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Baseline Studies of the Watershed Adjacent to Northair Mines Ltd. (N.P.L.), Brandywine, B.C.

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Pacific Region
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BASELINE STUDIES OF THE WATERSHED ADJACENT TO NORTHAIR MINES LTD., BRANDYWINE, B.C.

by

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Pollution Abatement Branch
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ABSTRACT

During 1975 the Environmental Protection Service and the British Columbia Fish and Wildlife Branch undertook a spring and fall assessment of the watershed adjacent to Northair Mines Ltd. now under construction near Brandywine, B.C. The chemical, physical and biological composition of the major streams draining the mine and mill sites were documented. The primary objective of these studies was two-fold; (a) to establish baselines to which future survey results may be related, and (b) to identify resource conflicts that may be remedied by incorporating good environmental engineering design and practices into the mining project.

The baseline data generated in this report demonstrated that the watershed, except immediately adjacent to the development, was in a natural, unaffected state. The waters removed from the construction activities were found to be low in residues, metals and nutrients content, with a moderately diverse benthos population. However, the combined mine seepage waters and mill site runoff resulted in excessive silting and complete elimination of benthos immediately downstream of the development.

Chemical analyses of mine seepage and simulated tailings supernatant indicated that metal levels in both exceeded the permissible levels to be specified by the National Mining Liquid Effluent Regulations and Guidelines.

Sulfate levels in the mine seepage suggested a possible future problem with acid generation and simulated tailings supernatant was found to be acutely toxic.

RÉSUMÉ

Pendant le printemps et l'automne 1975, le Service de protection de l'environnement et la Direction de la faune aquatique et sauvage de la Colombie-Britannique ont effectué une étude du bassin contigu aux installations de Northair Mines Ltd., actuellement en construction près de Brandywine (C.-B.). On a analysé la composition chimique, physique et biologique des principaux ruisseaux arrosant l'emplacement de la mine et de l'usine. Ces études avaient deux buts principaux: (a) établir une base de comparaison pour les études à venir, et (b) découvrir quels sont les problèmes de pollution auxquels on pourrait remédire en conduisant les travaux de la mine selon des plans et des méthodes destinés à protéger l'environnement.

Les données de base tirées de ce rapport indiquent que la qualité du bassin était acceptable, sauf dans la zone touchant le chantier. Les eaux prélevées dans le chantier contenaient peu de résidus, de métal et d'aliments nutritifs, et le benthos était moyennement diversifié. Toutefois, les eaux d'infiltration de la mine jointes aux eaux s'écoulant de l'usine avait provoqué des dépots vaseux trop importants et avaient éliminé complètement le benthos juste en aval des travaux.

Les analyses chimiques effectuées sur les eaux infiltrées dans la mine et sur les résidus de broyage surnageants ont révélé que, dans les deux cas, la proportion de métal dépassait les tolérances admises dans les règlements nationaux sur les effluents des mines.

Compte tenu du haut niveau de sulfate dans les infiltrations de la mine, il est possible qu'un problème se pose dans l'avenir à cause de la production d'acide. Les résidus de broyage surnageants étaient très toxiques.

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

LIST OF TABLES

SUMMARY AND CONCLUSIONS

(1) This report presents the results of a two-season, pre-production study, jointly conducted by Environment Canada and the British Columbia Fish and Wildlife Branch, Department of Recreation and Conservation, of the physical, chemical, and biological characteristics of the watershed draining the Northair Mines Ltd. development north of Squamish, B.C. The baseline data presented in this report is designed to facilitate post-operational environmental assessments of water quality changes in Anomaly Creek, determined from future monitoring. Also included are the results of chemical analyses and a 96-hour LC_{50} bioassay assessment of the simulated tailings decant supplied from bench-scale feasibility studies.

(2) Water chemistry and biological analyses have conclusively demonstrated that the pre-production development of the property has resulted in the visible degradation of the watershed immediately downstream of the development site. Excessive silt loads released from dewatering the tailings area over the summer period eliminated a modest benthos population of 70 organisms per square foot.

(3) Anomaly Creek at station 2, which includes the mine seepage and mill site drainage, contained excessive levels of metals, nutrients, suspended matter, and abnormally high readings in turbidity and hardness. The greatest proportion of this pollution was due to the construction phase of the development and is expected to be alleviated when Anomaly Creek is completely culverted past the development. However, the mine seepage, to be released untreated to Anomaly Creek after construction is completed, will pose the major source of environmental contamination.

(4) This study revealed that mine seepage contained levels of

suspended solids and total metals that exceeded the limits to be specified by the National Regulations and Guidelines for Metal Mining Liquid Effluents. In addition, on both sampling occasions, mine seepage contained greater than 100 mg/ℓ SO_4. This value represents double the maximum permissible limit of 50 mg/ℓ set for the British Columbia Pollution Control Objectives for the Mining, Mine Milling, and Smelting Industries. These high levels of SO_4 may be an indication that an unpredicted leaching of the sulfide in the ore is occurring on the exposed rock faces; however, an associated low pH was not observed.

(5) Chemical analysis of the mine seepage has shown that the dissolved fraction of the metals in the effluent was nearly always well below the toxic level to fish. The data suggest that by reducing the suspended solids to satisfy the National limits, the metal content would also be significantly reduced.

(6) An acceptable level of water quality and benthos was found at all stations removed from the mine/mill site. Statistical evaluations of benthic communities indicated that pollution-intolerant organisms such as stoneflies (plecoptera) and mayflies (ephemeroptera) added substantially to a satisfactory diversity. Metals were either well below the toxic level or below the detectable level.

(7) The simulated tailings decant sample supplied from bench-scale feasibility studies was found to be acutely toxic with a 96-hour LC_{50} of 42% concentration. Chemical analyses suggest that this toxicity may have been due to the high level of copper (0.51 ppm) in the decant. As an alternate to decanting excess tailings supernatant, Northair will store their excess water during the life of the mine in a separate holding pond. Through aging and dilution it is hoped that the toxic effects will have dissipated by the time mining operations cease and the

contents of the holding pond can then be safely released to the Callaghan Creek system.

(8) If stored tailings decant is to be released as planned at the termination of production, Environment Canada will require sufficient notification in order to conduct a separate chemical and biological assessment of that water and receiving waters to ensure that proper measures are instituted to protect the environment. It is anticipated that the untreated tailings decant will exceed future National Regulations and Guidelines for the Metal Mining Liquid Effluent with respect to both toxicity and metal content criteria.

1 INTRODUCTION

The Environmental Protection Service is engaged in assessing and monitoring various industrial operations that constitute potential ecological hazards to the environment, specifically those with potential deleterious effects to the fisheries resource, pursuant to section 33 of the Fisheries Act.

Information gathered from these studies provides a basis for early detection of possible environmental damage and subsequent recommendations for remedial action. This surveillance report presents the results of a baseline survey of selected physical, chemical, and biological parameters of Anomaly Creek and the watershed adjacent to Northair Mines Ltd. (N.P.L.). The surveys were conducted jointly by the Environmental Protection Service and the British Columbia Fish and Wildlife Branch during the spring and fall of 1975. Also included are the results of bioassay toxicity studies of simulated tailings samples supplied from bench-scale metallurgical testing.

2 STUDY AREA

The Northair mining property and transecting drainage are located within the Coast Mountain Range approximately 35 miles due north of Squamish, B.C., and 9 miles due west of Alta Lake (Figure 1). The mine and mill sites are situated on the eastern slope of Callaghan Creek valley at an elevation of 3250 feet above sea level. Sproatt Mountain, located two miles to the east of the mill site, exceeds the 6000 foot level and is snow-covered nearly year round.

Geologically, the area is underlain by Mesozoic volcanics of andesitic composition with granitic intrusions. Recent basalt flows are common in the valleys of this area. Mineralization consists of gold, silver, zinc, lead, and copper (in order of value to the mine), occurring in pyrite, sphalerite, galena, chalcopyrite, native gold, and electrum (in order of abundance) (McLeod, 1974). A variable layer of surface tills from the last glaciation form the basis for dystric brunisol, humoferric podzol, and regosol soil types.

The forest canopy consists mainly of even-aged Douglas fir, western hemlock, yellow and western red cedar, balsam, and some scattered pine. Red alder and big leaf maple have invaded the burned-out and logged areas.

The climate is that of the West Coast marine environment where the annual rainfall (56 in.) exceeds total evaporation (28 in.). Mean annual temperature is 5.7°C and mean annual snowfall is approximately 20 feet. Some nearby peaks are glaciated. (Figures quoted are for Alta Lake, Atmospheric Environment Service.)

