

Mr. Wile was responsible for coordinating and performing the field activities, compiling the analytical data and preparing the draft report.



ENVIRONMENTAL PROTECTION SERVICE
ENVIRONMENTAL PROTECTION BRANCH
TECHNICAL SERVICES GROUP

COMPLIANCE EVALUATION
OF THE CYPRUS ANVIL MINE,
FARO, YUKON TERRITORY

78-5

by: J. Villamere, G. Trasolini, K. Wile

Regional Program Report: 78-5

May 1978

LIBRARY
ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
PACIFIC REGION

ABSTRACT

During the period from July 24-26, 1977 the Environmental Protection Service carried out a monitoring study of the effluent discharges from the Cyprus Anvil Mine. The purpose of this study was to determine the state of compliance of the mine effluent discharges with the requirements of the Federal Metal Mining Liquid Effluent Guidelines.

The activities involved in this study included the following:

- 1) collecting composite and grab samples of the effluent discharges over a period of three consecutive days.
- 2) analyzing the effluent samples for a number of chemical parameters.
- 3) carrying out bioassay analyses on the collected samples.
- 4) collecting other information as necessary to assist in evaluating the state of compliance of this mine.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	i
TABLE OF CONTENTS	ii
List of Figures	iv
List of Tables	iv
List of Abbreviations and Definitions	v
CONCLUSIONS	vi
1 INTRODUCTION	1
2 MINE DESCRIPTION	3
2.1 General Information	3
2.2 Concentrator Operation	3
3 WASTEWATER SOURCES	6
4 SAMPLING AND ANALYTICAL METHODS	8
4.1 Sampling Program	8
4.2 Analytical Methods	8
4.2.1 Bioassay Determination	8
4.2.2 Total Metals	11
4.2.3 Dissolved Metals	11
4.2.4 Total Arsenic	12
4.2.5 Total Mercury	12
4.2.6 Non-Filterable Residue	12
4.2.7 Total Residue	12
4.2.8 pH Determination	13

	<u>Page</u>	
5	RESULTS	14
5.1	Composite Samples	14
5.2	Grab Samples	14
6	DISCUSSION	18
	REFERENCES	21

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	LOCATION OF CYPRUS ANVIL MINE SITE	4
2	WASTEWATER SOURCES	7
3	CYPRUS ANVIL MINE SITE LAYOUT AND SAMPLING STATION LOCATIONS	9

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	SAMPLE CONTAINERS AND PRESERVATION METHODS	10
2	CYPRUS ANVIL TAILINGS POND SUPERNATANT - COMPOSITE SAMPLE RESULTS	15
3	CYPRUS ANVIL TAILINGS POND SEEPAGE - COMPOSITE SAMPLE RESULTS	16
4	CYPRUS ANVIL GRAB SAMPLE RESULTS	17
5	COMPARISON OF TAILINGS POND SUPERNATANT RESULTS WITH FEDERAL GUIDELINES	18
6	COMPARISON OF TAILINGS POND SEEPAGE RESULTS WITH FEDERAL GUIDELINES	20

LIST OF ABBREVIATIONS AND DEFINITIONS

D	Dissolved
I.G.P.D.	Imperial Gallons per Day
L	Less Than
ml	Millilitres
mg/l	Milligrams per Litre
T	Total
t.p.d	Tons per Day
µg/l	Micrograms per Litre
Reference Mine Production Rate -	The greater of the design rated capacity and the maximum average annual production rate ever achieved during the operating life of a mine prior to February 25, 1977.

CONCLUSIONS

Based on the data collected at the Cyprus Anvil Mine from July 24 to 26, 1977 the following conclusions are presented:

1. The tailings pond seepage was in compliance with all parameters in the federal guidelines on all three days.
2. The tailings pond supernatant was out of compliance with the guideline limit for lead on days 1 and 3.
3. The tailings pond supernatant was out of compliance with the guideline limit for zinc on all three days.
4. The tailings pond supernatant was acutely toxic and thus out of compliance on day 1.
5. Cyanide, dissolved lead and dissolved zinc are the most probable causes of toxicity.

1 INTRODUCTION

On February 25, 1977 the Federal Metal Mining Liquid Effluent Regulations and Guidelines were promulgated. These documents were developed pursuant 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 (1). 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 (E.P.S.) was responsible for the overall co-ordination of all the necessary inputs required to develop the national effluent controls.

