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**NATURAL ACID ROCK DRAINAGE
AT MACMILLAN PASS, YUKON**

NHRI Contribution No.92046

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ABSTRACT

The Macmillan Pass area in east-central Yukon near the border with the Northwest Territories hosts many significant lead-zinc mineralization zones in sedimentary terrains with high acid rock drainage potential. To document the pre-mine water chemistry of the upper reaches of the South Macmillan River and its tributaries, the area was systematically sampled in the summers of 1990 and 1991, respectively. Parameters found failing to meet the water quality criteria for drinking water and/or for aquatic life in one or more locations include pH, Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Zn and very rarely Pb and conductivity. The water chemistry is largely controlled by the local geology such that acidic streams with high metal contents are mostly associated with sulfide-bearing, siliceous sediments of the Middle to Upper Devonian Lower Earn Group. Dilution, neutralization, complexing with organics, sorption onto iron and manganese oxides with or without subsequent chemical reactions and trapping of suspended particles by vegetation have been identified as the major mechanisms attenuating the transport of heavy metals in the area. The capacities of hydrated iron oxide and wetland/swamp systems to scavenge heavy metals, particularly under northern conditions, deserve more research. If the prominent lead-zinc prospects in the area were to be developed, it is recommended that milling and major waste disposal facility be located on the west side of the South Macmillan River to take advantage of the buffering capacity of the local lithology to minimize potential acid mine drainage problems.

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INTRODUCTION

In the Macmillan Pass area of east-central Yukon (Figure 1), black clastic rocks of Devonian-Mississippian age host many lead-zinc mineral occurrences (Abbot and Turner, 1990). Two of the more significant and relatively well defined deposits are the Tom Property and Jason Claims (Goodfellow and Rhodes, 1990; Turner, 1990). Together with similar mineralization found in the area, for example the Nidd Property of Cominco adjacent to the Jason Claims, these deposits have high potential to be developed into operating mines. To furnish pre-mine baseline environmental data, Soroka and Jack (1983) and Jack and Osler (1983) reported on the water chemistry and biodiversity of bottom fauna in the watersheds near the Tom and Jason Properties, respectively. To address the potential acid rock drainage problem in the area, Kwong and Whitley (1991) provided a cursory assessment of the impact of the prevailing acid rock drainage on the water quality of the South Macmillan River, which is the major water body susceptible to contamination if the prominent prospects were to be developed. To substantiate the preliminary findings of Kwong and Whitley (1991), the current project was initiated in June of 1991 under the DIAND MEND Program and jointly funded by the Water Resources Branch of Indian and Northern Affairs Canada and the National Hydrology Research Institute of Environment Canada. The objectives of the project are threefold: (i) to document the pre-mine water chemistry in the upper reaches of the South Macmillan River and its tributaries; (ii) to determine the relationship between stream chemistry and lithology; and, (iii) to identify major mechanisms of metal attenuation occurring in the area.

The general setting and physiography of the Macmillan Pass area and the field sampling methods have been described in earlier reports (Jack and Osler, 1983; Soroka and Jack, 1983; and, Kwong and Whitley, 1991) and will not be repeated here. Laboratory

analytical procedures not mentioned in these reports are briefly described in the appropriate appendices. The emphasis of this report lies in data interpretation. Though a whole array of physical, chemical and, to a limited extent, microbiological parameters have been measured during the course of this investigation, only geochemical data relevant to the three identified objectives will be discussed in detail in this report.

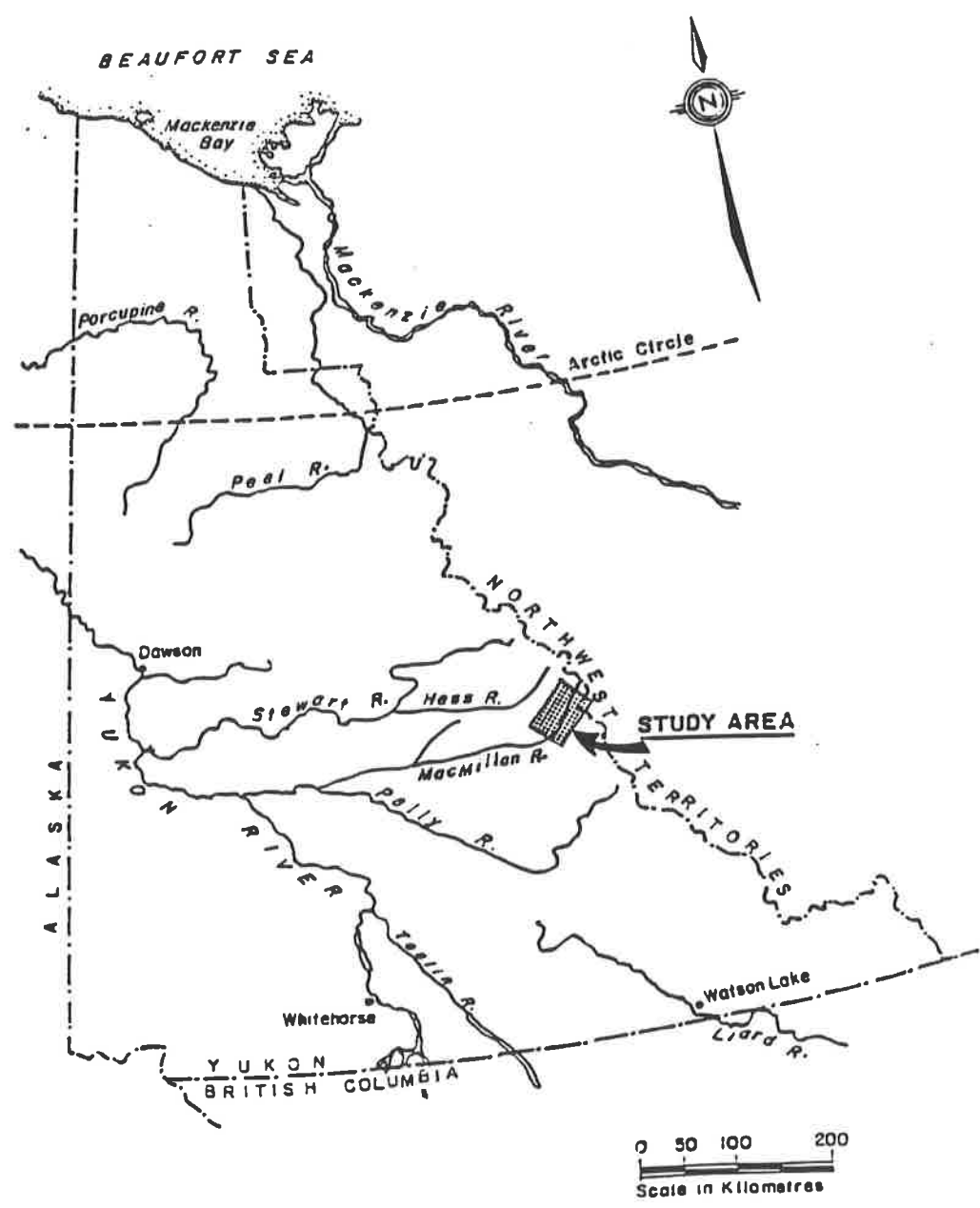


Figure 1. Location of the Macmillan Pass study area.

WATER QUALITY OF THE MACMILLAN PASS AREA

To facilitate interpretation of water chemistry data, the South Macmillan River drainage system in the Macmillan Pass area can be divided into three subsystems: (i) the main course of the South Macmillan River (Stations 1 through 12, Figure 2); (ii) acidic tributaries, located in the east side of the drainage basin, of which Macintosh Creek and Sekie Creek #2 are most prominent; and, (iii) near neutral streams located on the west side of the South Macmillan River and the southern portion of the study area (e.g. Sekie Creek #1). Appendices I and II tabulate the full analyses of water samples collected in the study area in August of 1990 and July of 1991. Salient characteristics of the three subsystems are briefly described as follows:

(i) The South Macmillan River Stations

From the Yukon-Northwest Territories border and extending southward for about 50 kilometres, 11 stations along the South Macmillan River were sampled. Most of the stations were located in the first 28 kilometres (Figure 2) which is the heart of the Macmillan Pass area. Whereas the dissolved metal content of this stretch of the river is generally low, manganese fails to meet the drinking water criteria and zinc exceeds the recommended level for aquatic life for all the stations. In the Macmillan Pass area, parameters that frequently do not meet the drinking water criteria include pH, iron and cadmium; and, those exceeding the recommended levels for aquatic life include pH, aluminium, cadmium and copper. The selenium data cannot be assessed because the analytical detection limit for the element exceeds both water quality criteria. A tabulation of the water quality criteria for drinking water and aquatic life (after Jack and Osler, 1983) is included in Appendix III.

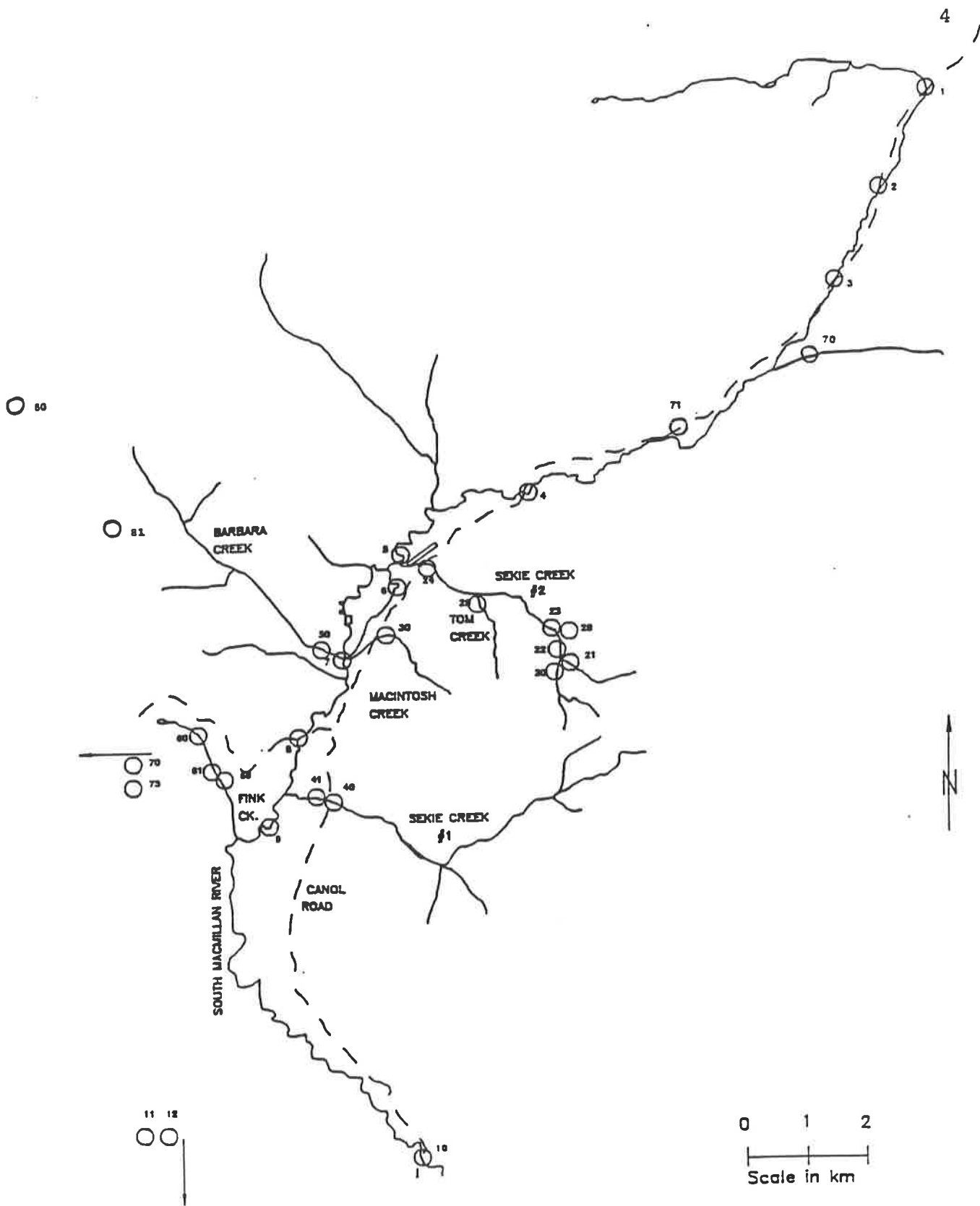


Figure 2. Location of stations along the South Macmillan River.

Figure 3 depicts a few parameters which exhibit prominent variations along the course of the River. The high acidity in the northernmost station along the Yukon-Northwest Territories border is rather unexpected and the peaks observed in the acidity curve at Stations 4 and 6 indicate further contributions of acidic drainage from the tributaries near these localities. Concomitant with the increase in acidity are increases in zinc and sulfate contents. The sulfate curve, however, suggests that further input into the river around Station 8 is likely. The major input of calcium and magnesium, on the other hand, occurs near Stations 3 and 5. As suggested by the pH curve and the variations of the other parameters plotted, dilution occurs between Stations 1 and 2; neutralization occurs around Stations 3 and 5; and, south of Station 8, dilution phenomenon predominates such that pH remains near neutral and all other parameters follow a decreasing trend.

