.001	0.001
Mo	0.0005	0.0005	0.0005	0.0005	0.0005
Zn	0.006	0.006	0.009	0.005	0.005
Mg	2.2	2.3	2.5	2.5	2.4
Ca	10.4	10.8	10.4	10.4	10.2

*Mean result of four water samples taken throughout the water column: one at surface, above the thermocline, below thermocline and at the bottom.

[a] unfiltered samples

TABLE 8 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - October 19 to 21, 1974

PARAMETERS*	STATIONS				
	1	2	3	4	5
pH	7.7	7.6	7.7	7.7	7.7
Total Alkal.$CaCO_3$($mg.l^{-1}$)	36.8	37.0	37.0	37.2	37.5
<u>Nutrients</u> ($mg.l^{-1}$)					
Total Org. C	9.5	13.0	10.5	9.0	9.0
Diss. P	0.003	0.003	0.003	0.003	0.003
Total P	0.011	0.006	0.006	0.006	0.006
Diss. N(NO_3+NO_2)	0.08	0.09	0.09	0.09	0.09
Total Kjeldahl N	0.39	0.26	0.16	0.15	0.14
Total N	0.47	0.34	0.25	0.24	0.23
React. SiO_2	4.4	4.5	4.4	4.5	4.8
Diss. Na	2.0	2.0	1.9	1.9	2.0
Diss. K	0.6	0.6	0.6	0.6	0.6
Diss. Cl	0.5	0.5	0.5	0.5	0.5
Diss. SO_4	5.0	5.0	5.0	5.0	5.0
Total Res. (105C)	65	65	61	63	63
Filt. Res. (105C)	61	63	59	60	60
Spect. Cond. ($umho.cm^{-2}$)	77	76	78	78	80
Turbidity (F.T.U.)	1.6	0.3	0.4	0.4	0.4
Colour	13	13	15	15	10
<u>Heavy Metals</u>[a] ($mg.l^{-1}$)					
Cd	0.0005	0.0005	0.0005	0.0005	0.0005
Cu	0.002	0.002	0.002	0.002	0.002
Fe	0.1	0.1	0.1	0.1	0.1
Pb	0.001	0.001	0.001	0.001	0.002
Mo	0.0005	0.0005	0.0005	0.0005	0.0005
Zn	0.005	0.005	0.005	0.005	0.005
Mg	2.8	2.8	2.7	2.6	2.7
Ca	10.4	10.5	10.4	10.3	10.44

*Mean result of surface and bottom samples.

[a] unfiltered samples

TABLE 9 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - May 24, 1975

PARAMETERS*	STATIONS				
	1	2	3	4	5
pH	7.4	7.4	7.4	7.4	7.4
Total Alkal.$CaCO_3$(mg.l^{-1})	35.0	36.8	36.8	36.7	36.9
Nutrients (mg.l^{-1})					
Total Org. C	8.5	7.0	7.5	7.5	7.0
Diss. P	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Total P	0.007	0.003	0.004	0.007	0.004
Diss. N(NO_3+NO_2)	0.07	0.09	0.09	0.11	0.10
Total Kjeldahl N	0.17	0.10	0.14	0.23	0.17
Total N	0.24	0.19	0.23	0.34	0.27
React. SiO_2	4.4	4.4	4.5	4.5	4.8
Diss. Na	1.9	1.9	1.9	1.9	1.9
Diss. K	0.6	0.6	0.6	0.6	0.6
Diss. Cl	0.5	< 0.5	< 0.5	< 0.5	< 0.5
Diss. SO_4	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total Res. (105C)	66	64	67	64	66
Filt. Res. (105C)	63	62	65	62	64
Spect. Cond. (umho.cm^{-2})	76	80	81	80	81
Turbidity (F.T.U.)	1.1	0.2	0.4	0.3	0.3
Colour	20	13	10	15	10
Heavy Metals[a](mg.l^{-1})					
Cd	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Cu	0.006	0.006	0.007	0.003	0.002
Fe	0.1	0.1	0.1	0.1	0.1
Pb	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mo	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Zn	0.013	0.008	0.018	< 0.005	< 0.005
Mg	2.6	2.7	2.6	2.7	2.7
Ca	10.0	10.0	10.5	10.5	10.5

*Mean result of surface and bottom samples.

[a] unfiltered samples

TABLE 10 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - July 19, 1975

PARAMETERS*	STATIONS				
	1	2	3	4	5
pH	7.4	7.5	7.5	7.4	7.5
Total Alkal.$CaCO_3$(mg.l^{-1})	36.0	36.7	37.2	37.3	37.3
Nutrients (mg.l^{-1})					
Total Org. C	8.3	7.0	7.0	7.5	6.8
Diss. P	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Total P	0.006	0.006	0.005	0.006	0.007
Diss. N(NO_3+NO_2)	0.06	0.07	0.08	0.08	0.13
Total Kjeldahl N	0.21	0.21	0.15	0.19	0.22
Total N	0.27	0.28	0.23	0.26	0.35
React. SiO_2	4.5	4.5	4.5	4.6	4.7
Diss. Na	1.9	1.9	1.9	1.9	1.9
Diss. K	0.5	0.5	0.5	0.6	0.6
Diss. Cl	0.5	0.5	0.5	< 0.5	< 0.5
Diss. SO_4	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total Res. (105C)	62	63	58	60	65
Filt. Res. (105C)	60	61	56	58	63
Spect. Cond. (umho.cm^{-2})	77	78	79	79	80
Turbidity (F.T.U.)	0.4	0.3	0.3	0.3	0.3
Colour	19	18	16	16	16
Heavy Metals[a](mg.l^{-1})					
Cd	< 0.0005	0.0005	< 0.0005	< 0.0005	0.0001
Cu	0.005	0.006	0.005	0.005	0.006
Fe	< 0.1	< 0.1	< 0.1	0.1	0.3
Pb	< 0.001	0.002	0.001	0.001	0.002
Mo	< 0.0005	< 0.0005	< 0.0005	0.0006	< 0.0005
Zn	< 0.005	0.006	< 0.005	0.006	0.008
Mg	2.6	2.6	2.6	2.6	2.6
Ca	10.2	10.5	10.3	10.5	10.7

*Mean result of surface, above thermocline, below thermocline and bottom samples.

[a] unfiltered samples

TABLE 11 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - October 18, 1975

PARAMETERS*	STATIONS				
	1	2	3	4	5
pH	-	-	-	-	-
Total Alkal.$CaCO_3$($mg.l^{-1}$)	33.2	34.1	34.6	34.3	35.1
Nutrients ($mg.l^{-1}$)					
Total Org. C	6.5	6.0	6.5	6.0	6.0
Diss. P	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Total P	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Diss. N(NO_3+NO_2)	0.05	0.08	0.05	0.07	0.06
Total Kjeldahl N	-	-	-	-	-
Total N	-	-	-	-	-
React. SiO_2	1.9	1.9	1.9	1.9	1.9
Diss. Na	1.9	1.9	1.9	1.9	1.9
Diss. K	0.53	0.53	0.53	0.52	0.54
Diss. Cl	-	-	-	-	-
Diss. SO_4	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total Res. (105C)	-	-	-	-	-
Filt. Res. (105C)	38	38	33	65	60
Spect. Cond. ($umho.cm^{-2}$)	79	78	77	78	78
Turbidity (F.T.U.)	-	-	-	-	-
Colour	18	18	18	18	18
Heavy Metals[a]($mg.l^{-1}$)					
Cd	-	-	-	-	-
Cu	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fe	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Pb	-	-	-	-	-
Mo	-	-	-	-	-
Zn	-	-	-	-	-
Mg	2.5	2.5	2.5	2.5	2.5
Ca	10.5	10.5	10.5	10.0	11.0

*Mean result of surface and bottom samples.

[a] unfiltered samples

TABLE 12 CHEMICAL DATA FOR THE MINE MONITORING STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - July 20, 1974

PARAMETERS*	STATIONS		
	Noranda	Granisle A	Granisle B
pH	7.8	7.7	7.8
Total Alkal.$CaCO_3$(mg.l^{-1})	36.8	37.3	37.5
Nutrients (mg.l^{-1})			
Total Org. C	6.5	8.0	8.5
Diss. P	0.003	0.003	0.003
Total P	0.005	0.007	0.005
Diss. $N(NO_3+NO_2)$	0.06	0.07	0.07
Total Kjeldahl N	0.21	0.17	0.23
Total N	0.27	0.24	0.30
React. SiO_2	4.2	4.1	2.1
Diss. Na	1.9	2.0	1.9
Diss. K	0.6	0.6	0.6
Diss. Cl	0.6	0.6	0.6
Diss. SO_4	< 5.0	5.0	5.0
Total Res. (105C)	63	64	63
Filt. Res. (105C)	61	62	61
Spect. Cond. (umho.cm^{-2})	79	81	80
Turbidity (F.T.U.)	0.8	0.5	0.6
Colour	25	20	25
Heavy Metals[a](mg.l^{-1})			
Cd	< 0.0005	< 0.0005	< 0.0005
Cu	0.004	0.006	0.005
Fe	< 0.1	< 0.1	< 0.1
Pb	< 0.001	< 0.001	< 0.001
Mo	< 0.0005	0.0008	0.0006
Zn	< 0.005	< 0.005	< 0.005
Mg	2.4	2.5	2.5
Ca	9.9	10.6	10.5

*Mean result for surface and bottom samples.

[a] unfiltered samples

TABLE 13 CHEMICAL DATA FOR THE MINE MONITORING STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - October 21, 1974

PARAMETERS*	STATIONS		
	Noranda	Granisle A	Granisle B
pH	7.7	7.8	7.8
Total Alkal.$CaCO_3$($mg.l^{-1}$)	36.9	37.9	37.3
Nutrients ($mg.l^{-1}$)			
Total Org. C	10.0	10.0	9.0
Diss. P	< 0.003	< 0.003	< 0.003
Total P	0.005	0.007	0.006
Diss. N(NO_3+NO_2)	0.07	0.09	0.07
Total Kjeldahl N	0.23	0.17	0.09
Total N	0.30	0.25	0.16
React. SiO_2	4.3	4.2	4.3
Diss. Na	2.0	2.3	2.0
Diss. K	0.6	0.7	0.6
Diss. Cl	< 0.5	< 0.5	< 0.5
Diss. SO_4	< 5.0	5.0	< 5.0
Total Res. (105C)	64	66	61
Filt. Res. (105C)	61	66	61
Spect. Cond. ($umho.cm^{-2}$)	76	84	80
Turbidity (F.T.U.)	0.4	0.5	0.9
Colour	10	10	10
Heavy Metals[a]($mg.l^{-1}$)			
Cd	< 0.0005	< 0.0005	< 0.0005
Cu	0.002	0.004	0.004
Fe	< 0.1	< 0.1	< 0.1
Pb	< 0.001	< 0.001	< 0.001
Mo	0.0007	0.0007	0.0007
Zn	< 0.005	< 0.005	< 0.005
Mg	2.8	2.7	2.6
Ca	10.7	10.9	10.8

*Mean result for surface and bottom samples.

[a] unfiltered samples

TABLE 14 CHEMICAL DATA FOR THE MINE MONITORING STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - May 24, 1975

PARAMETERS*	STATIONS		
	Noranda	Granisle A	Granisle B
pH	7.5	8.0	7.5
Total Alkal.$CaCO_3$(mg.l^{-1})	36.8	37.2	36.6
<u>Nutrients</u> (mg.l^{-1})			
Total Org. C	6.5	8.0	7.5
Diss. P	< 0.003	< 0.003	< 0.003
Total P	0.003	0.003	0.004
Diss. N(NO_3+NO_2)	0.09	0.10	0.08
Total Kjeldahl N	0.13	0.15	0.12
Total N	0.22	0.25	0.20
React. SiO_2	4.4	4.4	4.4
Diss. Na	2.0	2.2	2.1
Diss. K	0.6	0.6	0.6
Diss. Cl	0.5	0.5	0.5
Diss. SO_4	5.0	5.0	5.0
Total Res. (105C)	61	72	70
Filt. Res. (105C)	59	70	68
Spect. Cond. (umho.cm^{-2})	80	85	82
Turbidity (F.T.U.)	0.3	0.3	0.6
Colour			
<u>Heavy Metals</u>[a](mg.l^{-1})			
Cd	< 0.0005	< 0.0005	< 0.0005
Cu	0.005	0.004	0.005
Fe	0.2	< 0.1	0.1
Pb	< 0.001	< 0.001	< 0.001
Mo	0.0005	0.0005	0.0005
Zn	0.006	< 0.005	< 0.005
Mg	2.6	2.7	2.7
Ca	10.6	11.0	10.7

*Mean result of surface and bottom samples.

[a] unfiltered samples

TABLE 15 CHEMICAL DATA FOR THE MINE MONITORING STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - July 20, 1975

PARAMETERS*	STATIONS		
	Noranda	Granisle A	Granisle B
pH	7.6	7.8	7.7
Total Alkal.$CaCO_3$(mg.l^{-1})	36.5	37.4	37.4
Nutrients (mg.l^{-1})			
Total Org. C	8.0	8.0	9.0
Diss. P	< 0.003	< 0.003	< 0.003
Total P	0.006	0.005	0.005
Diss. N(NO_3+NO_2)	0.05	0.05	0.06
Total Kjeldahl N	0.26	0.34	0.20
Total N	0.31	0.39	0.26
React. SiO_2	4.3	4.2	4.2
Diss. Na	1.9	1.9	1.9
Diss. K	0.5	0.5	0.5
Diss. Cl	0.5	0.5	0.5
Diss. SO_4	< 5.0	7.5	< 5.0
Total Res. (105C)	60	62	68
Filt. Res. (105C)	58	60	66
Spect. Cond. (umho.cm^{-2})	79	81	81
Turbidity (F.T.U.)	0.5	0.5	0.3
Colour	20	15	15
Heavy Metals[a](mg.l^{-1})			
Cd	< 0.0005	< 0.0005	< 0.0005
Cu	0.004	0.004	0.004
Fe	< 0.1	< 0.1	< 0.1
Pb	0.002	< 0.001	< 0.001
Mo	< 0.0005	< 0.0005	< 0.0005
Zn	< 0.005	< 0.005	< 0.005
Mg	2.6	2.6	2.6
Ca	10.2	10.2	10.5

*Result of single sample at each station.

[a] unfiltered samples

TABLE 16 CHEMICAL DATA FOR THE MINE MONITORING STATIONS FROM THE BABINE LAKE WATERSHED CHANGE MONITORING PROGRAM - October 18, 1975

PARAMETERS*	STATIONS		
	Noranda	Granisle A	Granisle B
pH	-	-	-
Total Alkal.$CaCO_3$(mg.l^{-1})	35.5	35.1	35.5
Nutrients (mg.l^{-1})			
Total Org. C	6.5	6.0	6.0
Diss. P	< 0.01	< 0.01	< 0.01
Total P	< 0.01	< 0.01	< 0.01
Diss. N(NO_3+NO_2)	0.04	0.05	0.05
Total Kjeldahl N	-	-	-
Total N	-	-	-
React. SiO_2	1.8	1.8	1.8
Diss. Na	1.9	1.9	1.9
Diss. K	0.53	0.57	0.53
Diss. Cl	5.0	5.5	5.0
Diss. SO_4	< 5.0	5.5	5.0
Total Res. (105C)	-	-	-
Filt. Res. (105C)	45	55	65
Spect. Cond. (umho.cm^{-2})	79	84	81
Turbidity (F.T.U.)	-	-	-
Colour	18	18	18
Heavy Metals[a](mg.l^{-1})			
Cd	-	-	-
Cu	< 0.01	< 0.01	< 0.01
Fe	< 0.03	< 0.03	< 0.03
Pb	-	-	-
Mo	-	-	-
Zn	-	-	-
Mg	2.5	2.6	2.5
Ca	10.5	10.5	10.5

*Mean result of surface and bottom samples.

[a] unfiltered samples

TABLE 17 COPPER CONCENTRATIONS (mg/l) IN BABINE LAKE AND TRIBUTARY RIVERS ON SELECTED DATES IN 1974 AND 1975

STATION	DATE					
	July/74	Oct/74	May/75	July/75	Oct/75	x
1	0.003	0.003	0.006	0.005	< 0.01	0.004
2	0.003	0.003	0.006	0.006	< 0.01	0.005
3	0.002	0.002	0.007	0.005	< 0.01	0.004
4	0.003	0.002	0.003	0.005	< 0.01	0.003
5	0.002	0.002	0.002	0.006	< 0.01	0.003
$\bar{x}$	0.003	0.002	0.005	0.005	< 0.01	0.004
Noranda	0.004	0.002	0.005	0.004	0.01	0.004
Granisle A	0.006	0.004	0.004	0.004	0.01	0.005
Granisle B	0.005	0.004	0.005	0.004	< 0.01	0.005
$\bar{x}$	0.005	0.003	0.005	0.004	< 0.01	0.004
Babine R.	0.001	0.003	0.002	0.003	0.01	0.002
Pinkut R.	0.001	0.001	0.004	0.001	0.01	0.002
Fulton R.	0.001	< 0.001	0.001	0.001	0.01	0.002
Morrison R.	< 0.001	0.002	0.002	0.002	< 0.01	0.002
$\bar{x}$	0.001	0.002	0.002	0.002	0.01	0.002

TABLE 18 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE MONITORING PROGRAM - May 15 to 16, 1976

TYPE OF ANALYSIS*	STATION				
	1	2	3	4	5
pH	7.2	7.3	7.5	7.3	7.2
Spect. Cond. (umho.cm^{-2})	76.0	79.0	80.0	80.0	81.0
Turbidity (F.T.U.)	0.8	0.2	0.4	0.3	0.8
Colour	20.0	10.0	10.0	10.0	15.0
Nutrients (mg.L^{-1})					
Total Org. C	9.0	8.0	10.0	7.0	7.0
Diss. P	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Total P	0.005	0.004	0.006	0.004	0.006
Diss. N(NO3+NO2)	0.09	0.10	0.10	0.10	0.11
Total Kjeldahl N	0.17	0.15	0.18	0.16	0.44
Total N	0.26	0.25	0.28	0.26	0.55
React. SiO2	4.4	4.4	4.4	4.5	4.8
Diss. Na	2.0	2.0	2.0	2.0	2.2
Diss. K	0.5	0.5	0.6	0.6	0.7
Diss. Cl	0.6	0.5	0.5	0.7	< 0.5
Diss. SO4	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total Res. (105C)	64.0	66.0	62.0	64.0	70.0
Filt. Res. (105C)	60.0	64.0	60.0	62.0	66.0
Total Alkal.CaCO$_3$(mg.L^{-1})	33.6	35.5	36.5	35.5	36.0
Heavy Metals[a](mg.L^{-1})					
Cd	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0039
Cu	0.002	0.004	0.003	0.003	0.023
Fe	.2	< 0.1	< 0.1	0.1	0.1
Pb	< 0.001	< 0.001	< 0.001	< 0.001	0.01
Mo	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Zn	< 0.005	< 0.005	< 0.005	< 0.005	0.05
Mg	2.3	2.5	2.4	1.9	2.6
Ca	10.4	10.8	10.6	10.6	11.1

*From Stockner and Shortreed, 1978

[a] unfiltered samples

TABLE 19 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE MONITORING PROGRAM - July 18 to 20, 1976*

TYPE OF ANALYSIS*	STATION				
	1	2	3	4	5
pH	7.8	7.8	7.9	7.9	7.8
Spect. Cond. (umho.cm^{-2})	74.0	77.0	76.0	77.0	77.0
Turbidity (F.T.U.)	8.0	0.5	0.5	0.5	0.4
Colour	25.0	20.0	20.0	20.0	20.0
<u>Nutrients</u> (mg.L^{-1})					
Total Org. C	8.0	8.0	7.0	8.0	7.0
Diss. P	< 0.003	< 0.003	< 0.003	0.004	< 0.003
Total P	0.005	0.006	0.006	0.007	0.007
Diss. N(NO3+NO2)	0.07	0.07	0.07	0.08	0.06
Total Kjeldahl N	0.20	0.18	0.21	0.19	0.18
Total N	0.27	0.25	0.28	0.27	0.23
React. SiO2	4.2	4.2	4.3	4.5	4.7
Diss. Na	2.1	2.1	2.0	2.1	2.0
Diss. K	0.6	0.6	0.6	0.6	0.6
Diss. Cl	0.5	< 0.5	0.5	0.5	< 0.5
Diss. SO4	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total Res. (105C)	61.0	64.0	63.0	62.0	64.0
Filt. Res. (105C)	58.0	62.0	61.0	60.0	62.0
Total Alkal.$CaCO_3$(mg.L^{-1})	35.8	36.7	36.4	37.0	37.4
<u>Heavy Metals</u>[a](mg.L^{-1})					
Cd	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Cu	0.007	0.006	0.006	0.005	0.005
Fe	.01	0.1	< 0.1	0.1	0.1
Pb	0.002	< 0.001	0.002	0.002	< 0.001
Mo	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Zn	0.011	< 0.005	0.007	0.006	0.006
Mg	2.5	2.5	2.6	2.6	2.7
Ca	10.3	10.5	10.6	10.5	10.5

