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Coppermine River

Overview of the Hydrology and Water Quality

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Introduction

The purpose of the report is to provide a general overview of the water quantity and water quality data collected in the Coppermine River Basin. The hydrometric data are presented using mean annual hydrographs, extreme-year hydrographs and basic statistics. Comparisons were made between the flow regimes of the Coppermine River and the flow regimes of rivers in the Mackenzie Mountains. Also, flood frequency analyses using the Pearson theoretical distribution were done for the Coppermine River and for three sites in the Mackenzie mountains. The pumping rates for de-watering the lakes at the Ekati diamond mine, as specified in the water license, were compared with hydrology of the Coppermine basin. Water quality data at stations in the Coppermine River basin are presented and discussed in the context of mineral development within the basin. Trace elements concentration values were compared to the Canadian Water Guidelines.

The Coppermine River Basin Setting

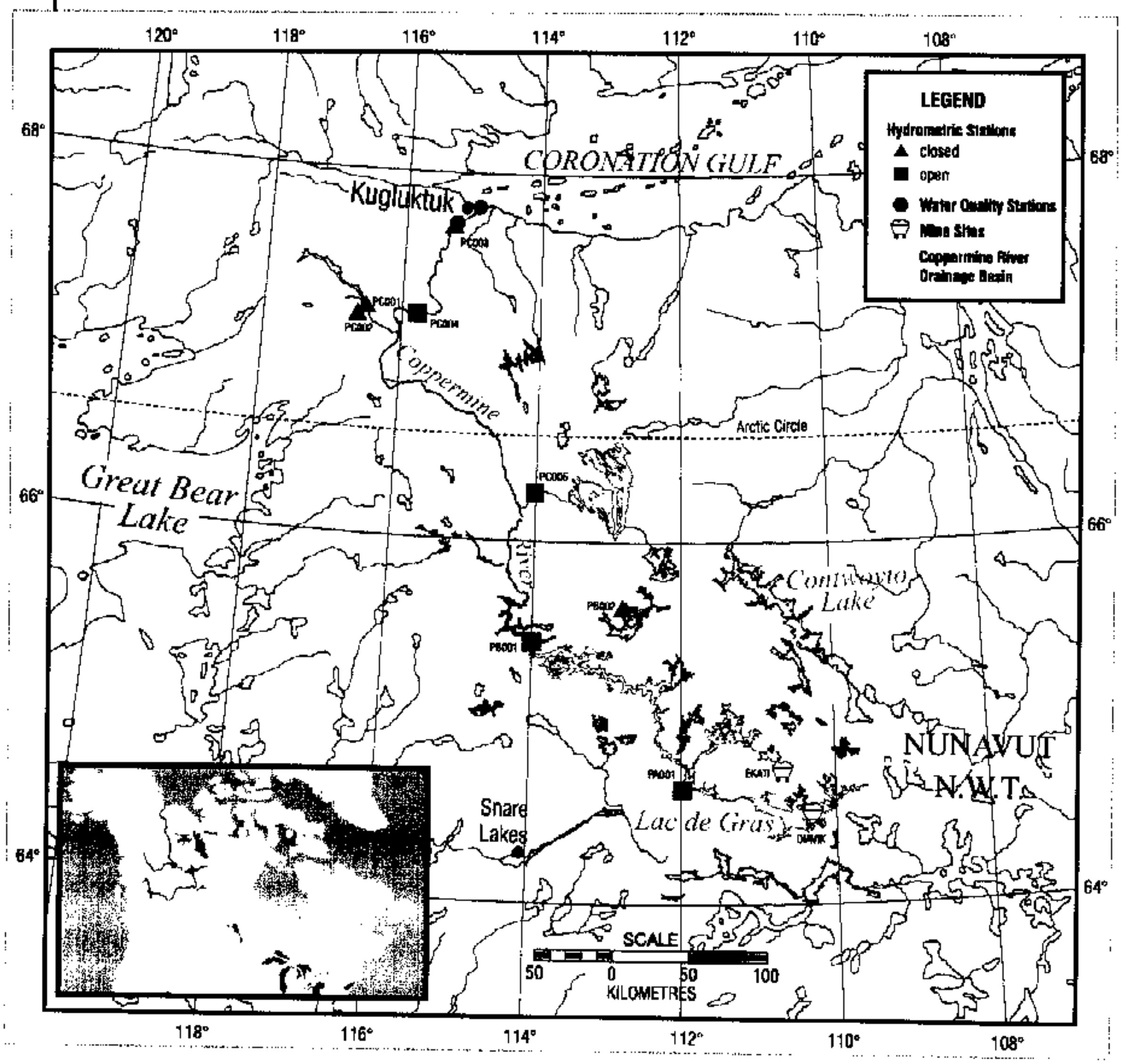
The Coppermine River basin is located in the north central region of the mainland Northwest Territories between 64°50' and 67°50' North latitude and 109°30' and 118°20' West longitude (Maps 1 & 2). The drainage basin is approximately 520 km in length, has an average width of about 100 km and a gross drainage area of 50,800 km^2 (Wedel *et al.*, 1988). From the headwaters in the Ursula Lake/Lac du Sauvage area at 460 metres above sea level, the Coppermine River flows in a generally northwest direction to its mouth at Coronation Gulf.

The Coppermine River basin is mostly above the tree line and is within the zone of continuous permafrost. Two different physiographic regions are represented within the Coppermine basin, the Bear-Slave upland in the central and southern part of the basin and the Coronation Hills in the northwest (Wedel *et al.*, 1988). The southeastern half of the basin, in the Slave geological province (Map 2), is characterized by a chain of long narrow lakes connected by short, turbulent streams. These large lakes in the upper basin play an important role in the Coppermine basin hydrology by attenuating the runoff from snow melt and rainfall events. Downstream in the Bear Province the Coppermine River has, in places, incised its channel into the bedrock forming spectacular canyons and rapids. The Precambrian bedrock of the Canadian Shield that underlies the entire Coppermine River basin has been sculpted repeatedly by episodes of continental glaciation.

Hydrometric Data in the Coppermine Basin

There are currently four hydrometric gauges in operation in the Coppermine basin, three of which are on the Coppermine River (above Copper Creek, at the outlet of Point Lake and at the outlet of Desteffany Lake) and the fourth is on the Fairy Lake River near the outlet of Napaktolik Lake (Map 1). In addition, there are data from four other stations in the Coppermine basin that are no longer operating; the Coppermine River above Bloody Falls, Kendall River near Dismal Lakes, Atitok Creek near Dismal Lakes and the Izok Lake Inflow (Map 1). The three stations in the Mackenzie Mountains that were used for comparisons with the Coppermine basin stations are the Arctic Red River near the mouth, South Nahanni River above Virginia Falls and South Nahanni River above Clausen Creek. The stream flow data are currently available to 1995 on the HYDAT database (© 1997 by Environment Canada).

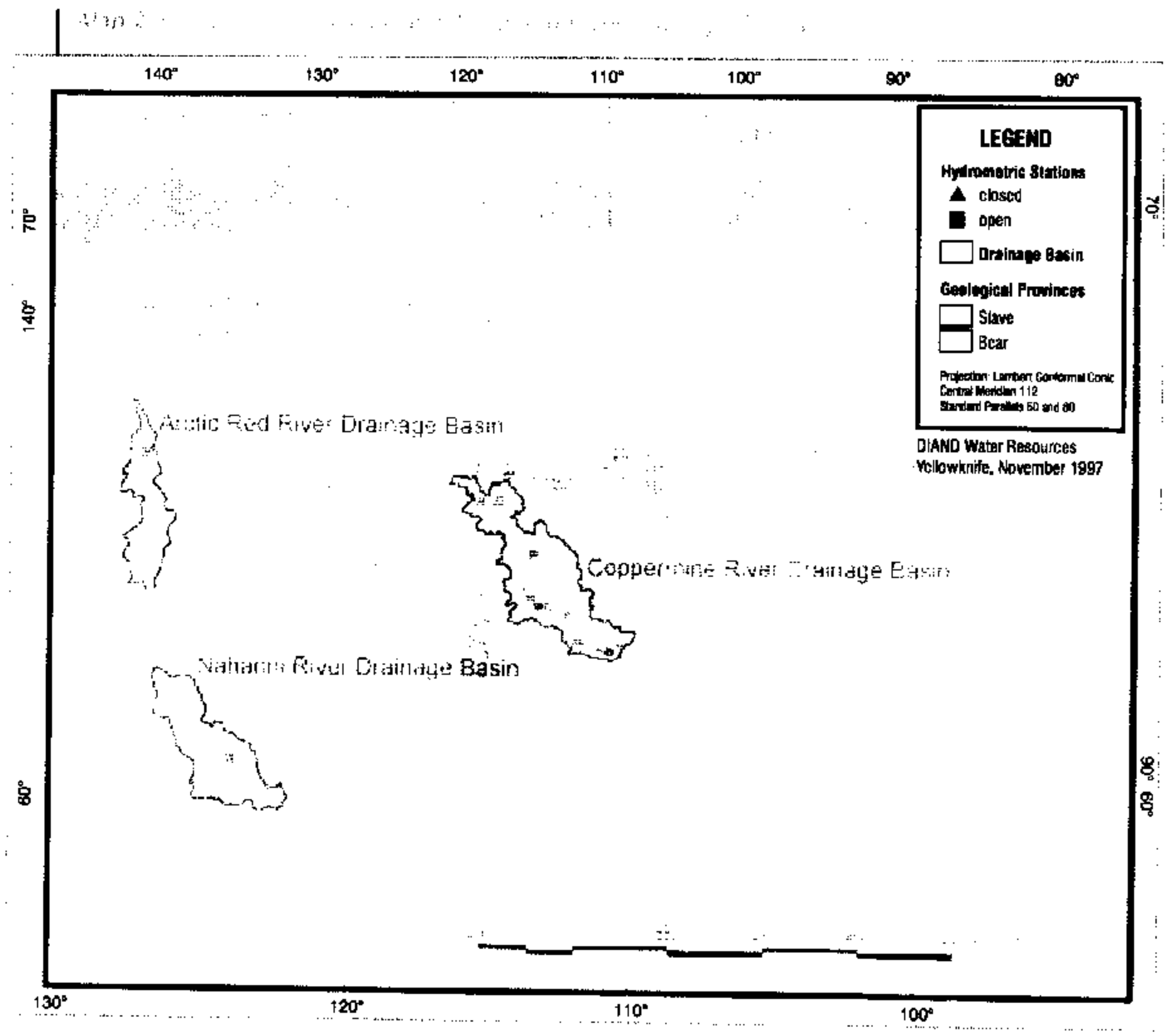
The only historical weather data available within the Coppermine River basin are from the Kugluktuk (Coppermine) airport but these were not obtained because the data are representative of the Arctic coast, not the inland



drainage basin. An automatic weather station has been operated by DIAND Water Resources since June 1996 at Daring Lake (64°52'N, 111°35'W) in the upper Coppermine basin but there are no data which correspond to the currently published hydrometric records.

Basic Statistics

Basic statistics, including the average annual discharge and the average peak and low flows, were calculated from daily flow data and are presented in Table 1. A ratio of the mean peak flow to the mean low flow was calculated for an index of the flow extremes. For each station, the total annual



discharge (m³/yr) was determined for every year with a complete data record and the mean annual total discharge was included in Table 1. The basin yield in mm/year was calculated from the mean annual total flow divided by the basin area.

Mean summer and winter discharges were also determined for each station to show the seasonal variation at each station (Table 1). The start of the "summer" period was identified as the time of the initial increase in the hydrograph in spring, rather than using the change from under-ice backwater conditions (as indicated by "B" in Hydat) to open channel conditions, i.e. break-up. The reason for this is that the Coppermine River at the Point Lake station remains open in winter, thus there are no backwater effects due to ice cover. From the mean annual hydrographs, Julian day 150 (30 May) was selected as the start of "summer" for the main-stem Coppermine River stations and for Atitok Creek and

Coppermine River Basin	ID Code	Years of Record	Mean Annual (m^3/s)	Mean Peak (m^3/s)	Mean Low (m^3/s)	Peak: Low Ratio	Mean Summer (m^3/s)	Mean Winter (m^3/s)	Summer: Winter Ratio	Mean Total Annual Flow (10^6 m^3/yr)	Basin Area (km^2)	Basin Yield (mm/yr)
Coppermine River at Desteffany Lake*	10PA001	1	27.6	98.9	11.9	8.31	45.3	16.0	2.8	872	6110	143
Coppermine River at Point Lake	10PB001	31	104	227	61.4	3.70	170	61.4	2.8	3290	19300	170
Coppermine River at Copper Creek**	10PC004	12	262	1330	60.1	22.13	479	118	4.1	8270	46800	177
Fairy Lake River	10PC005	2	34.1	49.5	20.3	2.44	41.3	28.5	1.4	1080	6680	162
Izok Lake	10PB002	2	2.21	19.3	0	N/A	4.92	0.07	N/A	69.6	300	232
Kendall River	10PC001	21	15.0	189	0	N/A	34.5	0.64	N/A	472	2790	169
Atitok Creek	10PC002	11	1.30	38.8	0	N/A	3.04	0.06	N/A	42.6	217	196

Other Basins	ID Code	Years of Record	Mean Annual (m^3/s)	Mean Peak (m^3/s)	Mean Low (m^3/s)	Peak: Low Ratio	Mean Summer (m^3/s)	Mean Winter (m^3/s)	Summer: Winter Ratio	Mean Total Annual Flow (10^6 m^3/yr)	Basin Area (km^2)	Basin Yield (mm/yr)
Arctic Red River	10LA002	26	157	1490	12.7	117.32	298	16.9	17.6	4960	18600	267
S. Nahanni River at Virginia Falls	10EB001	33	228	1510	25.9	58.30	427	32.9	13.0	7190	14600	492
S. Nahanni River at Clausen Creek	10EC001	26	404	2240	55.6	40.29	743	88.8	8.4	12700	31100	408

** Only one year of data* *** Combined data - Copper Creek and Bloody Falls*

Kendall River. For the Izok Lake Inflow and the Fairy Lake River, Julian day 140 was chosen as the start of "summer", but this earlier date may be skewed by the very short data record for these two stations. The start of "summer" was identified for the South Nahanni River as Julian day 125 and for the Arctic Red River as Julian day 120. The end of "summer" for all stations was arbitrarily chosen as Julian day 300 (27 October). A ratio of the mean summer discharge over the mean winter discharge was calculated as an index of seasonal variation for comparison between rivers in different physiographic areas. The seasonal means and the ratios were omitted on the ephemeral streams (Atitok Creek, Kendal River and Izok Lake Inflow) because of the arbitrary nature of selecting the seasons.

Discussion of Coppermine River Hydrology

A review of the hydrometric data was done for each of the stations in the Coppermine River basin and a short discussion is presented. For stations with three or more years of data, the mean annual hydrographs and the extreme high flow and low flow hydrographs were plotted to show the magnitude of the natural flow variability. The standard deviations were also plotted with the mean annual hydrographs for the Coppermine River at Copper Creek and at Point Lake.

