Environment Canada
Environmental Protection Service

COMPLIANCE EVALUATION OF UNITED KENO HILL MINES LTD., ELSA, YUKON TERRITORY

81-23

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ABSTRACT

During the period from August 5-7, 1980 the Environmental Protection Service carried out a monitoring study of the effluent discharge from United Keno Hill Mines Ltd. The purpose of this study was to determine the state of compliance of this mine effluent discharge with respect to the requirements of the Federal Metal Mining Liquid Effluent Guidelines.

The activities involved in this study include the following:

1) collect and analyse composite and grab samples at selected locations for three consecutive days;
2) perform static bioassays on the effluent;
3) perform in situ bioassays at selected locations.

The mine in compliance with respect to the Federal Metal Mining Liquid Effluent Guidelines on all three days of the study.

RÉSUMÉ

Du 5 au 7 août 1980, le Service de la protection de l'environnament a mené une étude sur les effluents rejetés par la mine "United Keno Hill Ltd". Cette étude a eu pour ojet de déterminer dans quelle mesure le rejet d'effluents provenant de cette mine était conforme au lignes directrices fédérales sur les effluents liquides des mines de métaux.

L'étude à comporté les opérations suivantes:

1) prélèvement à des endroits déterminés et analyse d'échantillons moyens et instantanés pendant trois jours consécutifs;
2) bioanalyses statiques effectuées sur les effluents;
3) bioanalyses effectuées sur place, à chacun des points de prélèvement.

Pendant les trois jours qu'a duré l'étude, les données recueillies sur le rejet des effluents par la mine ont été conformes aux lignes directrices fédérales sur les effluent liquides des mines de métaux.

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LIST OF ABBREVIATIONS AND DEFINITIONS

IGPD	Imperial Gallons per Day
<	Less Than
ml	Millilitres
mg/l	Milligrams per Litre
T	Total
t.p.d	Tons per Day
E	Extractable

SUMMARY

Based on the data obtained from August 5 to 7, 1980, the tailings pond supernatant at United Keno Hill Mines complied with all the requirements of the federal guidelines. The receiving waters of both Flat Creek and the South McQuesten River, downstream of the confluence with Flat Creek, exhibited zinc concentrations above levels recommended to maintain aquatic life.

1 INTRODUCTION

On February 25, 1977 the Federal Metal Mining Liquid Effluent Regulations and Guidelines were promulgated. These documents were developed according to Section 33 and 34 of the Fisheries Act. The requirements defined in these documents are based on best practicable technology and apply uniformly as national baseline requirements. The Regulations apply to every new, expanded and reopened base metal, uranium and iron ore mine, while the Guidelines apply to existing base metal, uranium and iron ore mines (Department of Fisheries, 1977). These control requirements were developed by a Task Force consisting of representatives of the mining industry, provincial and federal government regulatory agencies. The Environmental Protection Service (EPS) was responsible for the overall coordination of all the necessary inputs required to develop the national effluent controls.

In order to complete an assessment of the state of compliance for mining operations in Yukon, EPS carried out effluent surveillance studies for compliance verification at mines which discharged tailings pond supernatant to a receiving body of water. This report is an account of the effluent surveillance study conducted from August 5 to 7, 1980 at United Keno Hill Mines, in the Yukon Territory.

The following report includes a description of the mine, the procedures and methods used in this study, the results obtained and a determination of the state of compliance of this mine with the Federal Guidelines.

2 MINE DESCRIPTION

2.1 General Information

In 1906, silver, lead and zinc ore was discovered on Galena Hill which stimulated interest in the Keno Hill area and in 1919 rich veins of silver were discovered. Since then, there has been almost continuous production from veins in the area, except for the period 1942 to 1946.

In 1946 United Keno Hill Mines Ltd. acquired the holdings of Treadwell Yukon and began the mining operation which is still underway today. In the 30 year period up to the end of 1976, United Keno Hill Mines has produced over 126 million ounces of silver, 437 million pounds of lead, 329 million pounds of zinc and 4 million pounds of cadmium.

At the time of this study, the company produced approximately 100,000 tons of ore a year from five underground mines: Husky, No Cash, Elsa, Ruby and Keno 700. A pilot, open pit operation is presently being evaluated but it has not yet produced a significant amount of ore. Figure 1 is a map of the Yukon showing the location of United Keno Hill Mines. The reference mine production rate for this mine was established at approximately 120 000 tons of ore/year based on information supplied by the Company.

2.2 Concentrator Operation

The ore is transported to the mill by rail or truck depending on the location of the mine. In the mill, the ore is crushed and ground to a mesh size of 200. The ground ore is then classified, and diluted with water to achieve an semi-solid consistency. The resulting slurry is referred to as "pulp". Small quantities of surfactant chemicals are added to the pulp to modify the surfaces of the mineral particles. Other reagents, for example, calcium hypochlorite (HTH), lime, cresylic acid, xanthate (Z-11) among others, are specifically chosen and added with frothing agents to recover minerals. The

chemically treated pulp is then agitated and aerated which causes the mineral bearing froth to rise to the surface where it is skimmed off. The first concentrate to be skimmed is lead. After the lead concentrate is skimmed off, the remaining pulp is conditioned and the zinc concentrate is removed. The concentrated ore is thickened, filtered and dried. Some of the tailings are thickened and recycled through the zinc circuits. The unrecycled tailings are also thickened and approximately 8% of this is used for backfill in the mine. The remaining tailings are discharged to the impoundment.