The Northair property, primarily the mill and mine sites, is drained by Anomaly Creek, a tributary to Callaghan Creek, which is a tributary of the Cheakamus River (Figure 1). A British Columbia Hydro and Power Authority dam located approximately seven miles downstream from the Cheakamus-Challaghan confluence forms Daisy Lake, from which a portion of the upper Cheakamus flow is diverted to the Squamish River for power generation. The Cheakamus and Squamish rivers again merge about 8 miles north of the Town of Squamish prior to discharging into Howe Sound.

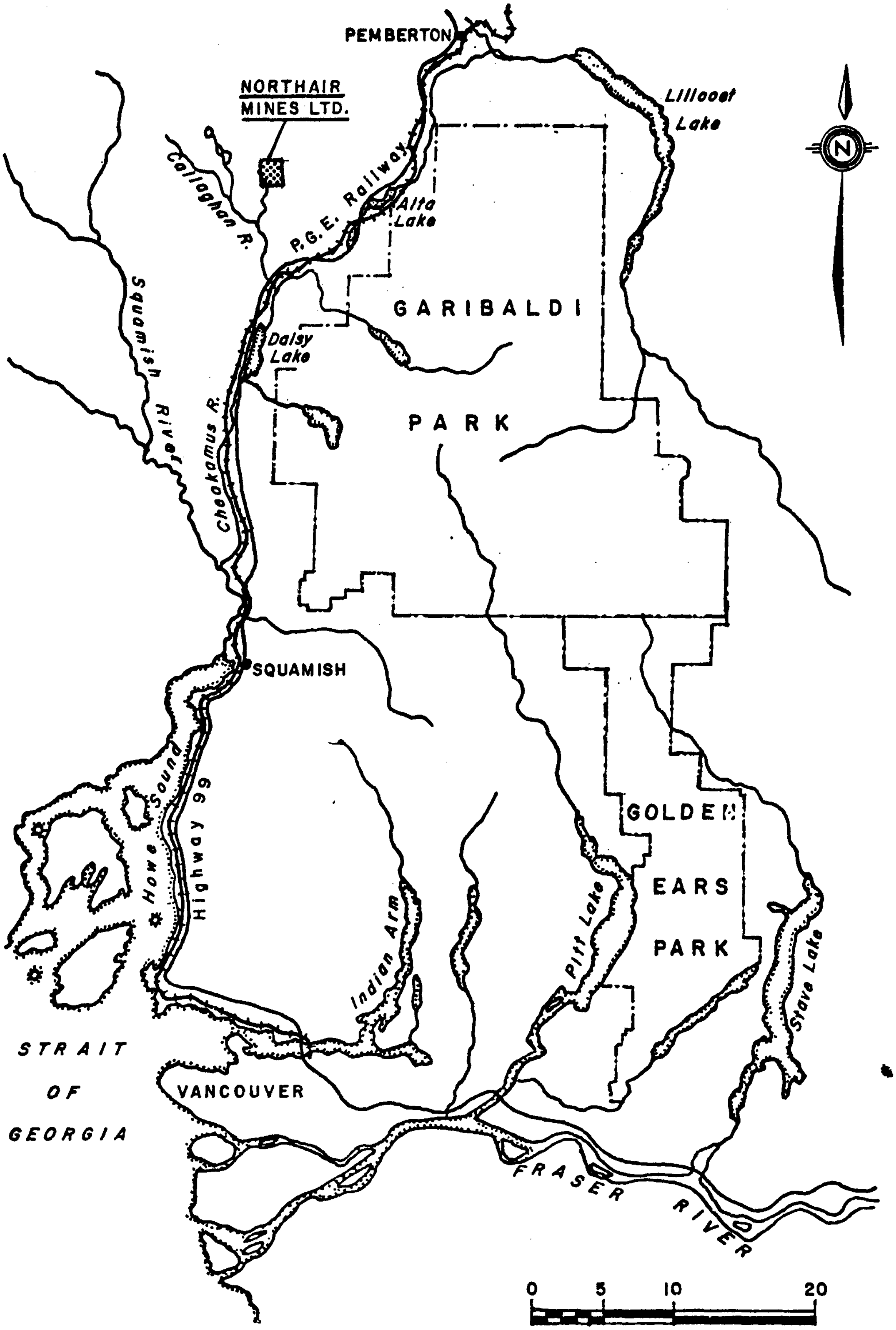

FIGURE I LOCATION MAP OF NORTHAIR MINES LTD. (N.P.L.)

3 FISHERIES RESOURCE

The Squamish and Cheakamus rivers provide extensive salmon spawning grounds in their lower reaches. For example, in an above-average year there may be as many as 250,000 chinook, 18,000 coho, 70,000 pink, 200,000 chum, and 18,000 steelhead spawners utilizing the Squamish River. The Cheakamus River, which becomes impassable at a point 8 to 9 miles above its confluence with the Squamish, supports an average of 3,000 chinook, 6,000 coho, 25,000 pink, 60,000 chum, and 3,000 steelhead. Both rivers in turn support an important Indian food fishery and intensive sport fishery. The B.C. Fish and Wildlife Branch reports that the estimated angler catch of steelhead in the Squamish-Cheakamus system averages 1,350 fish annually and the estimated combined number of days fished averages 10,000 per season.

A waterfall on the Cheakamus River, about 8 miles downstream from the B.C. Hydro and Power Authority dam at the outlet of Daisy Lake, is the upstream limit of migration for anadromous or sea-run species such as steelhead trout. However, populations of Dolly Varden, cutthroat trout, and rainbow trout in the Cheakamus system are found upstream from the falls and in the upper Cheakamus system above the dam. Daisy Lake also contains a number of kokanee.

Dolly Varden and rainbow trout have been taken in the lower reaches of Callaghan Creek but the upper reaches do not contain a fisheries resource. However, the British Columbia Fish and Wildlife Branch considers this area suitable for future stocking.

4 NORTHAIR MINES LTD. (N.P.L.)

The Northair development is scheduled to commence production early in 1976. Pre-production development of the two major zones (Warman and Manifold) has already begun (adits and drifting work). Although the full ore body is not yet explored, the projected life expectancy of the mine at a milling rate of 300 tons per day is 4-1/2 to 5 years.

At the request of Environment Canada, Northair Mines Ltd. retained B.C. Research to perform an acid generation potential test on their ore. The study findings demonstrated the ore incapable of producing enough excess acid to sustain the microbial oxidation and leaching of metals from the rock (B.C. Research, 1974). Since the possibility of acid mine drainage is minor, mine drainage will be released untreated.

The concentrator is located immediately adjacent to Anomaly Creek (Figure 2). Differential flotation will be employed to produce a Pb-Cu concentrate and a Zn concentrate. Although gold and silver will report in varying amounts to both concentrates, a separate jig concentrator will be employed to remove the bulk of these metals. The ore will be ground to 60% - 70% minus 200 mesh. The expected reagent requirements are as follows: $ZnSO_4$, $NaCO_3$, $CuSO_4$, CaOH, KCN, Polyglycol Frother, Z-200, and Ethyl Xanthate. Potassium Cyanide (KCN) will be utilized as needed for zinc sulfide depression; no leaching or cyanide circuit is planned.

Concentrates will be trucked directly to the Cominco Smelter at Trail, B.C.