Coppermine River - Point Lake (10PB001)

The Coppermine River at outlet of Point Lake station is located about midway in the Coppermine River basin (65°25'N, 114°00'30"W) and has been operating since 1964. The station gauges an area of 19,300 km^2 and is downstream of a chain of large lakes. Average annual flow at the Point Lake station is 104 m^3/s, the average peak flow is 227 m^3/s and the average low flow is 61.0 m^3/s (Figure 1a & 1b). Seasonal variation is quite low with an average summer flow of 170 m^3/s while the average winter flow is

61 m³/s for a ratio of 2.8. In summer, the outflow at Point Lake is equal to about 35% of the total flow at the mouth (Coppermine River at Copper Creek) while in winter, it represents about 50%.

The Coppermine River at Point Lake has a sub-arctic nival regime which is characterized by the discharge peak that occurs during spring snow melt (Woo, 1986), but the flow regime is modified considerably by the large upstream lakes. The important hydrological effect of lake storage is the attenuation of extreme high flows and the maintenance of sustained flow throughout the winter (Figure 1a). At the onset of the spring freshet, the discharge rises quickly to the annual maximum followed by a slow and smooth hydrograph recession through summer with a minimal response to rainfall events, as shown in the extreme year hydrographs. The discharge continues to decrease slowly through fall and winter and reaches the annual minimum flow just prior to spring break-up.

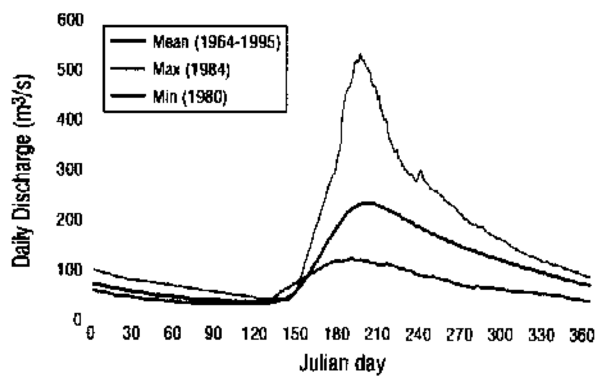


Figure 1a: [illegible]

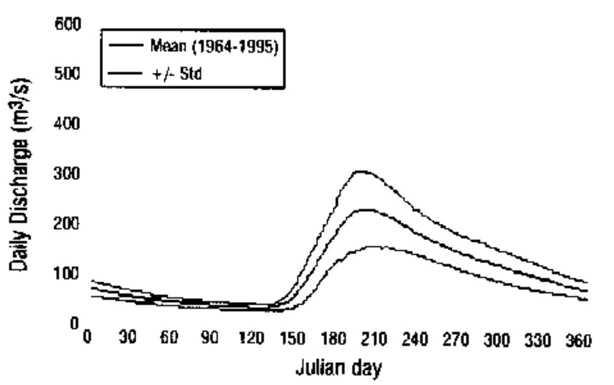


Figure 1b [illegible]

Coppermine River - Copper Creek (10PC004)

The Coppermine River above Copper Creek station (67°13'41"N, 115°53'17"W) is situated about 100 km above the river mouth, gauges a drainage area of 46,800 km² and has been in operation since 1987. A station was previously operated at Bloody Falls - 10PC003 - (67°44'25"N, 115°22'43"W) from 1983 to 1986, but it was relocated about 70 km upstream in 1987 to the Copper Creek site due to problems with slush ice during winter flow measurements.

Because of the short data record for the lower Coppermine River, the daily data record for the Copper Creek station was extended from 9 years to 12 years using data from the Bloody Falls station (Appendix 1). Based on the extended data set, the Coppermine River at Copper Creek has a mean annual flow of 262 m³/s, a mean peak flow of 1330 m³/s and a mean low flow of 60.1 m³/s (Figures 2a & b). Seasonal variations show an average summer flow of 479 m³/s and an average winter flow of 118 m³/s for a ratio of 4.1.

The flow regime of the Coppermine River at Copper Creek is also sub-arctic nival. Spring breakup is the most significant hydrological event and the hydrograph recession is steep after the breakup peak (Figures 2a & 2b). The Coppermine River at Copper Creek hydrograph is similar to Coppermine at Point Lake, but it is apparent that there is much less attenuation of the summer flows at Copper Creek (Figure 3). Also, the Copper Creek station hydrograph shows definite responses to summer storm events. Seasonal discharge variation is greater at Copper Creek than at Point Lake, with summer/winter flow ratios of 4.1 and

2.8, respectively. Figure 3 shows that the spring breakup peak is much greater at Copper Creek, but the winter flows are nearly the same at both Point Lake and Copper Creek. Lake storage in the upper Coppermine basin and in Napaktolik Lake (above Fairy Lake River station) contribute to the sustained winter flows at Copper Creek. The sum of the mean winter flows at Point Lake and Fairy Lake River is approximately equal to 76% of the flow at Copper Creek. In summer the flow at these two stations make up about 44% of the flow at the Copper Creek station.

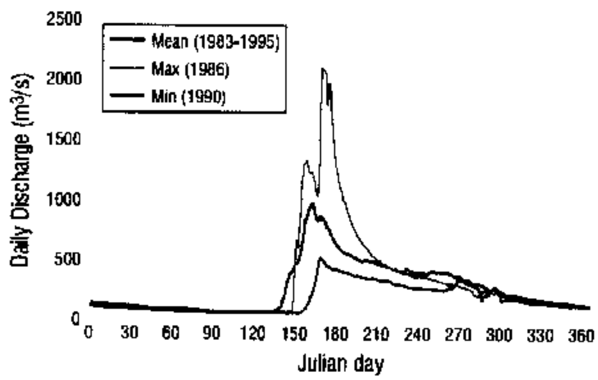


Figure 2a. [illegible]

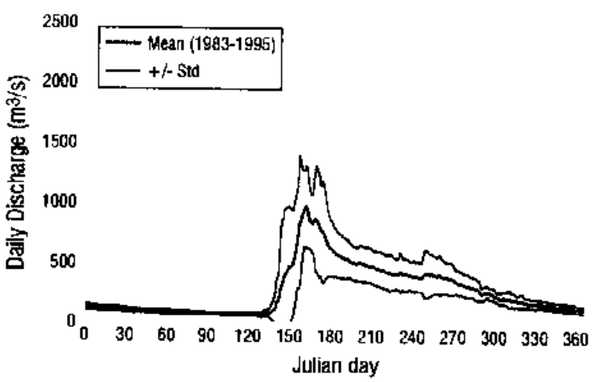
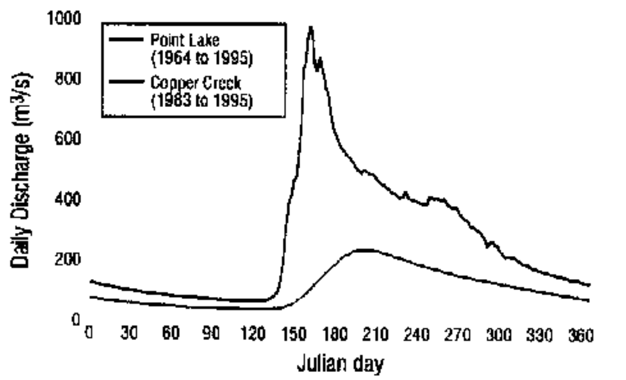
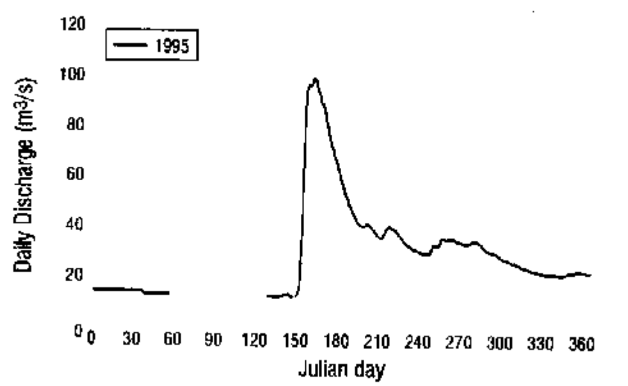


Figure 2b [illegible]



Coppermine River - Desteffany Lake (10PA001)

The Coppermine River at the outlet of Desteffany Lake station (64°36'57"N, 111°57'17"W) was constructed in the autumn of 1994. The drainage basin area at the Desteffany Lake outlet is approximately 6110 km^2. At present, there is only one partial year of data (1995) available in which the peak flow was 98.9 m^3/s in mid-June, the low flow was 11.9 m^3/s and the mean flow for the year was 27.6 m^3/s. A mean summer flow of 45 m^3/s and a mean winter flow of 18 m^3/s give a summer/winter flow ratio of 2.5. The 1995 hydrograph shows



a typical increase in discharge during the spring melt followed by a steep recession (Figure 4). The large headwater lakes attenuate summer rain events and maintain a relatively constant base flow once the freshet flood has passed through.

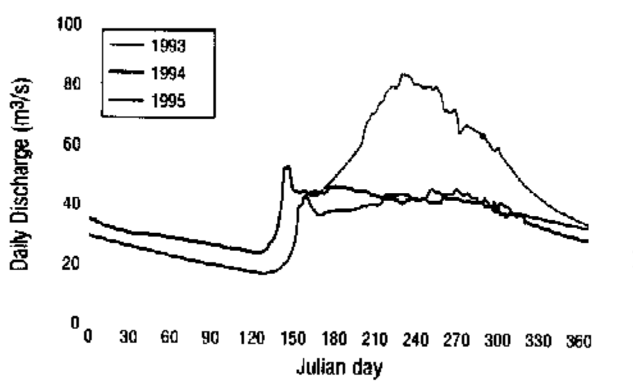
There is a period of missing data from the end of February until mid-May. Over this period, the recession was assumed to be constant and the values were estimated in order to produce the mean annual and total annual discharge. When a longer data record becomes available, verification of the winter flows and statistics will be possible.

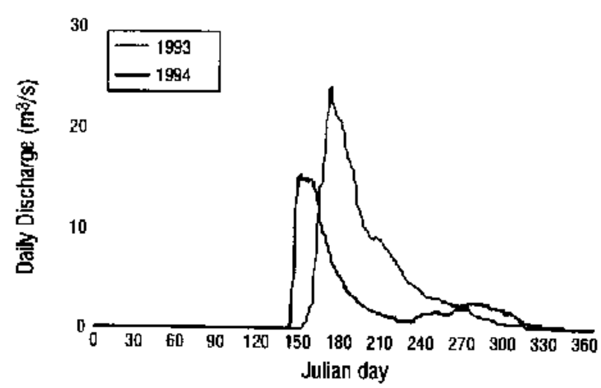
Fairy Lake River (10PC005)

Another new station in the Coppermine basin was built on the Fairy Lake River near the outlet of Napaktolik Lake (66°15'13"N, 113°59'29"W) in June 1993. There are two complete years of data, 1994 and 1995, plus the last six months of 1993. The drainage basin area at the Fairy Lake gauge is about 6680 km^2, slightly larger than the drainage area at the Desteffany outlet gauge. The Fairy Lake River hydrographs (Figure 5) show rapid increases during spring freshet followed by relatively constant summer flow rates, except in 1993 where there is a sustained increase throughout the summer with a slow recession from 20 August. The 1993 hydrograph seems extraordinary with a summer discharge nearly double that of the subsequent two years. Using the two years with the complete data record, the mean annual flow is 34.1 m^3/s, the mean peak flow is 49.5 m^3/s and the mean low flow is 20.3 m^3/s. The average summer flow of 41.3 m^3/s and the average winter flow of 28.5 m^3/s give a low summer/winter flow ratio of 1.4. The peak flow in 1993 was 84.0 m^3/s in mid-August, but 1993 data were not included in the statistics as the data set was incomplete for the year. The unexpected 1993 hydrograph is difficult to explain with the short data record but the data were verified with Water Survey of Canada as being accurate (Wedel, R., 1998, personal communication). Additional data for 1996 and 1997 will soon be available and will help explain the annual variations of the Fairy Lake River.

Izok Lake Inflow (10PB002)

The Izok Lake Inflow station (65°38'23"N, 112°51'45"W) was located between two small lakes in a small sub-basin (about 300 km^2) near the Coppermine River - Contwoyto Lake drainage divide. The gauge was installed to measure inflows to Izok Lake, the site of a large copper ore deposit, but when the site development plans were suspended, the gauging





station was closed. During the two years of operation, 1993 and 1994, the mean annual flow was 2.21 m³/s with a mean peak flow of 19.3 m³/s and a mean low flow of zero. Steep breakup peaks occurred in mid-June followed by similarly steep recessions to summer low flows. Zero flow occurs by early winter (Figure 6). The flow characteristics of the Izok Lake Inflow are typical of the arctic nival regime because of the small basin size. Lake storage effects are quite subtle on the Izok Lake inflow hydrograph compared with the larger Coppermine sub-basins but the small headwater lakes above the gauge provide some attenuation of the freshet peak and maintain flow in the Izok Lake inflow into the early fall. Late summer rain events are evident on the 1994 hydrograph with a gentle increase into September and a subsequent slow, smooth recession.

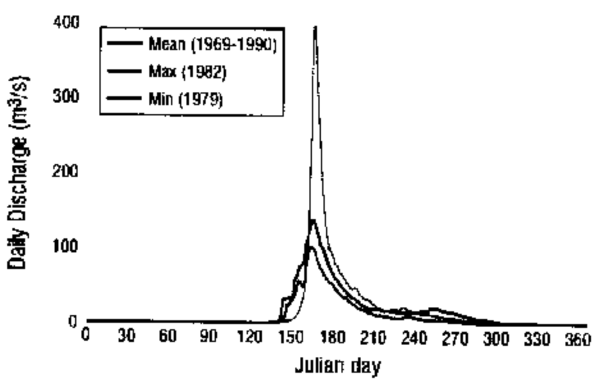
Kendall River (10PC001)

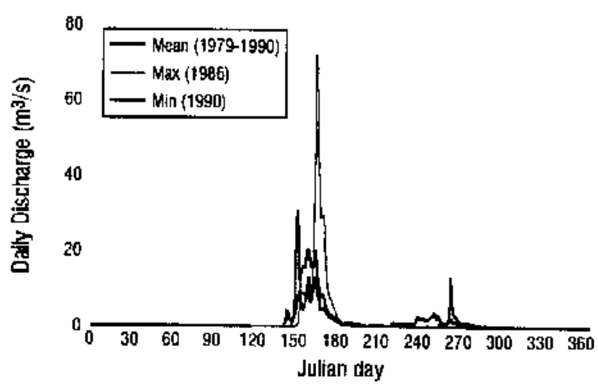
The Kendall River is a small Coppermine River tributary in the extreme northwest of the basin. At the former gauging station, Kendall River near the outlet of Dismal Lakes, (67°12'51"N, 116°34'33"W), the drainage area is 2790 km². From the data record, the Kendall River has a mean annual flow of 15.0 m³/s, an average peak flow of 189 m³/s and an average low flow of zero. The Kendall River goes to zero flow in early winter, usually freezing off in mid November until late May (Figure 7). The station operated from 1969 until 1990 and was closed after 21 years of operation because of increased operating costs and decreasing budgets. Summer flows of the Kendall River represent about 6% of the flow of the Coppermine River at the Copper Creek gauge.