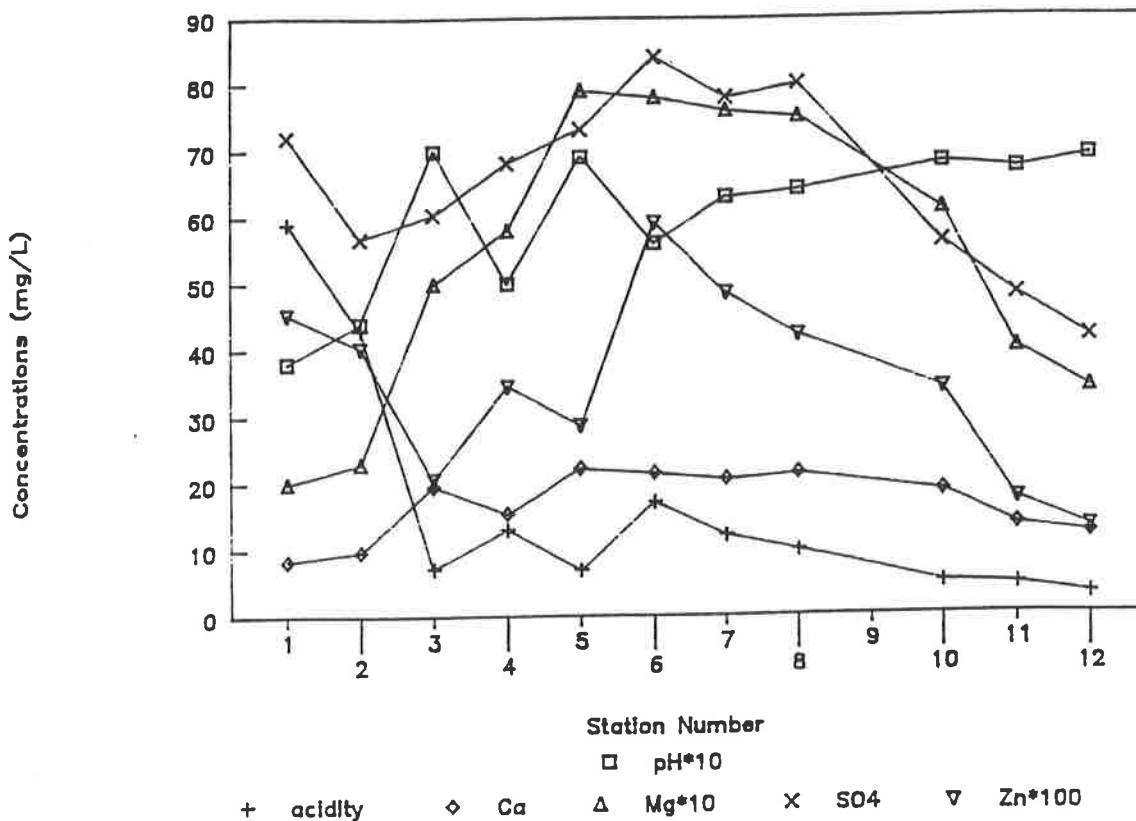


Figure 3. Variation of water chemistry along the South Macmillan River (as shown by selected parameters).

ii) Acidic Streams

With the exception of the headwaters area of the South Macmillan River near the Yukon-Northwest Territories border, which was not examined and sampled, all the acidic tributaries to the River encountered during the course of this investigation are located at the east side of the river. As will be explained in the next section, the distribution of acidic streams is largely controlled by lithology. The two acidic streams which have been sampled thoroughly are Sekie Creek #2, which is affected by intensive exploration activities at the Tom Property, and a relatively undisturbed stream known as Macintosh Creek (Figure 4).

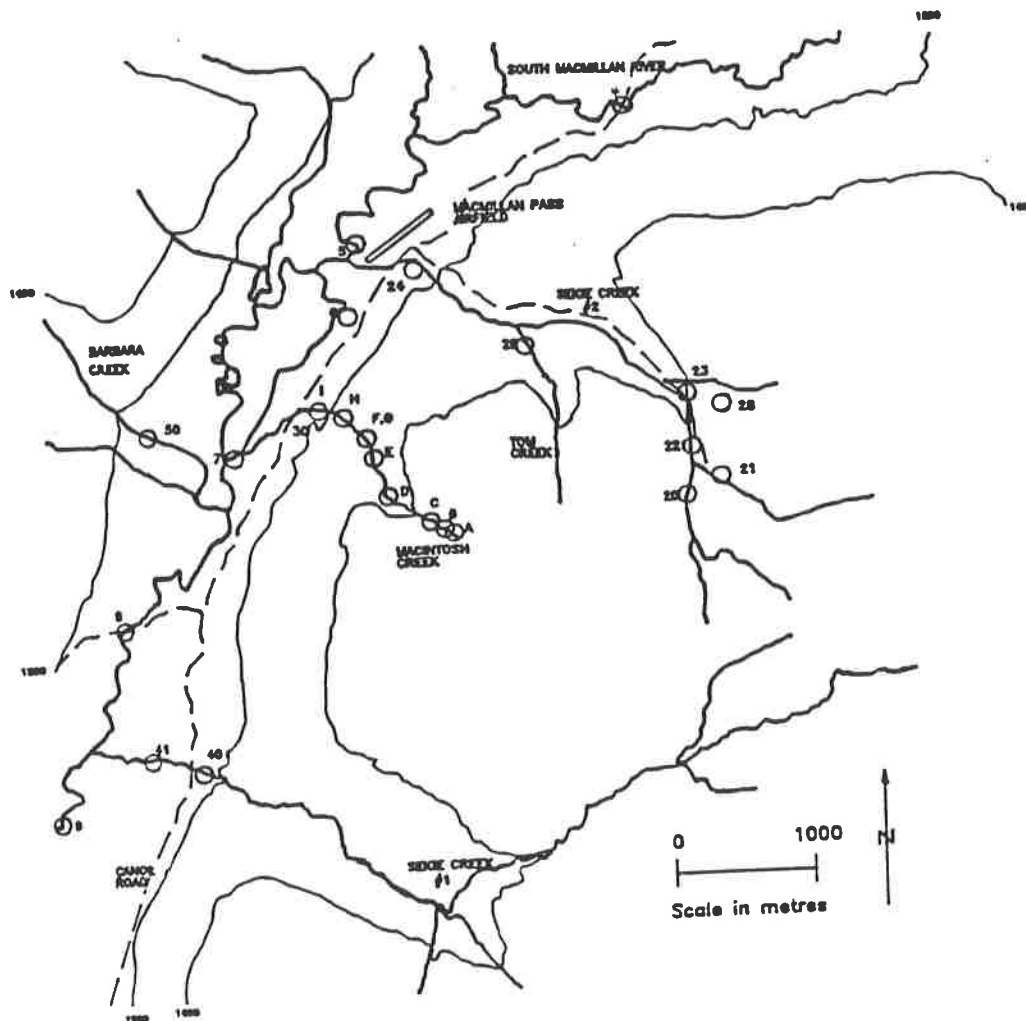


Figure 4. Sampling locations along Sekie Creek #2 and Macintosh Creek.

Except for the upper-most stations of both streams (which are dominated by snowmelt), all samples fail to meet the water quality criteria for drinking and aquatic life in pH, cadmium, iron and manganese. Metals that exceed the recommended level for aquatic life include aluminium, copper, nickel and zinc. Moreover, Macintosh Creek contains unacceptable levels of arsenic and chromium while some of the Sekie Creek #2 stations near the exploration adit of the Tom Property (Station 28) contain elevated levels of lead. Some of these parameters are depicted in Figure 5.

The highest dissolved metal input into Sekie Creek #2 derives from the Tom adit (Station 28, Figure 5). However, the acidity is relatively low associated with the discharge. This is because the ore itself carries siderite besides sulfides. Part of the acid generated by sulfide oxidation is neutralized in-situ by the iron carbonate. However, neutralization by siderite would not lead to a near neutral pH as evidenced by the discharge pH readings of 3.4 both in the 1990 and 1991 sampling. As for Macintosh Creek, the highest metal contents are associated with groundwater seeps (Stations B, G and G1). The discharge rate of these seeps, however, is relatively low and generally less than 2 litres per minute.

Another significant acidic tributary to the South Macmillan River is located about 2 Km south of Station 3. The tributary sampled at Station 70 (Figure 2) had a pH of 3.4 and acidity of 84 mg/L as CaCO_3 . The sample tested exceeds the water quality criteria for drinking water and aquatic life in iron and cadmium. In addition, manganese does not meet the drinking water criterion while dissolved aluminium, copper and zinc are higher than the recommended levels for aquatic life.

(iii) Near-Neutral Streams:

Limited by accessibility, only two non-acidic tributaries to the South Macmillan River were sampled in 1990. These include Stations 40 and 41 of Sekie Creek #1 and Station 60 of Fink Creek (Figure 2). Sekie Creek #1 is very low in total dissolved solids

A. Macintosh Creek

B. Sekie Creek

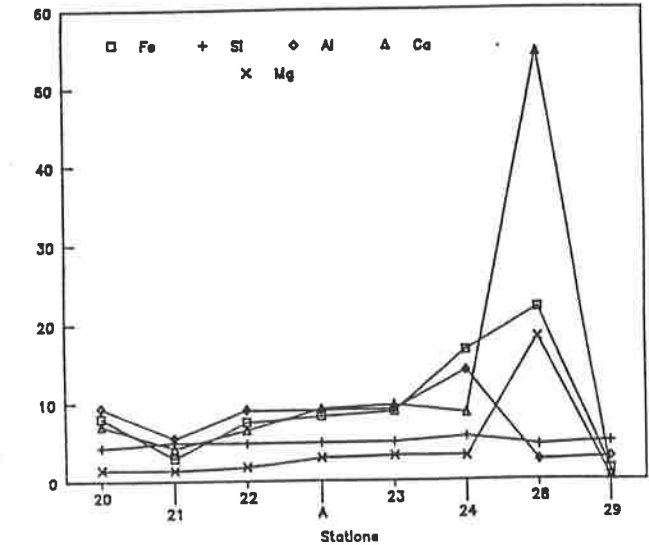
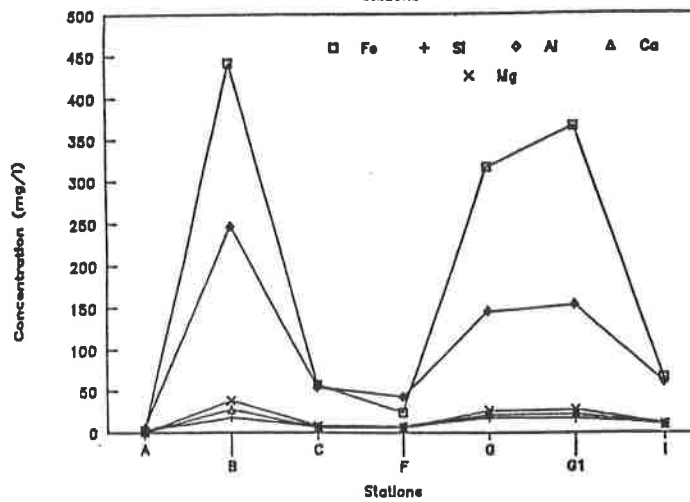
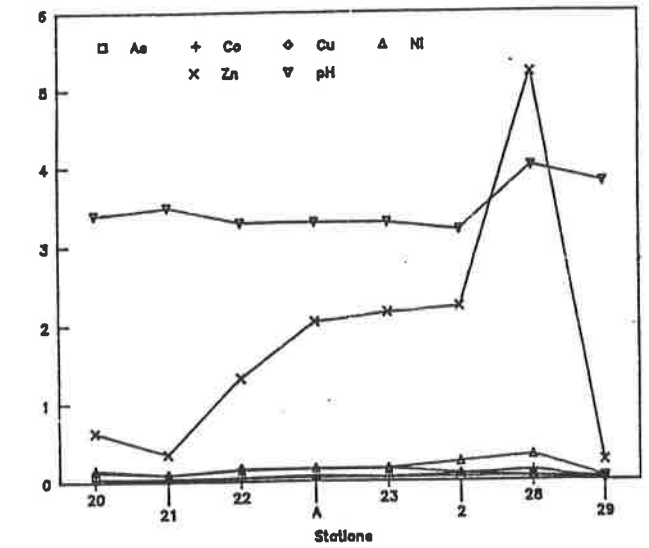
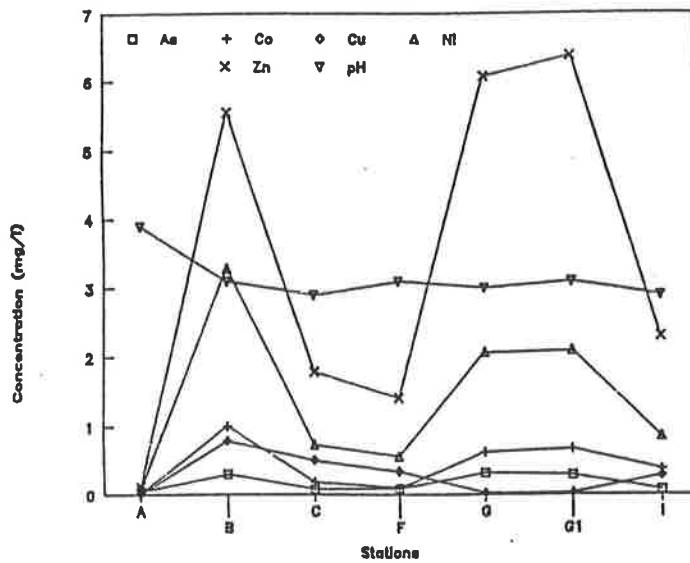
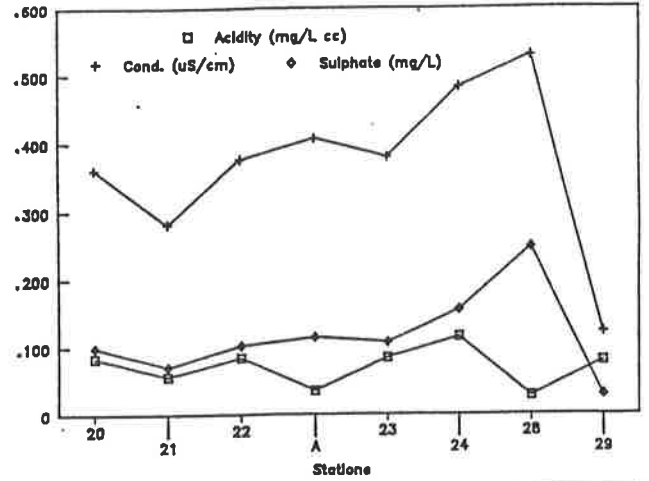
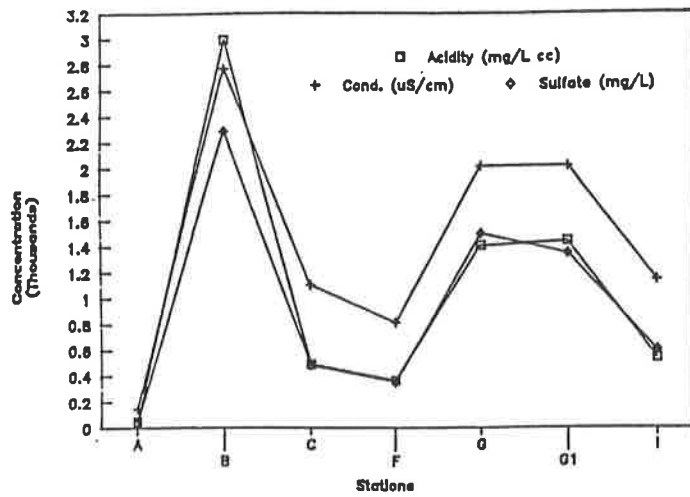