*From Stockner and Shortreed, 1978

[a] unfiltered samples

TABLE 20 CHEMICAL DATA FOR THE LAKE STATIONS FROM THE BABINE LAKE MONITORING PROGRAM - October 3 to 4, 1976

TYPE OF ANALYSIS*	STATION				
	1	2	3	4	5
pH	7.9	7.8	7.7	7.8	7.9
Spect. Cond. (umho.cm^{-2})	78.0	78.0	77.0	78.0	78.0
Turbidity (F.T.U.)	0.4	0.4	0.4	0.4	0.5
Colour	15	20	15	15	20
Nutrients (mg.L^{-1})					
Total Org. C	7.0	7.0	8.0	6.0	6.0
Diss. P	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Total P	0.005	0.004	0.004	0.005	0.006
Diss. N(NO3+NO2)	0.05	0.06	0.06	0.06	0.06
Total Kjeldahl N	0.19	0.17	0.13	0.14	0.17
Total N	0.24	0.23	0.19	0.20	0.23
React. SiO2	4.0	4.1	4.1	4.2	4.4
Diss. Na	1.9	2.0	2.0	2.0	2.0
Diss. K	0.5	0.6	0.6	0.6	0.6
Diss. Cl	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Diss. SO4	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total Res. (105C)	64	66	62	62	64
Filt. Res. (105C)	62	64	60	60	62
Total Alkal.$CaCO_3$(mg.L^{-1})	36.5	36.2	36.4	36.0	37.5
Heavy Metals[a](mg.L^{-1})					
Cd	< 0.0005	< 0.0005	< 0.0005	0.0007	< 0.0005
Cu	0.002	0.002	0.002	0.003	< 0.001
Fe	< .01	0.1	< 0.1	0.1	< 0.1
Pb	0.002	< 0.001	0.005	< 0.001	< 0.001
Mo	< 0.0005	< 0.0005	0.0005	0.0006	0.0005
Zn	< 0.005	< 0.005	0.020	0.008	< 0.005
Mg	2.6	2.6	2.6	2.6	2.7
Ca	10.1	9.8	9.8	9.6	9.9

*From Stockner and Shortreed, 1978

[a] unfiltered samples

TABLE 21 CHEMICAL DATA FOR THE MINE MONITORING STATIONS FROM THE BABINE LAKE MONITORING PROGRAM - May 15 to 16, 1976

TYPE OF ANALYSIS*	STATION		
	Noranda	Granisle A	Granisle B
pH	7.5	7.5	7.4
Spect. Cond. (umho.cm^{-2})	80	85	82
Turbidity (F.T.U.)	0.3	0.3	0.6
Colour	-	-	-
Nutrients (mg.L^{-1})			
Total Org. C	6.5	8.0	7.5
Diss. P	< 0.003	< 0.003	< 0.003
Total P	0.003	0.003	0.004
Diss. N(NO_3+NO_2)	0.09	0.10	0.08
Total Kjeldahl N	0.13	0.15	0.12
Total N	0.22	0.25	0.20
React. SiO_2	4.4	4.4	4.4
Diss. Na	2.0	2.2	2.1
Diss. K	0.6	0.6	0.6
Diss. Cl	0.5	0.5	0.5
Diss. SO_4	5.0	5.0	5.0
Total Res. (105C)	61	72	70
Filt. Res. (105C)	59	70	68
Total Alkal.$CaCO_3$(mg.L^{-1})	36.8	37.2	36.6
Heavy Metals[a] (mg.L^{-1})			
Cd	< 0.0005	< 0.0005	< 0.0005
Cu	0.005	0.004	0.005
Fe	0.2	< 0.1	0.1
Pb	< 0.001	< 0.001	< 0.001
Mo	0.0005	0.0005	0.0005
Zn	0.006	< 0.005	< 0.005
Mg	2.6	2.7	2.7
Ca	10.6	11.0	10.7

*From Stockner and Shortreed, 1978

[a] unfiltered samples

TABLE 22 CHEMICAL DATA FOR THE MINE MONITORING STATIONS FROM THE BABINE LAKE MONITORING PROGRAM - July 18 to 20, 1976

TYPE OF ANALYSIS*	STATION		
	Noranda	Granisle A	Granisle B
pH	7.7	7.8	7.8
Spect. Cond. (umho.cm^{-2})	76	84	80
Turbidity (F.T.U.)	0.4	0.5	0.9
Colour	10	10	10
Nutrients (mg.L^{-1})			
Total Org. C	10.0	10.0	9.0
Diss. P	< 0.003	< 0.003	< 0.003
Total P	0.005	0.007	0.006
Diss. N(NO_3+NO_2)	0.07	0.09	0.07
Total Kjeldahl N	0.23	0.17	0.09
Total N	0.30	0.25	0.16
React. SiO_2	4.3	4.2	4.3
Diss. Na	2.0	2.3	2.0
Diss. K	0.6	0.7	0.6
Diss. Cl	< 0.5	< 0.5	< 0.5
Diss. SO_4	< 5.0	5.0	< 5.0
Total Res. (105C)	64	66	61
Filt. Res. (105C)	61	66	61
Total Alkal.$CaCO_3$(mg.L^{-1})	36.9	37.9	37.3
Heavy Metals[a](mg.L^{-1})			
Cd	< 0.0005	< 0.0005	< 0.0005
Cu	0.002	0.004	0.004
Fe	< 0.1	< 0.1	< 0.1
Pb	< 0.001	< 0.001	< 0.001
Mo	0.0007	0.0007	0.0007
Zn	< 0.005	< 0.005	< 0.005
Mg	2.8	2.7	2.6
Ca	10.7	10.9	10.8

*From Stockner and Shortreed, 1978

[a] unfiltered samples

2.2 Monitoring Program of Supernatant Discharge by Bell Mine into the Hagan Arm

Bell Mine received approval to discharge supernatant from the tailings impoundment of Bell Mine into the Hagan Arm of Babine Lake on October 18, 1983. Various sampling surveys were conducted in order to determine the effect of effluent on the receiving water. The effluent discharge reports by P. Kennedy from February 1983 to August 1983 are summarized in the following paragraphs and tables.

2.2.1 Characteristics of the Effluent and the Receiving Water Data Conducted by Bell Mine.

During the period of October 1982 to February 1983 a total of 729,108 cubic metres of effluent with an average dissolved copper content 0.032 ppm was discharged into Hagan Arm. Average sulphate and specific conductivity values were 1500 ppm and 263 umhos/cm respectively. The low level of concentrations of heavy metals in the discharge water and the considerable dilution factor of the lake water present a problem if metals are to be selected as plume indicators. For this reason Bell Mine (Kennedy, 1983) used conductivity and sulphates which were in higher concentrations in an attempt to trace an effluent plume.

Bell Mine conducted a water sampling program in the last two weeks of January 1983 in the Rum Bay area of Hagan Arm to determine the effect of effluent in the receiving area. After temporary discontinuance of discharge, two more sampling surveys were conducted in the second week of February and in the second week of May. Sampling sites for these surveys are shown in Figure 7. Dissolved copper, conductivity and sulphate values are plotted against depth, and the results are shown in Figures 8 through 12.

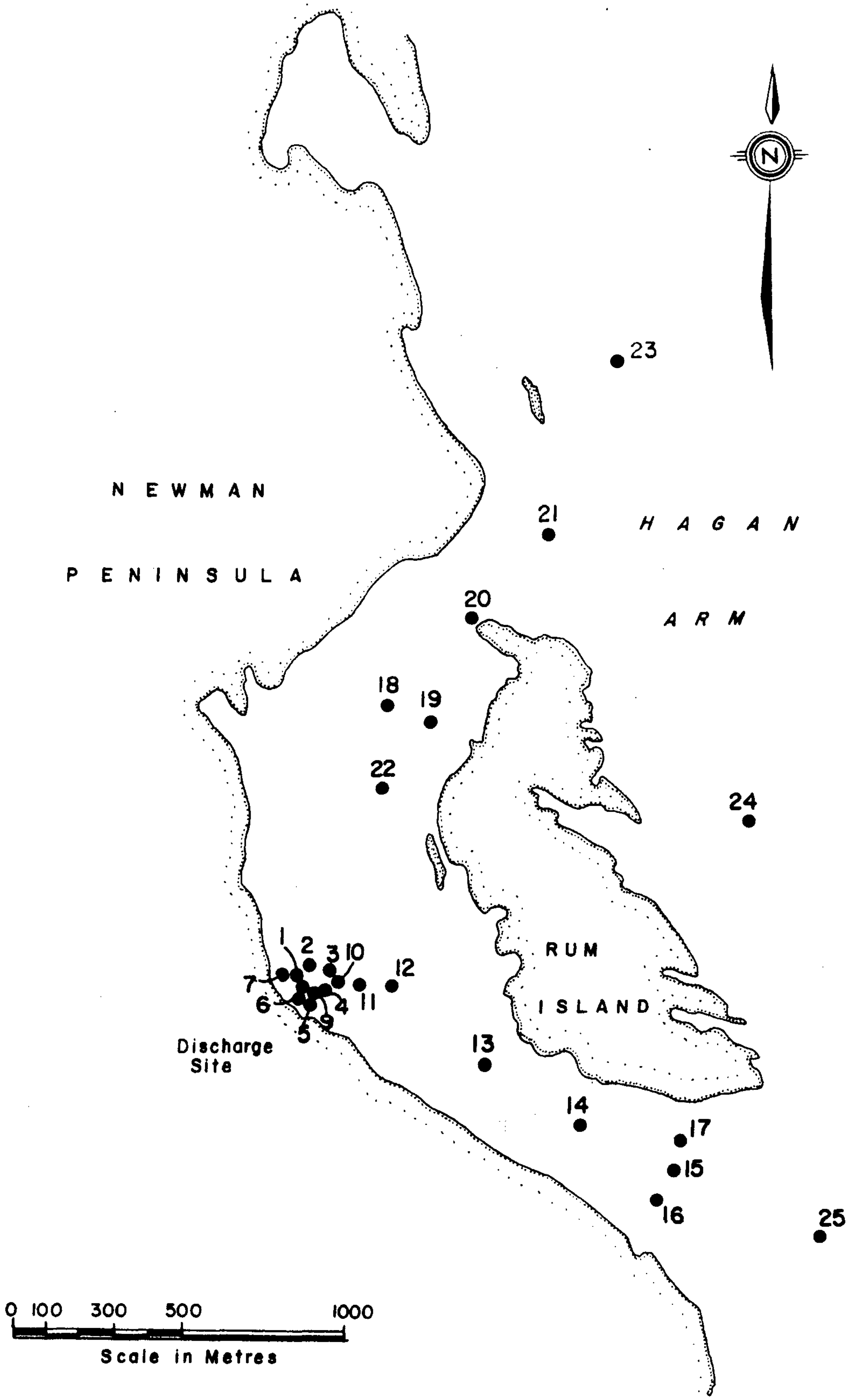


FIGURE 7 SAMPLING SITES FOR WATER MONITORING PROGRAM CONDUCTED BY BELL MINE AND WASTE MANAGEMENT BRANCH, January 1983 to May 1983

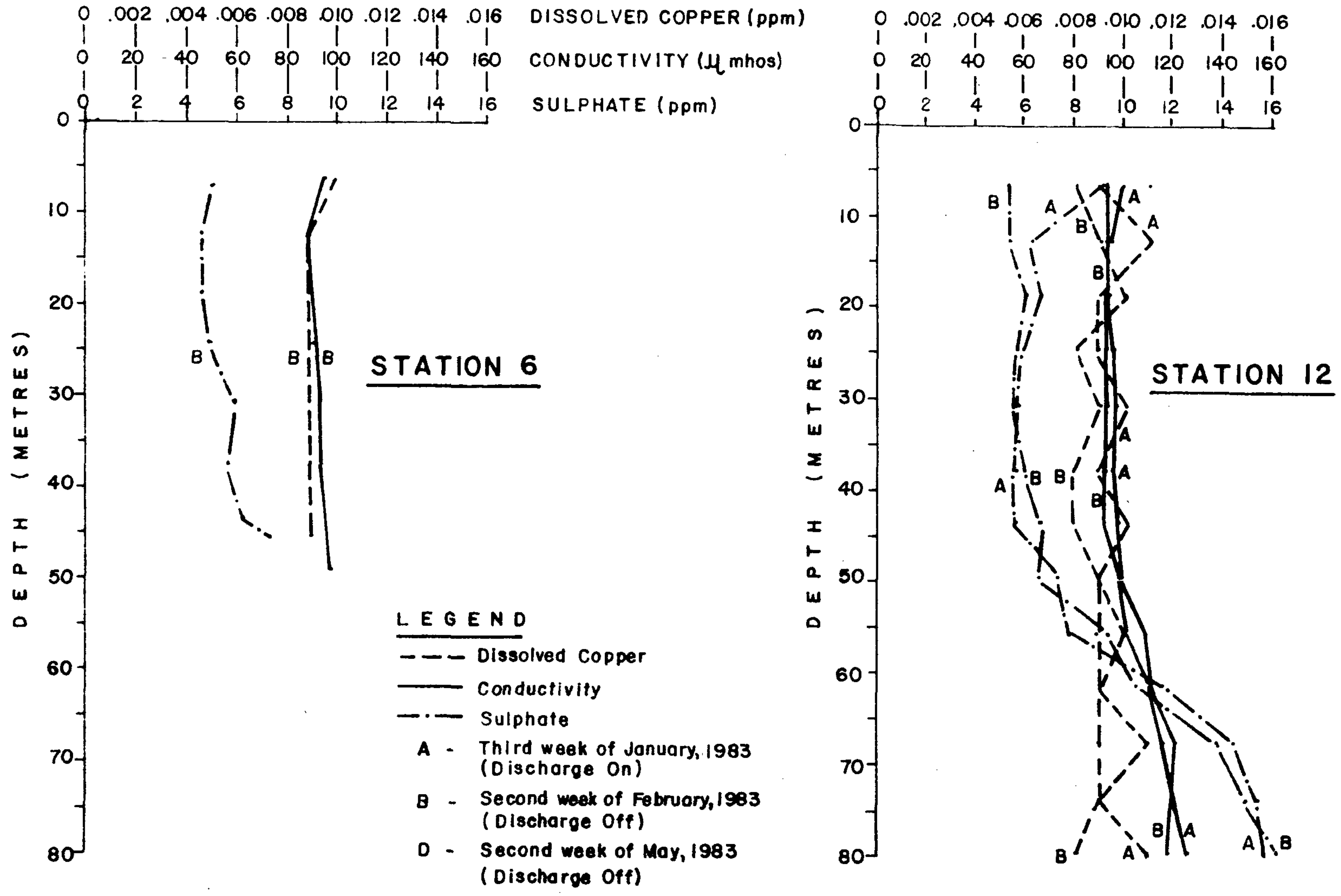


FIGURE 8 BELL MINE DISSOLVED COPPER, CONDUCTIVITY AND SULPHATE SURVEY RESULTS FROM STATIONS 6 AND 12 LOCATED NEAR THE HAGAN ARM EFFLUENT RECEIVING AREA

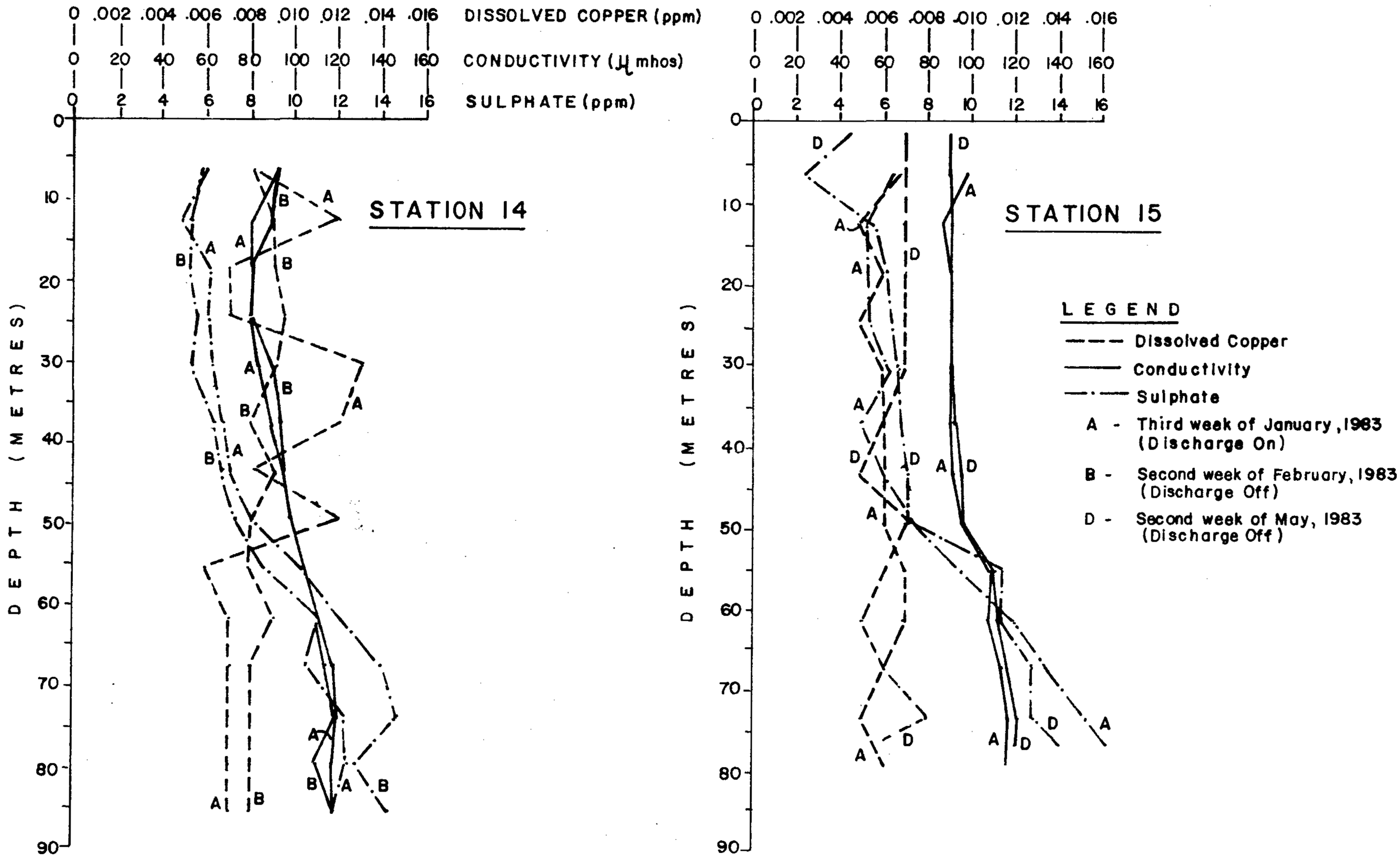


FIGURE 9 BELL MINE DISSOLVED COPPER, CONDUCTIVITY AND SULPHATE SURVEY RESULTS FROM STATIONS 14 AND 15 IN THE CHANNEL SOUTH OF RUM ISLAND