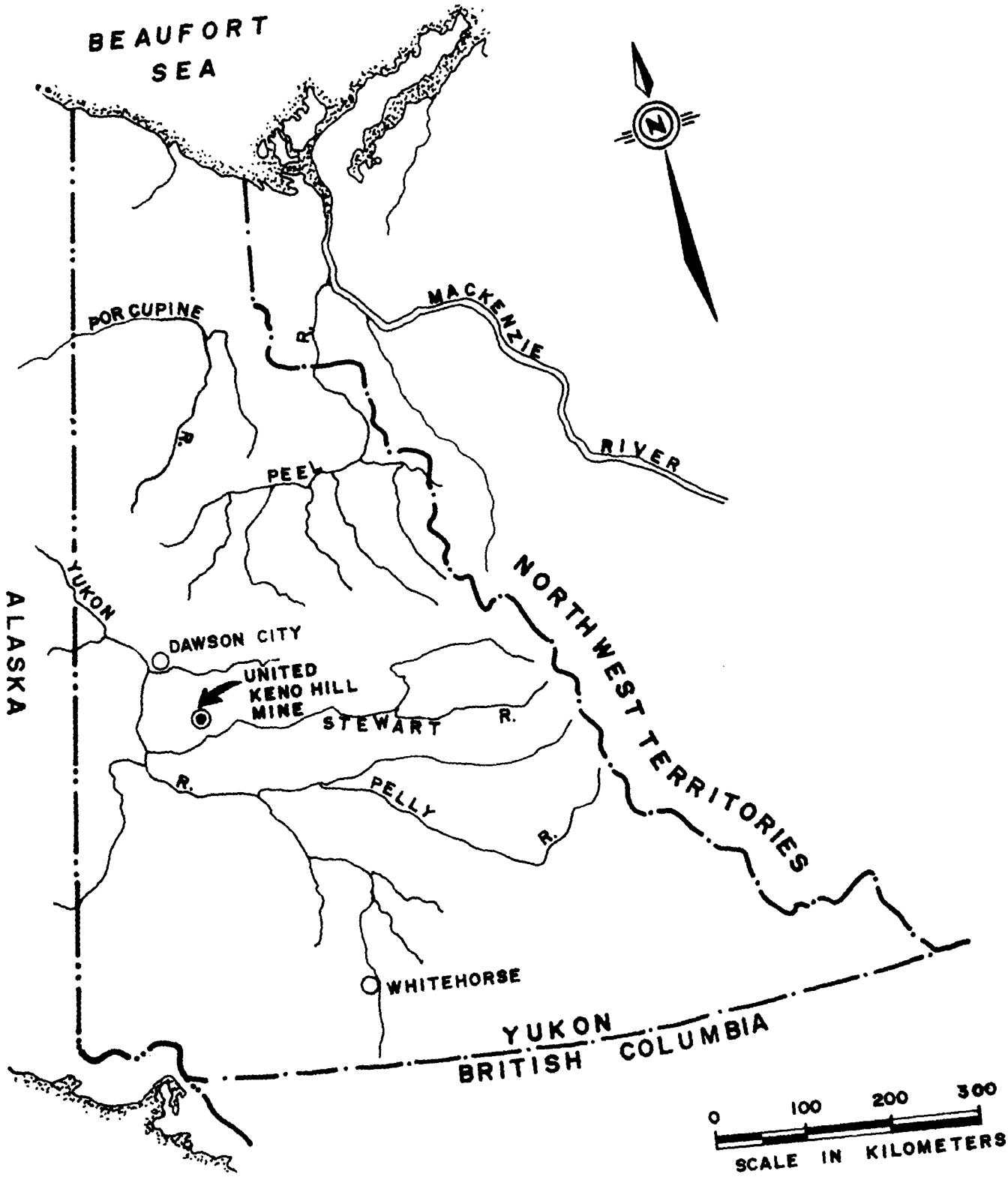

FIGURE 1: LOCATION OF UNITED KENO HILL MINE

3 WASTEWATER SOURCES

The mine/mill complex has three principal sources of wastewater: mill process water, mine water and surface drainage water (Figure 2).

The water used for milling is supplied entirely from the Elsa mine drainage water. The volume varies from 108,000 to 210,000 IGPD. An unknown volume of mill water is recycled through the zinc circuit. A maximum of 142,000 IGPD of mill tailings water is discharged to the tailings impoundment.

At the time this study was carried out, there were five operating mines supplying ore to the mill and four of these discharged drainage water. The discharge points for the drainage water are as follows:

Husky	Tailings impoundment
Elsa	Mill or tailings impoundment
Keno 700	Crystal Creek
No Cash	Star Creek in winter, unnamed creek in summer
Ruby	Tailings impoundment

The volumes of water discharged are unknown but it is estimated that 175 000 IGPD of mine drainage water enters the tailings impoundment.

In addition to the operating mines, there are several abandoned mine adits located between Elsa and Keno, which discharge unknown volumes of water to various creeks and streams which eventually flow into the McQuesten River. In order to determine the discharge impact of the abandoned adits and present tailings impoundment, two locations were chosen downstream on the McQuesten River and one downstream on Flat Creek which drains into the McQuesten River.

There are also numerous surface water flows which enter the tailings impoundment but the volume is unknown. It is assumed that most of this runoff flow would occur during spring freshet.