Following promulgation of these guidelines, the EPS Pacific Region undertook a review of all operating metal mines in the Region (B.C. and Yukon) to determine the state of compliance of each operation. The review indicated that 14 mines operated tailings impoundment systems such that there was no positive discharge of effluent to a receiving body of water and were therefore in compliance with federal guidelines. Four mines discharged unconfined tailings and were obviously out of compliance with federal requirements. The remaining seven mines operated a tailings impoundment system and discharged supernatant into a receiving body of water, and could thus be in or out of compliance depending upon the quality of the effluent being discharged.

In order to complete the assessment of the status of compliance for all mining operations in the Pacific Region, EPS carried out effluent surveillance studies for compliance verification at all 7 mines (5 in B.C., and 2 in the Yukon), which discharged tailings pond supernatant to a receiving body of water. This report is an account of the effluent surveillance study conducted on July 24, 25 and 26, 1977 at the Cyprus Anvil Mine in the Yukon Territories.

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

The Cyprus Anvil lead - zinc mine is situated approximately thirteen miles west of the town of Faro in the Yukon Territory (see Figure 1). The mine which has been in operation since 1969 consists of a 10 000 t.p.d. capacity mill fed by an open pit mine and produces lead and zinc concentrates. At this time there is only one active pit, however, a second pit is under development.

The ore reserves as of 1975 consisted of 46 million tons of sphalerite and galena containing 65-70 percent pyrite and 4 percent pyrrhotite. At a production rate of 10 000 t.p.d. the anticipated life of the mine is 9 years based on presently known reserves.

The reference mine production rate for this mine was established at 3 650 000 tons ore per year based on the 1976 operating year.

2.2 Concentrator Operation

The crushed ore is transported to a grinding circuit where both rod and ball mills grind the ore to a minus 200 mesh. The ground ore is classified and mixed with water to form a slurry referred to as "pulp". The pulp is separated into specific minerals in the flotation circuit. In this circuit chemicals and frothing agents specific to the desired mineral are added to the pulp. This mixture is agitated and aerated. The resulting froth which is composed of air bubbles with adhering mineral particles is skimmed off, thickened, filtered and dried. The first concentrate to be skimmed is the lead. The remaining pulp mixture is conditioned and re-floated in the zinc circuit where the zinc concentrate is collected. The Cyprus Anvil concentrator also produces bulk concentrates by combining "cleaned" lead and zinc concentrate.