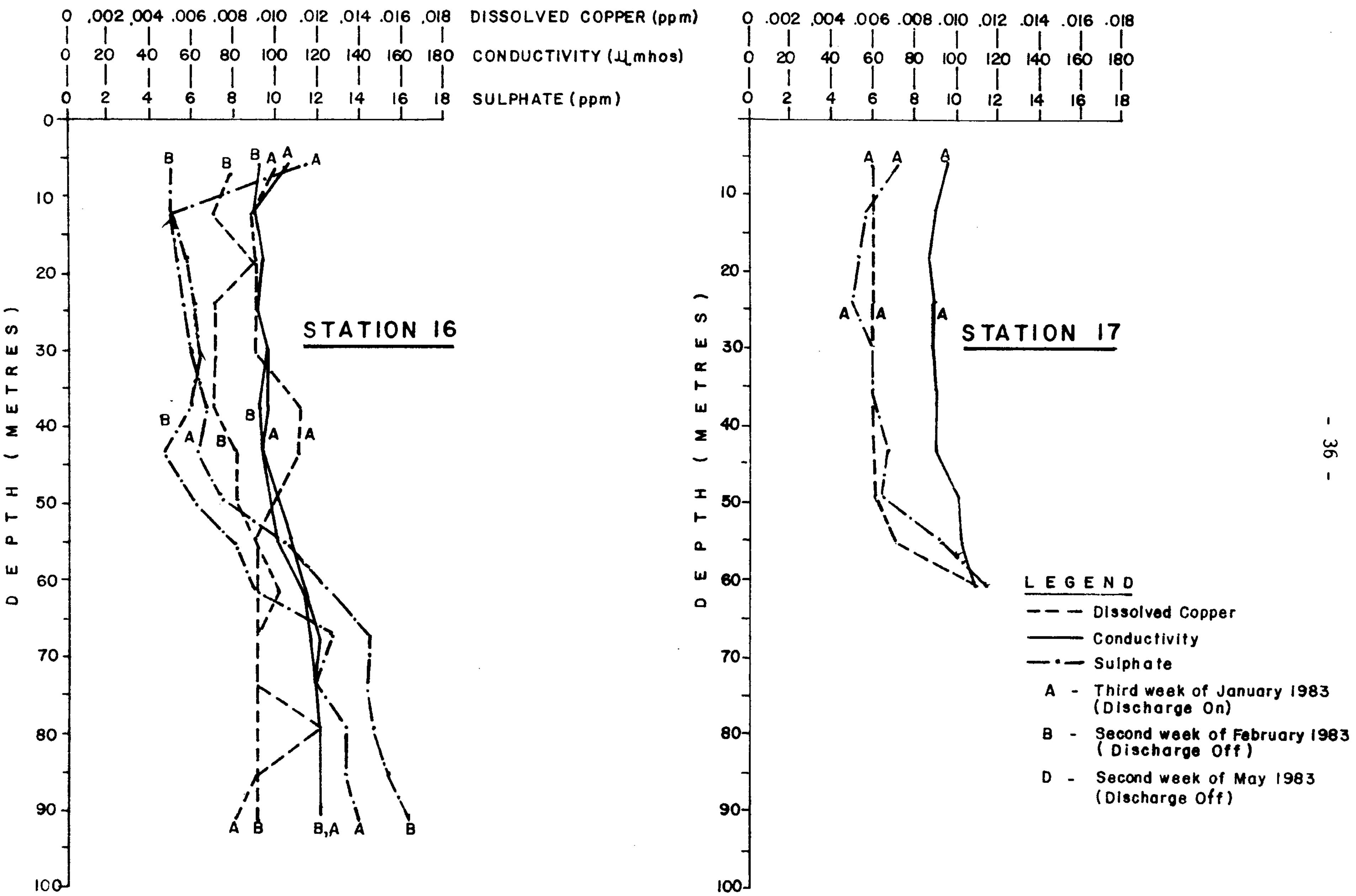


FIGURE 10 BELL MINE DISSOLVED COPPER CONDUCTIVITY AND SULPHATE SURVEY RESULTS FROM STATIONS 16 AND 17 SOUTH OF RUM ISLAND

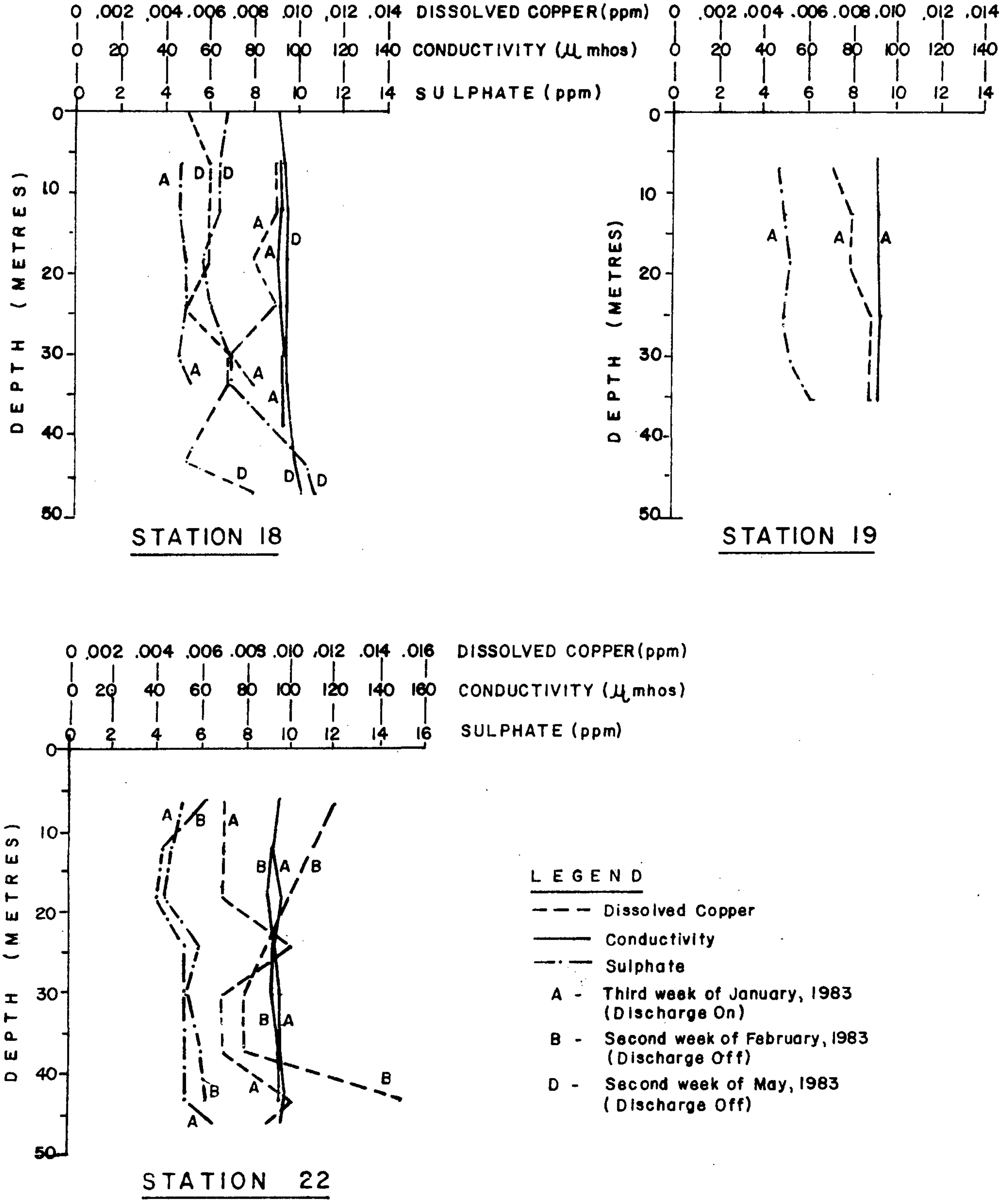


FIGURE 11 BELL MINE DISSOLVED COPPER, CONDUCTIVITY AND SULPHATE SURVEY RESULTS FROM STATIONS 18, 19 AND 22 IN RUM BAY NORTHEAST OF RUM ISLAND

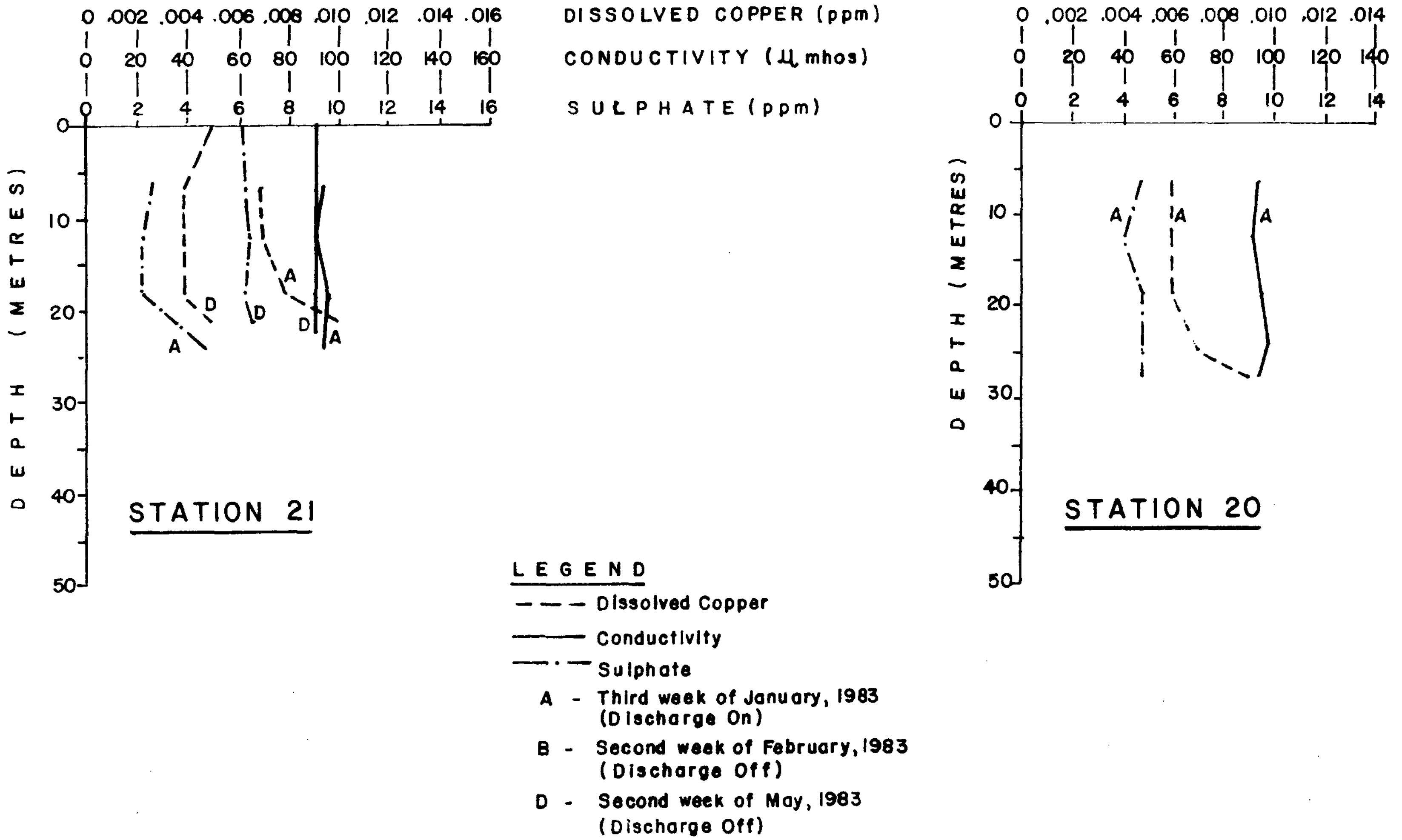
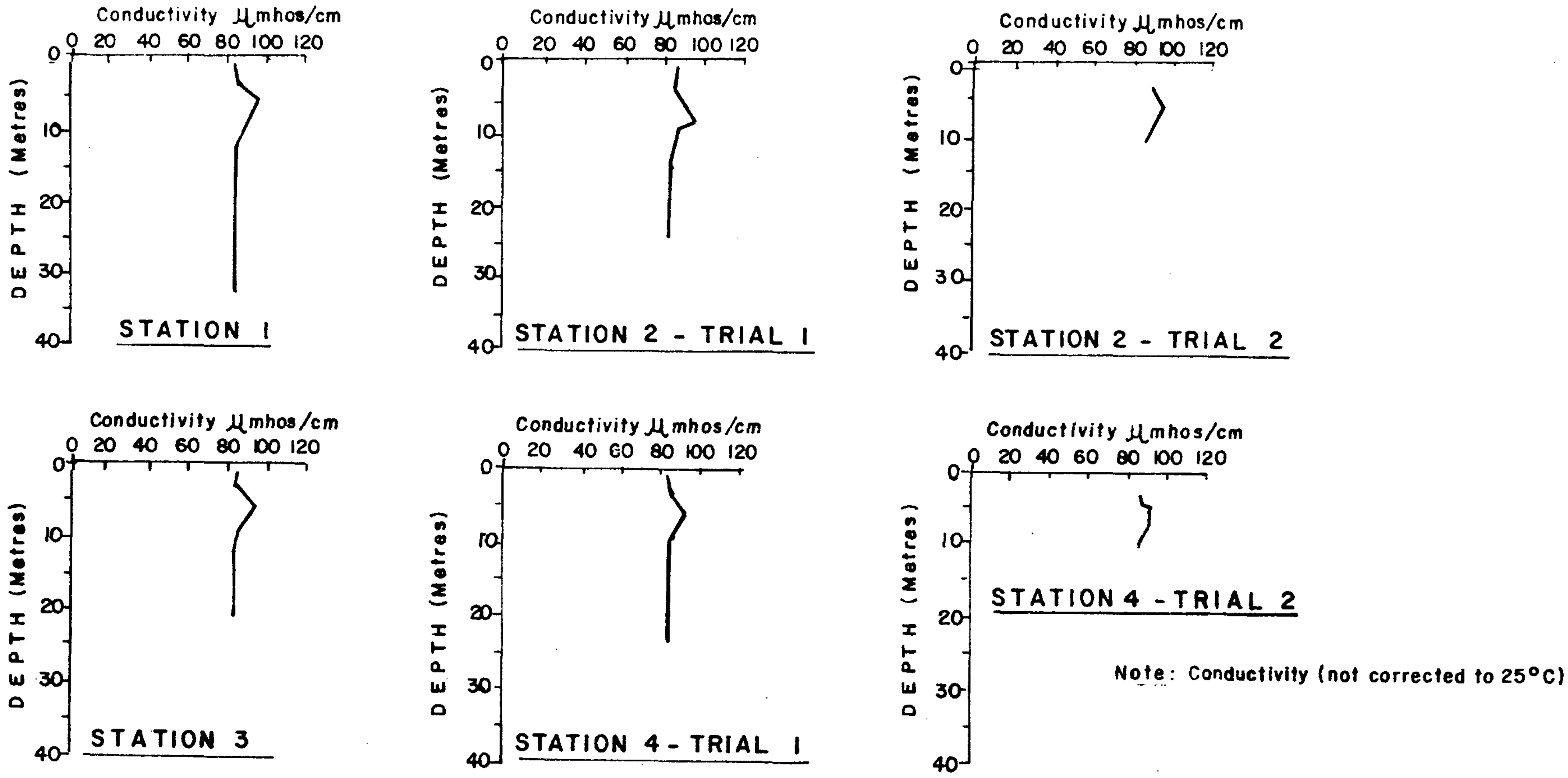


FIGURE 12 BELL MINE DISSOLVED COPPER, CONDUCTIVITY AND SULPHATE SURVEY RESULTS FROM STATIONS 20 AND 21 NORTH OF RUM ISLAND

2.2.2 Interpretation of Bell Mine Data. Data collected by Bell Mine during their water sampling surveys indicated that at Stations 12, 14, 15, 16 and 17 there was an increase in conductivity and sulphate content near the lake bottom. Unfortunately Stations 18, 19, 20, 21 and 22, were not sampled below 50 meters to the lake bottom so whether conductivity and sulphate concentrations increased near the lake bottom is unknown. Dissolved copper values did not always increase with depth.

February 1983 (discharge off) data show that in the upper zone (top 15 m), conductivity values at Station 14 had increased slightly and dissolved copper content at Station 22 had inreased considerably compared to January 1983 data. May 1983 (discharge off) surveys indicate an increase in sulphate concentrations at Station 15 compared to the data from January 1983 (discharge on). These findings do not indicate complete mixing and dilution of effluent during the shutdown period at the above-mentioned sites.

2.2.3 Hydrolab Survey Results of Waste Management Branch. The Waste Management Branch (Smithers , B.C.) conducted a water sampling and conductivity survey in the last two weeks of January 1983 in conjunction with Bell Mine Company. Vertical conductivity profiles were recorded with a Hydrolab 8000 system at Stations 1 through 12. From the results of this survey (Figures 13 through 15) the Waste Management Branch suggested that a lens of dilute effluent had spread horizontzally at a depth of between 5 and 10 metres under the ice and had a maximum concentration at 6 to 8 meters in depth. Conductivity of the effluent was 1600 umhos/cm at 1.8°C (2342 umhos/cm at 25°C) . The Hydrolab data gave consistent background readings of 83 umhos/cm at approximately 4°C (118 umhos/cm at 25°C) in the lake. The maximum elevation of conductivity was only about 11 umhos/cm above the background. The conductivity readings of the Stations 1, 7 and 8 which were 33 metres away from the discharge point were similar to Stations 11 and 12 which were located 0.3 and 0.5 km away from the discharge site. As the conductivity of the effluent at this survey was 1600 umhos/cm, clearly some dilution of the effluent took place.



STATION 1

STATION 2 - TRIAL 1

STATION 2 - TRIAL 2

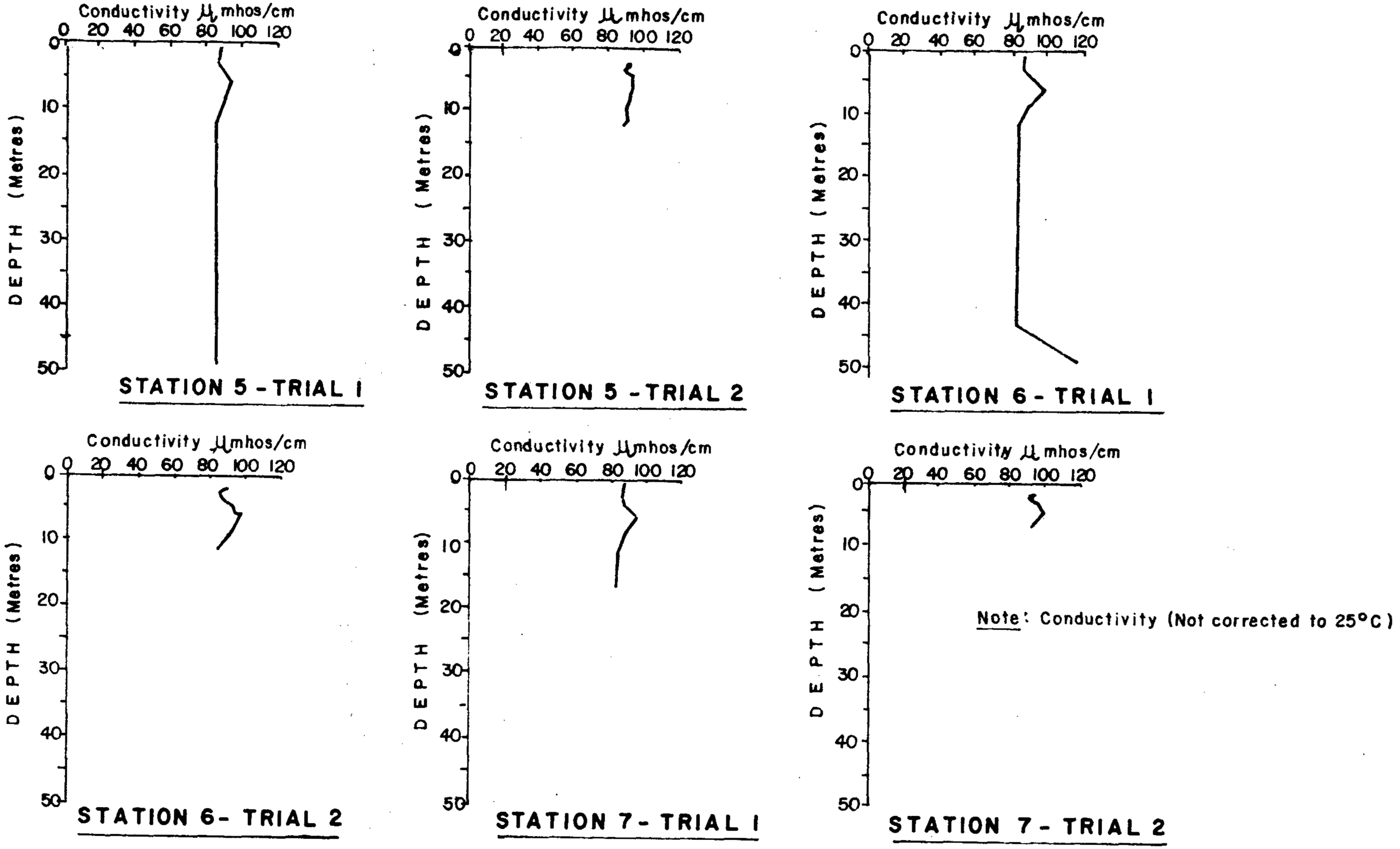
STATION 3

STATION 4 - TRIAL 1

STATION 4 - TRIAL 2

Note: Conductivity (not corrected to 25°C)