An 8-acre tailings impoundment will eliminate a small lake west of the mill site. Natural inflow from surrounding drainage that would inundate the tailings area during periods of high runoff are to be diverted to Anomaly Creek which will in turn be culverted past the development. Forty percent of the solids in the tailings are to be

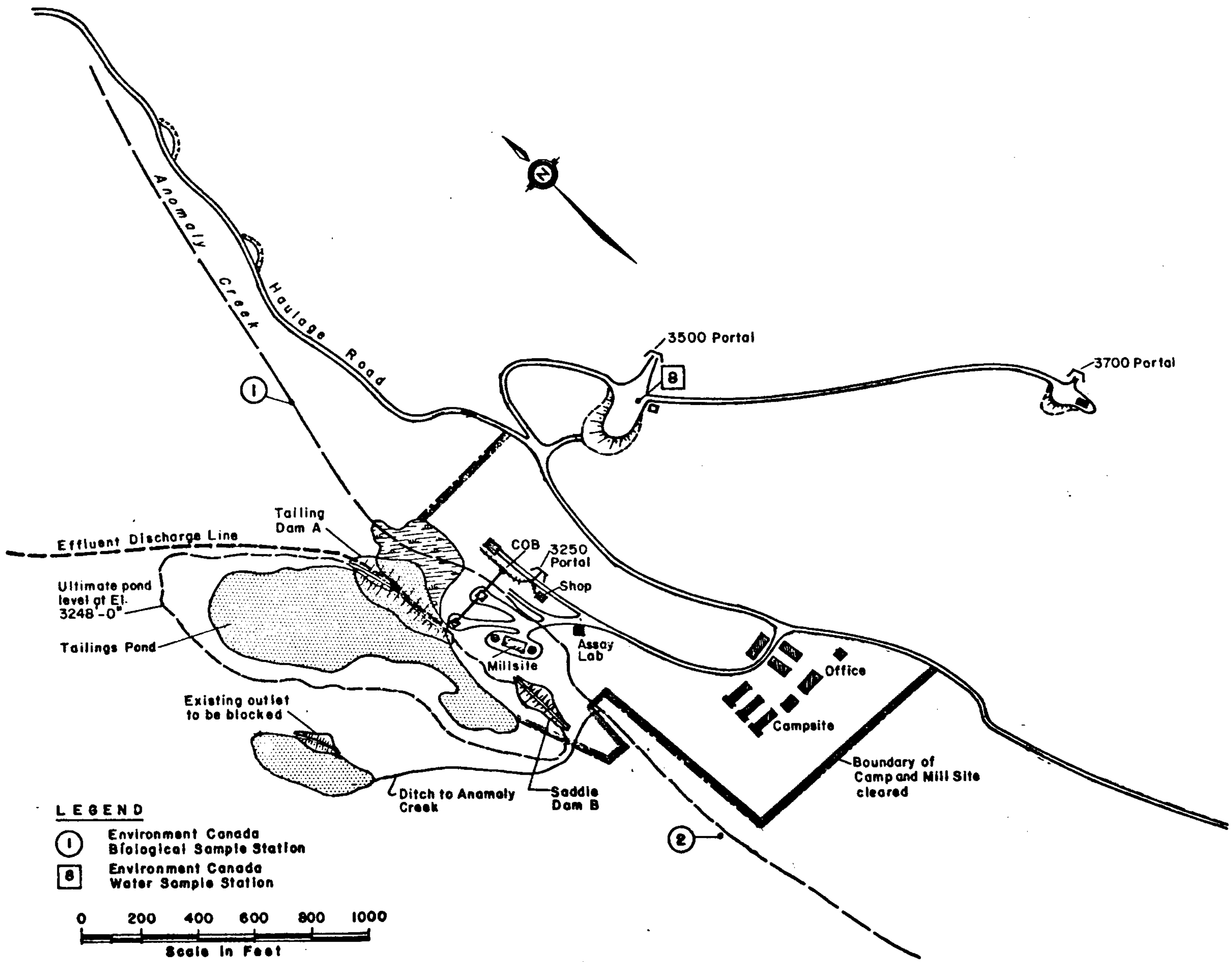

FIGURE 2 CONCENTRATOR AND MINE SITES

cycloned off and returned to the mine for backfill use. Even with these reductions in volume and 100% recyling of process water, the capacity of this impoundment is limited to 2-1/2 years of production. Consequently, a second or supplementary storage area one mile distant (McLeod Creek holding pond) will be brought into operation as a storage area for the excess water produced in the remaining years of operation (Ker, Priestman and Associates, Ltd., 1975). The company anticipates that through aging and dilution, the toxic effects, if any, will have dissipated by the time operations cease and the contents can then be safely released to the Callaghan system.

The townsite will consist of accommodation for 160 to 200 employees, mill offices, maintenance shops, cookhouse, assay lab, and recreational hall. Sewage from these facilities will be aerobatically batch-treated with chlorination prior to discharge to the tailings impoundment.

5 MATERIALS AND METHODS

5.1 Monitoring Stations

Six permanent stations were established for this baseline survey and future monitoring of the water quality of the stream adjacent to the mining site. All sites were marked with two-foot wooden stakes displaying fluorescent red paint and the station number. A seventh station representing the mine drainage was also established but may vary in location depending on from which portal the water is being discharged. The mill site, tailings ponds, and sample stations are shown in Figure 3. Four stations were selected for biological documentation.

All creek stations were typified by shallow, fast-running water with large aggregate bottom substrate and no aquatic macrophytes. Table 1 provides a brief description of each site with an explanation of its monitoring function. All sites are easily accessible from existing roadways.

5.2 Measurement of Physical Parameters

Water temperatures were determined in the field with a centigrade alcohol thermometer. At each site, polyethylene bottles were used to collect one-litre samples of water for determination of residue content. Within six hours of collection, turbidity and conductivity measurements were also made on the samples with a Hach 1860A Turbidimeter and a Seibold LTD conductivity meter. The Hach Turbidimeter utilizes the Nephelometric method, in that it measures scattered light from a formazin polymer standard (APHA, 1971).

Total residues were computed as the material remaining in a vessel after total evaporation in a muffle furnace at 103^{o}C for 2 hours. Filterable residues are that portion of the total residue which passes through a 4.25 cm Whatman GF/C for 2 hours (APHA, 1971). Analyses for total filterable and non-filterable residues were performed at the Environmental Protection Service laboratory in West Vancouver.

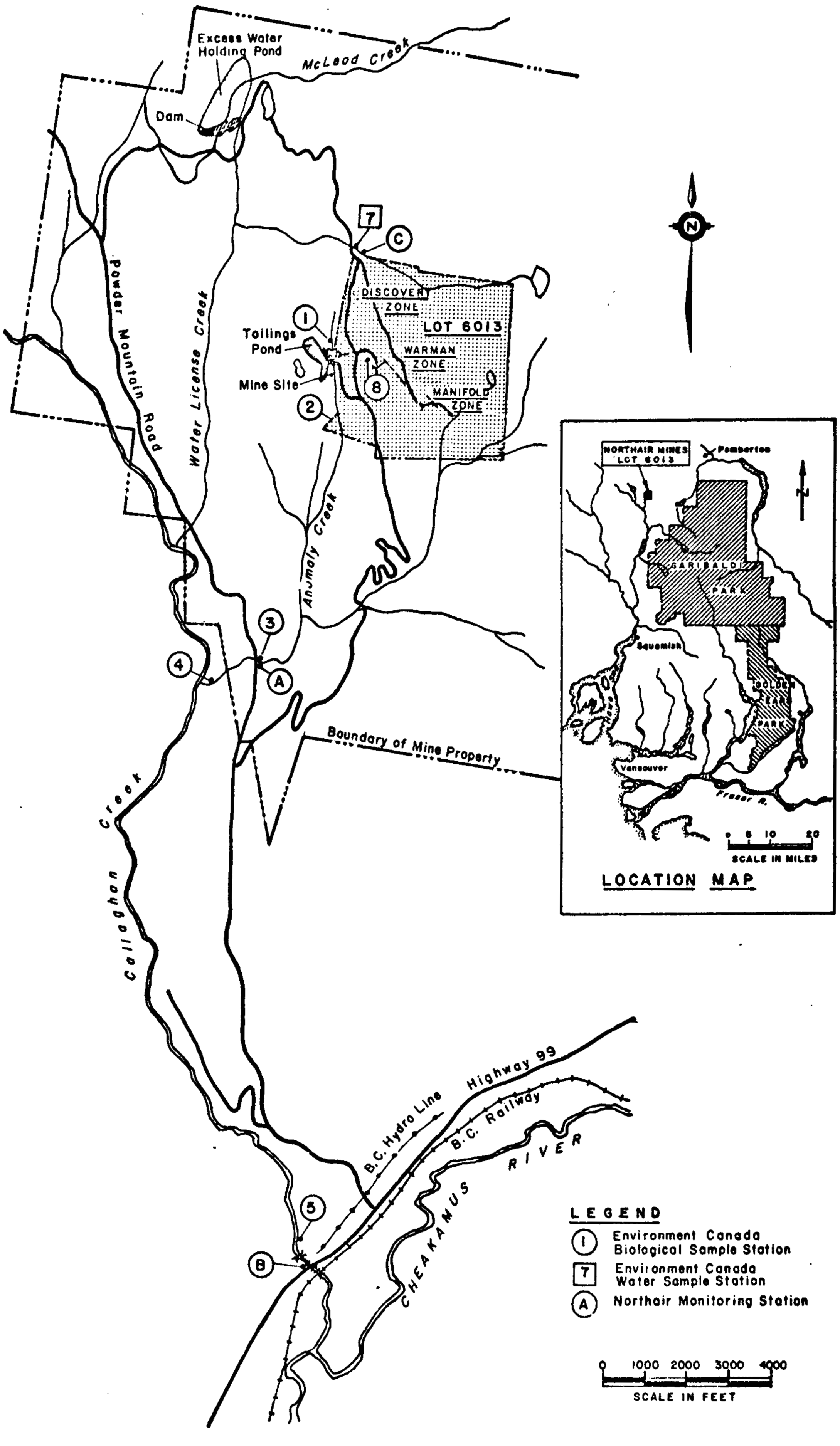

FIGURE 3 SAMPLE STATION LOCATIONS - NORTHAIR MINES LTD. (N.P.L.)