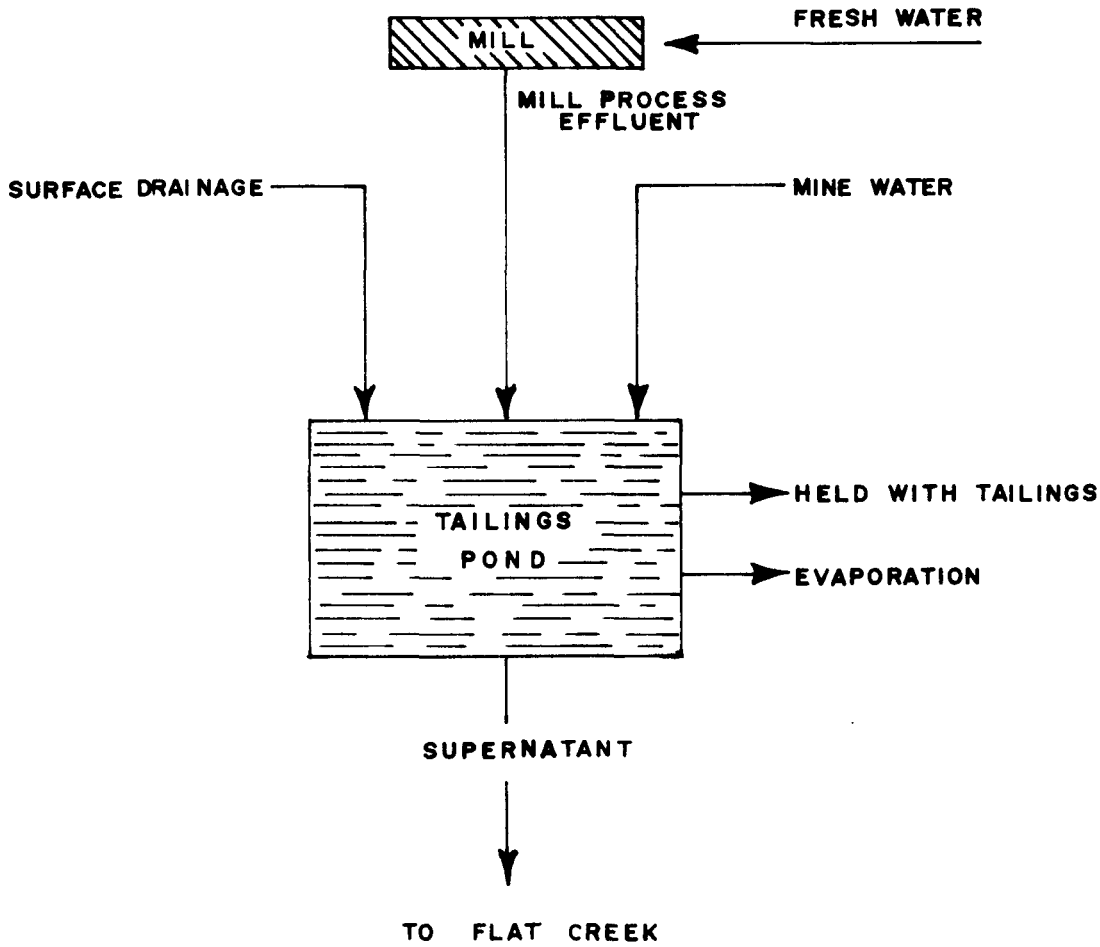

FIGURE 2: WASTEWATER SOURCES

The tailings impoundment consists of three settling ponds in series, as shown in Figure 3. The overflow from Pond #1 is treated with lime as it flows into Pond #2. The lime maintains a high pH which, in turn, promotes the precipitation and removal of metals. The retention time for Pond #2 was calculated to be approximately four weeks. The supernatant from Pond #2 then flows into the final settling pond of the series, Pond #3, which has a retention time of one week. Pond #3 functions as a polishing pond for final clarification before discharging into Flat Creek, a tributary of the McQuesten River, at an estimated rate in excess of 800,000 IGPD.

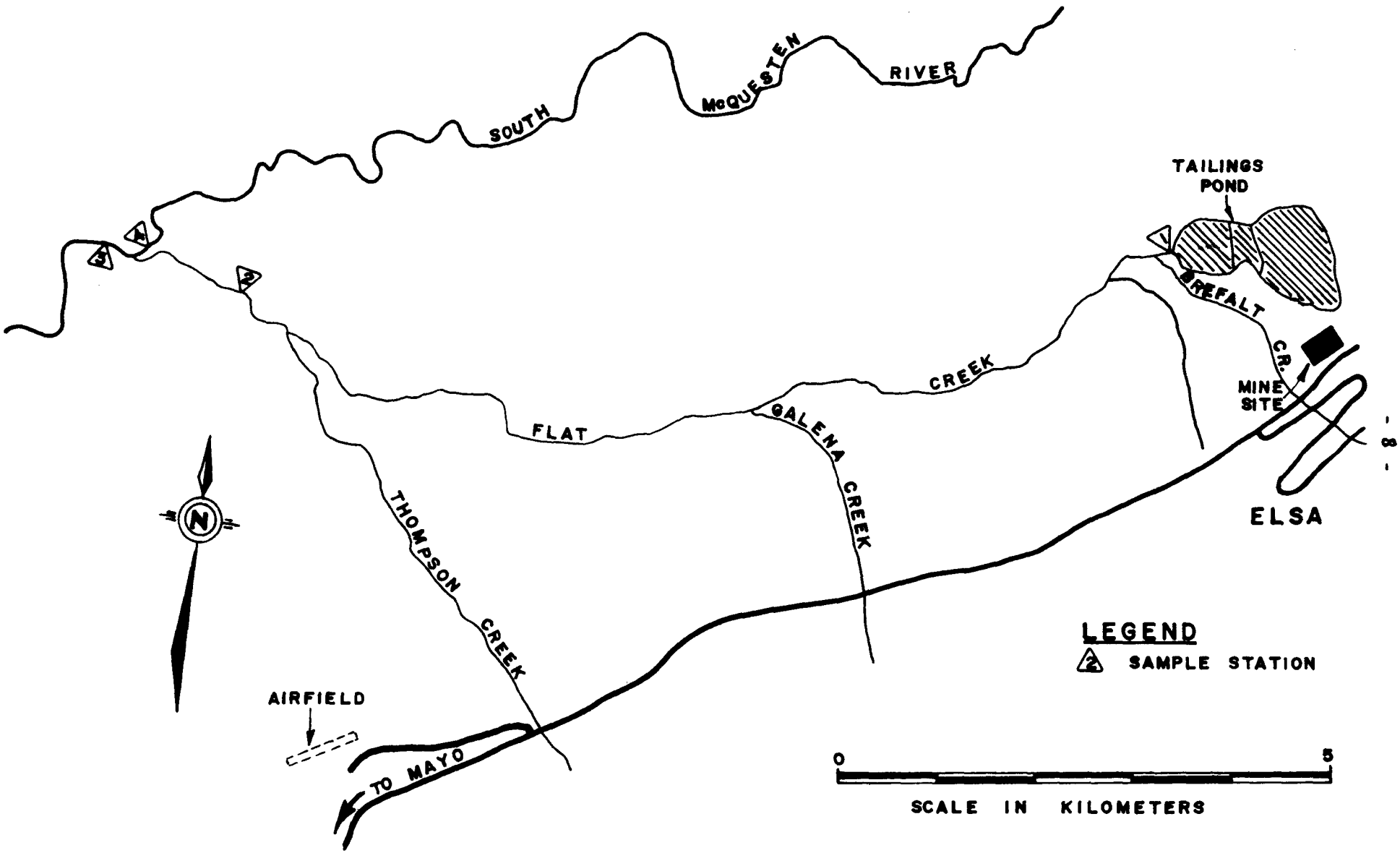

FIGURE 3: UNITED KENO HILL MINE SITE AND SAMPLING STATION LOCATION

4 STUDY ACTIVITIES, SAMPLE LOCATIONS AND PROGRAM

4.1 Study Activities

The activities involved in this study included the following:

1) collecting composite and grab samples of the effluent discharge over a period of three consecutive days;
2) collecting grab samples for water quality analysis at three locations downstream of the effluent discharge over a period of three consecutive days;
3) analyzing the collected samples for a number of chemical and metal parameters;
4) carrying out laboratory bioassay analyses on the samples collected from effluent discharge;
5) carrying out in situ bioassay analyses at four sampling locations;
6) collecting other information as necessary to assist in evaluating the state of compliance of this mine.

4.2 Sample Locations

Station 1	Tailings pond decant.
Station 2	On Flat Creek, 500 meters above confluence of South McQuesten River and Flat Creek.
Station 3	On South McQuesten River, 50 meters below confluence with Flat Creek.
Station 4	On South McQuesten River, 50 meters above confluence with Flat Creek.

The sampling locations are illustrated in Figure 3.

4.3 Sampling Program

Eight hour composite samples were collected once per day for three consecutive days at the tailings pond decant. Aliquots for bioassay analyses were collected hourly and stored in two 5-gallon polyethylene containers. Additional composite samples were collected each day at Station 1 for water quality analysis. Four sets of grab samples for water quality analyses were also collected once a day at Stations 1, 2, 3 and 4 for three consecutive days.