Figure 5. Selected water chemistry of Sekie Creek #2 and Macintosh Creek.

as reflected by the measured conductivities of 48 and 46 $\mu\text{S}/\text{cm}$, which are too low to sustain aquatic life. Fink Creek as sampled at Station 60 contains marginally too high a dissolved iron content to meet the drinking water criterion. All other parameters measured are at acceptable levels. In 1991, many near-neutral streams in the study area were field measured with respect to pH and conductivity but water samples were collected at only six stations. These include Station 40 of Sekie Creek #1, Stations 60 and 61 of Fink Creek, Station 71 north of Station 4 along the South Macmillan River and Stations 80 and 81, two creeks located near Cominco's Nidd Property which drain towards Hess River. Sekie Creek #1 again showed low conductivity. However, dissolved aluminium and zinc are barely higher and pH slightly lower than the acceptable levels for aquatic life. Stations 60, 61 and 81 showed a dissolved manganese content that barely exceeds the drinking water criterion and Station 61 had slightly higher dissolved zinc than recommended for aquatic life. Generally speaking, however, the near-neutral streams investigated in the area contain negligible levels of metal contaminants.

(iv) Comparison of the 1990 and 1991 data sets:

The two sets of data tabulated in full in Appendices I and II and briefly described above were obtained in a single sampling trip in the summer of 1990 and 1991, respectively. As such, they represent a "snap-shot" of the water chemistry at the time of sampling and thus are insufficient for assessing the effect of seasonal change. However, the 1991 sampling took place a month earlier than the 1990 sampling when the upper north-facing slopes of most hills were still covered with snow and the freshet might not have completely ended. A comparison of selected variables (Table 1) renders some interesting observations. Whereas the water chemistry in most stations along the south Macmillan River does not change much, a few stations along Macintosh Creek (notably B, C and G) and Sekie Creek #2 (e.g. Stations 24 and 28) have shown an increase in sulfate and zinc concentrations in 1991 relative to

1990. There are two possible explanations for the observation: (a) sulfide oxidation has intensified with time in these two acidic streams; or, (b) the increased sulfate and zinc simply result from flushing of acid rock drainage products stored in the rocks over the winter months. Flushing of sulfide oxidation products associated with spring freshet is a common phenomenon frequently observed elsewhere. For example, Kwong and Ferguson (1990) has documented the importance of flushing events in affecting the water chemistry of acidic drainage from an abandoned minesite on Mount Washington near Courtenay on Vancouver Island, British Columbia. Nonetheless, once entered the South Macmillan River, the increased sulfate and zinc loadings are camouflaged by dilution.

Table 1. A comparison of 1990 and 1991 water chemistry.

Station #	pH		SO ₄ (mg/L)		Zn (mg/L)	
	07/91	08/90	07/91	08/90	07/91	08/90
Macl-A	3.9	3.8	38	12.6	0.12	0.12
Macl-B	3.1	3.3	2290	1610	5.55	5.0
Macl-C	2.9	3.3	480	221	1.79	0.88
Macl-F	3.1	3.03	350	310	1.42	1.45
Macl-G	3.0	3.36	1500	983	6.07	4.8
Macl-I	2.9	3.16	606	540	2.31	2.35
1	3.8	3.8	72	74.7	0.429	0.448
2	4.4	4.2	56.8	63.7	0.345	0.419
3	7.0	7.1	60.4	69.6	0.167	0.209
4	5.0	4.9	68.2	72.7	0.297	0.332
5	6.9	7.2	73.2	77.1	0.239	0.228
6	5.6	6.9	84	80.7	0.517	0.338
7	6.3	6.8	78	82.5	0.379	0.354
8	6.4	6.7	80.8	80.8	0.359	0.361
10	6.8	7.0	56	61.7	0.271	0.236
11	6.7	6.9	48	46	0.148	0.145
12	6.9	6.9	41.7	38	0.11	0.103
24	3.0	3.2	280	156	3.42	2.23
28	3.4	4.0	314	248	6.17	5.21
40	5.6	6.5	21	15.1	0.045	0.031
60	7.8	7.8	17	14.4	0.013	0.014

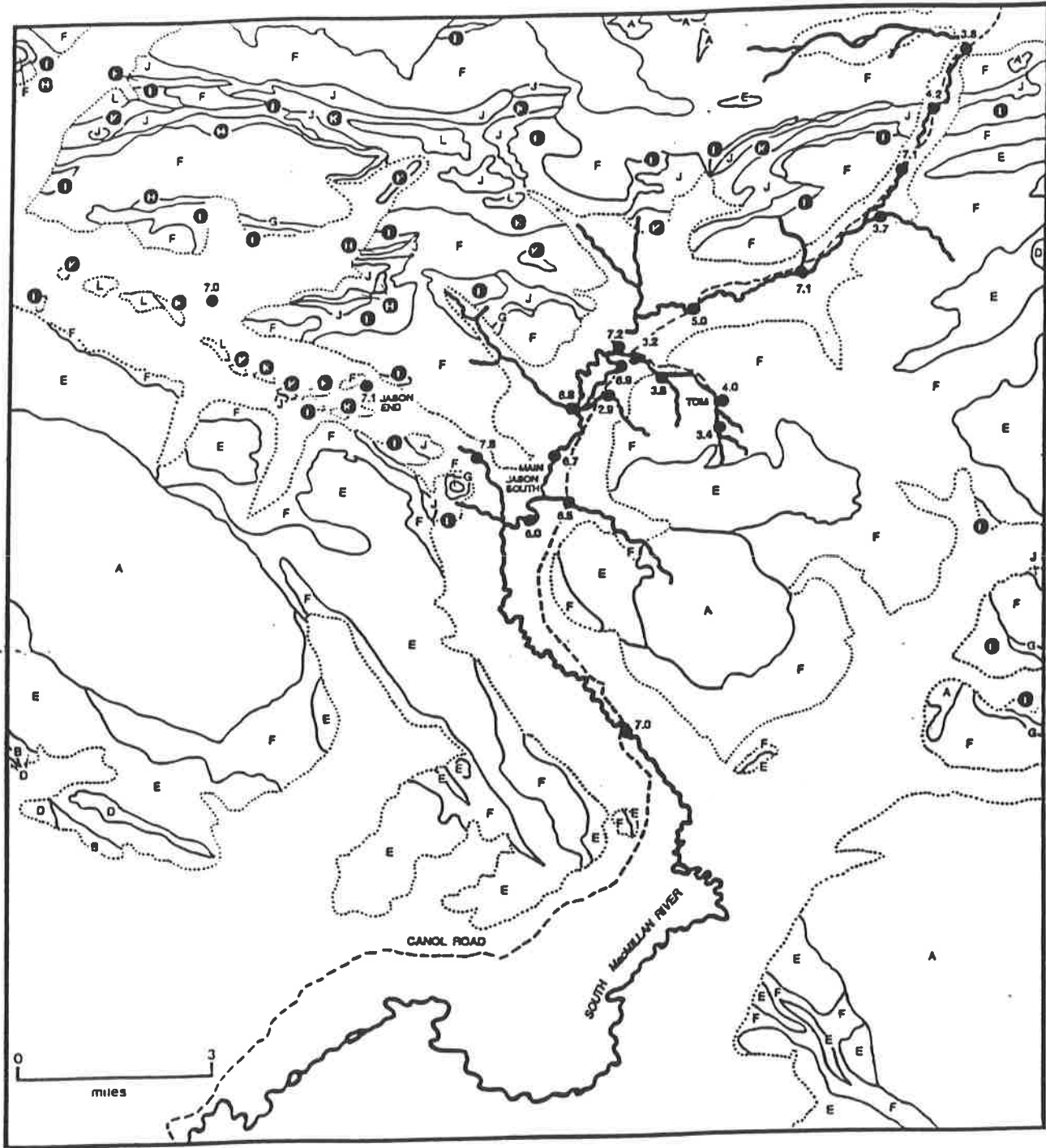
WATER CHEMISTRY - LITHOLOGY RELATIONSHIP

When examined in the light of rock distribution in the Macmillan Pass area, the restriction of acidic streams to the Yukon - Northwest Territories border and the east side of the South Macmillan River is no accident. Figure 6 plots the field measured pH at the many stations examined against the geology of the area (modified after Abbot, 1983). Evidently, rocks giving rise to acid rock drainage belong to the Lower Earn Group (Unit F) of Middle and Upper Devonian in age. The Lower Earn Group comprises black, carbonaceous and siliceous shale of marine origin, chert pebble conglomerate and some siltstone. These rocks commonly contain 2 to 8 per cent sulfide in the form of pyrite. Pyrite in the highly fissile shale units is particularly susceptible to alteration because mechanical weathering resulting from the freeze-thaw process would create new access for oxygen and water as well as replenishing fresh mineral surfaces for chemical weathering. Once acid is generated from sulfide oxidation, there are few buffering minerals in the siliceous matrix to neutralize it.

On the west side of the South Macmillan River, however, calcareous rock units (e.g. H, I, and J) are rather widespread. Even though sulfide oxidation may still occur, any acid generated will be neutralized in-situ and subsequent metal leaching is prevented. This explains why most streams draining the west side of the South Macmillan River are near neutral in character and contain little metal contaminants.

Near the northern boundary of the study area, silty limestone and calcareous shale (Unit I) underlie the South Macmillan River between Stations 2 and 3. Part of the acidity carried from the headwaters area is neutralized in this portion of the River rendering a measured pH of 7.1 at Station 3 in July, 1991.

In the previous section, it has been mentioned that Sekie Creek #1 (opposite Jason South in Figure 6) is very low in dissolved metals. The creek drains through mainly a Cretaceous intrusive and a non-sulfide-bearing assemblage of sandstone, siltstone and minor



LEGEND		
CRETACEOUS		
(A) basic quartz monzonite and basic gneiss	LOWER AND MIDDLE DEVONIAN	----- OUTCROP BOUNDARY
PERMIAN AND (?) PENNSYLVANIAN	(G) chert, cherty argillite, and siliceous shale	————— GEOLOGICAL CONTACT
(B) cherty shale	SILURIAN AND DEVONIAN	● STATION LOCATION
CARBONIFEROUS	(H) carbonate rich mafic volcanoclastic rocks	
(D) quartz arenite and silt shale	ORDOVICIAN, SILURIAN AND EARLY DEVONIAN	
MISSISSIPPIAN - UPPER EARON GROUP	(I) silty limestone and calcareous black shale	
(E) sandstone, siltstone, and shale	(J) chert, siliceous shale and mudstone	
(?) MIDDLE AND UPPER DEVONIAN - LOWER EARON GROUP	CAMBRIAN AND LOWER ORDOVICIAN	
(F) siliceous shale, chert pebbles conglomerates, and siltstone	(K) siliceous shale and limestone	
	(?) MADRYTIAN AND LOWER CAMBRIAN	
	(L) shale, siltstone, and sandstone	

Figure 6. Correlation of water chemistry with geology as evidenced by pH distribution.

shale of the Mississippian Upper Earn Group. The relatively massive rock units are less susceptible to mechanical weathering and chemical weathering of silicate minerals is retarded under low temperature conditions prevailing in the area most of the year. Consequently, there is very little metal input into the stream from the underlying and surrounding rocks which leads to the low conductivity.

