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Environment Canada
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7600-7

21 April 1994

PRAIRIE CREEK RERC DISTRIBUTION LIST

RE: Nahanni National Park Aquatic Quality 1992 Reports & Prairie Creek Mining Development/ Water Licensing.

Please find enclosed three reports summarizing 1992 and earlier water, suspended sediment and fish tissue results and assessment of compliance with Nahanni National Park water quality guidelines.

These reports are for your general information and have some relevance in light of possible future mining development on Prairie Creek and water licensing.

Multi-media aquatic quality data is available for the Prairie Creek area. Prairie Creek near the mouth water quality results are available for 1988, 1989 and 1992. Water quality (and, sometimes, water quantity) results are/will be available for 1993 and 1994. Suspended sediment and fish tissue results from the South Nahanni River downstream of Prairie Creek are/will be available for 1998, 1989, 1992, 1993 and 1994.

For further information, please contact me at 920-8516 (phone) or 873-6776 (fax). Alternatively, please contact Erik Val (Superintendent, Nahanni National Park) or Rob Prosper (Chief Park Warden, Nahanni National Park) of the Canadian Parks Service, Fort Simpson, NWT at 695-3151 (phone) or 695-2446 (fax).

Thank you.

Douglas Halliwell, P.Geol.
Regional Aquatic Quality Officer

Indian & Northern Affairs
Environment & Conservation
Division

APR 28 1994

Encl.

cc. Jesse Jasper
Scott McDonald
Erik Val

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WATER QUALITY MONITORING OF NAHANNI NATIONAL PARK RESERVE 1992 ASSESSMENT OF COMPLIANCE WITH WATER QUALITY OBJECTIVES

D.R. Halliwell, IWD-NWT Programs, Yellowknife, July 31, 1993

1.0 Background

Water quality objectives are a commonly used tool for managing discharges to waterbodies to ensure that water quality is not degraded and is of suitable quality for present and future uses. Objectives are designed to support and protect a designated use at a specific site. In Canada, the Canadian Water Quality Guidelines provide basic scientific information for the establishment of objectives (CCREM, 1992). The Guidelines have been developed by a variety of methods, depending on needs, issues, parameters and variables of concern, the amount of available data and other factors. By setting objectives to meet the needs of the most sensitive water use (often aquatic life), all other uses are also protected. The approach used is tailored to suit the needs of the water body concerned and the purposes of the responsible water management agency (Blachford, 1988).

The water quality objectives approach requires the collection of data on the ambient water quality conditions, development of water quality objectives and on-going water quality monitoring. If the objectives are exceeded; the cause, extent and severity of the exceedance must be investigated. Action can then be taken to remove or address the cause of the elevated water quality values (Environment Canada, 1991).

Since research on environmental and human health impacts is incomplete, water quality objectives must be reviewed on a routine basis. New scientific information must be incorporated into the objectives as it becomes available, and modifications to existing objectives must also be considered. On-going evaluation is required to ensure that the objectives are protecting the resource (Environment Canada, 1991).

Water quality objectives developed for Nahanni National Park Reserve in 1991 represent the first objectives designed for Canada's north. Nahanni National Park water quality objectives were derived using a similar approach to those developed for protection of recreational and fish consumption end uses at Prince Albert National Park (Blachford, 1988) and Waterton Lakes National Park (Blachford, 1990). Some caution is required when extending use of objectives developed for more temperate, Boreal Plain and Boreal Shield Prairie Ecosystems to the more rugged and subarctic Tundra Cordillera Ecosystem as our knowledge of the more northerly ecosystem is not as complete. The assumptions regarding safe levels of contaminants are, therefore, less well founded. The scientific knowledge base from which objectives are developed is substantial, however (Environment Canada, 1991).

2.0 The Approach

An unique approach was adopted for development of water quality objectives in Nahanni National Park Reserve, due to the goal of complying with Parks' policies on environmental conservation and the Nahanni National Park Regulations management plan. These state that natural resources will be managed with minimal interference to the natural processes, and that park waters will be protected to ensure that no unnatural change in water quality occurs. The approach recognizes that existing and future mining activities outside of the Park Reserve could seriously alter the natural water quality conditions, impacting on park aquatic life. (Environment Canada, 1991).

A two-level approach, involving short- and long-term indicators, has been developed by the Prairie Provinces Water Board. Water quality variables are monitored in conjunction with river discharge (flows), and data summarized statistically to aid in the formulation of indicators. All water quality variables are tested for seasonality to establish whether separate ice-cover and open water indicators are needed, or a single annual indicator is adequate. Maximum acceptable long-term concentrations are derived from the available literature on the effects on various elements on biota (Blachford, 1988).

Short-term indicators or objectives (STO's) are also required to protect the Park waters and the aquatic biota from large deviations in water quality conditions. Aquatic organisms can be stressed by short duration fluctuations in water quality concentrations that are outside the naturally- occuring range, or near the high or low ends of the natural range for longer periods of time than during regular seasonal cycles. Short-term objectives also address possible impacts from accidental or planned releases from mines and related activities (Environment Canada, 1991). Values are usually not seasonally differentiated. Concerns related to acute toxicity are addressed by consideration of the maximum acceptable concentration (Blachford, 1988).

Long-term indicators or objectives (LTO's) are required to characterize existing, or unspoiled, water quality conditions. Deviations from long-term objectives are a warning that the status of water quality in the Park is changing (Environment Canada, 1991). Long-term monitoring is required to show trends occurring over a long period of time, and for comparison with annual and seasonal means of historic data (Blachford, 1988).

A methodology used for total dissolved solids (TDS) and boron at Poplar River, Saskatchewan also accounts for seasonality and is sensitive to discharge (flow) rate. This methodology is more issue-based, has a mandatory review period and utilizes three-month and five-year flow-weighted means for STO's and LTO's, respectively (Blachford, 1988).

Nahanni National Park Reserve lies within the little-studied Tundra Cordillera Ecozone. The Park's South Nahanni River and its tributaries are "flashy" mountain streams characterized by spring snowmelt, summer rainstorms and winter low flow periods similar to those in British Columbia and the Yukon, not the prairie rivers found in Prince Albert and Waterton National Parks.

The methodology for Nahanni Park water quality objectives therefore must allow for seasonality. The STO's were determined by selecting 90th percentile values from the available study period dataset. As non-parametric statistics, they are not not sensitive to population distribution type and assume neither Normality nor Lognormality.

The percentile methodology used has its limitations, however. Many values exceeding STO's are due to natural conditions, such as high discharge rates with coincident low specific conductances. The 1992 South Nahanni freshet discharges exceeded those of 1988 and, especially, 1989. Water quality samplers were able to collect water quality samples at the peak of the 1992 spring freshet, especially at Flat River, on June 4. This sample timing resulted in a large number of exceedances of the STO's, which were related to the lack of data for high flow conditions rather than any change in natural basin conditions.

3.0 Water Quality Objectives

The short- and long-term water quality objectives for the five current water quality stations in Nahanni National Park Reserve are presented in Table 1.

The data from the Rabbitkettle and the South Nahanni stations upstream of their confluence defines water quality for the Park. Both have mineral occurrences and claims in their headwaters. The Flat River near its mouth is a major inflowing tributary, and is downstream from the mothballed Canada Tungsten Mine. Abundant mineral occurrences and claims exist near the Flat River and its major tributary, the Caribou River (Gordey and Anderson, 1993). The Cadillac Mine was constructed in the Prairie Creek watershed; it did not go into full production. The Nahanni Butte station represents water leaving the Park (Environment Canada, 1991).

Long-term indicators or objectives (LTO's) are calculated as the range of values +/- two standard deviations from the seasonal (open water and ice cover) or annual (for variables not exhibiting seasonality) mean concentration. They are developed to show trends which may occur over a period of time and compare annual or seasonal means between future and historical data (Blachford, 1988).

Nahanni Park LTO's have been developed as the average water quality variable values over the period of record (1972-1990 for Flat River, 1988-1989 for the other four sites). The use of standard deviations was avoided by using non-parametric statistics to avoid making assumptions concerning the Normality or Lognormality of distributions. The values were selected as appropriate because flow conditions during 1988 and 1989 appeared to be typical (slightly above and below the historic means, respectively) and water quality values are strongly governed by discharge. At Flat River, study and historic data also suggested that study period water quality was typical of long-term conditions (Environment Canada, 1991).

Short term indicators, or objectives (STO's) are calculated as a value midway between the mean annual concentration and the maximum acceptable concentration. These are not seasonally differentiated. Concerns related to acute toxicity are addressed by consideration of the maximum acceptable concentration (Blachford, 1988).

STO's for the Nahanni have been derived as the ninetieth percentile value over the period of record. This value includes almost all values on record except for infrequent outlier values, well outside the range of values (Environment Canada, 1991).

Table 1 shows that the LTO's and STO's are well below (generally, several orders of magnitude) Canadian Water Quality Guidelines (1992) for aquatic life. Fully 50% of all 1988 and 1989 water quality 1988 and 1989 values for the monitoring sites are at or below the laboratory's method detection limits (MDL's).

At such low concentrations, it is important to understand the limitations of laboratory analyses and results. For example, total and dissolved metal values near MDL's for atomic adsorption and induced coupling argon plasma (ICAP) lack precision and accuracy. This explains why the STO for dissolved Zn at the South Nahanni River above Rabbitkettle River is 0.499 mg/l while the corresponding value for total Zn is only 0.034 mg/l. Lab technology improvements resulted in ICAP- atomic emission spectroscopy (AES) becoming the standard method used by the Environment Canada's National Laboratory for Environmental Testing (NLET) in Burlington midway through 1992.

The same situation occurred for dissolved versus total concentrations for Ni at Flat River and Nahanni Butte, Pb at the two upstream water quality sites, Cu above Rabbitkettle River and Co at the mouth of Rabbitkettle River in 1992. 1992 dataset.

4.0 Interpretation of Objectives

Water quality data collected at the monitoring sites needs to be compared with the water quality objectives on a regular basis, to access whether or not they are within the natural variability.

STO's apply to single water quality grab samples, which can be directly compared to STO's. The same values are then rolled up into average values and compared to LTO's. Exceedance of STO's may or may not be a cause for concern. Flashy rainfall events, common summer events in the Cordillera, often result in extreme erosion and elevated concentrations of sediment-related metals. This natural occurrence does not require a management response in spite of exceedance of an objective. An exceedance not explainable by natural factors alone should be investigated and appropriate action taken.

Data collected for each variable has to be averaged over time and compared to the LTO's. Values from all seasons can be combined; at the minimum, data should represent spring freshet and fall recession conditions. Any positive or negative departure could be significant. The comparison is, however, somewhat subjective because the objectives are based upon a limited number of years of data and may or may not be representative of long-term natural variability. LTO's constitute the best information available at the time, and should be used until more comprehensive information becomes available.

Manugistics' StatGraphics Version 6.0 software was used to carry out linear regressions of water quality variables on either discharges measured at the IWD gauging station on the Flat River, calculated discharges at Nahanni Butte (where hydrometric data from the Clausen Creek hydrometric station can be "routed" downstream to the Butte), or specific conductance (at the other stations, where no flow data is available). Specific conductance was used in lieu of discharge for these sites because of its well-known, worldwide strong negative correlation with discharge. Flat River correlation matrix data from Flat River data confirms this pattern (e.g. Pearson's "r" of -0.9351).

For 1992 data, "natural factors" was interpreted to be "within the 95% confidence and prediction limits 'envelopes' about the appropriate flow as a water quality variable linear regression line". Values exceeding STO's, but lying within the 95% confidence and prediction limits of linear regression lines were considered to be the result of natural causes and not a cause for concern. Values exceeding both STO's and 95% confidence and prediction limits of the linear regression lines were identified for further analysis. Action should be taken if an anthropogenic cause can be determined for these exceedances.

5.0 Application of the Objectives

Water quality objectives serve as in-stream environmental targets or alert values, providing early warning of detrimental environmental conditions. The objectives alert future developers to requirements for maintenance of ambient water quality conditions. The historic South Nahanni watershed dataset collected by Environment Canada, DIAND and other entities serves as baseline data for developers. Developers should incorporate mitigative measures to ensure operations meet these environmental targets.

The mining industry conducts preliminary mining feasibility studies to determine the most cost-effective and environmentally-acceptable methods for mining, milling and mine/ mill decommissioning. The associated cost estimates for the most likely (base) case and other (sensitivity analysis) cases permit developers to decide whether or not to proceed with mine development and operation.

LTO's and STO's are intended for early detection of arising environmental problems. Water quality concerns should be addressed in a proactive way during the planning stage, however, and not later, when dealing with an adverse environmental change or impact. Regulatory agencies (e.g. DIAND) should be involved during planning and operation phases to ensure permit, lease and licence conditions will and are being met.

Exploration and development activities in the NWT are screened by the N.W.T. Water Board, DIAND's Regional Environmental Review Committee, etc. The Canadian Parks Service staff will participate in these screenings.

The water quality monitoring strategy for Nahanni Park involves provision of information on the state of the aquatic environment, for comparison to LTO's and STO's. Inland Waters Directorate and Canadian Parks Service should also participate when effluent quality standards are being established at exploration and development sites in the watershed during the water licencing process. Effluent standards need to reflect the LTO's and STO's developed for the Park.

Water quality monitoring for the purpose of compliance with LTO's and STO's needs to continue after temporary or permanent closures of mine and mill facilities. Proper decommissioning of facilities is also important to ensure that Park waters aren't degraded after mining activities are completed.

6.0 LTO and STO Exceedances Observed in 1992 Data

6.1 Long-Term Objective (LTO) Exceedances

At the Flat River station, averages of April, June and September

1992 data resulted in LTO exceedances (excursions) for NFR; NO_3-NO_2; SO_4; total cyanide; total Ba, Cd, Co, Cu, Pb, Ni and Zn; extractable Fe and Mn; and dissolved Co, Cu, Pb and Se. Further monitoring is needed to determine whether natural or anthropogenic long-term changes in the water quality are actually occurring.

For the Prairie Creek station, LTO exceedances were also noted for NFR; NO_3-NO_2; SO_4; total cyanide; total Cd, Pb, Ni, V and Zn; extractable Fe and Mn; and dissolved Cu, Pb and As. Further monitoring is required to discern if natural or anthropogenic long-term changes are actually occurring.

At Nahanni Butte, LTO exceedances were observed for specific conductance; NFR; SO_4; total cyanide; total Ba, Cd, Cu, Ni, V and Zn; extractable Fe and Mn; and dissolved Cd, Co, Ni, Se and Zn. Since the Nahanni Butte site integrates exceedances from upstream locations, these results are to be expected here. Further monitoring of long-term trends is warranted, at least until upstream causes can be identified.

At Rabbitkettle River, LTO occurrences were also observed for pH; specific conductance; NO_3-NO_2; SO_4; and total Cd, Co, Cu, Pb, Ni and Zn. Future monitoring of this station to discern long-term changes in water quality is recommended.

For South Nahanni River above Rabbitkettle River, LTO exceedances were observed for specific conductance; NFR; NO_3-NO_2; SO_4; total cyanide; total Ba, Cd, Co, Cu, Pb, Ni, V and Zn; extractable Fe and Mn; and dissolved Ba, Cu, Pb, Ni, Se and Zn. As waters entering the Park may be undergoing some deterioration in water quality, future monitoring appears warranted at this site.

6.2 Short-Term Objective (STO) Exceedances

STO exceedances outside water quality variable versus discharge (or specific conductance) regression line 95% confidence and prediction limits were observed at all five sites, especially during the June 1992 spring freshet.

At Flat River, STO exceedances not readily explainable by discharge occurred during the June 1992 spring freshet for extractable Fe (Figure 1) and Mn; total Cu (Figure 2), Pb, Zn, Ni, V, Co, Cd and Ba; NFR; total cyanide; and dissolved Cu, Pb and As. STO exceedances occurred under April 1992 baseflow conditions for dissolved Zn, Se, SO_4 and NO_3-NO_2. Figures 1 and 2 reveal that exceedances occurred in the spring freshets of 1988 and 1989 as well but the higher June 4, 1992 spring freshet daily discharge of 659 cms resulted in a higher value. Canadian Water Quality Guidelines (CWQG) for freshwater aquatic life were exceeded at Flat River for total Cu and Pb on June 4, 1992. High total Cu may originate from the Canada Tungsten (W-Cu) Mine. Additional samples should, therefore, be collected at the Flat River water quality site.

At Prairie Creek, STO exceedances not readily explainable by discharge or specific conductance occurred during the June 4, 1992 spring freshet sampling, under conditions of high daily discharge and low specific conductance, for total Zn (Figure 3), Pb (Figure 4), Cu, Ni, V, Co and Cd; extractable Fe and Mn; NFR; and dissolved Cu. August 1992 summer recession exceedances were observed for dissolved Zn (Figure 5) and Fe.

Canadian Water Quality Guidelines for aquatic life were exceeded at Prairie Creek for total Zn and Cu on June 4, 1992. The value of 0.063 mg/l total Zn is more than double the 0.03 mg/l Zn CWQG for freshwater aquatic life. This cannot be explained by high discharge/ low specific conductance. Due to the resumption of exploration upstream of this station in the vicinity of the Cadillac Mine, additional samples should be taken by CPS staff in July and August 1993 (as well as April, June and September 1993). This should help to determine whether the exceedance is a one-time incident or indicate that anthropogenic activity (or undiscovered Zn-Pb deposits) is affecting the water quality of Prairie Creek. Fish (i.e. burbot, arctic greyling, longnose sucker) muscle and liver sampling was conducted on Prairie Creek in 1992 and the results are currently being interpreted.

At Nahanni Butte, STO exceedances unrelated to discharge occurred on June 4, 1992 during the spring freshet for NFR; extractable Fe; and total Pb, Ni and V. High discharge rates explained apparent STO June 1992 exceedances for dissolved As, and total Cu, Zn, Co, Cd and Ba. STO exceedances also occurred during April 1992 baseflow for specific conductance, dissolved SO_4 and dissolved Ni, and during the September 1992 summer-fall recession for dissolved Ni. Canadian Water Quality Guidelines for aquatic life were exceeded at Nahanni Butte for total Pb during the June 1992 spring freshet. Similar exceedances for total Cu and Cd can be explained by the high discharge rates.

At Rabbitkettle River, STO exceedances not readily explainable by discharge or specific conductance occurred during the high discharge (i.e. low, 150 us/cm specific conductance) June 1992 spring freshet for total Zn, Ni and Cd; and dissolved NO_3-NO_2. Canadian Water Quality Guidelines for aquatic life were exceeded at Rabbitkettle River for total Zn on June 4, 1992, and should, therefore, be carefully monitored in the future.

At South Nahanni River above Rabbitkettle River, STO exceedances not readily explainable by discharge or specific conductance occurred during the high discharge (i.e. low, 130 us/cm specific conductance) June 1992 spring freshet for extractable Fe and Mn;

total Cu, Pb, Zn, Ni, Co, Cd and Ba; and dissolved Pb. A dissolved Pb exceedance was also observed in the April 1992 baseflow value. Canadian Water Quality Guidelines for aquatic life were exceeded in the South Nahanni River above Rabbitkettle River for total Cu on June 4, 1992, and should, therefore, be carefully monitored in the future.

Simple linear regression plots (on discharge or specific conductance), with superposed LTO, STO and CWQG thresholds used in the above analysis, illustrate that exceedances of STOs not explainable by high discharges or low specific conductances are fairly common during the 1988 and 1989 spring freshets as well. The higher discharges during the 1992 spring freshet resulted in more frequent exceedances and higher values. Some exceedances were observed under recession and baseflow conditions during 1992. Late summer to fall recession exceedances were rare during 1988 and 1989. No late winter exceedances were observed in 1988 and 1989 simply because no baseflow water quality samples were collected during those years.

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Figure 1

LINEAR REGRESSION. FLAT RIVER. EXTRACTABLE IRON ON DISCHARGE

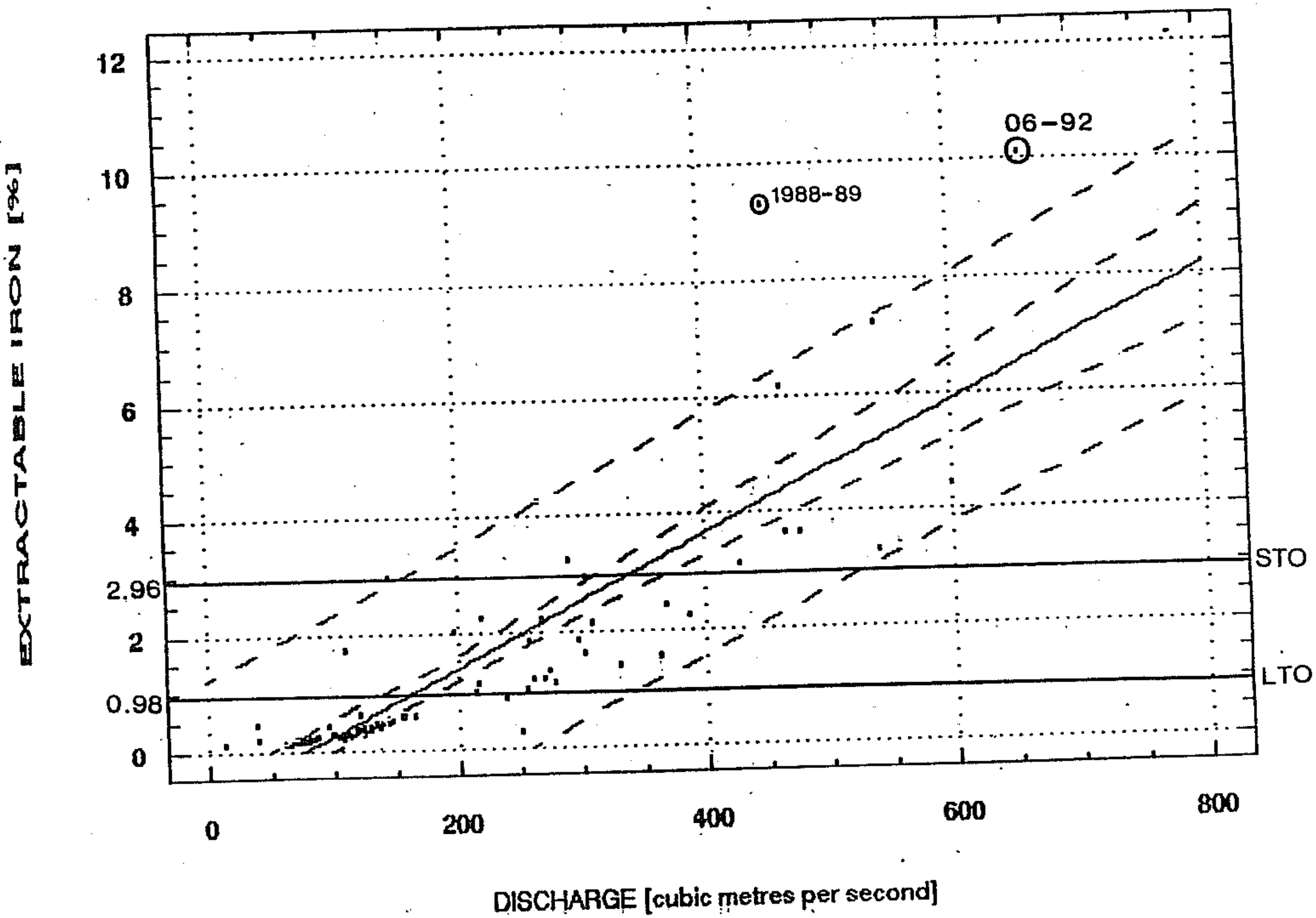

Figure 2

LINEAR REGRESSION. FLAT RIVER. TOTAL COPPER ON DISCHARGE.

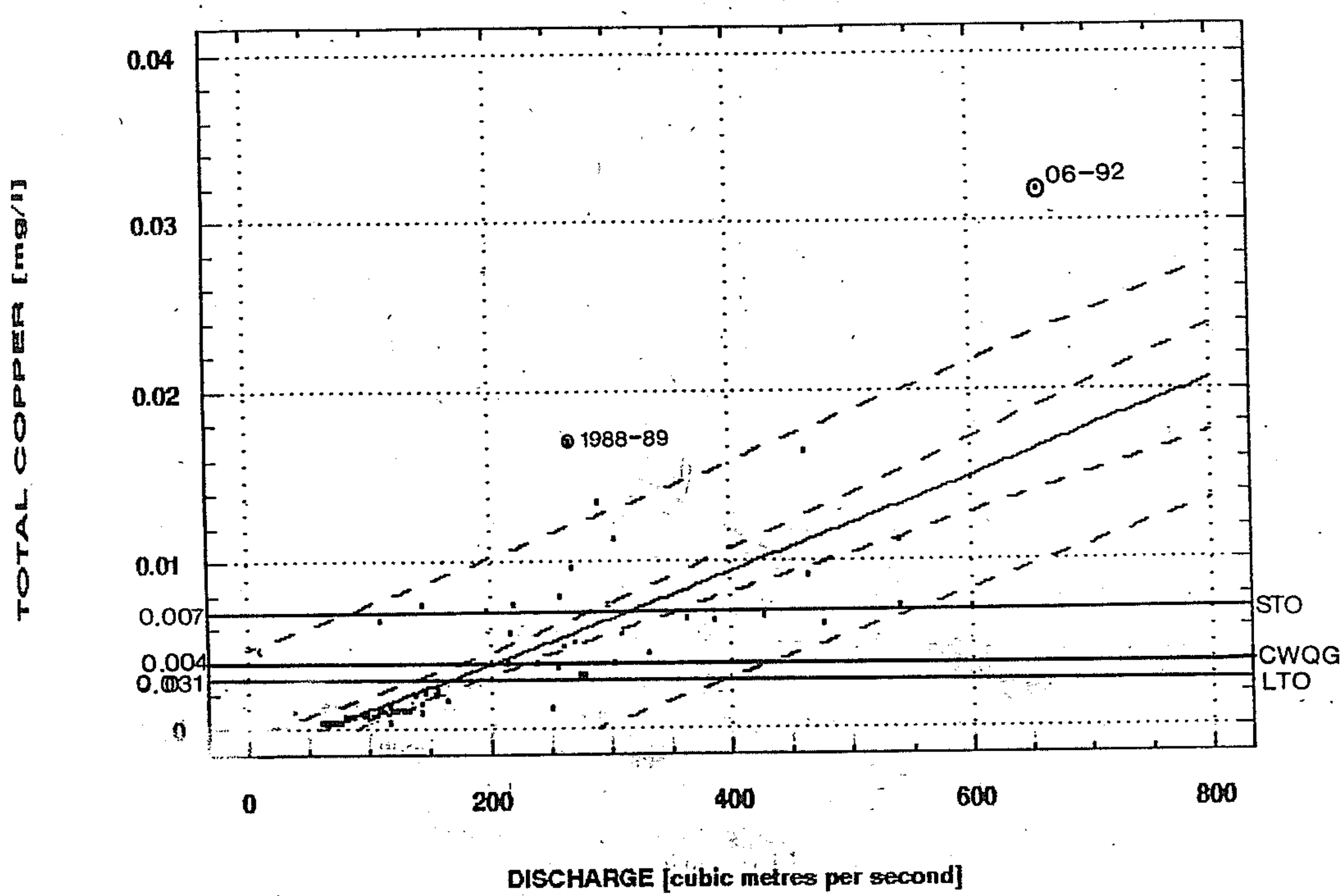

Figure 3

LINEAR REGRESSION. PRAIRIE CREEK. TOTAL ZINC ON SP.CONDUCT.

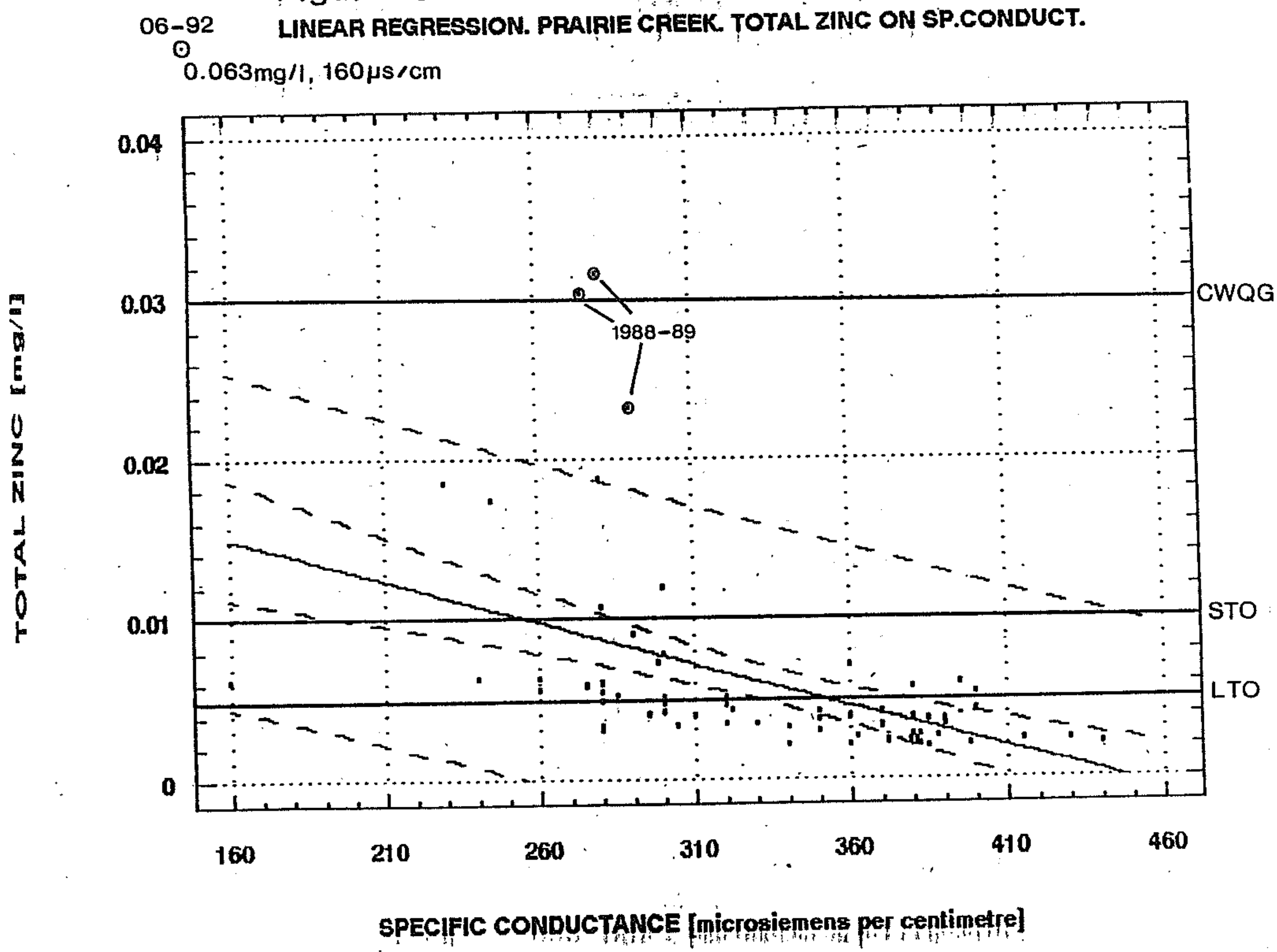

Figure 4
LINEAR REGRESSION. PRAIRIE CREEK. TOTAL LEAD ON SP.CONDUCT.