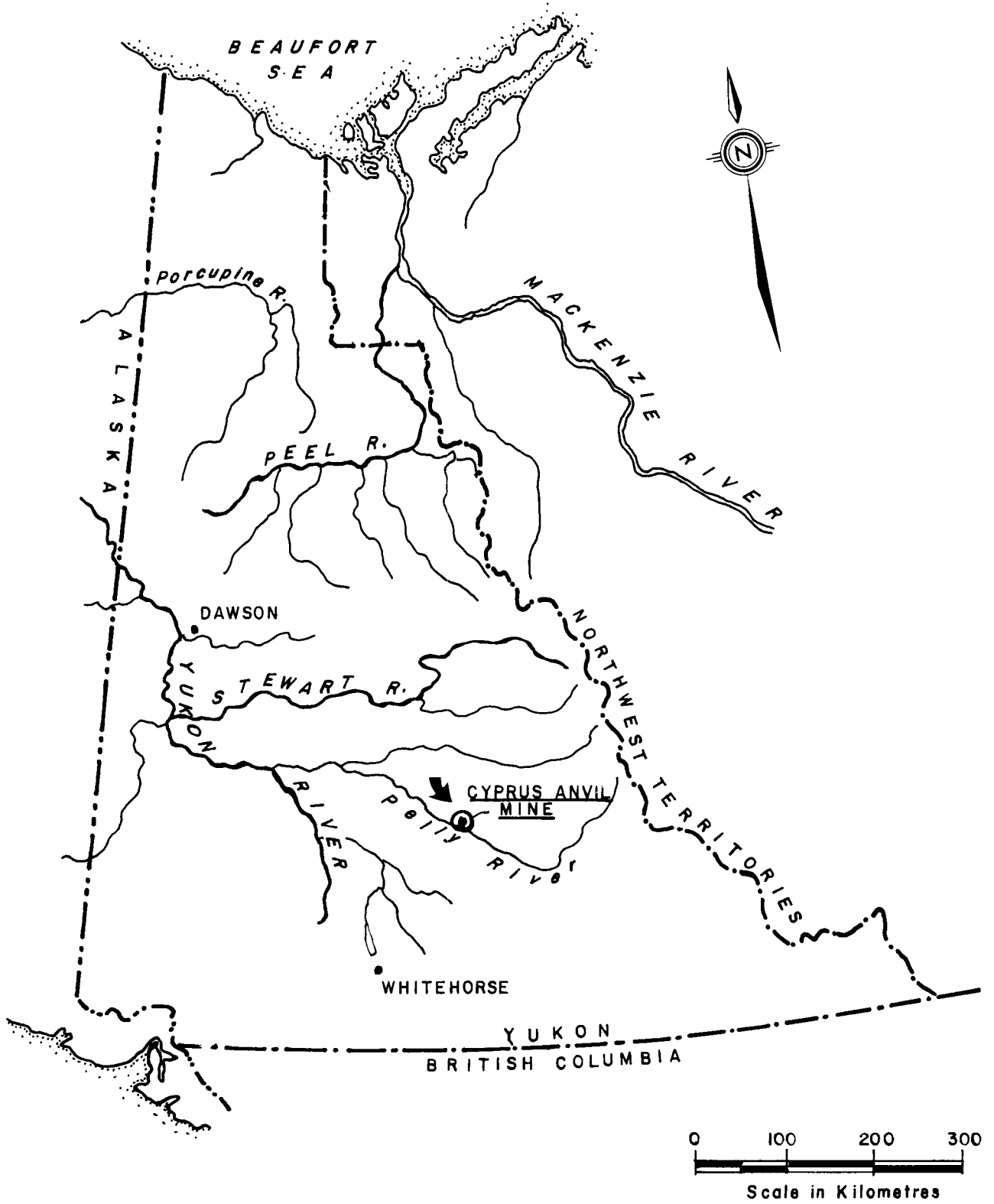


FIGURE 1 LOCATION OF CYPRUS ANVIL MINE SITE

The following chemicals are used in the flotation process
(lbs/ton ore):

sodium cyanide	0.17
soda ash	2.8 - 8.0
lime	4.73
zinc sulphate	0.01
copper sulphate	0.99
xanthate	0.27
M.I.B.C.	0.03
Dow 1012	0.03
Z - 200	0.01
Aero Float 242	0.005
Na ₂ S	intermittent use up to 4 lbs/ton ore

The average feed to the mill contains 1.0 ounce of silver per ton, 5.67 percent zinc and 3.33 percent lead (silver is extracted from the zinc concentrate at the smelter). Recovery efficiencies for zinc and lead are 77.5 and 87.5 percent respectively. The final cleaned lead and zinc concentrates contain 64 percent lead and 51 percent zinc. In 1975 the mine produced 264 943 000 pounds of lead concentrate, 254 834 000 pounds of zinc concentrate and 2 451 000 ounces of silver.

3 WASTEWATER SOURCES

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

The mill utilizes an average of 4 700 000 I.G.P.D. of fresh water. The primary consumption of water is in the flotation and grinding circuits which can use as much as 600 gallons per ton of ore. In the grinding circuit the water is used to facilitate grinding and classification. In the flotation circuit water is used for adjustment of the solids level in the flotation feed, froth destroying spray, pump gland water, floor washing and reagent solution addition.

Mine water consists of pit run-off, ground water seepage and drilling water. All the mine water, approximately 500 000 I.G.P.D. is pumped into the old stream bed of Faro Creek and discharges into the tailings pond.

The entire mine-mill site situated on the side of a hill drains in the general direction of Rose Creek. However, most of the contaminated surface drainage is collected and diverted to the tailings pond system for treatment.

All of the previously mentioned wastewater streams flow into a dual tailings pond system, 175 acres in area, with an estimated retention period of 30 days. The supernatant is discharged at an approximate rate of 5 380 000 I.G.P.D. into Rose Creek. Approximately 860 000 I.G.P.D. of seepage water escapes through the toe of the tailings pond dam into Rose Creek.