In summary, as pointed out previously by Kwong and Whitley (1991), in the Macmillan Pass area, the water chemistry of slow flowing tributaries (<0.5 m³/sec) to the River is largely controlled by the local geology. To facilitate assessment of acid rock drainage potential in the area, Table 2 presents acid-base accounting data for the common rock types found here. Except Sample 10 which is a recently formed conglomerate (ferric-crete) from Macintosh Creek, these are fresh drill core samples furnished by Cominco Exploration Limited. The first five samples are typical Lower Earn Group rocks which are invariably characterized by a negative net neutralization potential (NNP). In other words, they are potentially acid-generating. Samples 6 through 9 are typical calcareous rocks that abound on the west side of the River. These rocks have a higher neutralization potential (NP) than acid-generating potential (AP) and are thus potentially acid buffering.

Table 2. Acid-base accounting data for common rock types found in the Macmillan Pass area.

	ROCK TYPE	PASTE pH	TS	N.P. (kg CaCO ₃ /tonne)	A.P. (kg CaCO ₃ /tonne)	NNP
1	Gritty shale	4.37	2.18	1.92	68.13	-66.21
2	Carbonaceous shale/mudstone	6.01	3.50	1.68	109.38	-107.70
3	Carbonaceous mudstone	6.08	1.86	1.68	58.13	-56.45
4	Sand stripe mudstone	6.38	1.31	6.25	40.94	-34.69
5	Chert pebble conglomerate	5.00	0.96	16.60	30.00	-13.40
6	Calcareous mudstone	8.11	4.22	424.00	131.88	292.13
7	Intrusive	7.91	0.19	52.90	5.94	46.96
8	Volcanic	8.11	0.72	386.00	22.50	363.50
9	Calcareous mudstone	8.73	1.10	817.00	34.38	782.63
10	Conglomerate (recent)	5.90	0.09	1.20	2.81	-1.61

METAL ATTENUATION PROCESSES

In the presentation of water quality data of the South Macmillan River stations, dilution and neutralization have already been mentioned as important processes attenuating the transport of acid rock drainage products down the River. As acidic drainage occurrences, either naturally occurring or enhanced by exploration activities, abound in the study area, it is important to investigate metal attenuation mechanisms occurring in the acidic streams. The results would possibly allow one to (i) predict whether the water quality of the South Macmillan River will deteriorate with time resulting from continual contaminant loadings from its tributaries; and, (ii) devise mitigative strategy to safeguard the well-being of the ecosystem in the area.

One of the means to assess the mobility of a trace element in a given environment is to determine how it is partitioned among various mineral phases by sequential extraction analyses on sediment samples. For this purpose, stream sediments were collected from four localities, namely Macintosh Creek, the Tom adit, Station 2 and Station 70 and submitted for analyses. The extraction procedures are briefly outlined in Appendix IV and the results obtained are briefly described as follows:

Because of the naturally acidic nature of Macintosh Creek, it has been intensively sampled and examined during the course of this study. The creek generally has a rocky stream bed, intermittently coated with hydrated iron oxide, and carries very few fine-grained sediments until it reaches flat-lying landscape near the South Macmillan River. Near its crossing with Canol Road and along a few gentle stretches upstream, the creek banks are lined with a lavish growth of a bright green sphagnum frequently referred to in the field as zinc moss. From the Canol Road crossing to the confluence with South Macmillan River, the creek meanders through 600 metres of a deltaic wetland area with thick willow bushes and moss ground cover. From the distribution of various coloured sediments near the Canol Road crossing, it is evident that the creek has changed

course or overflowed its banks several times in the recent past.

In 1990, sediment samples were collected in triplicate at its junction with Canol Road and the results of sequential extraction analyses are shown in Table 3. Only arsenic, barium, chromium and vanadium are sufficiently abundant in the minus 80-mesh portion of the samples to render meaningful data. Arsenic and vanadium are predominately associated with the residual fraction of the sediment and are thus least mobile in the environment. A significant portion of barium (20%) is bound to organic materials while chromium is equally partitioned into the iron and manganese oxides fraction and the residual fraction (44% each) and the remainder mainly in the organic fraction (9%). The non-residual fractions are susceptible to remobilization with changes in surface characteristics or destruction of the host minerals/materials in response to significant changes in the prevalent geochemical environment. Despite a rather anomalous dissolved zinc value of 1.7 mg/L in the water, the analyzed portions of the sediments contained on the average only 10ppm Zn, too low to render accurate speciation data and are thus not reported.

Table 3. Results of sequential extraction analyses of sediments from Station 30 on Macintosh Creek, August, 1990.

Station: STN 30-AVG.(3)

Element	As	Ba	Cr	V
Carb.	0.00	0.00	2.43	0.00
Exch.	0.00	0.00	1.07	0.00
Fe+Mn	0.00	0.00	59.53	515.67
Org.	1.33	20.77	11.71	399.00
Res.	195.00	84.17	58.93	3023.33
Subtot.	196.33	104.93	133.68	3938.00
Sed.	196.33	104.93	133.67	3936.67
%Carb.	0.00	0.00	1.82	0.00
%Exch.	0.00	0.00	0.80	0.00
%Fe+Mn	0.00	0.00	44.54	13.10
%Org.	0.68	19.79	8.76	10.14
%Res.	99.32	80.21	44.09	76.80
Total	100.00	100.00	100.01	100.03

In 1991, three more sediments were sampled along Macintosh Creek. Two of the sample stations are located between Canol Road and South Macmillan River and the third one near the confluence with the River. Pertinent sequential extraction results are depicted in Figure 7. It is interesting to note the increase in zinc in the sediments as the River is approached (50, 75 and 139 ppm in MacI-1, 2 and 3, respectively). Most of the zinc is associated with the residual fraction. Apparently, vegetation in the wetland area serves to trap very fine suspended particles containing zinc and leads to its concentration at the sampling locations. The sediment in Station MacI-3 also contained sufficient copper to render internally consistent sequential extraction results. The detailed fractionation of copper is very similar to that of zinc except that relatively more copper rest with other fractions at the expense of the residual fraction.

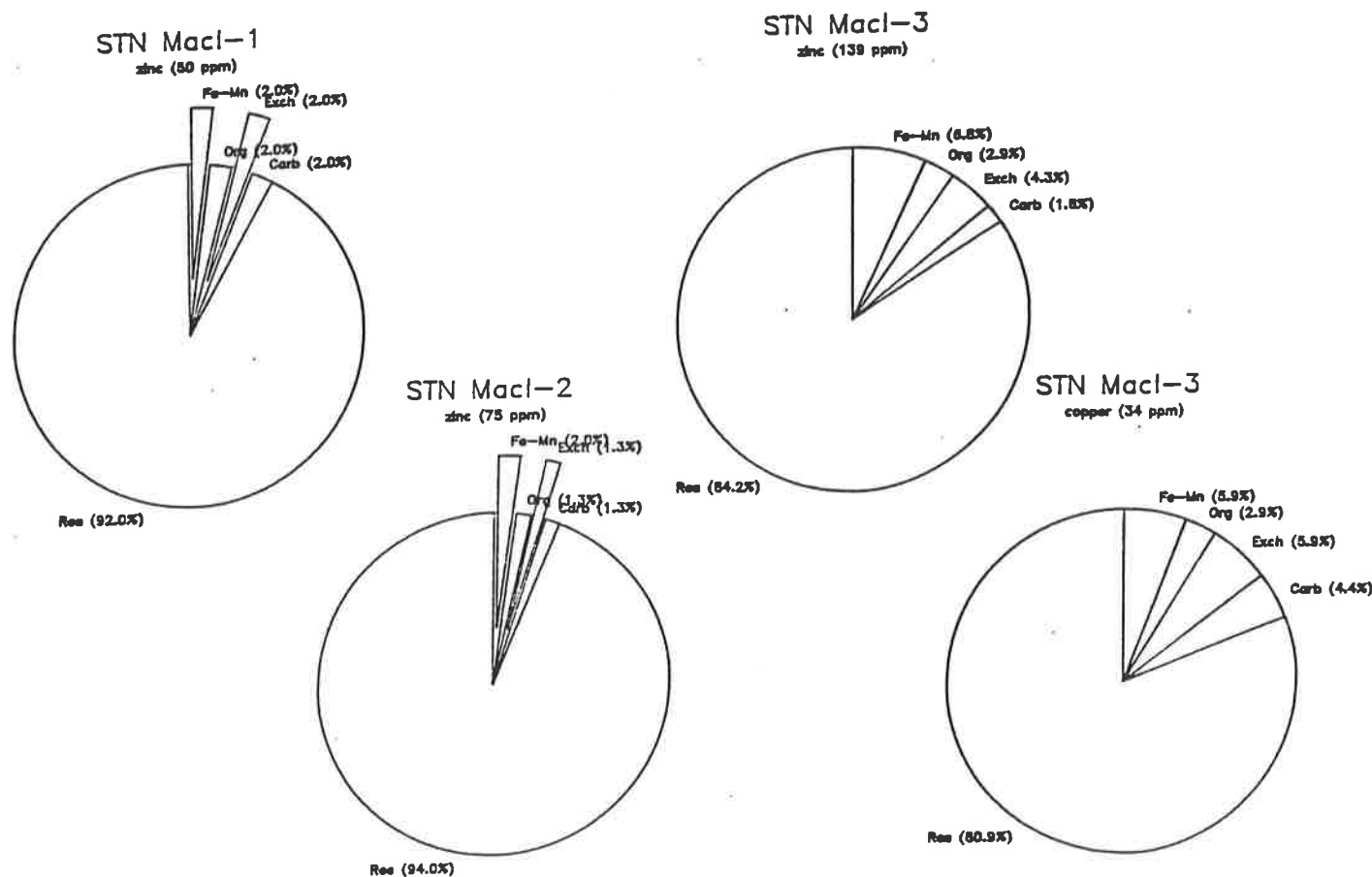


Figure 7. Sequential extraction of Macintosh Creek sediments, 1991.

Trapping of finely suspended particles by vegetation as a major mechanism of metal attenuation in the Macmillan Pass area is especially evident along Macintosh Creek. Near the Canol Road crossing where "zinc moss" abounds, yellowish brown hydrated iron oxide has been observed to build on the sphagnum layer upon layer. The sphagnum appears to behave as sponge soaking up the iron oxide. Chemical analyses of a very light, semi-lithified material collected from an abandoned stream bed in the vicinity gave roughly 68% Fe_2O_3 , 4% P_2O_5 , 2% SiO_2 , 1% S, 26% LOI, 206 ppm As and 53 ppm Zn as the predominant major and trace element components. Evidently, the analyzed sample is dried up sphagnum saturated with iron oxide. The ability of hydrated iron oxide to scavenge arsenic from solution is particularly noteworthy. In the sequential extraction analyses, arsenic is not found associated with the iron and manganese oxide fraction, it must have reacted chemically with iron to form a stable, amorphous arsenate compound that survives the sequential procedure to rest as a residual component.

The results of sequential extraction analyses performed on a sediment sampled near the Tom adit in the 1990 field season are shown in Table 4. Arsenic, barium, chromium and vanadium behave similarly as in the Macintosh Creek samples though the exact fractionation figures for each element may vary. On the other hand, proportionally less copper is bound to the carbonate and organics fractions and more zinc is bound to the exchangeable, iron and manganese oxides and organics fractions. The difference in composition of the aqueous matrix (i.e. different water chemistry as is evident from Figure 5) as well as the absolute concentrations of the elements themselves may lead to the observed variation in fractionation pattern. The sample also contained 561 ppm lead which is mainly bound to the residual, organics and iron and manganese oxides fractions though exchangeable lead (6.4%) cannot be completely ignored.

Table 4. Results of sequential extraction analyses on a sediment from the vicinity of the Tom adit.

Station: STN 28

Element	As	Ba	Cr	Cu	Pb	V	Zn
Carb.	0.00	0.00	0.30	0.74	7.20	0.00	5.34
Exch.	0.00	0.00	0.00	3.40	36.00	0.00	35.00
Fe+Mn	0.00	0.00	15.40	7.54	92.70	4.00	37.70
Org.	0.00	93.00	0.40	0.76	141.00	4.00	18.80
Res.	325.00	99.00	4.10	81.00	284.00	112.00	103.00
Subtot.	325.00	192.00	20.20	93.44	560.90	120.00	199.84
Sed.	325.00	192.00	20.20	93.40	561.00	120.00	200.00
%Carb.	0.00	0.00	1.49	0.79	1.28	0.00	2.67
%Exch.	0.00	0.00	0.00	3.64	6.42	0.00	17.50
%Fe+Mn	0.00	0.00	76.24	8.07	16.52	3.33	18.85
%Org.	0.00	48.44	1.98	0.81	25.13	3.33	9.40
%Res.	100.00	51.56	20.30	86.72	50.62	93.33	51.50
Total	100.00	100.00	100.00	100.04	99.98	100.00	99.92

Pertinent results of sequential extraction analyses on two sediment samples from Station 70 are depicted in Figure 8. Essentially, zinc and copper follow almost an identical partition pattern as the Macintosh Creek samples. Further description is therefore not necessary.