TABLE 1 NORTHAIR MINES LTD. (N.P.L.) MONITORING STATIONS, ESTABLISHED JUNE 10, 1975

STATION	LOCATION	DESCRIPTION
1	Anomaly Creek (control) above mill site.	Silt bottom, <1% gradient, slow flow, 1 to 2 feet wide, 6 inches deep.
2	Anomaly Creek immediately below mine camp area.	Large rock substrate with fine silt, 10% slope, some moss, but no large aquatic vegetation, average width ≃ 4 feet, average depth ≃ 6 inches, well shaded with forest canopy, swift-flowing.
3	Anomaly Creek immediately upstream of intersection with Powder Mountain Road.	Large boulders over bedrock, 1 to 6 inch rock and gravel, no macrophytes, average width ≃ 8 feet, average depth ≃ 2 feet, transected by fallen trees, open on south side by burn and partially shaded on north side, cascading, 15% slope.
4	Anomaly Creek downstream 2,000 ft. from Powder Mt. road, at large fallen log prior to discharge to Callaghan Creek.	Large boulders, 1 to 10 inch rock, gravel and sand, no macrophytes, open exposure, burned area to south, small waterfall above and below, average width ≃ 10 feet, average depth ≃ 18 inches, swift flow with ≃ 10% slope.
5	Callaghan Creek at Wooden Bridge just upstream from the Cheakamus River.	Boulders, large rock, gravel, and sand mix, no macrophytes, open exposure, swift flow, 5% slope, average width ≃ 40 feet, average depth ≃ 3 feet.
7	Water Licence Creek at intersection with mine access road.	Large boulders, 1 to 6 inch rock and gravel, no macrophytes, well shaded with forest canopy, cascading, 25% slope, average width ≃ 6 feet, average depth ≃ 1 foot.
8	3500 foot portal, mine drainage.	

5.3 Water Chemistry

The pH of the water was determined in the field with a narrow range "Hach Kit". A 300 ml sample collected in a B.O.D. bottle was preserved in the field with 2 mls of alkali-iodide-azide reagent and 2 mls of manganous sulfate solution. The Winkler Method for dissolved oxygen (D.O.) determination was employed (APHA, 1971). Titration against a .025N sodium thiosulfate solution was completed within six hours of preservation.

Two one-litre samples were collected at each site in polyethylene bottles. The first was preserved in the field with 5 mls of concentrated HNO_3 and analysed for dissolved metals.

A 250 ml water sample collected in a polyethylene bottle was immediately preserved in the field to a pH of 12 with NaOH for CN analyses. The lab analyses consist of converting the distillate of the sample to cyanogen chloride. Upon addition of pyridine-pyrozolone reagent, CNCl forms a blue dye, and its intensity is read on a spectrophotometer at 620 mμ.

Metal analyses were performed at the Environmental Protection Service Laboratory in West Vancouver. Direct aspiration in conjunction with a Jarrel-Ash 82-800 atomic absorption unit was employed in the analysis of all metals except lead which was previously complexed with ammonium 1 - pyrrolidine - dithiocarbamate (A.P.D.C.), extracted, and aspirated [Smith, 1973(b), 1973(c)].

An additional one-litre sample was collected at each station for nitrate (NO_3-N), nitrite (NO_2-N), ammonia (NH_3-N), and phosphate (PO_4) content and kept cool and in the dark until analyses the following day. Sulfate (SO_4) content was included in the analyses of the fall samples.

Total NO_2 and NO_3 are determined using the Technicon automated system. NO_3 is reduced to NO_2 on a copper-cadmium column and acidified. Under acidic conditions, NO_2 reacts with sulfanilamide and N-1-naphthylethylenediamine dihydrochloride to form a reddish-purple azo dye. The intensity of the dye is measured at 550 mμ using a 5 cm flow cell.

Levels of dissolved ammonia are measured using the Orion ammonia electrode. All ionic ammonia is converted to ammonia gas and the electrical potential created by the diffusion of free ammonia across the hydrophobic polymer membrane is a function of the concentration of ammonia in the sample.

Phosphates are converted to orthophosphates. These react with the molybdate ion $(MoO_4)^{-2}$ to form complex heteropoly-acids which are reduced with ascorbic acid to form a molybdenum blue complex colour. The absorbence is measured at 882 mμ on a Technicon colorimeter.

Sulfate concentrations are determined by titration against a known concentration of barium chloride in a non-aqueous medium at a pH range of 1.5 to 4.0. Interferences are removed by ion exchange. Thorin is used as an indicator causing a peach-pink endpoint.

Determination of these bionutrients (biogenic salts) was also performed at the Environment Canada Water Quality Laboratory. Details of the methods employed are described in APHA (1971).

5.4 Biological Assessment

Three separate samples for population distribution of benthic organisms were obtained from riffle areas of stations 2, 3, 4, and 5 with a one square foot circular sampler (modified Hess Sampler). The samples were later preserved with a formalin solution and forwarded to the Environment Canada Fresh Water Biology Laboratory at North Vancouver for sorting, classification, and enumeration. Identification was achieved using a Wild M5 Stereo Microscope, a Wild M11 Compound Microscope, and biological keys, including Pennak (1953), Ward and Whipple (1959), and Usinger (1968).

The invertebrate data was subjected to two different analyses:

(a) Organisms were placed into groups with respect to their sensitivity to pollution in accordance with MacKenthus's standards (1969). Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), characterize clean waters, while sludgeworms can tolerate a large amount of pollution.

(b) The Wilhm and Dorris (1968) measure of diversity ($\bar{d}$), which relates benthic communities to water quality was also applied. The formula which was first derived by Margalef (1956) from information theory and expanded by Wilhm and Dorris (1968) is shown below:

$$\bar{d} = - \sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

where $\bar{d}$ = diversity per sample

n_i = total number of individuals per taxon

n = total number of individuals per sample

s = total number of taxa

The diversity index ($\bar{d}$) is a numerical value which represents the relative "variety of life" in the sample by relating the number of individuals in each taxon to the total number of taxa.

Wilhm (1968) and Cole (1973) felt that values of less than one from the index ($\bar{d}$) were more representative of areas of heavy pollution while values above 3 suggested clean and/or highly productive water.

Pielou's (1966, 1967) "evenness" index (J), presented below, was also determined:

$$J = - \sum \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

Where Jmax = 1

a = total number of species sampled

The evenness index (J) is a measure of proportionate distribution of the numbers in each taxa. In a normal population the numbers are more or less evenly distributed between each taxa. Therefore, the higher the value for J, the more normal the population distribution and the more valid the value of $\bar{d}$. Statistical calculations were performed on a Hewlett Packard - 9830A computer.

5.5 Bioassays of Simulated Tailings

The supernatant of a simulated tailings sample, representing the theoretical mine effluent from the thickner overflow, was supplied by Northair Mines Ltd. from bench-scale metallurgical studies for bioanalyses. It was assumed that the sample was acutely toxic and a 96 hour LC_{50} (1) was performed to assess its median lethal concentration.

Bioassays were performed at concentrations of 100%, 56%, and 32% by weight, under static, aerated and without replacement conditions for 96 hours with dilution water (pH = 6.3; hardness = 7.5 ppm $CaCO_3$) obtained from the North Vancouver Capilano Reservoir. Five coho underyearlings (Oncorhynchus kisutch) per 30 kilo test sample ($\bar{x}$ loaded density = 1.85 gm/ℓ) were used as test species. Full bioassay details are appended. Observations of cumulative mortality were made at 16, 24, 48, 72, and 96 hours.

A subsample of the supernatant was forwarded to the Water Chemistry Laboratory for determinations of dissolved metals and non-filterable residue content. Procedures outlined in Section 5.2 and 5.3 were employed in the analyses.