Atitok Creek (10PC002)

The Atitok Creek near Dismal Lakes hydrometric station (67°12'52"N, 116°36'32"W) was operated on a small tributary of the Kendall River between 1979 and 1990. The Atitok Creek basin has a drainage area of 217 km². The mean annual flow is 1.30 m³/s, the mean peak flow is 38.8 m³/s and the mean low flow is zero. Atitok Creek is usually frozen off from late October or early November until late May (Figure 8). The station was closed in 1990 at the same time as the Kendall River station.

Atitok Creek and Kendall Rivers stream flow regimes can be classified as arctic nival as both rivers have steep flow peaks at the spring freshet with an equally quick recession (Figures 7 & 8) and both drop to zero flow in winter. Atitok Creek discharge drops to near zero during summer but the





hydrograph shows small rainfall spikes during autumn. The flow of the Kendall River is buffered somewhat by the storage effects of the Dismal Lakes and the discharge decreases steadily to zero by late fall.

Flow Trends of the Coppermine River

Graphs of the total annual discharge were plotted for the Point Lake and Copper Creek stations (Figures 9 & 10). Linear fit lines from simple linear regressions and the five-year moving averages were plotted to see if it was possible to identify climatic trends in the hydrometric data. The variability in the total annual discharge of the Coppermine River at Point Lake indicates the sensitivity of the river discharge to annual variations in the weather (Figure 9). The maximum total flow of $5,210 * 10^6$ m^3 is more than double the minimum total annual flow of $2,050 * 10^6$ m^3. The range of $3,106 * 10^6$ m^3 is high compared to the mean total discharge if $3,290 * 10^6$ m^3 and the standard deviation of $680 * 10^6$ m^3. However, the flat trend of the linear-fit line shows there is no evidence of climatic variability in 28 years of data.

As expected, the Coppermine River at Copper Creek station shows a the total annual discharge variability similar to Point Lake Station. The maximum total annual discharge is 10,486*106 m^3 and the minimum is $5,655 * 10^6$ m^3, for a range of approximately $4,800 * 10^6$ m^3. The average annual total discharge is $8,270 * 10^6$ m^3 with a standard deviation of $1,588 * 10^6$ m^3. The linear fit line (Figure 10) shows a decrease in the total annual discharge over the last 12 years at the Copper Creek station. However, the period of record at Copper Creek starts in 1984, one of the highest years on record, and ends in 1995, one of the lowest years on record. This decreasing trend can also be identified over the same 12 year period with the Point Lake data (Figure 9), but the trend over the 28 year time series at Point Lake is flat. A much longer data record is required to investigate annual discharge trends for a climate change signal.

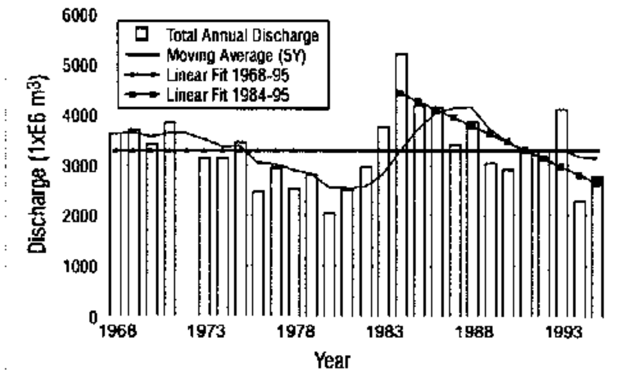


Figure 9 [illegible] Annual Discharge 1968-95.

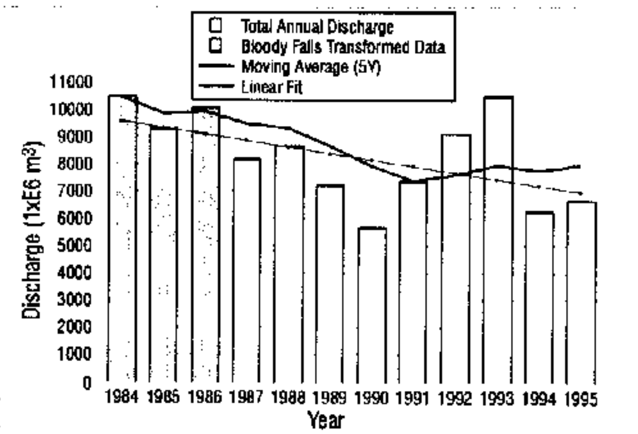


Figure 10 [illegible]

[illegible] Hydrometric Stations

For regional comparisons, the mean annual hydrographs of the Coppermine River stations were plotted with hydrographs of selected Cordillera stations. The Mackenzie Mountains region is characterized by steep topography, forest cover and little surface storage of surface water in contrast to the flatter, mostly treeless topography of the Coppermine River basin. Of the many large rivers flowing from the Mackenzie Mountains, the Arctic Red River and

South Nahanni River (Map 2) were selected for comparison with the Coppermine River because of the similarity of the drainage basin areas, latitude, and periods of record.

Arctic Red River (10LA002)

The Arctic Red River flows northward from the Mackenzie Mountains and joins the Mackenzie River just above Point Separation, the head of the Mackenzie Delta. The gauging station on the Arctic Red River near the mouth (66°47'24"N, 133°04'54"W) is located about 100 km upstream of its confluence with the Mackenzie River and has been in operation since 1969. At the gauge site, the drainage area is 18,600 km^2. The mean annual flow of the Arctic Red River is 157 m^3/s, with mean peak flow of 1490 m^3/s and a mean low flow of 12.7 m^3/s (Figure 11). The seasonal differences are quite extreme on the Arctic Red where the mean summer flow is 298 m^3/s and the mean winter flow is 16.9 m^3/s which give a summer/winter ratio of 17.6. The Arctic Red River has the characteristics of a sub-arctic nival regime, but with influence of the topographic elevation changes. The mean and sample hydrographs show evidence of summer precipitation events and they may be influenced by melting of late-lying snow packs at elevation and by rain-on-snow events.

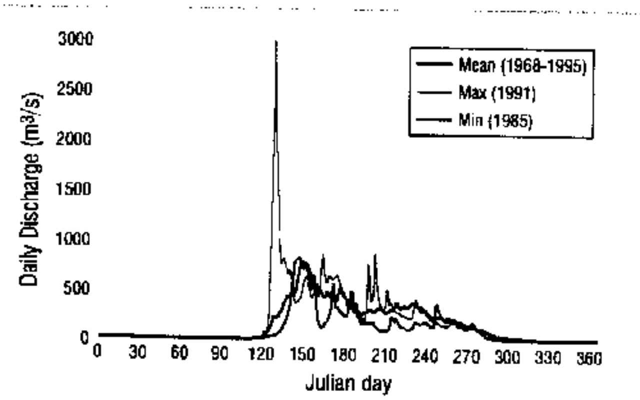
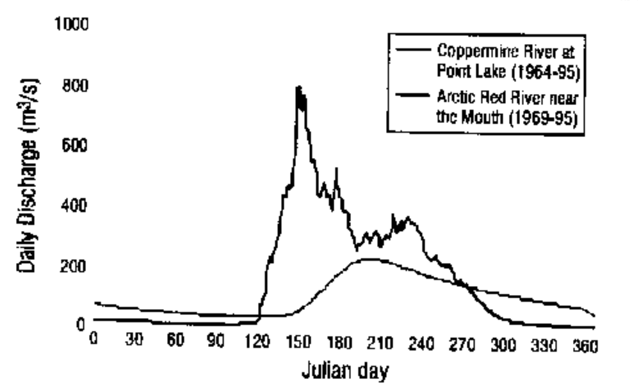


Figure 11 – [illegible]

The Coppermine River at Point Lake and the Arctic Red River near the mouth have similar basin areas, 19,300 km^2 and 18,600 km^2 respectively, and similar basin shapes. Both rivers are north- flowing and they are located at approximately the same latitude. However, Coppermine River at Point Lake is situated on the low topography of the Canadian shield at the outlet of a large lake while Arctic Red River drains a mountain region with no lake storage. Figure 12 shows that the Coppermine River at Point Lake has a much flatter mean annual hydrograph than the Arctic Red River. The smaller mean peak flow of the Coppermine River at Point Lake is delayed by about six weeks compared to the sharp peak on the Arctic Red River. The recession of the Coppermine at Point Lake is gradual and smooth, whereas the hydrograph for the Arctic Red River shows a rapid recession from the large spring flood with significant spikes from summer storm events. Winter flow on the Arctic Red River drops more rapidly at freeze-up and to lower magnitudes.

The basin yield of the Arctic Red River is 267 mm/year compared to 170 mm/year for Point Lake (Table 1). Although there are no snow data, the Arctic Red River basin possibly receives more snowfall in winter than the Coppermine River basin. Also, the forest cover and steeper topography in the Arctic Red basin probably limit snow pack ablation by



[illegible] 12 – [illegible]

blowing snow sublimation. Another factor that may account for the difference in basin yield is the area of lake surface in the upper Coppermine basin and the increased potential for water loss to lake evaporation in the summer.

South Nahanni River - Virginia Falls (10EB001)

The South Nahanni River flows from the southern Mackenzie Mountains in a southeasterly direction and joins the Liard River at Nahanni Butte. A stream flow gauge above Virginia Falls (61°38'09"N, 125°48'43"W) has been in operation since 1962. At the gauge site, the South Nahanni River drains a basin area of 14,600 km^2. Over the 33 years of record at the Virginia Falls site, the mean annual flow is 228 m^3/s, and the mean peak and low flows are 1510 m^3/s and 25.9 m^3/s, respectively (Figure 13). The seasonal variation is again quite extreme with a mean summer flow of 427 m^3/s and a mean winter flow of 32.9 m^3/s for a seasonal ratio of 12.9. The South Nahanni River is sub-arctic nival, but with some characteristics similar to the proglacial regime due to effects of topography, late-lying snow packs and rain-on-snow events. One characteristic to note is the high basin yield (492 mm/yr) relative to the Arctic Red (287 mm/yr) and Coppermine basins (177 mm/yr at Copper Creek).

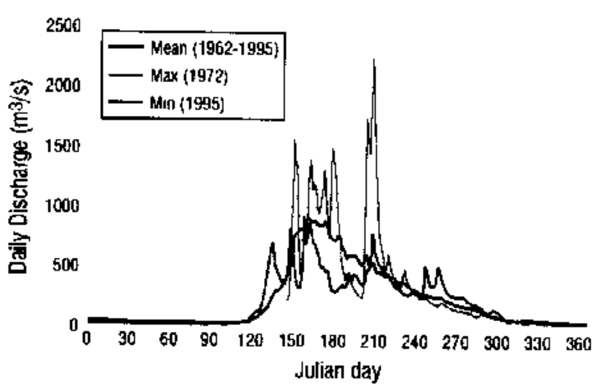


Figure 13.

South Nahanni River - Clausen Creek (10EC001)

Another gauge was operated close to the mouth of the South Nahanni River near Clausen Creek (61°15'48"N, 24°04'11"W) from 1969 until 1995. At the Clausen Creek gauge, the South Nahanni River has a drainage basin of 31,100 km^2. The average annual flow over the period of record is 404 m^3/s, the mean peak flow is 2240 m^3/s and the mean low flow is 55.6 m^3/s (Figure 14). The mean summer and winter flows are 743 m^3/s and 89 m^3/s, respectively, for a seasonal ratio of 8.4.

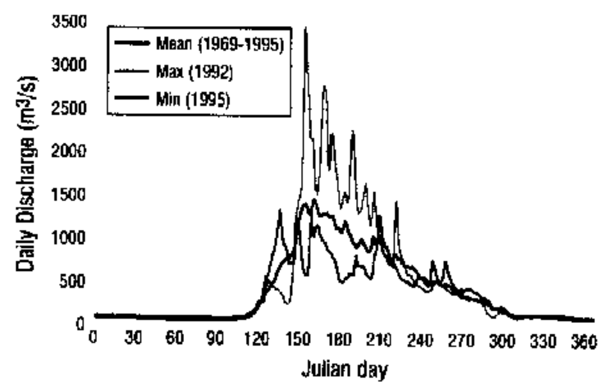


Figure 14.

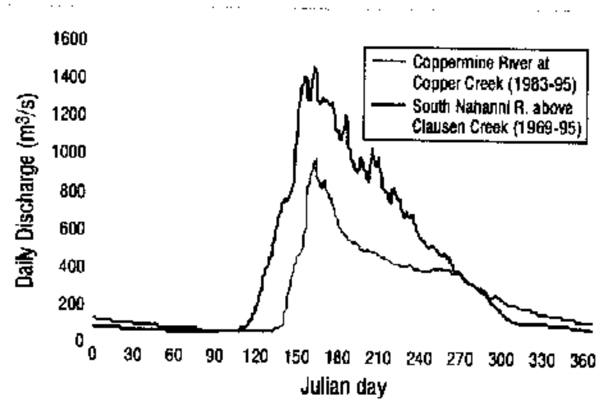


Figure 15.

The Coppermine River at Copper Creek drainage basin (46,800 km^2) is 1.5 times larger than South Nahanni River above Clausen Creek drainage basin (31,100 km^2). The calculated basin yields for the Coppermine at Copper Creek and the South Nahanni above Clausen Creek are 177 mm/year and 407 mm/km^2, respectively (Table 1). The difference between the basin yields may be caused by differences in precipitation, evapotranspiration and snow sublimation, and may be affected by more rapid runoff in the steep terrain. The spring breakup peak flow is the most significant event of the annual hydrograph for both stations. After break up the hydrograph of the South Nahanni above Clausen Creek decreases relatively slowly compared to the Coppermine River at Copper Creek (Figure 15). This may be due to the gradual melt of glacier ice or late-lying snow at higher elevations. Again, the absence of lake storage in the South Nahanni basin accounts for the rapid response of the stream flows to rainfall events.

Flood Frequency Analyses

Flood frequency analysis was used to evaluate the probability that a given yearly maximum flow value occurs. The analysis has been applied to four station data sets: Coppermine River at Point Lake, Coppermine at Copper Creek, Arctic Red River and South Nahanni River at Virginia Falls. For each station, the return period graph has been plotted (Figures 16 to 19).