The samples for chemical and metal analyses were preserved according to the Environmental Protection Service Pacific Region Sampling Handbook (1979), as illustrated in Appendix I. All samples (including laboratory bioassays) were received by the Environmental Protection Service Laboratory facilities in North and West Vancouver within six days of collection.

5 RESULTS AND DISCUSSION

5.1 Water Chemistry

5.1.1 Composite Samples. The parameters listed in the Federal Guidelines (DFO 1977) have been compared with each daily composite sample (Table 1) collected from the decant. Table 1 and 2 list the Federal Guideline metals as total and the decant metals as extractable. Extractable values were more useful when making comparisons to prescribed limits (extractable) for metal concentrations in the water licence for United Keno Hill Mines issued by the Yukon Territory Water Board. Total and extractable metals are the same or similar where the NFR or non-filterable residue is found to be generally less than 10 mg/l. (Department of Environment, 1979). A full listing of all data is provided in Appendix II.

The results indicate that the tailings supernatant was in compliance with all the Federal Guidelines requirements on all three days of the study.

5.1.2 Grab Samples. The decant effluent was compared to the Federal Guidelines for grab samples (Table 2). Grab samples from Stations 2, 3 and 4 were compared to levels recommended to maintain aquatic life. A complete listing of all parameters analyzed is provided in Appendix III.

The decant supernatant complied with the guidelines on all three days of the study.

Stations 2 and 3 have significantly elevated levels of extractable zinc when compared to levels recommended for aquatic life. Station 4 (control) has zinc concentrations slightly above the recommended level.

5.2 Bioassays

5.2.1 Laboratory Bioassays. The laboratory static bioassay tests performed on the decant effluent (Station 1) composite samples were non-toxic on all three days of the study. This is in compliance with the Federal Guidelines (DFO 1977).

5.2.2 In Situ Bioassays. Because EPS in Whitehorse is not equipped with facilities to properly hold or transfer fish without stress, the test has been regarded as scientifically invalid. However, the practical application of this test was to demonstrate the effect of treated mine effluent on Arctic grayling. After exposing the fish to the effluent and receiving streams for 96 hours and finding no fatalities (Table 6), we conclude that the effluent and receiving streams exhibited no acute toxicity during the study.

TABLE 1 COMPARISON OF ANALYSIS OF THE COMPOSITE SAMPLES WITH FEDERAL GUIDELINES AT DECANT

PARAMETER	GUIDELINE REQUIREMENT(2) (T)	DAY 1 (E)	DAY 2 (E)	DAY 3 (E)
pH	5.5 minimum	7.4	7.5	7.5
As mg/l	0.75	0.0007	0.0008	0.0012
Cu mg/l	0.45	0.047	0.047	0.047
Pb mg/l	0.30	<0.08	<0.08	<0.08
Ni mg/l	0.75	<0.08	<0.08	<0.08
Zn mg/l	0.75	0.365	0.339	0.323
NFR mg/l	37.5	<5	9	7
96 h LT_{50}(%)	non-toxic	non-toxic	non-toxic	non-toxic

TABLE 2 COMPARISON OF ANALYSIS OF THE GRAB SAMPLES WITH FEDERAL GUIDELINES AT DECANT

PARAMETER	GUIDELINE REQUIREMENT(2) (T)	DAY 1 (E)	DAY 2 (E)	DAY 3 (E)
pH	5.0 minimum	7.3	7.4	7.5
As mg/l	1.0	<0.0005	0.0008	0.0007
Cu mg/l	0.6	0.045	0.046	0.05
Pb mg/l	0.4	<0.08	<0.08	<0.08
Ni mg/l	1.0	<0.08	<0.08	<0.08
Zn mg/l	1.0	0.389	0.325	0.332
NFR mg/l	50	<5	6	<5

(2) Department of Fisheries (1977)

TABLE 3 COMPARISON OF ANALYSIS OF THE GRAB SAMPLES COLLECTED FROM STATION 2 (FLAT CREEK) WITH LEVELS RECOMMENDED TO MAINTAIN AQUATIC LIFE

PARAMETER	RECOMMENDED LEVEL FOR AQUATIC LIFE	DAY 1	DAY 2	DAY 3	REFERENCE
pH	6.5 - 9.0	7.7	7.9	7.9	7
As mg/l	0.05 - 0.1	0.0015	0.0018	0.0011	4, 6
Cu mg/l	0.005 - 0.02	<0.01	<0.01	<0.01	6, 5
Pb mg/l	0.005 - 0.1	<0.08	<0.08	<0.08	5, 4
Ni mg/l	0.025 - 0.25	<0.08	<0.08	<0.08	4
Zn mg/l	0.030	0.39	0.309	0.293	6
Cd mg/l	0.0002	<0.01	<0.01	<0.01	4

TABLE 4 COMPARISON OF ANALYSIS OF THE GRAB SAMPLES COLLECTED FROM STATION 3 (DOWNSTREAM OF FLAT CREEK AND MCQUESTEN RIVER CONFLUENCE) WITH LEVELS RECOMMENDED TO MAINTAIN AQUATIC LIFE

PARAMETER	RECOMMENDED LEVEL FOR AQUATIC LIFE	DAY 1	DAY 2	DAY 3	REFERENCE
pH	6.5 - 9.0	7.7	7.7	8.0	7
As mg/l	0.05 - 0.1	0.0012	0.0016	0.0021	4, 6
Cu mg/l	0.005 - 0.02	<0.01	<0.01	<0.01	6, 5
Pb mg/l	0.008 - 0.1	<0.08	<0.08	<0.08	5, 4
Ni mg/l	0.025 - 0.25	<0.08	<0.08	<0.08	4
Zn mg/l	0.030	0.223	0.216	0.293	6
Cd mg/l	0.0002	<0.01	<0.01	<0.01	4

TABLE 5 COMPARISON OF ANALYSIS OF THE GRAB SAMPLES COLLECTED FROM STATION 4 (UPSTREAM FLAT CREEK AND MCQUESTEN RIVER CONFLUENCE) WITH LEVELS RECOMMENDED TO MAINTAIN AQUATIC LIFE

PARAMETER	RECOMMENDED LEVEL FOR AQUATIC LIFE	DAY 1	DAY 2	DAY 3	REFERENCE
pH	6.5 - 9.0	7.7	7.8	7.9	7
As mg/l	0.05 - 0.1	0.0010	0.0006	0.0009	5, 6
Cu mg/l	0.005 - 0.02	<0.01	<0.01	<0.01	6, 5
Pb mg/l	0.005 - 0.1	<0.08	<0.08	<0.08	5, 4
Ni mg/l	0.025 - 0.25	<0.08	<0.08	<0.08	4
Zn mg/l	0.030	0.051	0.049	0.065	6
Cd mg/l	0.0002	<0.01	<0.01	<0.01	4