(1) 96 hour LC_{50} - This term refers to Median Lethal Concentration or that level of a measurable lethal agent required to kill the 50th percentile in a group of test organisms, over the time period of 96 hours. The 50th percentile is meant to represent the average organism.

6. RESULTS AND DISCUSSION

6.1 Physical Parameters

Although generally not directly toxic, physical parameters such as turbidity, temperature, and flow rates often influence the quality of the aquatic environment and the natural biota as much as chemical pollutants. When tailings from a mining operation are discharged directly into the environment, the receiving waters may suffer vast changes in these physical characteristics.

Turbidity, conductivity and residue measurements are summarized in Table 2. Turbidity measurements indicated that during the spring development of the Northair property the watershed was relatively undisturbed. Formazin Turbidity Units (FTU's) of less than 5 are essentially transparent while values of 100 appear slightly translucent to the eye. The slight elevations of turbidity at station 2 (14 FTU's) just downstream of the development dissipated quickly. However, accelerated construction of the mill, draining of the tailings area, and construction of Tailings Dam A during the fall of 1975 resulted in complete disruption of the water clarity (9,000 FTU's) and bottom substrate composition of Anomaly Creek downstream from the development. This was evident as far downstream as the confluence of Anomaly Creek with Callaghan Creek. A significant portion of the turbidity was due to the mine drainage which forms the largest portion of the discharge volume of Anomaly Creek at station 2.

The turbid waters at station 5, Callaghan Creek, during the fall originate from glacial melt miles upstream and occur naturally every year. Station 7, Water Licence Creek, is fed by snow melt and remained unchanged throughout the study period.

During the spring, at all stations except station 2, the total residues and filterable fraction were low (≈50 ppm) and indicative of

TABLE 2 TURBIDITY, CONDUCTIVITY, AND RESIDUE ANALYSES - JUNE 10 AND SEPTEMBER 23, 1975

Station		Turbidity F.T.U.'s	Conductivity μS/cm	Total Residues mg/ℓ ± 3.0	Filterable Residues mg/ℓ ± 3.0	Non-Filterable Residues mg/ℓ ± 3.0
1	Spring	-	-	-	-	-
	Fall	2.3	460	139	≃139	< 3
2	Spring	14	137	188	102	86
	Fall	9000	410	6600	1300	5300
3	Spring	0.55	52	57	≃57	< 3
	Fall	3.6	180	118	≃118	< 3
4	Spring	0.57	50	54	≃54	< 3
	Fall	3.5	175	123	≃123	< 3
5	Spring	1.1	25	41	41	< 3
	Fall	22	37	49	36	13
7	Spring	0.17	126	34	≃34	< 3
	Fall	0.5	121	65	≃65	< 3
8	Spring	-	-	-	-	-
	Fall	360	455	1720	745	975

< indicates less than the detection limit.

clear water. Even at station 2, which includes the sediments carried by the mine drainage, residues were moderate but could markedly influence the water quality of Anomaly Creek if allowed to escape.

The excessive levels of residues at station 2 during the fall will undoubtedly be significantly reduced with the culverting of Anomaly Creek past the concentrator complex. But the level of residues carried by the mine drainage are of serious concern.

Waters with turbidity concentration ranging from 80 to 400 ppm sometimes support fish but they are unlikely to be good in the sense of quality, quantity or diversity, even in the lower part of this range, while concentrations greater than 400 ppm are totally unsuitable for fish life (Gammon, 1970).

Conductivity, which is a measure of the water's ability to conduct electrical current is primarily due to the mobile ionic constituents available. An approximate correlation exists between the amount of filterable residues present and the conductance [conductivity (μmho/cm) $\times$ .6 to .7 $\simeq$ filterable residues (ppm)]. However, this relationship does not hold true in this water basin. This may be due to high levels of non-ionized soluble organics, and non-ionized colloidal inorganics resulting from land disturbance during construction, dumping of organic detritus while dewatering the tailings impoundment, and glacial melt.

Heavy silting can be deleterious to macro-invertebrates and fish populations. Fish have an avoidance reaction towards turbid water and trout and salmon are primarily sight feeders. Concentrations of suspended solids exceeding 25 mg/ℓ cause difficulties in the feeding habits of such fish. Further increases in the levels of suspended solids cause a reduction in growth and disease resistance as well as physically eroding and clogging the gill membranes (Hynes, 1966; Lantz, 1971).

The effects of settled suspended materials on the stream environment are also well documented. Blanketing of the stream bottom causes a reduction of flow through the bottom gravel; often the segment of the stream that is affected becomes unsuitable for fish egg development. Silting may also drastically change the population of bottom-dwelling invertebrates, impede fry emergence, and cause high mortality and poor fry quality at emergence (Gammon, 1970).

Direct entry of tailings or mine workings into the watershed would undoubtedly result in deleterious effects on the biota of the Callaghan system and possibly the fisheries resource downstream. Should such a situation arise, settling facilities will have to be provided to facilitate the settling of sediments contained in the mine seepage.

Temperature, dissolved oxygen, and pH are important factors in stream ecology. Periodism and cercadian rhythms of the many aquatic organisms are dependent on natural seasonal changes in temperature. Fecundity rates, the number of generations per year, biomass production, and the species present are also related to the prevailing conditions. Trout, an important species in this area, are very sensitive to fluctuations in ambient conditions and cannot sustain temperatures above $25^{o}C$ or shortages of dissolved oxygen for long periods (Hynes, 1970).

Water temperature, dissolved oxygen, and pH are depicted in Table 3. All streams drain runoff from the melting snowpack and probably a portion of a nearby glacier. Stream temperatures were slightly above freezing in the spring and increased over the summer to an average $9^{o}C$.

Dissolved oxygen was found to be above 100% saturation at all sample sites (temperature and altitude corrected). The pH at all stations during both sampling periods fell between 6.7 and 7.3, which is a satisfactory range for good water quality.

TABLE 3 NON-METAL ANALYSES - JUNE 10 AND SEPTEMBER 23, 1975

Station		Cl^- ppm ± 0.1	CN^- ppm ± 0.03	pH	D.O. ppm	Temp. °C	Hardness mg/ℓ $CaCO_3$
1	Spring	-	-	-	-	-	-
	Fall	-	-	-	-	8	-
2	Spring	0.5	< 0.03	6.8	11.4	-	70
	Fall	-	-	-	-	8	-
3	Spring	< 0.5	< 0.03	6.6	11.7	3.5	22
	Fall	-	-	7.3	-	10	-
4	Spring	< 0.5	< 0.03	6.8	11.5	-	22
	Fall	-	-	7.3	-	10	-
5	Spring	< 0.5	< 0.03	6.6	11.5	-	9.6
	Fall	-	-	6.7	-	10	-
7	Spring	< 0.5	< 0.03	6.7	12.3	2	17
	Fall	-	-	-	-	-	-
8	Spring	< 0.5	-	6.8	-	-	170
	Fall	-	-	-	-	-	-

6.2 Water Chemistry

6.2.1 Water Hardness, Chlorine and Cyanide. These waters were found to be relatively soft (i.e., <100 mg/ℓ $CaCO_3$ equivalents) except for station 8, the mine drainage, which contained elevated levels of calcium (Table 3). Station 2, although classifiably soft, exhibited elevated levels of total magnesium during the fall survey but by subtraction this phenomenon could be attributed to the sediment load added by construction activity and not to the mine drainage.

Waters low in calcium and magnesium ions (soft), increase the toxicity of many metals to aquatic life by several fold (E.P.A., 1973). For instance, cadmium (Cd) which itself acts synergistically with zinc and other metals to increase toxic effects is considered "safe" at 0.03 mg/ℓ in hard waters but "safe" only at 0.0004 mg/ℓ in soft waters (E.P.A., 1973).

Zinc, which is also greatly affected by water hardness, is regarded acceptable at the 0.03 mg/ℓ level in hard water (E.P.A., 1973). In soft water such as Anomaly Creek a larger safety margin should be considered, as 0.04 ppm zinc in soft water prevented the hatching of rainbow trout (McKee & Wolf, 1963).

Background levels of anionic chlorine (Cl^-) and cyanide (CN^-) were below the detection limits (Table 3). Both were of major concern during the preliminary feasibility studies when some discharge of tailing decant was anticipated. Now that the Northair operation will be impounding all their excess water, it can be expected that through aging and dilution, both these toxic anions will be reduced to ambient levels. Since the toxicity of CN^- depends largely on pH, dissolved oxygen, temperature, and hardness, the actual toxicity of the tailings supernatant cannot be determined from the concentration of CN^- alone. Therefore, the toxicity of the McLeod Creek holding pond contents should be determined by bioanalyses prior to the granting of a permit to release stored supernatant to the Callaghan system once the mine is closed.