FIGURE 13 WMB CONDUCTIVITY PROFILES FOR STATIONS 1 TO 4 IN RUM BAY NEAR EFFLUENT RECEIVING AREA - January 18, 1983


STATION 5 - TRIAL I

STATION 5 - TRIAL 2

STATION 6 - TRIAL I

STATION 6 - TRIAL 2

STATION 7 - TRIAL I

STATION 7 - TRIAL 2

FIGURE 14 WMB CONDUCTIVITY PROFILES FOR STATIONS 5 TO 7 IN RUM BAY NEAR EFFLUENT RECEIVING AREA - January 18, 1983

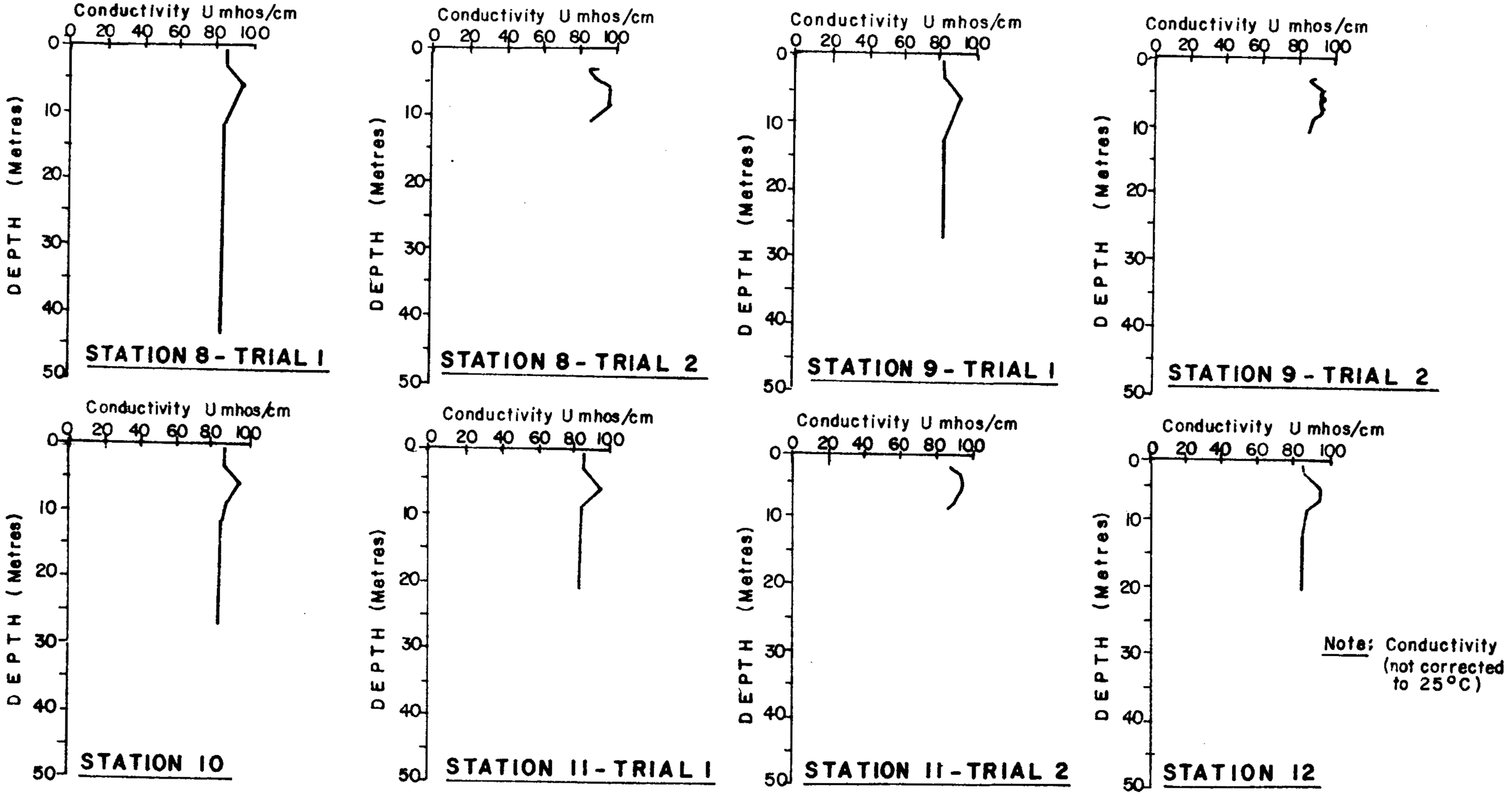


FIGURE 15 WMB CONDUCTIVITY PROFILES FOR STATIONS 8 TO 12 IN RUM BAY NEAR EFFLUENT RECEIVING AREA - January 18, 1983

3. COMPLEXING CAPACITY OF BABINE LAKE WATER

A study by Chau and Wong (1975) suggests that compared to the Great Lakes, Babine Lake has normal pH but low conductivity (Figure 16, Table 23). The low conductivity implies low hardness, which in turn indicates that the lake water is quite sensitive to toxic effect of heavy metals. However, due to high dissolved organic matter indicated by dissolved organic carbon and nitrogen (Table 23), Babine Lake has a high complexing capacity. This high complexing capacity reflects that the water has ample capacity to complex ionic copper or other heavy metals to overcome toxicity (Chau and Wong, 1975). The dissolved organic carbon concentration was quite uniform at the six sampling stations, whereas dissolved organic nitrogen varied considerably (Table 23).

Concentration of trace metals (Zn, Cd, Pb and Cu) were not exceedingly high. Zn was present in labile state, whereas Pb and Cu were completely in bound form, indicating water had a reasonable capacity to complex ionic copper and other heavy metals. Copper complexing capacity of Babine Lake is 1.64 umole cu/L (Chau and Wong, 1975) (Table 24). This implies that one litre of Babine Lake water should be able to complex slightly in excess of 100 mg cu^{++}. The dissolved organic matter and copper complexing capacity increases during the summer months when organic degradation rates are higher (Chau and Wong, 1975).

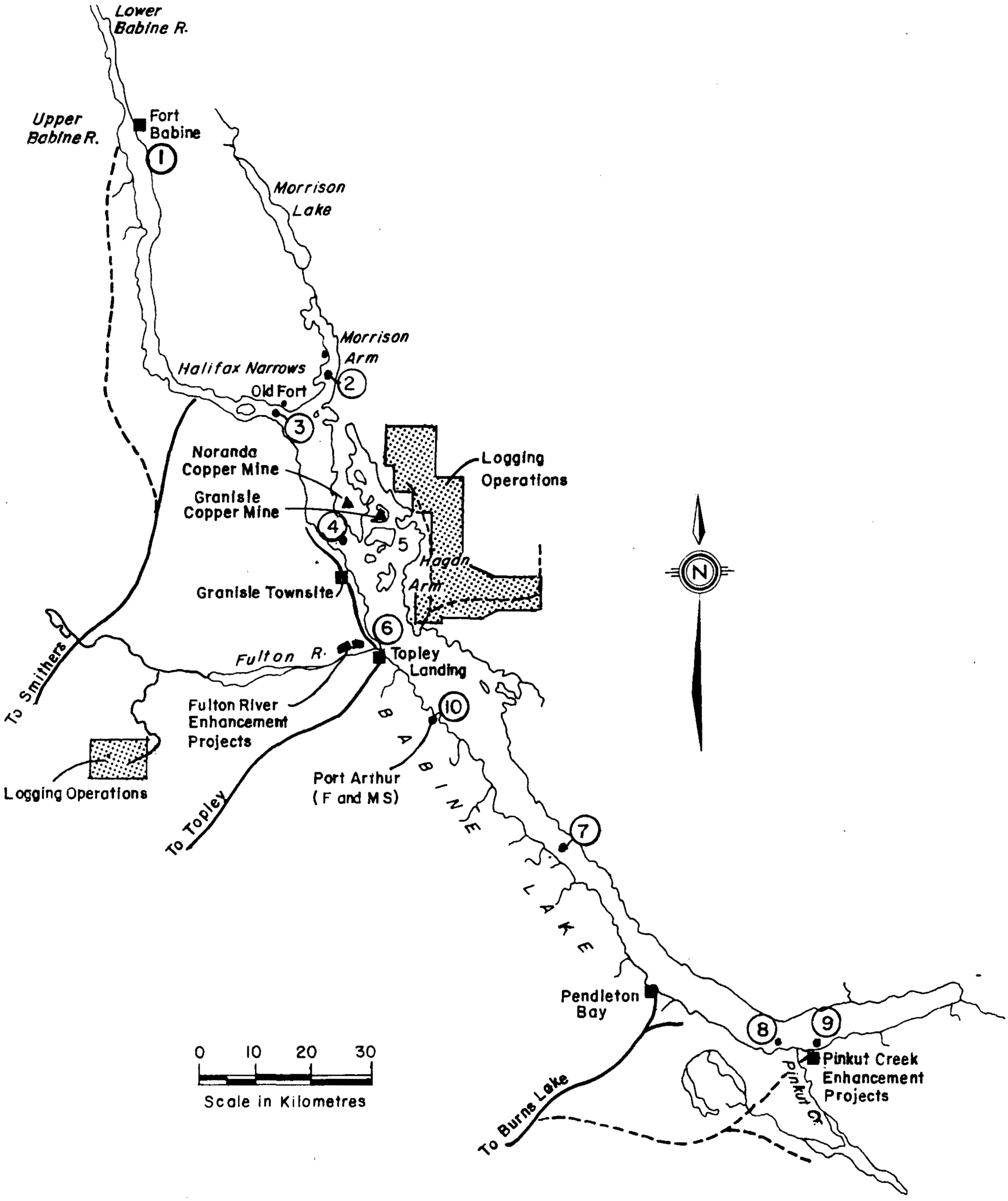


FIGURE 16 SAMPLING STATIONS FOR BABINE LAKE WATERSHED CHANGE PROGRAM (1975)

TABLE 23 CHEMICAL ANALYSES OF BABINE LAKE WATER BY CHAU AND WONG (IWD) (October 20 to 26, 1974)

STATIONS	pH	CONDUCTIVITY uM	DOC mg/1	DON ug/1	TOTAL PHOSPHORUS mg/1	TOTAL ALKALINITY mg/1 $CaCO_3$	TOTAL HARDNESS mg/1 $CaCO_3$	CHLOROPHYLL a mg/m3
1	---	58	7.0	271	0.012	37.1	36.7	2.58
2	8.1	58	6.6	194	0.007	36.1	36.2	1.55
4	7.9	57	7.0	208	0.008	36.2	36.3	2.18
5	7.8	57	7.4	167	0.014	35.5	36.2	1.41
6	7.8	61.5	7.4	248	0.005	35.8	36.1	1.56

DOC - dissolved organic carbon; DON - dissolved organic nitrogen

TABLE 24 COMPLEXING CAPACITY AND HEAVY METALS OF BABINE LAKE WATER BY CHAU AND WONG, 1975

Metals: labile and total (in brackets) ug/l

STATIONS	Zn	Cd	Pb	Cu	COMPLEXING CAPACITY um/l Cu
1	21.2 (26.0)	0 (0)	0 (10.6)	0 (43.8)	1.78
2	21.8 (21.0)	0 (0)	0 (15.3)	0 (37.4)	1.62
4	12.0 (20.0)	0 (0)	0 (5.8)	0 (26.8)	1.93
5	3.9 (21.6)	0 (0)	0 (4.5)	0 (16.6)	1.34
6	5.7 (19.4)	0 (0)	0 (4.6)	0 (16.4)	1.54

4. PHYSICAL PARAMETERS

The following physical parameters are considered important in determining the environmental impact of the effluent discharge.

4.1 General Characterisitics

Babine Lake is 150 km long, 4 km wide and 230 m at its deepest, and has an annual mean residence time of 20 years. The lake is characteristically ice covered for four months and there is generally no winter through-flow (Carmack and Farmer, 1982). Babine Lake is considered a temperate dimictic lake, as its water passes through the temperature of maximum density twice yearly, in autumn and in spring. The temperature of maximum density at atmospheric pressure and salinity of 65 mg kg-1, applicable to Babine Lake, is 3.97°C (Farmer and Carmack, 1981).

4.2 Temperature Stratification

The effect of decreasing temperature in Babine Lake begins in early August and thereafter decreases rapidly. Isothermal conditions occur in early November. By December 30, the mixed layer retreats to the surface of the lake and the thermal structure remains unchanged until early April when the solar radiation warms the water beneath the ice, causing a convecting mixing layer that progressively deepens (Farmer and Carmack, 1981).

In summer, as the temperature of the surface water increases, the density difference between the surface and the deeper layer becomes greater. Since the thermal density gradient opposes the energy of the wind, it becomes more difficult for the water to mix. As a result, a mixing barrier is established. The warm freely circulating surface water with small but variable temperature gradient is the epilimnion. Below this is the wall of metalimnion, a zone characterized by a very steep and rapid decline in temperature. Within the metalimnion is the thermocline, the plane at which the temperature drops most rapidly: 1°C for each metre of depth. Below these is the hypolimnion, a deep, cold layer, in which the temperature drop is gentle (Smith, 1966). The greatest thermal gap is in the transition from spring turnover to summer stratification which begins deep, often at the lake bottom, and progressively rises to the level at which it eventually stabilizes (Wetzel, 1975).

Farmer and Spearing conducted a series of temperature measurements in Babine Lake during the ice-free period of 1972 and 1973 (Figure 17). The northern arm became ice covered in December about 3-4 weeks earlier than the main lake and remained warmer during the winter. In the south end water immediately under the relatively thin ice was warmed by solar radiation and some vertical circulation began prior to ice break-up. This can be observed in the temperature profiles at Station 64 taken on March 7 and April 15, 1973 (Figure 18). The bathythermograph run of May 24, 1973 shows (Figure 19) a period of spring convection following the ice break-up and subsequent formation of thermal stratification.

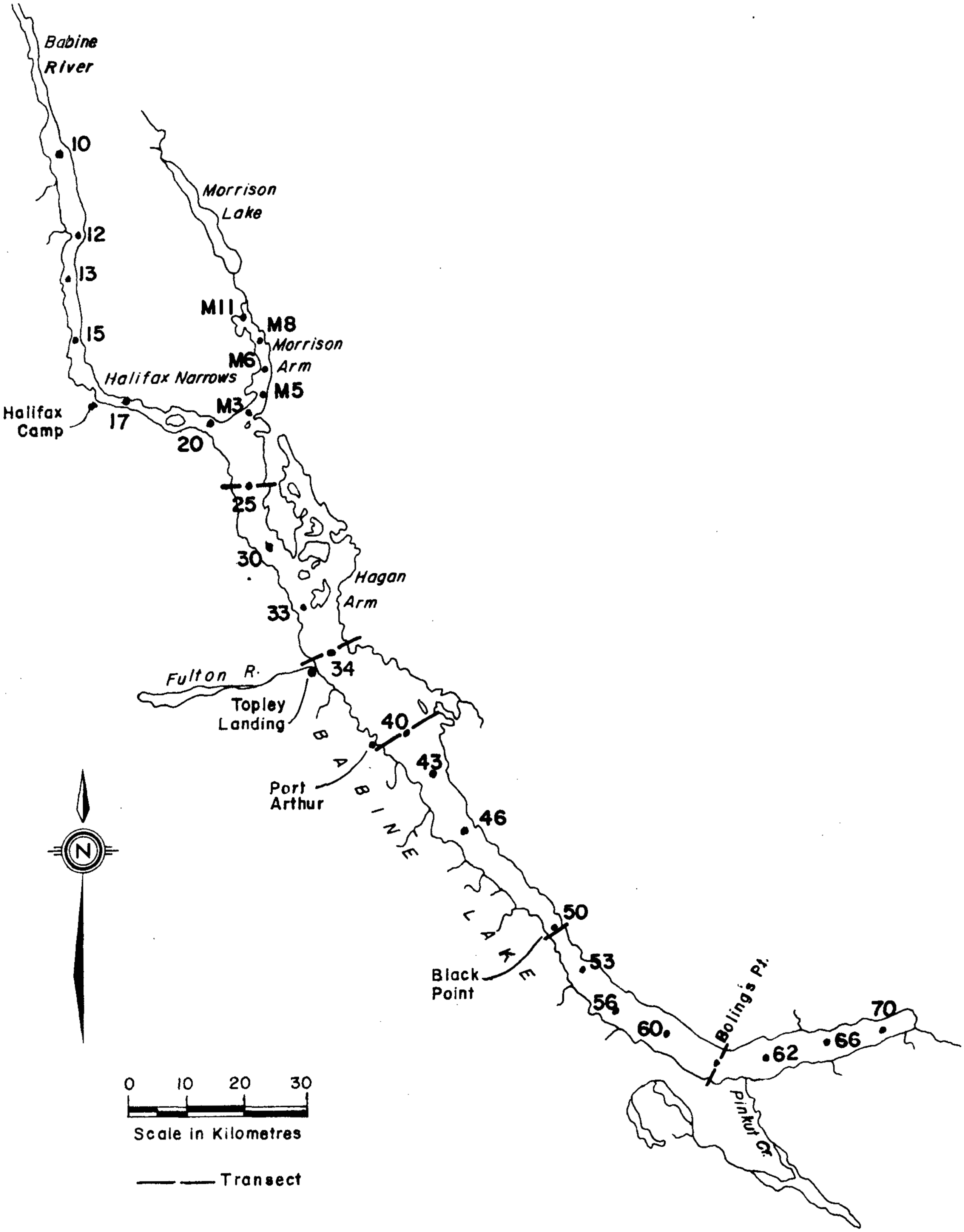


FIGURE 17 STATION LOCATIONS OF TEMPERATURE PROFILES IN BABINE LAKE BY FARMER AND SPEARING (1972-1973)

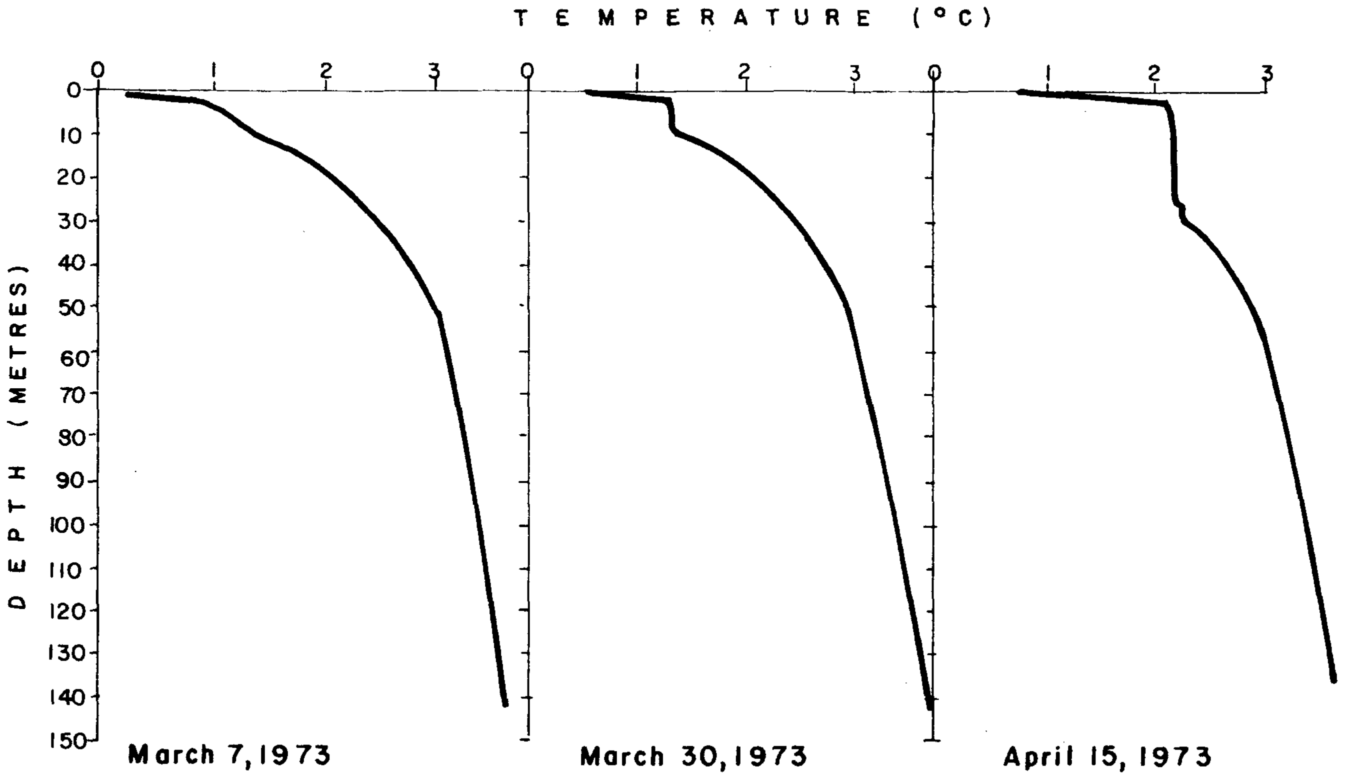


FIGURE 18 TEMPERATURE PROFILES AT STATION 64 (SOUTH OF BOILING POINT) SHOWING PROGRESSIVE EFFECT OF SOLAR RADIATION PENETRATING THE ICE AND CAUSING CONVECTING MIXING (After FARMER, Unpublished MS 1973)