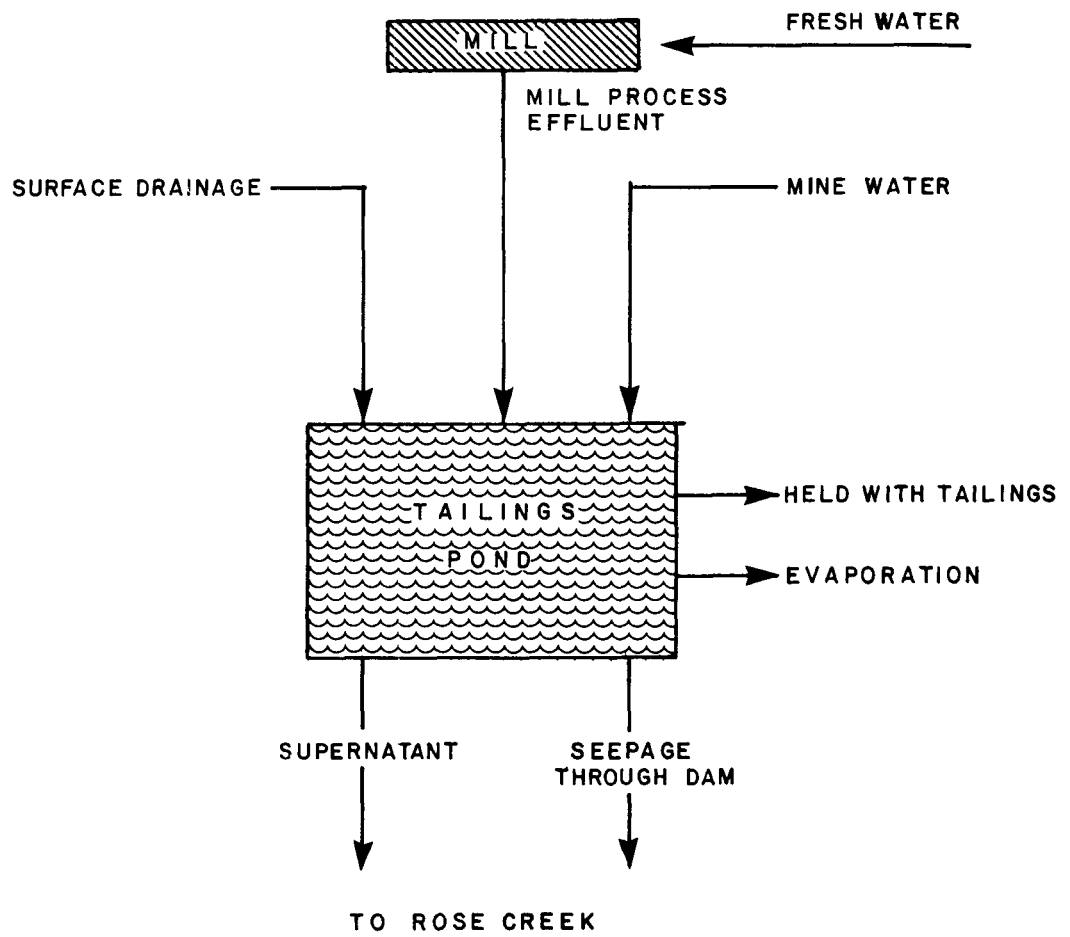


FIGURE 2 WASTEWATER SOURCES

4 SAMPLING AND ANALYTICAL METHODS

4.1 Sampling Program

Time proportional 8 hour composite samples and grab samples were collected at the following points:

1. Tailings pond decant
2. Tailings pond seepage

The sampling point locations are illustrated in Figure 3.

Eight hour composite samples were collected once per day for three consecutive days. Aliquots were collected hourly and stored in 30 gallon polyethylene containers. One set of grab samples was also collected.

The effluent stored in the polyethylene container was well mixed prior to sample division. Composite samples for chemical analysis were collected on all three days whereas composite samples for bioassay were collected on the first and third days only. The samples for chemical analysis were preserved according to the Environmental Protection Service, Pacific Region, Sampling Handbook (1976) as illustrated in Table 1. All samples were received by the Environmental Protection Service Laboratory facilities in North and West Vancouver within 48 hours of collection.

4.2 Analytical Methods

Further to the methods outlined in the Environment Canada Laboratory Manual (2), the following notes are added.

4.2.1 Bioassay Determination (96 hour LC₅₀). The static fish bioassay gives an approximate value of the biological toxicity of an effluent. It is defined as the concentration or level of a measurable lethal agent required to kill the 50th percentile in a group of test organisms over a period of 96 hours.