6.2.2 Metal Analyses. Cation analyses for the fall and summer surveys are presented in Tables 4 and 5. Except for stations 2 and 8 the metal levels examined were low and representative of pristine conditions.

Station 2, the drainage immediately adjacent to the development contained abnormally high levels of Pb and Zn during the spring survey. These, however, did not exceed the National Regulations and Guidelines of 0.2 mg/ℓ Pb and 0.5 mg/ℓ Zn. The situation had deteriorated in the fall to the point where the Regulations and Guidelines were exceeded in both these metals, and total cadmium was detected and total iron increased 200-fold. Station 8, the mine seepage, exceeded the National Regulations and Guidelines in Pb and Zn, and Cu fell just short of the maximum permissible limits.

Since the mine seepage forms the bulk of the volume of Anomaly Creek at station 2 and improvements are expected in controlling the disruption of Anomaly Creek adjacent to the mill site, it is clear that the mine drainage poses the major source of water pollution. In most cases the dissolved fractions of these metals are well below the hazardous level; therefore, removal of the solids fraction would appreciably reduce the total metal levels.

6.2.3 Nutrient Analyses. Several processes in the dressing of ore use reagents that contain bases or bi-products of PO_4, NO_2, NO_3, and SO_4. If the quantities of these materials are large, they could constitute a threat to the biota of Anomaly and Callaghan creeks.

Sulfates, for example, that could originate from the microbial leaching of mineral deposits and various common flotation reagents are known to be lethal to a number of common fish species at concentrations

TABLE 4 TOTAL EXTRACTABLE AND DISSOLVED METAL ANALYSES - JUNE 10, 1975 (ppm)

Metal		Station						
		1	2	3	4	5	7	8
Ca	total	-	26	8.1	8.2	3.4	6.4	63
	dissolved	-	-	-	-	-	-	-
Cd	total	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	dissolved	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-
Cu	total	-	0.01	< 0.01	< 0.01	< 0.01	0.01	0.02
	dissolved	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-
Fe	total	-	1.26	0.07	0.07	0.05	0.04	0.08
	dissolved	-	0.04	< 0.03	< 0.03	< 0.03	< 0.03	-
Mg	total	-	1.3	0.33	0.4	0.28	0.31	3.1
	dissolved	-	-	-	-	-	-	-
Mo	total	-	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
	dissolved	-	-	-	-	-	-	-
Ni	total	-	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	dissolved	-	-	-	-	-	-	-
Pb	total	-	0.03	0.02	< 0.02	< 0.02	< 0.02	0.03
	dissolved	-	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	-
Zn	total	-	0.06	0.02	0.02	< 0.01	0.03	0.07
	dissolved	-	0.02	< 0.01	0.01	< 0.01	< 0.01	-

TABLE 5 TOTAL EXTRACTABLE AND DISSOLVED METAL ANALYSES - SEPTEMBER 23, 1975 (ppm)

Metal		Station						
		1	2	3	4	5	7	8
Ca	total	80	70	27	25	5	19	120
	dissolved	-	-	-	-	-	-	-
Cd	total	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	dissolved	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cu	total	< 0.01	0.49	< 0.01	< 0.01	< 0.01	< 0.01	0.15
	dissolved	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fe	total	0.4	260	0.28	0.18	0.48	0.05	6.4
	dissolved	< 0.03	< 0.03	< 0.03	< 0.03	0.03	< 0.03	< 0.03
Mg	total	2.6	180	1.3	1.3	0.65	0.8	6.5
	dissolved	-	-	-	-	-	-	-
Mo	total	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
	dissolved	-	-	-	-	-	-	-
Ni	total	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	dissolved	-	-	-	-	-	-	-
Pb	total	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.38
	dissolved	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Zn	total	0.14	5.4	0.03	0.03	0.02	0.02	1.03
	dissolved	0.02	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03

of 100 mg/ℓ over a period of 120 hours (McKee and Wolfe, 1963). Phosphates and nitrates originating from the domestic sewage batch treatment plant or frothing and promoting agents may result in algae blooms that are ultimately responsible for degrading water quality.

Table 6 summarizes the nutrient content of the water at each station for both the spring and fall surveys. Station 2, the watershed immediately downstream of the mine and mill site, contained elevated levels of all nutrients measured in the fall survey. This was mainly attributed to the consequences of construction at that time and except in the case of sulfate, these parameters dropped to background levels at station 3. The mine drainage, station 8, which contributes significantly to Anomaly Creek flow, contained excessive levels of sulfate which were detectable in decreasing amounts as far downstream as station 5.

Natural sulfate (SO_4) levels originate from leaching of common minerals, the oxidation of pyrites or as the oxidized state of organic matter in the sulfur cycle. A degree of importance should be attached to the high levels of SO_4 recorded at station 8, since this indicates that leaching may be occurring on the exposed faces of the ore body. This is of particular concern as there is no proposal to treat this effluent before discharge. This level exceeds the "A" level standards (50 mg/ℓ) of the Provincial objectives set for the Mining, Mine Milling and Smelting Industries of B.C. (1973).

In most instances NH_3, NO_3, NO_2, PO_4, and OPO_4 (orthophosphate) were undetectable in the streams examined. No explanation can be offerred for the detectable levels of NH_3, NO_2, and NO_3 found in Water Licence Creek, station 7, since it is entirely unaffected by the development to date.

Hypothetically, the discharge of excessive amounts of nutrients to Anomaly Creek could result in the overabundant growth of algae in both Anomaly and Callaghan creeks. In extremes this could result in concomitant odors, reduction in oxygen and accelerated eutrophication

TABLE 6 NUTRIENT ANALYSES - JUNE 10 AND SEPTEMBER 23, 1975

Station		TPO_4 mg/ℓP ± 0.01	OPO_4 mg/ℓP ± 0.005	TSO_4 mg/ℓSO_4 ± 5.0	NH_3 mg/ℓN ± 0.01	NO_2 mg/ℓN ± 0.005	NO_3 mg/ℓN ± 0.01
1	Spring	-	-	-	-	-	-
	Fall	0.01	< 0.005	135	< 0.01	< 0.005	0.02
2	Spring	0.19	0.042	-	< 0.01	< 0.005	< 0.01
	Fall	5.8	0.05	98	0.025	0.04	0.26
3	Spring	0.011	0.007	-	< 0.01	< 0.005	< 0.01
	Fall	< 0.01	< 0.005	33	0.012	< 0.005	0.02
4	Spring	< 0.01	< 0.005	-	< 0.01	< 0.005	< 0.01
	Fall	< 0.01	< 0.005	35	< 0.01	< 0.005	< 0.01
5	Spring	< 0.01	< 0.005	-	< 0.01	< 0.005	< 0.01
	Fall	0.03	< 0.005	6	0.012	< 0.005	< 0.01
7	Spring	< 0.01	< 0.005	-	< 0.01	< 0.005	0.011
	Fall	< 0.01	< 0.005	12.5	0.23	0.11	0.52
8	Spring	< 0.01	-	110	-	< 0.005	< 0.01
	Fall	0.7	< 0.005	103	< 0.01	< 0.005	< 0.01

of the Daisy Lake reservoir. What effect this may have on developing fish eggs and algae growth in the spawning gravels further downstream is not known.

6.3 Biological Assessment

6.3.1 Benthic Invertebrates. Populations of invertebrates, each with their unique requirements, have proven to be excellent indicators of environmental changes. All organisms have specific tolerance ranges to many different environmental factors. Some are highly tolerant of modified conditions, others are moderately tolerant and those that cannot cope with even small environmental changes are highly intolerant.

In pristine ecological conditions a diversified flora and fauna exists (tolerant and intolerant) in a highly integrated, interdependent system. Even a subtle disruption of this system may manifest itself in a large re-adjustment in the relative population proportions. For example, a change in the nutrient supply may cause reduced numbers of some species while others become more predominant. Community structure will adjust to stress by shifts in species diversity, density, and dominance (Smith, 1966). However, sudden changes in the biota also occur quite naturally from season to season and year to year. It must be remembered that in most communities there is an overabundance of the members at any one trophic level that protects most species from total elimination by fluctuating seasonal changes.

Tables 7 and 8 represent the combined counts of three invertebrate samples for the spring and fall programs respectively. The invertebrates were identified to family and then placed into one of three groups: Group I is considered highly tolerant of polluted waters; Group II, moderately tolerant; and Group III, very intolerant. Figures 4 and 5 graphically show the relative proportions of these three groups at stations 2, 3, 4, and 5 on June 10 and September 23, 1975.