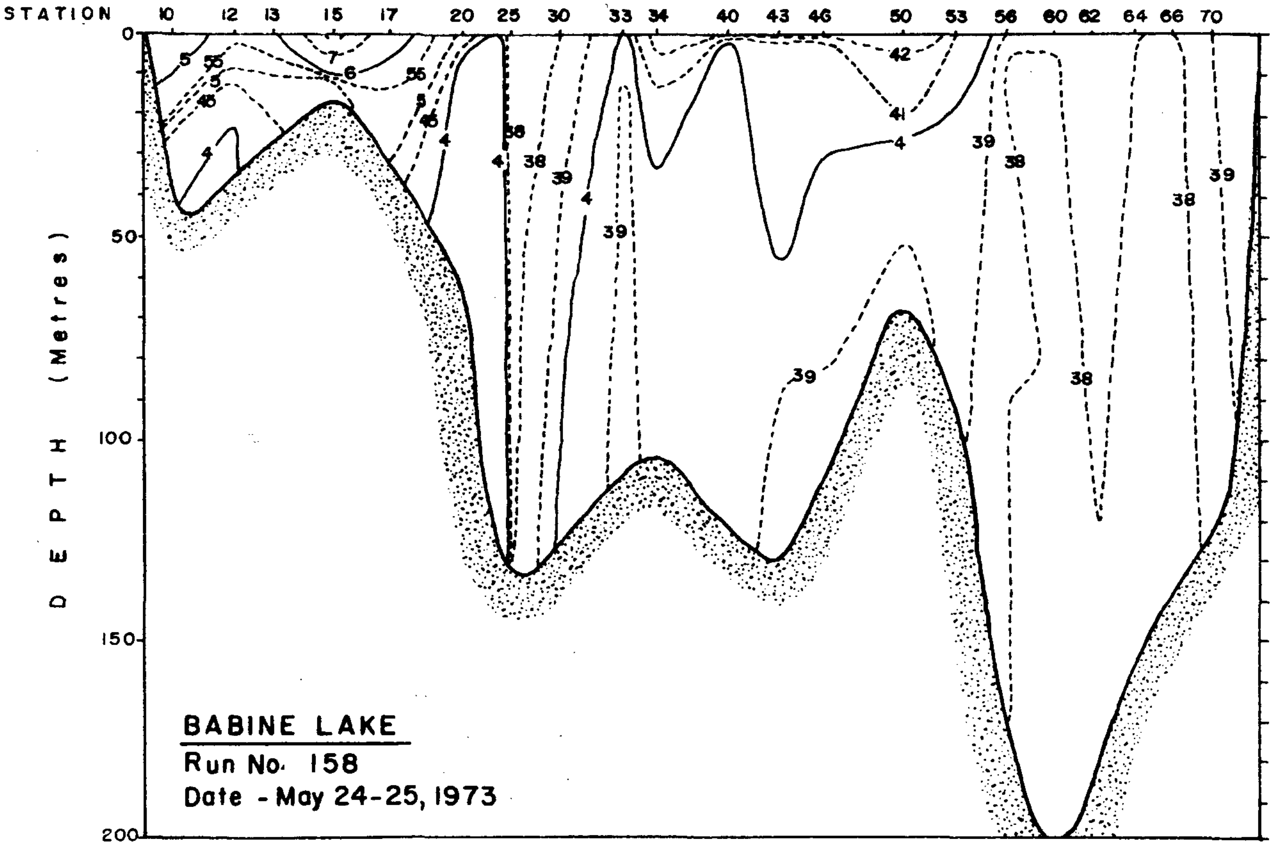


FIGURE 19 BATHYTHERMOGRAPH RUN OF MAY 24, 1973 AFTER ICE BREAK-UP AND SHOWING FORMATION OF THERMAL STRATIFICATION (FARMER & SPEARING, 1975)

Several vertical isotherm plots in early 1973 indicated that convection warming proceeds in Babine Lake at this time had reached different stages in different locations. Evidence of this observation was clear during run 156 (Main Lake, May 13, 1973) which showed convection had not yet penetrated to the lake bed (Figure 20). On the other hand, on May 21, 1973, although convection continued, there was no longer any trace of winter stratification (Figure 21).

Temperature depth profiles for the 1974-75 season (Stockner and Shortreed, 1976) are similar to physical data reported by Farmer and Spearing (MS, 1975). A stable thermocline was observed in the northern basin at Station 1 (Figure 22) in July 1974, whereas in the main lake (Stations 2, 3, 4, 5) spring overturn with complete mixing took place. Autumn 1974 data showed a similar condition as 1973 with the thermocline greater than 30 m deep and a small temperature gradient between the epilimnion and hypolimnion water masses (Figure 23).

4.2.1 Regions of Upwelling. Surrounding mountains near Babine Lake induce horizontal divergence of the wind stress. This in turn produces local areas of upwelling and downwelling (Farmer and Spearing, 1975). Examples of upwelling in the northern basin can be seen in bathythermograph runs 7 and 8 (June 1972) (Figures 24, 25). Similarly in the southern basin upwelling can be seen in runs 17 and 20 taken in July 1972 (Figures 26, 27). These distortions of thermocline are often associated with generation of internal waves.

4.2.2 Mixing. In Babine Lake the depth of the mixed layer varied throughout the season. Stratification developed in mid-June and remained unstable during summer months. In the north, in Hagan and Morrison Arm, due to greater wind protection, a stable stratification and greatly reduced mixed layer (less than 6 m) was observed in 1973, while from Topley Landing southward greater exposure to strong summer winds created a less stable stratification and greatly increased mixed layer (greater than 15-20 m) (Stockner and Shortreed, 1974).

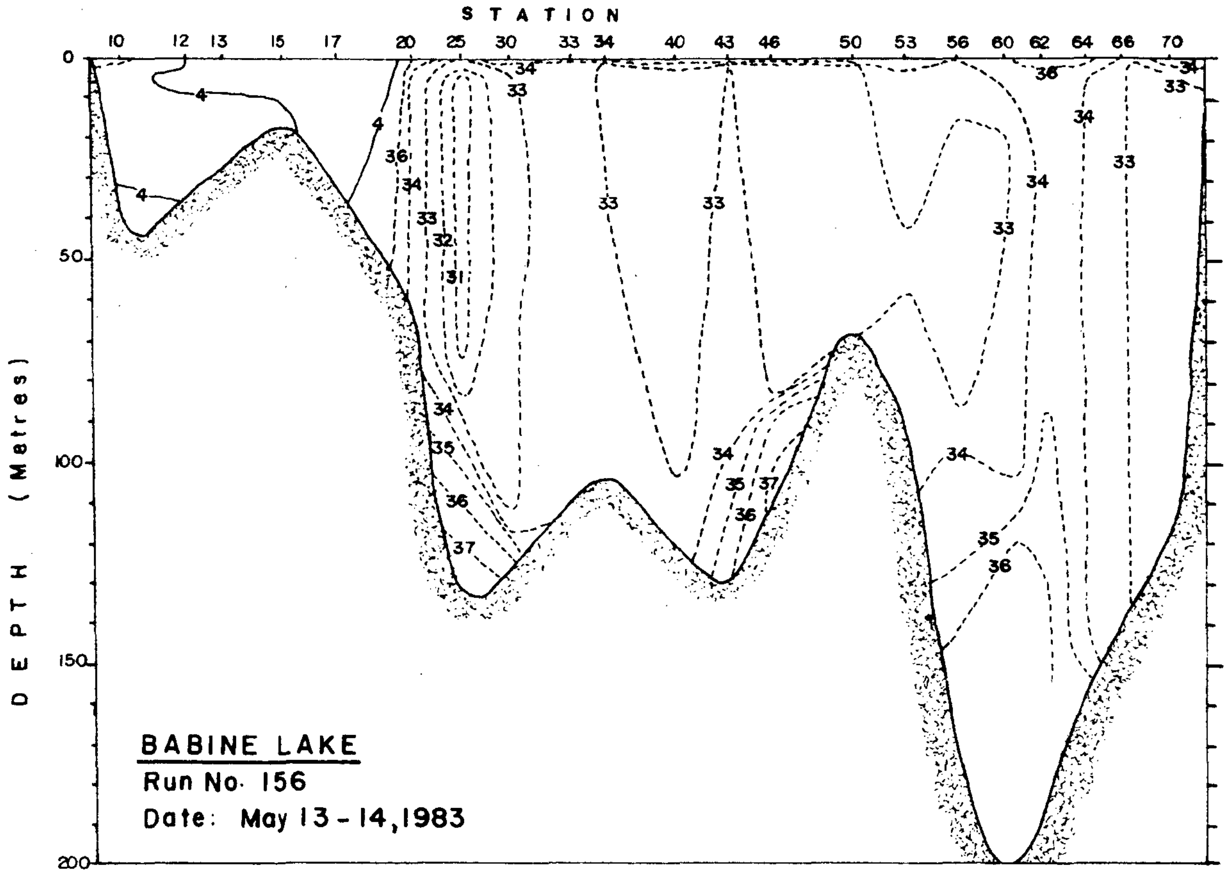


FIGURE 20 BATHYTHERMOGRAPH SHOWING CONVECTION HAD NOT PENETRATED TO LAKE BED AT ALL LOCATIONS BY MID-MAY (FARMER & SPEARING, 1975)

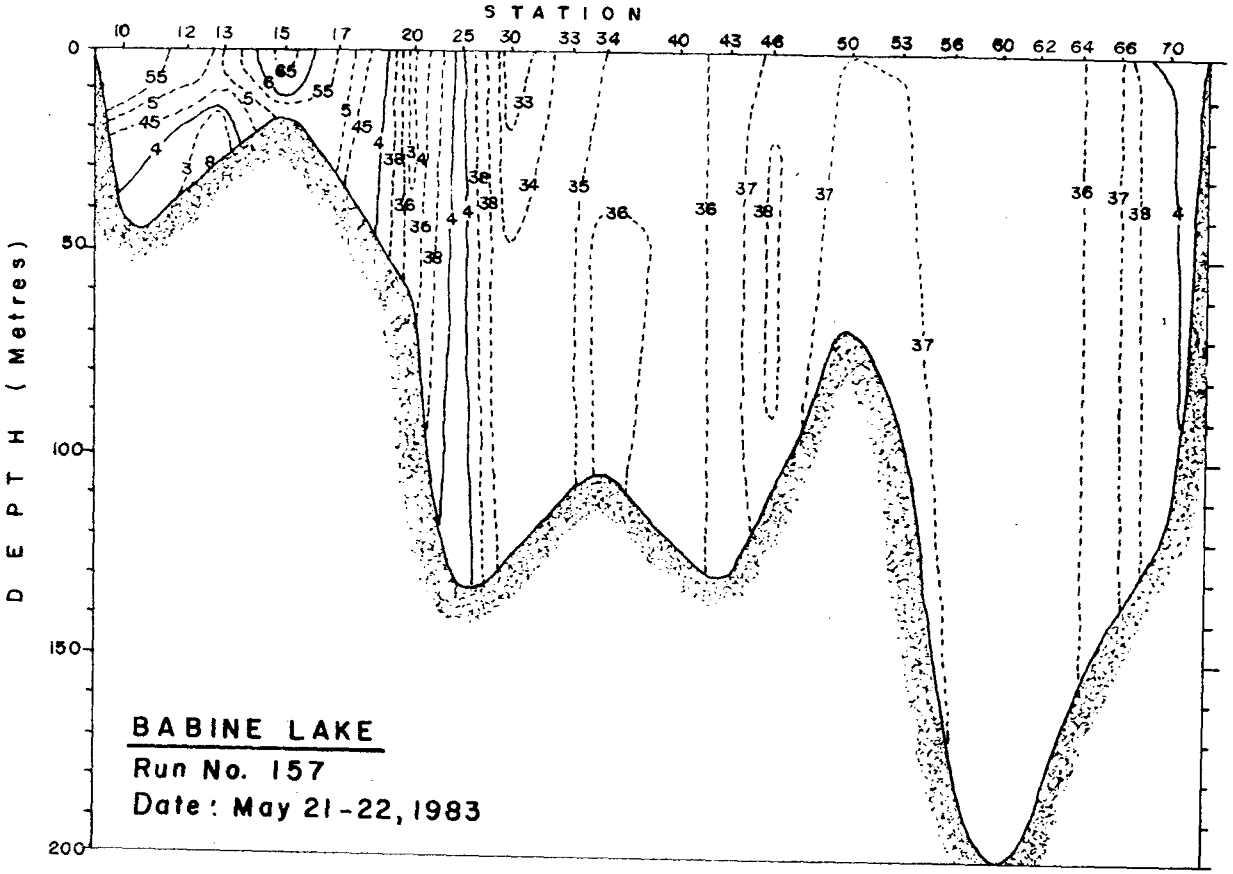
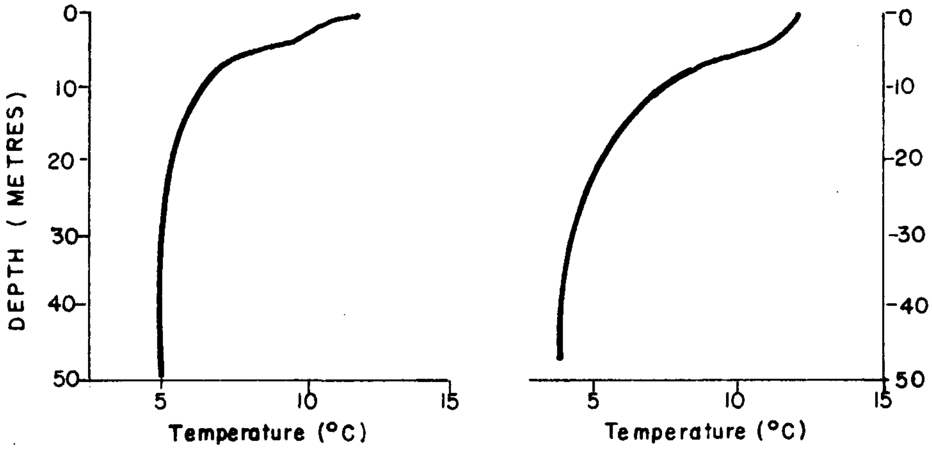
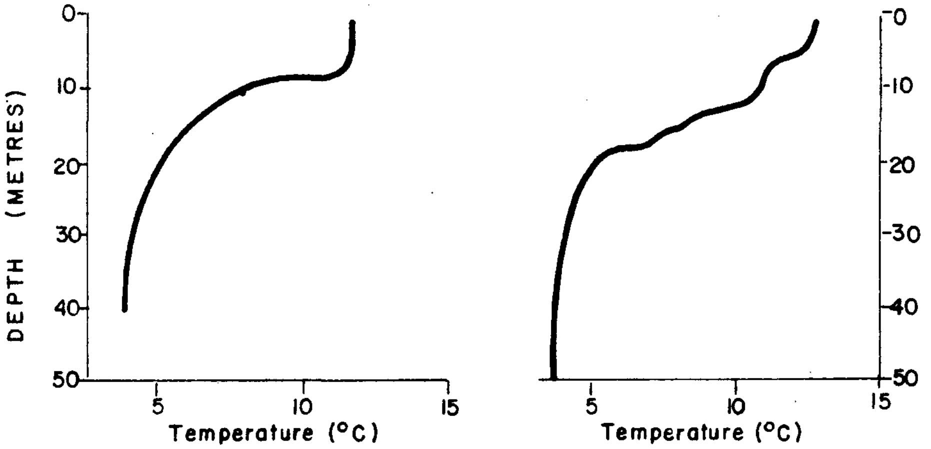


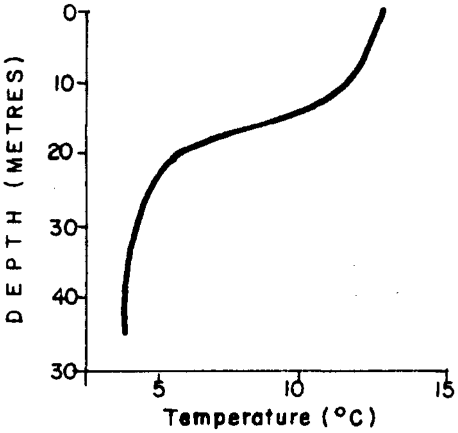
FIGURE 21 BATHYTHERMOGRAPH SHOWING NO TRACE OF WINTER STRATIFICATION WHILE CONVECTION CONTINUED (FARMER & SPEARING, 1975)



STATION 1 STATION 2

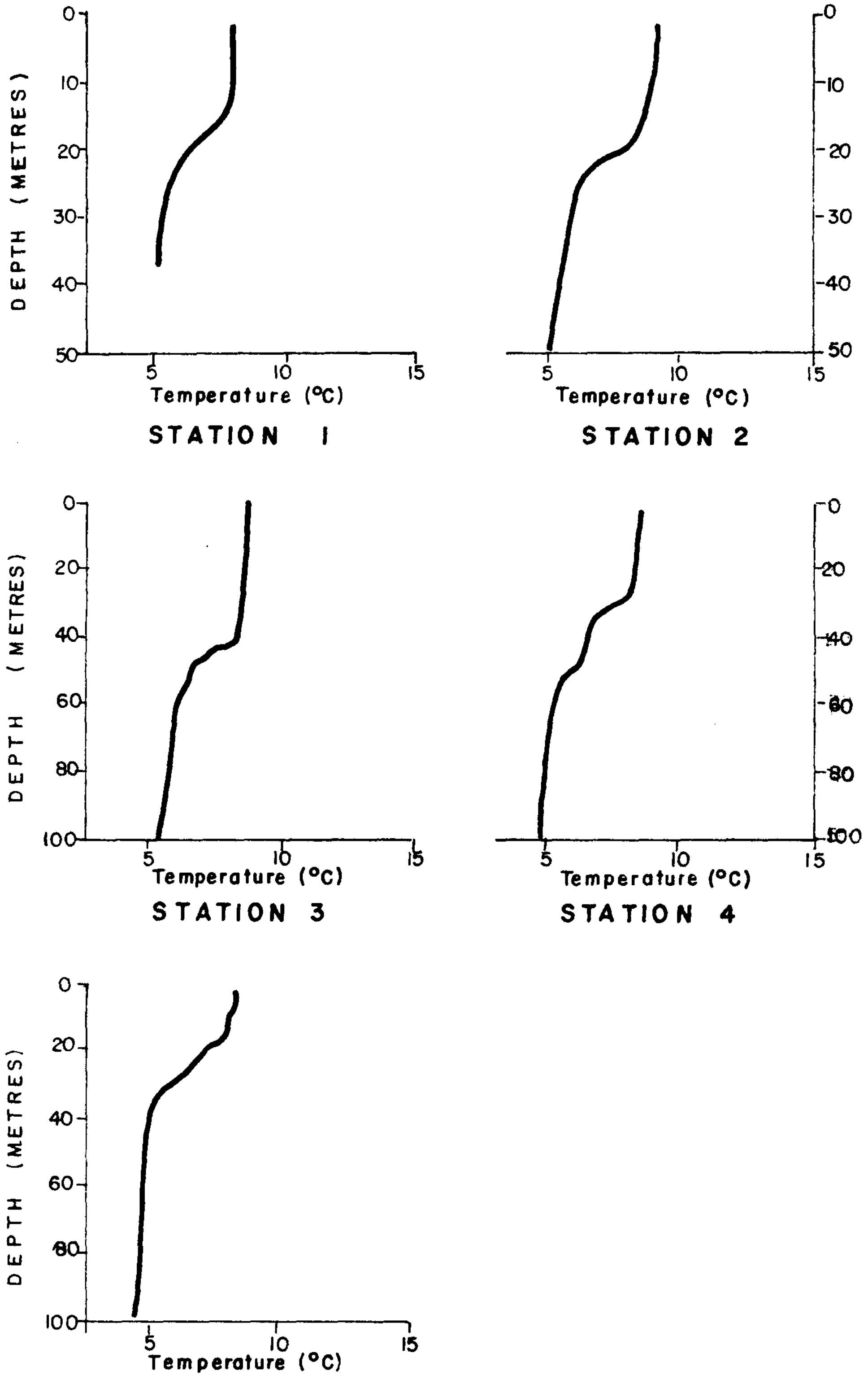


STATION 3 STATION 4



STATION 5

FIGURE 22 TEMPERATURE PROFILES FOR BABINE LAKE WATERSHED CHANGE PROGRAM STATIONS 1 TO 5 (July 1974)