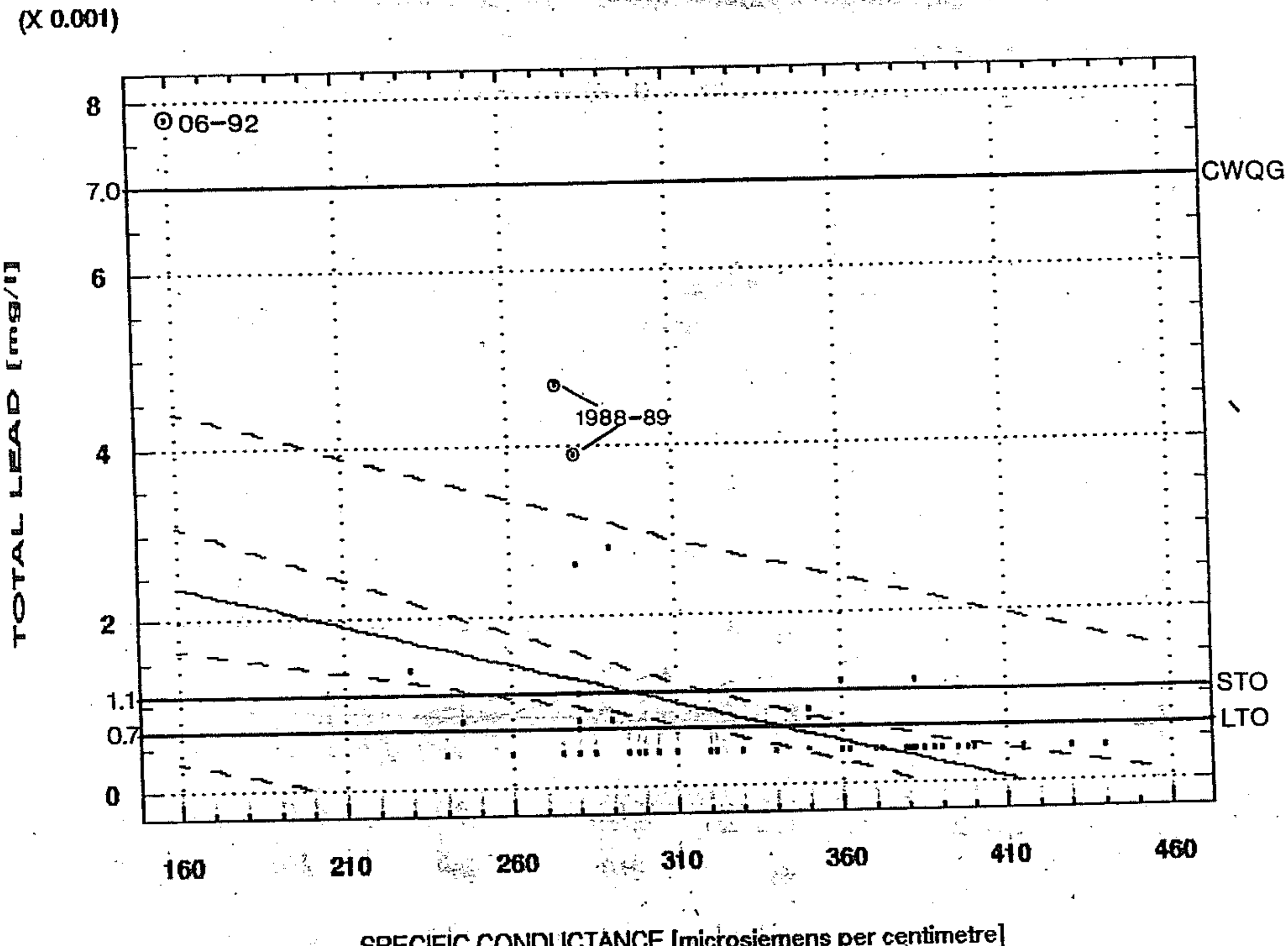

Figure 5

LINEAR REGRESSION. PRAIRIE CREEK. DISSOLVED ZINC ON SP.COND.

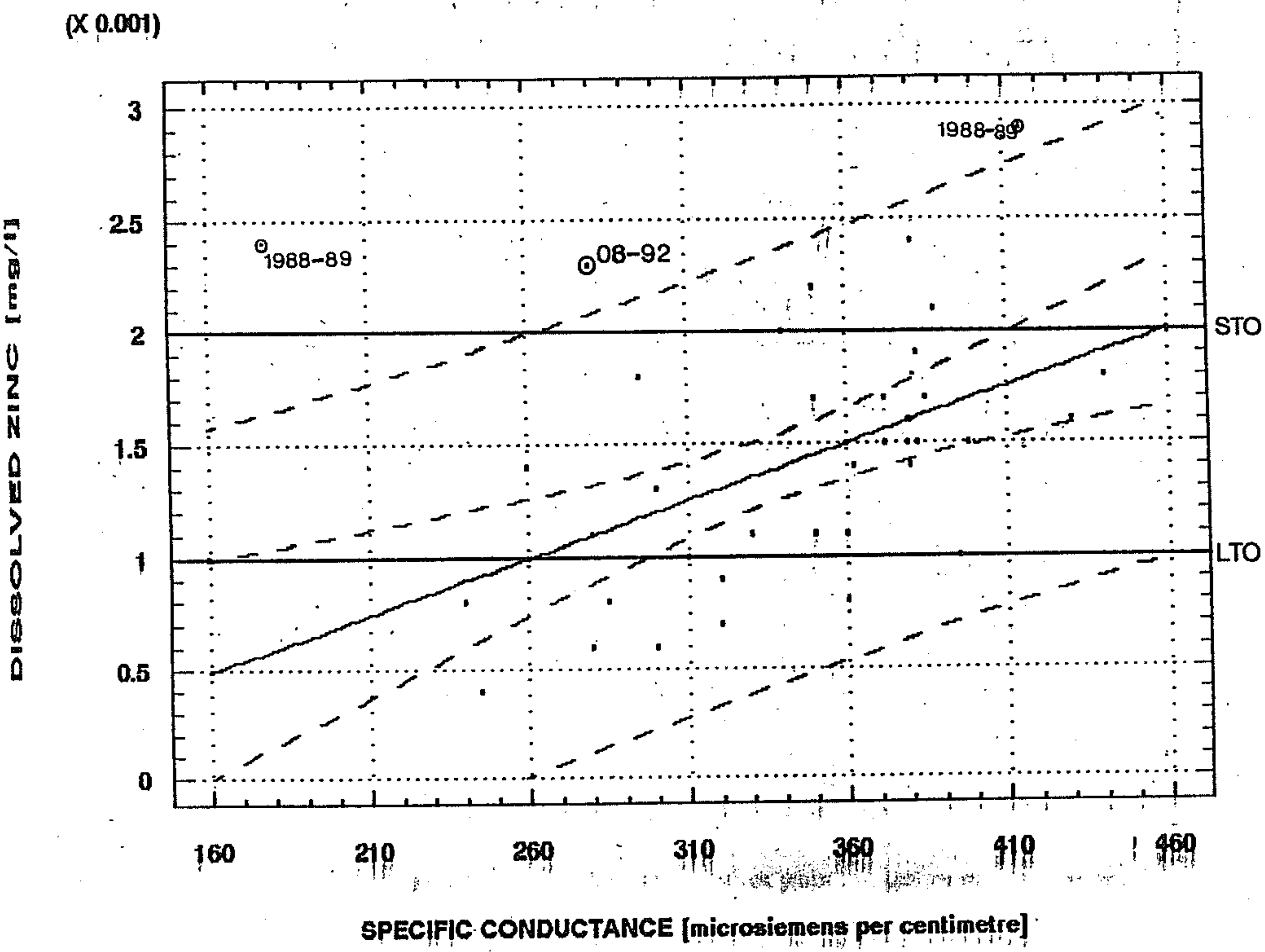

TABLE 1. Water Quality Objectives for Nahanni National Park Preserve

LTO Long Term Objectives | STO Short Term Objectives

Parameter			South Nahanni River above Rabbitkettle River		Rabbitkettle River at mouth		Flat River at mouth		Prairie Creek at mouth		South Nahanni River above Nahanni Butte	
			LTO	STO	LTO	STO	LTO	STO	LTO	STO	LTO	STO
Conductance		usie/cm	222	280	198	245	314	400	337	395	256	325
Non-filterable Residue			70	230	87	227	68	204	14	23	166	335
Nitrite/Nitrate		mg/l	0.04	0.05	0.08	0.10	0.07	0.13	0.12	0.14	0.11	1.77
Total Ammonia		mg/l	0.005	0.005	0.005	0.005	0.005	0.014	0.005	0.005	0.005	0.045
pH			8.1	8.4	7.9	8.2	8.0	8.2	8.4	8.8	8.0	8.3
Sulphate		mg/l	29	41	21	31	27	36	34	46	32	43
Arsenic	Dissolved	ug/l	0.50	0.50	1.74	1.95	0.50	0.8	0.50	0.5	0.50	0.7
Barium	Dissolved	mg/l	0.04	0.04	—	—	0.08	0.04	0.08	0.08	—	—
	Total	mg/l	0.08	0.08	0.08	0.14	0.08	0.19	0.08	0.10	0.08	0.19
Cadmium	Dissolved	ug/l	0.1	0.1	—	—	0.1	0.2	0.1	0.1	0.01	0.3
	Total	ug/l	0.17	0.4	0.29	0.60	0.45	0.80	0.10	0.10	0.30	0.60
Cobalt	Dissolved	ug/l	0.5	0.5	—	—	0.5	1.4	0.5	0.5	0.5	0.5
	Total	ug/l	1.0	2.3	1.0	2.2	1.2	3.0	0.5	0.7	1.6	3.3
Copper	Dissolved	ug/l	2.1	0.9	—	—	0.5	0.7	0.5	0.5	0.5	0.9
	Total	ug/l	1.8	3.9	2.1	4.9	3.1	7.0	0.8	1.8	3.7	7.3
Cyanide		ug/l	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Iron	Dissolved	mg/l	0.04	0.14	—	—	0.03	0.04	0.004	0.007	—	—
	Extractable	mg/l	0.53	1.32	1.04	2.64	0.98	2.96	0.19	0.36	1.60	2.69
Lead	Dissolved	ug/l	1.0	2.0	—	—	0.7	1.3	0.7	1.9	0.7	0.9
	Total	ug/l	1.0	2.7	1.05	2.5	1.64	3.8	0.70	1.1	2.37	5.7
Manganese	Dissolved	mg/l	0.007	0.024	—	—	0.005	0.007	0.002	0.004	—	—
	Extractable	mg/l	0.028	0.058	0.037	0.087	0.036	0.100	0.008	0.019	0.067	0.106
Nickel	Dissolved	ug/l	2.90	3.9	—	—	3.17	4.5	0.46	1.0	1.11	2.4
	Total	ug/l	6.80	9.8	5.37	8.4	6.81	11.7	1.57	3.0	7.60	15.2
Selenium	Dissolved	ug/l	0.50	0.95	1.21	1.75	0.59	0.80	0.50	1.0	0.68	1.2
Vanadium	Total	ug/l	1.1	3.2	4.6	11.3	2.2	6.1	0.5	1.4	3.9	6.7
Zinc	Dissolved	mg/l	0.016	0.499	—	—	0.005	0.009	0.001	0.002	0.002	0.007
	Total	mg/l	0.019	0.034	0.024	0.048	0.024	0.047	0.005	0.010	0.027	0.059

Submitted by IAZ NWT
DRAFT 08

11(b)

HEAVY METAL EVALUATION FOR FISH SAMPLES FROM THE SOUTH NAHANNI RIVER

Caroline Lafontaine/A. Wilson
DFO Yellowknife
July 1993

High concentrations of heavy metals can lead to toxemias in fish and may result in direct mortality, biological accumulation, chronic toxicity and changes in physiological functions (Post, 1987). Reproduction, respiration and locomotion, are among other categories of behaviour that may be affected by exposure (Kelly, 1988).

METHODS

In September, 1992 Parks Canada staff and Fisheries and Oceans staff travelled into the Nahanni National Park to carry out test-netting of fish. The intent was to sample twelve fish of similar age and size for various heavy metal parameters. Samples were collected from two sites on the South Nahanni River: immediately downstream of the confluence with Prairie Creek; and downriver almost two kilometres, just upstream of the confluence with Dry Canyon Creek. Fish were netted using two 2.5" gill nets, 25 metres long, set overnight. Numerous grayling were caught, with those which were in good shape being released. The burbot was an accidental catch, having swallowed one of the grayling caught in the net. All the longnose suckers caught were kept. Each fish was weighed to the nearest 50 grams, and measured to the millimetre. Ageing structures were removed; scales for the Arctic grayling, pectoral fin rays for the longnose suckers, and otoliths for the burbot. Livers were removed and put into sterile, contaminant-free whirlpaks. Those fish which were too small to remove a 50 gram muscle sample were cleaned and frozen whole in sterile, contaminant-free bags, otherwise just the muscle sample was taken. Tissues were shipped frozen to the Freshwater Institute in Winnipeg for analysis by the Environmental Chemistry Lab. All analyses were done on a wet weight basis, by atomic absorption detection. Quality assurance/control data is available on request. The parameters examined were: mercury, arsenic, copper, zinc, cadmium, nickel, and lead.

RESULTS & DISCUSSION

Table XX summarizes the biological descriptors and the heavy metal concentrations detected in the arctic grayling, longnose suckers and burbot captured.

ARSENIC

Arsenic occurs mostly as arsenic trioxide (McKee and Wolf, 1963), a very toxic form (Santaniello, 1971). Arsenious ions accumulate mainly in the liver (Falk et al., 1973) but also concentrate in muscle cells, where they interfere with enzyme activity (Drill, 1958 cited by Falk et al., 1973). Arsenic is a cumulative toxin (Falk et al., 1973). The Canadian Food and Drug (C.F.D.D.) has set 5 ppm arsenic as a maximum level in dressed muscle tissues for human consumption.

Arsenic concentration in the three fish species captured in the Nahanni River can be viewed as at background levels as less than 0.05 ppm were found in both liver and muscle tissues.

CADMIUM

Cadmium is a byproduct of smelting zinc (E.S.B., 1973). The toxicity of cadmium to freshwater fish is mainly governed by the nature of the water and in particular those characteristics associated with hardness. These regulate the solubility of cadmium, the chemical species present and the biological factors within the fish that control the rates of cadmium uptake (Sprague). Generally, cadmium accumulates in kidney, liver and gill tissues and to a lesser extent in the muscle tissue (Windom et al., 1973; Sprague). Also, Windom et al. (1973) note that higher levels of this metal are found in lower trophic level fish than in predatory fish such as northern pike. He suggests a depletion in this metal up the food chain, since plankton had even higher concentrations of cadmium.

Cadmium was present in all the muscle and liver samples tested except for the muscle of one arctic grayling. Fish tend to concentrate cadmium in the liver: the concentrations range from 0.197 to 3.317 ppm in the liver; compared to <0.001 to 0.019 ppm in the muscle. Arctic grayling of 3 to 6 years of age contained higher liver levels of cadmium than the older (age 7 to 14) longnose suckers of similar length and weight. This seems to indicate uptake via the zooplankton/insect food path.

No previous data on zinc levels for fish from this drainage are available for comparison. However, the values observed in this study are higher than those found by Stein and Miller (1973) in their investigation of the effects of a lead-zinc mine on the aquatic environment of the Great Slave Lake. The concentrations of cadmium they reported ranged from nil to 0.10 ppm in muscle, and from 0.09 to 0.37 ppm in the liver. The cadmium levels in the livers of the South Nahanni River fishes are in the same range as those described by Ash and Harbicht (1991) for lake trout (liver mean: 0.93 to 3.232 ppm) from Contwoyto Lake, which is affected by mining activity.

COPPER

Copper is an essential trace element. It is a constituent of metalloenzymes and respiratory pigments (Demayo et al., 1982) and consequently has important biochemical functions; but in excess amounts it is very toxic (Forstner and Wittman, 1979). As for cadmium, toxicity of copper varies with the physical and chemical characteristics of the water and with the fish species (Falk et al., 1973; Demayo et al., 1982). Copper is not considered to be a cumulative poison as most of it is excreted by the body, and very little is retained (Falk et al., 1973). Warren et al. (1971; cited by Falk et al., 1973) reports that values up to 80 ppm in liver tissues from British Columbia trout are not unusual. Fishes from Baker Creek, a water body affected by gold mining wastes, had copper concentrations of up to 18.5 ppm in the muscle tissues and up to 39.7 ppm in the livers (Falk et al., 1973). The C.F.D.D. has set a maximum level of 100 ppm for copper in dressed fish muscle tissue.

The mean copper concentration in Prairie Creek fishes range from 0.19 to 1.30 ppm in the muscle and from 2.24 to 41.4 ppm in the liver. Fish tend to concentrate copper in the liver. The highest levels were detected in longnose suckers (mean = 29.68 ppm).

MERCURY

Mercury and mercury compounds occur naturally in the environment but human activities have increased their concentrations. The mercury present in fish tissue occurs predominately in the form of methylmercury and results from the bioaccumulation of methylmercury from the environment (Harbicht and Ash, 1991). As a consequence of this biomagnification within a given fish community, piscivorous fish tend to contain higher concentrations of mercury . In Canada, the maximum allowable level of mercury in muscle tissue of commercial fish is 0.5 ppm (or mg/kg;wet weight).

Mercury was present in low levels in all the fish samples analyzed. The concentrations detected varied between 0.017 and 0.16 ppm, with the concentrations in liver tissue sightly higher than those in muscle tissue. This range is comparable to results of <0.001 to 0.170 ppm reported for a study conducted in Flat River in 1978 (Sigma Resources Consultants Ltd. and J.A. Jemmett Associates Ltd.).

LEAD

Lead toxicity varies with water chemistry. In soft water, lead may be more toxic to fish than an equivalent concentration in hard water (McKee and Wolf, 1963). The primary mode of uptake of lead ions is directly through the gills (Merlini and Pozzi, 1977b). Once in the body, lead tends to deposit in the bones, scales, kidney and liver (Spry and Wiener, 1991). The latter authors report that lead, as for cadmium, does not biomagnify in the aquatic food chains and that it does not typically increase with increasing body size or age.

None of the liver or muscle samples analyzed contained lead in quantities above detection limits.

NICKEL

As a pure metal nickel is not a problem in water pollution, but many nickel salts are highly soluble (McKee and Wolf, 1963) and therefore are more likely to be toxic. Nickel is however less toxic than copper, zinc, lead or iron (Falk et al., 1973; Kelly, 1988). Bowen (1966) estimates that 4.5 ppm of nickel in fish tissue is in the range of natural background levels.

Nickel was detected in the muscle of one arctic grayling; none of the other muscle tissues contained nickel. However, nickel was present in the livers of burbot, longnose suckers and of 3 arctic grayling. Quantities varied between 0.08 and 0.52 ppm, with the highest levels found in longnose suckers. This is considerably lower than nickel levels found in livers and muscles by Sigma Resources Consultants Ltd. and J.A. Jemmett Associates Ltd. (1978) which ranged between <0.5 and 8.0 ppm.

SELENIUM

Selenium occurs in nature chiefly in combination with other metals. Santaniello (1971) reports that selenium, an essential trace mineral, is toxic to animals when it accumulates in the tissue at concentrations of 5 ppm or higher.

As with many of the metals examined, selenium tends to concentrate in the liver. Selenium varies from 0.2 to 1.01 ppm in muscle tissue, while concentrations range from 1.12 to 3.64 ppm in liver tissue. Arctic grayling (liver mean = 2.24) tend to accumulate this metal more than longnose suckers do (liver mean= 1.22).

ZINC

Zinc is a trace element of major importance in the metabolic functions of cells. The sensitivity of fish to zinc varies with fish species, size and age, and also with the physical and chemical characteristics of the water. Weiss and Bolts (1957) associated the presence of zinc with the production of gill mucus precipitates, which reduce effective respiration, which in turn induces stress that leads to death. Falk et al. (1973) note that most of the literature which refers to zinc poisoning in fish indicates that stress and/or death is due to the disruption or destruction of gill tissue. According to Bowen (1966), levels of 360 ppm of zinc in fish tissue can be considered natural in origin.

Zinc was present in concentrations ranging from 2.23 to 15.24 ppm in muscle and from 18.84 to 35.76 ppm in liver tissue of the fishes from the South Nahanni River. The liver means for the 3 species range from 25.92 to 29.50 ppm. In 1978, the amount of zinc in muscle and liver of fish from the Flat River ranged between 3.1 and 17.7 ppm and between 8.7 and 39.0 ppm, respectively. Hence, the concentrations detected in this study are not unusual.

SUMMARY AND RECOMMENDATIONS

The fishes from the Nahanni River were tested for heavy metal contamination for the first time in 1992. Arsenic and lead were not detected in any of the tissues analyzed, while mercury and nickel were present in trace amounts. Cadmium, copper and zinc were found in concentrations similar to those recorded for fish living in an environment modified by mining activities. Cadmium concentrations reported here for the Nahanni River fish are somewhat unusual for an undisturbed system. Cadmium acts synergistically with zinc and copper, rendering them more toxic (E.S.B., 1973). Effects of cadmium on fish are not well documented, but increased vulnerability to predation, impaired swimming and death of eggs and juveniles have been reported (Sprague). Further monitoring is therefore recommended to assess the levels of heavy metals in fish tissue. It is suggested that monitoring be continued at two year intervals. As well, the effort should be extended to include a minimum of 10 specimens of each of the fish species present in the South Nahanni River, or at least the species targeted by sport fishermen. This should provide sufficient data that assessments can be done for human health as well as for fish health.

APPENDIX 1: RELATIVE STAGE OF MATURITY

A description of the relative stages of maturity used for northern fish.

SEX F	SEX M	MATURITY STAGE	
1	6	Immature:	virgin fish, gonad thin and threadlike, often incomplete.
2	7	Maturing:	virgin or non-virgin fish not spawning in current year, gonad full length, firm, eggs of small size, gonads partially filling body cavity.
3	8	Mature:	fish spawning in current year, gonads full size filling body cavity, eggs prominent, full size.
4	9	Ripe:	mature fish in spawning condition, eggs translucent, milt or eggs expelled under slight pressure.
5	10	Spent:	mature fish completed spawning, gonads collapsed with ruptured blood vessels prominent.

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Table XX: Biological parameters and heavy metal concentrations (ppm wet weight) detected in 3 fish species caught in September 1992 in Nahanni River, Nahanni Park

Species		Length (mm)	Weight (g)	Age (years)	Maturity**		As		Cd		Cu		Hg		Ni		Pb		Se		Zn	
					F	M	*muscle*	*liver*	*muscle*	*liver*	*muscle*	*liver*	*muscle*	*liver*	*muscle*	*liver*	*muscle*	*liver*	*muscle*	*liver*	*muscle*	*liver*
	Max.	328	400	6	2	7	<0.05	<0.05	0.019	3.317	1.3	3.6	0.109	0.16	0.08	0.09	<0.01	<0.01	1.01	3.64	4.4	29.91
	Min.	271	200	3	2	6	<0.05	<0.05	<0.001	0.197	0.28	2.24	0.017	0.033	<0.05	<0.05	<0.01	<0.01	0.2	1.48	2.23	18.84
Arctic Grayling	Mean	294.6	291.7	4.4	2	7	<0.05	<0.05	0.004	1.298	0.58	2.96	0.037	0.072	0.03	0.038	<0.01	<0.01	0.5	2.24	3.34	25.92
Thymallus arcticus	S.D.	21.4	65.1	0.9			<0.05	<0.05	0.005	1.032	0.26	0.47	0.027	0.035	0.016	0.024	<0.01	<0.01	0.2	0.69	0.66	3.11
	N	12	12	12	7	5	12	11	12	11	12	11	12	12	12	11	12	12	12	12	12	11
	n	0	0	0	-	-	12	11	1	0	0	0	0	0	11	8	12	12	0	12	0	11
	Max.	322	425	14	1	-	<0.05	<0.05	0.0058	1.518	0.31	41.4	0.047	0.0724	<0.05	0.52	<0.01	<0.01	0.39	1.31	15.24	35.76
	Min.	262	200	7	0	-	<0.05	<0.05	0.0031	0.477	0.27	19.3	0.0176	0.0206	<0.05	0.35	<0.01	<0.01	0.15	1.12	6.56	21.5
Longnose sucker	Mean	304.7	291.7	10.3	0	-	<0.05	<0.05	0.0042	0.976	0.29	29.68	0.0336	0.0432	<0.05	0.43	<0.01	<0.01	0.23	1.22	9.99	29.5
Catostomus catostomus	S.D.	37.2	118.15	3.5		-	<0.05	<0.05	0.0014	0.522	0.02	11.11	0.01487	0.0265	<0.05	0.085	<0.01	<0.01	0.1357	0.0954	4.62	7.29
	N	3	3	3	3	-	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	n	0	0	0	-	-	3	3	0	0	0	0	0	0	3	0	3	3	0	0	0	0
Burbot ***Lota lota***	Value*	850	2500	19	-	7	<0.05	<0.05	0.0028	0.992	0.19	11.76	0.0225	0.162	<0.05	0.19	<0.01	<0.01	0.53	2.83	3.16	26.23

* Only one (1) burbot was caught during the sampling period.
** For the maturity the mode is reported.

Submitted by INAC NOV 19/08

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1992/93 ANNUAL REPORT ON WATER QUALITY OBJECTIVES MONITORING NAHANNI NATIONAL PARK RESERVE, NWT

Prepared For

Canadian Parks Service
Prairie & Northern Region
Environment Canada

and

Conservation and Protection Service
Western & Northern Region
Environment Canada

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Executive Summary

The challenges of water resource protection and management that have plagued southern Canada and much of the world are only now starting to be considerations in the north and specifically the South Nahanni River basin. There is still time to apply lessons learned elsewhere from the examples of resource degradation due to encroaching development. The Nahanni National Park Reserve is located in the downstream reaches of the South Nahanni River basin. Current and potential mining development of tributaries of the South Nahanni River raise concerns regarding the possible degradation of Park waters and the need to actively preserve the water in its current state. Late 1992 and 1993 publications by DIAND and the N.W.T. Chamber of Mines, and recent Northern Miner articles describe current advanced stage exploration activities at and in the vicinity of the Prairie Creek (Cadillac) Zn-Pb-Ag Mine. The currently mothballed Canada Tungsten W-Cu Mine is located in the Flat River upstream of the Park.

Baseline water quality data were collected throughout the Park. The Park water is considered to be pristine or very close to pristine. Short and long term water quality objectives were developed to provide water managers with a measure for assessing any changes that may occur in the waters that are beyond the bounds of natural variability. Some of these objectives lie close to the lower method detection limits of laboratory analysis methods , creating certain limitations and problems, such as water quality objectives for **dissolved** metals exceeding the corresponding objectives for **total** metals (levels of dissolved metals often subequal total metals).

The 1992 monitoring program provided the water quality data necessary for evaluating compliance with the water quality objectives. It is imperative for the preservation of the Park waters that such water quality objectives be incorporated into the water management plans of the Park and the entire South Nahanni Watershed. It is also essential that frequency of water quality monitoring be increased if the pace of development in the basin accelerates, especially if exceedances of objectives and Canadian Water Quality Guidelines (CWQG) are observed downstream from past or present mining activities. This was the case in June 1992 for total Zn and total Cu at the Prairie Creek and Flat River sites, respectively.

Correlation analyses of Flat River data revealed that specific conductance has an almost perfect negative correlation with discharge and can be substituted for discharge in simple linear regression analyses on discharge where no measured or calculated discharge data is available. Two-thirds of the time, water quality variables at sample sites exhibit at least moderate correlation with discharge/ specific conductance. The 95% confidence and prediction limits about simple linear regression line on discharge or specific conductance define natural conditions in high energy

Cordilleran environments. Objective and CWQG exceedances within these limits can be downplayed; those outside require further examination. The spatial and temporal (seasonal) variation of the water quality objectives at the five sites are described using geology maps, hydrographs and multiple box-and-whisker plots. Water quality variable values are <u>spatially</u> controlled by bedrock and surficial geology, and hydrology. Values are <u>temporally</u> controlled by dilution effects, particulate effects (including early flushing of particulates), temperature effects and other effects.