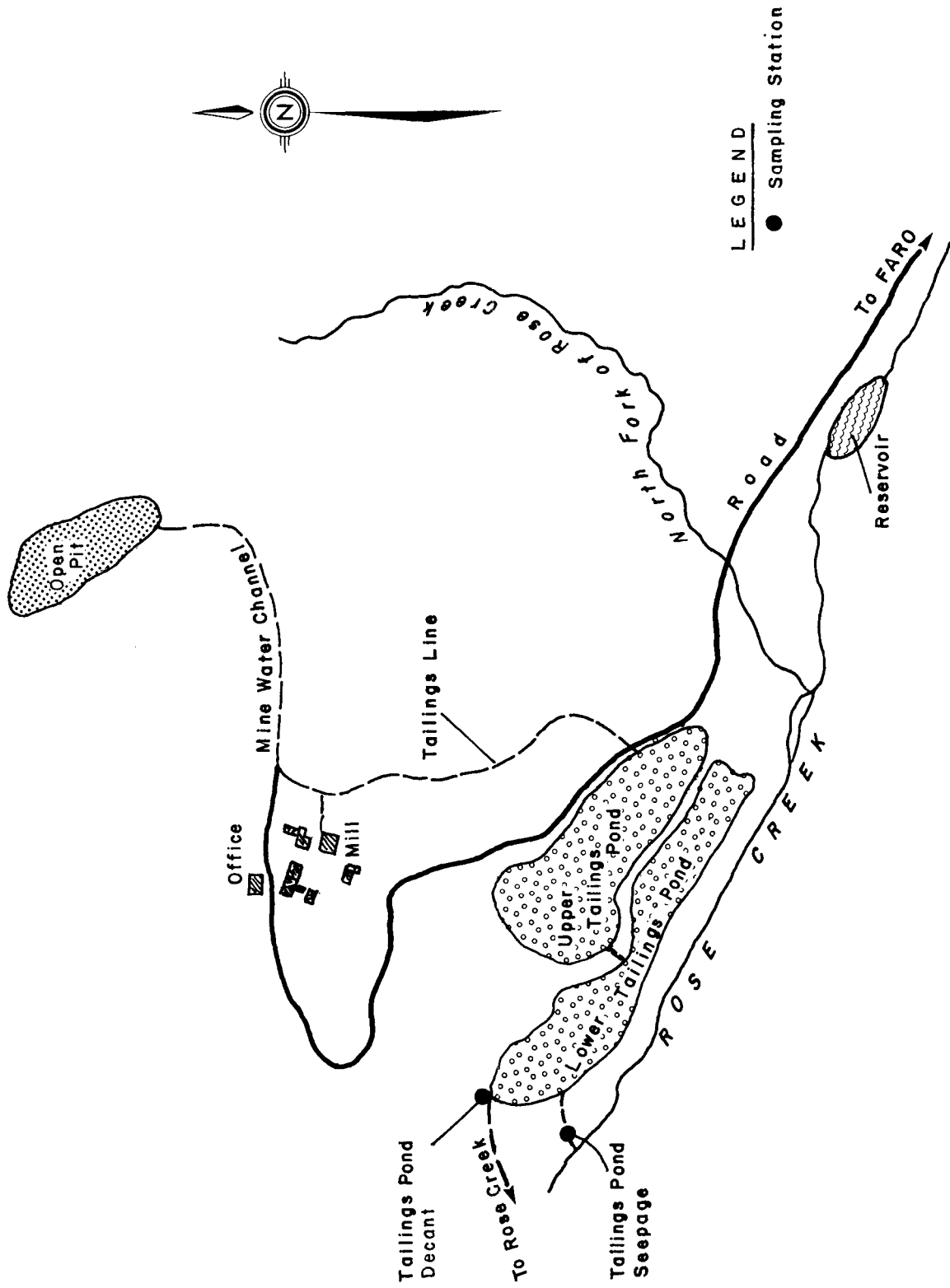


FIGURE 3 CYPRUS ANVIL MINE SITE LAYOUT AND SAMPLING STATION LOCATIONS

TABLE 1 SAMPLE CONTAINERS AND PRESERVATION METHODS
AS OUTLINED IN THE E.P.S. SAMPLING HANDBOOK (1976)