The exceedance probability is the probability of having a flow magnitude over a specific value. The exceedance probability is often expressed as return period (T), which is the time interval in which a given flow magnitude should be exceeded one time. For example, if a certain flow value is exceeded once in hundred years, its exceedance probability is 0.01 and its return period (1/T) is one hundred years. With a sufficiently long data

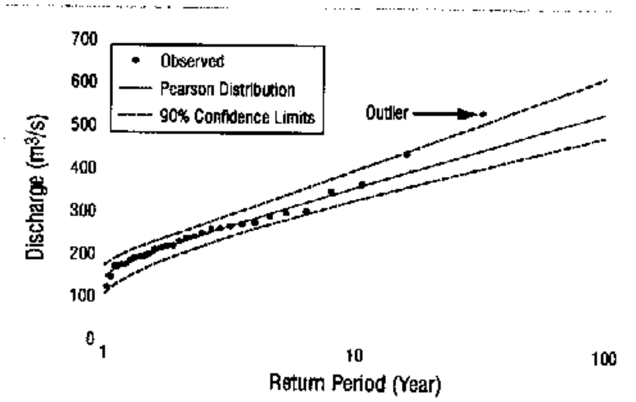


Figure 16 [illegible]

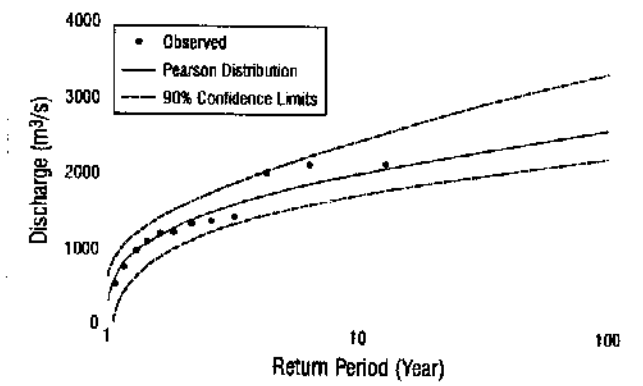
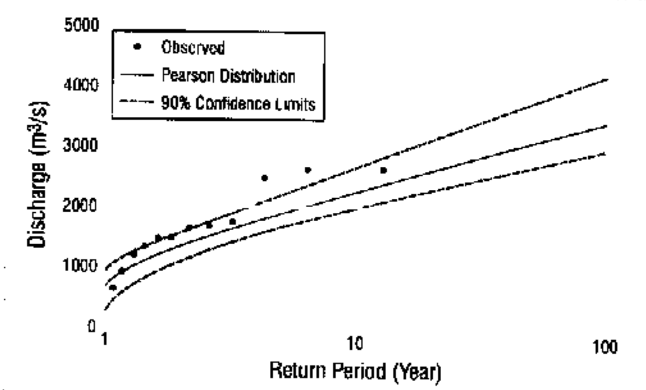


Figure 17 [illegible]



[illegible]

Table 2 [illegible]

	10 years	25 years	50 years	100 years
Coppermine R. at Point Lake	357	427	480	533
Coppermine R. at Copper C.	1980	2240	2420	2590
Arctic Red R. Near the Mouth	2270	2740	3090	3430
Nahanni R. above Clausen C.	2840	3140	3340	3540
Nahanni R. above Virginia Falls	1960	2160	2290	2410

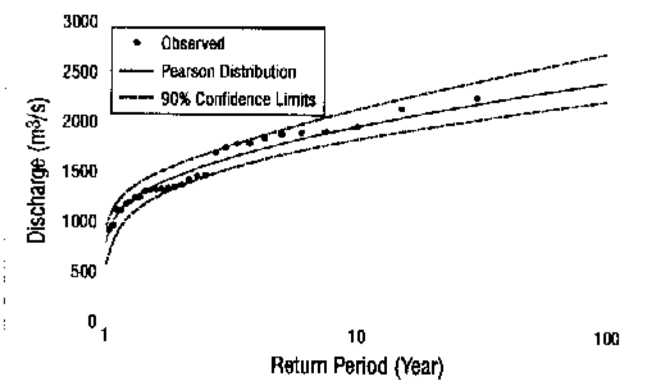


Figure 19. [illegible]

record, it is possible to evaluate precisely the exceedance probabilities and return periods of maximum flows.

However, the length of data record for the Coppermine River is only 31 years, thus a theoretical distribution was used to calculate flood probabilities. Theoretical distribution techniques use the mean, the standard deviation and the skewness of the observed annual maximum flow distribution to evaluate the return period of annual maximum flows. The theoretical distribution, and the 90% confidence limits, were calculated using the Pearson distribution on the entire data set (Appendix 2). A second technique is to plot the actual observed data using the Weibull technique (Appendix 2). Techniques for analysing extreme events frequency were taken from Maidment (1993), Lemieux (1996), Chow (1964) and Hogg & Carr (1985).

Only years with a complete data record during the breakup period were used in the frequency analysis to be certain that the maximum annual flow was recorded. The theoretical distribution seems to fit better near the average maximum flow than at the extreme high flows (Figure 16 - 19). Also, theoretical distributions fit the observed data best when a long period of record is available, such as with the South Nahanni River above Virginia Falls. The 31 years of data for the Coppermine River at Point Lake were expected to fit well with the Pearson distribution, however, the graph (Figure 16) shows a difference between theoretical and observed distributions caused by an extreme high flow of 530 m^3/s, which falls outside of the 90% confidence limits. The theoretical distribution predicts a return period of 100 years for a flow of this magnitude (Table 2), although it was observed within the 31 year data set. As more data are received, the fit between the observed data and the theoretical distribution should improve. Table 2 gives the maximum flows expected for given return periods using the Pearson distribution for the Coppermine, South Nahanni and Arctic Red Rivers.

Natural River Discharge versus Mine Pit [illegible]

The BHP Ekati diamond mine, located in the Coppermine River basin, is licensed to pump water from small lakes on the mine site into natural drainage channels which ultimately flow into Lac de Gras. Since Lac de Gras is one of the headwater lakes of the Coppermine River basin, concerns have been raised about the effect of the pumping on the river flow rates. The water license allows BHP to pump water from the small lakes at a maximum rate of 2.25 m^3/s from May to July and at a maximum of 0.52 m^3/s from August to April.

Table 3 [illegible]

		May-July (2.25 m^3/s)			August-April (0.52 m^3/s)		
		[illegible]	[illegible]	[illegible]	Mean	Max	Min
Coppermine River at Copper Creek	Flow	483	1030	215	195	318	118
	%	0.5%	0.2%	1.2%	0.3%	0.2%	0.4%
Coppermine River at Point Lake	Flow	130	253	67.1	98.3	156	52
	%	2.0%	1.0%	3.8%	0.5%	0.3%	1.0%
Coppermine River at Desteffany Lake*	Flow	48.0	98.9	11.9	25.0	39.8	12.9
	%	4.7%	2.3%	19%	2.1%	1.3%	4.0%

** There is only one year of data for the Coppermine River at Desteffany Lake.*

The license pump rates were compared to the natural flow rate at the three gauging stations on the Coppermine River by calculating the percentage of the pump rates versus the natural mean daily discharge, and the natural maximum and minimum discharges for the two time periods (Table 3). Table 3 shows that the pump rate percentages versus natural flow are higher during the May-July period than during August-April. Also, the pump rate percentages decrease further downstream on the Coppermine River as the natural discharge volumes increase. In the May to July period, the pump rate percentage drops from 4.7% of average natural flow at Desteffany Lake to 2.0% at Point Lake and to 0.5% at Copper Creek. Obviously, the pump rate percentage is highest during the minimum flow period which occurs in May prior to break up. At minimum flows (May-June), the pump rates are equal to 19% of the natural flow at the Desteffany Lake gauge, 3.8% at Point Lake and 1.2% at Copper Creek. An important factor when attempting to identify effects of pumping on the natural river system is the accuracy of the measured discharge data, which is approximately 5% (Jones, M. 1998, personal communication). Thus, if the pump rates are less than 2.5% of the natural flow rates, the change is too small to be determined within the measurement accuracy.

The percentages in Table 3 are simple mathematical comparisons only, and flow increases of 2.25 m^3/s will not occur on the Coppermine River from lake de-watering due to the attenuation of flow by the small lakes and by Lac de Gras. Lake de-watering is accomplished by pumping the water from one small lake to the next in a chain of small lakes located on the mine site. Each lake attenuates the pump flows before the water enters Lac de Gras. Lac de Gras, which has a surface area of 577 km^2 (Wedel, 1988), will greatly attenuate the pumps flows. For example, if the pumps were operated at the maximum allowable rate of 2.25 m^3/s for one day, the total volume of water pumped would be 194,400 m^3. If pumped directly to Lac de Gras, rather than through the chain of lakes, this volume of water would increase the level of Lac de Gras by about 0.3 millimetres. Continued pumping at this rate for a month, and assuming there was no outflow from Lac de Gras, would increase the water level of Lac de Gras by about 10 mm. A water level increase by this amount would have a negligible effect on the outflow.

Water Quality Data in the Coppermine Basin

There are four sites in the Coppermine River basin that have water quality data. Water quality data have been available from the early 1960s to the present date. There are data for 1997 and 1998, but these are unavailable at this time as they have not been checked and verified yet. The locations of the four water quality sites in the basin are illustrated in Map1. These water quality sites are part of the NWT Water Quality Network Program whose objective is to gather long term baseline data of the ambient water quality conditions throughout the Northwest Territories for evaluating the effects of possible future mineral development.

Various water quality data for the following sites have been plotted: Coppermine River at Desteffany Lake (PA0004), Coppermine River at Outlet of Point Lake (PB0001), Coppermine River at Bloody Falls (PC0008) and Coppermine River near the mouth (PC0018). All the water quality data were obtained from Environment Canada (water quality data 1996/97 as supplied by D. Halliwell). The graphs attempt to show seasonal variations for selected parameters from 1960 to 1996. The parameters plotted and summarized in the following summary tables were considered pertinent to the diamond mining activity that is occurring in the basin at the present time. Note: although there are very few water quality data available for aluminum, a by-product of diamond mining, the values were still plotted.

Also illustrated in this report are comparisons of the following: flow data vs. TSS; flow data vs. turbidity; and TSS vs. turbidity for Coppermine River at Outlet of Point Lake and Coppermine River near the Mouth.

Summary of Water Quality Results

Parameter	Maximum Value	Minimum Value	Average Value	Median Value	Standard Deviation	N
pH	6.78	4.08	6.14	6.52	0.79	9
Conductivity (µS/cm)	33.6	11.1	16.32	15.7	6.64	9
Turbidity (ppm)	1.2	0.1	0.61	0.6	0.36	9
Total Dissolved Solids (ppm)	18	10	14.1	15	3.07	9
Total Suspended Solids (ppm)	9	3	4.11	3	1.85	9
Total Aluminum (ppm)	80.6	13.7	38	28.85	25.73	4
Total Arsenic (ppm)	NA	NA	NA	NA	NA	NA
Total Copper (ppm)	4.5	0.5	1.39	0.9	1.15	9
Total Iron (ppm)	98	20	41.7	31	22.25	9
Total Lead (ppm)	0.001	0.0002	0.0004	0.0003	0.0003	9
Total Manganese (ppm)	13.8	1.7	4.53	4.1	3.49	9
Total Zinc (ppm)	21	0.8	5.13	3.2	5.81	9

Parameter	Maximum Value	Minimum Value	Average Value	Median Value	Standard Deviation	N
pH	8.58	6.1	6.94	6.82	0.44	73
Conductivity (µS/cm)	28	7.1	13.77	13.4	2.52	71
Turbidity (ppm)	5	0.07	0.77	0.3	1.04	72
Total Dissolved Solids (ppm)	11	4	6.93	7	1.32	42
Total Suspended Solids (ppm)	11.2	1.0	1.58	1	1.64	50
Total Aluminum (ppm)	NA	NA	NA	NA	NA	NA
Total Arsenic (ppm)	NA	NA	NA	NA	NA	NA
Total Copper (ppm)	0.0028	0.0006	0.0012	0.001	0.0005	31
Total Iron (ppm)	NA	NA	NA	NA	NA	NA
Total Lead (ppm)	0.0021	0.0007	0.0009	0.0007	0.00032	32
Total Manganese (ppm)	NA	NA	NA	NA	NA	NA
Total Zinc (ppm)	0.020	0.0007	0.0035	0.002	0.0042	32

Table 4c [illegible]

Parameter	Maximum Value	Minimum Value	Average Value	Median Value	Standard Deviation	N
pH	7.7	6.9	7.44	7.55	0.25	13
Conductivity (µS/cm)	79	8.3	52.53	69	26.41	14
Turbidity (ppm)	130	0.2	19.09	8.5	33.02	14
Total Dissolved Solids (ppm)	44	26	37.4	37.5	4.32	10
Total Suspended Solids (ppm)	168	2.0	62.1	41.5	48.54	10
Total Aluminum (ppm)	NA	NA	NA	NA	NA	NA
Total Arsenic (ppm)	NA	NA	NA	NA	NA	NA
Total Copper (ppm)	0.011	0.002	0.0041	0.003	0.0025	10
Total Iron (ppm)	NA	NA	NA	NA	NA	NA
Total Lead (ppm)	0.007	0.001	0.0017	0.001	0.0018	10
Total Manganese (ppm)	NA	NA	NA	NA	NA	NA
Total Zinc (ppm)	0.031	0.003	0.0083	0.005	0.008	10

Table 4d [illegible]

Parameter	Maximum Value	Minimum Value	Average Value	Median Value	Standard Deviation	N
pH	8.3	6.4	7.34	7.33	0.34	74
Conductivity (µS/cm)	14200	12	585.93	62.9	2184.87	70
Turbidity (ppm)	71	0.2	8.19	3.2	12.17	76
Total Dissolved Solids (ppm)	83	25	41.4	39	12.81	35
Total Suspended Solids (ppm)	127	3.0	17.18	6	28.45	38
Total Aluminum (ppm)	1760	66.8	913.4	913.4	846.6	2
Total Arsenic (ppm)	0.5	0.5	0.5	0.5	0	3
Total Copper (ppm)	6	0.4	2.58	2	1.45	35
Total Iron (ppm)	70.4	0.28	7.21	1.88	13	35
Total Lead (ppm)	0.003	0.0002	0.001	0.0007	0.0008	32
Total Manganese (ppm)	24.5	0.1	6.2	3.4	6.63	23
Total Zinc (ppm)	45.5	0.9	11.35	8.9	10.71	35

Gr[illegible]

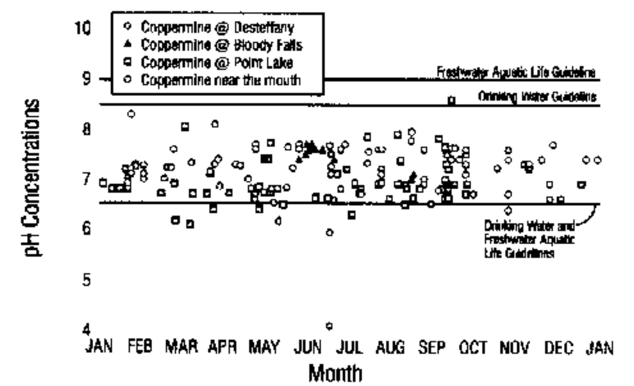
This section of the report will show the water quality at the following sites: 1. Coppermine River at Desteffany Lake (2 years of data), 2. Coppermine River at Outlet of Point Lake (21 years of data), 3. Coppermine River at Bloody Falls (11 years of data) and 4. Coppermine River near the mouth (19 years of data). The results shown include pH, conductivity, turbidity, total suspended solids, total dissolved solids, total iron, total lead, total manganese, total zinc, total aluminum, total copper. These results were compared to Canadian Council for Ministers of the Environment Water Quality Guidelines for Protection of Freshwater Aquatic Life and Drinking Water Guidelines (Environment Canada, 1995).