4 - Environment Canada (1979-1980)

5 - McKee (1963)

6 - Ontario Ministry of Environment (1978)

7 - Thurston, R.V. (1979)

TABLE 6 IN SITU BIOASSAY RESULTS, AUGUST 4-8, 1980
(96 hr LT_{50} at 100% concentration)

START OF TEST	NUMBER OF SURVIVORS AFTER:			
00 h	24 h	48 h	72 h	96 h
STATION 1				
10 FISH	10	10	10	10
STATION 2				
10 FISH	10	10	10	10
STATION 3				
10 FISH	10	10	10	10
STATION 4				
10 FISH	10	10	10	10

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APPENDICES

APPENDIX I

WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	IN SITU BIOASSAY PROCEDURE
In situ bioassay test	The fish for the in situ bioassay determination were obtained by pole seine net from Fox Creek (40 miles north of Whitehorse) and transported in polyethylene bags, five fish in each. The water was kept cool and frequently aerated with pure oxygen. Upon arrival at UKHM, the bags containing the fish were set in the water at the respective locations prior to being placed in cages.	The in situ bioassays were conducted using fingerling Arctic grayling (Thymallus articus) in EPS Laboratory-made cages 1 m x 0.3 m x 0.3 m. The bioassays were put in at Stations 1, 2, 3 and 4 on the evening of August 4, 1980. The cages were set in the water parallel to the current so that the tops were just above the surface of the water to allow air space. Ten fish were put in each cage at each of the four test sites. Each test site was checked and recorded twice daily. After the completion of the in situ bioassay test, all fish were released.

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	BIOASSAY PROCEDURE[3]
96 h LT_{50} Bioassay	Each bioassay sample was collected in two 5-gallon polyethylene containers. Each container was pre-washed with 10% HCl, rinsed with distilled water and finally rinsed again three times with sample water. Each 5-gallon carbuoy is filled with composite sample so that no air space remains in neck of container. Once filled and capped, the top is sealed with tape. After proper labelling, the container is sent to Vancouver for analysis.	The static fish bioassay is an approximate value of biological toxicity of an effluent. It is defined as the lethal time required to kill 50% of the fish at 100% effluent concentration. The static bioassay test consists of an all glass test vessel and control vessel. The test was conducted at 15 $\pm$ 1°C. Test solution is preaerated for one half hour before the test begins and thereafter is aerated at the rate of 200 ml/minute for the rest of test period with oil free compressed air. Not less than five under-yearling Rainbow Trout (Salmo gardneri) were placed in each test vessel. The fish loading density in each test vessel did not exceed 1 gram of fish per two litres of test water. The number of dead fish were observed and recorded at scheduled periods after the test was started. Fish mortality was plotted against time on semi-log graph paper and a 96 hour LT_{50} was established.

3 Department of Fisheries (April 1977).

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Temperature		In-situ temperature reading.	A thermometer or Y.S.I. Model 33 salinity, conductivity, temperature) meter was used.	
Dissolved Oxygen (D.O.)	1.0 mg/l	Duplicate samples were collected at each station in 300 ml glass BOD bottles. The BOD bottle was rinsed 3 times with sample before filling. The D.O. samples were each preserved with 2 ml of manganese sulfate solution and 2 ml of alkali-iodide-azide solution. The samples were mixed by inverting them 15 times. D.O. analysis was done within 7 days.	Iodometric Azide Modification Winkler Titration Method.	048
pH		Small aliquots of sample were taken and read soon after collection at field camp. No preservatives were required, however, temperature was noted. Lab measurements were taken as well.	Potentiometric. pH meter determines the difference in e.m.f. developed by a reference electrode and the e.m.f. from the precision or calomel electrode. A change in 1 pH unit requires an electrical change of 59.1 mV at 25°C.	080

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Conductivity	0.2 umhos/cm	Conductivity measurements were performed in the lab. The measurement was taken from the same sample as described in NH_3 below.	Conductivity Cell. This cell measures the solution's capacity for transmitting electricity.	044
Ammonia NH_3-N	0.005 mg/l	Single samples were collected in a 2 litre linear polyethylene container. The container was rinsed 3 times with sample before it was filled. No preservatives required. Stored at 4°C.	Phenol hypochlorite-colorimetric-automated. Under basic conditions ammonia reacts with phenol and is oxidized by sodium hypochlorite to form an organic complex, indolphenol blue. The intensity of indolphenol blue is measured at a wavelength of 630 nm. Reported as mg/l nitrogen. (1 mg/l N = 1.22 mg/l NH_3).	058
Color	5	Same sample as NH_3.	Platinum - Cobalt - Visual Comparison Method. Reported as color units.	040
Turbidity	1.0 FTU	Same sample as NH_3.	Nephelometric Turbidity. This is an empirical measurement of the light scattered by the sample compared to the intensity of the light scattered by a standard reference suspension. Light is directed through a tube containing the sample and the relative intensity of the scattered light at 90° to the light source is measured by photocells. Results are given in FTU's.	130

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Filterable Residue (F.R.)	10 mg/l	Same sample as NH_3.	A well mixed known volume of sample is filtered through a standard glass fibre filter paper. The filtrate is then evaporated and dried at 103°C. This dry filtrate, when weighed, gives filterable residue (FR) in mg/l.	100
Non-filterable Residue (N.F.R.)	5 mg/l	Same sample as NH_3.	A known volume of sample is filtered through a pre-weighed, dried, standard glass fibre filter paper. The paper is then dried and weighed again. The difference in weight represents the non-filterable residue (NFR) in mg/l.	104
Total Alkalinity	1.0 mg/l as $CaCO_3$	Same sample as NH_3.	Potentiometric Titration. Total alkalinity is determined by titration with sulfuric acid which has been standardized with sodium carbonate.	006
Total Organic Carbon (TOC)	1.0 mg/l	One sample was collected at each station using a 125 ml glass jar. The jar was rinsed 3 times with sample before it was filled. Stored at 4°C.	Carbon infra red analyzer measures total and inorganic carbon. The difference of these two measurements is taken to get organic carbon.	016
Total Inorganic Carbon (TIC)	1.0 mg/l	Same sample as TOC.		