STATION 1

STATION 2

STATION 3

STATION 4

STATION 5

FIGURE 23 TEMPERATURE PROFILES FOR BABINE LAKE WATERSHED CHANGE PROGRAM STATIONS 1 TO 5 (October, 1974)

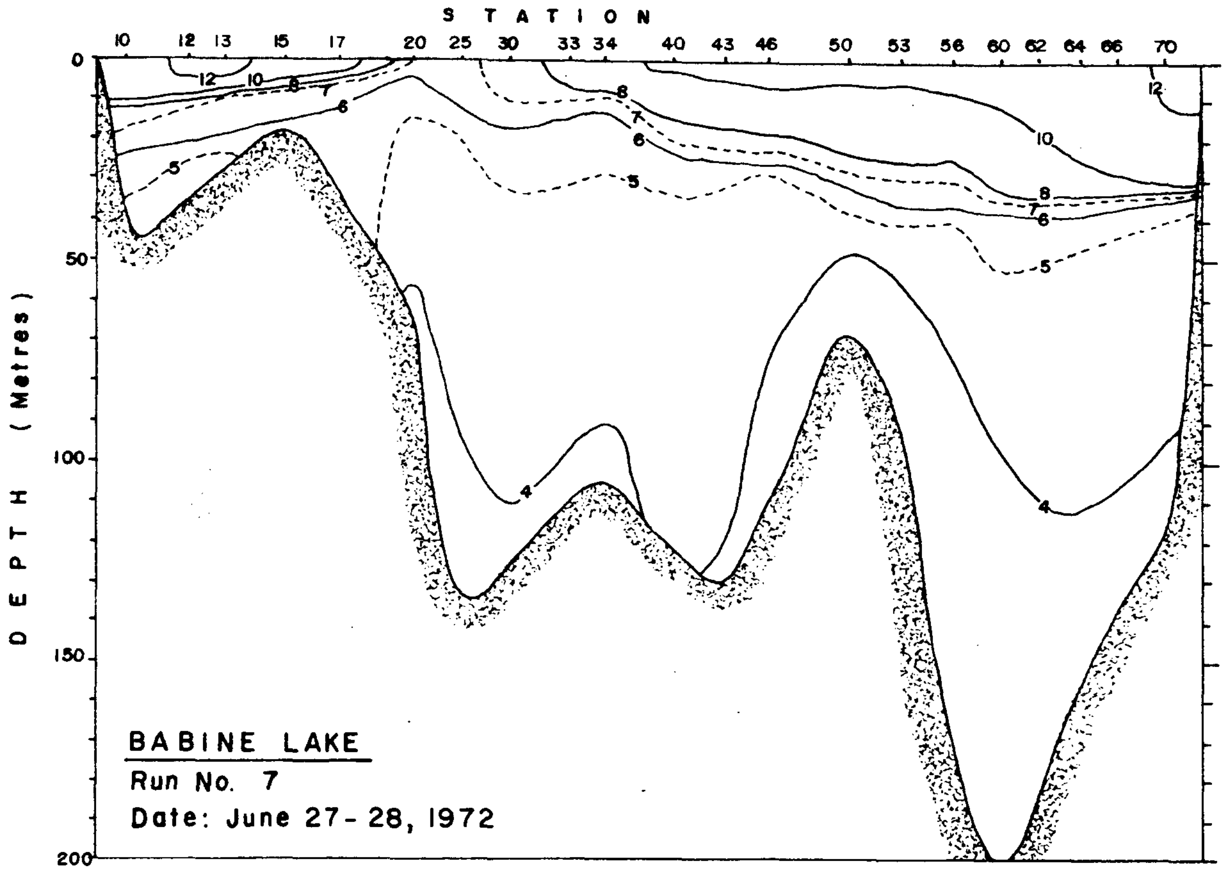


FIGURE 24 EXAMPLE OF UPWELLING IN NORTHERN BASIN ON JUNE 27-28, 1972 (FARMER & SPEARING, 1975)

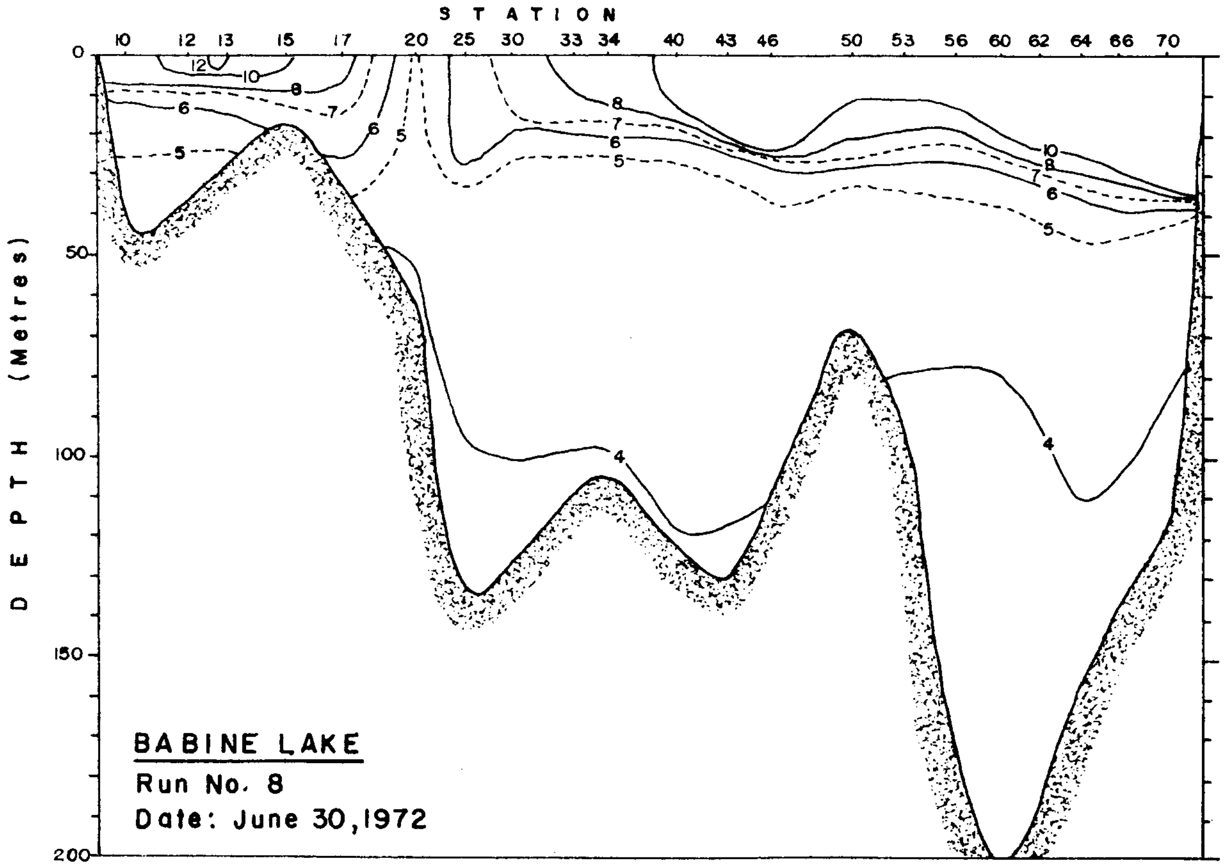


FIGURE 25 EXAMPLE OF UPWELLING IN NORTHERN BASIN ON JUNE 30, 1972 (FARMER & SPEARING, 1975)

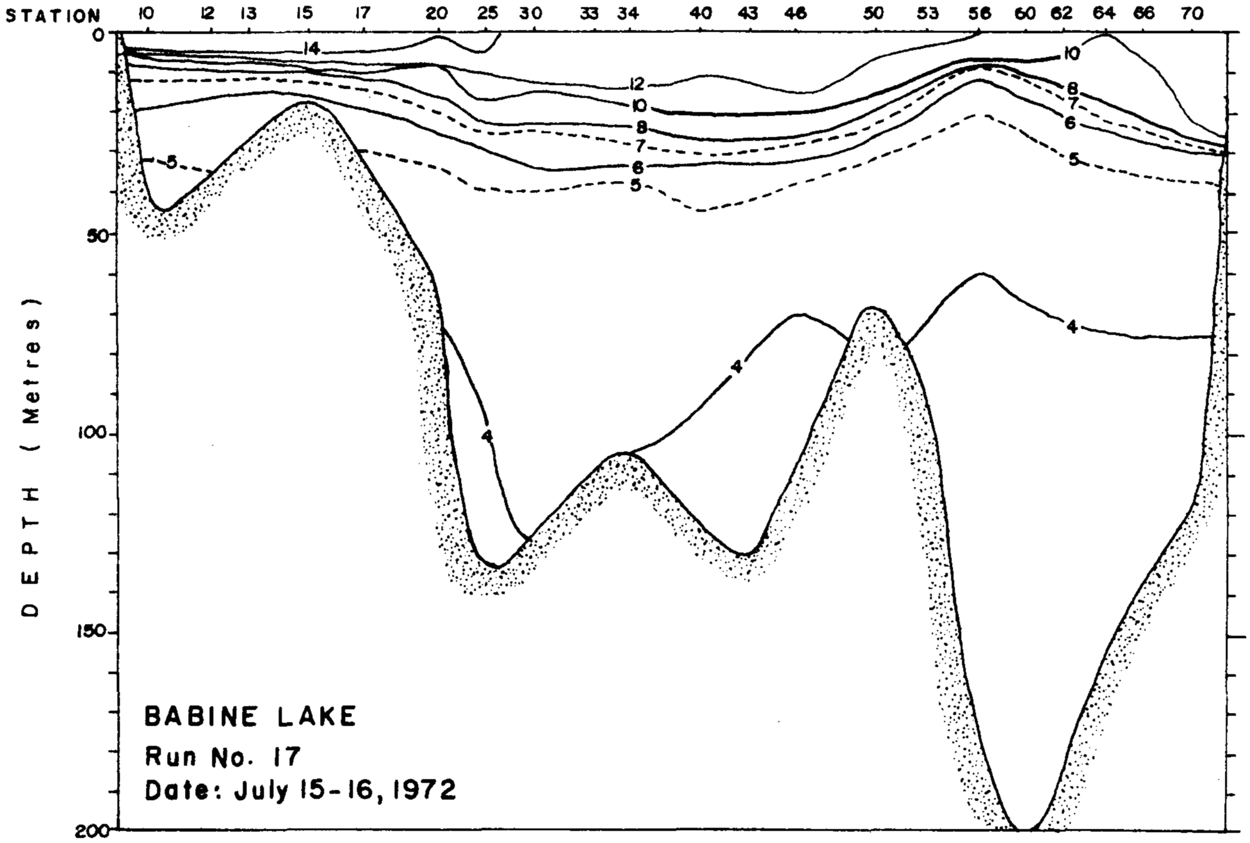


FIGURE 26 EXAMPLE OF UPWELLING IN SOUTHERN BASIN ON JULY 15-16, 1972 (FARMER & SPEARING, 1975)

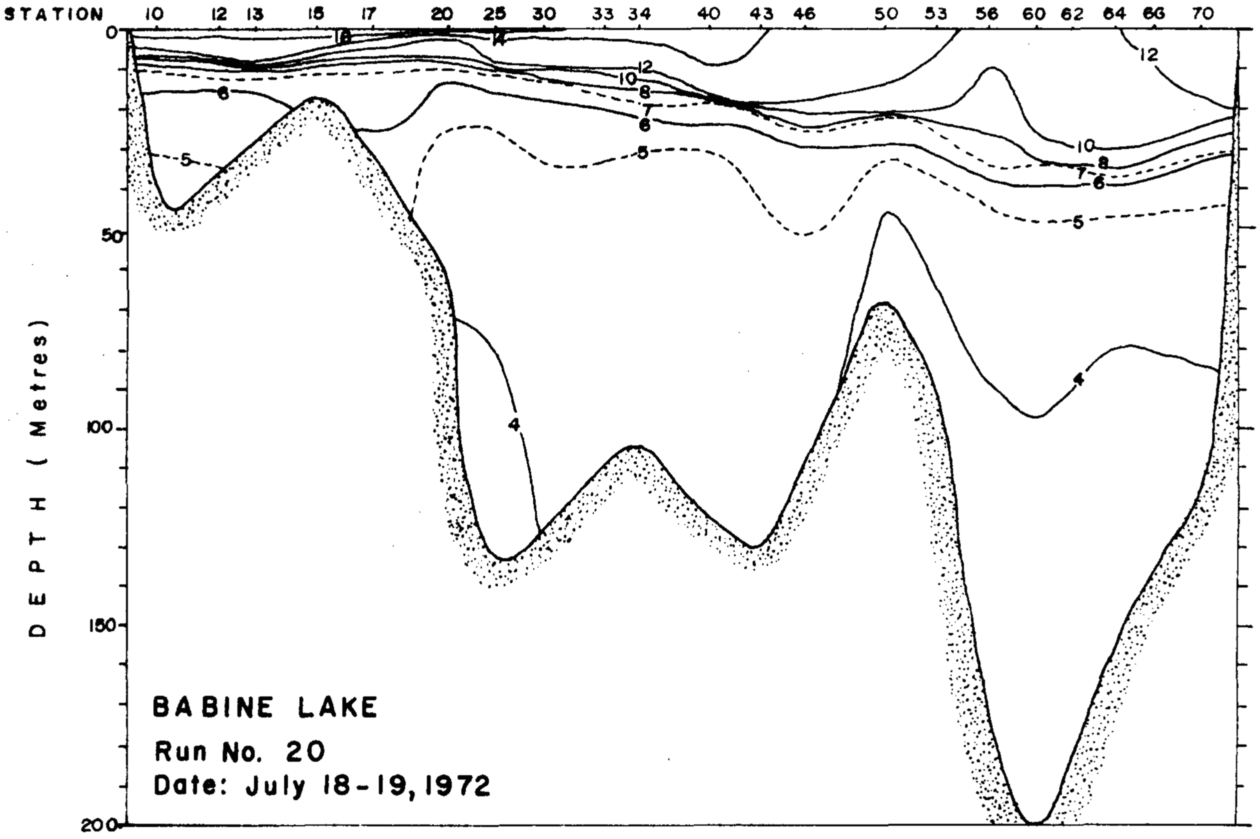


FIGURE 27 EXAMPLE OF UPWELLING IN SOUTHERN BASIN ON JULY 18-19, 1972 (FARMER & SPEARING, 1975)

4.2.3 Factors Influencing Temperature Variations. Thermal stratification, depth and position of the thermocline, circulation of nutrients, are all influenced by several factors.

One of the important factors which enhances vertical mixing of the thermocline is large amplitude internal seiches. The internal seiches are caused by the action of the wind on surface water and by the density difference between warm and cold water (Smith, 1966).

Another factor which influences spring overturn is thermal bar circulation in tributary bays. This convective phenomenon is driven by the mixing together of warm (greater than °^{0}C) inshore water with cold (less than 4°C) offshore water to form a common dense water mass.

Other factors which affect characteristics of thermocline structure are wind mixing, non-linearity in the pressure-volume-temperature properties of water, surface buoyancy flux, effect of riverine upwelling on mixed layer deepening, thermal bar circulation due to river inflow, and gravity flows resulting from differential wind sheltering (Carmack and Farmer, 1982 and Farmer and Carmack, 1981).

4.3 Light Intensity and Sechi Depth

As Secchi disk transparency is influenced by light absorption characteristics of water and its dissolved particulate matter (Wetzel, 1975) both extinction co-efficient of light and Secchi depth are considered as important physical parameters in the Babine Lake study.

In 1974 Stockner and Shortreed reported mean extinction co-efficient of light and Secchi depth of different zones in Babine Lake. A Montedoro-Whitney illuminace meter (Model LMT-8B) was used to measure light extinction as a function of depth. These data were plotted on a Hewlett-Packard calculator-plotter as the natural log of intensity vs depth. A line was regressed through the point and its slope gave a mean extinction co-efficient. Typical light plot in September from extreme north and south ends of the lake are shown in Figures 28 and 29.

Mean extinction co-efficient for the fall period ranged from 0.538 to 0.821. A gradual increase of extinction co-efficient was found from north to south in Babine Lake (Table 25).

In 1973 Secchi depths in zones 1 and 2 were 2.5 m in May and increased slowly through the season, reaching values of 6.0 - 6.5 m by early October (Figure 30). In zone 4 values ranged from 5.0 m in late June and early July, reaching 6.0 - 6.5 m in October. Secchi depths in Hagan Arm (zone 3) were fairly constant (5.0 - 6.0 m) throughout the open water period. Secchi depths in zones 5 and 6 and in the south basin decreased from 7 m in May to 4.0 - 4.5 m in late June, increased through July and August to 5.5 - 6.0 m and decreased again in September and early October to 4.5 - 5.0 m (Figure 31).