Suspended sediment values from Nahanni Butte are elevated with respect to total Zn and other metals. Fish muscle and liver have been sampled by DFO in 1992 on Prairie Creek; conclusions from the report now completed are collated with the water and sediment data.

All five sites warrant 1993-94 water quality monitoring along the guidelines of the 1992 MOU. Additional water samples are required at (and are proposed for) the Prairie Creek and, possibly Flat River sites; the latter site should continue to be sampled opportunistically during the winter as part of another project. Additional suspended sediment and biota sampling are also recommended to ensure a more holistic ecosystem approach in this poorly- known Tundra Cordillera Ecozone.

Acknowledgement

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I wish to thank Jesse Jasper for his technical input and his editing skills. John Kerr's assistance in providing discharge estimates for the South Nahanni River via flow routings to the Nahanni Butte water quality station is also appreciated. Marnie Fyten's assistance in preparing the 1992 database, providing technical input and editing the report is greatly appreciated. Paul Squires assistance in the drafting of figures, the adding 1992 discharge data to the 1988 and 1989 discharge data from the three hydrometric stations and preparing discharge comparison graphs for the three April-September seasons is also much appreciated.

List of Figures

List of Tables
in Appendix II

1.0 INTRODUCTION

This report describes environmental water and sediment quality monitoring three times during the 1992 open water season at five sites in the Nahanni National Park Reserve as described in the Memorandum of Understanding between the Canadian Parks Service and the Conservation & Protection Service (Appendix I).

Nahanni National Park Reserve is one of Canada's premier wild river national parks. The uniqueness of the Park waters, the deep canyons, falls, white water and meandering reaches make the Reserve renowned for its pristine beauty. It is recognized nationally and internationally as a Canadian Heritage River and as a UNESCO World Heritage Site (Environment Canada, 1991).

The near pristine water quality of the Park waters is vulnerable to stresses from upstream in the basin, since the Park is located in the lower reaches of the South Nahanni River watershed. Current and potential mining developments on tributaries of the South Nahanni, such as the Flat River and Prairie Creek, has raised concern over potential effects of development on the aquatic ecosystem of the Park (Environment Canada, 1991).

Implementation of Canadian Parks Service (CPS) policies, management strategies for national parks, and recognition of the potential effects of upstream developments led to the realization that comprehensive water quality data and monitoring would be required to prevent degradation of the Nahanni waters. In 1988, CPS signed a Memorandum of Understanding, (or MOU) with Inland Waters Directorate (IWD) on collection of baseline water quality data and development of water quality objectives. The December 1991 report entitled "Protecting the Waters of Nahanni National Park Reserve, N.W.T." resulted from the joint 1988-90 CPS/IWD Park water assessment.

In 1992, a second MOU signed by IWD and CPS (Appendix I) outlined arrangements for collection of water and sediment quality samples on three occasions each year, and one set of suspended sediment samples. The MOU covers the collection and analysis of stream waters and suspended sediments (by IWD) as well as biota (by CPS).

The list of water and sediment quality variables monitored appears in Table 1 in the Appendix. The list of variables that suspended sediment samples were analyzed for is also shown (particle size analysis was also carried out). Fish samples are collected and measurements made of biological parameters (i.e. weight, sex, length) and chemical parameters (As, Se, Hg, Cd, Pb, Ni, Zn).

Snow samples for atmospheric deposition of contaminants were collected under a separate but complementary program for NWRI (DOE) Burlington. Water levels, actual flow measurements and computed daily flows are available for the Flat River and two other water quantity stations on the mainstem South Nahanni River (i.e. above Virginia Falls and near Clausen Creek).

This report summarizes activities and water and sediment quality lab analytical results for the 1992 field season, with the exception of the biota and snow sampling, as required under the MOU.

2.0 NAHANNI NATIONAL PARK

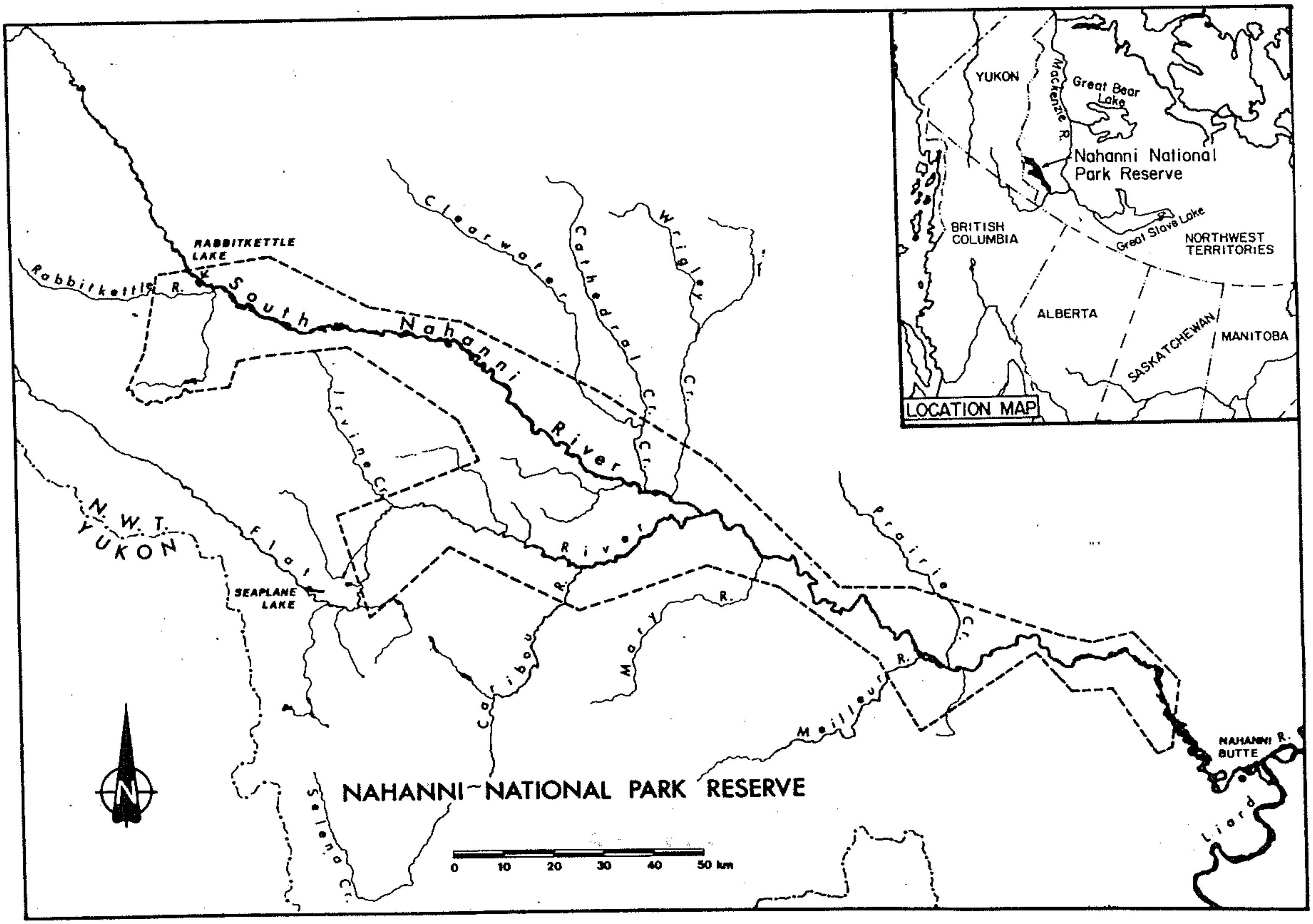
2.1 The Environment

Nahanni National Park encompasses a spectacular region of waterfalls, canyons, rapids, caves, mountains, hills, valleys, plateaus, karst topography and mineral springs in the lower reaches of the South Nahanni Basin, NWT (Figure 1). The South Nahanni River drains an area of 37,000 square kilometres, extending from its icefield origin just east of the Yukon-Northwest Territories boundary, along its course eastward for 540 kilometres through the Mackenzie Mountains into the Liard and, eventually, Mackenzie Rivers.

Geologically, Figure 2 shows the Park to be underlain by sedimentary rock formations of marine shales, shallow marine fossiliferous limestones and lesser dolostones, and terrestial sandstones. Granitoid rocks intrude in the western portion. The area is structurally complex due to extensive folding, especially in the west near the intrusions. There is extensive development of karst topography, solution channels, caves and sinkholes in the carbonate rocks due to chemical dissolution and reprecipitation. Long periods of river erosion and short periods of glacial action have also sculpted the present-day geomorphology (Canadian Parks Service, 1984).

Limestone and less common dolostone formations are host rocks for lead-zinc deposits and are cut by silver-lead-zinc veins, particularly in the Prairie Creek (e.g. Cadillac Mine) area. Shallow marine carbonates and terrestial sandstones contain important silver and coal deposits. Further west in the Howards Pass area of the Yukon, shale-hosted Pb-Zn-Ag-barite deposits occur. Tungsten-copper mineral deposits (e.g. Canada Tungsten Mine) occur in the western portion of the South Nahanni River (-Flat River) Basin, associated with the contacts between granitoid intrusive rocks and carbonate rocks baked by the intrusion (Hamilton et al, 1988). The so-called Mississippi Valley lead-zinc, arsenide vein silver, sediment-hosted sulphide-barite and skarn tungsten-copper mineral deposits present are well-described in Economic Geology Report 36 (GSC, 1984).

Elevations within the South Nahanni watershed range from 2770 metres above sea level to about 180 metres at the confluence of the



after Environment Canada, 1991

Figure 1. Nahanni National Park Reserve

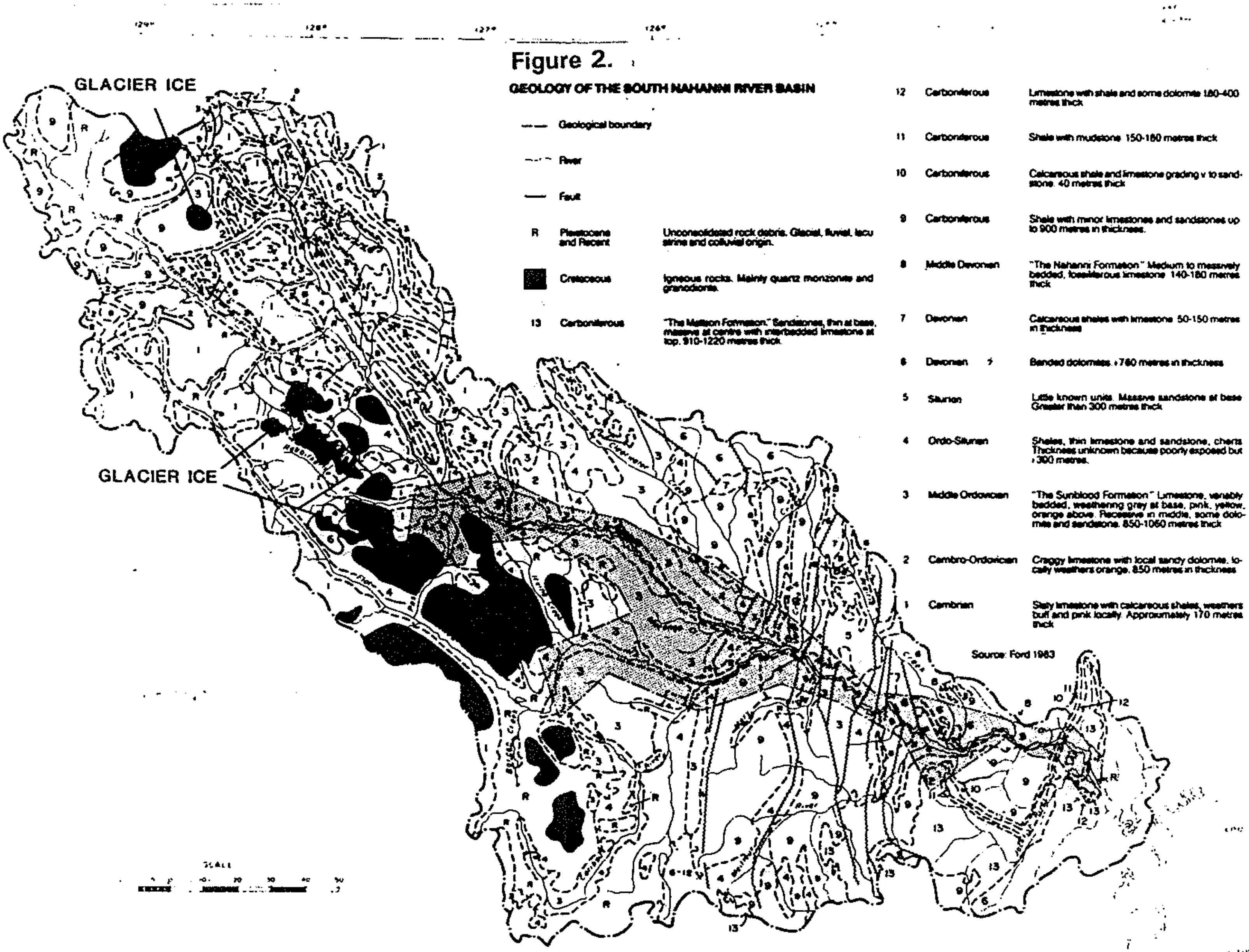


Figure 2.
GEOLOGY OF THE SOUTH NAHANNI RIVER BASIN

After Canadian Parks Service, 1984

Liard and South Nahanni Rivers. Within the Park, the mainstem South Nahanni enters at an elevation of 825 metres and exits at 350 metres, 90 metres of this vertical drop accounted for at Virginia Falls. The rest of the River has an average gradient of 1.2 metres per kilometre.

Hydrographs from Flat River (Figure 3), Virginia Falls (Figure 4) and Clausen Creek (Figure 5) reveal that annual peak flows (discharges) generally occur from Late May to Late June due to spring snowmelt, the timing varying with reaches and hydrometric stations due to lag time downstream. The recession conditions prevail through freeze-up until November. Baseflow conditions are approximated between November and Mid-April, true baseflow being best monitored in Early April. Summer mountain rainstorms appear in hydrographs as short-wavelength "spikes"; these may occur from Mid-April to Late August. The discharge of "slugs" of water produced by such rainstorms can be monitored as they move down-drainage through the three hydrometric stations. The relative contributions of surface (meteoric) water and groundwater to the total discharge is not known. Groundwater in the Park includes formational (connate) waters within the karsted carbonate rocks and hydrothermal (magmatic) waters from hot springs. The relative abundances of meteoric, formational and magmatic waters and their distributions would require thorough oxygen isotope analysis studies.

The volume of water flowing through the South Nahanni River can range from 55 to 1500 cubic metres per second, making the river a significant contributor to the Liard and Mackenzie Rivers (Canadian Parks Service, 1984).

According to CPS (1984), park vegetation is characterized by northern boreal forest species in the lowlands, with transition to alpine tundra at higher elevations. Montane and subalpine zones are the most common, with extensive stands of spruce and pine and diverse habitats supporting over 750 plant species , including 40 not found elsewhere in the Mackenzie Mountains.

According to CPS (1984), wildlife found in the Park includes more than 120 bird, 40 mammal and 13 fish species. River flats along the South Nahanni and Flat Rivers provide quality moose and deer habitat, while higher elevation valleys support woodland caribou. Dall sheep live in alpine tundra areas and black and grizzly bear, white tail and mule deer are also present.

CPS (1984) describes the climate of the Park as cold continental with wide monthly and annual temperature and precipitation variations. Summer and fall are dominated by westerly air currents from the Pacific Ocean, while arctic airstreams predominate in winter and spring. The eastern end of the Park tends to be cooler and wetter and chinook winds are common throughout the winter.

Figure 3. Hydrograph. Flat River Near the Mouth. Station 10EA003. Years 1988, 1989, 1992.

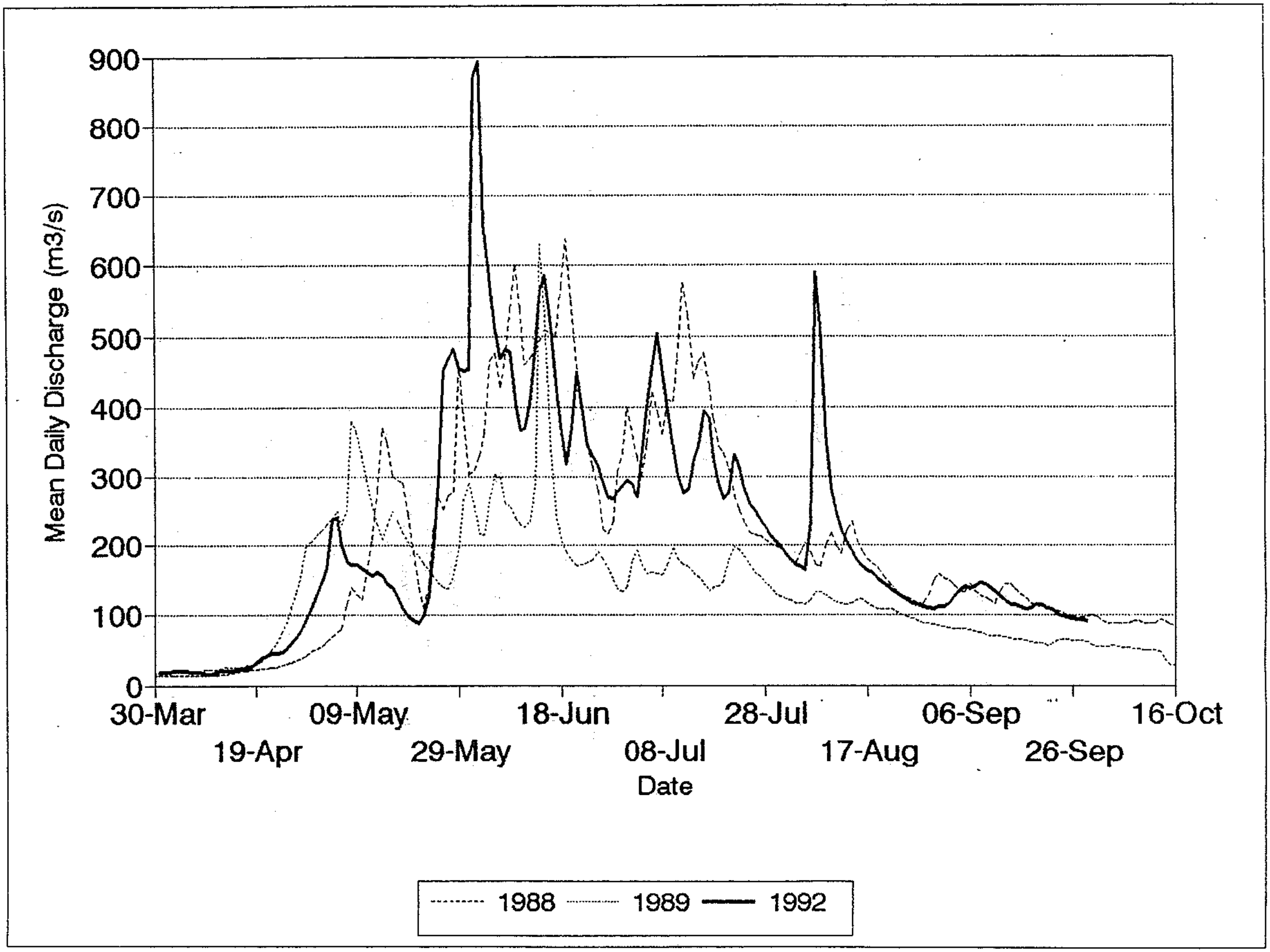


Figure 4. Hydrograph. South Nahanni River Above Virginia Falls. Station 10EB001. Years 1988, 1989, 1992.

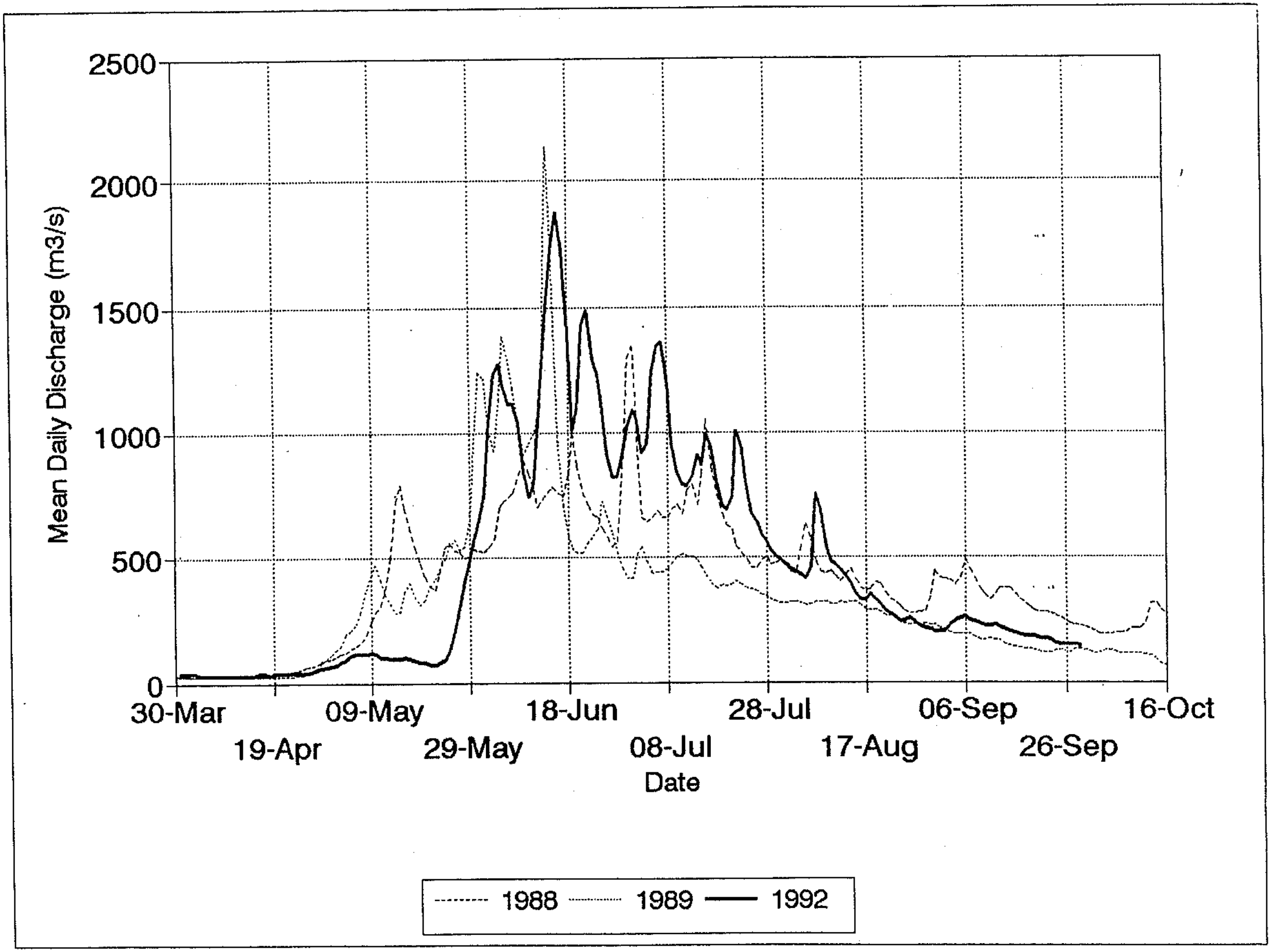
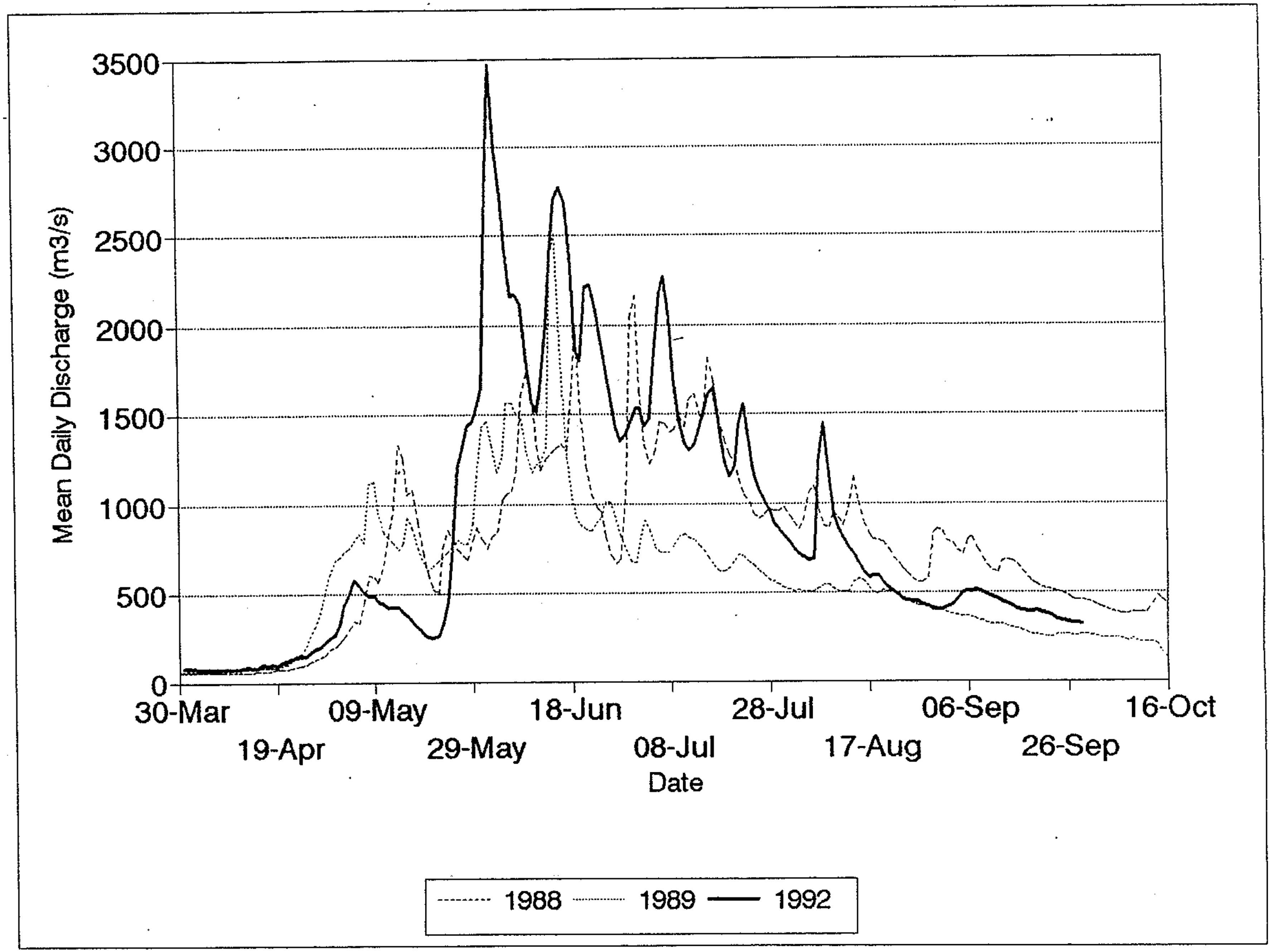


Figure 5. Hydrograph. South Nahanni River Above Clausen Creek. Station 10EC001. Years 1988, 1989, 1992.



Some 1000 to 2000 visitors are reported per year, mainly via chartered float plane from Fort Simpson, NWT or Watson Lake, YT and via the Canol Road. Chartered float planes are the usual mode of access to the Park itself. The Park offers outstanding river touring (including wild river touring by canoe, kayak or raft), camping, hiking and fishing opportunities. The short visitor season runs from late June to early September; optimal travel times on the river are July and August (Canadian Parks Service, 1984).

The South Nahanni was designated as a Park Reserve in 1976 by the Canadian Parks Service. In 1978, the Reserve was designated a World Heritage Site by UNESCO. The river was nominated as a Canadian Heritage River in 1987, and became one in 1992 (Canadian Parks Service, 1984).

2.2 The Issue

The Park has not yet experienced enough development to cause deterioration of water quality. However, it remains vulnerable to activities outside the Park and to stresses external to the South Nahanni River watershed, such as airborne contaminants (Environment Canada, 1991).

The Park area is particularly rich in tungsten, lead, zinc, copper and silver mineral deposits with two past producing mines, the Cadillac (Pb-Zn-Ag) Mine on Prairie Creek and the Canadian Tungsten (W-Cu) Mine on the Flat River (Figure 6). Numerous mineral claims have been staked and recorded in the area surrounding the Park (Environment Canada, 1991).

At least three major mining projects may be developed in the future should international commodity prices rise. Union Carbide's Lened Creek project had encouraging exploration results in the early 1980's before being mothballed due to low mineral prices. At Howards Pass, a major lead-zinc-silver mine was postponed for similar reasons. At Prairie Creek, San Andreas Resources and Nanisivik Mines are re-examining the Cadillac Pb-Zn-Ag Mine Property and finding it to be a high proven tonnage (i.e. four million or more metric tonne), continuous stratiform base metal deposit (Northern Miner, 1992; DIAND, 1992; NWT Chamber of Mines, 1992).