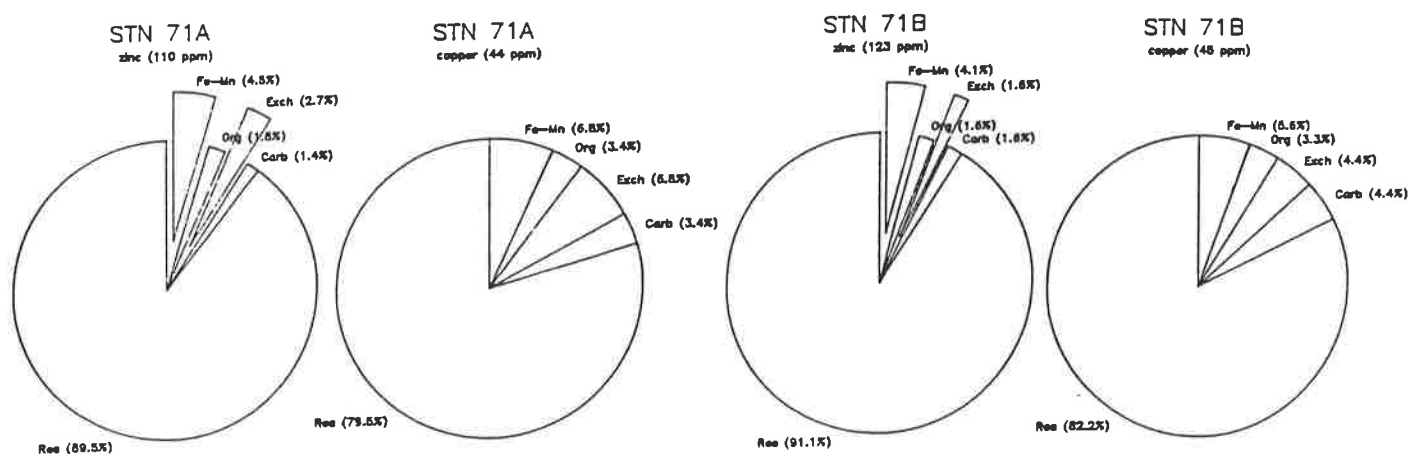


Figure 8. Partition of zinc and copper in sediments of Station 70.

The river bed at Station 2 on South Macmillan River near the northern boundary of the study area is prominently coated with a yellowish hydrated iron oxide. The minus-80-mesh portion of a sediment sample gave 542 ppm Zn, 381 ppm V, 166 ppm Cu, 2727 ppm Ba, 134 ppm Ni and 20 ppm Pb. Arsenic was not analyzed and the fractionation of only zinc, copper and nickel are investigated (Figure 9). Zinc and nickel behave very similarly and are mainly bound to the residual and iron and manganese fractions. On the other hand, a significant portion of copper is also bound to organics. Compared to the Tom adit sample which is also enriched in copper, it appears that the cause of the observed variation in fractionation pattern of copper is related to lead. Both copper and lead can form stable complexes with organics but the affinity of lead for organics is higher than that of copper. Consequently, in presence of abundant lead, as in the Tom adit sample, copper cannot compete with lead for the available sites on the organics for sorption and subsequent reactions and is therefore bound to next most favourable substrate.

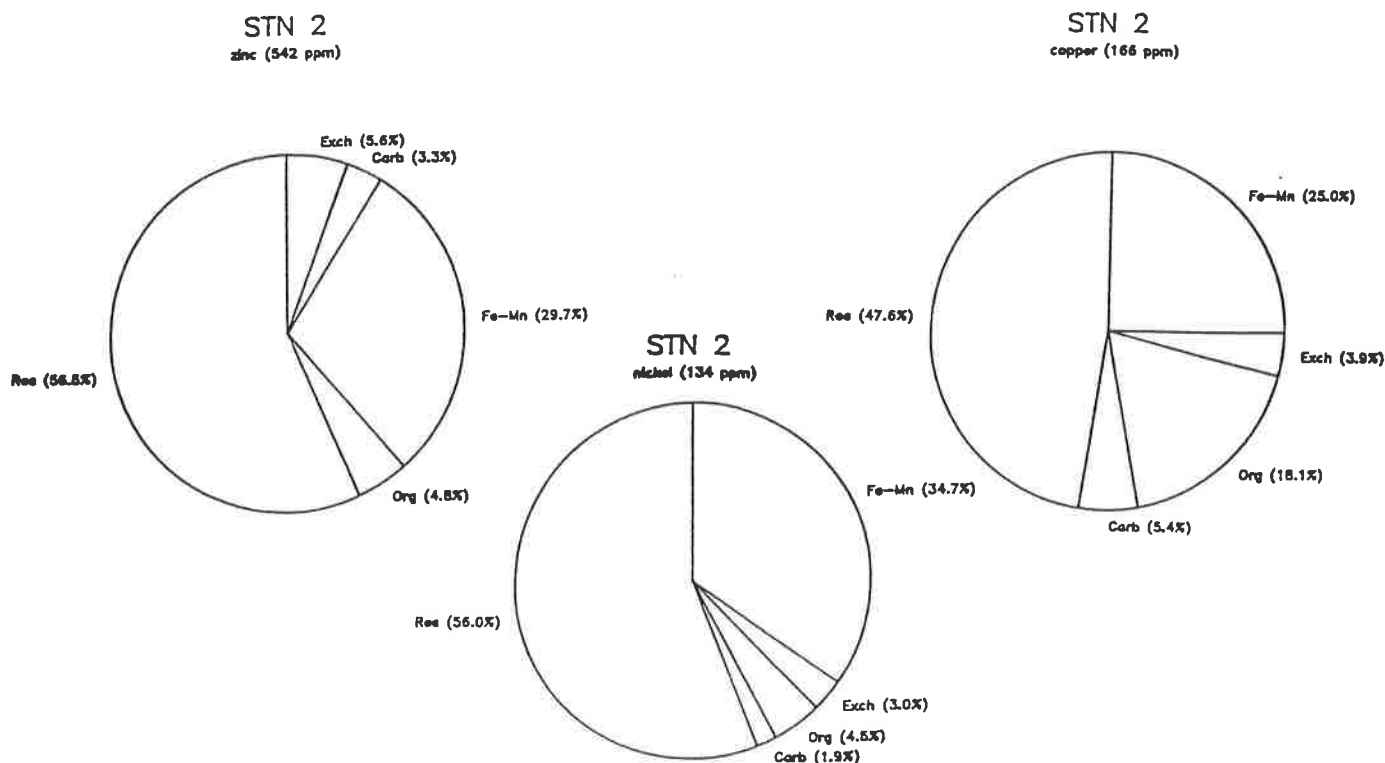


Figure 9. Fractionation of selected metals at Station 2.

Summing up the results of all the sequential extraction analyses, it is apparent that detailed fractionation patterns are governed by the ambient water chemistry as well as the concentration of the elements concerned. However, evidently only very small portions of the heavy metals occurring in the stream sediments in the Macmillan Pass area are bound to the highly leachable carbonate and exchangeable fractions. Complexing with organics appear to provide a rather stable sink for copper, lead and possibly barium. Sorption onto iron and manganese oxides provides for at least temporary storage to various degrees for zinc, nickel, chromium and copper. The chemical reaction between arsenic and hydrated iron oxide, on the other hand, appears to completely immobilize arsenic. All these processes render the heavy metals in the sediments not readily bio-available in the study area.

Given the slow flow regime of most tributaries to the South Macmillan River, suspended sediment loadings to the River is expected to be minimal most of the year. Figure 10 comparing the dissolved and total contents of selected metals at various stations along Sekie Creek #2 and Station 30 located on Macintosh Creek suffices to illustrate the contention. Note that total metals were determined on unfiltered samples which include contributions from suspended particles. With the exception of discharge from the Tom adit (Station 28), the dissolved and total metals for all the stations are very comparable suggesting low suspended load. Among the four metals plotted, iron shows a more pronounced disparity between the dissolved and total metal content. This is caused by continual precipitation of ferric hydroxide resulting from the slow hydrolysis of ferrous ion introduced to the streams through ground water discharge. Because of the low suspended loads, the major concern of water quality in the area at its current state lies in the readily bio-available dissolved metal content, especially zinc.

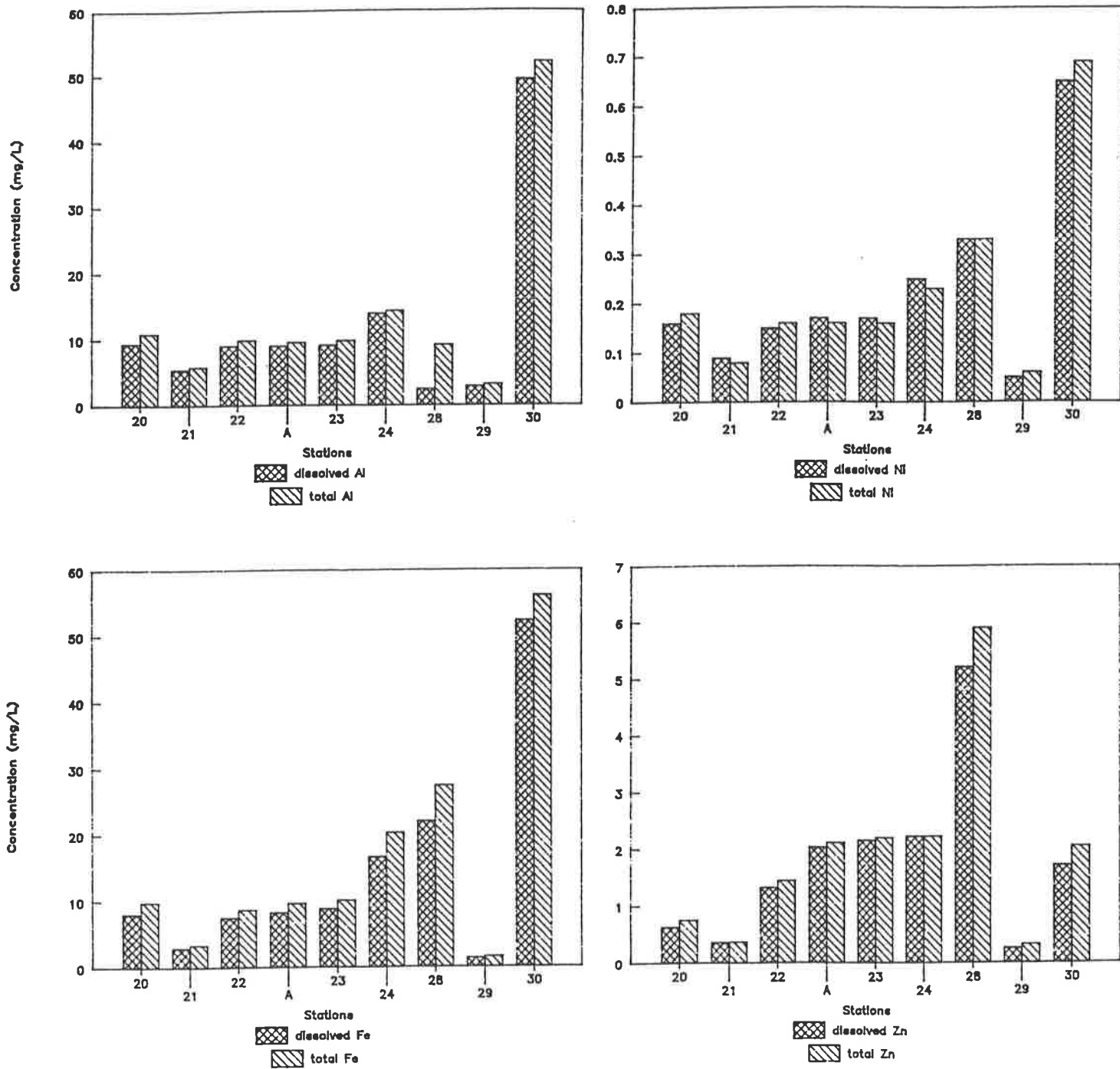


Figure 10. A comparison of dissolved and total metals in Sekie Creek #2 (Stations 20-29) and Macintosh Creek (Station 30).

DISCUSSION AND CONCLUSION

1. Preventive Measures for Acid Rock Drainage

It follows from the presentation of water quality data and elucidation of water chemistry - lithology relationship that the Macmillan Pass area is very susceptible to acid rock drainage problems. Mining development in the area should incorporate necessary precautionary measures to address this environmental issue in order to reduce or limit its potential impact. The sizes and distribution of potential ores defined to date suggest that the mining of all the mineralized zones scattered on both sides of the South Macmillan River together may be the only economically viable option. Given the scenario, it makes sense to locate, if at all possible, milling and major waste disposal facilities on the west side of the River to take advantage of the potential buffering capacity of many prevalent rock types. Mining strategies that would produce the least amount of waste rocks and cause least disturbance to the landscape should be given preference to strategies involving major treatment and reclamation schemes. Furthermore, detailed delineation of the distribution of acid-generating rocks and close monitoring of the acid rock drainage situation should be incorporated at every stage of any prospective mining schemes.

2. Further Research

Through sequential extraction analyses on sediments, it has been found that in the Macmillan Pass area sorption of heavy metals onto various mineral fractions with possible subsequent reactions are relatively effective in limiting the bioavailability of these potentially harmful elements. While the immobilization of arsenic by reaction with hydrated iron oxide appears to be permanent, it is not clear how long-lasting is the association of other heavy metals like copper, lead and zinc with the iron and manganese oxides. Some of the metals held by sorption may actually be squeezed out

upon recrystallization of the oxide phases with aging. Besides, the potential application of heavy metal sorption onto hydrated iron oxides as a practical means of reducing acid rock drainage contamination problem has largely not been researched. More work is recommended.

Besides physically trapping suspended contaminants by vegetation, the geochemical and biogeochemical setting of swamps and wetland is so different from that of an open stream environment that an entirely new array of chemical reactions must have occurred. Whereas mechanisms controlling metal distribution and mobility in wetland under warmer climate conditions have been investigated (e.g. Walton-Day et al., 1990), northern wetland/swamp systems like those abound in the Macmillan Pass area have not been studied in any detail. It is recommended that further research be carried out to investigate the detailed mechanisms and processes of metal transport and attenuation in wetland located in discontinuous permafrost terrains. Either the Macmillan Pass area or other sites in Yukon or the Northwest Territories with natural or man-induced acid rock drainage will be suitable for a detailed study. Indeed, it is desirable to examine different sites with different metal contamination problems so that a database can be constructed and relevant research findings will be more widely applicable.