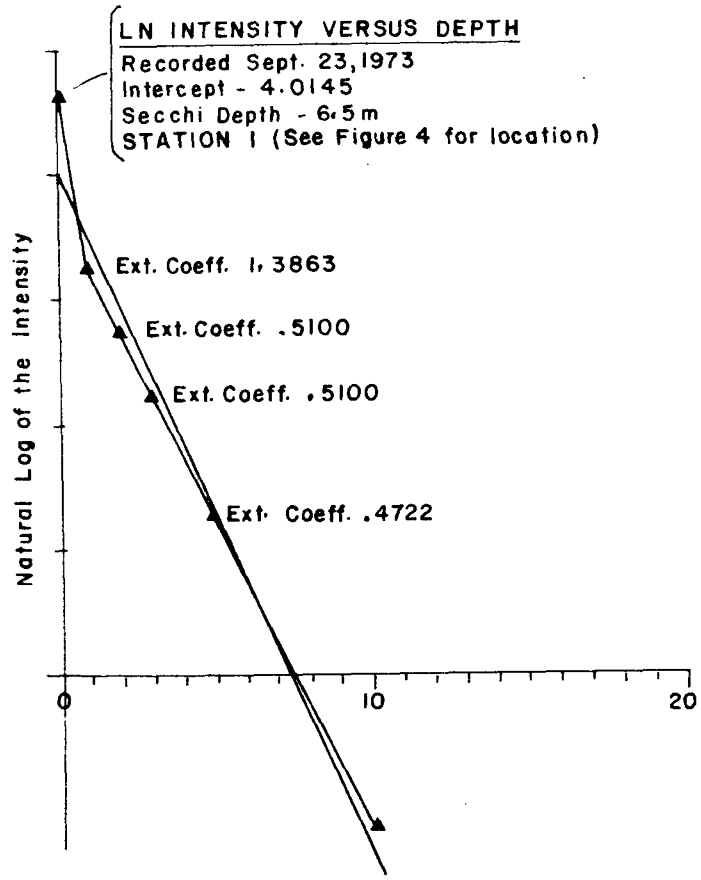


FIGURE 28 LIGHT PLOT AT EXTREME NORTH END OF BABINE LAKE IN SEPT. 1973 (STOCKNER & SHORTREED, 1974)

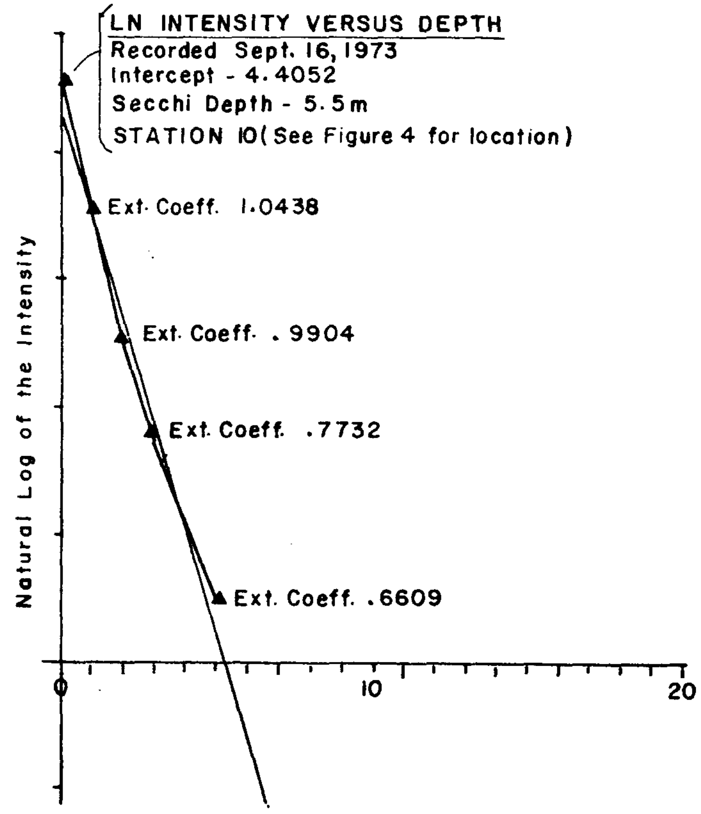


FIGURE 29 LIGHT PLOT AT EXTREME SOUTH END OF BABINE LAKE IN SEPT. 1973 (STOCKNER & SHORTREED, 1974)

TABLE 25 MEAN EXTINCTION COEFFICIENTS FOR BABINE LAKE DURING THE SEPTEMBER AND OCTOBER, 1973 (Stockner and Shortreed, 1974)

ZONE*	MEAN EXTINCTION COEFFICIENTS (k)	# of OBS.
1	.577	2
2	.669	3
3	.593	2
4	.593	4
5	.598	4
6	.771	6

*Zones as indicated in Figure 4

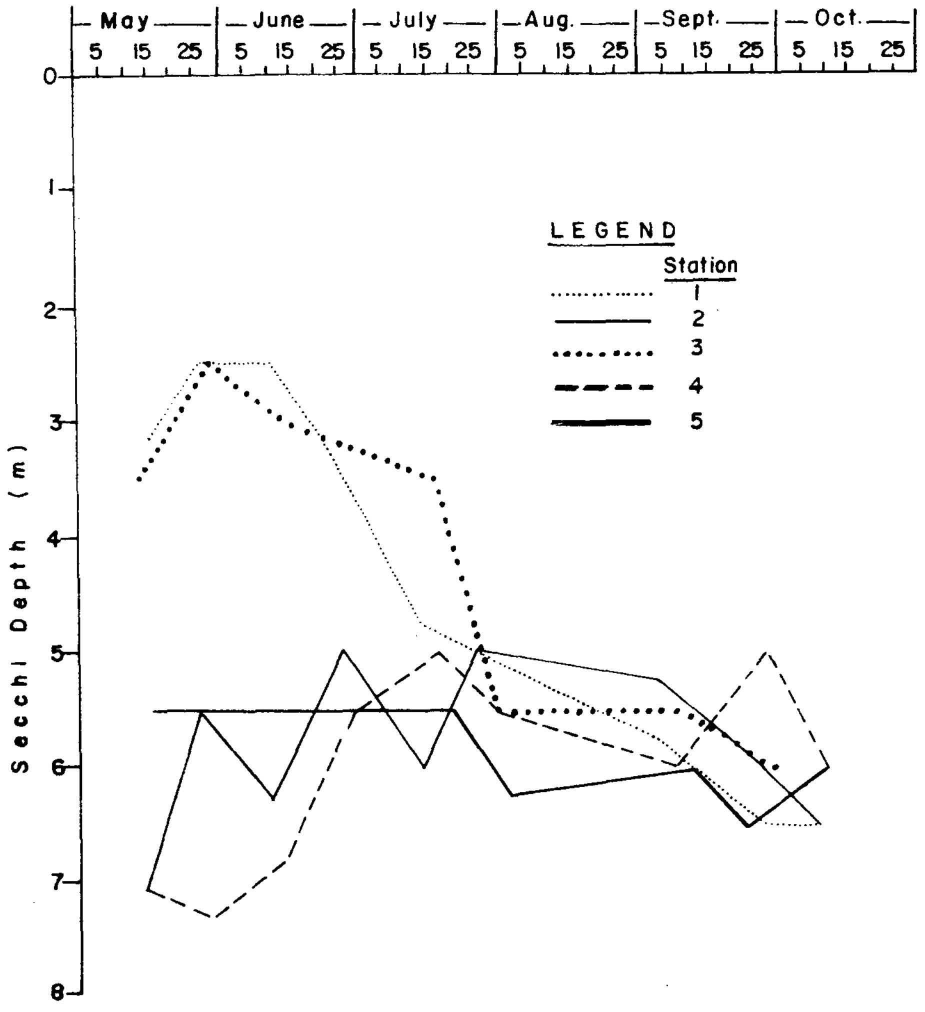


FIGURE 30 SECCHI DEPTH AT STATIONS 1 TO 5 FROM MAY TO OCTOBER, 1973 (STOCKNER & SHORTREED, 1974)

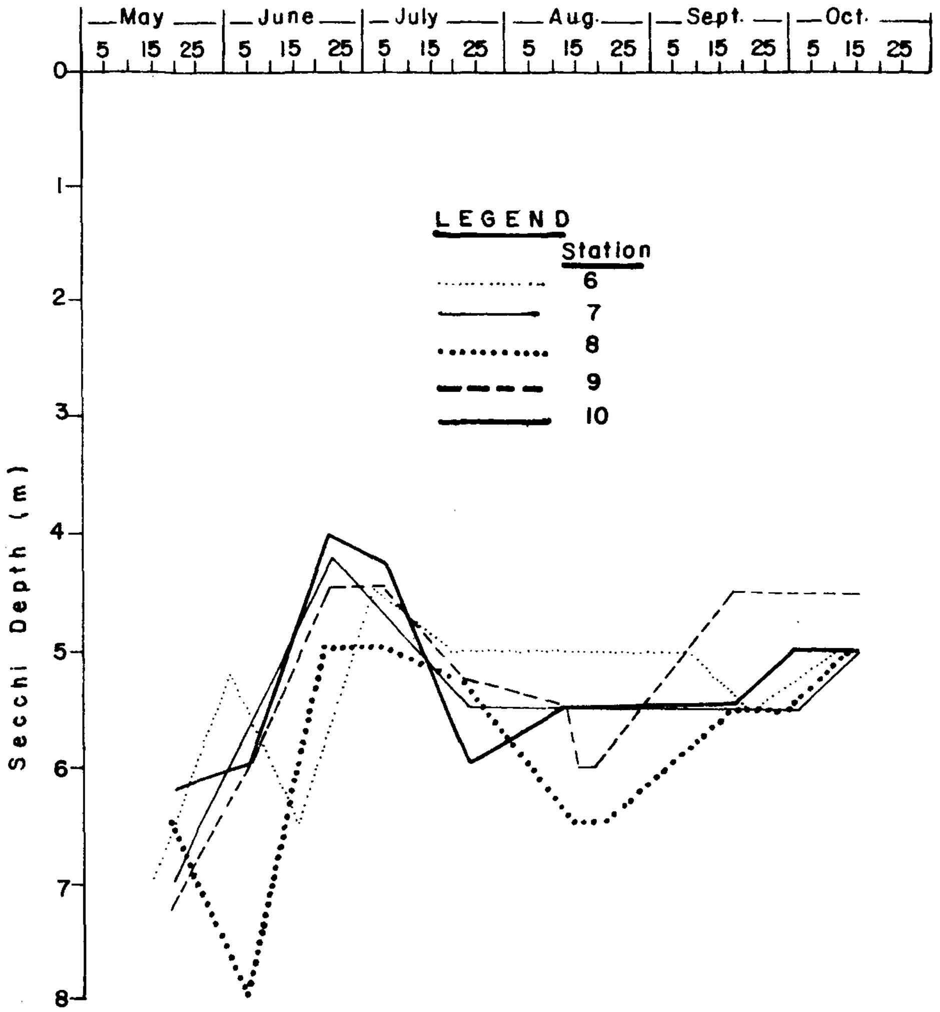


FIGURE 31 SECCHI DEPTH AT STATIONS 6 TO 10 FROM MAY TO OCTOBER, 1973 (STOCKNER & SHORTREED, 1974)

5. SEDIMENT ANALYSIS

5.1 Selected Chemical Parameters of Babine Lake Sediments

In view of the potential environmental change resulting from anticipated increases in logging and mining activities in the Babine Lake watershed, Stockner and Smith (1974) reported selected chemical analyses of Babine Lake sediments. The sampling locations referred to here are shown in Figure 32. Ten Phleger cores were obtained from the deep water regions of Babine Lake. A general description of the surface sediment characteristics from each core location is given in Table 26.

Sediments were generally dark brown. However, the top one centimeter of the core taken from Hagan Arm, 300 m from McDonald Island was white and had a detectable odour. There was some indication of annual layering in cores B7 and B8 (Stations 7 and 8). The latter showed 20 dark evenly spaced horizontal bands between 20 and 24 cm. Supposing these were annual deposits, a deposition rate of 2 mm/yr was approximated in the southerly part of the lake in the corresponding period of its sediment history.

Table 27 shows that average concentrations of all measured constituents of bottom sediments except zinc were highest in the north region of the lake (samples B-B5, north of Fulton River).

Sample values for organic carbon, total phosphorous, copper and zinc are plotted against depths in sediments (Figure 33). Highest values of total phosphorous and organic carbon occurred in surface sediments (0 - 4.5 cm) (Table 28). Particularly high copper concentrations in the surface layer at Station B5 in Hagan Arm (Table 29) a few hundred metres east of Granisle were observed and are considered significant because there were two active copper mine sites in this zone.

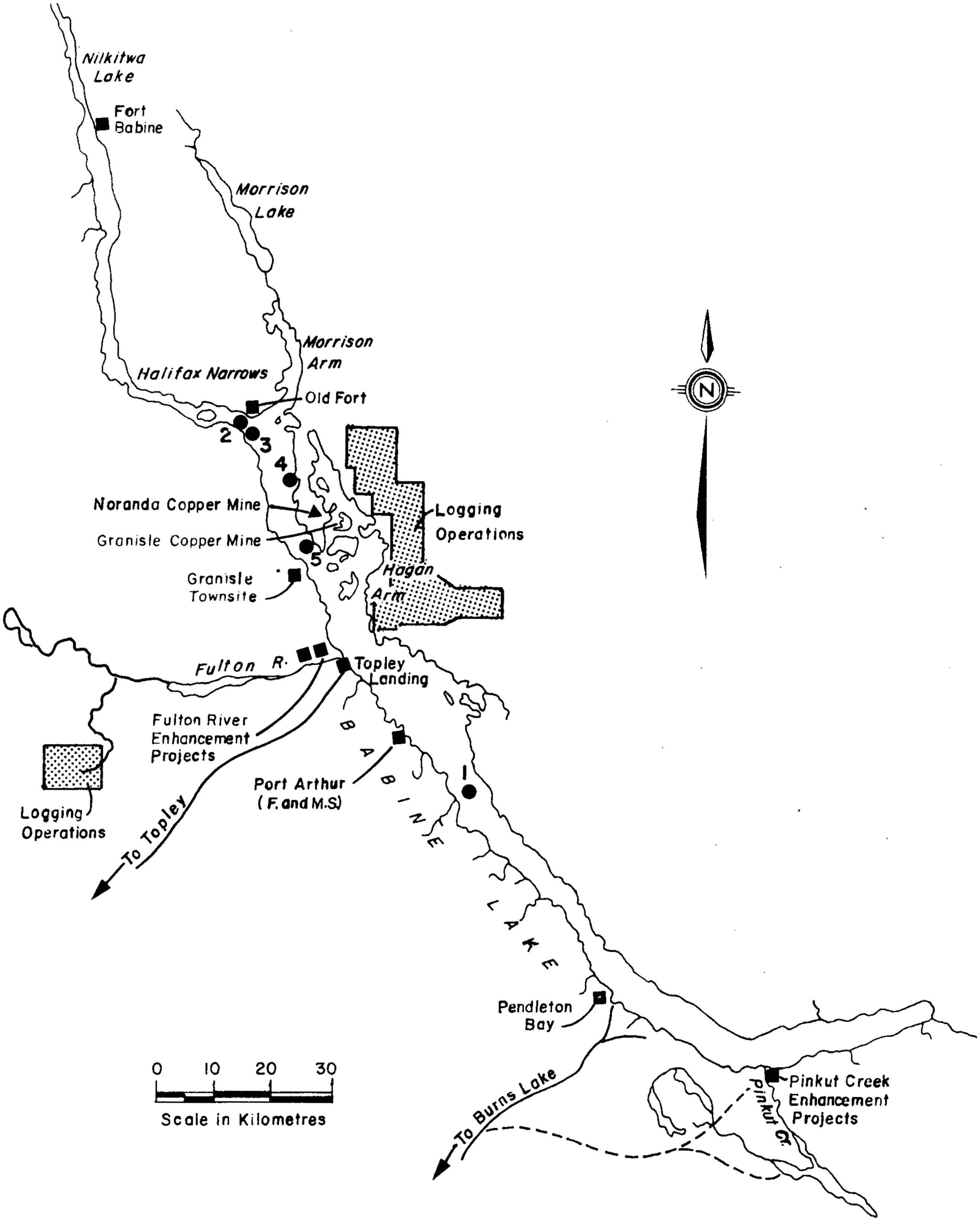


FIGURE 32 BABINE LAKE SHOWING LOCATIONS OF MAJOR ACTIVITIES AND 1972 CORE SITES (STOCKNER & SMITH, 1974)

TABLE 26 CORE LOCATIONS, WATER DEPTHS AND GENERAL SEDIMENT CHARACTERISTICS IN 1972 (Stockner and Smith, 1974)

CORE NO.	LOCATION	WATER DEPTH (m)	CORE LENGTH (cm)	LENGTH OF UNCONSOLIDATED MATERIALS (cm)	GENERAL CHARACTERISTICS
B1	North Arm, Norlakes, mid-lake	42	50	1.5	dark brown; soft; banding evident
B2	Morrison Arm, mid-lake	28	43	4.5	dark green-brown; soft; no banding top 5-6 cm
B3	Main lake, 1 km S. of Old Fort mid-lake	120	37	3.0	dark brown; soft; distinct banding
B4	Rabbit Is., mid-lake	110	35	3.0	dark brown; soft; some banding
B5	Hagan Arm, 300 m from McDonald Is.	55	42	2.5	top 1 cm white; detectable odour; no banding top 6 cm
B6	Fulton R., 1 km N.E. of mouth	90	34	3.0	brown; gritty; sand, bark and other particulates
B7	Twin Cr., mid-lake	110	44	2.0	dark brown; soft; thin bands less distinct than elsewhere
B8	Bolings Pt., mid-lake	180	41	2.0	dark brown changing to gray at 2 cm; banding as in B7
B9	Pinkut Cr., 1 km N. of mouth	120	33	2.0	brown, gritty; bark, grass and other particulates; no banding top 15 cm
B10	Port Arthur, mid-harbour	28	44	2.0	dark brown top 11 cm; gritty and more clay 11-20 cm; dense clay 20-44 cm

TABLE 27 AMOUNTS OF TOTAL PHOSPHOROUS, ORGANIC CARBON, ZINC AND COPPER IN NORTH AND SOUTH REGION SEDIMENTS IN 1972 (Stockner and Smith, 1974)

CORE NO		TOTAL P (mg/g)	ORGANIC C (%)	Cu (ug/g)	Zn (ug/g)
			NORTH REGION		
B1		1.78	2.40	65	122
B2		2.84	6.25	68	156
B3		2.51	4.28	60	109
B4		2.89	3.79	50	155
B5		2.35	4.71	86	152
	$\bar{x}$	2.47	4.29	66	139
			SOUTH REGION		
B6		2.23	3.42	no sample	no sample
B7		2.62	3.25	43	173
B8		2.28	2.79	27	145
B9		2.48	2.45	31	106
	$\bar{x}$	2.40	2.98	34	141
			ALL REGIONS		
		2.43	3.63	50	140

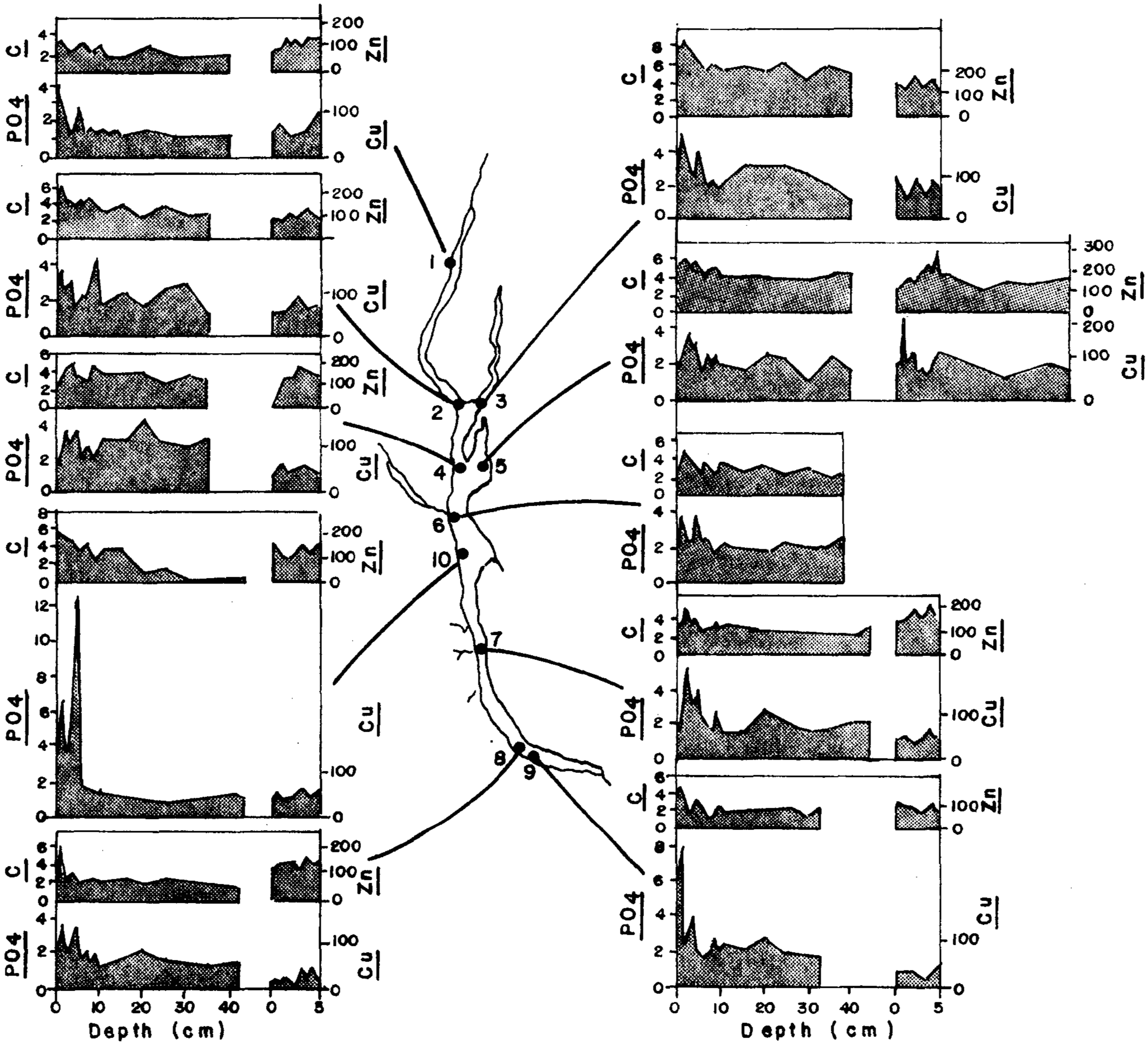


FIGURE 33 DISTRIBUTION OF SELECTED ELEMENTS WITH DEPTH IN BABINE LAKE SEDIMENTS (STOCKNER & SMITH, 1974)