3.0 ENVIRONMENT CANADA AND INDIAN AND NORTHERN AFFAIRS ACTIVITIES

3.1 1992 Monitoring Program Design

The 1992 monitoring program design is largely the result of the IWD-CPS 1988-90 study. The objectives of this earlier study were:

1. To characterize variability of water quality variables associated with the mining industry;

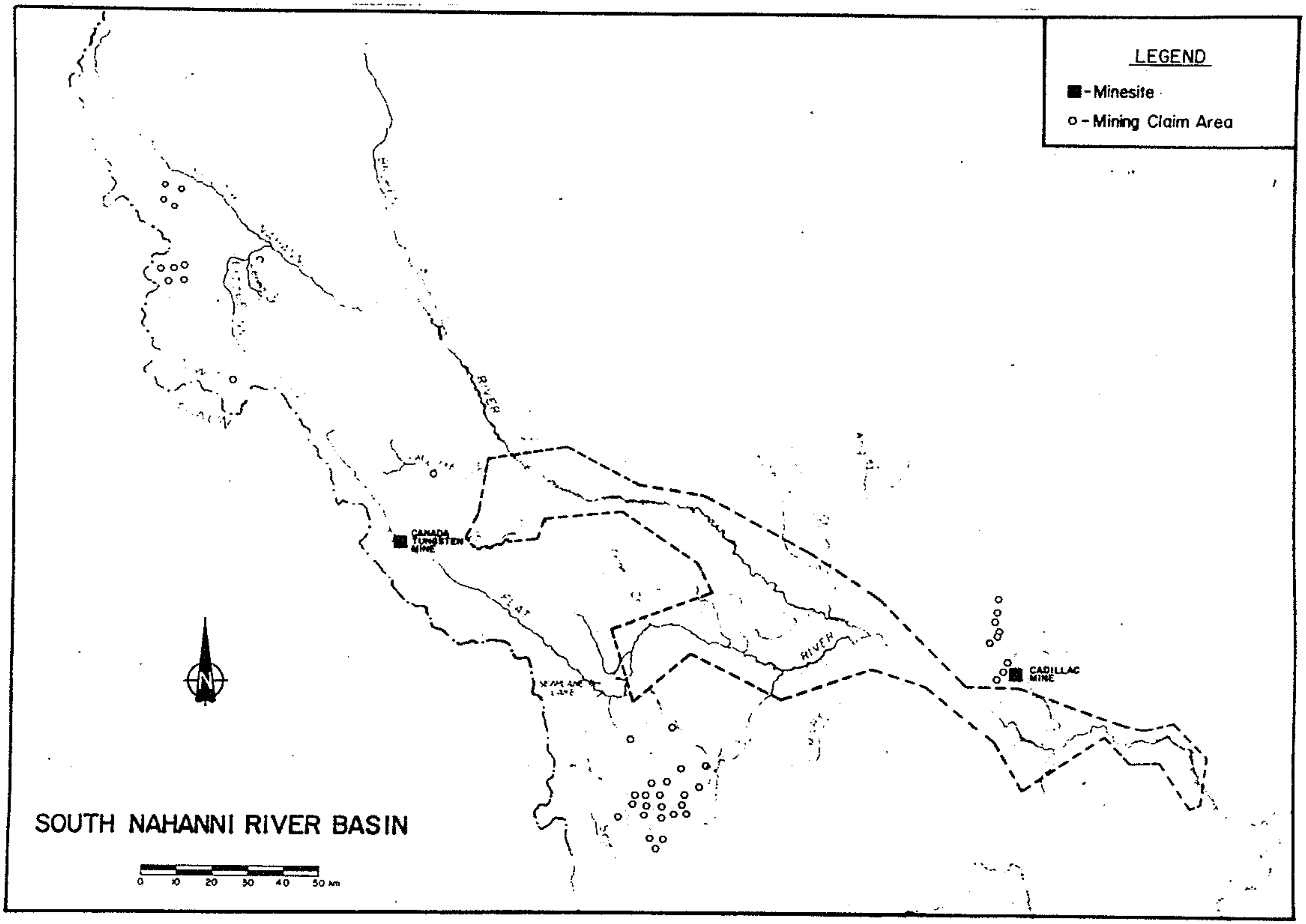


Figure 6. Mining Activities in the South Nahanni River Basin.

after Blachford, Olding, et al. 1991

2. To develop water quality objectives for major streams entering the Park; and

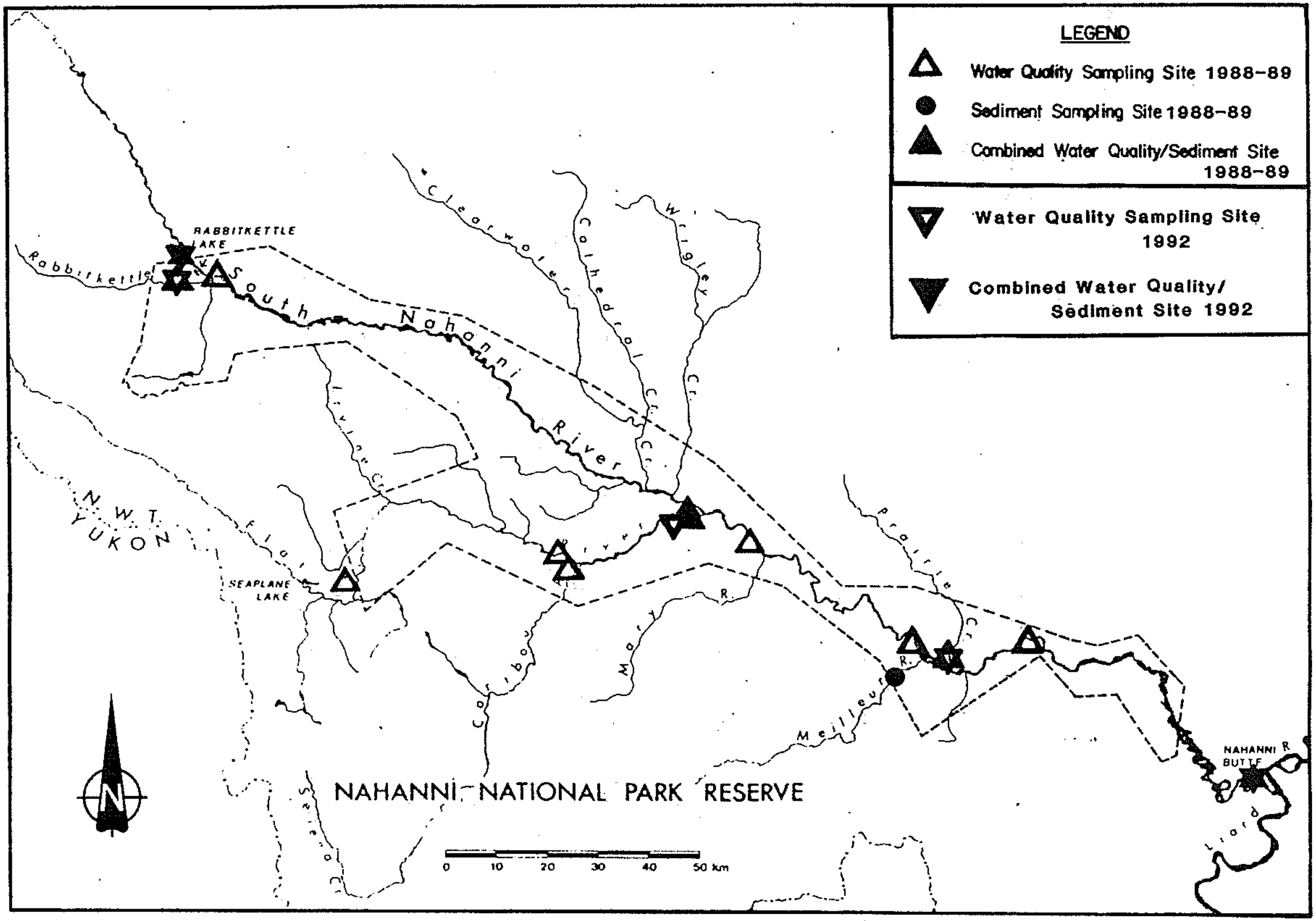
3. To design an on-going water quality monitoring program for monitoring compliance with the water quality objectives.

Thirteen sampling sites (Figure 7) were selected to provide representative data for the South Nahanni River and tributaries potentially affected by upstream mining development. Sampling took place in the open water seasons of 1988 and 1989. Spring (May 23-June 11, 1988; May 24-June 11, 1989) and fall (September 9-28, 1988; August 31-September 19, 1989) sampling periods were selected to represent the extremes in variability with respect to concentrations of water quality variables occurring largely as the result of different water flow rates. Historic records from the Flat River at the mouth station from 1972 to 1990 suggest that 1988 and 1989 discharge rates are typical, 1988 being slightly above and 1989 being slightly below the historic mean discharge (Environment Canada, 1991).

The selected water quality parameters were those associated with tungsten, silver, lead, zinc and copper mining activities. These included a wide range of metals, nitrogen compounds (possibly released from blasting operations), sulphates (possibly leached by acid mine drainage), and various physical and chemical parameters. All (unfiltered) water samples were analyzed for "total" (dissolved and particulate) metals; at some sites (when logistics permitted), "dissolved" metals (a more accurate estimate of the metal readily available to aquatic biota and of concern for the protection of aquatic life) were also analyzed. Metals released from mining activities are present in both dissolved and particulate forms. Quality control/ quality assurance samples (e.g. triplicates, duplicate blanks) were collected at five sites both years (Environment Canada, 1991).

Since metals are commonly associated with particulate matter, suspended sediments were, therefore, collected at five sites (Figure 7) using a continuous-flow centrifuge and analyzed for a range of metals. Metals have a greater affinity for smaller particle sizes which are more likely to be suspended sediments than bottom sediments in the high-energy environment of the South Nahanni River and its tributaries (Ongley, 1992; Environment Canada, 1991).

Recommendations which evolved from the 1988-89 study included adoption of water quality objectives, water quality monitoring at five sites, sampling and analysis of suspended sediment (IWD) and fish (DFO-CPS), the expansion of monitoring if exploration and development activities in the South Nahanni River Basin proceeds, the noting of analytical results of snow samples collected in the vicinity of the watershed, continuance of at least the Flat River at the mouth hydrometric station and the marketing of the principle



after Environment Canada, 1991

Figure 7. Water and Suspended Sampling Sites, 1988, 1989, 1992

of water quality objectives to federal and territorial agencies (Environment Canada, 1991).

This led to the August 20, 1992 signing of a Memorandum of Understanding by Inland Waters Directorate (IWD) and Canadian Parks Service (CPS) to implement a water quality study in the Nahanni National Park Reserve (Appendix I).

3.2 IWD/CPS 1992 Water Quality Study

Figure 7 shows the locations of the five 1992 water and suspended sediment sample sites. These were sampled during the late winter **baseflow** (April 21, 1992), spring **freshet** high flow (June 4, 1992) and summer **recession** low flow (August 31, 1992). Suspended sediment was also collected by IWD at the South Nahanni River above Nahanni Butte on September 1, 1992 as part of a long-term plan to collect suspended sediment at that site every other year.

The 1992 results appear in the Appendix in Tables 2, 3, 4, 5 and 6; for Flat River, Prairie Creek, Nahanni Butte, Rabbitkettle River and South Nahanni River above Rabbitkettle River; respectively.

Tables 1-6 summarize the field and lab water quality and lab sediment quality NAQUADAT/ENVIRODAT Parameter Codes. The codes describe the laboratory analytical methods used, the instrumentation used, the method lower detection limit and the units and precision the data is reported in.

Field quality assurance/ quality control was carried out in 1992. A triplicate river sample and one field blank were collected at Prairie Creek at the mouth (June 4, 1992) and South Nahanni River above Nahanni Butte (August 31, 1992).

Water quality data for 1992 was interpreted in light of 1992 water stages (levels) and discharge (flow) rates for the Flat River at the mouth hydrometric station (co-located with the water quality station), South Nahanni River above Virginia Falls and South Nahanni River above Clausen Creek. Synthetic flow data were produced for Nahanni Butte by "routing" flows at Clausen Creek 55 kilometres downstream to the Nahanni Butte water/sediment quality station.

Manugistics, Inc. StatGraphics Version 6.0 software was used to perform linear regression analyses, perform correlation matrix ANOVA and produce multiple box-and-whisker plots showing medians, upper and lower quartiles and outlier non-parametric values for late winter baseflow, spring freshet and summer recession samplings.

Exceedance (excursion) values not falling within an 95% confidence envelope of linear regression lines on discharge at Flat River (or specific conductance at Prairie Creek, Rabbitkettle Creek and Upper

South Nahanni River) were noted as non-compliances. Discharge data from the South Nahanni River at Nahanni Butte was estimated by mathematically "routing" flows downstream from the Clausen Creek gauge, to permit linear regressions on (estimated) discharges at the Nahanni Butte water quality station. For compliance monitoring purpose, the Nahanni Butte water quality station in the mainstem was treated similarly to the Flat River station.

4.0 WATER QUALITY OF THE PARK

The South Nahanni River basin may be subjected to extensive natural resource development in the future. These anthropogenic activities have the potential to adversely affect water quality and disrupt aquatic life. Effective water management plans require knowledge of the basin's water quality dynamics. The cumulatative knowledge of the Park's water quality from the 1988-89 and 1992 surveys is summarized here.

4.1 Spatial Variability

Ground and surface water runoff dissolves minerals and nutrients as these pass through the bedrock and surficial deposits of the watershed. Differences between the mainstem and the tributaries, and amongst the tributaries, largely reflects the spatial variation in the geology of the area (Environment Canada, 1991).

Prairie Creek flows through bare upland and steep canyon terrain, and carries sediment concentrations which are an order of magnitude lower than that carried by the mainstem. Since most metals are transported in association with suspended sediments, concentrations of all **total** metals are, therefore, also lower than elsewhere in the Park. Levels of **dissolved** metals, however, can be as much as twice as high as in the mainstem, likely due to mineral springs in the karsted area of carbonate rocks. Prairie Creek flows through areas rich in calcium and calcium-magnesium carbonate-precipitating streams.

Prairie Creek flows in July are very low, and apparently have little influence on South Nahanni water quality (Environment Canada, 1991).

The Park portion of the Prairie Creek watershed is underlain by Devonian banded dolostones and lesser fossiliferous limestone (Canadian Parks Service, 1984) that likely host the Cadillac Mine/ Prairie Creek zinc-lead deposits and zinc-lead-silver veins (Indian and Northern Affairs Canada, 1992). Further upstream and outside the Park, Prairie Creek is underlain by shale, calcareous shale and minor sandstone (Canadian Parks Service, 1984).

The Flat River shows distinct water quality changes between the Park boundary and its confluence with the South Nahanni. The sediment content increases dramatically near the confluence, reflecting erosion of till and glaciolacustrine silts in its valley (Canadian Parks Service, 1984). Dissolved solid concentrations increase only slightly, however, due largely to increases in calcium. The Flat River flows through areas rich in calcium and calcium-magnesium carbonate-precipitating streams. Comparison of water quality data from the South Nahanni River above and below its confluence with the Flat River suggests the tributary has little affect on the mainstem (Environment Canada, 1991).

Within the Park, the Flat River cuts through unconsolidated material of glacial, alluvial, glaciolacustrine and colluvial origin, underlain, in the headwaters, by limestone and lesser dolostone and sandstone, and, further downstream, by shale and lesser limestone, sandstone and chert. Above the Park, the Flat River is underlain by quartz monzonitic and granodioritic felsic intrusions and lesser banded dolostones (Canadian Parks Service, 1984). The Canada Tungsten Mine involves tungsten- copper- (zinc-molybdenum) mineralization hosted at the contact of metamorphosed limestones and calcareous shales with felsic intrusions (Geological Survey of Canada, 1984).

Figure 3 shows that the Flat River's peak mean daily discharge (600 cms in 1988-89, 900 cms in 1992) is lower than that of the South Nahanni River mainstem at Virginia Falls (Figure 4) and Clausen Creek (Figure 5). The mean daily discharges on the mainstem for 1988, 1989 and 1992 are much higher, South Nahanni River above Virginia Falls peaking at 1400 to 2200 cubic metres per second, and South Nahanni River above Clausen Creek peaking at 2200 to 3500 cubic metres per second (Water Survey of Canada, 1992).

The Caribou River, a tributary of the Flat, has low sediment loads with higher concentrations of metals, calcium, sodium carbonates than expected. The Caribou cuts through the same surficial and bedrock geological units as the Flat, with lesser volumes of felsic intrusive rocks. Water quality of the Caribou River appears to have little effect on the water quality of the Flat River (Environment Canada, 1991).

The Rabbitkettle River and the northwest (upstream) portion of the South Nahanni have very similar water quality, with slightly higher metal concentrations in the Rabbitkettle. Some metals (e.g. Zn, Cu, Mn) are higher in the Rabbitkettle because it drains an area underlain by felsic intrusions and dolostones (Environment Canada, 1991).

Concentrations and variability of parameters increase slightly downstream through the South Nahanni River basin (i.e. sediment, copper and sulphate concentrations) (Environment Canada, 1991). The South Nahanni River at Nahanni Butte station, just outside the Park, reflects concerns about further increases in constituents and temporal variability downstream, and for sampling convenience.

Elevated (% levels, rather than ppm levels) total iron content of suspended sediments at South Nahanni River above Nahanni Butte may be due to naturally occurring iron contents in red-orange-yellow varicoloured sedimentary rocks (i.e. Sunblood Formation limestones outcropping upstream from all water quality sites except Prairie Creek). Prairie Creek's Pb-Zn-Ag mineralization might also contain abundant iron sulphides, such as pyrite and marcasite (Geological Survey of Canada, 1984).

4.2 Temporal (Seasonal) Variability

Concentrations of water quality parameters fluctuate over the hydrologic year. The effects of mine development, construction, production and decommissioning remain relatively minor, with natural cycles of substances predominating. The relatively continuous, long-term record of water quality data for Flat River near the Mouth station illustrates seasonal and long-term temporal variability, according to StatGraphics and WQStatII software statistical testing.

Verified, validated water quality data from 1988, 1989 and 1992 were entered into Lotus 1-2-3 respecting the analytical precision available/significant figures and entering non-detects as half the method detection limit (eliminating conservative or liberal bias). Lotus files were exported to StatGraphics Version 6.0 for analyses (linear regressions, multiple box-and-whisker plots and other statistics and graphics). Since only the open water season is represented in the three years of water quality sampling, no time series plots and analysis were carried out using the available StatsGraphics or WQStat II software. Time series analyses can be performed on the Flat River database if the full water year, historic (1966-92) database is used.

Flat River At Mouth Water Quality Station

Figure 3 illustrates the annual flow discharge pattern of the Flat River. Low flows occur from December to Mid-April, followed by rising levels in Mid-April from snowmelt from lower altitudes. June, July and August show the highest flows, but the timing of high summer flows varies with summer rainfall. Historic September to October flows are higher on the Flat River due to greater forest cover and retentive soils (Environment Canada, 1991).

The water quality variable most clearly reflecting discharge variations is specific conductance (Pearson's "r" = -0.8634, Spearman's "rho" = -0.8599). Specific conductance is directly proportional to total dissolved solids (TDS) and inversely proportional to non-filterable residue (NFR). NFR correlates well with discharge (Pearson's "r" = +0.8238). Dissolved solids (i.e. minerals, such as carbonates and sulphates) are contributed from mineral springs via ground and surface water runoff.

At Flat River, an inverse relationship exists between flow and dissolved solids concentration, due to dilution of dissolved solids during all periods of high flow, when contact of water with soluble minerals in the rock or soils, and baseflow through mineral-rich rock are reduced. 1988-89 specific conductance values ranged from 125 to 500 microsiemens per centimetre (uS/cm) (Environment Canada, 1991). 1992 specific conductance values ranged from 130 to 375 uS/cm, reflecting the higher flow rate in 1992. See Table 2 in the Appendix.

Other water quality variables **positively** correlated with discharge (Pearson's "r" in brackets) include extractable Fe (+0.8645), total V (+0.8520), dissolved Pb (+0.8287), total Cu (+0.8283), extractable Mn (+0.7969), total Ba (+0.7822), total Co (+0.7646), total Pb (+0.7492) and total Zn (+0.7335). Refer to Figure 8. Other water quality variables **negatively** correlated with discharge (Pearson's r in brackets) include specific conductance (-0.8634) and dissolved sulphate (-0.8231). Refer to Figure 9.

Total Cu, Zn, Pb, Ni, V, Co, Cd and Ba values **increase** with increasing discharge. Dissolved Pb, Cu, Fe, Co and As values also increase with increasing discharge as do extractable Fe and Mn, NFR and total cyanide. Dissolved Zn, Se, Ni, Mn and Ba values **decrease** with increasing discharge, as do dissolved sulphate and specific conductance. Dissolved Cd, pH and dissolved NO_3-NO_2 values appear to be unrelated to discharge. It appears that Zn, Ni and Ba are partitioned mostly into the particulate phase while Cu and Pb are partitioned mostly into the dissolved phase. Twelve of 27 water quality variables are moderately to strongly discharge-controlled (i.e. $r >= +0.7$ or $r <= -0.7$).

Correlation matrices show that very high positive "r" correlation coefficients (in excess of +0.9) are common between total metals such as Cu, Pb, Zn, Ni, Co and Ba and extractable metals such as Fe and Mn; all are positively correlated with discharge. Similar high "r" values exist between specific conductance, dissolved SO_4, dissolved Ba and dissolved Ni; all are negatively correlated with discharge.

Multiple box-and-whisker plots (Figures 10-12) illustrate seasonality of water quality variables during the late winter baseflow, the spring freshet and the summer-fall recession. As no baseflow samples were collected during 1988 and 1989, consequently late winter baseflow sample was collected in early April 1992 and so the baseflow box-and-whisker plots for water quality variables at all stations appear as single horizontal lines.

Multiple box-and-whisker plots are easily understood. Freshet and recession box-and-whisker plots show 25th and 75th percentiles (top and bottom of the "boxes", respectively), and the 50th percentiles or median values (the middle of the "boxes"). The 25th percentile-

Figure 8. Flat River. Linear Regression of Extractable Fe on Discharge Showing LTO, STO, CWQG Exceedances.

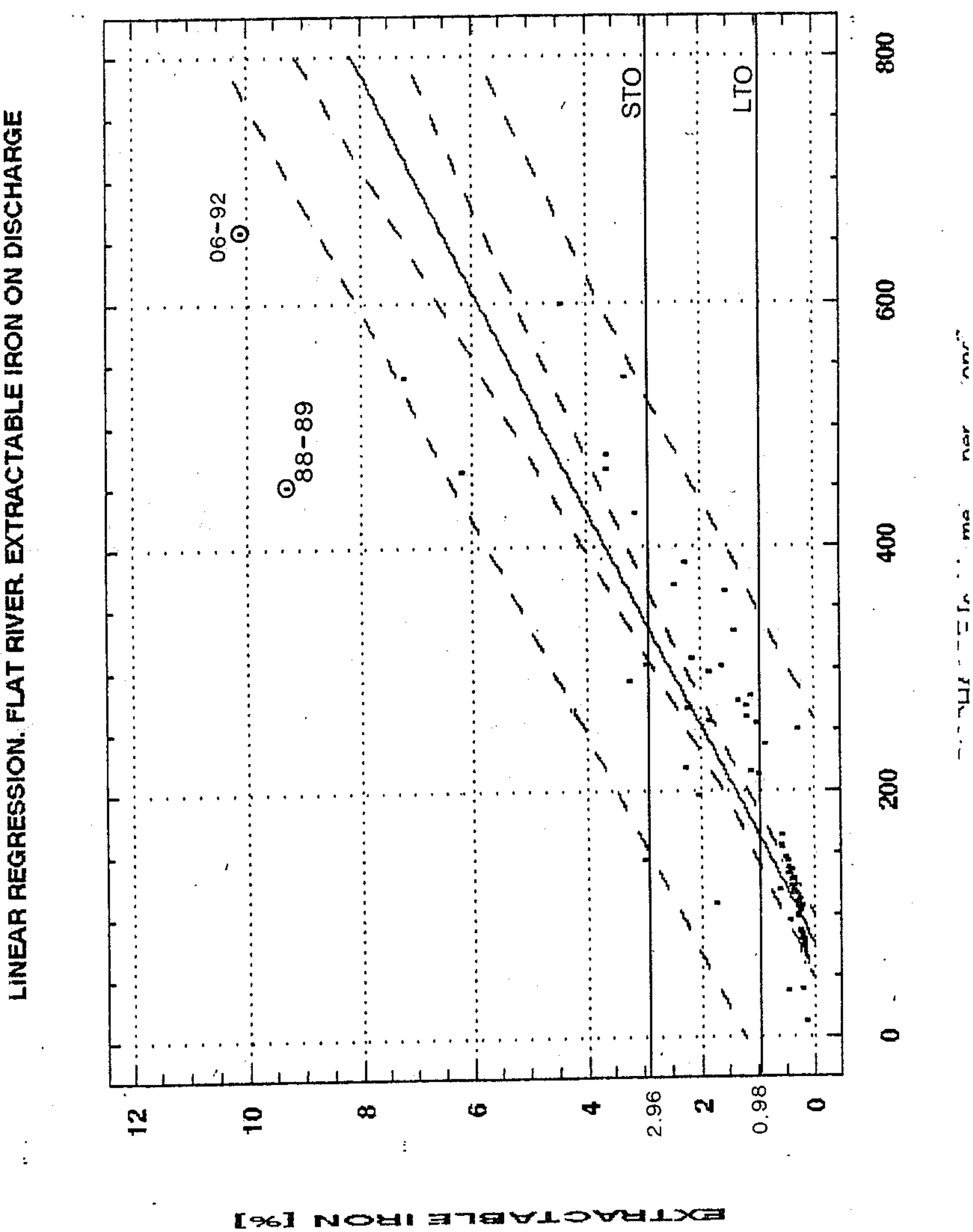


Figure 9. Flat River. Linear Regression of Specific Conductance on Discharge Showing LTO, STO, CWQG Exceedances.

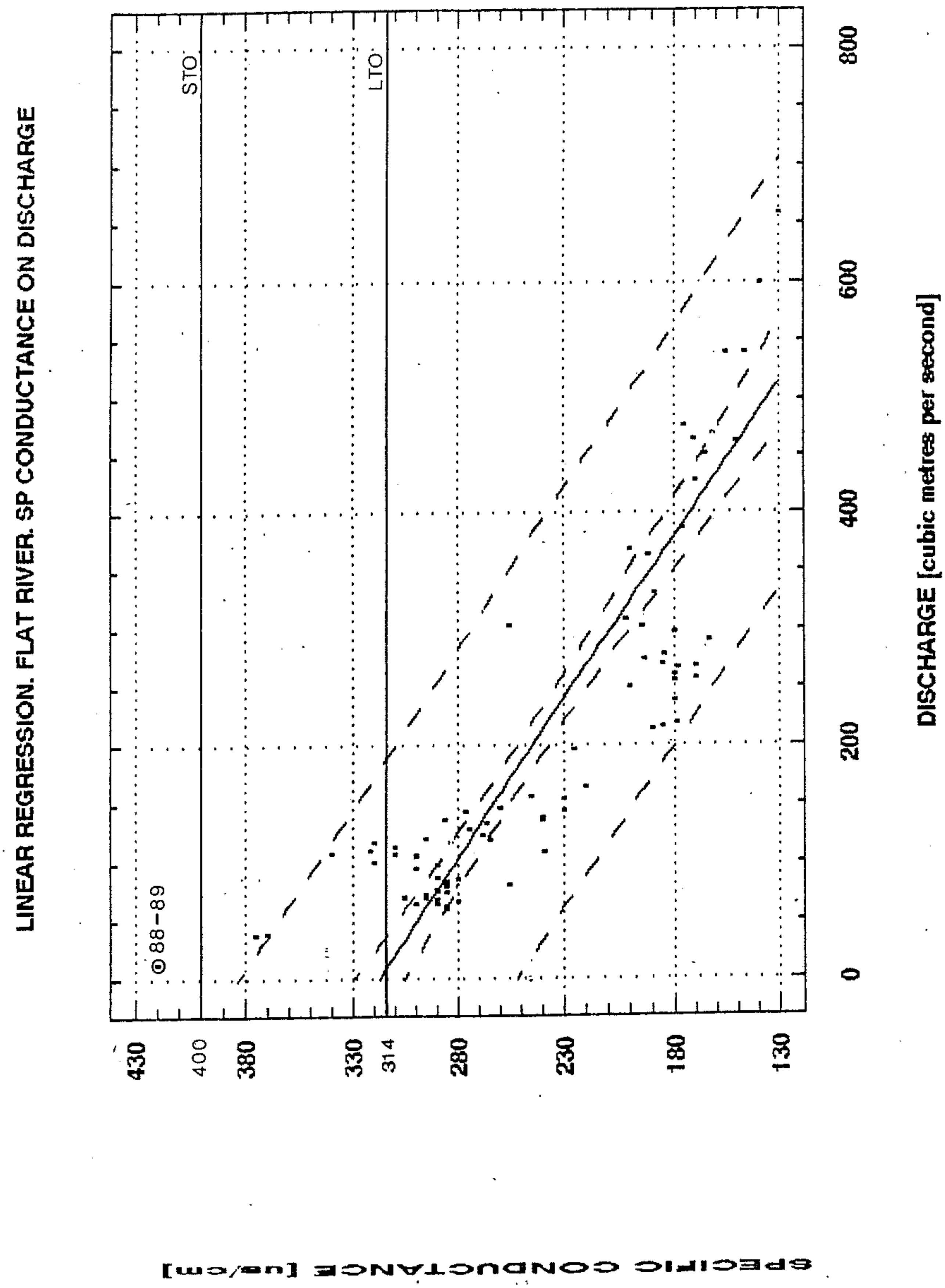


Figure 10. Flat River. Multiple Box-and-Whisker Plot. Dissolved Zinc.