Graphs illustrating the seasonal distribution of water quality results are shown in Figures 20 to 31. The results indicate that the parameters of interest have higher concentrations during the month of June for the years between 1960 and 1996 for the most part. There do not seem to be any large variances throughout the January to December months of any given year other than there is a difference in water quality concentrations between sites that can be seen in the following graphs.

pH Results

pH values ranged from 4.08 to 6.78 at the Coppermine River at Desteffany site (N=9), 6.1 to 8.58 at the Coppermine River at Outlet of Point Lake site (N=73), 6.9 to 7.7 at Coppermine River at Bloody Falls site (N=13) and 6.4 to 8.3 at the Coppermine River near the Mouth site (N=74). All the pH data were collected between 1960 and 1996.

With the exception of the thee readings (3 of 9) at Coppermine at Desteffany Lake, the five readings (5 of 73) at Coppermine River at Outlet of Point Lake and the one reading (1 of 74) at Coppermine River at the Mouth, all the readings were within the guidelines (6.5 to 8.5).

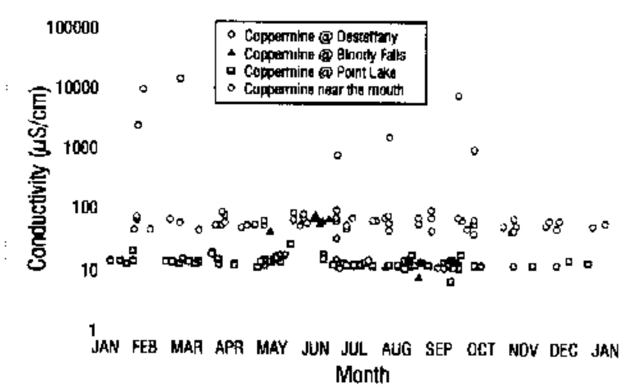


[illegible]

Conductivity Results

Conductivity values ranged from 11.1 to 33.6 µS/cm at the Coppermine River at Desteffany site (N=9), 7.1 to 28 µS/cm at the Coppermine River at Outlet of Point Lake site (N=71), 8.3 to 79 µS/cm at Coppermine River at Bloody Falls site (N=14) and 12 to 14200 µS/cm at the Coppermine River near the Mouth site (N=70). All data were collected between 1960 and 1996.

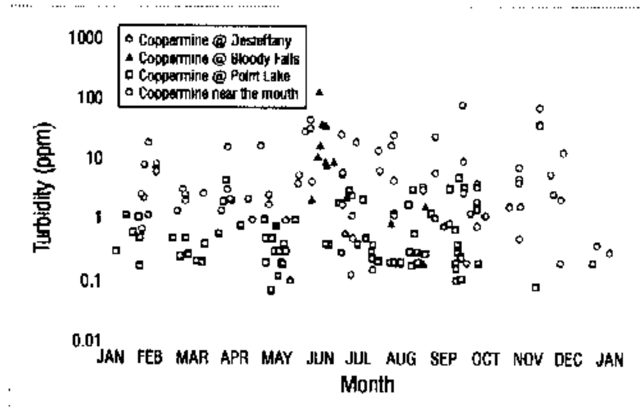
There is a distinct difference between the conductivity readings at the Coppermine River at Outlet of Point Lake site and the Coppermine River near the Mouth site. The standard deviation at the Coppermine River at Outlet of Point Lake site is 2.52 indicating very little variation in the data range, as opposed to the standard deviation of 2184.87 at Coppermine River near the Mouth site which is has a large variance due to the seven high readings that occurred in January (2), February (1), June (1), July (1) and August (2). It was thought that high conductivity values near the mouth were from the influence of saltwater, however, the Coppermine River near the mouth site is too far upstream from such influence.



[illegible]

Turbidity Results

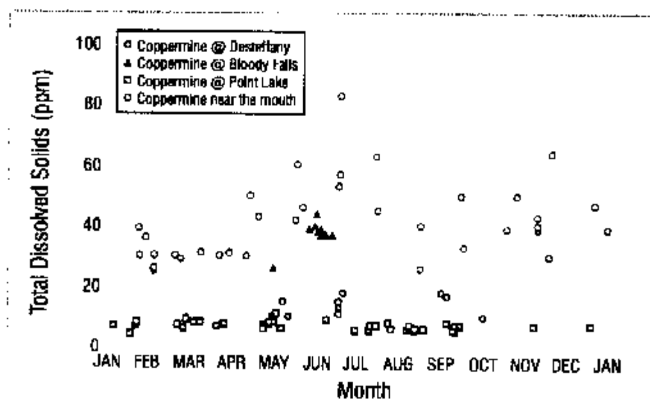
Turbidity values ranged from 0.1 to 1.2 ppm at the Coppermine River at Desteffany site (N=9), 0.07 to 5 ppm at the Coppermine River at Point Lake site (N=72), 0.2 to 130 ppm at Coppermine River at Bloody Falls site (N=14) and 0.2 to 71 ppm at the Coppermine River near the Mouth site (N=76). All data were collected between 1960 and 1996. There is no indication of any seasonal trends at any of the sample sites, very little variation from month to month and no indication of a cyclic pattern in the data.



Total Dissolved Solids (TDS)

TDS values ranged from 10 to 18 ppm at the Coppermine River at Desteffany site (N=9), 4 to11 ppm at the Coppermine River at Outlet of Point Lake site (N=42), 26 to 44 ppm at Coppermine River at Bloody Falls site (N=10) and 25 to 83 ppm at the Coppermine River near the Mouth site (N=35). The data were collected between 1980 and 1996.

The TDS concentrations are highest at the Coppermine River near the Mouth site and there seems to be more of a cyclic pattern as the data shows two peaks, one in June and another in November. The TDS concentrations were fairly constant throughout the months at the Coppermine River at Outlet Point Lake site and Coppermine River at Desteffany Lake site, indicating no cyclic pattern.



Total Suspended Solids (TSS)

TSS values ranged from 3 to 9 ppm at the Coppermine River at Desteffany site (N=9), 1 to 11.2 ppm at the Coppermine River at Outlet of Point Lake site (N=50), 2 to 168 ppm at Coppermine River at Bloody Falls site (N=10) and 3 to 127 ppm at the Coppermine River near the Mouth site (N=38). The data were collected between 1967 and 1996.

The TSS values were highest at the Coppermine River above Bloody Falls site and show what looks like a peak at the end of June/beginning of July. However, with so few data points this cannot be confirmed. The data continue to exhibit the same characteristics as the TDS results where the concentrations are higher at Coppermine near the mouth site and with a slight peak in the open water periods, that may indicate a cyclic pattern in the data.

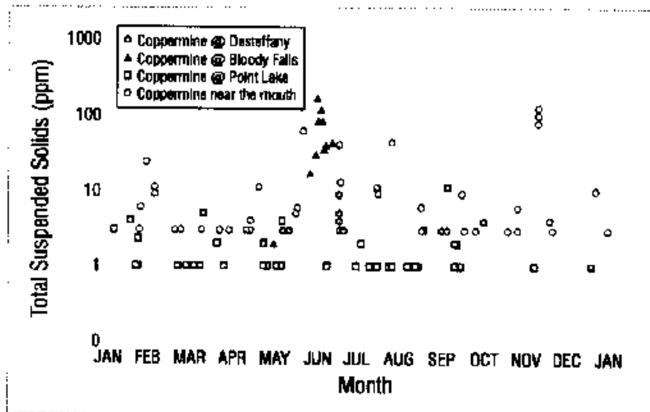


Figure 24 [illegible] Coppermine River Water Quality Stations

Total Aluminum Results

According to the protection of freshwater aquatic life guidelines which are set at 0.005 to 0.1 ppm, the aluminium levels at Coppermine River at Desteffany Lake and Coppermine River near the Mouth exceed the guidelines (Figure 25). The aluminum values at Desteffany lake site ranged from 13.7 to 80.6 ppm (N=4) and 66.8 to 1760 ppm (N=2) at the Mouth site.

Note: The sample sizes, N=4 and N=2, are too small to make the assumption that these are the normal conditions at those water quality sites. Once the new data for 1997 and 1998 are checked and verified, a better assessment can be made with regards to the ambient water quality conditions at the two sites.

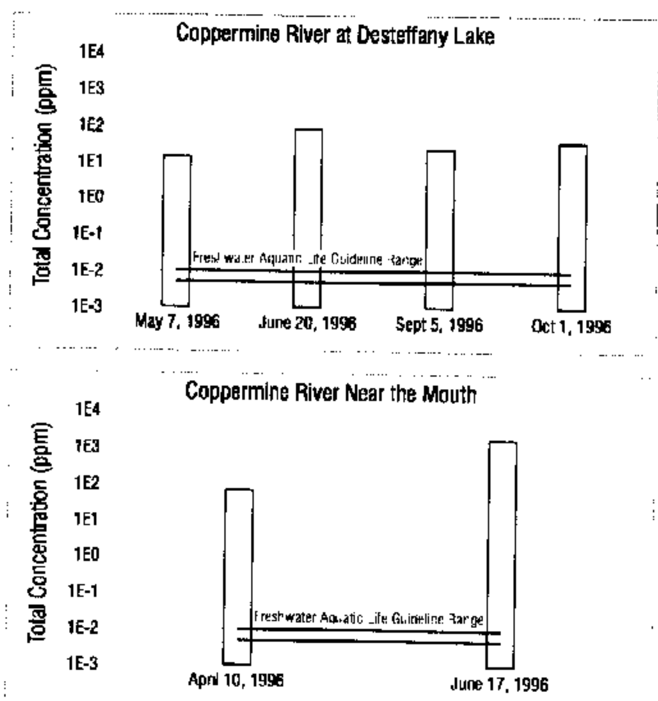


Figure 25. [illegible]

Canada

Total Arsenic Results

The arsenic concentrations exceeded both guidelines for drinking water and protection of freshwater aquatic life, 0.025 and 0.05 respectively at the Coppermine near the Mouth site (Figure 26). The average value was 0.5 ppm (N=3) but again, the sample size is too small to make any decision on what the ambient conditions for total arsenic are at the site. However, after checking and verifying the 1997 and 1998 data, one will be able to better assess the water quality at that site.

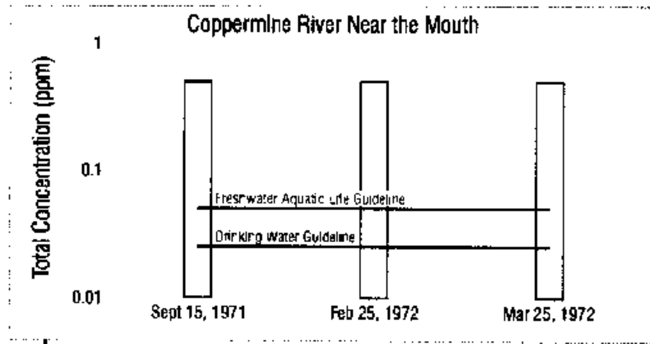


Figure 26 [illegible]

Total Iron Results

The only total iron data available were at Coppermine River at Desteffany Lake and Coppermine River near the Mouth. The results for Desteffany Lake site ranged from 20 to 98 ppm (N=9) and 0.28 to 70.4 ppm (N=35) at the Mouth site (Figure 27). The limit set for both the protection of freshwater aquatic life and drinking water guidelines is 0.3 ppm.

Both sites' data exceeded the guidelines except for one time where the result was below (0.28 ppm) at the Mouth site. At the Mouth site, the iron concentrations have been decreasing since 1992. The average iron concentrations are higher at the Desteffany Lake site (41.7 ppm) when compared to the Mouth site (7.21 ppm).

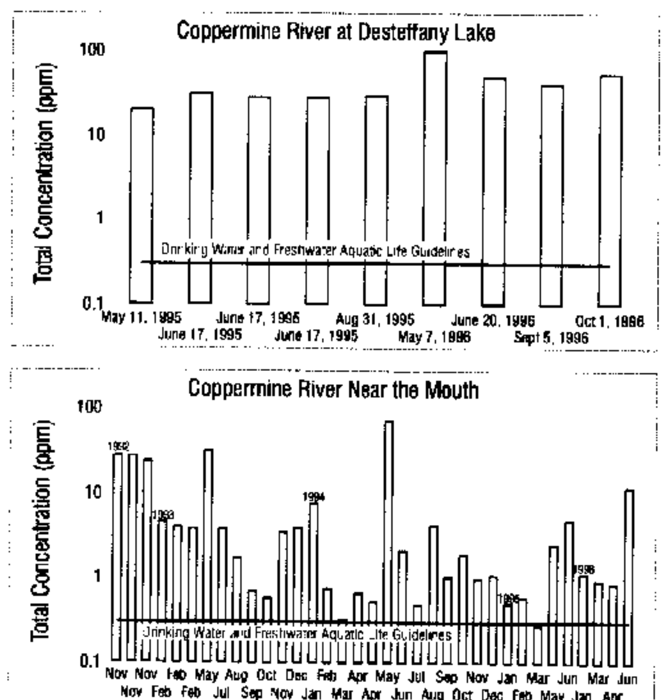


Figure 27 [illegible]

Total Copper Results

The copper concentrations at the Coppermine River at Desteffany Lake site ranged from 0.5 to 4.5 ppm and exceeded the protection of freshwater aquatic life guidelines in all cases (0.002-0.004, changes with hardness). The concentrations exceeded the drinking water guidelines (≤1.0 ppm) four times (N=9) (Figure 28). The values at the Point Lake site ranged from 0.0006 to 0.0028 ppm (N=31) and were well under the drinking water guidelines and never exceeded the protection of freshwater quality life guidelines.

The copper concentrations at the Coppermine River at Bloody Falls sites had similar results to the Point Lake site when compared to the drinking water guidelines. The water quality data ranged from 0.002 to 0.011 ppm (N=10) and exceeded the protection of freshwater aquatic life guidelines two times. In general, all the copper data at the Bloody Falls site exceeded both guidelines, the results ranging from 0.4 to 6.0 ppm (N=35).