TABLE 28 AVERAGE AMOUNTS OF TOTAL PHOSPHOROUS AND ORGANIC CARBON IN SURFACE (0-4.5 cm) AND DEEPER (5.0-bottom) SEDIMENTS IN 1972 (Stockner and Smith, 1974)

CORE	TOTAL P (mg/g)				ORGANIC C (%)			
NO.	n	0-4.5	n	5.0-bottom	n	0-4.5	n	5.0-bottom
B1	10	2.43	16	1.38	10	2.71	16	2.22
B2	10	3.40	12	2.46	10	7.51	12	5.61
B3	10	2.76	10	2.28	10	5.01	10	3.63
B4	9	2.90	11	2.88	6	4.12	11	3.61
B5	10	2.67	12	2.10	10	5.04	12	4.44
B6	10	2.39	12	2.10	9	3.60	12	2.99
B7	10	3.30	13	2.10	9	3.83	13	2.84
B8	10	3.01	13	1.66	9	3.51	13	2.23
B9	10	3.02	11	1.98	10	2.82	11	2.33
B10	10	4.64	13	1.27	10	4.61	13	2.23
	$\bar{x}$	3.05		2.02		4.28		3.21

TABLE 29 RESULTS OF CORE SAMPLE NO. B5 FROM HAGAN ARM (Stockner and Smith, 1974)

SAMPLE	DEPTH (cm)	TOTAL P (mg/g)	ORGANIC C (%)	Cu (ug/g)	Zn (ug/g)
1	0.0-0.5	1.60	5.86	90	120
2	0.5-1.0	2.10	5.98	60	100
3	1.0-1.5	4.10	5.29	230	110
4	1.5-2.0	3.85	5.34	70	150
5	2.0-2.5	2.15	5.36	70	165
6	2.5-3.0	3.30	5.51	80	165
7	3.0-3.5	1.95	4.84	120	140
8	3.5-4.0	3.20	4.47	120	120
9	4.0-4.5	2.40	3.78	65	115
10	4.5-5.0	2.00	3.99	65	110
11	5	2.55	3.86	60	160
12	6	1.50	4.39	65	190
13	7	2.70	5.05	60	210
14	8	2.00	5.20	80	149
15	9	2.45	4.95	90	290
16	10	1.95	4.55	110	175
17	15	1.60	4.45	90	155
18	20	2.60	3.95	70	120
19	25	2.40	3.97	58	155
20	30	1.25	3.91	70	135
21	35	2.65	4.57	85	155
22	40	1.50	4.37	80	165
	MEAN	2.35	4.71	86	152

6. ACID LEACHING POTENTIAL OF MINERALIZED ROCKS

As part of the Babine Watershed Change Steering Committee program initiated by Fisheries and Marine Service (FMS), Strasdine and Razzell (MS, 1974) tested a total of 249 mineralized rock samples. These samples were taken from near the shoreline on the periphery of Babine Lake and analyzed for total sulfur and acid-consuming capability. This study was undertaken because the chemical or biological oxidation of sulfide-bearing ore produces sulfuric acid which in turn results in solubilization of mineralized deposits. Industrial processes such as mining and logging increase the exposed surfaces of mineralized deposits and promote leaching. Since many metals are highly toxic to aquatic life, damage occurs when the solubilized mineral deposits find their way into the lake water or ground water systems.

The leaching of metals from rocks proceeds to a larger extent by the bacteriological conversion of metalic sulfides to sulfates. For this reaction process to proceed certain conditions must first be met:

1. There must be an appreciable quantity of sulfide minerals in the sample.
2. The ore must be exposed to the air.
3. The alkalinity of the sample must be such that sufficient acid can be generated to lower the pH to about 2.5 (the pH at which the bacteria are most active). Samples which are relatively highly alkaline prevent the pH from becoming sufficiently acid for leaching to progress.

Babine Lake was divided into 16 zones (A to P), (Figure 34) according to the alkalinity of the mineralized rocks. Locations of samples in zone L near the Hagan Arm are shown in Figure 35. To assess the possibility for leaching, the acid-consuming ability of the sample was determined by titration with sulfuric acid. The volume is expressed as

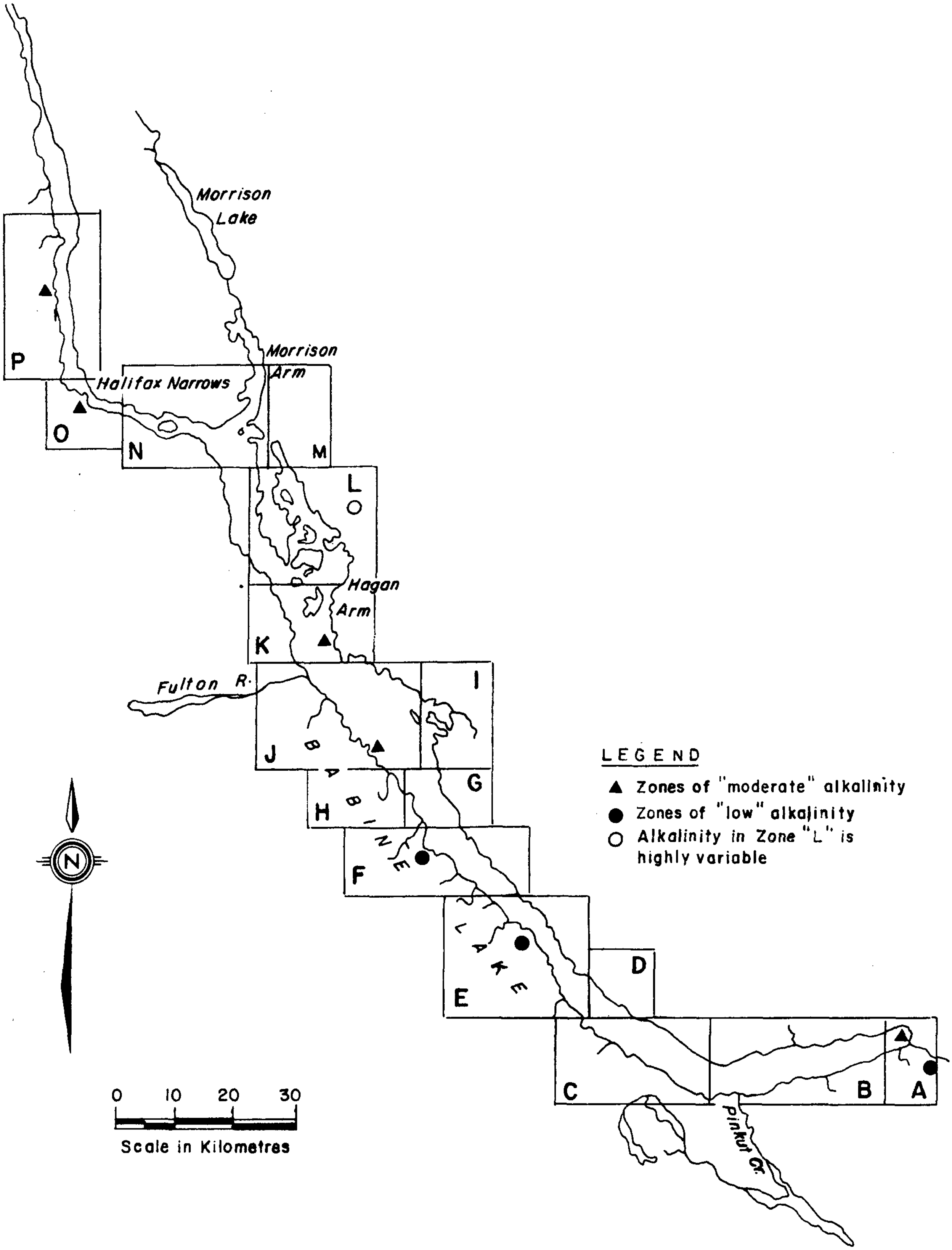


FIGURE 34 BABINE LAKE DIVIDED INTO ZONES ACCORDING TO ALKALINITY OF MINERALIZED ROCKS (STRASDINE & RAZZELL, 1974)

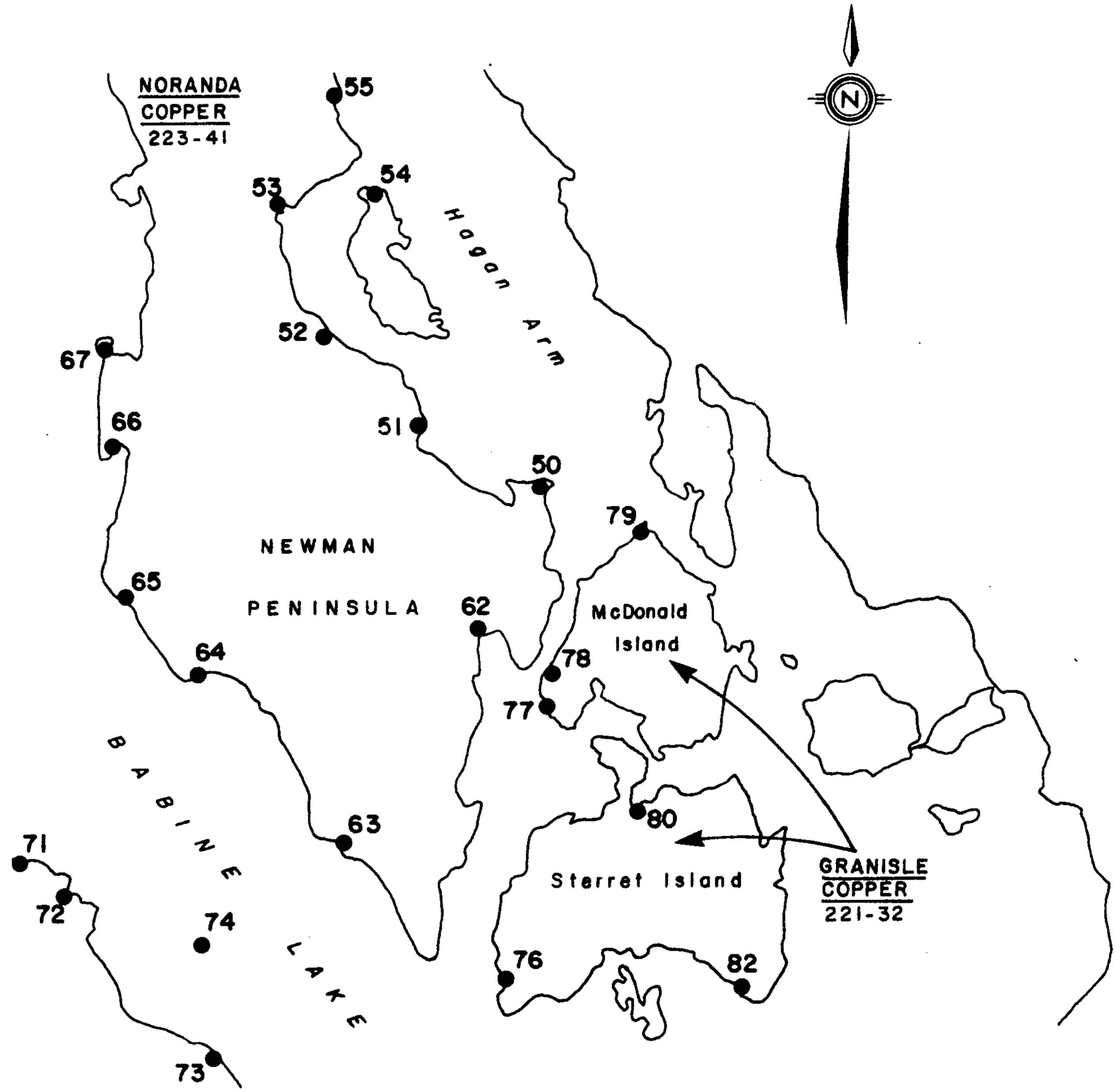


FIGURE 35 LOCATION OF SAMPLES IN ZONE L NEAR HAGAN ARM (STRASDINE & RAZZELL, 1974)

TABLE 30 ACID CONSUMPTION OF SAMPLES FROM ZONES L AND M
(Strasdine and Razzell, 1974)

SAMPLE	ACID CONSUMPTION (lb/ton)	SAMPLE	ACID CONSUMPTION (lb/ton)
50	31	65	130
51	112	66	24
52	63	67	72
53	55	71	90
54	92	72	22
55	133	73	8
56	63	74	22
57	38	75	201
58	20	76	332
59	62	77	263
60	133	78	118
61	21	79	52
62	114	80	75
63	12	81	69
64	36	82	39

TABLE 31 DISTRIBUTION OF ACID-CONSUMING CAPABILITY OF SAMPLES WITHIN ZONES
(Strasdine and Razzell, 1974)

ALKALINITY		HIGH		MODERATE		LOW			
ZONE	SAMPLES	Consuming more than 61 lb acid/ton		Consuming 31-61 lb acid/ton		Consuming less than 31 lb acid/ton		Average Acid consumption lb/ton	Alkalinity Index*
		No.	%	No.	%	No.	%		
A_1	163-172	0	0	1	10	9	90	22	low
A_2	173-184	5	42	7	58	0	0	63	moderate
B	1-49	31	63	17	35	1	2	137	high
D	185-190	4	67	2	33	0	0	236	high
E	146-162	0	0	6	35	11	65	26	low
F	191-199	0	0	4	44	5	56	27	low
I_1	200-210	7	64	2	18	2	18	77	high
I_2	211-220	0	0	10	100	0	0	46	moderate
J_1	103-112								
	140-145								
	242-245	3	15	10	50	7	35	41	moderate
J_2	113-139	20	74	3	11	4	15	257	high
K	98-102								
	246-249	2	22	3	33	4	45	38	mod.-low
L	50-67								
	71-82	17	57	6	20	7	23	83	high
N	68-70								
	88-97	9	70	2	15	2	15	105	high
O-P	83-87	1	20	3	60	1	20	69	moderate
TOTAL		99	43	76	33	53	24		

The number of samplse in this category is equal to or greater than the sum of the samples in the remaining two categories.

pounds of sulfuric acid consumed per ton of sample. The theoretical acid-producing capability was determined on a selected group of rock samples obtained from existing mine sites. Where sampling was concentrated in two or more specific areas within a zone, the areas have been designated by a subscript to that zone, e.g. A_1, A_2, etc.

The acid consumption values for rock samples collected from the Hagan Arm area (zones L and M) are given in Table 30. The data for the entire lake are summarized in Table 31, along with distribution of samples within a particular zone consuming more than 61 lb. of acid/ton, 31-61 lb./ton and less than 31 lb./ton. These values correspond to the theoretical amount of acid that could be produced from a ton of sample with a sulfide-sulfur content of 1% or greater, 0.5% to 1%, and 0.5% or less, respectively.

Twelve mined rock samples were obtained from the Granilse property of McDonald Island (location #1) and 9 samples from Noranda Mine property (location #2) on the Newman Peninsula. Both sulfur and acid consuming capability were determined on all mined samples. These data are presented in Table 32. One tailing sample (225) and three waste rock samples (229, 231, 232) were theoretically capable of producing more sulfuric acid than the alkalinity of these samples can neutralize (Columns (a) and (c) of Table 32).

Despite the overall moderate to high alkalinity index of the Babine area, a number of spots seem prone to acid leaching. These zones are E, F and A_1, where more than 50% of the sample consumed less than 30 lb. of acid/ton. The data from zone L indicate that grab-type rock samples and mined samples differ in their acid consuming capability. Of the 30 grab-type rock samples, 57% consumed more than 61 lb. of acid/ton, indicating a zone of high alkalinity. Mined samples, on the other hand, taken from the same zone displayed a narrow range of alkalinity, only 33% of the sample consumed 61 lb. of acid/ton. Based on mined samples, the alkalinity index for the zone L (Hagan Arm area) would rate as moderate to low.

Overall data interpreted suggest that rock formations in the Babine Lake region do not present an obvious leaching hazard (Strasdine and Razzell, 1974).

TABLE 32 ACID CONSUMPTION AND SULFUR CONTENT OF MINED ROCK SAMPLES FROM ZONE L (Strasdine and Razzell, 1974)

Sample	Nature of Sample	Acid Consumption (lb/ton) (a)	% total Sulfur (b)	Theoretical Acid Production (lb/ton) (c)	Potential Excess Acid Producer
221	Stripped	35	0.11	7	No
222	Overburden (1)	25	0.07	4	No
223		35	0.06	4	No
224		18	0.09	6	No
225	Mine	18	0.31	19	Yes
226	Tailings (1)	26	0.29	18	No
227		23	0.28	17	No
228		28	0.28	17	No
229	Waste	79	2.02	124	Yes
230	Rock (1)	46	0.52	32	No
231		68	2.38	146	Yes
232		23	0.72	44	Yes
233	Stripped Overburden (2)	30	0.03	2	No
234	Waste	74	0.25	15	No
235	Type 1	52	0.26	16	No
236	Location 2	93	0.61	37	No
237		74	0.94	58	No
238	Waste - Type 2	58	0.21	13	No
239	Location 2	52	0.18	11	No
240		104	0.93	57	No
241		76	1.18	72	No

REFERENCES

Beak Consultants Limited, 1972. Chemical and Biological Surveys of Babine Lake, September, 1971, May 1972 and July 1972. A Report for Noranda Mines Ltd., Granisle, B.C.

Chau, Y. K., R. Gaechter, and K. Lum-Shue-Chan, 1974. Determination of the Apparent Complexing Capacity of Lake Waters. J. Fish. Res. Board Can. 31:1515-1519.

Chau, Y. K. and P. T. S. Wong, 1975. Chemical and Biological Studies of Babine Lake, B.C., (unpublished report) Canada Centre for Inland Waters. Department of the Enivronment, Burlington, Ontario.

Carmack, E. C. and D. M. Farmer, 1982. Cooling Process in Deep, Temperate Lakes: A Review with Examples from Two Lakes in British Columbia. Journal of Marine Research, 40:85-108.

Farmer, D. M., 1975. Penetrative Convection in the Absence of Mean Shear. Quart. J. R. Met. Soc. 101 pp. 869-891.

Farmer, D. M. and E. Carmack, 1981. Wind Mixing and Restratification in a Lake Near the Temperature of Maximum Density. J. of Physical Oceanography. 11:1516-1533.

Farmer, D. M. and L. A. F. Spearing, 1975. Isotherm Plots of Babine Lake During the Ice Free Season. Pacific Marine Science Report, 75-9. Institute of Ocean Sciences, Patricia Bay, Victoria, B.C.

Hallam R., 1975. A Brief of EPS Water Quality Monitoring and Surveillance Activities on Babine Lake, 1974-75.

Kennedy, P., 1983. Report on Monitoring Program of the Supernatant Discharge at Maclaren Forest Products Inc., Babine Mining Division, Bell Mine, under Letter of Approval No. SK-20-AE.

Kussat, R. H., W. D. Knapp and R. A. McIndoe, 1972. A Preliminary Evaluation of the Environmental Impact of Mining, Community Development and Logging Activites on the Water Quality of Babine Lake. Department of the Environment, Pacific Region. Fisheries Service, Northern Operations Branch.

Smith, H. D. ed. Babine Watershed Change Program. Annual Reports for 1972 to 1976.

Smith, R. L., 1965. Ecology and Field Biology. Harper and Row, New York, pp. 162-181.

Strasdine, G. A. and W. E. Razzell, 1974. Acid Leaching Potential of Rock Formations Surrounding Babine Lake, B.C. Fish. Res. Bd., Canada. FMS Tech. Rept. No. 435. 22 p.

Stockner, J. G. and H. W. Smith, 1974. Chemical Studies of the Recent Sediments of Babine Lake, B.C. Fish. Res. Bd. Canada. MS Rept. No. 1268. 20 pp.

Stockner, John G. and K. R. S. Shortreed, 1975. Phytoplankton Succession and Primary Production in Babine Lake, British Columbia. Fish. Res. Board Canada. Vol. 32, No. 12.

Stockner, John G. and K. R. S. Shortreed, 1976. Babine Lake Monitor Program: Biological, Chemical and Physical Data for 1974 and 1975. Fish. Res. Bd. Canada. MS Rept. Series, No. 1373.

Stockner, J. G. and K. R. S. Shortreed, 1978. Limnological Surveys of Babine Lake, British Columbia: Results of the Monitoring Program, 1974-1978. Fisheries and Marine Service Manuscript Report No. 1494.

Wetzel, R.G., 1975. Limnology. Toronto, Sanders, 743 pp., 68-71.