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Appendix IA: Results of analyses of the 1991 suite of water samples from stations along the South Macmillan River.

Parameter Analyzed	Unit	1	2	3	4	5	6	7	8	10	11	12	
ACIDITY	mg/l	59	45	7.2	15	6.9	17	12	9.7	4.8	4.4	5.0	
ALKALINITY	mg/l	<.5	<.2	14	<.5	19	1.7	7.3	8.0	4.8	4.8	6.1	
CHLORIDE	mg/l	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	
COLOUR/TRUE	Rel.U.	5	5	5	5	5	5	5	5	5	5	5	
CONDUCTIVITY	US/cm	218	162	170	169	206	211	210	207	175	129	115	
FLUORIDE	mg/l	0.241	0.241	0.140	0.139	0.169	0.148	0.142	0.125	0.130	0.122	0.111	
NITROGEN:AMMONIA	mg/l	.01	.007	<.002	.009	.005	.021	.013	.019	.006	.006	.003	
NITRATE	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	
NITRITE+NITRATE	mg/l	.034	.031	.038	.051	.053	.059	.057	.048	.046	.031	.028	
PH	Rel.U.	5.8	4.4	7.0	5.0	6.9	5.6	6.3	6.4	6.3	6.7	6.9	
PHOSPHORUS/TOTAL	mg/l	.005	.004	.007	.025	.025	.032	.029	.027	.027	.012	.011	
RESIDUE/FILTERABLE	mg/l	120	100	110	110	160	160	160	150	130	90	90	
NON-FILTERABLE	mg/l	5	5	13	23	22	24	25	27	21	11	10	
SULFATE	mg/l	72	56.8	60.4	68.2	75.2	84	7E	80.8	56	48	41.7	
TURBIDITY	FTU	<.1	1.0	2.5	5.3	8.3	16	15	16	11	4.4	4.0	
METALS/DISS. (WATER-ICP SCAN)	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	
AL	mg/l	5.93	4.56	<.05	.67	.07	.34	.1	.05	.05	.05	.05	
AS	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.01	<.01	<.01	<.01	<.01	
B	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	
BA	mg/l	.025	.043	.041	.033	.036	.037	.036	.042	.041	.041	.046	
BE	mg/l	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	
CA	mg/l	8.3	9.7	19.6	15.4	22.2	21.4	20.5	21.3	18.6	13.4	12.2	
CD	mg/l	.007	.007	<.005	<.005	<.005	.005	<.005	<.005	.01	.008	.005	
CU	mg/l	.02	.015	.006	.01	.01	.025	.015	.013	.016	.009	<.005	
CR	mg/l	<.005	<.005	<.005	<.005	<.005	.006	<.005	<.005	.007	<.005	<.005	
CU	mg/l	.045	.037	<.005	.01	<.005	.02	.01	<.005	.005	<.005	<.005	
FE	mg/l	.885	.423	.093	.374	.239	1.8	1.13	1.08	.586	<.098	<.065	
K	mg/l	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	
HG	mg/l	2	2.3	5	5.8	7.9	7.8	7.6	7.5	6.1	4	3.4	
MN	mg/l	.213	.172	.089	.14	.11	.144	.126	.126	.101	.065	.063	
MO	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	
NA	mg/l	.2	.2	.2	.2	.2	.2	.2	.2	.4	.5	.6	
NI	mg/l	.14	.12	.06	.09	.08	.1	.09	.08	.07	.04	.03	
P	mg/l	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	
PB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	
SB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	
SE	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	
SI	mg/l	2.77	2.71	2.14	2.36	2.4	2.81	2.36	2.54	2.76	2.91	2.69	
SN	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	
SK	mg/l	.046	.044	.056	.058	.068	.068	.066	.067	.059	.047	.046	
T1	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	
V	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	
ZN	mg/l	.429	.345	.167	.297	.239	.517	.379	.259	.271	.148	.11	
HC	mg/l	29	32.6	69.7	62.4	88	85.7	82.4	84.5	71.7	50.2	44.7	
HT	mg/l	52.8	52.2	70.3	66.4	89.4	91.4	85.8	87.5	73.5	50.9	45.3	
						.HAZARDOUS/CA+HG							
						/TOTAL							

Appendix IB: Results of analyses of the 1991 suite of water samples from the Macintosh Creek stations.

Parameter Analyzed	Units	A	B	C	F	G	G1	I	Blank
ACIDITY	mg/l	50	2275	488	364	1410	1448	546	1.9
ALKALINITY	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
CHLORIDE	mg/l	<0.2	1	10	5	125	120	15	<0.2
COLOUR/TRUE	Rel. U.	5	360	1100	814	2020	2020	1150	5
CONDUCTIVITY	uS/cm	149	2770	1100	814	2020	2020	1150	1.9
FLUORIDE	mg/l	0.059	3.96	0.63	0.56	2.55	3.57	0.80	<0.020
NITROGEN/AMMONIA	mg/l	0.31	.128	.529	.353	1.35	.222	.473	<0.002
/NITRITE	mg/l	<0.002	.002	<0.002	<0.002	.005	.003	<0.002	<0.002
/NITRATE	mg/l	.166	<0.002	.209	.291	.01	<0.002	.223	.027
PH	Rel. U.	3.9	3.1	2.9	3.1	3.0	3.1	2.9	5.7
PHOSPHORUS/TOTAL	mg/l	.19	8.21	.048	.014	4.28	5.44	.067	.008
RESIDUE/FILTERABLE	mg/l	70	4070	780	850	2380	3110	860	<10
/NON-FILTERABLE	mg/l	5	360	5	5	210	260	5	5
SULPHATE	mg/l	38	2290	480	250	1500	1250	606	5.5
TURBIDITY	FTU	0.5	100	0.4	0.2	100	27	0.2	0.2
METALS/DISS. (WATER-ICF SCAR)	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
AL	mg/l	5.25	247	55.1	43.8	147	155	61.6	<0.05
AS	mg/l	<0.05	.3	.08	.09	.32	.29	.07	<0.05
B	mg/l	<0.01	.02	.03	.02	.02	.02	.02	<0.01
BA	mg/l	.087	.011	.053	.02	.003	.003	.018	<0.01
BE	mg/l	<0.001	.005	.002	.002	.003	.004	.002	<0.001
CA	mg/l	1	28	6	6.8	21.6	22.1	9.8	<0.1
CD	mg/l	<0.005	.114	.038	.026	.083	.092	.038	<0.005
CO	mg/l	.016	1.01	.185	.097	.630	.676	.38	<0.005
CR	mg/l	<0.005	.331	.103	.054	.192	.22	.077	<0.005
CU	mg/l	.007	.795	.504	.344	.022	.026	.285	<0.005
FE	mg/l	2.68	442	58.1	24.8	317	366	67.2	.029
K	mg/l	<2	14	<2	<2	9	10	3	<2
MG	mg/l	.9	38.6	8.4	7.2	27	28.1	10.8	<0.1
MN	mg/l	.044	1.68	.372	.321	1.06	1.1	.463	<0.001
MO	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NA	mg/l	.2	.7	.3	.4	.6	.6	.4	<0.1
NI	mg/l	.07	3.29	.74	.57	2.07	2.1	.86	<0.02
P	mg/l	<0.1	4.5	.6	.2	7.1	8	1.1	<0.1
PB	mg/l	<0.05	.08	<0.05	<0.05	<0.05	.06	.05	<0.05
SB	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SE	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SI	mg/l	3.16	17.8	6.36	6.94	17.7	17.1	9.97	<0.05
SN	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SR	mg/l	.137	.019	.019	.026	.093	.087	.039	<0.001
T1	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
V	mg/l	3.12	1.18	.18	.05	1.81	1.98	.31	<0.01
ZN	mg/l	5.55	1.79	1.79	1.42	6.07	6.37	2.31	<0.002
HAZARDOUS/CA+MG	mg/l	5.9	229	49.6	46.8	165	171	68.8	<0.4
/TOTAL	mg/l	30.6	2080	363	258	1250	1420	423	<0.4

Appendix IB: (cont.)

Parameter Analyzed	Units	A	B	C	F	G	G1	I	Blank
METALS/EXT. (WATER-ICF SCAN)									
AG	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AL	mg/l	5.23	245	56.1	44	146	158	62.8	<.05
AS	mg/l	<.05	.34	.09	<.05	.33	.28	.15	<.05
B	mg/l	<.01	.04	.02	.01	.03	.03	<.01	<.01
BA	mg/l	.084	.011	.051	.052	.002	.002	.02	<.001
BE	mg/l	<.001	<.009	.002	.002	.006	.007	.002	<.001
CA	mg/l	1	30.6	6.1	7	24.2	24.3	9.8	<.1
CD	mg/l	<.005	.111	.026	.015	.057	.07	.04	<.005
CO	mg/l	.01	2.06	.224	.114	1.02	1.14	.48	<.005
CR	mg/l	<.005	.404	.099	.053	.206	.243	.071	<.005
CU	mg/l	.006	.795	.489	.336	.024	.036	.287	<.005
FE	mg/l	2.61	462	57.8	25.1	317	366	67.9	.039
K	mg/l	<.2	14	<.2	<.2	10	13	<.2	<.2
HG	mg/l	.8	38.3	8.1	7	27	27.8	10.9	<.1
MN	mg/l	.041	1.57	.394	.336	1.06	1.08	.472	<.001
MO	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
NA	mg/l	.1	.7	.3	.4	.6	.6	.4	<.1
NI	mg/l	.03	3.45	.63	.47	1.93	2.19	.88	<.02
P	mg/l	<.1	7.2	.5	.2	7	7.5	1.1	<.1
PB	mg/l	<.05	.06	<.05	<.05	<.05	.15	<.05	<.05
SB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SE	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SI	mg/l	2.87	17.4	6.5	7.32	17.3	17.4	10.2	<.05
SN	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SR	mg/l	.008	.137	.017	.024	.092	.082	.04	<.001
TI	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
V	mg/l	<.01	3.21	.13	.04	1.86	2.16	.31	<.01
ZN	mg/l	.118	5.99	1.87	1.47	6.76	6.93	2.37	<.002
HC	mg/l	5.7	224	48.6	46.2	172	172	69.5	<.4
HT	mg/l	28.4	>1510	347	246	>1080	>1090	429	<.4
AG	mg/l	<.01	<.01	<.01	.01	<.01	<.01	<.01	<.01
AL	mg/l	5.25	251	56.8	44	153	160	61.4	.07
AS	mg/l	<.06	.34	.08	<.06	.24	.14	.08	<.06
B	mg/l	<.01	.01	.02	.03	.02	.03	.02	<.01
BA	mg/l	.093	.013	.063	.029	.003	.003	.025	<.001
BE	mg/l	<.001	.005	.003	.002	.003	.004	.002	<.001
CA	mg/l	1.8	29.5	6.4	7.6	23.3	24	10	.1
CD	mg/l	<.006	.151	.041	.029	.089	.098	.037	<.006
CO	mg/l	.026	3.04	.461	.219	1.73	1.91	.497	<.006
CR	mg/l	<.006	.397	.11	.061	.2	.234	.075	<.006
CU	mg/l	.013	.849	.547	.371	.024	.033	.299	<.006
FE	mg/l	2.62	494	61.9	26.2	317	383	68.9	.041
K	mg/l	<.2	14	<.2	<.2	9	10	<.2	<.2
HG	mg/l	.9	39.3	8.8	7.5	28.1	29.2	11	<.1
MN	mg/l	.046	1.74	.391	.333	1.11	1.15	.472	.001
MO	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
NA	mg/l	.2	.7	.3	.4	.6	.6	.4	<.1
NI	mg/l	.19	3.41	.82	.61	2.18	2.29	.9	<.02
P	mg/l	.1	8	.6	.2	7.8	8.6	1.2	<.1
PB	mg/l	<.06	<.06	<.06	<.06	<.06	.07	<.06	<.06
SB	mg/l	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
SE	mg/l	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
SI	mg/l	3.38	18.8	7.58	8.39	18.7	19.3	10.2	<.06
SN	mg/l	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
SR	mg/l	.009	.144	.02	.026	.098	.091	.04	<.001
TI	mg/l	<.005	<.002	<.002	<.002	<.002	<.002	<.002	<.002
V	mg/l	.02	3.37	.19	.06	1.94	2.12	.31	<.01
ZN	mg/l	.208	6.07	2.01	1.57	6.73	7.01	2.49	.008

.HARDNESS/CA+HG
/TOTAL
/TOTAL (WATER-ICF)

Appendix IC: Results of analyses of the 1991 suite of water samples from miscellaneous locations.