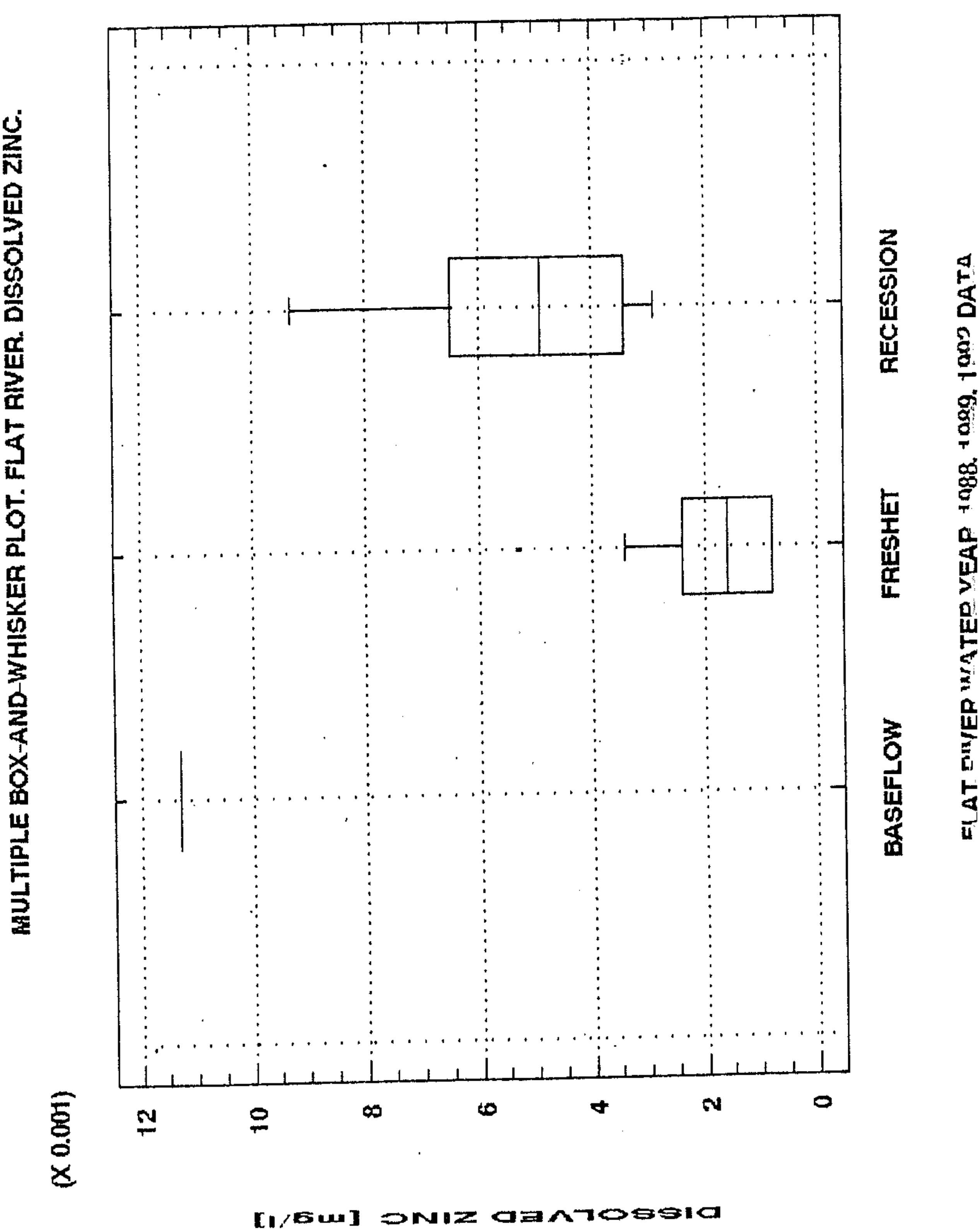


Figure 11. Flat River. Multiple Box-and-Whisker Plot. Total Copper.

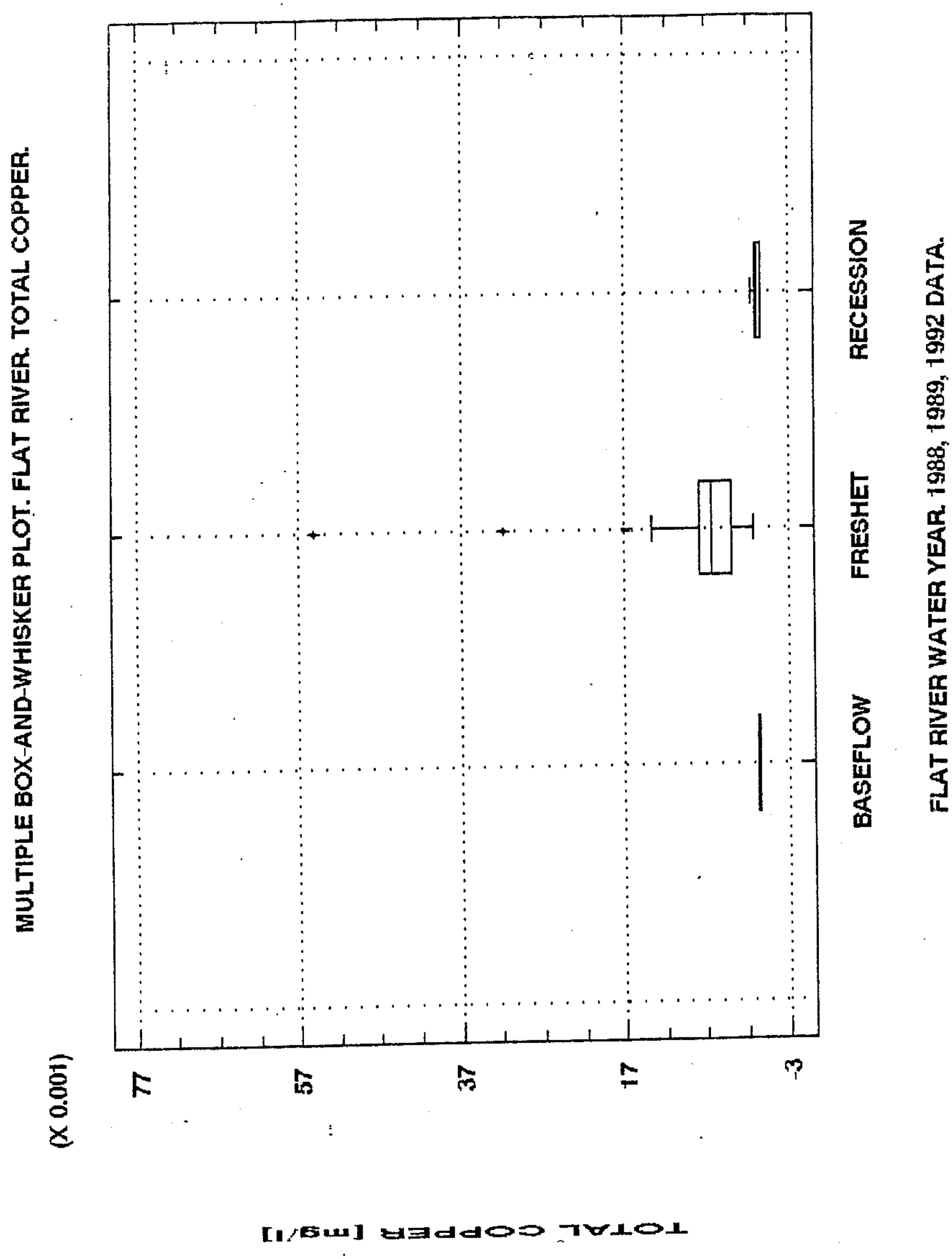
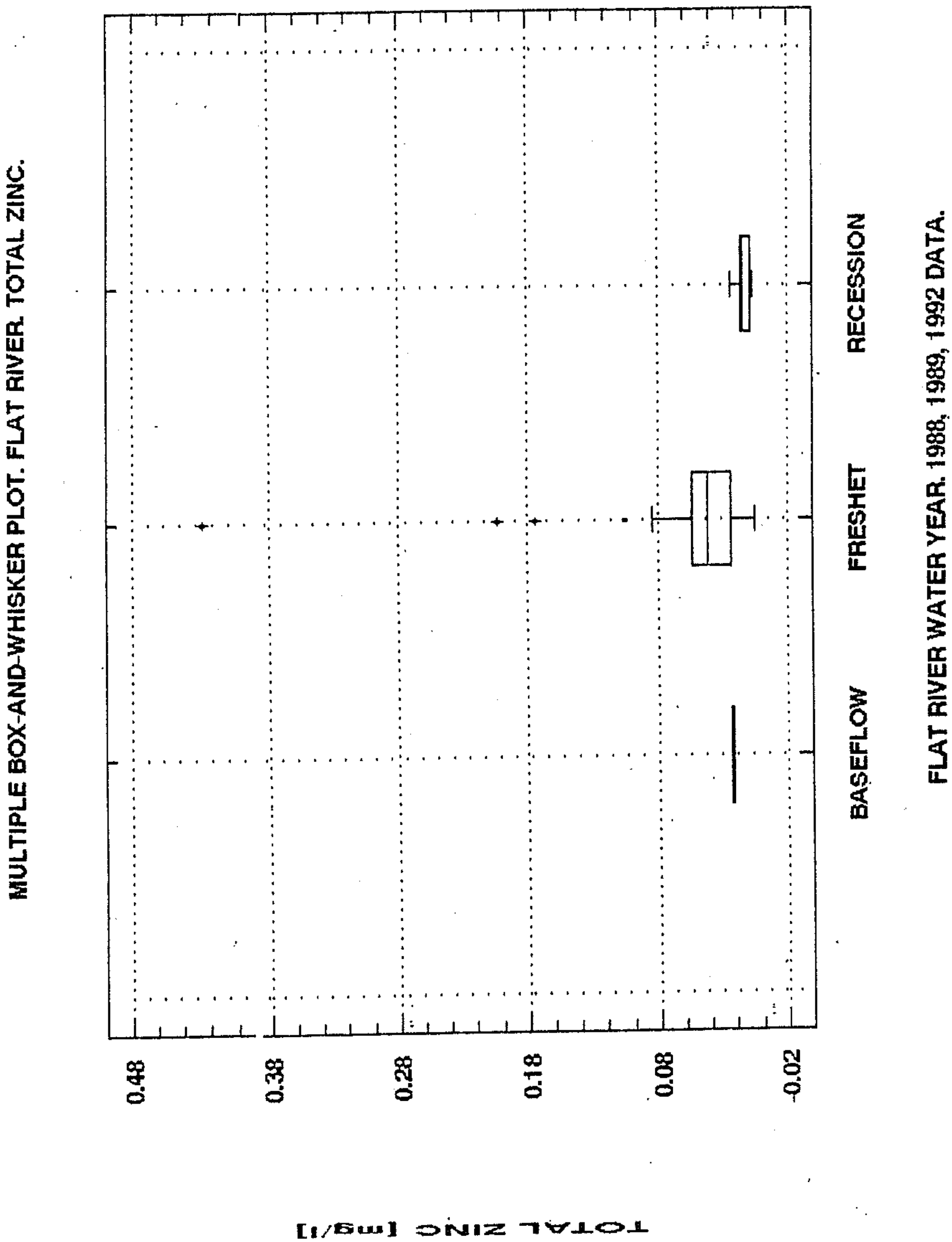


Figure 12. Flat River. Multiple Box-and-Whisker Plot. Total Zinc.



75th percentile range is known as the quartile range, or "hinge width". "Whiskers" extend above and below boxes to the highest and lowest values lying within 1.5 hinge widths above and below the median, respectively. Significant values not lying within 1.5 hinge widths of the median are considered "outliers" (shown individually).

Multiple box-and-whisker plots and percentiles involve ranked values of variables and non-parametric statistics. Such statistical parameters are, therefore, universally applicable to all variables whether or not they are Normally (or Lognormally) Distributed.

Figure 10 (for dissolved Zn) illustrates a negative discharge (Q) dependence relationship, involving dilution effects with high baseflow values, low freshet values and intermediate recession values. A similar pattern exists for dissolved Ni, Se, SO_4 and NO_3-NO_2. Figure 11 (for total Cu) illustrates a positive Q dependence, involving particulate effects and positive counterclockwise hysteresis; with low baseflow values, high freshet values and intermediate recession values. A similar pattern exists for NFR; extractable Fe and Mn; total cyanide; total Ba and V; and dissolved Cu and As. Figure 12 (for total Zn) illustrates a near-positive Q dependence relationship involving positive counterclockwise hysteresis and early flushing of particulates with intermediate baseflow values, high freshet values and low recession values. A similar pattern exists for NFR; extractable Fe and Mn; dissolved Pb; and total Co, Cu, Pb, Ni and V. Dissolved Cd exhibits a near-negative Q dependence relationship involving negative clockwise hysteresis and possible temperature dependence.
Figure 13 illustrates the seasonal behaviour for all water quality variables at all five water quality stations.

<u>Prairie Creek at Mouth Water Quality Station</u>

Table 3 in the Appendix shows the same relationships occur in Prairie Creek, where spring specific conductance is distinctly lower than in the fall, due to dilution during flashy spring freshet discharge and very low flows for the remainder of the open water season. 1988-89 specific conductances ranged from 230 to 440 us/cm. Much lower 1992 specific conductance values ranged from 160 to 395 us/cm, reflecting the higher flow rate in 1992.

Figure 14 (linear regression of total Zn on specific conductance) illustrates that some water quality variables are **negatively** correlated with specific conductance (and **positively** correlated with discharge). Such variables (Pearson's "r" in brackets) include total Cu (-0.6566), dissolved Pb (-0.5800), total Zn (-0.5390), total Ni (-0.5252) and dissolved Mn (-0.5184). Figure 15 (linear regression of dissolved Zn on specific conductance) exemplifies water quality variables **positively** correlated with

Figure 13. Seasonal Behaviour, Water Quality Variables at Five Water Quality Sample Sites.

Seasonal Behaviour	Negative Discharge Dependence, Dilution Effects	Positive Discharge Dependence, Particulate Effects	Positive Discharge Dependence, +ve CCW Hysteresis, Early Flushing of Particulates	Negative Discharge Dependence, +ve CW Hysteresis, Temperature Dependence	No Discharge Dependence, Positive Temperature Effects	No Discharge Dependence, Negative Temperature Effects
Water Quality Site Name/WQ Values	Baseflow Values > Recession Values > Freshet Values	Freshet Values > Recession Values > Baseflow Values	Freshet Values > Baseflow Values > Recession Values	Recession Values > Baseflow Values > Freshet Values	Recession Values > Freshet Values > Baseflow Values	Baseflow Values > Freshet Values > Recession Values
Flat R.near the Mouth	COND,NO3-NO2,SO4D NiD,SeD,ZnD	NFR,AsD,BaT,CuD, CuT,CN,FeE,MnE,VT	NFR,CoT,CuT,FeE, PbD,PbT,NiT,VT,ZnT CoT,CuT,MnE	CdD		
Prairie Ck. at Mouth	ZnD,NO3-NO2,COND, SO4D	VT,NiT,NiD,PbD,PbTMn E,FeE,CN,CuT,CuDCdT, CoT,NFR,AsD, BaT	ZnT,VT,CdT,NFR	ZnD,SeD,SO4D	pH	
So.Nahanni R.above Nahanni Bte	COND,SO4D	ZnT,VT,CuD,CuT,FeE PbT,MnE,NiT,CoT, CdT,AsD,NFR	NiT,NO3-NO2	SeD	pH,CN,PbD	ZnD,NiD
Rabbitkettle R. at Mouth	SO4D,COND	ZnT,VT,NiT,MnE,FeE CuT,CuD,CoT,BaT, AsD,pH,NFR	PbT,CdT,BaT	SeD	ZnD,NiD,CN,CoD	PbD,NO3-NO2
So.Nahanni R. above RabbitkettleR	SO4D,COND	ZnT,ZnD,VT,NiT,MnE PbT,CN,CuT,CoT,CuD CdT,BaT,AsD,NFR	ZnD,CuD	SeD,NiD	pH	PbD,NO3-NO2

Figure 14. Prairie Creek. Linear Regression of Total Zinc on Specific Conductance Showing LTO, STO, CWQG Exceedances.

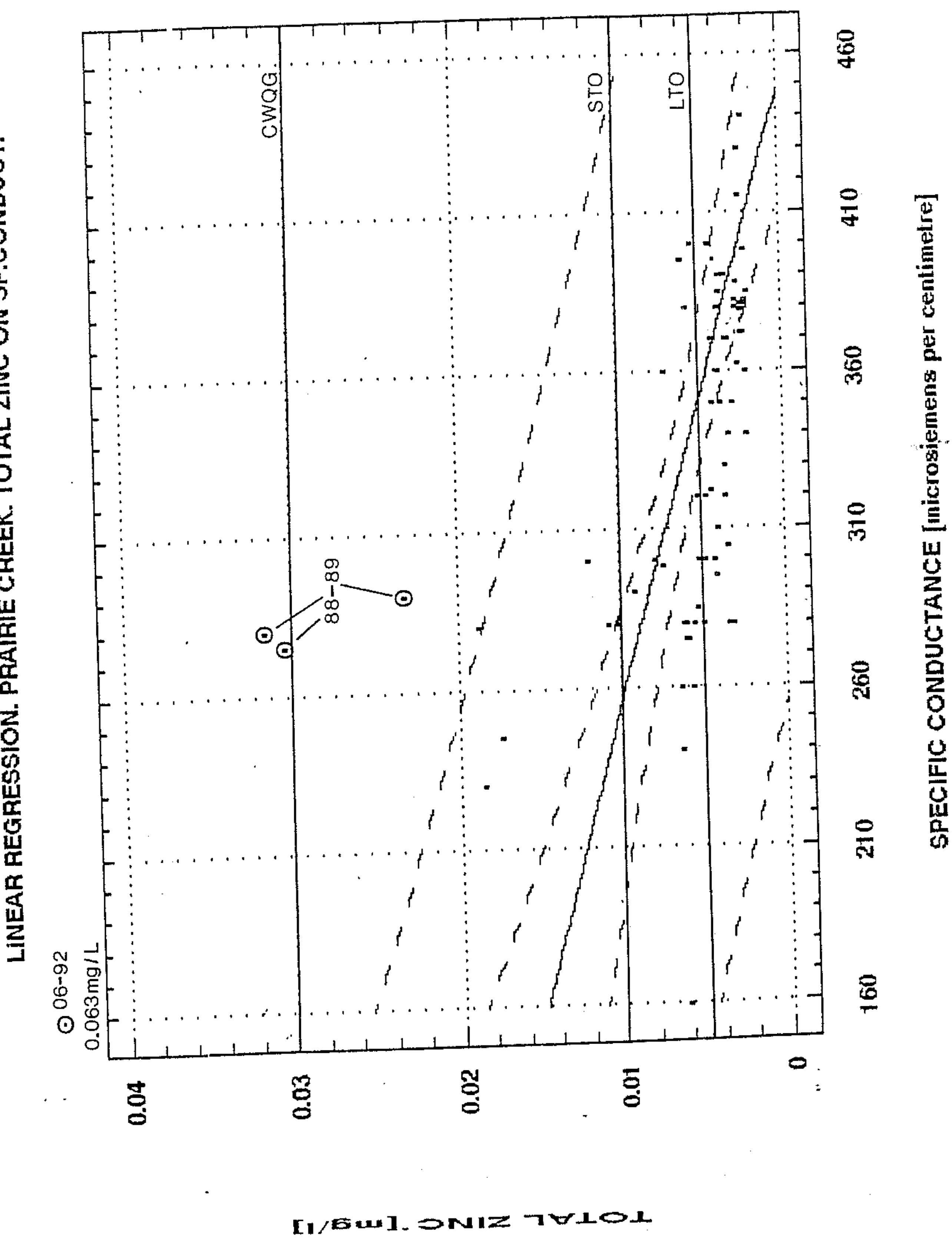
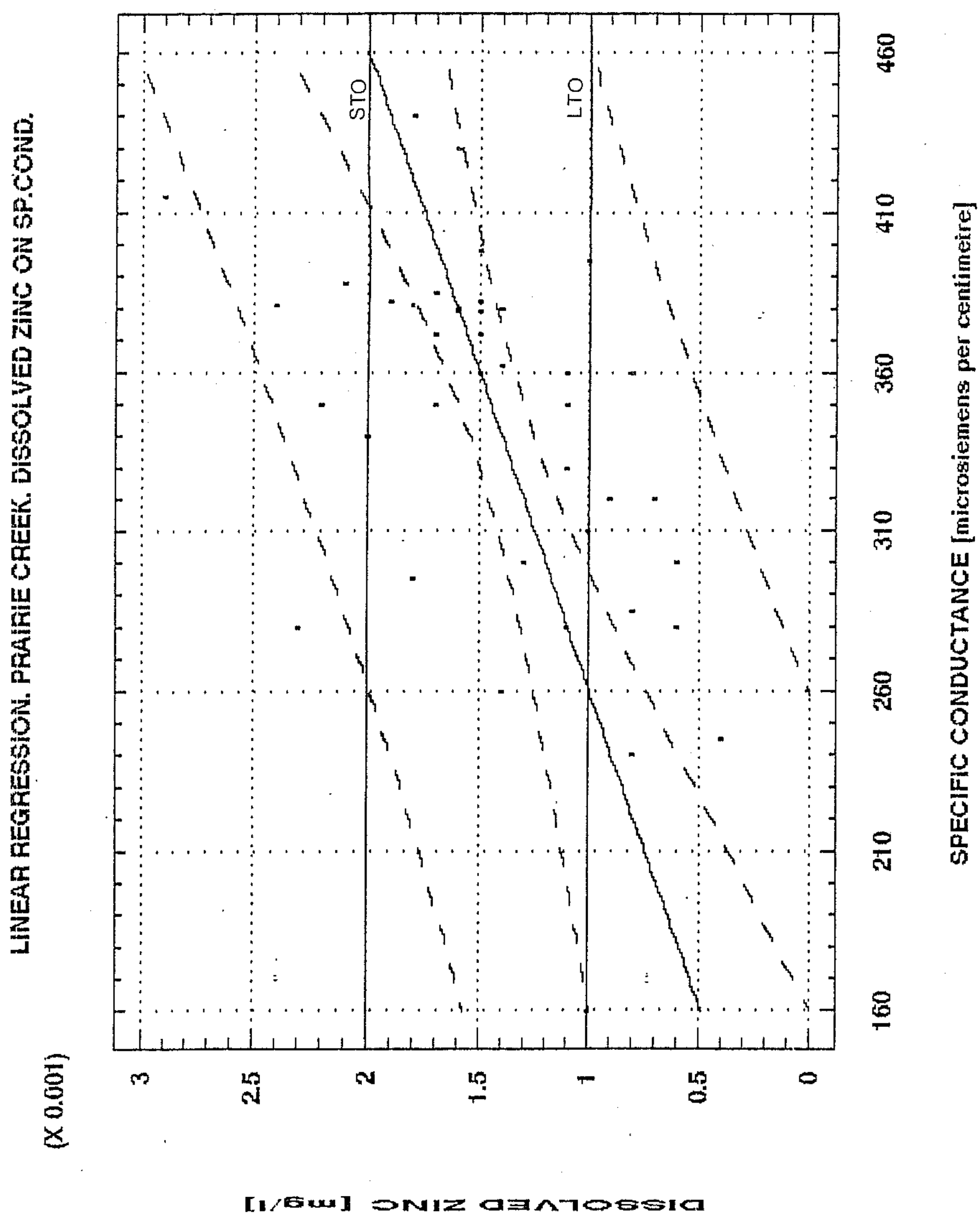


Figure 15. Prairie Creek. Linear Regression of Dissolved Zinc on Specific Conductance Showing LTO, STO, CWQG Exceedances.



specific conductance (and **negatively** correlated with discharge);such variables include dissolved SO_4 (r=+0.9216), dissolved Se (+0.8170), dissolved NO_3-NO_2 (+0.7172) and dissolved Zn (+0.5843). (linear regression of dissolved Zn on specific conductance).

Extractable Fe and Mn; NFR; total Cu, Pb, Zn, Ni, Co, Cd and V; and dissolved Pb, Fe and Mn are directly proportional to discharge. Dissolved Zn, Se, SO_4 and NO_3NO_2 are inversely proportional to discharge while pH; total cyanide; and dissolved Zn, Cu and As appear to be unrelated to discharge. Pb appears to be largely partitioned into the dissolved phase while Zn is largely partitioned into the particulate phase. No variables exhibit strong to moderate correlation (i.e. r >= +0.7) with specific conductance while only dissolved Se, SO_4 and NO_3-NO_2 exhibit strong to moderate negative correlation (i.e r <= -0.7).

Figure 13 illustrates that dissolved Zn, SO_4, NO_3-NO_2 and specific conductance exhibit a negative discharge (Q) dependence relationship and dilution effects. Extractable Fe and Mn; total cyanide; NFR; dissolved Pb, Cu, Ni and As; and total Pb, Cu, Ni, Co, Cd, Ba and V exhibit a positive Q dependence relationship and particulate effects. NFR and total Zn, V and Cd may have lower recession values than baseflow values, suggesting early flushing of particulates (i.e. positive counterclockwise hysteresis). pH values increase with increasing temperature, from the winter baseflow to the spring freshet to the summer recession. Dissolved Zn, Se and SO_4 exhibit a near-negative Q dependence relationship (i.e. negative clockwise hysteresis).

South Nahanni River Above Nahanni Butte Water Quality Station

Table 4 in the Appendix shows that less pronounced differences between spring and fall specific conductances occur in the South Nahanni River at Nahanni Butte, where 1988-89 data ranged from 190 to 370 us/cm, and more variable 1992 specific conductances ranged from 150 to 450 us/cm.

Data on flows is not available the Nahanni Butte water quality station. However, synthetic discharge data was produced by "routing" flows 55 kilometres down the mainstem South Nahanni River from Clausen Creek to Nahanni Butte. This was accomplished using a U.S. Army Corps of Engineers' SSARR algorithmn. These estimates of daily discharge for the 1988, 1989 and 1992 dates of water quality sampling were used for linear regressions against water quality variables.

Water quality variables **positively** correlated with discharge include dissolved Cu (r=+0.8901), total Cu (+0.7011), total Ni (+0.6985), total Cd (+0.6728), total V (+0.6716), total Zn (+0.6562), NFR (+0.6497) and extractable Fe (+0.6238). Water quality variables **negatively** correlated with discharge include specific conductance (r=-0.7056) and dissolved SO_4 (-0.5028). Dissolved As has a weak positive correlation with discharge. Nitrate-nitrite; pH; and dissolved Zn, Pb, Ni, Co and Se exhibit no apparent correlation with discharge.

Extractable Fe and Mn; NFR; total cyanide; total Cu, Zn, Pb, Ni, Co, Cd, Ba and V; and dissolved Cu are directly proportional to discharge. Specific conductance and dissolved SO_4 are inversely proportional to discharge while pH; NO_3-NO_2; and dissolved Zn, Ni, Pb and Co appear to be unrelated to discharge. The elements Cu, Pb and Co appear to be weakly partitioned into the dissolved phase and nothing appears to be partitioned into the particulate phase. Only total and dissolved Cu exhibit strong to moderate correlation (i.e. r >= +0.7) with discharge while only specific conductance exhibits strong to moderate negative correlation (i.e r <= -0.7).

Figure 13 shows that specific conductance and dissolved SO_4 are effected by dilution effects and exhibit a negative discharge (Q) dependence relationship. NFR; extractable Fe and Mn; dissolved Cu and As; and total Cu, Zn, Pb, Ni, Co, Cd and V are effected by particulates and exhibit a positive Q dependence relationship. Total Ni and NO_3-NO_2 exhibit a positive Q dependence relationship with positive counterclockwise hysteresis due to early flushing of particulates. Dissolved Se baseflow, freshet and recession values suggest a negative Q dependence relationship and a positive temperature dependence relationship. Positive temperature dependence is exhibited by pH, total cyanide and dissolved Pb. Negative temperature dependence is exhibited by dissolved Zn and Ni.

Rabbitkettle River At Mouth Water Quality Station

Table 5 in the Appendix shows that 1992 specific conductances at Rabbitkettle River ranged from 150 to 315 us/cm, compared to 105 to 250 us/cm in 1988-89. 1992 specific conductances at South Nahanni River above Rabbitkettle River ranged from 130 to 370 us/cm, compared to 140 to 300 us/cm in 1988-89.

Like Prairie Creek, flow data is not available for Rabbitkettle River nor can it be reliably estimated. StatGraphics software was used with the Flat River water quality database to produce a correlation matrix. Discharge is more strongly, albeit negatively, correlated with specific conductance (Pearson's "r" of -0.9351 for n=28 values) than any other water quality variable, as expected. Linear regressions of water quality variables were carried out against specific conductance at the Rabbitkettle River water quality sites.

Strong to moderate negative correlations (r <= -0.7) exist between specific conductance and dissolved Cu (-0.9461), extractable Mn, total V, total Co, extractable Fe, total Zn and NFR; indicating strong positive correlation with discharge. Dissolved SO_4 exhibits a strong negative correlation with discharge as indicated by a +0.8158 "r" value against specific conductance.

NFR; extractable Fe and Mn; dissolved Cu, Zn, Ni and As; and total Cu, Pb, Zn, Ni, Co, V, Cd and Ba are directly proportional to discharge. Dissolved Pb, Se and SO_4 are inversely proportional to discharge while pH, total cyanide and NO_3NO_2 appear to be unrelated. Pb is partitioned largely into the particulate phase while Cu, Zn and Ni are partitioned largely into the dissolved phase. Sixteen of 21 water quality variables exhibit some correlation with discharge, eight of these exhibiting strong to moderate correlations.