Parameter	Type of Container	Preservation
LC ₅₀ (96 hour)	5 gallon Polyethylene jerry cans	none
Total Arsenic	500 ml wide mouth Polyethylene bottle	none
Total Metals (Cu, Cd, Fe, Ni, Pb, & Zn)	100 ml wide mouth Polyethylene bottle	acidified with HNO ₃ to pH 1.5
Total Mercury	100 ml wide mouth Polyethylene bottle	acidified with HNO ₃ to pH 1.5
Dissolved Metals (Cu, Cd, Fe, Ni, Pb & Zn)	100 ml wide mouth Polyethylene bottle	filtered and acidified with HNO ₃ to pH 1.5
Residues (NFR, TR)	1000 ml wide mouth Polyethylene bottle	none

The static bioassay test consisted of a series of 30 litre, all-glass test vessels containing different sample dilutions. The test vessels were placed into a controlled environment room where the temperature was maintained at 13 degrees \pm 1°C and the photo period was limited to 16 hours for each 24 hour day. The samples were continuously aerated throughout the 96 hour test period with oil-free compressed air. Eight to ten underyearling Rainbow Trout (Salmo gairdneri) were placed in each test vessel. The fish - loading density in each test vessel did not exceed 0.60 grams of fish per litre of test water. The fish mortality versus sample dilution for each test vessel was plotted on a graph and a 96 hour LC₅₀ was established.

4.2.2 Total Metals (Cd, Cu, Fe, Ni, Pb and Zn). The total volume of the sample (approx. 100 ml) was transferred to a beaker. The sample bottle was rinsed with 6 ml hydrochloric acid and 2 ml concentrated nitric acid (aqua regia). This rinse plus deionized water rinses were added to the sample in the beaker. This solution was evaporated to 50 ml on a hot plate, then made up to the original volume with deionized water in the original sample bottle. The samples were then analyzed by direct aspiration on the Jarrell - Ash 810 Atomic Absorption Spectrophotometer with background correction used for Pb, Ni, Cd and Zn. The detection limits are Cd - 0.01 mg/l, Cu - 0.01 mg/l, Fe - 0.03 mg/l, Ni - 0.05 mg/l, Pb - 0.1 mg/l and Zn - 0.01 mg/l.

4.2.3 Dissolved Metals (Cd, Cu, Fe, Ni, Pb and Zn). The samples were filtered through a 45 micron filter and the pH was adjusted in the field to 1.5 with concentrated nitric acid. The samples were analyzed by direct aspiration on the Jarrell - Ash 810 Atomic Absorption Spectrophotometer for Ni, Cu, Zn, Cd and Fe. Pb was extracted into methylisobutylketone (MIBK) using ammonium pyrrolidinedithiocarbamate (APDC) and sodium dithiodiethylcarbamate (DDC) complexing agents buffered with sodium acetate. The MIBK extract was analyzed by aspiration on a Jarrell - Ash 810 Atomic Absorption Spectrophotometer. The detection limits are Cd - 0.01 mg/l, Cu - 0.01 mg/l, Fe - 0.03 mg/l, Ni - 0.05 mg/l, Pb - 0.1 mg/l and Zn - 0.01 mg/l.

4.2.4 Total Arsenic (As). A 100 ml aliquot was removed from the sample, 2 ml of concentrated nitric acid was added and the acidified aliquot was then boiled for 10 minutes. Distilled water was added to bring the volume back to the original 100 ml and nickel nitrate was added to fix the Arsenic. The arsenic concentration was determined using the Graphite Furnace technique employing a Perkin Elmer Model 306 Atomic Absorption Spectrophotometer equipped with an HGA graphite furnace. The detection limit is 0.001 mg/l.

4.2.5 Total Mercury (Hg). A 60 ml portion of the above aqua regia leached sample was digested with a 1:2 nitric: sulfuric acid mixture. The mercury was then reduced to elemental mercury with a solution of hydrazine sulfate and stannous chloride. The volatilized mercury vapour was passed through an absorption cell and measured on a Jarrell Ash 810 Atomic Absorption Spectrophotometer. The detection limit is 0.2 µg/l.

4.2.6 Non-Filterable Residue (N.F.R.). Non-filterable residue is that portion of the total residue retained by a GF/C filter. NFR is also referred to as suspended matter or suspended solids.

The sample was filtered through a pre-weighed Gooch crucible containing GF/C filter paper. The crucible was dried at 103°C, cooled, and brought to constant weight, then re-weighed. The increased weight was used to calculate the NFR and the results are reported as mg/l. The minimum amount detectable is 10 mg in a 1 litre sample.

4.2.7 Total Residue (T.R.). Total residue refers to the material left in an evaporating dish after the evaporation of the sample.