Parameter Analyzed	Units	24	28	40	60	61	70	71	80	81
ALUMINUM	mg/l	246	136	4.6	6.2	3.4	84	3.1	3.8	2.7
ALKALINITY	mg/l	<0.5	<0.5	<0.5	41.5	54.9	<0.5	91	97	59
ARSENIC	mg/l	5	5	1.2	10	15	<0.2	<5	5	<5
BARIUM	mg/l	5	5	5	10	15	<5	<5	385	232
CHLORIDE	mg/l	752	717	53	157	140	335	302	385	232
COLOUR/TRUE	US/cfm	0.47	0.67	0.078	0.085	0.088	0.26	0.138	0.101	0.085
CONDUCTIVITY	mg/l	0.004	0.299	0.006	0.24	0.061	0.046	<0.002	<0.002	<0.002
FLUORIDE	mg/l	0.002	<0.002	0.004	0.04	0.009	<0.002	<0.002	<0.002	<0.002
NITROGEN/AMMONIA	mg/l	0.054	0.024	0.049	0.012	0.022	0.047	0.046	0.029	0.097
NITRATE	mg/l	3.0	3.4	5.6	7.8	7.8	3.4	8.2	8.0	8.0
NITRITE/NITRATE	mg/l	0.016	0.043	0.008	0.39	0.48	0.044	0.018	0.01	0.007
PHOSPHORUS/TOTAL	mg/l	580	620	40	100	100	210	190	250	150
RESIDUE/FILTERABLE	mg/l	15	67	<5	770	370	8	<5	7	<5
RESIDUE/NON-FILTERABLE	mg/l	280	314	21	17	14.9	99	50.1	89	52.5
SULPHATE	mg/l	0.2	0.5	1.3	90	86	26	<0.1	2.9	0.7
TURBIDITY	FTU	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
METALS/DISS. (WATER-ICF SCAN)	mg/l	24.5	6.92	0.11	0.05	0.05	7.49	0.05	<0.05	0.11
AL	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
AS	mg/l	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	mg/l	0.049	0.012	0.028	0.077	0.093	0.025	0.074	0.038	0.022
BA	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BE	mg/l	10.8	51.8	5.1	23	19.4	7.1	43.2	47.6	31
CA	mg/l	0.035	0.039	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005
CD	mg/l	0.206	0.224	<0.005	<0.005	<0.005	0.06	<0.005	0.007	0.005
CO	mg/l	0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
CR	mg/l	0.21	0.251	<0.005	<0.005	<0.005	0.033	<0.005	<0.005	<0.005
CU	mg/l	33.6	29.6	0.045	0.423	0.212	6.45	0.009	0.021	0.01
FE	mg/l	<2	2	<2	<2	<2	<2	<2	<2	<2
K	mg/l	4.6	20.3	1	4.2	3.9	3.6	9.5	15.6	7.5
MG	mg/l	0.521	2.98	0.025	0.054	0.068	0.299	<0.001	0.025	0.066
MN	mg/l	<0.1	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MO	mg/l	0.3	0.2	0.5	0.3	0.2	0.2	0.2	0.3	0.2
NA	mg/l	0.42	0.41	<0.2	0.02	0.02	0.16	0.02	0.03	0.03
N	mg/l	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
P	mg/l	0.05	0.05	<0.05	0.05	0.05	0.05	0.05	0.05	0.05
PB	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SB	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SE	mg/l	5.73	4.36	2.14	2.26	2.55	3.5	1.49	2.45	1.9
SI	mg/l	<0.05	0.05	<0.05	0.05	0.05	0.05	<0.05	0.05	0.05
SN	mg/l	0.047	0.215	0.02	0.07	0.058	0.02	0.124	0.138	0.068
SR	mg/l	0.002	0.002	<0.002	0.002	0.002	0.002	0.002	0.002	0.002
STR	mg/l	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
V	mg/l	0.42	6.17	0.045	0.013	0.045	0.595	0.009	0.014	0.02
ZN	mg/l	46	213	16.9	74.8	34.6	32.6	147	183	108
TOTAL	mg/l	204	307	17.6	76	65.4	73.5	148	184	109

Appendix IC: (cont.)

PARAMETER	UNIT	24	28	40	60	61	70	71	80	81
NETALS-EXT. WATER- ICF SCOR	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AL	mg/l	24.9	11.1	.63	.52	1.12	7.2	.08	1.11	.54
AS	mg/l	.08	.1	<.05	<.05	<.05	<.05	<.05	<.05	<.05
B	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
B4	mg/l	.051	.01	.028	.021	.051	.024	.035	.042	.021
BE	mg/l	<.001	.001	.001	.001	.001	.001	.001	.001	.001
CA	mg/l	10.8	52.2	5.9	24.9	22.1	7.8	42.4	49.3	52.2
CD	mg/l	.04	.042	.009	.005	.005	.005	.005	.006	.005
CO	mg/l	.251	.294	.006	.009	.014	.061	.005	.005	.005
CR	mg/l	.015	.007	<.005	.005	.005	.016	.005	.005	.005
CU	mg/l	.21	.26	<.005	.007	.011	.04	.005	.005	.019
FE	mg/l	34.2	36.8	.243	2.18	3.9	4.5	.011	.702	.09
K	mg/l	<.2	3	<.2	<.2	<.2	3	<.2	3	3
MG	mg/l	4.7	20.1	1.1	4.2	4.2	2.6	9.4	15.9	7.2
MR	mg/l	.525	2.92	.028	.101	.147	.294	<.001	.037	.036
MD	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
MA	mg/l	.3	.3	.5	.3	.3	.3	.2	.2	.2
NI	mg/l	.43	.41	<.02	<.02	<.02	.14	.02	.03	.02
F	mg/l	.2	<.1	<.1	.2	.3	<.1	<.1	<.1	<.1
PR	mg/l	.06	.09	<.05	<.05	<.05	.05	.05	.05	.05
SE	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	.05	.05	.05
SE	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	.05	.05	.05
SI	mg/l	5.96	4.71	2.24	2.41	3.39	3.22	1.56	2.92	1.79
SN	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SR	mg/l	.047	.212	.019	.07	.065	.023	.124	.143	.063
TI	mg/l	<.002	<.002	.008	.002	.004	.002	.002	.002	.002
V	mg/l	.06	.02	<.01	<.01	<.01	.02	<.01	<.01	<.01
ZN	mg/l	3.49	6.21	.045	.042	.197	.619	.009	.046	.011
HC	mg/l	46.2	215	19.3	79.5	72.7	24.5	144	189	110
HT	mg/l	207	336	23.2	85.8	84.6	74.5	145	194	115
AL	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AS	mg/l	25.4	11.3	.71	5.56	10.1	7.54	.06	1.16	.61
B	mg/l	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
BA	mg/l	.01	<.01	<.01	<.01	.03	<.01	<.01	<.01	<.01
BE	mg/l	.057	.01	.031	.22	.872	.026	.037	.045	.024
CA	mg/l	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
CD	mg/l	11	55.1	5.7	24.8	22.9	7.6	44.3	51	31.8
CC	mg/l	.022	.044	<.006	<.006	<.006	.015	<.006	.006	.006
CC	mg/l	.263	.297	<.006	.059	.091	.068	<.006	.01	.006
CK	mg/l	.022	.006	<.006	.013	.02	<.006	<.006	.007	<.006
CU	mg/l	.229	.272	<.006	.021	.032	.037	<.006	.009	.017
FE	mg/l	34.7	37.3	.275	9	13.9	6.56	.018	.751	.131
K	mg/l	<.2	<.2	<.2	2	4	<.2	<.2	<.2	<.2
MG	mg/l	4.8	20.5	1	4.8	5.1	3.7	9.6	16.1	7.5
MN	mg/l	.528	2.96	.029	.121	.18	.298	.001	.026	.09
MD	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
MA	mg/l	.3	.3	.4	.4	.5	.2	.2	.2	.2
NI	mg/l	.43	.42	.04	.04	.06	.17	.02	.07	.03
F	mg/l	.2	.1	<.1	.2	.6	.1	<.1	.1	.1
PR	mg/l	.07	<.06	<.06	.06	.06	.06	<.06	.06	.06
SE	mg/l	<.06	<.06	<.06	.06	.06	.06	.06	.06	.06
SE	mg/l	5.91	4.72	2.52	3.7	3.1	3.67	1.49	2.98	1.69
SI	mg/l	<.06	<.06	<.06	.06	.06	.06	.06	.06	.06
SN	mg/l	.06	.06	.06	.06	.06	.06	.06	.06	.06
SR	mg/l	.048	.215	.02	.079	.08	.024	.127	.142	.07
TI	mg/l	<.002	<.002	.01	.211	.254	.002	.002	.002	.002
V	mg/l	.08	.08	.08	.08	.1	.01	.01	.01	.01
ZN	mg/l	3.67	6.56	.055	.213	.282	.634	.018	.056	.043

.HARDNESS/CH+MG
/TOTAL
/TOTAL (WATER-ICF)

Appendix IIA: (cont.)

Parameter Analyzed	Units	STN 1	STN 2	STN 3	STN 4-A	STN 4-B	STN 4-C	STN 5	STN 6	STN 7	STN 8	STN 10	STN 11	STN 12	BLANK 2
/EXT. (WATER-ICP SCAN)	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AL	mg/l	5.97	5.15	2.79	3.33	2.92	2.92	2.84	3.92	4.28	4.63	5.22	2.83	1.76	<.05
AS	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
B	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
BA	mg/l	.039	.042	.045	.071	.056	.049	.069	.077	.081	.094	.112	.068	.07	<.001
BE	mg/l	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
CA	mg/l	8.5	9.8	22.7	13.9	17.4	17.7	23.9	22.9	23.9	23.2	20.2	14.6	13.1	<.1
CD	mg/l	.008	.006	<.005	<.005	<.005	.005	<.005	.006	.01	.009	.009	.005	<.005	<.005
CU	mg/l	.024	.018	.01	.029	.026	.024	.025	.032	.038	.04	.04	.018	.013	<.005
CR	mg/l	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
CU	mg/l	.041	.036	.02	.028	.026	.024	.023	.027	.029	.027	.03	.012	.007	.032
FE	mg/l	.631	.449	<.314	2.1	1.98	1.5	1.91	3.21	3.67	4.34	3.22	2.32	1.62	.011
K	mg/l	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
HG	mg/l	2.3	2.5	.112	6.4	7	7.1	8.7	8.2	8.3	.197	6.3	4.2	3.6	<.1
HI	mg/l	.247	.216	<.01	.223	.204	.188	.186	.197	.208	.197	.148	.096	.076	<.001
HO	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
NA	mg/l	.2	.2	.2	.2	.3	.2	.2	.2	.2	.3	.4	.6	.7	<.1
NI	mg/l	.14	.12	.07	.1	.1	.1	.08	.09	.11	.1	.2	.04	.04	<.02
P	mg/l	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
PU	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SE	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SI	mg/l	3.21	3.27	2.62	3.24	3.29	3.26	3.18	3.44	3.64	3.77	4.21	3.69	3.43	<.05
SH	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SR	mg/l	.053	.054	.076	.049	.077	.079	.083	.079	.085	.095	.072	.088	.054	<.001
TI	mg/l	<.002	<.002	<.002	.004	.003	<.002	.003	.003	.003	.003	.009	.008	.019	<.002
V	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
ZH	mg/l	.438	.392	.217	.327	.341	.337	.283	.419	.448	.43	.356	.209	.157	.004
IC	mg/l	30.5	34.9	81.4	66	72.4	73.4	93.7	91	93.8	90.9	76.5	53.9	47.6	<.4
IT	mg/l	55.1	56	93	83.3	87.1	88	111	113	118	117	106	69.1	57.5	<.4
AL	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AS	mg/l	5.77	4.94	2.78	4.32	3.32	3.25	3.56	4.65	5.03	5.73	7.36	3.29	2.05	<.05
AS	mg/l	<.05	<.07	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
D	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
BA	mg/l	.037	.041	.046	.123	.083	.069	.113	.121	.132	.159	.235	.09	.086	<.001
BE	mg/l	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
CA	mg/l	8.4	9.7	23.7	16.2	17.8	18.1	23.8	22.3	21.9	21.4	18.9	14	12.6	<.1
CD	mg/l	.008	<.005	<.005	.006	.005	.007	<.005	.005	.005	<.005	.039	<.005	<.005	<.005
CD	mg/l	.023	.019	.012	.028	.022	.022	.025	.032	.031	.035	.009	.015	.009	<.005
CR	mg/l	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
CU	mg/l	.039	.033	.02	.026	.024	.022	.023	.026	.028	.029	.032	.011	.007	.031
FE	mg/l	.626	.444	.342	2.94	1.91	1.74	2.6	3.94	4.23	5.24	7.16	2.7	1.85	.01
K	mg/l	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
HG	mg/l	2.2	2.4	.115	6.4	7	7.1	8.6	8.2	8.1	7.8	6.3	4.1	3.6	<.1
HI	mg/l	.24	.21	<.01	.226	.204	.191	.185	.198	.199	.19	.146	.094	.074	<.001
HO	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
NA	mg/l	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.4	.6	.6	<.1
NI	mg/l	.13	.11	.08	.11	.1	.11	.09	.11	.1	.1	.2	.05	.03	<.1
P	mg/l	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
PB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SE	mg/l	3.06	3.07	2.63	4.53	3.87	3.71	4.23	4.46	5.11	5.26	7.14	4.3	3.87	<.05
SI	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SN	mg/l	.051	.052	.075	.069	.077	.078	.082	.079	.079	.079	.074	.057	.053	<.001
SR	mg/l	<.002	<.002	<.002	.021	.019	.006	.018	.017	.024	.026	.054	.015	.023	<.001
TI	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
V	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
ZH	mg/l	.7	.07	.231	.348	.364	.372	.291	.429	.434	.421	.364	.211	.156	.005

Appendix IIA: Results of analyses of the 1990 suite of water samples from stations along the South Macmillan River.