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Total Phosphate T PO_4-P	0.005 mg/l	Same sample as NH_3.	Acid-persulfate, Autoclave Digestion. Total phosphate (T PO_4) is measured by converting all phosphorus compounds to orthophosphates by using an acid-persulfate digestion. Then the measurement of total phosphate is based on a reaction between phosphate and molybdate ion to form complex heteropoly-acids. This is then reduced with ascorbic acid to form a blue molybdophosphoric acid color and the absorbance is measured at a wavelength of 885 nm. A technicon automated system is used.	086
Nitrite NO_2-N	0.005 mg/l	Same sample as NH_3.	Diazotization-Colorimentric-Automated. Under acidic conditions nitrite ions react with sulfanilic acid to form a diazo compound. This compound, coupled with d-napthylamine, forms intense red azo dye which exhibits maximum absorbance at a wavelength of 520 nm. Reported as mg/l nitrogen. 3.29 mg/l NO_2^- = 1 mg/l N.	070
Nitrate NO_3-N	0.010 mg/l	Same sample as NH_3.	Cadmium-Copper Reduction-Colorimetric Automated. The sample was passed through a column containing cadmium granules coated with a porous layer of copper. The nitrate in the sample was reduced to nitrite. The sample was then	072

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
			analyzed using the nitrite method listed above and the total nitrite/nitrate-N concentration was determined. The nitrate concentration was found by difference and reported in mg/l Nitrogen. (4.43 mg/l NO_3^- = 1 mg/l N)	
Sulfate SO_4	1.0 mg/l	Same sample as NH_3.	Barium chloranilate - UV Spectrophotometric. In an aqueous solvent system containing 80% isopropyl alcohol the sulfate ion reacts with solid barium chloranilate to form a precipitate of barium sulfate and chloranilic acid. After centrifugation the absorbance of chloranilic acid is read at a wavelength of 310 nm. The absorbance is then compared to a standard plot.	122
Cyanide CN	0.03 mg/l	The sample was collected in a 1 litre nalgene wide mouth bottle, which was rinsed 3 times before filling. The sample was preserved with NaOH pellets to pH >12 and stored at 4°C.	Tetracyanonickelate (II) - UV - Colorimetric. Sample is refluxed with the addition of H_2SO_4. The simple and complex cyanides in the sample are converted to HCN gas which is then absorbed in an ammonium-nickelate trapping solution. The resulting solution of the nickel-tetracyanodianion may then be quantitatively measured on a UV Spectrophotometer at wavelengths 267 nm and 284 nm.	032

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PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Chloride Cl	0.50 mg/l	Same sample as NH_3.	Thiocyanate - Combined Reagent - Colorimetric - Automated. This method is based on the displacement of SCN ion from mercuric thiocyanate by Cl^- ion. The liberated SCN reacts with the ferric ion to form the colored complex, ferric thiocyanate. This complex is proportional to original Cl^- concentration and its absorbance is measured at a wavelength of 465 nm.	024
Extractable Metals	mg/l	Single samples were collected at each station using a 200 ml linear polyethylene bottle. The sample bottle was rinsed 3 times with sample before filling. Each bottle was then preserved to a pH of <1.5 using 2.0 ml of concentrated nitric acid. The extractable method used measures the dissolved metals in addition to those (inorganic, organic, adsorbed, precipitated and particulate) which will be brought into solution by the addition of nitric acid.	An excitation source called the Inductively Coupled Argon Plasma (ICAP) combined with a computer controlled Optical Emission Spectrometer (OES) was used to measure the metal concentration.	210 592
Al	0.090			
As	0.0005			
Ba	0.0030			
Ca	0.025			
Cd	0.010			
Co	0.015			
Cr	0.015			
Cu	0.010			
Fe	0.010			
Mg	0.025			
Mn	0.0040			
Mo	0.15			
Na	0.030			
Ni	0.08			
Pb	0.0005			
Sb	0.0005			
Se	0.15			

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Sn	0.20			
Sr	0.0040			
Ti	0.0085			
V	0.050			
Zn	0.020			
Total Hardness			Total hardness is computed in the ICAP by multiplying magnesium by a factor of 4.116 and calcium by a factor of 2.497. The resulting sum of these cations will give a $CaCO_3$ concentration equivalent which will be reported as mg/l $CaCO_3$.	
Silica Si	0.5 mg/l	Same sample as NH_3.	Ascorbic Acid Reduction - Colorimetric - Automated. This reaction is based upon the reduction by ascorbic acid of silicomolybdate in acidic solution to molybdenum blue. The color is measured at a wavelength of 660 nm.	118
Mercury Hg	0.00020 mg/l	Samples were collected at each station using a 200 ml linear polyethylene bottle. Each bottle was rinsed 3 times with sample before being filled. Each sample was then preserved by the addition of 10 ml of 5% nitric dichromate solution.	Open Flameless System for Hg - AAS Determination. Organo mercury compounds in the sample are oxidized to inorganic mercury compounds by the use of sulfuric and nitric acid and potassium persulfate. The mercury is swept with argon from the solution and passed through an absorption cell which is situated in the light path of a mercury lamp. Mercury absorption	211 224 284 411

APPENDIX I WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS, BIOASSAY, IN SITU BIOASSAY METHODS

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
			is determined at a wavelength of 253.7 nm with a background absorbance measured at a wavelength of 254.7 nm, using a tin hollow cathode lamp.	
Silver Ag	0.030 mg/l	Same sample as metals.	Flame Atomic Absorption Spectrophotometry.	210 290
Potassium K	0.010 mg/l	Same sample as metals.	Flame Atomic Emission Spectrophotometry.	210 423

[1] Department of the Environment, Department of Fisheries and Oceans, Laboratory Manual, Environmental Protection Service, Fisheries and Marine Service, (1979).

APPENDIX II

COMPOSITE RESULTS IN DECANT

APPENDIX II UNITED KENO HILL MINES - COMPOSITE - STATION 1
WATER QUALITY DATA (EXCLUDING METALS)

PARAMETER	DAY 1	DAY 2	DAY 3
TEMPERATURE	-	-	-
DISSOLVED OXYGEN	-	-	-
IN SITU pH	8.00	8.05	8.00
LAB pH	7.4	7.5	7.5
LAB COND. (mhos/cm)	1410	1410	1380
LAB DIL. COND. (mhos/cm)	116	116	116
COLOR (color units)	10	10	10
TURBIDITY (FTU)	3.4	4.4	3.9
NF RESIDUE (mg/l)	<5	9	7
F RESIDUE (mg/l)	1168	1160	1162
TOTAL ALKALINITY (mg/l $CaCO_3$)	51.3	52.8	53.3
TOTAL HARDNESS (mg/l $CaCO_3$)	724.0	744.0	719.0
TOC (mg/l)	6.0	6.0	6.0
TIC (mg/l)	12.0	12.0	12.0
TOTAL PO_4-P (mg/l)	0.0189	0.0223	0.0191
NO_2-N (mg/l)	0.074	0.076	0.075
NO_3-N (mg/l)	0.0683	0.0747	0.0725
NH_3-N (mg/l)	1.22	1.22	1.17
SO_4 (mg/l)	666	667	674
CN (mg/l)	<0.03	<0.03	<0.03
Cl (mg/l)	34.7	32.7	32.2