100 cc of the sample was placed in a dried pre-weighed evaporating dish and evaporated at 90°C. The residue was then heated to 103°C for one hour. The dish was cooled, brought to constant weight then re-weighed. The increase in weight was used to calculate the TR concentration in the sample and reported as mg/l. The minimum amount detectable is 10 mg in a 1 litre sample.

4.2.8 pH Determination. pH is a measure of the H⁺ ion concentration.

Numbers above seven indicate increasing basic condition with increasing numerical value. Numbers below seven indicate increasing acidic conditions with decreasing numerical value. (pH 7 is neutral). All pH values quoted in this report are the results of on-site measurements using a Fisher Accumet 107. The Accumet 107 has a precision of ± 0.03 pH units.

5 RESULTS

5.1 Composite Samples

The chemical analyses and bioassay test results for the composite samples are presented in Tables 2 and 3.

5.2 Grab Samples

The chemical analyses results for the grab samples collected on day 3 are presented in Table 4.

TABLE 2 CYPRUS ANVIL TAILINGS POND SUPERNATANT - COMPOSITE
SAMPLE RESULTS

A. Chemical Analyses

Parameter	Day 1	Day 2	Day 3
As (T) mg/l	0.002	0.005	0.005
Cd (T) mg/l	L0.01	L0.01	L0.01
Cd (D) mg/l	L0.01	L0.01	L0.01
Cu (T) mg/l	0.03	0.02	0.04
Cu (D) mg/l	0.03	L0.01	L0.01
Fe (T) mg/l	0.91	0.56	2.3
Fe (D) mg/l	0.15	L0.03	0.04
Hg (T) µg/l	0.39	0.28	0.39
Ni (T) mg/l	L0.05	L0.05	L0.05
Ni (D) mg/l	L0.05	L0.05	L0.05
Pb (T) mg/l	0.40	0.21	0.50
Pb (D) mg/l	0.37	L0.1	0.19
Zn (T) mg/l	1.3	0.95	1.1
Zn (D) mg/l	1.0	0.67	0.80
N.F.R. mg/l	L10	L10	10
T.R. mg/l	600	620	620
pH	7.90	7.90	8.00

B. Toxicity Determination

	<u>Day 1</u>	<u>Day 3</u>
LC ₅₀ (96 hour)	61 %	non-toxic

TABLE 3 CYPRUS ANVIL TAILINGS POND SEEPAGE - COMPOSITE
SAMPLE RESULTS

A. Chemical Analyses

Parameter	Day 1	Day 2	Day 3
As (T) mg/l	0.002	0.007	L0.001
Cd (T) mg/l	L0.01	L0.01	L0.01
Cd (D) mg/l	L0.01	L0.01	L0.01
Cd (T) mg/l	0.02	0.02	0.01
Cd (D) mg/l	0.02	0.02	L0.01
Fe (T) mg/l	1.1	2.9	1.6
Fe (D) mg/l	0.13	0.14	0.04
Hg (T) µg/l	0.20	0.28	0.28
Ni (T) mg/l	L0.05	L0.05	L0.05
Ni (D) mg/l	L0.05	L0.05	L0.05
Pb (T) mg/l	L0.1	L0.1	L0.1
Pb (D) mg/l	L0.09	0.14*	L0.02
Zn (T) mg/l	0.24	0.45	0.23
Zn (D) mg/l	0.29*	0.34	0.29*
N.F.R. mg/l	L10	L10	L10
T.R. mg/l	750	740	770
pH	7.40	7.70	7.60

B. Toxicity Determination

	<u>Day 1</u>	<u>Day 3</u>
LC ₅₀ (96 hour)	non-toxic	non-toxic

* the dissolved result is higher than the total result, possibly due to contamination.

TABLE 4 CYPRUS ANVIL GRAB SAMPLE RESULTS
(Day 3 only, 1430 hours)

Parameter	Tailings Pond Supernatant	Tailings Pond Seepage
As (T) mg/l	L0.001	L0.001
Cd (T) mg/l	0.02	L0.01
Cd (D) mg/l	L0.01	L0.01
Cu (T) mg/l	L0.02	L0.01
Cu (D) mg/l	L0.01	L0.01
Fe (T) mg/l	0.61	0.77
Fe (D) mg/l	0.11	0.07
Hg (T) µg/l	0.28	0.20
Ni (T) mg/l	L0.05	L0.05
Ni (D) mg/l	L0.05	L0.05
Pb (T) mg/l	0.18	0.16
Pb (D) mg/l	0.17	L0.03
Zn (T) mg/l	0.99	0.17
Zn (D) mg/l	0.92	0.28*
N.F.R. mg/l	L10	L10
T.R. mg/l	630	770
pH	7.95	7.60

* the dissolved result is higher than the total result, possibly due to contamination.