Parameter Analyzed	Units	STN 1	STN 2	STN 3	STN 4-A	STN 4-B	STN 4-C	STN 5	STN 6	STN 7	STN 8	STN 10	STN 11	STN 12	BLANK 2
ALCALINITY	mg/l	<1	<1	12	<1	<1	<1	17	B	7	B	10	B	B	<1
CHLORIDE	mg/l	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
CURVE TRUE	mg/l	5	5	5	5	5	5	5	5	5	5	5	5	5	5
DUCTIVITY	US/cm	214	169	192	176	184	182	205	215	203	213	177	138	119	2.5
BROMIDE	mg/l	0.21	0.23	0.14	0.15	0.15	0.15	0.17	0.15	0.14	0.13	0.14	0.12	0.10	0.05
ROSEN/AMMONIA	mg/l	<.002	.004	.004	.01	.015	.014	.007	.019	.02	.022	.016	.006	.007	.01
NITRATE	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
NITRATE+NITRATE	mg/l	.021	.043	.029	.058	.049	.059	.039	.062	.062	.059	.052	.036	.026	.013
AMMONIUM	mg/l	3.8	4.2	7.1	4.9	5.0	5.0	7.2	6.9	6.8	6.7	7.0	6.9	6.9	5.7
PHOSPHORUS/TOTAL	mg/l	<.002	<.002	.008	.067	.052	.032	.089	.097	.103	.11	.171	.057	.033	<.002
PHOSPHORUS/FILTERABLE	mg/l	130	120	130	117	110	120	150	150	140	150	110	90	80	<10
NON-FILTERABLE	mg/l	<10	<10	20	60	50	30	70	70	80	90	140	40	30	<10
PHOSPHATE	mg/l	74.7	63.7	69.6	72.7	74.9	78.7	77.1	80.7	82.5	80.8	61.7	46	38	0.1
AMMONIUM	mg/l	<0.1	<0.1	1.0	10	8.5	5.5	10	20	23	23	20	6.0	3.0	0.1
ALCALINITY	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
CHLORIDE	mg/l	5.81	5.03	5.05	.92	.7	.84	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05
CHLORIDE	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AMMONIUM	mg/l	.037	.042	.044	.037	.037	.036	.04	.041	.041	.042	.043	.043	.049	.001
AMMONIUM	mg/l	10.1	12.4	28.5	19.2	20.5	19.6	26.4	23.6	24.3	23	21.2	16	14.8	<.01
AMMONIUM	mg/l	.013	.017	.014	.014	.009	.003	.006	.003	.003	.006	.003	.003	.003	<.005
AMMONIUM	mg/l	.024	.019	.01	.02	.015	.015	.017	.015	.018	.017	.008	.008	.003	<.005
AMMONIUM	mg/l	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
AMMONIUM	mg/l	.038	.036	<.005	.02	.018	.018	<.005	.007	.008	.007	<.005	<.005	<.005	.020
AMMONIUM	mg/l	.619	.417	.074	.368	.363	.349	.175	.703	.726	.753	<.005	.06	.053	.007
AMMONIUM	mg/l	<2	2.8	6.8	6.9	7.3	7.2	6	<2	<2	<2	<2	<2	<2	<2
AMMONIUM	mg/l	2.5	2.8	6.8	6.9	7.3	7.2	6	8.1	8.4	8.4	8.4	4.4	3.8	<.1
AMMONIUM	mg/l	.256	.233	.119	.226	.172	.179	.172	.173	.183	.18	.121	.081	.057	<.001
AMMONIUM	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AMMONIUM	mg/l	.2	.2	.2	.3	.3	.3	.2	.2	.3	.3	.4	.6	.7	<.01
AMMONIUM	mg/l	.15	.14	.08	.11	.1	.09	.08	.07	.09	.1	.07	.04	.03	<.02
AMMONIUM	mg/l	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
AMMONIUM	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
AMMONIUM	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
AMMONIUM	mg/l	3.24	3.31	2.55	2.85	2.97	2.97	2.68	2.76	2.83	2.94	2.8	2.84	2.73	<.05
AMMONIUM	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
AMMONIUM	mg/l	.053	.053	.076	.066	.073	.072	.077	.071	.073	.074	.063	.054	.051	<.001
AMMONIUM	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
AMMONIUM	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AMMONIUM	mg/l	.448	.419	.209	.332	.32	.319	.228	.338	.354	.361	.236	.145	.103	.006
AMMONIUM	mg/l	35.6	42.4	99.1	76.4	81.3	78.4	102	92.5	93.2	97.1	79.2	57.8	52.4	<.1
AMMONIUM	mg/l	59.5	63	99.9	81.5	83.5	83.1	104	94.9	97.7	99.6	80.3	58.3	53	<.1
HARDNESS/CA/MG	mg/l														
TOTAL	mg/l														

Appendix IIB: (cont.)

Parameter Analyzed	Units	STN 20	STN 21	STN 22	STN A	STN 23	STN 24	STN 28	STN 29	STN 30	STN 40	STN 41	STN 6C	BLANK 1
AG	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AL	mg/l	10.4	5.95	9.85	9.89	10	14.8	9.67	3.31	55.7	<.01	<.01	<.01	<.05
AS	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	.06	<.05	<.05	<.05	<.05	<.05	<.05
B	mg/l	<.01	<.01	<.01	.01	<.01	<.01	.02	<.01	.02	<.01	<.01	<.01	<.01
BA	mg/l	.231	.108	.205	.202	.205	.161	.013	.096	.017	.024	.025	.086	<.001
BE	mg/l	<.001	<.001	<.001	<.001	<.001	.001	.001	<.001	.004	<.001	<.001	<.001	<.001
CA	mg/l	7.2	3.7	6.2	8.5	8.6	7.8	52.7	.8	9.4	5.8	5.6	26.5	.2
CU	mg/l	.013	.005	.016	.017	.017	.023	.03	<.005	.018	<.005	<.005	<.005	<.005
CS	mg/l	.073	.03	.048	.079	.078	.153	.234	.015	.47	<.005	<.005	<.005	<.005
CR	mg/l	.007	<.005	.009	.007	.009	.013	<.005	<.005	.06	<.005	<.005	<.005	<.005
CJ	mg/l	.14	.102	.176	.166	.17	.162	.06	.005	.202	<.005	<.005	<.005	.025
FE	mg/l	9.61	3.31	8.71	9.93	10.1	21	28.6	1.6	60.8	<.33	<.325	.943	.009
K	mg/l	<.2	<.2	<.2	<.2	<.2	<.2	3	<.2	3	<.2	<.2	<.2	<.2
MS	mg/l	1.5	1.3	1.7	2.8	2.8	2.9	18.2	.4	9.4	.9	.9	4.6	<.1
HN	mg/l	.187	.167	.216	.366	.367	.335	2.42	.033	.408	.027	.028	.053	.001
MO	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
NA	mg/l	.6	.9	.7	.5	.5	.5	3	.3	.4	.5	.5	.3	<.1
NI	mg/l	.18	.09	.15	.17	.16	.23	.33	.05	.77	<.02	<.02	<.02	<.02
F	mg/l	.2	<.1	.1	<.1	.1	.2	<.1	<.1	1.1	<.1	<.1	<.1	<.1
FB	mg/l	<.05	<.05	.15	.19	.16	.09	.07	<.05	<.05	<.05	<.05	<.05	<.05
SB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SE	mg/l	<.05	<.05	<.05	5.12	5.1	5.72	4.82	5.19	11.4	2.4	2.39	2.48	<.05
SI	mg/l	4.61	5.23	5.13	5.12	5.1	5.72	4.82	5.19	11.4	2.4	2.39	2.48	<.05
SR	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SR	mg/l	.032	.029	.034	.044	.044	.041	.226	.015	.044	.019	.019	.086	<.001
TI	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.013	.012	<.002	<.002
V	mg/l	.04	<.01	.03	.02	.02	.06	.01	<.01	.31	<.01	<.01	<.01	<.01
ZN	mg/l	.754	.366	1.45	2.18	2.18	2.29	6.05	.527	2.2	.041	.039	.016	.014
HC	mg/l	24.1	14.5	22.5	33	33.2	31.4	207	3.5	62.1	18.3	17.7	85.1	.5
HT	mg/l	81.7	43.7	77.7	92	93.2	129	308	19.3	382	21.7	21	87.4	.6
AD	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
AL	mg/l	10.9	5.86	9.91	9.58	9.88	14.4	9.21	3.21	52.2	.79	.78	.12	<.05
A3	mg/l	<.05	<.05	<.05	<.05	.06	.07	.09	<.05	.13	<.05	<.05	<.05	<.05
B	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	.01	<.01	.01	<.01	<.01	<.01	<.01
BA	mg/l	.264	.108	.252	.348	.252	.243	.012	.093	.016	.024	.024	.083	<.001
BE	mg/l	<.001	<.001	<.001	<.001	<.001	<.001	.001	<.001	.003	<.001	<.001	<.001	<.001
CA	mg/l	7	3.5	5.9	8.1	8.6	7.4	51	.8	8.6	5.2	5.4	25.3	.3
CD	mg/l	.01	<.005	.013	.013	.017	.022	.03	.007	.041	<.005	<.005	<.005	<.005
CO	mg/l	.055	.025	.055	.061	.067	.116	.182	.312	.312	<.005	<.005	<.005	<.005
CR	mg/l	.006	<.005	.01	.008	.012	.013	<.005	<.005	.06	<.005	<.005	<.005	<.005
CU	mg/l	.138	.097	.169	.156	.164	.095	.056	.056	.19	<.005	<.005	<.005	.025
FE	mg/l	9.86	3.38	8.71	9.67	10.1	20.3	27.4	1.55	56.1	.369	.348	.935	.039
K	mg/l	<.2	<.2	<.2	<.2	<.2	<.2	3	<.2	2	<.2	<.2	<.2	<.2
MG	mg/l	1.7	1.3	1.7	2.7	2.8	2.8	17.5	.4	8.9	.9	.9	4.4	<.1
HI	mg/l	.164	.164	.213	.349	.363	.322	2.33	.032	.378	.025	.025	.052	.001
MO	mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
NA	mg/l	.5	.8	.6	.5	.5	.4	.3	.2	.4	.5	.4	.3	<.1
NI	mg/l	.18	.08	.16	.16	.16	.23	.33	.06	.69	<.02	<.02	<.02	<.02
P	mg/l	<.1	<.1	.1	.1	.1	.2	.06	<.05	.9	<.1	<.1	<.1	<.1
FB	mg/l	<.05	<.05	.14	.17	.18	.08	.06	<.05	<.05	<.05	<.05	<.05	<.05
SB	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SE	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SI	mg/l	5.86	5.13	5.66	5.12	5.07	5.78	4.5	4.93	10.3	2.56	2.53	2.4	<.05
SH	mg/l	<.05	<.05	<.05	.042	.043	.039	.212	<.05	<.05	<.05	<.05	<.05	<.05
SR	mg/l	.032	.028	.033	.042	.043	.039	.014	.014	.041	.018	.018	.081	<.001
TI	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	.079	.014	<.002	<.002
V	mg/l	.04	<.01	.02	.02	.03	.05	.01	<.01	.28	<.01	<.01	<.01	<.01
ZN	mg/l	.759	.367	1.45	2.12	2.2	2.23	5.9	.324	2.05	.042	.04	.017	.006

.HARDNESS/CA+MG
/TOTAL
/TOTAL (WATER-ICP)

Total Inorganic Carbon (TIC)				
Total Organic Carbon (TOC)	5.0	5		
Vanadium (V)			0.030	5
Zinc (Zn) mg/l	5.0	1		

* Soft water has a total hardness less than 95 mg/l as CaCO₃. Hard water has a total hardness of more than 95 mg/l as CaCO₃ (Reference 6).

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4. Anonymous, Guidelines for Establishing Water Quality Objectives for the Territorial Waters of the Yukon and Northwest Territories. Report of the Working Group on Water Quality Objectives to the Chairmen, Water Boards, Yukon and Northwest Territories, July (1977).
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Appendix IV: A brief description of sequential extraction procedures.

The sediment sample is air-dried and sieved to obtain the -80 mesh fraction of the sample. A subsample of the latter is digested for analysis according to the scheme outlined below. The metals associated with each fraction are determined by Inductively Coupled Plasma or Atomic Absorption analyses as appropriate.

- the CARBONATE metals fraction represents metals bound to carbonates in the sediment samples. Release is associated with a reduction in pH. These metals are extracted at pH 5 with an acetate buffer, after the exchangeable metals fraction is removed.
- the EXCHANGEABLE metals fraction represents metals bound to the sediments by weak adsorption onto the sediment particles. These metals are likely to be released from the sediment by changes in the ionic strength of surrounding water. Metals are extracted from this fraction with 1 M magnesium chloride.
- the FE+MN OXIDE (iron and manganese oxide) fraction represents metals bound to those oxides. Under reducing (eg. anoxic) conditions, these metals are unstable and can be released from the sediments. This fraction is extracted with a hot, acidic hydroxylamine hydrochloride solution after extraction of the exchangeable and carbonate fractions.
- the ORGANIC BOUND fraction represents metals bound to organic materials that may be released under oxidative degradation of those materials. Metals in this fraction are extracted with a hot, acidic hydrogen peroxide solution after removal of the exchangeable, carbonate and iron/manganese oxide fractions.
- the RESIDUAL metals fraction represents the strong-acid extractable metals remaining in the sediment samples after removal of the exchangeable, carbonate, iron/manganese oxide and organic-bound fractions. Metals are extracted with a nitric acid/hydrochloric acid digestion which does not totally dissociate metals bound in a refractory or silica matrix.
- metals data are reported in dry weight.

(Source of information: C & P Laboratories, Environment Canada, West Vancouver, B.C.).