TOXICITY DETERMINATION

	DAY 1	DAY 2	DAY 3
96 h LT_{50}(50% effluent concentration)	non-toxic	non-toxic	non-toxic

APPENDIX II UNITED KENO HILL MINES - COMPOSITE - STATION 1
METAL ANALYSES (ALL UNITS IN mg/l)

PARAMETER	DAY 1	DAY 2	DAY 3
Al	0.139	<0.09	<0.09
As	0.0007	0.0008	0.0012
Ba	0.0254	0.0236	0.0224
Ca	257.0	264.0	253.0
Cd	<0.01	<0.01	<0.01
Co	<0.015	<0.015	<0.015
Cr	<0.015	<0.015	<0.015
Cu	0.047	0.047	0.047
Fe	0.58	0.562	0.449
Hg	<0.00020	<0.00020	<0.00020
K	4.18	4.21	4.17
Mg	19.9	20.6	21.1
Mn	1.94	1.94	1.97
Mo	<0.15	<0.15	<0.15
Na	32.1	32.1	32.4
Ni	<0.08	<0.08	<0.08
Pb	<0.08	<0.08	<0.08
Sb	<0.0005	<0.0005	<0.0005
Se	<0.0005	<0.0005	<0.0005
Si	1.36	1.38	1.37
Sn	<0.2	<0.2	<0.2
Sr	0.446	0.448	0.449
Ti	<0.0085	<0.0085	<0.0085
V	<0.05	<0.05	<0.05
Zn	0.365	0.339	0.323

APPENDIX III

GRAB RESULTS
STATIONS 1 TO 4 INCLUSIVE

APPENDIX III TABLE 1 UNITED KENO HILL MINES - GRAB - STATION 1 - WATER QUALITY DATA (EXCLUDING METALS)

PARAMETER	DAY 1	DAY 2	DAY 3
TEMPERATURE	15	15	15
DISSOLVED OXYGEN	8.78	8.80	8.84
IN SITU pH	7.65	7.90	7.75
LAB pH	7.3	7.4	7.5
LAB COND. (mhos/cm)	1410	1400	1400
LAB DIL. COND. (mhos/cm)	114	115	116
COLOR (color units)	10	10	10
TURBIDITY (FTU)	3.9	3.7	4.4
NF RESIDUE (mg/l)	<5	<5	<5
F RESIDUE (mg/l)	1160	1168	1160
TOTAL ALKALINITY (mg/l $CaCO_3$)	51.3	52.3	52.6
TOTAL HARDNESS (mg/l $CaCO_3$)	739.0	750.0	727.0
TOC (mg/l)	7.0	7.0	5.0
TIC (mg/l)	12.0	12.0	12.0
TOTAL PO_4-P (mg/l)	0.0171	0.0166	0.0165
NO_2-N (mg/l)	0.073	0.073	0.075
NO_3-N (mg/l)	0.0672	0.0661	0.0677
NH_3-N (mg/l)	1.67	1.19	1.49
SO_4 (mg/l)	675	648	668
CN (mg/l)	<0.03	<0.03	<0.03
Cl (mg/l)	35.0	33.5	32.4

APPENDIX III TABLE 1 UNITED KENO HILL MINES - GRAB STATION 1 - EXTRACTABLE METAL ANALYSIS (ALL UNITS IN mg/l)

PARAMETER	DAY 1	DAY 2	DAY 3
Al	<0.09	<0.09	<0.09
As	<0.0005	0.0008	0.0007
Ba	0.0207	0.0208	0.0211
Ca	263.0	266.0	256.0
Cd	<0.01	<0.01	<0.01
Co	<0.015	<0.015	<0.015
Cr	<0.015	<0.015	<0.015
Cu	0.045	0.046	0.05
Fe	0.412	0.437	0.458
Hg	<0.00020	<0.00020	<0.00020
K	4.23	4.13	4.20
Mg	20.0	20.8	21.3
Mn	1.93	1.95	2.0
Mo	<0.15	<0.15	<0.15
Na	32.5	32.3	31.4
Ni	<0.08	<0.08	<0.08
Pb	<0.08	<0.08	<0.08
Sb	<0.0005	<0.0005	<0.0005
Se	<0.0005	<0.0005	<0.0005
Si	1.37	1.37	1.37
Sn	<0.2	<0.2	<0.2
Sr	0.455	0.451	0.451
Ti	<0.0085	<0.0085	<0.0085
V	<0.05	<0.05	<0.05
Zn	0.389	0.325	0.332

APPENDIX III TABLE 2 UNITED KENO HILL MINES - GRAB - STATION 2 - WATER QUALITY DATA (EXCLUDING METALS)

PARAMETER	DAY 1	DAY 2	DAY 3
TEMPERATURE	-	-	-
DISSOLVED OXYGEN	10.0	9.53	10.01
IN SITU pH	8.00	8.20	8.00
LAB pH	7.7	7.9	7.9
LAB COND. (mhos/cm)	680	650	640
LAB DIL. COND. (mhos/cm)	104	103	102
COLOR (color units)	20	25	25
TURBIDITY (FTU)	3.9	4.8	3.7
NF RESIDUE (mg/l)	<5	6	<5
F RESIDUE (mg/l)	501	478	469
TOTAL ALKALINITY (mg/l $CaCO_3$)	128	129	134
TOTAL HARDNESS (mg/l $CaCO_3$)	355.0	331.0	339.0
TOC (mg/l)	5.0	5.0	5.0
TIC (mg/l)	29.0	29.0	30.0
TOTAL PO_4-P (mg/l)	0.0123	0.0133	0.0109
NO_2-N (mg/l)	0.023	0.026	0.025
NO_3-N (mg/l)	0.226	0.214	0.218
NH_3-N (mg/l)	1.23	0.0668	0.0387
SO_4 (mg/l)	213	198	190
CN (mg/l)	<0.03	<0.03	<0.03
Cl (mg/l)	9.70	8.96	8.18

APPENDIX III TABLE 2 UNITED KENO HILL MINES - GRAB STATION 2 - EXTRACTABLE METAL ANALYSIS (ALL UNITS IN mg/l)