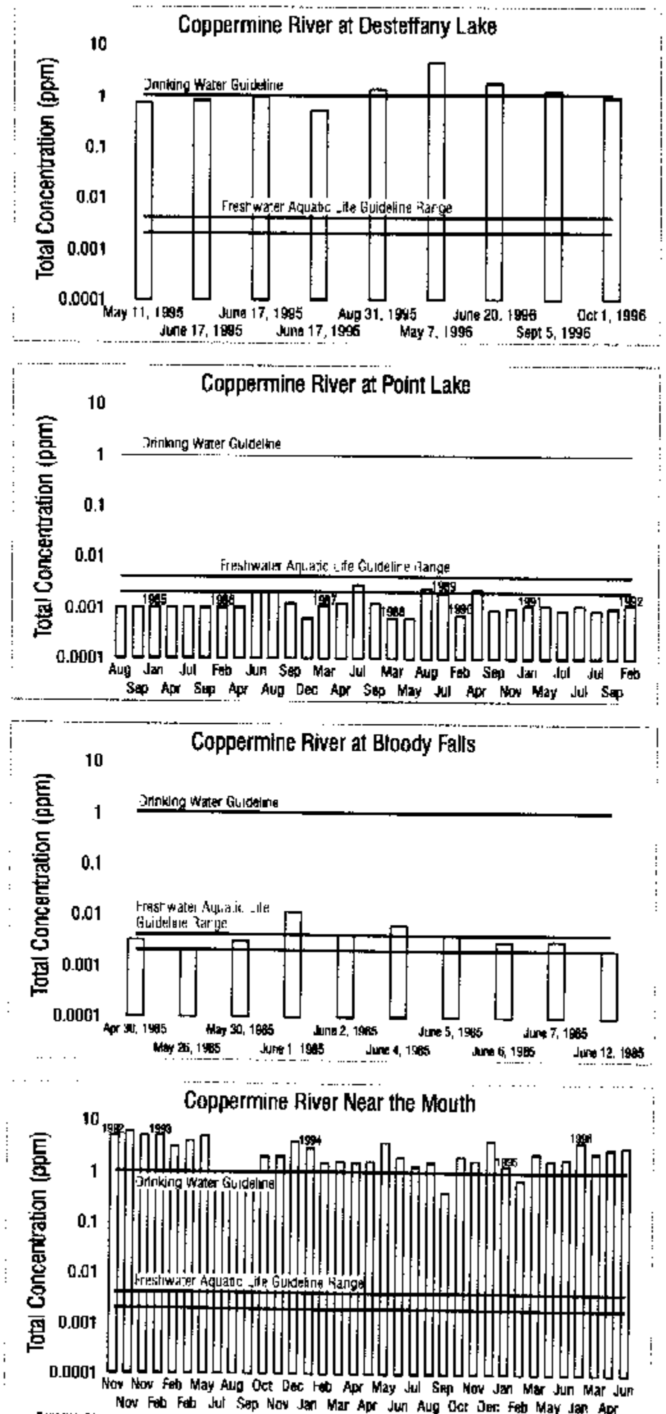
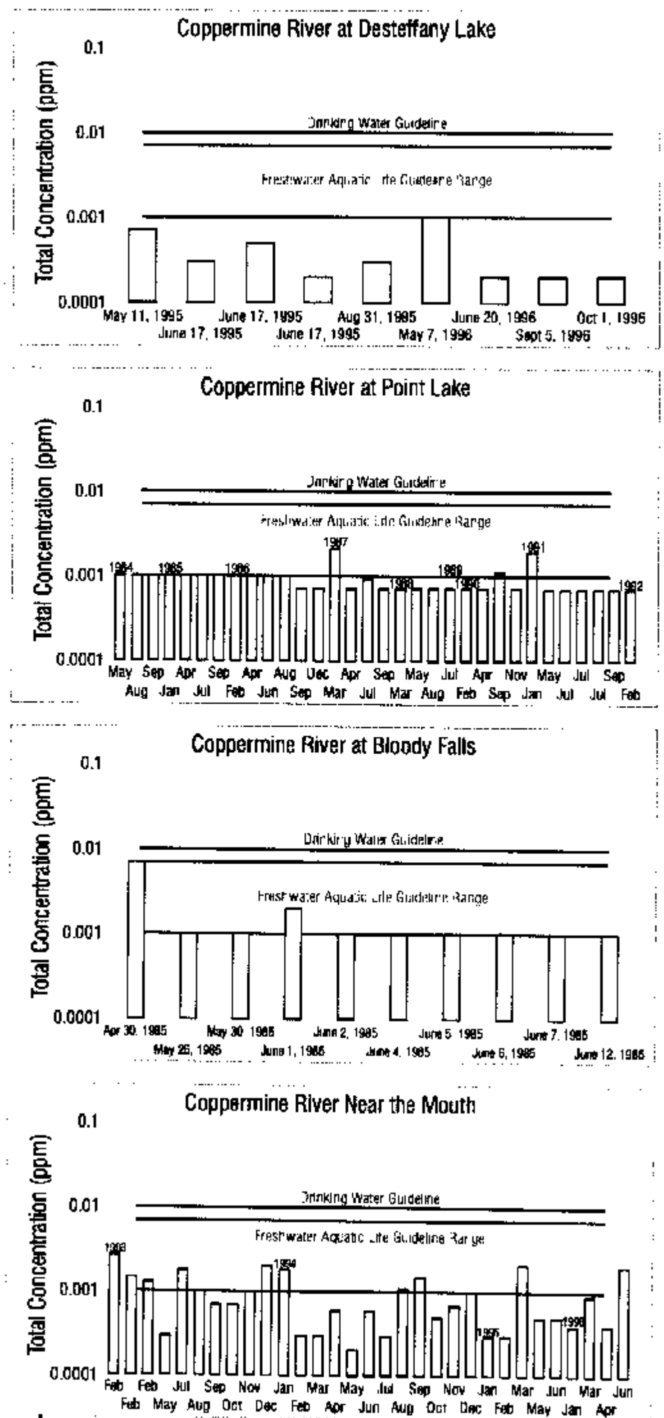


Figure 28

Canada

Total Lead Results

The total lead concentrations for Coppermine River at Desteffany Lake ranged from 0.002 to 0.01 ppm (N=9), Coppermine River at Outlet of Point Lake ranged from 0.0007 to 0.0021 ppm (N=32), Coppermine River at Bloody Falls ranged from 0.001 to 0.007 ppm (N=10) and Coppermine River near the Mouth ranged from 0.0002 to 0.0027 ppm (N=31). The guideline for the protection of freshwater aquatic life (FWAL) ranges from 0.001 to 0.007 ppm and changes with water hardness while the guideline for drinking water (DW) is 0.01 ppm (Figure 29). Overall, there was one reading (of 9) at the Desteffany Lake site that exceeded the FWAL guideline and 10 readings (of 31) at the Mouth site fell between the FWAL guidelines and all readings were below the DW guidelines. The lead concentrations tended to be highest at the Mouth site followed by the Point Lake and Bloody Falls sites. The Coppermine River at Desteffany Lake site had the lowest lead concentration compared to the rest of the sample sites.



Total Manganese Results

The only data available are from the Coppermine River at Desteffany Lake and Coppermine River near the Mouth sites. Total manganese concentrations ranged from 1.7 to 13.8 ppm (N=9) at the Desteffany Lake site and from 0.1 to 24.5 ppm (N=23) at the Mouth site (Figure 30). Both sites exceed the guideline for drinking water which is set at ≤0.05 ppm.

Overall the two sites display similar results, however, there seems to be more of an annual cyclic pattern in the Coppermine River near the Mouth site, which is more evident because there were more data collected at this site.

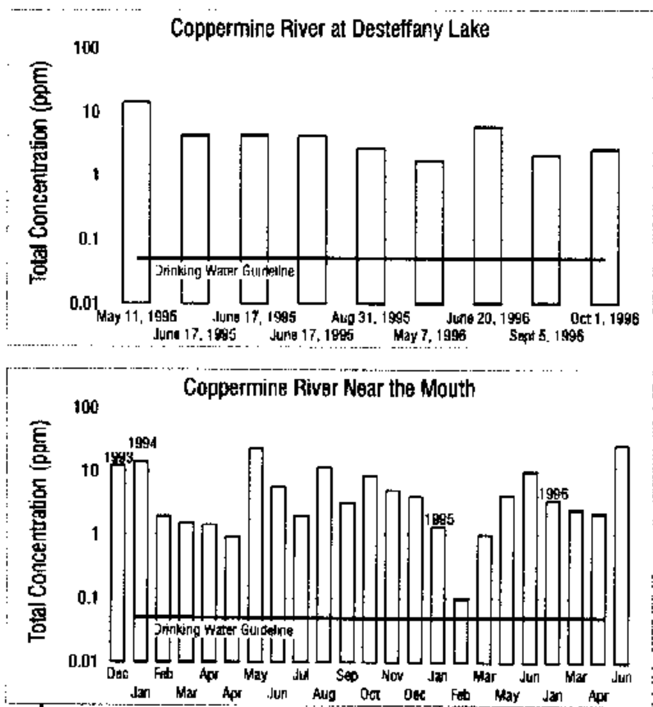
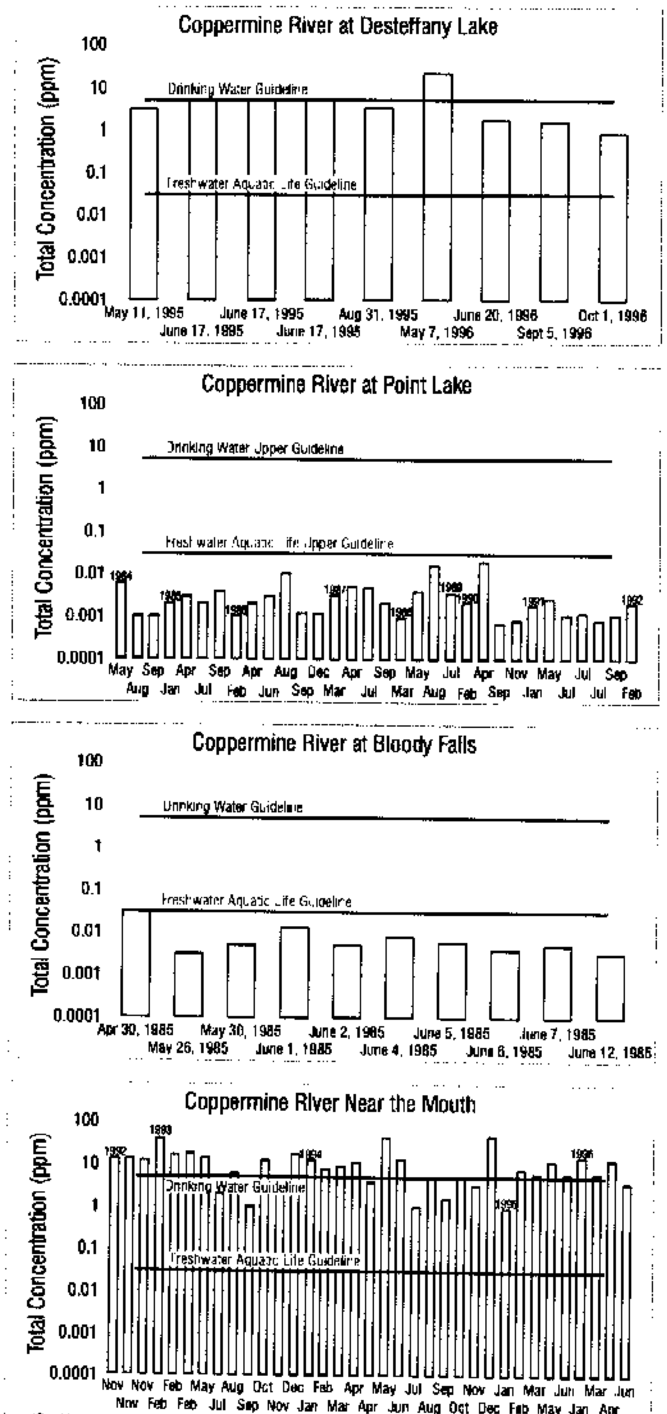


Figure 30 Total Manganese Concentration

Total Zinc Results

There are total zinc data available for all four stations, the total zinc concentrations ranging from 0.8 to 21 ppm (N=9) at the Coppermine River at Desteffany Lake, 0.0007 to 0.020 ppm (N=32) at Coppermine River at Outlet of Point Lake, 0.003 to 0.031 ppm (N=10) at Coppermine River at Bloody Falls and 0.9 to 45.5 ppm (N=35) at Coppermine River near the Mouth (Figure 31).

All the zinc concentrations at Coppermine River at Desteffany Lake site exceed the guideline for the protection of freshwater aquatic life set at 0.03 ppm and one of nine readings exceeded the drinking water guideline which is set at ≤5.0 ppm. All the values at the Coppermine River at Outlet of Point Lake and Coppermine River at Bloody Falls sites were below both guidelines unlike the majority of the values at the Mouth site that exceeded both guidelines.



Overall Comments on the Data

There seems to be a pattern in the water quality concentrations from site to site. Values are greater at the highest station (Coppermine River at Desteffany Lake) in the drainage basin and at the lowest station (Coppermine River near the mouth) then at the two middle sample stations. This is consistent throughout the data sets where the concentrations in general are higher at the first and last sample station. The middle stations may be good sites for monitoring the upstream development since variations in water quality will show up better due to lower natural concentrations. Table 5 shows this pattern with a breakdown of the number of exceedances (expressed as a percent) for protection of freshwater aquatic life and drinking water guidelines at each sample site for the following parameters: total aluminum, total arsenic, total copper, total iron, total lead, total manganese and total zinc.

The water quality data were also compared among sample sites to see if there were any significant differences. The comparison was done by using the student "t-test method" for the following parameters: dissolved arsenic, total copper, extractable iron, total iron, total lead, dissolved, extractable and total manganese and total zinc. Note that, because there was a lack of total concentration data, dissolved and extractable data were also used to do the comparisons.

Most of the water quality data comparison tests rejected the hypothesis that there were any similarities. However, there were a few parameters that did show some similarities at the following sites: dissolved arsenic (Coppermine River at Bloody Falls site and Coppermine River at Outlet of Point Lake site); total manganese (Coppermine River at Desteffany Lake and Coppermine River near the Mouth) and; total zinc (Coppermine River at Desteffany Lake and Coppermine River near the Mouth). See Appendix (3) for matrix and Appendix (4) for actual test results. These similarities in water quality between stations confirm the pattern of high values at either end of the basin.

The data provide good background information on the water characteristics at the four water quality sites in the basin which is important for pre-development purposes. The sample station closest to the diamond development area is Coppermine River at Desteffany Lake, followed by Coppermine River at Outlet of Point Lake site, then Coppermine River at Bloody Falls and lastly Coppermine River near the Mouth. It is recommended that at least three of these four water quality sites continue to be sampled in the future. These are Coppermine River at Desteffany Lake, Coppermine River at Outlet of Point Lake and Coppermine River near the mouth. Note: Coppermine River above Bloody Falls was sampled in the past, however, it is presently not being sampled and is recommended to be permanently closed.

It had been suggested that the Coppermine River near the Mouth site be closed due to greater variance in such parameters as conductivity, turbidity, total dissolved solids. However, this may be due to the fact that there are higher values at the end of the Coppermine River system. And the variance may be one of accumulation and not of influence from the saltwater as this site is approximately four kilometres upstream of the community of Kugluktuk, NT (formerly known as Coppermine). A logistical reason for keeping this site is that it has the easiest access of all the sites (all season access), where the sampler can travel by boat, all terrain vehicle (ATV) or snowmobile in the winter months from Kugluktuk, NT.