Figure 13 shows that a negative discharge (Q) dependence relationship, suggesting dilution effects, is exhibited by specific conductance and dissolved SO_4. A positive Q dependence relationship suggesting particulate effects is exhibited by NFR; pH; extractable Fe and Mn; dissolved Cu and As; and total Cu, Zn, Ni, V, Co and Ba. Total Pb, Cd and Ba have a near-positive Q dependence relationship with positive counterclockwise hysteresis, suggesting effects of early flushing of particulates. Total cyanide and dissolved Zn, Ni and Co exhibit positive temperature dependence relationship, values increasing from the winter baseflow to the spring freshet to the summer recession. Dissolved Pb and NO_3-NO_2 exhibit a negative temperature dependence relationship. Dissolved Se exhibits a negative temperature dependence relationship with negative clockwise hysteresis.

<u>South Nahanni River Above Rabbitkettle River Water Quality Station</u>

The South Nahanni River above Rabbitkettle River water quality station (Table 6 in the Appendix) lacks a currently operating hydrometric station. Furthermore, stage (water level) and discharge (flow rate) data cannot be "routed" (extrapolated) upstream from Virginia Falls hydrometric station. Therefore, linear regression of water quality variables was carried out on specific conductance instead of discharge.

Strong to moderate negative correlations (i.e. $r <= -0.7$) exist between specific conductance and dissolved Cu (-0.7861), total Zn, extractable Mn and total Co and NFR; indicating strong positive correlation with discharge. Dissolved Ba and SO_4 exhibit strong negative correlations with discharge as indicated by a +0.9887 and +0.9124 "r" correlation coefficients with specific conductance.

NFR; total cyanide; extractable Fe and Mn; dissolved Cu, Pb, Zn, Cd, Co and As; and total Cu, Pb, Zn, Ni, Co, V and Ba are directly proportional to discharge. Dissolved Se, Ni, Ba and SO_4 are inversely proportional to discharge while pH and NO_3NO_2 appear to be unrelated. Ni and Ba are partitioned largely into the particulate phase while Cu, Pb, Zn and Co are partitioned largely into the dissolved phase. Fourteen of 24 water quality variables exhibit some correlation with discharge, five of these exhibiting strong to moderate correlations.

A negative discharge (Q) dependence relationship suggesting dilution effects is exhibited by specific conductance and dissolved SO_4. A positive Q dependence relationship suggesting particulate effects is exhibited by NFR; total cyanide; extractable Fe and Mn; dissolved Cu, Zn and As; and total Cu, Pb, Zn, Ni, V, Co, Cd and Ba. Dissolved Cu and Pb have a near-positive Q dependence relationship with positive counterclockwise hysteresis. pH values exhibit positive temperature dependence relationship, values increasing from the winter baseflow to the spring freshet to the summer recession. Dissolved Pb and NO_3-NO_2 exhibit a negative temperature dependence relationship. Dissolved Se and Ni exhibits a negative temperature dependence relationship with negative clockwise hysteresis (i.e. intermediate baseflow values, low freshet values, high recession values).

Non-Filterable Residue (NFR) Values

Non-filterable residue (NFR) is a measure of suspended particles such as silt, clay and organic matter. Large glaciolacustrine deposits of silts and clays occur in valleys of the South Nahanni River Basin. Easily eroded, these are supplied to the river as suspended load. NFR is directly proportional to flow rate and reaches a maximum during the June-July flow peak at Flat River and, to a lesser extent, Prairie Creek. Prairie Creek flows through a resistant canyon and has a smaller supply of erodable material (Environment Canada, 1991).

The positive correlation between NFR and discharge is not as strong as the negative correlation between specific conductance and discharge. Banks are frozen at the start of the spring high flows. Bank slumps occur unrelated to flow. Rainfall events cause localized sediment contibutions. Variable particle sizes remain in suspension for different lengths of time. The turbid matter is largely inorganic and settles out rapidly in quiet waters. The seasonal-temporal variability of NFR results in spectacular NFR peaks corresponding to peak spring water flows (Environment Canada, 1991).

The June 4, 1992 water quality samples were collected right during the peak flow at Flat River (Figure 4) and the other four stations. 1992 high water NFR values of 996 mg/l (Flat), 463 mg/l (Prairie), 1204 mg/l (Nahanni Butte), 129 mg/l (Rabbitkettle) and 333 mg/l (South Nahanni above Rabbitkettle) contrast with 1992 low water NFR values of 8 to 16 mg/l, <1 to 2 mg/l, 2 to 12 mg/l, 1 to 14 mg/l and 5 to 25 mg/l; respectively.

pH Values

pH values are known to become depressed by up to 1.0 pH unit during heavy rainfall events in the Western Cordillera, of which the South Nahanni River Basin is a part (Whitfield and Dalley, 1987). In this study area during 1988-92, pH appears unrelated to discharge with the exception of the Rabbitkettle River station where pH went up during the spring freshet and down during the recession. At the other four stations, the pH exhibited temperature dependence increasing from late winter (baseflow) to spring (freshet) to summer-fall (recession). The effect of the greater contribution of higher pH, carbonate-rich groundwater during the late winter baseflow period appears to be negligible. The effect of surface waters appears to dominate.

In the relative sense, lower pH values due to increased discharge do not occur in the 1988-89 and 1992 freshet water data. In the absolute sense, the waters of the Reserve have higher pH values relative than much of the eastern Northwest Territories due to the abundance of carbonate rocks, such as limestones and dolostones. Most of the eastern N.W.T. is underlain by gneisses, meta-intrusives and lesser "greenstones" of the Canadian Shield, and are less capable of buffering acidic rainfall.

Nutrients Values

Nutrients; such as nitrogen, phosphorus and carbon in various chamical forms; exhibit spatial and temporal variabilities. Several of the nitrogen and phosphorus forms are essential for plant growth, and seasonal cycles tend to mirror periods of productivity. Orthophosphate and nitrate-nitrite decline in concentration during summer and fall due to biological uptake and dilution and flushing of the compounds from the system. Particulate-associated nitrogen and phosphorus are at low levels in the winter and peak in spring (Environment Canada, 1991).

4.3 Significance and Variability of Metals

Metals can pose a threat to the health of the aquatic system, due to their toxicity to organisms, bioconcentration within organisms, biomagnification within the food chain and resultant human health hazards. Existing levels of metals in the South Nahanni River Basin are very low and likely from natural sources. Increased mining activity could increase metal concentrations in the water, adversely affecting resident biota that are adapted to natural levels (Environment Canada, 1991).

The impact of metals is determined by their availability to aquatic life. Toxicity is influenced by physico-chemical characteristics of metals in dissolved and particulate states and chemical properties of the water. Dissolved metals are more readily available for biological uptake than particulate or extractable metals.

Sediment-related metals can be directly ingested. Sediments are of biological importance as regulators of elements in the dissolved state when physical and chemical interchanges between the solute and particulate phases occur (Environment Canada, 1991). Anthropogenic chemicals from point or diffuse sources can be scavenged (adsorbed) by fine sediment particles at any point along pathways from source to sink (Thomas and Meybeck, 1990).

Heavy metals are often concentrated in the sediment loads of the first flush of storm runoff. Annual heavy metal loadings from small catchments require accurate sediment load determination on a storm by storm basis. Long-term metal loads of major river systems are usually dominated by particulate sources during flood flows or by particulate scavenging any time a sediment concentration increases (Bobba and Ongley, 1987).

Despite the physiological need of aquatic organisms for many metals, bioaccumulation of concentrations exceeding biological needs may be toxic to organisms. Effects include impaired reproductive capacities, retarded growth and maturation of juveniles, shorter lifespans, decreased viability of populations and reduced species diversity (Environment Canada, 1991).

Biomagnification of metal in aquatic food chains is a major concern. Metals are accumulated in fauna and flora; the upper trophic levels (including humans) may receive highly elevated concentrations of metals when they were originally present in aqueous form at low or undetectable concentrations. Human exposure to high metal levels (e.g. lead, mercury, aluminum) may cause neurological and physiological impairment (Environment Canada, 1991).

Metals exhibit temporal and spatial variability for both total amounts and amounts present in various phases. Under natural conditions, metals can be found dissolved in water or attached to solid matter. The chemistry of the metal and ambient physical and chemical conditions (e.g. pH, Eh or oxidation potential, temperature, atmospheric pressure, dissolved oxygen content, salinity) play important roles. Most of the metals, particularly iron and manganese, are transported almost entirely in association with solids (Environment Canada, 1991). Copper (Cu), Hg, Cr and Pb also occur largely in the particulate phase with particles finer than 0.45 micrometers (Bobba and Ongley, 1987). Arsenic (As) and Se exist predominantly in the dissolved state. Metals in the dissolved phase shift in equilibrium towards the solid phase, this occurring along the course of a river under regular flow conditions. Exchange of metals between the dissolved and solid-associated phases results from changes in pH, Eh, salinity and other factors (Environment Canada, 1991).

The seasonal temporal pattern of metal concentrations depends on whether metals occur in the dissolved or extractable phase. Changes in total concentration and in the proportion of metals in the dissolved or solid-associated state occur over the year, reflecting changes in metal sources, flow and sediment regimes, and biological uptake. Metals introduced from point sources, such as mines or municipalities, are diluted during high flow conditions. Metals from natural sources, such as bank erosion, may be increased or diluted as metals are mobilized from the drainage basin in solution and associated with mineral and organic solids (Environment Canada, 1991).

Dissolved metal concentrations peak during periods of low flow and low sediment concentration. Copper (Cu), Mn and other metals essential for biological activity may decline in the dissolved phase as the available fraction is assimilated by organisms for growth and reproduction (Environment Canada, 1991).

Solid-associated metals increase in the spring along with the flow and sediment levels, with concentrations remaining low during the rest of the year. They may also respond to short-term fluxes in the summer and fall sediment regimes. The seasonal pattern is evident from 1988-89 and 1992 Nahanni Butte data, where the sum of metals throughout the basin is accumulated, and in the 1988-89 and 1992 Prairie Creek data, where metal concentrations are extremely low. In both cases, the metals concentration is highest and most variable during the spring freshet (Environment Canada, 1991). This is readily shown in multiple box-and-whisker plots (Figures 10-12).

Metal concentrations in the basin did not appear to be of concern in the 1988-89 and 1992 studies as levels were almost always below water quality guidelines for the protection of aquatic life (Appendix II). More exceedances were noted during the 1992 study than during the 1988-1989 study, due to higher discharges (Figures 2-4) and collection of samples during peak 1992 spring freshet discharges (e.g. June 4 at Flat River). Generally, existing concentrations are not a threat to the health of the aquatic ecosystem.

1988-89 metal concentrations in fish tissue from the Flat River were not significantly above background levels (Environment Canada, 1991).

Following the September 1992 survey at Prairie Creek, Caroline Lafontaine and Ann Wilson of DFO Yellowknife noted in their August 1993 report that As and Pb were not detected in 17 fish (arctic grayling, longnose sucker, burbot) collected from two sites on the South Nahanni River just downstream of Prairie Creek. Mercury (Hg) and Ni were present in trace amounts. Copper (Cu) and Zn were found in concentrations similar to those recorded for fish living in an environment modified by mining activities. Cadmium (Cd) concentrations reported were somewhat unusual for an undisturbed system. Further monitoring was recommended at two year intervals (i.e. next sampling in September 1995?) and with a minimum of 10 specimens of each of the fish species present (or at least species targetted by sport fishermen) to assess the levels of heavy metals in fish tissue.

Interpretation of metal in suspended sediments is not possible due to lack of particle size information and guidelines on sediment for the protection of aquatic life. They do provide a baseline, however, and will become more useful when sediment guidelines are established (Environment Canada, 1991). High (per cent) values were noted for total iron and total aluminum. High total iron values are believed to be due to the presence of exposures of pink, yellow and orange "Sunblood Formation" limestone and lesser dolostone and sandstone in all sub-basins with the exception of Prairie Creek. Prairie Creek is a minor contributor to the water and sediments downstream at Nahanni Butte and iron sulphide (i.e pyrite, marcasite) gangue minerals may be associated with Pb-Zn-Ag mineralization near the Cadillac Mine. The high aluminum values are likely due to contamination from techniques employed for handling suspended sediment samples before analysis, such as using aluminum foil to help seal sediment jars (a situation remedied in 1993). Aluminum is low in Nahanni Butte stream waters, suggesting it is not a real environmental concern.

5.0 WATER QUALITY MONITORING

5.1 Background

Water quality **objectives** are a commonly used tool, in Canada and abroad, for managing discharges to waterbodies so that water is not degraded and is of suitable quality for all present and future uses at a specific site. In Canada, the Canadian Water Quality **Guidelines** (CWQG) provide the basic scientific information for the establishment of objectives (CCREM, 1992). The Guidelines have been developed by different methods depending on the need, issues, parameters and variables of concern, the amount of available data and other factors. By protecting the most sensitive water use (i.e. usually freshwater aquatic life), all other uses are also protected. The approach used is tailored to suit the needs of the water body concerned and the purposes of the responsible water management agency (Blachford, 1988).

The water quality objectives approach requires the collection of data on the ambient water quality conditions, development of water quality objectives and on-going water quality monitoring. If the objectives are exceeded; the cause, extent and severity of the exceedance must be investigated. Action can then be taken to address the cause of the elevated water quality values (Environment Canada, 1991).

Since research on environmental and human health impacts is incomplete, water quality objectives must be reviewed on a routine basis. New scientific information must be incorporated into the objectives as it becomes available and modifications to existing objectives must also be considered. On-going evaluation is required to ensure that the objectives are protecting the resource (Environment Canada, 1991).

Water quality objectives developed for Nahanni National Park Reserve in 1991 represent the first objectives designed for Canada's north. Nahanni National Park water quality objectives were derived using a similar approach to those developed for protection of recreational and fish consumption end uses at Prince Albert National Park (Blachford, 1988) and Waterton Lakes National Park (Blachford, 1990). Some caution is required when extending use of objectives developed for more temperate, Boreal Plain and Boreal Shield Prairie Ecosystems to the more rugged and subarctic Tundra Cordillera Ecosystem as our knowledge of the more northerly ecosystem is not as complete. The assumptions regarding safe levels of contaminants are, therefore, less well founded. The scientific knowledge base from which objectives are developed is substantial, however (Environment Canada, 1991).

5.2 The Approach

An unique approach was adopted for the development of water quality objectives in Nahanni National Park Reserve, due to the goal of complying with Parks' policies on environmental conservation and the Nahanni National Park Regulations management plan. These state that natural resources will be managed with minimal interference to the natural processes, and that Park waters will be protected to ensure that no unnatural change in water quality occurs. The approach recognizes that existing and future mining activities outside the Park Reserve could seriously alter the natural water quality conditions, impacting on park aquatic life (Environment Canada, 1991).

A two-level approach, involving short- and long-term indicators has been developed by the Prairie Provinces Water Board. Water quality variables are monitored in conjunction with river discharge, and data summarized statistically parameters to aid in the formulation of indicators. All water quality variables are tested for seasonality to establish whether separate ice-cover and open water indicators are needed, or a single annual indicator is adequate. Maximum acceptable concentrations are derived from the available literature on the effects of various elements on biota (Blachford, 1988).

Short-term indicators or objectives (STO's) are also required to protect the Park waters and the aquatic biota from large deviations in water quality conditions. Aquatic organisms can be stressed by short duration fluctuations in water quality concentrations that are outside the naturally-occuring range, or near the high or low ends of the natural range for longer periods of time than during regular seasonal cycles. Short-term objectives also address possible impacts from accidental or planned releases from mines and related activities (Environment Canada, 1991). Values are usually not seasonally differentiated. Concerns related to acute toxicity are addressed by consideration of the maximum acceptable concentration (Blachford, 1988).

Long-term indicators or objectives (LTO's) are required to characterize existing, or unspoiled, water quality conditions. Deviations from long-term objectives are a warning that that status of water quality in the Park is changing (Environment Canada, 1991). Long-term monitoring is required to show trends occuring over a long period of time, and for comparison with annual and seasonal means of historic data (Blachford, 1988).

A methodology used for total dissolved solids (TDS) and boron at Poplar River, Saskatchewan also accounts for seasonality and is sensitive to discharge (flow) rate. This methodology is more issue-based, has a mandatory review period and utilizes three-month and five-year flow-weighted means for STO's and LTO's, respectively (Blachford, 1988).

Nahanni National Park Reserve lies within the little-studied Tundra Cordillera Ecozone. The Park's South Nahanni River and its tributaries are "flashy" mountain streams characterized by spring snowmelt, summer rainstorms and winter low flow periods similar to those in British Columbia and the Yukon, not the prairie rivers found in in Prince Albert and Waterton National Parks.

The methodology for Nahanni Park water quality objectives therefore must allow for seasonality. The STO's were determined by selecting 90th percentile values from the available study period dataset. As non-parametric statistics, they are not sensitive to population distribution type and assume neither Normality nor Lognormality.

The percentile methodology used has its limitations, however. Many values exceeding STO's are due to natural conditions, such as high discharge rates with coincident low specific conductances. The 1992 South Nahanni freshet discharges exceeded those of 1988 and, especially, 1989. Water quality samplers were able to collect water quality samples at the peak of the 1992 spring freshet, especially at Flat River, on June 4. This sample timing resulted in a large number of exceedances of the STO's, which were related to the lack of data for high discharge conditions rather than any change in natural basin conditions.

5.3 Water Quality Objectives

The short- and long-term water quality objectives for the five current water quality stations in Nahanni National Park Reserve are presented in Table 7.

The data from the Rabbitkettle and South Nahanni stations upstream of their confluence defines the water quality for the Park. Both have mineral occurrences and claims in their headwaters. The Flat River near its mouth is a major inflowing tributary and is downstream from the mothballed Canada Tungsten Mine. Abundant mineral occurrences and claims exist near the Flat River and its major tributary, the Caribou River (Gordey and Anderson, 1993). The Cadillac Mine was constructed in the Prairie Creek watershed; it did not go into full production. The Nahanni Butte station represents water leaving the Park (Environment Canada, 1991).

Long-term indicators or objectives (LTO's) are calculated as the range of values +/- two standard deviations from the seasonal (open water and ice cover) or annual (for variables not exhibiting seasonality) mean concentration. They are developed to show trends which may occur over a period of time and compare annual or seasonal means between future and historical data (Blachford, 1988).

Nahanni Park LTO's have been developed as the average water quality variable values over the period of record (1972-1990 for Flat River, 1988-89 for the other four sites). The use of means and standard deviations was avoided by using non-parametric statistics to avoid making assumptions concerning the Normality or Lognormality of distributions. The values were selected as appropriate because flow conditions during 1988 and 1989 appeared to be typical (slightly above and below the historic means, respectively) and water quality values are strongly governed by discharge. At Flat River, study data and historic data also suggested that study period water quality was typical of long-term conditions (Environment Canada, 1991).

Short term indicators, or objectives (STO's) are calculated as a value midway between the mean annual concentration and the maximum acceptable concentration. These are not seasonally differentiated. Concerns related to acute toxicity are addressed by consideration of the maximum acceptable concentration (Blachford, 1988).

STO's for the Nahanni have been derived as the ninetieth percentile value over the period of record. This value includes almost all values on record except for infrequent outlier values well outside the range of values (Environment Canada, 1991).

Table 7 shows that the LTO's and STO's are well below (generally, several orders of magnitude) Canadian Water Quality Guidelines (1992) for freshwater aquatic life. Fully 50% of all 1988 and 1989 water quality values for the monitoring sites are at or below the lower laboratory method detection limits (MDL's).

At such low concentrations, it becomes important to understand certain limitations of laboratory analyses and results. For example, total and dissolved metal values near MDL's for atomic adsorption and induced coupling argon plasma (ICAP) lack precision and accuracy. This explains why the STO for dissolved Zn at the South Nahanni River above Rabbitkettle River is 0.499 mg/l while the corresponding value for total Zn is only 0.034 mg/l. Lab technology improvements resulted in ICAP- atomic emission spectroscopy (AES) became the standard method used by the Environment Canada's National Laboratory for Environmental Testing (NLET) in Burlington, Ontario midway through 1992.

The same situation occurred for dissolved versus total concentrations for Ni at Flat River and Nahanni Butte, Pb at the two upstream water quality sites, Cu above Rabbitkettle River and Co at the mouth of Rabbitkettle River in 1992.

5.4 Interpretation of Objectives

Water quality data collected at the monitoring sites needs to be compared with the water quality objectives on a regular basis to assess whether or not they are within the natural variability.

STO's apply to single water quality grab samples, which can be directly compared to STO's. The same values are then rolled up into average values and compared to LTO's. Exceedance of STO's may or may not be a cause for concern. Flashy rainfall events, common in the summer in the Cordillera, often result in extreme erosion and elevated concentrations of sediment-related metals. This natural occurrence would not require a management response in spite of exceedance of an objective. An exceedance not explainable by natural factors alone should be investigated and appropriate action taken.

Data collected for each variable has to be averaged over time and compared to the LTO's. Values from all seasons can be combined. At the minimum, data should represent spring freshet and fall recession conditions. Any positive or negative departure could be significant. The comparison is, however, somewhat subjective because the objectives are based upon a limited number of years of data and may not be representative of long-trem natural variability. LTO's constitute the best information available at the time, and should be used until more comprehensive information becomes available.

Manugistics' StatGraphics Version 6.0 software was used to carry out linear regressions of water quality variables on either discharges measured at the IWD gauging station on the Flat River, calculated discharges at Nahanni Butte (where hydrometric data from the Clausen Creek hydrometric station can be "routed" downstream to the Butte), or specific conductance (at the other three stations, where no discharge data is available). Specific conductance was used in lieu of discharge for these sites because of its well-known, worldwide strong negative correlation with discharge. Flat River correlation matrix data confirms this pattern (e.g. Pearson's "r" of -0.9351).

For 1992 data, "natural factors" was interpreted to be "within the 95% confidence and prediction limits 'envelopes' about the appropriate linear regression line". Values exceeding STO's, but lying within the 95% confidence and prediction limits of linear regression lines were considered to be the result of natural causes and not a cause for concern. Values both exceeding STO's and prediction limits of linear regression lines were identified for further analysis. Action should be taken if an anthropogenic cause can be determined for exceedances.

5.5 Application of the Objectives

Water quality objectives serve as in-stream environmental targets, or alert values, providing early warning of environmental conditions. The objectives alert future upstream developers to requirements for maintenance of ambient water quality conditions. The historic South Nahanni watershed dataset collected by Environment Canada, DIAND and other entities serves as baseline data for developers. Developers should incorporate mitigative measures to ensure operations meet these environmental targets.

The mining industry conducts preliminary feasibility studies to determine the most cost-effective and environmentally-acceptable methods for mining, milling and mine/ mill decommissioning. The associated total cost estimates for the most likely (base) case and other (sensitivity analysis) cases permit the developers to decide whether or not to proceed with mine development and operation.

LTO's and STO's are intended for early detection of arising environmental problems. Water quality concerns should be addressed in a proactive way during the planning stage, however, and not later, when dealing with an adverse environmental change or impact. Regulatory agencies (e.g. DIAND) should be involved during planning and operation phases to ensure permit, lease and licence conditions will and are being met.

Exploration and development activities in the N.W.T. are screened by the N.W.T. Water Board, DIAND's Regional Environmental Review Committee, etc. The Parks Canada staff will participate in these screenings.

The water quality monitoring strategy for Nahanni Park involves provision of information on the state of the aquatic environment, for comparison to LTO's and STO's. Inland Waters Directorate and Parks Canada should also participate when effluent quality standards are being established at sites in the watershed during the water licencing process. Effluent standards need to reflect the LTO's and STO's developed for the Park.

Water quality monitoring for the purpose of compliance with LTO's and STO's needs to continue after temporary or permanent closures of mine and mill facilities. Proper decommissioning of facilities is also important to ensure that Park waters aren't degraded after mining activities are completed.

5.6 LTO, STO and CWQG Exceedances Observed in 1992 Data

Long-Term Objective (LTO) Exceedances

At the Flat River station, averages of April, June and September 1992 data resulted in LTO exceedances (excursions) for NFR; NO_3-NO_2; SO_4; total cyanide; total Ba, Cd, Co, Cu, Pb, Ni and Zn; extractable Fe and Mn; and dissolved Co, Cu, Pb and Se. Further monitoring is needed to determine whether natural or anthropogenic long-term changes in the water quality are actually occurring.

For the Prairie Creek station, LTO exceedances were also noted for NFR; NO_3-NO_2; SO_4; total cyanide; total Cd, Pb, Ni, V and Zn; extractable Fe and Mn; and dissolved Cu, Pb and As. Further monitoring is required to discern if natural or anthropogenic long-term changes are actually occurring.

At Nahanni Butte, LTO exceedances were observed for specific conductance; NFR; SO_4; total cyanide; total Ba, Cd, Cu, Ni, V and Zn; extractable Fe and Mn; and dissolved Cd, Co, Ni, Se and Zn. Since the Nahanni Butte site integrates exceedances from upstream locations, these results are to be expected here. Further monitoring of long-term trends is warranted, at least until upstream changes can be identified.

At Rabbitkettle River, LTO occurrences were also observed for pH; specific conductance; NO_3-NO_2; SO_4; and total Cd, Co, Cu, Pb, Ni and Zn. Future monitoring of this station to discern long-term changes in water quality appears is recommended.

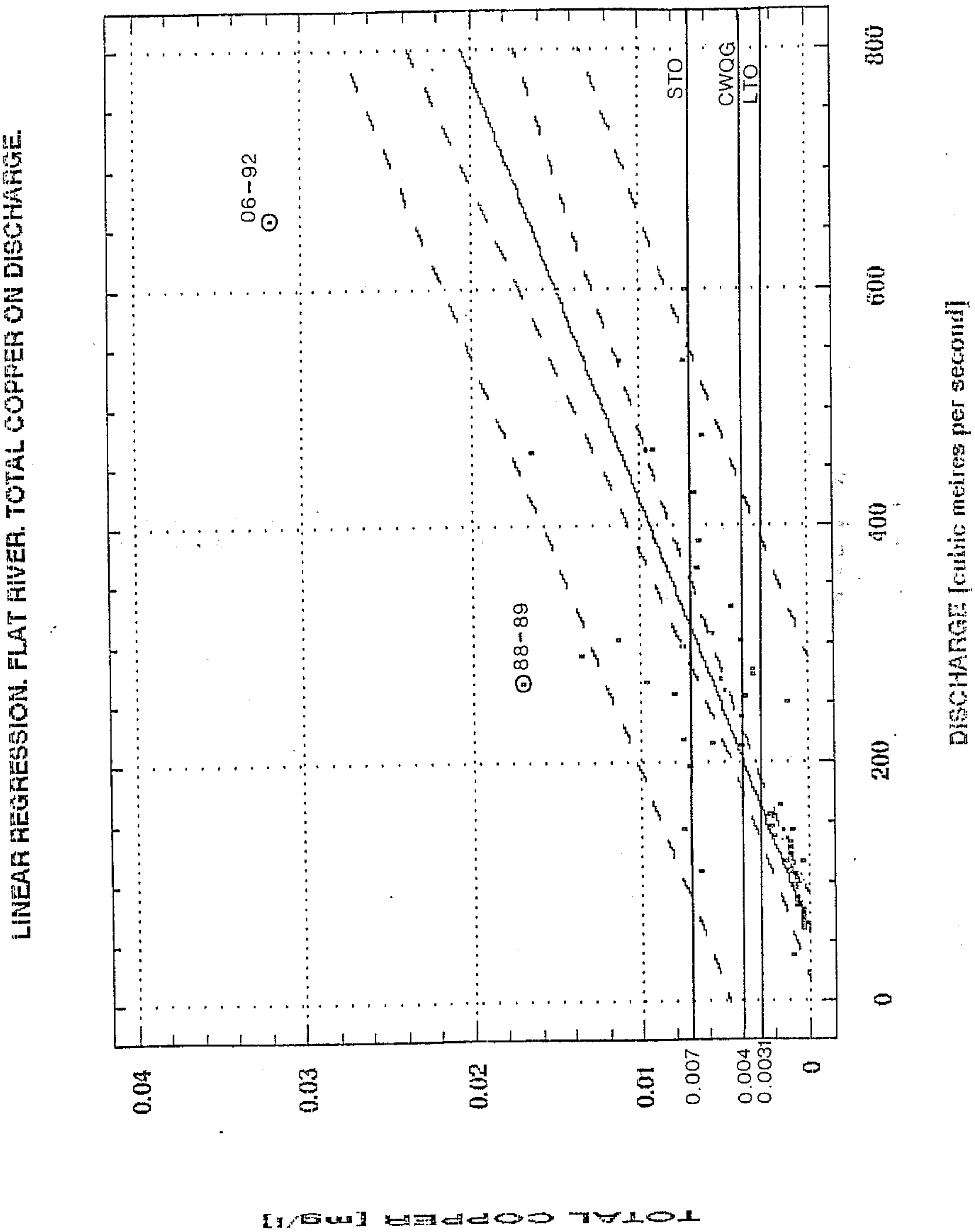
For South Nahanni River above Rabbitkettle River, LTO exceedances were observed for specific conductance; NFR; NO_3-NO_2; SO_4; total cyanide; total Ba, Cd, Co, Cu, Pb, Ni, V and Zn; extractable Fe and Mn; and dissolved Ba, Cu, Pb, Ni, Se and Zn. As waters entering the Park may be undergoing some deterioration in water quality, future monitoring appears warranted at this site.

Short-Term Objective (STO) Exceedances

STO exceedances outside water quality variable versus discharge (or specific conductance) regression line 95% confidence and prediction limits were observed at all five sites, especially during the June 1992 spring freshet.