TABLE 7 POPULATION DISTRIBUTIONS OF BENTHIC INVERTEBRATES AT STATIONS 2, 3, 4, AND 5 - JUNE 10, 1975

	Station Number			
	2	3	4	5
GROUP I (Pollution Tolerant)				
Oligochaeta, plesiopora	24	4	18	-
Platyhelminthes, Rhabdocoel	27	1	3	1
GROUP II (Moderately Tolerant)				
Diptera				
Helidae	1	-	2	-
Blepharoceridae	-	3	-	-
Empididae	-	3	3	7
Tendipedidae	133	75	61	65
Tipulidae	-	7	4	-
Dolichopodidae	-	-	2	-
Arachnida				
Hydracarina sp.[1]	-	-	1	-
Hydracarina sp.[2]	-	-	1	-
Hemiptera Hebridae	-	-	-	-
Coleoptera Elmidae	26	1	1	-
GROUP III (Intolerant)				
Ephemeroptera				
Baetidae	-	53	132	104
Heptageniidae	1	62	160	9
Plecoptera Chloroperlidae	-	15	21	12
Trichoptera				
Hydropsychidae	-	-	1	1
Psychomyiidae	-	8	16	-
Total Individuals	212	232	426	199
Total Taxa	6	11	15	7

TABLE 8 POPULATION DISTRIBUTIONS OF BENTHIC INVERTEBRATES AT STATIONS 2, 3, 4, AND 5 - SEPTEMBER 23, 1975

	Station Number			
	2	3	4	5
<u>GROUP I</u> (Pollution Tolerant)	Complete absence of organisms			
Oligochaeta, plesiopora		3	-	-
Platyhelminthes, Rhabdocoel		8	6	-
<u>GROUP II</u> (Moderately Tolerant)				
Diptera				
Helidae		2	-	-
Blepharoceridae		-	-	-
Empididae		-	-	-
Tendipedidae		7	13	133
Tipulidae		4	-	4
Dolichopodidae		-	-	-
Arachnida				
Hydracarina sp.[1]		2	1	-
Hydracarina sp.[2]		-	-	-
Hemiptera Hebridae		2	3	1
Coleoptera Elmidae		3	5	-
<u>GROUP III</u> (Intolerant)				
Ephemeroptera				
Baetidae		95	24	24
Heptageniidae		167	50	31
Plecoptera Chloroperlidae		130	43	65
Trichoptera				
Hydropsychidae		-	1	-
Psychomyiidae		18	12	-
Total Individuals		441	158	258
Total Taxa		12	10	6

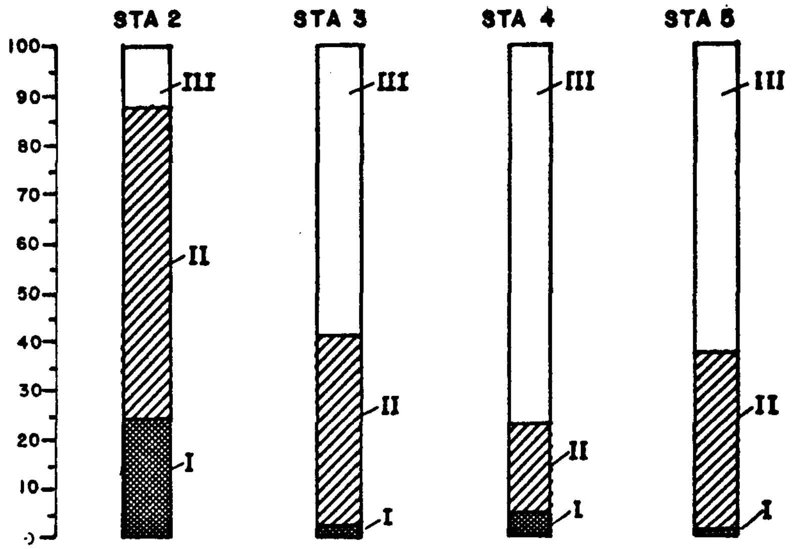

FIGURE 4 THE ACCUMULATIVE PERCENTAGE DISTRIBUTION OF GROUPS I, II, AND III FOR STATIONS 2, 3, 4 AND 5. JUNE 10, 1975.

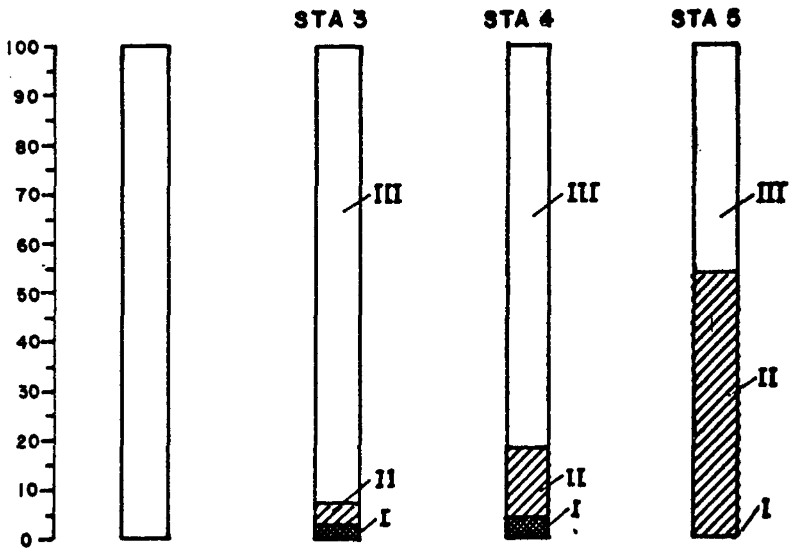

FIGURE 5 THE ACCUMULATIVE PERCENTAGE DISTRIBUTION OF GROUPS I, II, AND III FOR STATIONS 3, 4 AND 5 SEPTEMBER 23, 1975.

The data indicates that in all cases Groups II and III are well represented with only limited representation from Group I (e.g., <5% at each station). In optimum conditions, however, Group III usually forms the larger proportion. Diptera, especially Tendipedidae (midges) formed the bulk of Group II, while Ephemeroptera (Mayflies) and Plecoptera (Stoneflies) formed the majority in Group III. A future rise in the proportion of Group I at the expense of Group III may be indicative of a degrading environment. The invertebrate distribution here indicates that the waters of Anomaly Creek were in satisfactory condition during the spring. However, during the fall, the entire population at station 2, immediately below the mine site, was completely void of benthic invertebrates. The benthos distribution and density had recovered at station 3.

The calculated values for $\bar{d}$ and J for each site sampled on the two surveys are presented in Table 9. Diversity indices of the benthic communities near the Northair development averaged 2.093. Some sensitivity of the index is lost when diversities are based on higher taxonomic categories (Egloff & Brakel, 1973); however, this relatively low value is considered accurate in that both the evenness values and total individuals collected were high. These low values may be attributable to the lack of accumulated nutrients in these cold northern streams but a more likely mechanism is that the stream biota at station 2 is possibly suffering from the silting resulting from the construction activities upstream, and in the case of station 5, to the natural glacial siltation carried by Callaghan Creek. Figure 6 clearly demonstrates the drop in diversity at stations 2 and 5 while evenness values stay more or less constant.

6.3.2 Tailings Chemistry and Bioassay Results. The tailings decant sample supplied from bench-scale studies was found to be toxic with a 96 hour LC_{50} of 42% concentration. Results of the bioassays are summarized in Table 10 and full details are appended. These bioassays

TABLE 9 CALCULATED VALUES OF $\overline{d}$ AND J FOR STATIONS 2, 3, 4, AND 5 - JUNE 10 AND SEPTEMBER 23, 1975

Station	Date	$\overline{d}$	J
2	June 10	1.601	0.619
3	June 10	2.428	0.702
4	June 10	2.359	0.604
5	June 10	1.709	0.609
2	September 23*	-	-
3	September 23	2.181	0.608
4	September 23	2.566	0.772
5	September 23	1.804	0.698
Average		2.093	0.659

* Not included in calculating the average.