6 DISCUSSION

A comparison between the effluent monitoring results and the federal guidelines is presented in Tables 5 and 6.

The bioassay results show that the tailings pond supernatant was acutely toxic on day 1 and that the tailings pond seepage was non-toxic on both days. Although a discussion of causes of toxicity is beyond the scope of this report there are three likely toxic agents. Since the mill uses sodium cyanide in the flotation circuit, cyanide levels could account for the toxicity. Cyanide is reported to be toxic at levels as low as 0.05 mg/l (3). Unfortunately, samples collected for cyanide determination contained substances which interfered with the analysis. However, data submitted by the company in 1977 shows that the total cyanide levels ranged from 0.001 to 0.19 mg/l. A review of the analytical data obtained shows that the dissolved lead and zinc levels were greatest on day 1 (0.37 mg/l and 1.0 mg/l respectively). It is well documented in the literature that dissolved lead as low as 0.1 mg/l and dissolved zinc as low as 0.01 mg/l are acutely toxic to fish (3).

The overall compliance summary shows that the tailings pond seepage was in compliance with all parameters on all three days. However, noting the composite sample results, the tailings pond supernatant was out of compliance with the lead requirement on days 1 and 3 and with the zinc requirement on days 1, 2 and 3. Further the tailings pond supernatant was out of compliance with the toxicity requirement on day 1.

TABLE 5 COMPARISON OF TAILINGS POND SUPERNATANT RESULTS WITH FEDERAL GUIDELINES

A. Composite Samples

Parameter	Guideline			
	Requirement	Day 1	Day 2	Day 3
As (T) mg/l	0.75	0.002	0.005	0.005
Cu (T) mg/l	0.45	0.03	0.02	0.04
Pb (T) mg/l	0.30	0.40	0.21	0.50
Ni (T) mg/l	0.75	L0.05	L0.05	L0.05
Zn (T) mg/l	0.75	1.3	0.95	1.1
N.F.R. mg/l	37.50	L10	L10	10
pH	5.5 minimum	7.90	7.90	8.00
LC ₅₀ (%)	100	61	-	non-toxic

B. Grab Samples

Parameter	Guideline	
	Requirement	Day 3
As (T) mg/l	1.00	L0.001
Cu (T) mg/l	0.60	0.02
Pb (T) mg/l	0.40	0.18
Ni (T) mg/l	1.00	L0.05
Zn (T) mg/l	1.00	0.99
N.F.R. mg/l	50.0	L10
pH	5.0 minimum	7.95

TABLE 6 COMPARISON OF TAILINGS POND SEEPAGE RESULTS WITH FEDERAL GUIDELINES

A. Composite Samples

Parameter	Guideline			
	Requirement	Day 1	Day 2	Day 3
As (T) mg/l	0.75	0.002	0.007	LO.001
Cu (T) mg/l	0.45	0.02	0.02	0.01
Pb (T) mg/l	0.30	LO.01	LO.01	LO.01
Ni (T) mg/l	0.75	LO.05	LO.05	LO.05
Zn (T) mg/l	0.75	0.24	0.45	0.23
N.F.R. mg/l	37.50	L10	L10	L10
pH	5.5 minimum	7.40	7.70	7.60
LC ₅₀ (%)	100	non-toxic	-	non-toxic

B. Grab Samples

Parameter	Guideline	
	Requirement	Day 3
As (T) mg/l	1.00	LO.001
Cu (T) mg/l	0.60	LO.01
Pb (T) mg/l	0.40	0.16
Ni (T) mg/l	1.00	LO.05
Zn (T) mg/l	1.00	0.17
N.F.R. mg/l	50.0	L10
pH	5.0 minimum	7.60

REFERENCES

1. Metal Mining Liquid Effluent Regulations and Guidelines, Department of Fisheries and the Environment (1977).
2. Laboratory Procedures, Environmental Protection Service, Pacific Region (1974).
3. Water Quality Criteria, McKee and Wolf, California State Water Resources Control Board (1963).