PARAMETER	DAY 1	DAY 2	DAY 3
Al	<0.09	<0.09	<0.09
As	0.0015	0.0018	0.0011
Ba	0.0487	0.0434	0.0438
Ca	113.0	105.0	107.0
Cd	<0.01	<0.01	<0.01
Co	<0.015	<0.015	<0.015
Cr	<0.015	<0.015	<0.015
Cu	<0.01	<0.01	<0.01
Fe	0.633	0.513	0.486
Hg	<0.00020	<0.00020	<0.00020
K	1.17	1.05	0.988
Mg	17.6	16.6	17.4
Mn	1.31	0.936	0.847
Mo	<0.15	<0.15	<0.15
Na	9.0	8.14	7.9
Ni	<0.08	<0.08	<0.08
Pb	<0.08	<0.08	<0.08
Sb	<0.0005	<0.0005	<0.0005
Se	<0.0005	<0.0005	<0.0005
Si	2.11	2.07	1.97
Sn	<0.2	<0.2	<0.2
Sr	0.226	0.211	0.215
Ti	<0.0085	<0.0085	<0.0085
V	<0.05	<0.05	<0.05
Zn	0.39	0.309	0.293

APPENDIX III TABLE 3 UNITED KENO HILL MINES - GRAB - STATION 3 - WATER QUALITY DATA (EXCLUDING METALS)

PARAMETER	DAY 1	DAY 2	DAY 3
TEMPERATURE	-	-	-
DISSOLVED OXYGEN	9.50	9.77	9.50
IN SITU pH	-	-	-
LAB pH	7.7	7.7	8.0
LAB COND. (mhos/cm)	560	560	470
LAB DIL. COND. (mhos/cm)	105	103	104
COLOR (color units)	20	20	15
TURBIDITY (FTU)	3.5	3.0	2.6
NF RESIDUE (mg/l)	<5	<5	<5
F RESIDUE (mg/l)	398	401	336
TOTAL ALKALINITY (mg/l $CaCO_3$)	118	122	115
TOTAL HARDNESS (mg/l $CaCO_3$)	251.0	277.0	237.0
TOC (mg/l)	4.0	5.0	5.0
TIC (mg/l)	26.0	28.0	26.0
TOTAL PO_4-P (mg/l)	0.0109	0.0098	0.0095
NO_2-N (mg/l)	0.019	0.020	0.014
NO_3-N (mg/l)	0.150	0.152	0.112
NH_3-N (mg/l)	0.0659	0.0506	0.0229
SO_4 (mg/l)	162	151.3	123
CN (mg/l)	<0.03	<0.03	<0.03
Cl (mg/l)	6.87	6.55	4.78

APPENDIX III TABLE 3 UNITED KENO HILL MINES - GRAB STATION 3 - EXTRACTABLE METAL ANALYSIS (ALL UNITS IN mg/l)

PARAMETER	DAY 1	DAY 2	DAY 3
Al	<0.09	<0.09	<0.09
As	0.0012	0.0016	0.0021
Ba	0.0508	0.0602	0.0499
Ca	77.1	86.0	72.0
Cd	<0.01	<0.01	<0.01
Co	<0.015	<0.015	<0.015
Cr	<0.015	<0.015	<0.015
Cu	<0.01	<0.01	<0.01
Fe	0.369	0.38	0.486
Hg	<0.00020	<0.00020	<0.00020
K	0.756	0.850	0.684
Mg	14.2	15.2	17.4
Mn	0.662	0.635	0.847
Mo	<0.15	<0.15	<0.15
Na	5.28	6.02	7.9
Ni	<0.08	<0.08	<0.08
Pb	<0.08	<0.08	<0.08
Sb	<0.0005	<0.0005	<0.0005
Se	<0.0005	<0.0005	<0.0005
Si	2.01	2.00	1.85
Sn	<0.2	<0.2	<0.2
Sr	0.179	0.185	0.215
Ti	<0.0085	<0.0085	<0.0085
V	<0.05	<0.05	<0.05
Zn	0.223	0.216	0.293

APPENDIX III TABLE 4 UNITED KENO HILL MINES - GRAB - STATION 4 - WATER QUALITY DATA (EXCLUDING METALS)

PARAMETER	DAY 1	DAY 2	DAY 3
TEMPERATURE	-	-	-
DISSOLVED OXYGEN	10.0	9.78	9.85
IN SITU pH	8.10	8.00	8.20
LAB pH	7.7	7.8	7.9
LAB COND. (mhos/cm)	245	248	250
LAB DIL. COND. (mhos/cm)	106	105	74.0
COLOR (color units)	20	15	15
TURBIDITY (FTU)	1.9	1.9	1.5
NF RESIDUE (mg/l)	<5	<5	<5
F RESIDUE (mg/l)	169	150	166
TOTAL ALKALINITY (mg/l $CaCO_3$)	83.5	85.3	87.6
TOTAL HARDNESS (mg/l $CaCO_3$)	128.0	124.0	127.0
TOC (mg/l)	5.0	5.0	6
TIC (mg/l)	19.0	18.0	19.0
TOTAL PO_4-P (mg/l)	0.0087	0.0088	0.0090
NO_2-N (mg/l)	<0.0050	<0.0050	<0.0050
NO_3-N (mg/l)	0.0192	0.0187	0.0152
NH_3-N (mg/l)	0.0075	0.0069	0.0064
SO_4 (mg/l)	40.8	38.2	38.8
CN (mg/l)	<0.03	<0.03	<0.03
Cl (mg/l)	0.88	0.88	0.80

APPENDIX III TABLE 4 UNITED KENO HILL MINES - GRAB STATION 4 - EXTRACTABLE METAL ANALYSIS (ALL UNITS IN mg/l)

PARAMETER	DAY 1	DAY 2	DAY 3
Al	<0.09	<0.09	<0.09
As	0.0010	0.0006	0.0009
Ba	0.046	0.0447	0.0465
Ca	35.5	34.5	35.3
Cd	<0.01	<0.01	<0.01
Co	<0.015	<0.015	<0.015
Cr	<0.015	<0.015	<0.015
Cu	<0.01	<0.01	<0.01
Fe	0.157	0.132	0.136
Hg	<0.00020	<0.00020	<0.00020
K	0.278	0.284	0.289
Mg	9.61	9.27	9.52
Mn	0.0457	0.037	0.0366
Mo	<0.15	<0.15	<0.15
Na	1.04	0.966	0.991
Ni	<0.08	<0.08	<0.08
Pb	<0.08	<0.08	<0.08
Sb	<0.0005	<0.0005	<0.0005
Se	<0.0005	<0.0005	<0.0005
Si	1.44	1.71	1.63
Sn	<0.2	<0.2	<0.2
Sr	0.124	0.123	0.129
Ti	<0.0085	<0.0085	<0.0085
V	<0.05	<0.05	<0.05
Zn	0.051	0.04	0.065