Table [illegible]

Sample Sites / Parameters	Guideline Exceedances (expressed as a %)	
	Freshwater Aquatic Life	Drinking Water
Coppermine River at Desteffany Lake		
Total Aluminum	(4/4) 100%	NA
Total Copper	(9/9) 100%	(4/9) 44%
Total Iron	(9/9) 100%	(9/9) 100%
Total Lead	(1/9) 11%	(0/9) 0%
Total Manganese	NA	(9/9) 100%
Total Zinc	(9/9) 100%	(1/9) 11%
Coppermine River at Outlet of Point Lake		
Total Aluminum	NA	NA
Total Copper	(0/9) 0%	(0/9) 0%
Total Iron	NA	NA
Total Lead	(0/9) 0%	(0/9) 0%
Total Manganese	NA	NA
Total Zinc	(0/9) 0%	(0/9) 0%
Coppermine River at Bloody Falls		
Total Aluminum	NA	NA
Total Copper	(2/9) 22%	(0/9) 0%
Total Iron	NA	NA
Total Lead	(0/9) 0%	(0/9) 0%
Total Manganese	NA	NA
Total Zinc	(0/9) 0%	(0/9) 0%
Coppermine River Near the Mouth		
Total Aluminum	(2/2) 100%	NA
Total Arsenic	(3/3) 100%	(3/3) 100%
Total Copper	(35/35) 100%	(30/35) 86%
Total Iron	(34/35) 97%	(34/35) 97%
Total Lead	(0/31) 0%	(0/31) 0%
Total Manganese	NA	(23/23) 100%
Total Zinc	(35/35) 100%	(24/35) 69%

Relationships Between Water Flow, TSS and Turbidity

A relationship between water turbidity, total suspended solids (TSS) and flow rate was investigated. Of the four water quality stations only two sites had complementary data sets where flow data matched up with TSS and turbidity data. The two sites are Coppermine River at Copper Creek and Coppermine River at Outlet of Point Lake.

Possible correlations were verified using graphs and R^2 values. An R^2 of 1.0 means a perfect correlation between two variables, and a R^2 of 0.0 means there is no correlation.

Log/log relations between TSS, turbidity and mean monthly flow were also tested. However, the log/log relation did not give better correlations. So, the linear regression was used.

Correlation between TSS and flow rate

From 1979 to 1992, 50 samples from the Coppermine River at Outlet of Point Lake were analysed for TSS. The graph (Figure 32) shows no correlation between the monthly mean flow rate and the TSS values. The statistical test also shows no relationship between the data ($R^2 = 0.006$).

At the Coppermine River near the mouth, 31 samples (from 1992 to 1995) were used to evaluate the correlation between the TSS and the flow rate. Figure 33 again shows a random relation between the TSS and the flow rate, the R^2 value is 0.02.

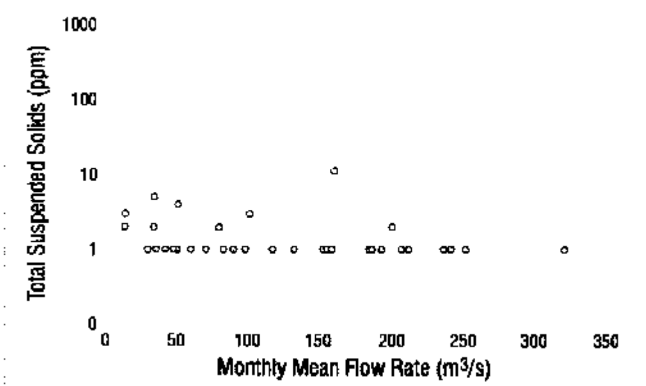


Figure 32. TSS vs Flow Rate: Coppermine River at Point Lake

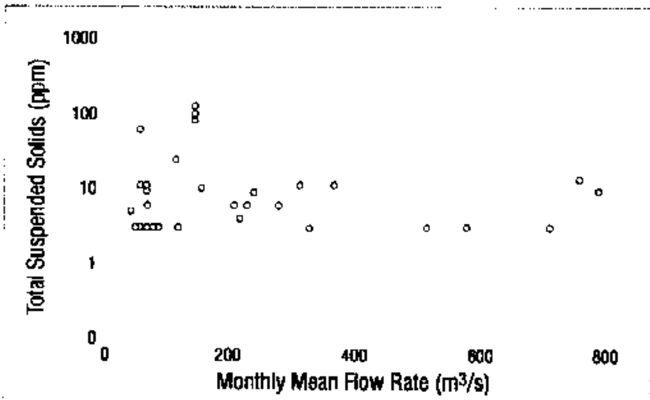


Figure 33. TSS vs Flow Rate, Coppermine River [illegible]

The graph (Figure 34) and the R^2 value of 0.01 indicate there is no relationship between the variables. Thirty-one samples, taken from 1992 to 1995 showed no correlation ($R^2 = 0.02$) between turbidity and flow rate at Coppermine River near the Mouth (Figure 35).

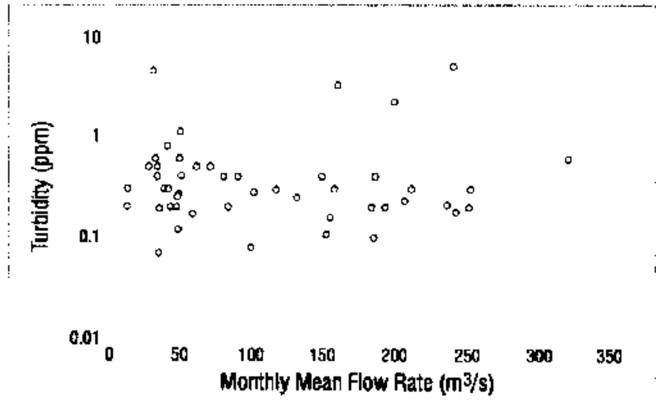


Figure 34. Turbidity vs Flow Rate: Coppermine River at Point Lake

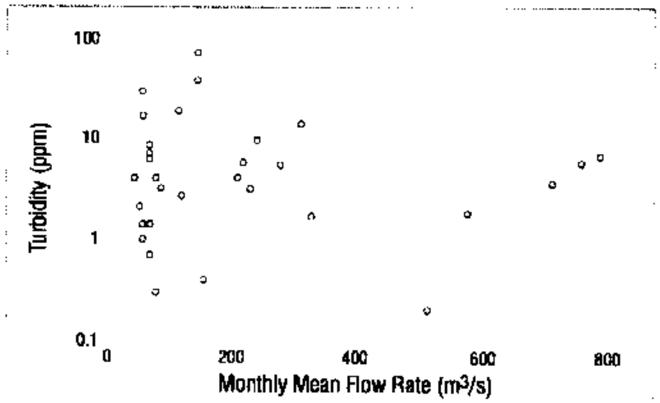


Figure 35. Turbidity vs Flow Rate Coppermine River [illegible]

Correlation between flow rate and turbidity

51 samples taken from 1979 to 1992 on the Coppermine River at Outlet of Point Lake were used to check if a relationship exists between the flow rate and the turbidity.

Correlation between TSS and turbidity

No relationship was found between TSS and turbidity at Coppermine at Outlet of Point Lake. The analysis of 50 samples gave an R^2 of 0.1 (figure 36). The absence of a relationship might be caused by low TSS values. NOTE: The high number of non detect values, which are valued at the detection limit induce errors in the relation. Once those samples were eliminated, a small linear relationship between TSS and turbidity appeared with an R^2 of 0.5.

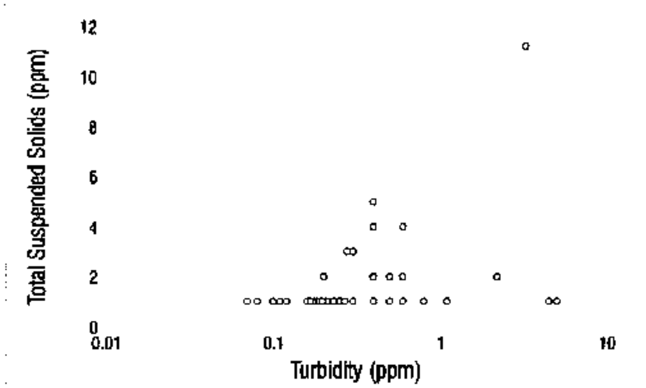


Figure 36. [illegible]

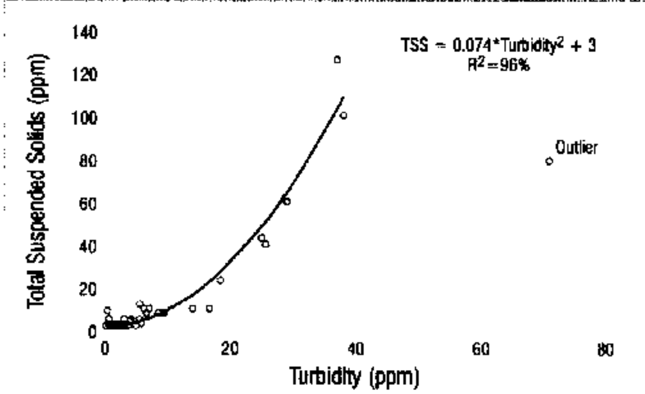


Figure 37. TSS [illegible]

Thirty-seven samples were analysed at Coppermine River near the Mouth station. A strong relationship existed between TSS and turbidity (Figure 37). Once the outlier was eliminated, a polynomial relation between TSS and turbidity was determined. The relation can be expressed by the formula: **TSS = 0.074*Turbidity^2 + 3.** This is the best relationship between data sets, based on R^2 values (0.96), and should be followed up with further examination of future water quality data at this site.

Conclusion

Hydrology

The Coppermine River has a sub-arctic nival flow regime, but with influence from lake storage. The upper half of the Coppermine basin is responsible for the lake effects on the flows, but these effects are evident along the entire length of the river as seen in the sustained winter flows at Copper Creek from storage in both Point Lake and Napaktolik Lake. Another effect of the lake storage in the upper Coppermine basin is that the seasonal flows are much less variable on the Coppermine compared with the mountain rivers. The basin yields for the Coppermine River are also much lower than in the mountain rivers, possibly due to higher evaporation losses from the lake surface and lower precipitation.

Flood frequency analysis shows that in the 31 year data record for the Coppermine River at Point Lake, there is an event with a statistical probability of over 100 years. A longer data record is required to verify this and to bring the value into the 90% confidence limits. The 100-year flood on the Coppermine River at Point Lake is 533 m^3/s, which is an order of magnitude lower than the 100- year flood on the Arctic Red River (3430 m^3/s), a mountain river with a similar drainage basin area.

The Coppermine River data were examined for possible signals of climate change, but no evidence was found. Over the short term record (12 years), a trend of decreasing flows was seen but in the longer term data, stream flows appear to be quite stable. The Coppermine River shows sensitivity to meteorological variability at both the Point Lake and Copper Creek stations as shown by the annual variation in discharge.

The effects of de-watering on the Ekati mine site are negligible on Lac de Gras and on Coppermine River. If there is any increase in outflow of Lac de Gras, it will be within the natural variation of the flows and will probably not be measurable with the accuracy of the metering equipment.

Water Quality

As indicated in the water quality graphs, the data used from 1967 to1996 from the Coppermine River at Outlet of Point Lake and Coppermine River near the mouth sites show TSS and turbidity are independent of monthly flow rates. However, a relationship does exist between TSS and turbidity at Coppermine near the Mouth site which is most likely visible due to the higher TSS and turbidity values. Future data should consider monitoring this site as it ls the only one that exhibits any type of relationship between parameters that are relevant to the diamond mining industry.

It was noted that water quality values were highest at the Coppermine River near the mouth and Coppermine River at Outlet of Desteffany Lake sites. The lowest concentrations were at the two middle water quality sites, Coppermine River at Outlet of Point Lake and Coppermine River above Bloody Falls. The concentrations usually exceeded the freshwater aquatic life and drinking water guidelines at Coppermine River at the Mouth and Coppermine River at Desteffany Lake but are the ambient conditions and should be used to monitor the water quality in the basin.

In addition, TSS, turbidity and total aluminum data should continue to be monitored in the future, focussing on total aluminum (by-product) as this parameter is virtually not existent in the database and is pertinent to the diamond industry.

Overall, the present water quality database is a good representation of the ambient water quality conditions in the Coppermine River Basin and does provide a good bench mark for monitoring future activity in and downstream of the diamond mining area.

This Basin is of a high cultural value to the resource users of the NWT. Future work will be done on developing a water quality index. The index will be derived using the CCME National Water Quality Index Formula and the water quality database for the Coppermine River Basin. The index can be used as guide, indicating what the water quality conditions are at each site with respect to recreational uses, drinking water uses, fishing etc. and will be based on a simple rating system ranging from poor to excellent.

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Appendices

Appendix 1: Extension of Coppermine River at Copper Creek Station **Using Coppermine River at Bloody Falls Data**

Because of the short data record for the lower Coppermine River, the daily data record for the Copper Creek station was extended from 9 years to 12 years using data from the Bloody Falls station. A scaled-area method (Stevens, 1986) was applied to find the mathematical relationship between the two stations using the logic that drainage basins with similar characteristics of size, shape, location, climate and topography should have comparable flow data. As there are no major tributary inflows between the Copper Creek and Bloody Falls sites, the basin characteristics were considered identical except for the basin area. Therefore, the ratio of the discharge (Q_1/Q_2) should be equal to the ratio of the drainage areas (A_1/A_2). The basin areas of 50,700 km^2 for Bloody Falls and 46,800 km^2 for Copper Creek give the relationship $Q_{CC} = 0.93\ Q_{BF}$. The effect of lag time on daily data was considered negligible for this work as the distance between the Copper Creek and Bloody Falls stations is small. The main difference in the mean annual hydrographs for Copper Creek, Bloody Falls and the combined data (Figure A1-1) is the higher mean for the Bloody Falls data. The Bloody Falls mean is skewed upward by the extreme high flows in 1984, which are also evident in the Coppermine River at Point Lake data (Figure 1a). The Point Lake data were not used in the calculations because of lake storage effects, lag time and many tributary inflows between Point Lake and Copper Creek.

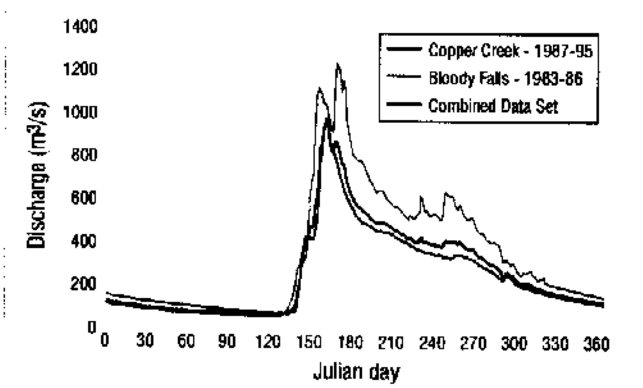

Figure A1-1 [illegible]

Appendix 2: Flood Frequency Analysis

Frequency analyses are used to evaluate return periods of given discharge values using observed flow data. This paper shows how to plot Pearson distributions and its confidence limits. The information was extracted from an applied hydrology course handout (GCI 420) at Sherbrooke University, Civil Engineer Department (Lemieux, 1996).

All years with missing period of record during the peak discharge period have to be eliminated from frequency analyses because the maximum daily recorded discharge cannot be determined unequivocally. Quatro Pro 8 "@ functions" were used when possible.