At Flat River, STO exceedances not readily explainable by discharge

Figure 16. Flat River. Linear Regression of Total Copper on Discharge Showing LTO, STO, CWQG Exceedances.



occurred during the June 1992 spring freshet for extractable Fe (Figure 8) and Mn; total Cu (Figure 16), Pb, Zn, Ni, V, Co, Cd and Ba; NFR; total cyanide; and dissolved Cu, Pb and As. STO exceedances occurred under April 1992 baseflow conditions for dissolved Zn, Se, SO_4 and NO_3-NO_2. Figures 8 and 16 reveal that exceedances occurred in the spring freshets of 1988 and 1989 as well but the higher June 4, 1992 spring freshet daily discharge of

659 cms resulted in a higher value. Canadian Water Quality Guidelines (CWQG) for freshwater aquatic life were exceeded at Flat River for total Cu and Pb on June 4, 1992. High total Cu may originate from the Canada Tungsten (W-Cu) Mine. Additional samples should, therefore, be collected at the Flat River water quality site.

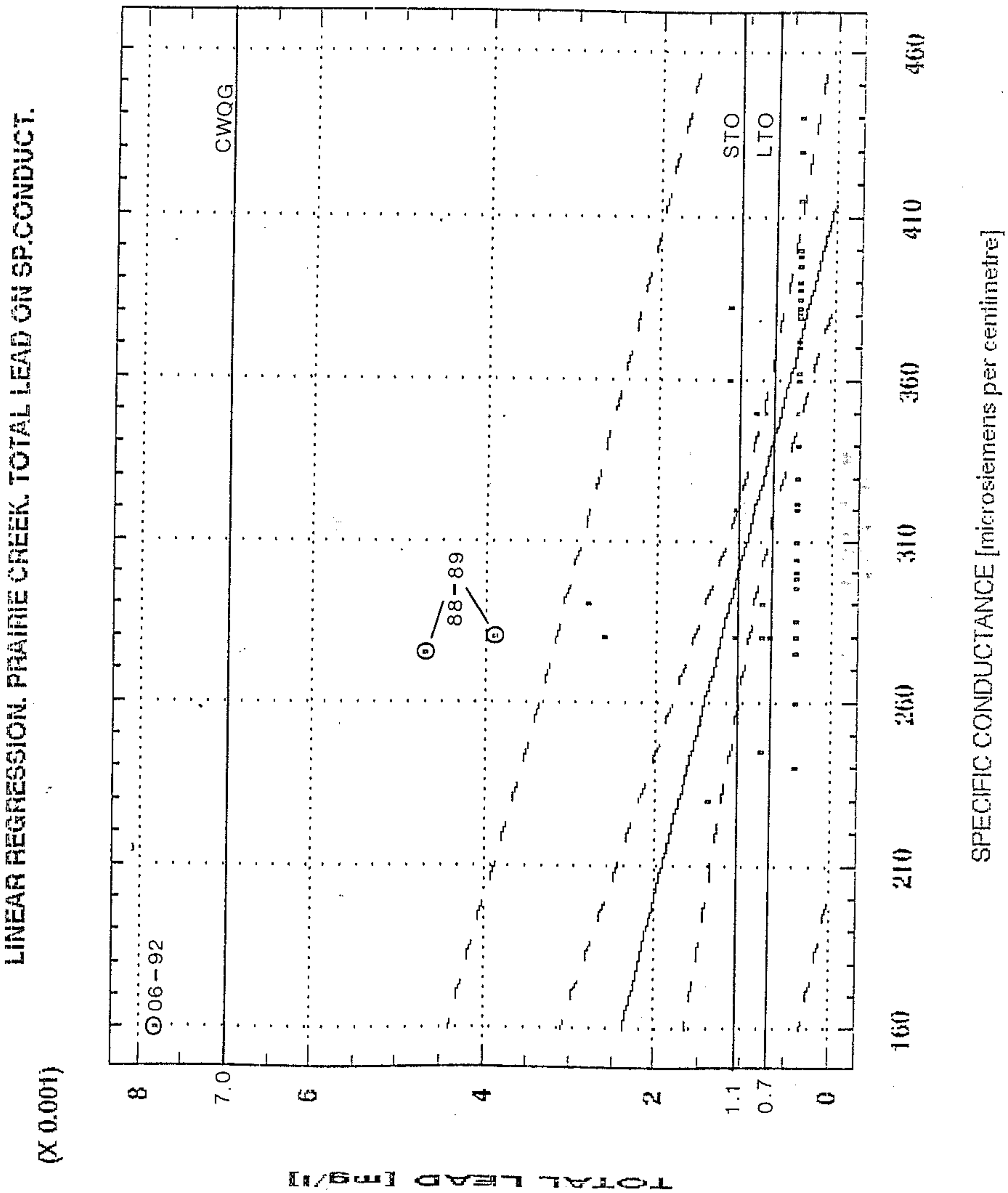
At Prairie Creek, STO exceedances not readily explainable by discharge or specific conductance occurred during the high June 4, 1992 spring freshet sampling, under conditions of high daily discharge and low specific conductance, for total Zn (Figure 14), Pb (Figure 17), Cu, Ni, V, Co and Cd; extractable Fe and Mn; NFR; and dissolved Cu. August 1992 summer recession exceedances were observed for dissolved Zn (Figure 15) and Fe.

CWQG's for aquatic life were exceeded at Prairie Creek for total Zn and Cu on June 4, 1992. The value of 0.063 mg/l total Zn more than doubles the 0.03 mg/l Zn CWQG for freshwater aquatic life. It cannot be explained by high discharge/ low specific conductance. Due to the resumption of exploration upstream of this station in the vicinity of the Cadillac Mine, additional samples should be taken in July and August 1993 (as well as April, June and September 1993). This should help to determine whether this is a one-time incident or indicate that anthropogenic activity (or undiscovered Zn-Pb deposits) is affecting the water quality of Prairie Creek. Fish (i.e. burbot, arctic greyling, longnose sucker) muscle and liver sampling was conducted on Prairie Creek in 1992 and the results suggest slightly elevated concentrations of Cd, Cu and Zn.

At Nahanni Butte, STO exceedances unrelated to discharge occurred on June 4, 1992 during the spring freshet for NFR; extractable Fe; and total Pb, Ni and V. High discharge rates explained apparent STO June 1992 exceedances for dissolved As; and total Cu, Zn, Co, Cd and Ba. STO exceedances also occurred during April 1992 baseflow for specific conductance, dissolved SO_4 and dissolved Ni. STO exceedances also occurred during the September 1992 summer-fall recession for dissolved Ni. CWQG's for aquatic life were exceeded at Nahanni Butte for total Pb during the June 1992 spring freshet. Similar exceedances for total Cu and Cd can be explained by high discharge rates.

At Rabbitkettle River, STO exceedances not readily explainable by

Figure 17. Prairie Creek. Linear Regression of Total Lead on Specific Conductance Showing LTO, STO, CWQG Exceedances.



discharge or specific conductance occurred during the high discharge (i.e. low, 150 us/cm specific conductance) June 1992 spring freshet for total Zn, Ni and Cd; and dissolved NO_3-NO_2. CWQG's for aquatic life were exceeded at Rabbitkettle River for total Zn on June 4, 1992. Total Zn concentrations should be carefully monitored in the future.

At South Nahanni River above Rabbitkettle River, STO exceedances not readily explainable by discharge or specific conductance

occurred during the high discharge (i.e. low, 130 us/cm specific conductance) June 1992 spring freshet for extractable Fe and Mn; total Cu, Pb, Zn, Ni, Co, Cd and Ba; and dissolved Pb. A dissolved Pb exceedance was also observed in the April 1992 baseflow value. CWQG's for aquatic life were exceeded in the South Nahanni River above Rabbitkettle River for total Cu on June 4, 1992. Total Cu concentrations should be carefully monitored in the future.

Simple linear regression plots (on discharge or specific conductance) with superposed LTO, STO and CWQG thresholds used in the above analysis illustrate that exceedances of STO's not explainable by high discharges or low specific conductances are fairly common during the 1988 and 1989 spring freshets as well. The higher discharges during the 1992 spring freshet resulted in more frequent exceedances and higher values. Some exceedances were observed under recession and baseflow conditions during 1992. Late summer to fall recession exceedances were rare during 1988 and 1989. No late winter exceedances were observed in 1988 and 1989 simply because no baseflow water quality samples were collected during those years.

6.0 NAHANNI BUTTE SUSPENDED SEDIMENTS

On September 1, 1992 suspended sediments were sampled using a stainless steel Alfa-Laval centrifuge modified and thoroughly cleaned to avoid contamination. Specific conductance, pH and temperature were noted in the field. The suspended sediments were sent to DOE's National Laboratory for Environmental Testing (NLET) in Burlington for analysis of total Hg, As, Se, Cu, Mo, Mn, Fe, Zn, Cr, Al, Cd, Pb, V, Co and Ni (Table 1). DOE's National Water Research Institute (NWRI)'s sedimentology laboratory in Burlington also performed particle-size distribution analysis.

The values obtained appear in Table 8. The high total Fe value of 31300 mg/kg (ppm), or 3.13%, is likely real given the high Fe content of sedimentary rocks, such as the Sunblood Formation limestone, upstream. The enigmatically high total Al value of 65400 mg/kg (ppm), or 6.54%, is due to contamination during sample preparation before shipping and this data was censored out.

Without sediment quality guidelines or objectives, it is difficult to assess the meaning of these numbers in the absolute sense. Particle-size distribution analysis reveals that most of the suspended sediment sample was 6.0 to 10.0 microns in particle size and all the sample was in the minus 177 micron size class. There are few suspended sediments collected throughout Canada, so it is difficult to compare results with any other data. Table 9 gives statistics on the over 31,200 minus 177 micron sized bedload (bottom) stream sediments collected in the active channels by or for the Geological Survey of Canada in the Canadian Cordillera as part of the National Geochemical Reconnaissance (NGR) dataset for data released to December 1984 (Ballantyne, 1981). The area of the Selwyn Basin just to the west of Nahanni National Park Reserve has been the focus of one of the most intensive stream geochemical surveys carried out in Canada to date by the Geochemistry Subdivision of the Geological Survey of Canada (Bonham-Carter and Goodfellow, 1984; Goodfellow and Aronoff, 1988).

The September 1992 suspended sediment data from Nahanni Butte can be compared to the 31,200 plus samples in the NGR Canadian Cordillera dataset (Table 9). The value of 60 ppm Hg lies at the 60th percentile of the NGR dataset. The value of 21 ppm As lies just below the 90th percentile of the dataset, and is significantly high. The value of 30.8 ppm Cu lies at the 65th percentile of the dataset. The 10 ppm Mo lower method detection limit is too high for meaningful comment. The value of 412 ppm Mn is just below the median value (50th percentile) of the dataset. The value of 3.13% Fe slightly exceeds the 80th percentile for the dataset. The value of 324 ppm Zn is high, approximately three times the 109.2 ppm arithmetic mean, and lies between the 95th and 98th percentiles. (Recall that Zn CWQG's for aquatic life were exceeded at Prairie Creek and Rabbitkettle River). The value of 16.5 ppm Pb is slightly above the 80th percentile of the NGR dataset. The value of 16.0 ppm Co is slightly above the 80th percentile. The value of 73.9 ppm Ni lies between the 90th and 95th percentiles for the dataset.

The Nahanni Butte suspended sediment sample is, therefore, anomalously elevated for Zn, Co, Ni, As, Pb and Fe contents, in that order. The elevated total Zn may be related to high total and dissolved Zn values observed in stream waters on Rabbitkettle River and Prairie Creek.

7.0 SUMMARY AND RECOMMENDATIONS

The large number of LTO, STO and CWQG exceedances encountered in the 1992 data, and to a lesser extent 1988 and 1989 data, suggest that all five water quality sites and one suspended sediment site be maintained in the future.

The large number of LTO non-compliances suggest that there is a possibility of deteriorating water quality in Nahanni National Park Reserve. Hydrometric data, specific conductance and other water quality data, from the 1992 water year confirm that the higher spring freshet discharges elevated many total and dissolved trace metals levels. Individual values frequently exceeded STO's and, in some cases, total trace metal values on June 4, 1992 exceeded CWQG's for freshwater aquatic life (Cu, Pb at Flat River; Cu, Zn at Prairie Creek; Pb at Nahanni Butte; Zn at Rabbitkettle River; and Cu at South Nahanni River above Rabbitkettle River).

Furthermore, the suspended sediment values from Nahanni Butte on September 1, 1992 for Zn, Co, Ni, As, Pb and Fe (in order of descending percentiles) exceed the 80th percentiles from a population of 31,200 plus minus 177 micron-sized bedload stream sediments collected in the Canadian Cordillera by or for the Geological Survey of Canada. The total Zn content fell between the 95th and 99th percentiles. The suspended sediment sample media is an excellent integrator of water quality of the four upstream sites in the Nahanni National Park Reserve portion of the South Nahanni River basin.

The STO and CWQG exceedances noted above cannot be explained by natural variation due to varying discharges. The above mentioned exceedances fall outside the 95% confidence and prediction limits of the simple linear regression of water quality variables on discharge or specific conductance. Correlation analyses and matrices derived from Flat River water quality data confirm a not surprising, near-perfect negative correlation between discharge and specific conductance.

Correlation analyses and matrices confirm strong relationships between water quality variables in two distinct groupings, variables directly proportional to discharge and variables inversely proportional. Water quality variables exhibited some correlation (Pearson's "r" >0.5 or <-0.5) with discharge/ specific conductance 76% of the time at Rabbitkettle River, 75% of the time at South Nahanni River above Rabbitkettle River, 67% of the time at Flat River, 64% of the time at Nahanni Butte and only 39% of the time on Prairie Creek. The cause for the lower discharge/ specific conductance control over water quality variable values on Prairie Creek is unknown.

Copper is partitioned largely into the dissolved phase at all five water quality sites. Lead is partitioned largely into the dissolved phase at all sites except Rabbitkettle River, where dissolved Pb is inversely proportional to discharge while total Pb is directly proportional suggesting partitioning into the particulate phase in this flashy, high energy mountain stream. Zinc can be partitioned largely into the particulate phase (Prairie Creek, Nahanni Butte) or the dissolved phase (other three sites). Nickel can be partitioned largely into the particulate phase (Flat River, South Nahnni River above Rabbitkettle River) or the dissolved phase (other three sites).

Specific conductance, dissolved SO_4, dissolved NO_3-NO_2 and sometimes dissolved Zn exhibit a negative discharge (Q) relationship with dilution effects; the box-and-whisker plot "signature" of this is high baseflow, low freshet and intermediate recession water quality values. Extractable Fe and Mn; NFR; total Cu, Pb, Zn, Ni, Co, Cd, Ba and V; and dissolved Cu and As (sometimes Pb, Zn, Ni, Cd, Se) exhibit a positive Q relationship with particulate effects and sometimes early flushing of particulates (positive counterclockwise hysteresis); the box-and-whisker plot is marked by high spring freshet water quality values and low, subequal baseflow and recession values (having only one baseflow value, it is probably irrelevant and meaningless whether the baseflow or the recession values are higher). Dissolved Se (and, sometimes Zn, Cd, Ni) exhibit negative Q dependence and positive temperature dependence relationships. pH; total cyanide; and (sometimes) dissolved Pb, Zn., Ni, Co exhibit positive temperature dependence relationships, with water quality variables increasing in value from late winter baseflow (coldest) to spring freshet to summer recession (warmest). Dissolved Zn, Pb, Ni and NO_3-NO_2 exhibit a negative temperature dependence relationship with values decreasing from winter baseflow to summer recession.

The water and suspended sediment quality of Nahanni National Park Reserve is essentially pristine but 1992 LTO exceedance data suggests a **possible** deterioration of water quality in the Reserve. STO and CWQG exceedances (for Zn, Cu, Pb, etc.) at all five sites confirm that future water quality and other media monitoring is warranted.

The 1992 program involving water, suspended sediment, fish and snow sampling should be continued (and is being continued) in fiscal year 1993-94.

The quality assurance/ quality control protocols should continue for waters and duplicate suspended sediment samples should continue to be archived.

High values and Al contamination problems from the 1992 suspended sediment samples suggest a need for one or two suspended sediment samples in 1993 at the Nahanni Butte site.

More baseflow water quality data is sorely needed to further examine the role of particulate effects in the Park waters.

Two additional 1993 water quality samples should be collected at the Prairie Creek (and possibly the Flat River) site, one in July and one in August-September, to better assess the present-day effects of past base metal mining activity.

Opportunistic water quality sampling at the Flat River site during the winter season would prove useful for time trend analysis, and in defining separate water quality objectives at Flat River for the ice-covered portion of the water year.

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Appendix I

Memorandum of Understanding
Environmental Water Quality Monitoring
and Assessment Program

NAHANNI NATIONAL PARK RESERVE
NORTHWEST TERRITORIES

ENVIRONMENTAL WATER QUALITY MONITORING AND ASSESSMENT PROGRAM

MEMORANDUM OF UNDERSTANDING

BETWEEN

CANADIAN PARKS SERVICE
PRAIRIE & NORTHERN REGION
ENVIRONMENT CANADA

AND

CONSERVATION & PROTECTION SERVICE
WESTERN & NORTHERN REGION
ENVIRONMENT CANADA

FOR

WORK AND COST SHARED

ENVIRONMENTAL MONITORING AND ASSESSMENT SERVICES

August 20, 1992

Memorandum of Understanding (MOU)
between
Canadian Parks Service, Prairie & Northern Region
(herein referred to as CPS)
and
Conservation & Protection, Western & Northern Region
(herein referred to as C&P)

1. PURPOSE

This Memorandum of Understanding (MOU), outlines the procedures to be followed by Inland Waters Directorate (IWD) of Conservation & Protection and Nahanni National Park Reserve of Canadian Parks Service (CPS) (herein referred to as the Parties) with respect to the implementation and management of the Environmental Water Quality Monitoring and Assessment Program (herein referred to as the Program) for the Nahanni National Park Reserve in the Northwest Territories. The annual program will be designed to meet the recommendations made in Section 7.0 of the December 1991 report entitled "Protecting the Waters of Nahanni National Park Reserve, N.W.T." However, other services can be negotiated on an as required basis.

The parties are committed to promoting shared utilization of resources to maximize the overall performance and effectiveness of the program under Canada's Green Plan.

2. ADMINISTRATION

2.1 The Administrators of this MOU will be the Chief, NWT Programs for IWD and the Superintendent, Nahanni National Park Reserve for CPS.

2.2 The Administrators will be fully responsible for the planning, implementation, monitoring and reporting of the Program; and

2.3 The Administrators will meet at least once per year. Other Meetings will be held at such times as required for the effective planning and delivery of the Program.

3. <u>ENVIRONMENTAL WATER QUALITY MONITORING AND ASSESSMENT PROGRAM</u>

3.1 The Program will be initiated in 1992-93 and will be continued annually, contingent on the availability of appropriate financial and human resources to carry out joint cost-shared and/or work-shared activities;

3.2 The Administrators will meet prior to February 28 of each year, to review the previous years activities, approve the format of the Annual Report and finalize and sign off the next years operating schedules. Schedules to be appended to this MOU will include:

Schedule 'A' - A summary of the Annual Financial Contributions to be made by each party;

Schedule 'B' - The Annual Work Plan of activities to be undertaken by each party; and

Schedule 'C' - Details of additional Environmental Services to be provided by each party on an as required basis.

3.3 The parties will ensure that; all sampling is carried out to establish standards; a quality assurance/quality control program is implemented; and samples are processed, handled and shipped for analysis without undue delay;

3.4 IWD will ensure that; all laboratory analyses are carried out; laboratory results are obtained on the priority basis; results are verified on receipt, and CPS advised immediately should any significant deviations in environmental quality be observed;

3.5 The Parties agree that significant deviations will be analyzed promptly and that immediate joint action will be taken as appropriate;

3.6 IWD will produce for inclusion in the Annual Report a tabulation of all verified data, by May 31 of the following year;

3.7 The Parties will jointly produce for inclusion in the Annual Report an assessment of compliance with the Water Quality Objectives established in the December 1991 Report "Protecting the Waters of Nahanni National Park Reserve, N.W.T. and including any other work carried out by July 31 of the following year; and

3.8 The Annual Report will be produced and released by August 15th of the following year; and

3.8 All verified data produced under this MOU are public data, equally accessible by both parties.

4. FINANCIAL CONSIDERATIONS

4.1 The Annual Work Plan will be carried out on a cost-shared basis, according to funding provided in Schedule 'A' and the arrangements defined in Schedule B;

4.2 Each Party will be responsible for the delivery of those activities and the subsequent payment of those expenditures associated with their defined responsibilities under Schedule 'B';

4.3 Up-to-date information on the implementation of the Annual Work Plan and associated costs will be shared between the parties on a regular basis; and

4.4 The parties will prepare an annual Financial Report, to be part of the Annual Report, which identifies the actual costs associated with the delivery of the Program including, but not limited to, capital, operating and maintenance and salary expenditures.

NOTICE OF CHANGE

Notices of change in financial and/or for working practices and procedures, by either Party, will be provided immediately in writing to the other party for review and endorsement by the Administrators.

Approved by:

Conservation & Protection
Western & Northern Region
Environment Canada

[signature]

B.M. Burns
Director General
August 20, 1992

Canadian Parks Service
Prairie & Northern Region
Environment Canada

[signature] for

W.D. Harper
Director General

SCHEDULE 'A'

NAHANNI NATIONAL PARK RESERVE

"ENVIRONMENTAL QUALITY MONITORING AND ASSESSMENT PROGRAM"

MEMORANDUM OF UNDERSTANDING
between
Canadian Parks Service
Prairie & Northern Region
and
Conservation and Protection Service
Western & Northern Region
for
1992-93 Program Implementation

This schedule provides a summary of the annual financial contributions, made by the Canadian Parks Service and the Conservation & Protection Service of Environment Canada, for the implementation of the 1992-93 Nahanni Environmental Monitoring and Assessment Program.

Canadian Parks Service	$15,000
Conservation & Protection Service	$15,000
	$30,000
	=====

The expenditure of these funds will be in accordance with procedures defined in the Memorandum of Understanding.

Approved by Administrators:

For Conservation & Protection Service

Arthur G. Redshaw
Chief, NWT Programs
Inland Waters Directorate

July 20, 1992

For Canadian Parks Service

Steve Langdon
Superintendent
Nahanni National Park Service

SCHEDULE 'B'
1992-93 Annual Work Plan

NAHANNI NATIONAL PARK RESERVE

"ENVIRONMENTAL WATER QUALITY MONITORING AND ASSESSMENT PROGRAM"

MEMORANDUM OF UNDERSTANDING
between
Canadian Parks Service
Prairie & Northern Region
and
Conservation and Protection Service
Western & Northern Region
for
1992-93 Program Implementation

This Schedule provides a summary of the Annual Work Plan, made by the Canadian Parks Service and the Conservation & Protection Service of Environment Canada, for the implementation of the 1992-93 Nahanni Environmental Water Quality Monitoring and Assessment Program.

1.0 Sampling Stations

1.1 Water Quality:

00NW10EC0017 South Nahanni River above Nahanni Butte
00NW10EC0014 Prairie Creek at Mouth
00NW10EA0004 Flat River near Mouth
00NW10EB0013 Rabbitkettle River at Mouth
00NW10EB0012 South Nahanni River above Rabbitkettle River

1.2 Water Quantity

10EA003 Flat River near the Mouth

2.0 Sampling Parameters

2.1 Water Quality Grab Samples:

The following parameters will be measured in each sample:

In the field:
Temperature (air & Water), pH and Conductivity

.../2

In the Laboratory:

- Physical: pH, Conductivity, Turbidity, Temperature & Colour (true), Non-filerable residue;
- Cyanide;
- Dissolved metals: Arsenic, Barium, Cadimun, Cobalt, Copper, Iron, Lead, Manganese, Nickel, Selenium, Zinc, Copper;
- Total metals: Barium, Cadimun, Cobalt, Lead, Copper, Nickel, Vanadium and Zinc;
- Extractable Metals: Iron and Manganese;
- Nitrate/Nitrite
- Sulphate

Quality Assurance/Quality Control Samples will be collected and shipped and analyzed according to Environment Canada standard practices and procedures.

2.2 Suspended Sediment Samples

A Sample will be collected by Centrifuge for analysis of the following:

- Total metals: Barium, Cadimun, Cobalt, Lead, Nickel, Vanadium and Zinc;
- Arsenic, Selenium and Mercury;
- Organic Carbon and Nitrogen Content;
- Particle Size Distribution.

2.3 Fish Samples

The following parameters will be included:

- Biological Parameters: Weight, sex and Length;
- Chemical Parameters: Arsenic, Selenium and Mercury
  - Metals: Barium, Cadimun, Cobalt, Lead, Nickel, Vanadium and Zinc;
  - Total Lipids

2.4 Snow Samples

Snow samples for atmospheric deposition of contaminants will be collected under a separate but complimentry program for the National Water Research Institute, Environment Canada, Burlington, Ontario.

2.5 Water Quantity Measurements

Water levels, actual flow measurements and completed daily flows.

.../3

3.0 Sampling Frequency

3.1 Water Quality Grab Samples:

- Collected at each of the five (5) stations listed under 1.0 Sampling Stations during April, June and September 1992 .
- Quality Assurance/Quality Control samples to be collected from Prairie Creek at Mouth during June 1992 and at the South Nahanni River above Nahanni Butte during September 1992.

3.2 Suspended Sediment Samples:

- Collected at the South Nahanni River above Nahanni Butte in September 1992.

3.3 Fish Samples

- Fish Samples to be taken from the South Nahanni River just below Prairie Creek at a time to be arranged between Canadian Parks Service and Fisheries and Oceans Canada (Yellowknife, NWT).

3.4 Snow Samples

- Snow samples to be collected on the South Nahanni River just upstream of the Village of Nahanni Butte in March 1993.

4.0 Responsibilities

All field activities will be implemented under the joint planning and management of the Chief Park Warden, Nahanni National Park Reserve for CPS and the Officer-in-Charge, IWD, Fort Simpson Office for C&P. These officers will ensure that all required staff including staff training, is provided for each aspect of the Program, and that samples are collected and shipped to Environment Canada's National Water Laboratory in Burlington, Ontario for analysis according to standard procedures.

The Head, Water Quality, IWD, C&P in Yellowknife, NWT will be responsible for overall project management; and data verification, evaluation, and distribution to CPS, Fort Simpson.

.../4

5.0 Financial Administration

Canadian Parks Service will be responsible for the payment of costs associated with:

- Aircraft rental and direct fuel costs; and
- Fish Sampling and analysis

Conservation and Protection Service will be responsible for the payment of costs associated with:

- The operation and maintenance of the Water Quantity Station located at the Flat River near the Mouth.
- Sample shipping and Laboratory analysis costs associated with Water Quality grab samples, Quality Assurance/quality control and Suspended Sediment sampling; and
- Aircraft fuel used from IWD fuel caches.

Approved by Administrators:

For Conservation & Protection Service

Arthur G. Redshaw
Chief, NWT Programs
Inland Waters Directorate

August 20, 1992

For Canadian Parks Service

Steve Langdon
Superintendent
Nahanni National Park Service

Appendix II

Tables

Table 1. NAQUADAT/ENVIRODAT Field and Lab Parameter Codes for Waters and Suspended Sediments Sampled in 1992.

Sample Media	Water/Sediment Quality Variable	NAQUADAT/ENVIRODAT Parameter Code	Lab
Water	Temperature (Field)	02061F	-
Water	pH (Field)	10301F	-
Water	Specific Conductance	02041F	-
Water	Turbidity	02081L	Sask.
Water	Non-Filterable Residue	10401L	Sask.
Water	Nitrate-Nitrite	07110L	Sask.
Water	Dissolved Sulphate	16306L	Burl.
Water	Dissolved Arsenic	33108L	Burl.
Water	Dissolved Barium	56109L	Burl.
Water	Dissolved Cadmium	48109P	Burl.
Water	Dissolved Cobalt	27109P	Burl.
Water	Dissolved Copper	29109P	Burl.
Water	Dissolved Iron	26109P	Burl.
Water	Dissolved Lead	82109P	Burl.
Water	Dissolved Manganese	25109P	Burl.
Water	Dissolved Nickel	28109P	Burl.
Water	Dissolved Selenium	34108L	Burl.
Water	Dissolved Vanadium	23109P	Burl.
Water	Dissolved Zinc	30109P	Burl.
Water	Extractable Iron	26304P	Burl.
Water	Extractable Manganese	25304P	Burl.
Water	Total Barium	56001P	Burl.
Water	Total Cadmium	48002P	Burl.
Water	Total Cobalt	27002P	Burl.
Water	Total Copper	29005P	Burl.
Water	Total Lead	82002P	Burl.
Water	Total Nickel	28002P	Burl.
Water	Total Vanadium	23002P	Burl.
Water	Total Zinc	30005P	Burl.
Water	Total Cyanide	06610P	Burl.
Sediment	pH	10301F	-
Sediment	Specific Conductance	02041F	-
Sediment	Temperature	02061F	-
Sediment	Total Aluminum	13053L	Burl.
Sediment	Total Arsenic	33052L	Burl.
Sediment	Total Cadmium	48053L	Burl.
Sediment	Total Chromium	24053L	Burl.
Sediment	Total Cobalt	27053L	Burl.
Sediment	Total Copper	29053L	Burl.
Sediment	Total Iron	26053L	Burl.
Sediment	Total Lead	82053L	Burl.
Sediment	Total Manganese	25053L	Burl.
Sediment	Total Mercury	80050L	Burl.
Sediment	Total Molybdenum	42053L	Burl.
Sediment	Total Nickel	28053L	Burl.
Sediment	Total Selenium	34052L	Burl.
Sediment	Total Vanadium	23053L	Burl.
Sediment	Total Zinc	30050L	Burl.