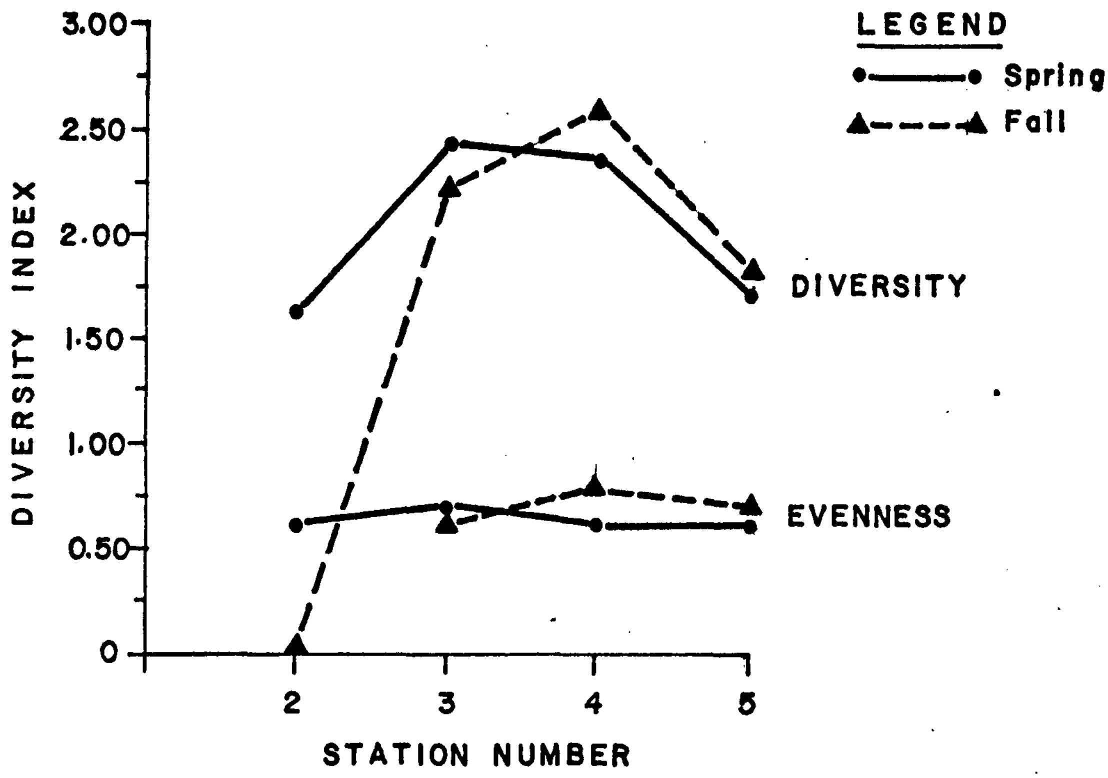

FIGURE 6 GRAPHIC REPRESENTATION OF THE DIVERSITY AND EVENNESS VALUES OF THE BENTHIC COMMUNITIES AT STATIONS 2, 3, 4, AND 5 - JUNE 10 AND SEPTEMBER 23, 1975.

were, however, performed on the clear supernatant of the settled tailings and, therefore, sublethal factors such as abrasion to fish gills from the tailings sands could not be determined. Nor could a proper assessment be made at this time of other influencing factors, such as the effects of sewage effluent if it is to be combined with the tailings and the toxicity build-up in the tailings impoundment.

The threshold of toxicity, being defined as the highest concentration tested that resulted in no mortality over a 96-hour period, was found to be 32% of the tailings decant concentration.

Provided the tailings sample supplied from the bench-scale studies is a reasonable indication of the tailings quality with respect to the pulp settleability, then turbidity and suspended solids are not expected to present a problem if there was an accidental release from the tailings impoundment. The simulated tailings sample examined contained 5 mg/ℓ suspended solids.

A brief chemical analysis of the tailings decant revealed that the sample contained potentially toxic levels of copper and zinc [E.P.A., 1973, (Table 11)]. These two metals may have been responsible for the acute toxicity of the tailings sample.

Based on heavy metal concentrations and toxicity results, operational decanting of the supernatant from either the tailings pond or the McLeod Creek holding pond would be unacceptable.

TABLE 10 BIOASSAY RESULTS ON SIMULATED TAILINGS EFFLUENT FROM BENCH-SCALE STUDIES

Concentration %	Cumulative Mortality at Time (hours)					Assessment
	16	24	48	72	96	
100%	0/5	0/5	0/5	2/5	5/5	Toxic
56%	0/5	1/5	5/5	5/5	5/5	Toxic
32%	0/5	0/5	0/5	0/5	0/5	Non-Toxic
Control	0/5	0/5	0/5	0/5	0/5	Non-Toxic

TABLE 11 TAILINGS CHEMISTRY

Non-Filterable Residues ppm ± 3.0 (Suspended Solids)	Cd ppm ± 0.01	Cu ppm ± 0.01	Fe ppm ± 0.03	Mo ppm ± 0.3	Pb ppm ± 0.02	Zn ppm ± 0.01
5	< 0.01	0.51	0.08	< 0.3	0.03	0.16

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APPENDIX

BIOASSAY RECORD

Environment Canada / Environnement Canada
Environmental Protection / Protection de l'Environnement

BIOASSAY RECORD – RELEVÉ D'ESSAIS BIOLOGIQUES

SAMPLE NO. / Échantillon nº	COMPANY / Société	ATTENTION / À l'attention de
3414	Northair Mines Ltd. (N.P.L.)	Bob Hallam

SAMPLE DESCRIPTION, AMOUNT AND CONTAINER / Description de l'échantillon, quantité et récipient

Northair Mines Ltd. (N.P.L.)
Simulated Tailings effluent from bench scale studies. (decanted)

COLLECTED BY / Prélevé par	DATE	TIME / Heure	WITNESS / Témoin
Bob Hallam	17/March/75	-	

ANALYSIS REQUIRED / Analyse demandée: 96 hour LC_{50}

DILUTION WATER (Check one) / Eau de dilution (Cocher selon le cas): ☐ Salt Water / Eau saline ☒ Fresh Water / Eau fraîche

SAMPLE HANDLING (Check one) / Manipulation de l'échantillon (Cocher selon le cas): ☐ Legal / Légale ☒ Routine / Courante

FOR LAB USE ONLY – RÉSERVÉ AU LABORATOIRE

RECEIVED IN LABORATORY BY / Reçu au laboratoire par	DATE	TIME / Heure	WITNESS / Témoin
Linda Patterson	17/03/75	1100	

ORIGINAL SAMPLE / Échantillon initial: pH A 7.34, B 7.23; SALINITY / Teneur en sel: ‰

DILUTION WATER / Eau de dilution: pH 6.3; HARDNESS (ppm) / Dureté 7.5 $CaCO_3$; SALINITY / Teneur en sel: ‰

DILUTIONS MEASURED BY / Dilutions mesurées d'après: ☒ Weight / Le poids ☐ Volume / Le volume

FISH SPECIES / Espèce de poisson	BIOASSAY TEMPERATURE / Température lors de l'essai	FISH SIZE / Taille du poisson	FISH LOADING DENSITY / Densité de la charge de poissons
Coho	7.5 ± 1 °C	☒ Weekly Average / Moyenne Hebdomadaire ☐ Actual / Actuelle	1.85 gm/l/g./l

FORK LENGTH (avg.) / Longueur de la fourchette (app.)	RANGE / Portée	WEIGHT (avg.) / Poids (app.)	RANGE / Variation
10.1 cm	9.4 cm. TO À 10.7 cm.	11.12 gm/g.	8.97 gm/g. TO À 14.05 gm/g.

Concentration	Test Vol. / Vol de l'échant.	Start Date / Essai commencé le	Start / Initial pH	Start / Initial D.O. / O.D.		.25	.5	1	2	4	8	16	24	48	72	96	Final pH	Final D.O. / O.D.	
						CUMULATIVE MORTALITY AT TIME (hr) / Mortalité cumulative													
100%	30 kilo	17/03/75	7.57	7.1								0/5	0/5	0/5	2/5	5/5	7.50	11.2	
56%	30 kilo	24/03/75	6.87	11.8						0/5		0/5	1/5	5/5	5/5	5/5	7.07	10.9	
32%	30 kilo	17/03/75	7.23	10.5								0/5	0/5	0/5	0/5	0/5	6.93	10.6	
Control / Contrôle	30 kilo	24/03/75	6.28	12.2						0/5		0/5	0/5	0/5	0/5	0/5	6.59	10.7	

ANALYSIS RESULTS / Résultats de l'analyse

Threshold of Toxicity = 32% concentration
96 hr LC_{50} = 42% concentration

Linda Patterson
ANALYST / Analyste

3 April 1975
DATE

EPS-1101 (3/74)

Man. min. 150