Pearson Distributions

The basic formula of theoretical distributions is:

$$X = \overline{X} + K_t \cdot S_X$$

- X = Year maximum discharge value
- $\overline{X}$ = Mean of observed maximum discharge values
- S_x = Standard deviation of observed maximum discharge values
- K_t = Frequency factor

The formula for the Pearson distribution is:

$$K_t = Z + (Z^2 - 1)\cdot\frac{C}{6} + \frac{z^3 - 6\cdot Z}{3}\cdot\left(\frac{C}{6}\right)^2 - (Z^2-1)\cdot\left(\frac{C}{6}\right)^3 + Z\cdot\left(\frac{C}{6}\right)^4 + \frac{1}{3}\cdot\left(\frac{C}{6}\right)^5$$

$$Z = @NormsInv(p)$$

$$C = @Skew(\text{"max values"})$$

- Z = Z value (normal distribution) for a probability of p
- p = Discharge probability = 1-1/T
- T = Return period = 1/(1-p)
- C = Skewness of the observed maximum discharges

Confidence Limits

Observed data are a sample of "n" maximum discharge values over an unknown population. Since only a sample is used to estimate maximum discharge for a specific return period, the "real" maximum discharge might be different than the estimated one. This explain why confidence limits are plotted around the theoretical distribution. For example, 90% confidence limits mean that the "real" maximum discharge has a 90% chance of being within those limits.

$$\alpha = \frac{1-\beta}{2}$$

β = Confidence level (ex: .90)
α = Significance level

Confidence Limits of the Pearson Distribution are:

$$U = \overline{X} + K^U \cdot S_X$$

$$L = \overline{X} - K^L \cdot S_X$$

Where:

$$K^U = \frac{K_t + \sqrt{K_t^e - a \cdot b}}{a}$$

$$K^L = \frac{K_t - \sqrt{K_t^2 - a \cdot b}}{a}$$

$$a = 1 - \frac{Z_\alpha^2}{2 \cdot (n-1)}$$

$$b = K_t^2 - \frac{Z_\alpha^2}{n}$$

$$Z\alpha = @NormsInv(\alpha)$$

U = Upper confidence limit
L = Lower confidence limit
K^U = Frequency factor of the upper confidence limit
K^L = Frequency factor of the lower confidence limit
S_x = Standard deviation
K_t = Frequency factor of the Pearson distribution
$Z\alpha$ = Z value (Normal distribution) for a exceedance probability of α
n = Number of observed values

This method is derived from an approximate method used to determine the confidence limits of the log-Pearson distribution. The Pearson distribution method is assumed to be the same as the log-Pearson distribution method but uses the actual data values, instead of log values, to find the mean and the standard deviation.

Data Plotting

Many empirical formulae have been developed to plot the observed data. Using these, a plot of the estimated values from theoretical distributions can then be compared with the observed data. When an observed value is outside of the confidence limits, it means that the value cannot be explained by the theoretical distribution. The value is said to be an aberrant value or an outlier. Outliers are eliminated from the observed distribution and theoretical distributions are recalculated.

Author	Formulas
Hazen	$pi = \frac{i-0.5}{n}$
Weibull	$pi = \frac{i}{n+1}$
Chegodayev	$pi = \frac{i-0.3}{n+0.4}$
Blom	$pi = \frac{i-3/8}{n+1/4}$
Tukey	$pi = \frac{i-1/3}{n+1/3}$
Gringorten	$pi = \frac{i-0.44}{n+0.12}$
Cunnane	$pi = \frac{i-0.4}{n+0.2}$

pi = Exceedance probability
n = Number of observed values
i = Rank of the observed value, the highest one being "1"

Appendix 3: T-Test Results (90% confidence limits)
Trace Elements at Coppermine River Quality Stations

Aluminum

Mouth	----			
Bloody F.	N/A	----		
Point L.	N/A	N/A	----	
Dest. L.	N/A	N/A	N/A	----
	Mouth	Bloody F.	Point L.	Dest. L.

Arsenic

Mouth	----			
Bloody F.	N/A	----		
Point L.	N/A		----	
Dest. L.	N/A	N/A	N/A	----
	Mouth	Bloody F.	Point L.	Dest. L.

Copper

Mouth	----			
Bloody F.	Rejected	----		
Point L.	Rejected	Rejected	----	
Dest. L.	Rejected	Rejected	Rejected	----
	Mouth	Bloody F.	Point L.	Dest. L.

Iron

Mouth	----			
Bloody F.	Rejected**	----		
Point L.	N/A	N/A	----	
Dest. L.	Rejected	N/A	N/A	----
	Mouth	Bloody F.	Point L.	Dest. L.

Lead

Mouth	----			
Bloody F.	Rejected	----		
Point L.	Rejected	Rejected	----	
Dest. L.	Rejected	Rejected	Rejected	----
	Mouth	Bloody F.	Point L.	Dest. L.

Manganese

Mouth	----			
Bloody F.	Rejected*	----		
Point L.	N/A	Rejected**	----	
Dest. L.		N/A	N/A	----
	Mouth	Bloody F.	Point L.	Dest. L.

Zinc

Mouth	----			
Bloody F.	Rejected	----		
Point L.	Rejected	Rejected	----	
Dest. L.		Rejected	N/A	----
	Mouth	Bloody F.	Point L.	Dest. L.

Default is Total
* Dissolved
** Extractable

Appendix 4

Arsenic Dissolved
Bloody Falls and Point Lake

Ho: Mean BF = Mean PL		S^2 =	1.28E-06
Ha: Mean BF != Mean PL		S =	0.001131
Mean BF =	0.0002	t =	-0.88613
Mean PL =	0.000531	v =	63
Std BF =	0.000128		
Std PL =	0.001232	Limits = ±	1.998341
n BF =	11		
n PL =	54	Ho	[illegible]
Signif. Level =	0.05	Ha	Rejected

Copper Total
Bloody Falls and Desteffany Lake

Ho: Mean BF = Mean DL		S^2 =	0.6226904
Ha: Mean BF != Mean DL		S =	0.7891074
Mean BF =	0.0041	t =	-3.819372
Mean DL =	1.388889	v =	17
Std BF =	0.002548		
Std DL =	1.150309	Limits = ±	2.1098156
n BF =	10		
n DL =	9	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Copper Total
Bloody Falls and The Mouth

Hypothesis is accepted for Bloody Falls and Point Lake using dissolved data.

Ho: Mean BF = Mean Mth		S^2 =	1.667734
Ha: Mean BF != Mean Mth		S =	1.291408
Mean BF =	0.0041	t =	-5.55663
Mean Mth =	2.577143	v =	43
Std BF =	0.002548		
Std Mth =	1.452306	Limits = ±	2.016692
n BF =	10		
n Mth =	35	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Copper Total
Desteffany Lake and The Mouth

Ho: Mean DL = Mean Mth		S^2 =	1.959481
Ha: Mean DL != Mean Mth		S =	1.3998146
Mean DL =	1.388889	t =	-2.271264
Mean Mth =	2.577143	v =	42
Std DL =	1.150309		
Std Mth =	1.452306	Limits = ±	2.0180817
n DL =	9		
n Mth =	35	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Copper Total
Point Lake and The Mouth

Ho: Mean PL = Mean Mth		S^2 =	1.120508
Ha: Mean PL != Mean Mth		S =	1.058541
Mean PL =	0.001216	t =	-9.86663
Mean Mth =	2.577143	v =	64
Std PL =	0.000533		
Std Mth =	1.452306	Limits = ±	1.99773
n PL =	31		
n Mth =	35	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Copper Total
Point Lake and Bloody Falls

Ho: Mean PL = Mean Mth		S^2 =	1.72E-06
Ha: Mean BF != Mean PL		S =	0.00131
Mean PL =	0.001216	t =	-6.053313
Mean BF =	0.0041	v =	39
Std PL =	0.000533		
Std BF =	0.002548	Limits = ±	2.0226909
n PL =	31		
n BF =	10	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Appendix 4 (cont'd)

Copper Total

Point Lake and Desteffany Lake

Ho: Mean PL = Mean DL		S² =	0.278571
Ha: Mean PL != Mean DL		S =	0.527798
Mean PL =	0.001216	t =	-6.94371
Mean DL =	1.388889	v =	38
Std PL =	0.000533		
Std DL =	1.150309	Limits = ±	2.024394
n PL =	31		
n DL =	9	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Iron Extractable

Station 1 Bloody Falls
Station 2 Point Lake

Ho: Mean 1 = Mean 2		S² =	0.2279151
Ha: Mean 1 != Mean 2		S =	0.4774045
Mean 1 =	0.895714	t =	5.9940053
Mean 2 =	0.045017	v =	71
Std 1 =	1.113699		
Std 2 =	0.031555	Limits = ±	1.9939434
n 1 =	14		
n 2 =	59	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Manganese Extractable

Station 1 Point Lake
Station 2 Bloody Falls

Ho: Mean 1 = Mean 2		S² =	0.000222
Ha: Mean 1 != Mean 2		S =	0.014914
Mean 1 =	0.009661	t =	-5.87634
Mean 2 =	0.035714	v =	71
Std 1 =	0.008262		
Std 2 =	0.03017	Limits = ±	1.993943
n 1 =	59		
n 2 =	14	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Manganese Total

Station 1 Desteffany Lake
Station 2 The Mouth

Ho: Mean 1 = Mean 2		S² =	35.484872
Ha: Mean 1 != Mean 2		S =	5.956918
Mean 1 =	4.533333	t =	-0.713459
Mean 2 =	6.204348	v =	30
Std 1 =	3.495394		
Std 2 =	6.62915	Limits = ±	2.0422725
n 1 =	9		
n 2 =	23	Ho	[illegible]
Signif. Level =	0.05	Ha	Rejected

Zinc Total

Station 1 Desteffany Lake
Station 2 Bloody Falls

Ho: Mean 1 = Mean 2		S² =	15.88814
Ha: Mean 1 != Mean 2		S =	3.985993
Mean 1 =	5.133333	t =	2.798367
Mean 2 =	0.0083	v =	17
Std 1 =	5.810527		
Std 2 =	0.008063	Limits = ±	2.109816
n 1 =	9		
n 2 =	10	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Zinc Total

Station 1 The Mouth
Station 2 Bloody Falls

Ho: Mean 1 = Mean 2		S² =	90.611863
Ha: Mean 1 != Mean 2		S =	9.5190264
Mean 1 =	11.34571	t =	3.3216842
Mean 2 =	0.008063	v =	43
Std 1 =	10.70501		
Std 2 =	0.008063	Limits = ±	2.0166922
n 1 =	35		
n 2 =	10	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Appendix 4 (cont'd)

Zinc Total

Station 1 Point Lake
Station 2 Bloody Falls

Ho: Mean 1 = Mean 2		S^2 =	2.82E-05
Ha: Mean 1 != Mean 2		S =	0.005312
Mean 1 =	0.003459	t =	-2.51509
Mean 2 =	0.0083	v =	40
Std 1 =	0.004188		
Std 2 =	0.008063	Limits = ±	2.021075
n 1 =	32		
n 2 =	10	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Zinc Total

Station 1 Desteffany Lake
Station 2 The Mouth

Ho: Mean 1 = Mean 2		S^2 =	99.200174
Ha: Mean 1 != Mean 2		S =	9.9599284
Mean 1 =	5.133333	t =	-1.668902
Mean 2 =	11.34571	v =	42
Std 1 =	6.810627		
Std 2 =	10.70501	Limits = ±	2.0180817
n 1 =	9		
n 2 =	35	Ho	[illegible]
Signif. Level =	0.05	Ha	Rejected

Zinc Total

Station 1 The Mouth
Station 2 Point Lake

Ho: Mean 1 = Mean 2		S^2 =	59.94323
Ha: Mean 1 != Mean 2		S =	7.742301
Mean 1 =	11.34571	t =	5.989643
Mean 2 =	0.003459	v =	65
Std 1 =	10.70501		
Std 2 =	0.004188	Limits = ±	1.997138
n 1 =	35		
n 2 =	32	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Iron Total

Station 1 Desteffany Lake
Station 2 The Mouth

Ho: Mean 1 = Mean 2		S^2 =	246.0619
Ha: Mean 1 != Mean 2		S =	15.68636
Mean 1 =	41.66667	t =	5.877134
Mean 2 =	7.211143	v =	42
Std 1 =	22.2461		
Std 2 =	13.69359	Limits = ±	2.018082
n 1 =	9		
n 2 =	35	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Lead Total

Station 1 Bloody Falls
Station 2 Desteffany Lake

Ho: Mean 1 = Mean 2		S^2 =	5.05E-06
Ha: Mean 1 != Mean 2		S =	0.0022463
Mean 1 =	0.0017	t =	-2.228469
Mean 2 =	0.004	v =	17
Std 1 =	0.001792		
Std 2 =	0.002667	Limits = ±	2.1098156
n 1 =	10		
n 2 =	9	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Lead Total

Station 1 Bloody Falls
Station 2 The Mouth

Ho: Mean 1 = Mean 2		S^2 =	4.38E-05
Ha: Mean 1 != Mean 2		S =	0.006617
Mean 1 =	0.0017	t =	-3.48857
Mean 2 =	0.010063	v =	40
Std 1 =	0.001792		
Std 2 =	0.007454	Limits = ±	2.021075
n 1 =	10		
n 2 =	32	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Appendix 4 (cont'd)

Lead Total

Station 1 Bloody Falls
Station 2 Point Lake

Ho: Mean 1 = Mean 2		S² =	8.01E-07
Ha: Mean 1 != Mean 2		S =	0.0008952
Mean 1 =	0.0017	t =	2.4570028
Mean 2 =	0.000903	v =	40
Std 1 =	0.001792		
Std 2 =	0.00032	Limits = ±	2.0210754
n 1 =	10		
n 2 =	32	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Lead Total

Station 1 Desteffany Lake
Station 2 The Mouth

Ho: Mean 1 = Mean 2		S² =	4.56E-05
Ha: Mean 1 != Mean 2		S =	0.006754
Mean 1 =	0.004	t =	-2.3789
Mean 2 =	0.010063	v =	39
Std 1 =	0.002667		
Std 2 =	0.007454	Limits = ±	2.022691
n 1 =	9		
n 2 =	32	Ho	Rejected
Signif. Level =	0.05	Ha	Accepted

Lead Total

Station 1 Desteffany Lake
Station 2 Point Lake

Ho: Mean 1 = Mean 2		S² =	1.54E-06
Ha: Mean 1 != Mean 2		S =	0.0012409
Mean 1 =	0.004	t =	6.6142507
Mean 2 =	0.000903	v =	39
Std 1 =	0.002667		
Std 2 =	0.00032	Limits = ±	2.0226909
n 1 =	9		
n 2 =	32	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Lead Total

Station 1 The Mouth
Station 2 Point Lake

Ho: Mean 1 = Mean 2		S² =	2.78E-05
Ha: Mean 1 != Mean 2		S =	0.005275
Mean 1 =	0.010063	t =	6.944904
Mean 2 =	0.000903	v =	62
Std 1 =	0.007454		
Std 2 =	0.00032	Limits = ±	1.998972
n 1 =	32		
n 2 =	32	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted

Manganese Dissolved

Station 1 The Mouth
Station 2 Bloody Falls

Ho: Mean 1 = Mean 2		S² =	0.1786181
Ha: Mean 1 != Mean 2		S =	0.4226323
Mean 1 =	0.004225	t =	-19.92577
Mean 2 =	3.61	v =	20
Std 1 =	0.004881		
Std 2 =	0.63	Limits = ±	2.0859634
n 1 =	12		
n 2 =	10	Ho	[illegible]
Signif. Level =	0.05	Ha	Accepted