TABLE 2

NAHANNI NATIONAL PARK RESERVE, N.W.T.

Environmental Quality Monitoring and Assessment Program

WATER QUALITY GRAB SAMPLES

Flat River at the mouth
00NW10EA0004

PHYSICALS / IONS

Sample Date	Sample Number	Sample Type	pH (F) 10301F	Specific Cond(F) 02041F usie/cm	Water Temp(F) 02061F Deg C	Turb 02081L NTU	Residue nonfiltr. 10401L mg/l	N03+NO2 dissolved 07110L mg/l	Chloride dissolved 17206L mg/l	Silica 14108L mg/l	Sulphate dissolved 16306L mg/l
21-Apr-92	920189	regular	7.7	375	0.0	20	16	0.109			40.10
04-Jun-92	920459	regular	8.3	130	5.5	805	996	0.068			19.90
31-Aug-92	921063	regular	8.6	310	7.0	11	8	0.060	0.330	5.950	39.30

TOTAL, EXTRACTABLE AND DISSOLVED METALS

Aluminum D-ICP 13109P mg/l	Barium Total 56001P mg/l	Barium D-ICP 56109P mg/l	Beryllium D-ICP 04111P mg/l	Cadmium Total 48002P mg/l	Cadmium Diss - AA 48102P mg/l	Cadmium D-ICP 48109P mg/l	Chromium D-ICP 24109P mg/l	Cobalt Total 27002P mg/l	Cobalt Diss - AA 27102P mg/l	Cobalt D-ICP 27109P mg/l	Copper Total 29005P mg/l
	L0.08			0.0003	0.0003			0.0010	L0.0005		0.0009
	0.567			0.0027	0.0004			0.0103	L0.0005		0.0318
0.050	L0.08	0.0570	L0.05	0.0003		0.0002	0.0003	0.0006		0.0004	0.0008

Flat River at the mouth

TOTAL, EXTRACTABLE AND DISSOLVED METALS cont..

Sample Date	Copper Diss - AA 29105P mg/l	Copper D-ICP 29109P mg/l	Iron Extrble 26304P mg/l	Iron D-ICP 26109P mg/l	Lead Total 82002P mg/l	Lead Diss - AA 82103P mg/l	Lead D-ICP 82109P mg/l	Lithium D-ICP 03109P mg/l	Manganese Extrble 25304P mg/l	Manganese D-ICP 25109P mg/l	Molybdenu D-ICP 42109P mg/l
21-Apr-92	L0.0005		0.445		0.0010	0.0010			0.010		
04-Jun-92	0.0021		10.100		0.0115	0.0052			0.354		
31-Aug-92		0.0008	0.217	0.0101	0.0011		L0.0002	0.0085	0.010	0.0056	0.0025

Nickel Total 28002P mg/l	Nickel Diss - AA 28102P mg/l	Nickel D-ICP 28109P mg/l	Strontium D-ICP 38109P mg/l	Vanadium Total 23002P mg/l	Vanadium D-ICP 23109P mg/l	Zinc Total 30005P mg/l	Zinc Diss - AA 30105P mg/l	Zinc D-ICP 30109P mg/l	Arsenic dissolved 33108L mg/l	Selenium dissolved 34108L mg/l	Cyanide total 06610P mg/l
0.0073	0.0046			0.0006		0.0239	0.0113		0.0003	0.0009	L0.001
0.0655	0.0026			0.0202		0.2020	0.0053		0.0014	0.0007	0.003
0.0023		0.0048	0.1630	L0.0005	0.0002	0.0159		0.0061	0.0008	0.0006	L0.001

TABLE 3

NAHANNI NATIONAL PARK RESERVE, N.W.T.

Environmental Quality Monitoring and Assessment Program

WATER QUALITY GRAB SAMPLES

Prairie Creek at the mouth
00NW10EC0014

PHYSICALS / IONS

Sample Date	Sample Number	Sample Type	pH (F) 10301F	Specific Cond(F) 02041F usie/cm	Water Temp(F) 02061F Deg C	Turb 02081L NTU	Residue nonfiltr. 10401L mg/l	N03+NO2 dissolved 07110L mg/l	Chloride dissolved 17206L mg/l	Silica 14108L mg/l	Sulphate dissolved 16306L mg/l
21-Apr-92	920190	regular	7.8	395	0.0	1	L1.0	0.206			42.50
04-Jun-92	920460	QC triplicate	8.3	160	5.0	405	460	0.130			20.30
04-Jun-92	920461	QC triplicate				396	437	0.124			20.50
04-Jun-92	920462	QC triplicate				405	463	0.130			20.70
31-Aug-92	921062	regular	8.5	350	8.0	3	2	0.165	0.540	3.140	52.50
04-Jun-92	920463	field blank				0	L1.0	L0.01			0.60

TOTAL, EXTRACTABLE AND DISSOLVED METALS

Aluminum D-ICP 13109P mg/l	Barium Total 56001P mg/l	Barium D-ICP 56109P mg/l	Beryllium D-ICP 04111P mg/l	Cadmium Total 48002P mg/l	Cadmium Diss - AA 48102P mg/l	Cadmium D-ICP 48109P mg/l	Chromium D-ICP 24109P mg/l	Cobalt Total 27002P mg/l	Cobalt Diss - AA 27102P mg/l	Cobalt D-ICP 27109P mg/l	Copper Total 29005P mg/l
	L0.08			L0.0001	L0.0001			L0.0005	L0.0005		L0.0005
	0.152			0.0004	L0.0001			0.0032	0.0005		0.0055
	0.157			0.0004	L0.0001			0.0031	L0.0005		0.0050
	0.111			0.0003	L0.0001			0.0035	L0.0005		0.0048
0.005	0.088	0.0743	L0.05	L0.0001		L0.0001	0.0008	L0.0005		0.0001	L0.0005
	L0.08			0.0002	L0.0001			L0.0005	L0.0005		L0.0005

Prairie Creek at the mouth

TOTAL, EXTRACTABLE AND DISSOLVED METALS cont..

Sample Date	Copper Diss - AA 29105P mg/l	Copper D-ICP 29109P mg/l	Iron Extrble 26304P mg/l	Iron D-ICP 26109P mg/l	Lead Total 82002P mg/l	Lead Diss - AA 82103P mg/l	Lead D-ICP 82109P mg/l	Lithium D-ICP 03109P mg/l	Manganese Extrble 25304P mg/l	Manganese D-ICP 25109P mg/l	Molybdenu D-ICP 42109P mg/l
21-Apr-92	L0.0005		0.023		L0.0007	L0.0007			L0.002		
04-Jun-92	L0.0005		1.890		0.0079	L0.0007			0.096		
04-Jun-92	0.0007		1.840		0.0075	0.0007			0.095		
04-Jun-92	0.0005		1.810		0.0081	L0.0007			0.096		
31-Aug-92		0.0005	0.024	0.0032	0.0008		L0.0002	0.0029	L0.002	0.0001	0.0025
04-Jun-92	L0.0005		L0.007		0.0012	L0.0007			L0.002		

Nickel Total 28002P mg/l	Nickel Diss - AA 28102P mg/l	Nickel D-ICP 28109P mg/l	Strontium D-ICP 38109P mg/l	Vanadium Total 23002P mg/l	Vanadium D-ICP 23109P mg/l	Zinc Total 30005P mg/l	Zinc Diss - AA 30105P mg/l	Zinc D-ICP 30109P mg/l	Arsenic dissolved 33108L mg/l	Selenium dissolved 34108L mg/l	Cyanide total 06610P mg/l
0.0005	L0.0005			0.0005		0.0056	0.0013		0.0001	0.0007	L0.001
0.0143	0.0005			0.0060		0.0628	0.0010		0.0003	0.0004	L0.001
0.0127	0.0005			0.0063		0.0593	0.0008		0.0002	0.0004	0.001
0.0129	0.0006			0.0061		0.0663	0.0009		0.0002	0.0004	L0.001
L0.0005		0.0005	0.268	L0.0005	0.0003	0.0032		0.0022	0.0005	0.0007	L0.001
L0.0005	L0.0005			L0.0005		0.0006	L0.0003		0.0001	0.0001	L0.001

TABLE 4
NAHANNI NATIONAL PARK RESERVE, N.W.T.
Environmental Quality Monitoring and Assessment Program
WATER QUALITY GRAB SAMPLES

South Nahanni River above Nahanni Butte
00NW10EC0017

PHYSICALS / IONS

Sample Date	Sample Number	Sample Type	pH (F) 10301F	Specific Cond(F) 02041F usie/cm	Water Temp(F) 02061F Deg C	Turb 02081L NTU	Residue nonfiltr. 10401L mg/l	N03+NO2 dissolved 07110L mg/l	Chloride dissolved 17206L mg/l	Silica 14108L mg/l	Sulphate dissolved 16306L mg/l
21-Apr-92	920191	regular	7.8	450	0.0	3	2	0.121			146.00
04-Jun-92	920464	regular	8.2	150	7.0	975	1204	0.073			24.40
31-Aug-92	921058	QC triplicate	8.2	350	10.0	15	11	0.059	2.070	5.060	52.60
31-Aug-92	921059	QC triplicate				15	12	0.060	2.060	5.070	53.70
31-Aug-92	921060	QC triplicate				14	12	0.059	2.060	5.050	53.80
31-Aug-92	921061	field blank				0	L1.0	L0.01	0.050	L0.02	L0.2

TOTAL, EXTRACTABLE AND DISSOLVED METALS

Aluminum D-ICP 13109P mg/l	Barium Total 56001P mg/l	Barium D-ICP 56109P mg/l	Beryllium D-ICP 04111P mg/l	Cadmium Total 48002P mg/l	Cadmium Diss - AA 48102P mg/l	Cadmium D-ICP 48109P mg/l	Chromium D-ICP 24109P mg/l	Cobalt Total 27002P mg/l	Cobalt Diss - AA 27102P mg/l	Cobalt D-ICP 27109P mg/l	Copper Total 29005P mg/l
	0.129			0.0002	L0.0001			L0.0005	L0.0005		L0.0005
	0.438			0.0022	L0.0001			0.0082	L0.0005		0.0258
0.079	L0.08	0.0661	L0.05	0.0005		0.0001	0.0003	0.0005		0.0002	0.0007
0.081	0.097	0.0656	L0.05	0.0001		L0.0001	0.0003	0.0007		0.0002	0.0011
0.081	L0.08	0.0662	L0.05	0.0001		0.0001	0.0003	0.0006		0.0002	0.0009
0.002	L0.08	L0.0002	L0.05	0.0001		L0.0001	0.0003	L0.0005		L0.0001	L0.0005

South Nahanni River above Nahanni Butte

TOTAL, EXTRACTABLE AND DISSOLVED METALS cont..

Sample Date	Copper Diss - AA 29105P mg/l	Copper D-ICP 29109P mg/l	Iron Extrble 26304P mg/l	Iron D-ICP 26109P mg/l	Lead Total 82002P mg/l	Lead Diss - AA 82103P mg/l	Lead D-ICP 82109P mg/l	Lithium D-ICP 03109P mg/l	Manganese Extrble 25304P mg/l	Manganese D-ICP 25109P mg/l	Molybdenu D-ICP 42109P mg/l
21-Apr-92	L0.0005		0.128		L0.0007	L0.0007			0.039		
04-Jun-92	0.0016		8.270		0.0119	L0.0007			0.338		
31-Aug-92		0.0005	0.225	0.0032	0.0008		0.0005	0.0095	0.015	0.0105	0.0025
31-Aug-92		0.0005	0.244	0.0036	L0.0007		0.0002	0.0094	0.022	0.0105	0.0026
31-Aug-92		0.0004	0.227	0.0032	0.0010		L0.0002	0.0094	0.016	0.0105	0.0026
31-Aug-92		0.0002	L0.007	0.0015	L0.0007		L0.0002	L0.0001	L0.002	L0.0001	L0.0001

Nickel Total 28002P mg/l	Nickel Diss - AA 28102P mg/l	Nickel D-ICP 28109P mg/l	Strontium D-ICP 38109P mg/l	Vanadium Total 23002P mg/l	Vanadium D-ICP 23109P mg/l	Zinc Total 30005P mg/l	Zinc Diss - AA 30105P mg/l	Zinc D-ICP 30109P mg/l	Arsenic dissolved 33108L mg/l	Selenium dissolved 34108L mg/l	Cyanide total 06610P mg/l
0.0042	0.0031			L0.0005		0.0073	0.0030		0.0003	0.0009	L0.001
0.0608	0.0025			0.0201		0.1760	0.0021		0.0008	0.0008	0.002
0.0021		0.0027	0.2410	0.0007	0.0003	0.0075		0.0013	0.0005	0.0007	L0.001
0.0017		0.0027	0.2420	0.0011	0.0003	0.0072		0.0015	0.0005	0.0007	0.001
0.0015		0.0029	0.2420	0.0007	0.0003	0.0070		0.0012	0.0005	0.0007	L0.001
L0.0005		L0.0002	0.0004	L0.0005	L0.0001	L0.0003		0.0004	L0.0001	L0.0001	L0.001

TABLE 5

NAHANNI NATIONAL PARK RESERVE, N.W.T.

Environmental Quality Monitoring and Assessment Program

WATER QUALITY GRAB SAMPLES

Rabbitkettle River at the mouth
00NW10EB0013

PHYSICALS / IONS

Sample Date	Sample Number	Sample Type	pH (F) 10301F	Specific Cond(F) 02041F usie/cm	Water Temp(F) 02061F Deg C	Turb 02081L NTU	Residue nonfiltr. 10401L mg/l	N03+NO2 dissolved 07110L mg/l	Chloride dissolved 17206L mg/l	Silica 14108L mg/l	Sulphate dissolved 16306L mg/l
21-Apr-92	920187	regular	7.7	315	0.0	1	1	0.142			40.90
04-Jun-92	920457	regular	8.2	150	5.0	72	129	0.183			26.00
31-Aug-92	921065	regular	8.3	220	5.0	12	14	0.115	0.270	5.090	37.20

TOTAL, EXTRACTABLE AND DISSOLVED METALS

Aluminum D-ICP 13109P mg/l	Barium Total 56001P mg/l	Barium D-ICP 56109P mg/l	Beryllium D-ICP 04111P mg/l	Cadmium Total 48002P mg/l	Cadmium Diss - AA 48102P mg/l	Cadmium D-ICP 48109P mg/l	Chromium D-ICP 24109P mg/l	Cobalt Total 27002P mg/l	Cobalt Diss - AA 27102P mg/l	Cobalt D-ICP 27109P mg/l	Copper Total 29005P mg/l
	L0.08			0.0003	0.0001			L0.0005	L0.0005		L0.0005
	0.152			0.0012	0.0001			0.0033	L0.0005		0.0044
0.066	L0.08	0.0504	L0.05	0.0002		0.0001	0.0004	0.0006		0.0008	0.0008

Rabbitkettle River at the mouth

TOTAL, EXTRACTABLE AND DISSOLVED METALS cont..

Sample Date	Copper Diss - AA 29105P mg/l	Copper D-ICP 29109P mg/l	Iron Extrble 26304P mg/l	Iron D-ICP 26109P mg/l	Lead Total 82002P mg/l	Lead Diss - AA 82103P mg/l	Lead D-ICP 82109P mg/l	Lithium D-ICP 03109P mg/l	Manganese Extrble 25304P mg/l	Manganese D-ICP 25109P mg/l	Molybdenu D-ICP 42109P mg/l
21-Apr-92	L0.0005		0.067		0.0007	0.0026			0.005		
04-Jun-92	0.0010		2.050		0.0023	0.0017			0.068		
31-Aug-92		0.0005	0.207	0.0043	0.0008		L0.0002	0.0069	0.012	0.0127	0.0015

Nickel Total 28002P mg/l	Nickel Diss - AA 28102P mg/l	Nickel D-ICP 28109P mg/l	Strontium D-ICP 38109P mg/l	Vanadium Total 23002P mg/l	Vanadium D-ICP 23109P mg/l	Zinc Total 30005P mg/l	Zinc Diss - AA 30105P mg/l	Zinc D-ICP 30109P mg/l	Arsenic dissolved 33108L mg/l	Selenium dissolved 34108L mg/l	Cyanide total 06610P mg/l
0.0018	0.0011			0.0009		0.0076	0.0029		0.0010	0.0010	L0.001
0.0145	0.0026			0.0099		0.0819	0.0054		0.0014	0.0011	0.001
0.0010		0.0076	0.164	0.0014	0.0002	0.0162		0.0082	0.0018	0.0011	L0.001

TABLE 6

NAHANNI NATIONAL PARK RESERVE, N.W.T.

Environmental Quality Monitoring and Assessment Program

WATER QUALITY GRAB SAMPLES

South Nahanni River above Rabbitkettle River
00NW10B0012

			PHYSICALS						IONS		
Sample Date	Sample Number	Sample Type	pH (F) 10301F	Specific Cond(F) 02041F usie/cm	Water Temp(F) 02061F Deg C	Turb 02081L NTU	Residue nonfiltr. 10401L mg/l	N03+NO2 dissolved 07110L mg/l	Chloride dissolved 17206L mg/l	Silica 14108L mg/l	Sulphate dissolved 16306L mg/l
21-Apr-92	920188	regular	7.5	370	0.0	1	L1.0	0.077			43.30
04-Jun-92	920458	regular	8.2	130	5.0	204	333	0.063			20.20
31-Aug-92	921064	regular	8.8	290	8.0	6	5	0.047	0.300	4.630	52.00

TOTAL, EXTRACTABLE AND DISSOLVED METALS

Aluminum D-ICP 13109P mg/l	Barium Total 56001P mg/l	Barium D-ICP 56109P mg/l	Beryllium D-ICP 04111P mg/l	Cadmium Total 48002P mg/l	Cadmium Diss - AA 48102P mg/l	Cadmium D-ICP 48109P mg/l	Chromium D-ICP 24109P mg/l	Cobalt Total 27002P mg/l	Cobalt Diss - AA 27102P mg/l	Cobalt D-ICP 27109P mg/l	Copper Total 29005P mg/l
	L0.08			0.0002	0.0001			0.0005	L0.0005		L0.0005
	0.180			0.0008	L0.0001			0.0064	0.0005		0.0089
0.046	L0.08	0.0435	L0.05	0.0002		0.0001	0.0004	0.0010		0.0002	0.0009

South Nahanni River above Rabbitkettle River

TOTAL, EXTRACTABLE AND DISSOLVED METALS cont..

Sample Date	Copper Diss - AA 29105P mg/l	Copper D-ICP 29109P mg/l	Iron Extrble 26304P mg/l	Iron D-ICP 26109P mg/l	Lead Total 82002P mg/l	Lead Diss - AA 82103P mg/l	Lead D-ICP 82109P mg/l	Lithium D-ICP 03109P mg/l	Manganese Extrble 25304P mg/l	Manganese D-ICP 25109P mg/l	Molybdenui D-ICP 42109P mg/l
21-Apr-92	0.0009		0.057		L0.0007	0.0078			0.005		
04-Jun-92	0.0018		2.680		0.0068	0.0101			0.141		
31-Aug-92		0.0003	0.115	0.0028	0.0012		L0.0002	0.0047	0.015	0.0040	0.0037

Nickel Total 28002P mg/l	Nickel Diss - AA 28102P mg/l	Nickel D-ICP 28109P mg/l	Strontium D-ICP 38109P mg/l	Vanadium Total 23002P mg/l	Vanadium D-ICP 23109P mg/l	Zinc Total 30005P mg/l	Zinc Diss - AA 30105P mg/l	Zinc D-ICP 30109P mg/l	Arsenic dissolved 33108L mg/l	Selenium dissolved 34108L mg/l	Cyanide total 06610P mg/l
0.0041	0.0034			L0.0005		0.0085	0.0060		0.0003	0.0007	L0.001
0.0262	0.0030			0.0047		0.0767	0.0032		0.0006	0.0004	0.001
0.0041		0.0036	0.131	L0.0005	0.0008	0.0154		0.0076	0.0005	0.0006	L0.001

Table 7. Water Quality Objectives for Nahanni National Park Reserve.

LTO - Long Term Objectives STO - Short Term Objectives

Parameter			South Nahanni River above Rabbitkettle River		Rabbitkettle River at mouth		Flat River at mouth		Prairie Creek at mouth		South Nahanni River above Nahanni Butte	
			LTO	STO	LTO	STO	LTO	STO	LTO	STO	LTO	STO
Conductance		usie/cm	222	280	198	245	314	400	377	395	256	325
Non-filterable Residue			70	230	87	227	68	204	14	23	166	335
Nitrite/Nitrate		mg/l	0.04	0.05	0.08	0.10	0.07	0.13	0.12	0.14	0.11	1.77
Total Ammonia		mg/l	0.005	0.005	0.005	0.005	0.005	0.014	0.005	0.005	0.005	0.045
pH			8.1	8.4	7.9	8.2	8.0	8.2	8.4	8.8	8.0	8.3
Sulphate		mg/l	29	41	21	31	27	36	34	46	32	43
Arsenic	Dissolved	ug/l	0.50	0.50	1.74	1.95	0.50	0.8	0.50	0.5	0.50	0.7
Barium	Dissolved	mg/l	0.04	0.04	--	--	0.08	0.04	0.08	0.08	--	--
	Total	mg/l	0.08	0.08	0.08	0.14	0.08	0.19	0.08	0.10	0.08	0.19
Cadmium	Dissolved	ug/l	0.1	0.1	--	--	0.1	0.2	0.1	0.1	0.01	0.3
	Total	ug/l	0.17	0.4	0.29	0.60	0.45	0.80	0.10	0.10	0.30	0.60
Cobalt	Dissolved	ug/l	0.5	0.5	--	--	0.5	1.4	0.5	0.5	0.5	0.5
	Total	ug/l	1.0	2.3	1.0	2.2	1.2	3.0	0.5	0.7	1.6	3.3
Copper	Dissolved	ug/l	2.1	0.9	--	--	0.5	0.7	0.5	0.5	0.5	0.9
	Total	ug/l	1.8	3.9	2.1	4.9	3.1	7.0	0.8	1.8	3.7	7.3
Cyanide		ug/l	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Iron	Dissolved	mg/l	0.04	0.14	--	--	0.03	0.04	0.004	0.007	--	--
	Total	mg/l	0.53	1.32	1.04	2.64	0.98	2.96	0.19	0.36	1.60	2.69
Lead	Dissolved	ug/l	1.0	2.0	--	--	0.7	1.3	0.7	1.9	0.7	0.9
	Total	ug/l	1.0	2.7	1.05	2.5	1.64	3.8	0.70	1.1	2.37	5.7
Manganese	Dissolved	mg/l	0.007	0.024	--	--	0.005	0.007	0.002	0.004	--	--
	Total	mg/l	0.028	0.058	0.037	0.087	0.036	0.100	0.008	0.019	0.067	0.106
Nickel	Dissolved	ug/l	2.90	3.9	--	--	3.17	4.5	0.46	1.0	1.11	2.4
	Total	ug/l	6.80	9.8	5.37	8.4	6.81	11.7	1.57	3.0	7.60	15.2
Selenium	Dissolved	ug/l	0.50	0.95	1.21	1.75	0.59	0.80	0.50	1.0	0.68	1.2
Vanadium	Total	ug/l	1.1	3.2	4.6	11.3	2.2	6.1	0.5	1.4	3.9	6.7
Zinc	Dissolved	mg/l	0.016	0.499	--	--	0.005	0.009	0.001	0.002	0.002	0.007
	Total	mg/l	0.019	0.034	0.024	0.048	0.024	0.047	0.005	0.010	0.027	0.059

after Environment Canada, 1991

TABLE 8

NAHANNI NATIONAL PARK RESERVE, N.W.T.
Environmental Quality Monitoring and Assessment Program
SUSPENDED SEDIMENT SAMPLE

South Nahanni River above Nahanni Butte
00NW10EC0017

			PHYSICALS (FIELD)			TOTAL METALS IN SEDIMENT				
Sample Date	Sample Number	Sample Type	pH (F) 10301F	Specific Cond(F) 02041F usie/cm	Water Temp(F) 02061F Deg C	Aluminum Total 13053L mg/kg	Arsenic Total 33052L mg/kg	Lead Total 82053L mg/kg	Cadmium Total 48053L mg/kg	Chromium Total 24053L mg/kg
01-Sep-92	921189	Centrifuge	6.5	370	10.0	65400*	21.0	16.5	2.30	69.7

Cobalt Total 27053L mg/kg	Copper Total 29053L mg/kg	Iron Total 26053L mg/kg	Manganese Total 25053L mg/kg	Mercury Total 80050L mg/kg	Molybdenur Total 42053L mg/kg	Nickel Total 28053L mg/kg	Selenium Total 34052L mg/kg	Vanadiun Total 23053L mg/kg	Zinc Total 30053L mg/kg
16	30.8	31300	412	0.06	L10	73.9	1.4	218	324

* Contaminated

Environment Canada, Inland Waters Directorate - NWT Programs

Table 9. Summary Statistics (31212 Samples) for Canadian Cordillera Minus 177 Micron Stream Sediments and Stream Waters From National Geochemical Reconnaissance data Set Compiled For data released to December 1984.

VARIABLE NAME	UNITS	N	MINIMUM	MAXIMUM	MEDIAN	GEOM MEAN	ARITH MEAN	PERCENTILES				
								1st	2nd	5th	10th	20th
Zn	ppm	31211	2.	12000.	68.	72.3	109.2	15.	18.	24.	31.	40.
Cu	ppm	31212	1.	2850.	22.	21.8	30.1	3.	4.	6.	8.	12.
Pb	ppm	31208	1.	4500.	6.	5.7	12.4	1.	1.	1.	1.	2.
Ni	ppm	31212	1.	2050.	20.	18.7	31.2	1.	2.	4.	6.	9.
Co	ppm	31212	1.	550.	9.	8.8	11.1	1.	1.	3.	4.	5.
Mn	ppm	31212	5.	75000.	420.	432.8	639.1	70.	90.	130.	170.	235.
Fe	pct	31212	.05	32.25	2.10	2.008	2.305	.35	.50	.80	1.05	1.35
Used	ppm	31081	.1	430.0	3.2	3.59	5.97	.5	1.0	1.0	1.4	2.0
Mo	ppm	31213	1.	475.	1.	1.6	2.3	1.	1.	1.	1.	1.
Hg	ppb	20009	5.	99999.	40.	42.6	73.3	5.	5.	10.	10.	20.
Ag	ppm	31206	.1	39.0	.1	.12	.16	.1	.1	.1	.1	.1
As	ppm	12885	.2	1000.0	3.0	3.56	10.29	.5	.5	.5	.5	1.0
Sb	ppm	7152	.1	54.5	.4	.41	.96	.1	.1	.1	.1	.1
W	ppm	27806	1.	1200.	2.	1.9	2.9	1.	1.	1.	1.	1.
Sn	ppm	5192	.5	520.0	1.0	1.72	3.46	.5	.5	.5	1.0	1.0
Ba	ppm	10144	20.	17000.	800.	865.0	1657.4	140.	200.	280.	370.	490.
UWAT	ppb	30345	.01	89.80	.10	.105	.405	.01	.01	.02	.02	.02
FWAT	ppb	30363	5.	9600.	40.	40.4	69.0	10.	10.	10.	10.	20.
pH	pH	30605	2.3	9.1	7.6	7.49	7.52	5.4	6.0	6.5	6.8	7.0

VARIABLE NAME	PERCENTILES											
	25th	30th	40th	50th	60th	70th	75th	80th	90th	95th	98th	99th
Zn	45.	50.	58.	68.	80.	95.	105.	118.	174.	265.	500.	865.
Cu	14.	15.	18.	22.	26.	32.	36.	42.	56.	75.	105.	137.
Pb	2.	3.	5.	6.	8.	11.	12.	15.	24.	36.	60.	96.
Ni	11.	13.	16.	20.	24.	29.	32.	37.	57.	86.	148.	235.
Co	6.	7.	8.	9.	11.	12.	14.	15.	19.	24.	34.	43.
Mn	260.	290.	350.	420.	501.	615.	690.	780.	1100.	1600.	2600.	3800.
Fe	1.50	1.60	1.85	2.10	2.40	2.70	2.90	3.10	3.75	4.30	5.10	5.85
Used	2.0	2.3	2.8	3.2	3.9	4.7	5.5	6.5	14.2	18.2	33.7	51.0
Mo	1.	1.	1.	1.	1.	2.	2.	3.	4.	7.	12.	18.
Hg	20.	30.	40.	40.	60.	70.	80.	90.	130.	180.	290.	410.
Ag	.1	.1	.1	.1	.1	.1	.1	.1	.2	.4	.8	1.1
As	1.0	1.5	2.0	3.0	5.0	7.5	9.0	12.0	22.8	37.2	70.0	105.0
Sb	.2	.2	.2	.4	.4	.6	.8	1.0	2.0	4.0	7.4	10.2
W	1.	2.	2.	2.	2.	2.	2.	2.	4.	6.	14.	25.
Sn	1.0	1.0	1.0	1.0	1.0	2.0	3.0	5.0	8.0	11.0	19.0	32.0
Ba	540.	590.	680.	800.	920.	1100.	1200.	1400.	2250.	3750.	7000.	9999.
UWAT	.02	.05	.05	.10	.14	.24	.30	.42	.84	1.60	3.00	4.60
FWAT	22.	26.	32.	40.	50.	62.	72.	86.	140.	210.	360.	500.
pH	7.2	7.3	7.4	7.6	7.8	7.9	8.0	8.1	8.2	8.3	8.5	8.5

after Ballantyne, EMR 1991