Pan Canadian Consultants Limited

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Vancouver
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(604) 688-8618

Environmental and
engineering consultants
to industry
and government

12 October 1983

United States Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, CA 94105
U.S.A.

Attn: Mr. Harry Seraydarian,
Director, Toxics & Waste Management Division.

Dear Sir,

We were requested recently by Mr. C. N. Thodos, President of Ruskin Developments Ltd., to provide you with copies of data we had collected during the project work we undertook for Ruskin on the Iron Mountain property. Some of the paperwork in our files is not relevant to your investigation, so we have sorted out the information that may be useful.

The enclosures are:

- our final report to Ruskin (which contains much earlier data in the appendices)

- copies of chemical analyses on acid mine drainage, and on treated water samples (after our tests).

We do not possess any other information that would be useful to your investigation. We understand that Ruskin will be asking their geological consultant to forward data relating to the geology of the area.

Please confirm that you have received this information.

Yours truly
PAN CANADIAN CONSULTANTS LIMITED

W. B. Alderton, P.Eng.,
President.

1652-00035

test ltd.

1523 WEST 3rd AVENUE, VANCOUVER, B.C. V6J 1J8 • TELEPHONE (604) 734-7276 • TELEX 04-54210

Report On: Analysis of solution samples

File No.: 1298F

Report No.:

Reported To: C. G. Environmental Engineering
5583 Spruce St.
Burnaby, B.C. V5G 1Y7

P.O. #:

Date: July 26, 1983

Attention: Dr. C. Guarnaschelli, P. Eng.

We have tested the samples submitted by you on July 18, 1983 and report as follows:

SAMPLE IDENTIFICATION:

The samples were submitted in plastic bottles labelled as given on the following Plasma Certificates.

METHOD OF TESTING:

Prior to analysis the samples were digested using an ultra pure nitric acid. The resulting solutions were then analyzed for metals using an Inductively Coupled Argon Plasma Spectrograph.

RESULTS OF TESTING:

See attached Plasma Certificate.

CAN TEST LTD.

Richard S. Jornitz
Supervisor
Trace Metals Laboratory

/cs

Form No. 7 L

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1523 WEST 3rd AVENUE, VANCOUVER, B.C. V6J 1J8 • TELEPHONE (604) 734-7276 • TELEX 04-54210

To: C. G. Environmental Engineering

5583 Spruce St.

Burnaby, B.C. V5G 1Y7

Attention: Dr. C. Guarnaschelli, P. Eng.

PLASMA SPECTROGRAPHIC ANALYSIS CERTIFICATE

File No. 1298F

Date July 26/83

We hereby Certify that the following are the results of plasma spectrographic analysis made on solution samples submitted.

Sample Identification		10/Superna-tant 3.2	10/superna-tant 3.9	1/superna-tant 4.2	Compsite (As received)	ppt 3.9	
Neutralised with NaOH to pH →		3.2	3.9	4.2	Original Sample	Sludge from pH 3.9.	Detection Limit
Aluminum	Al	742.	556.	594.	763.	2030.	1.5
Antimony	Sb	L	L	L	L	L	1.5
Arsenic	As	L	L	L	L	L	3.0
Barium	Ba	0.10	0.067	0.027	0.020	0.36	0.01
Beryllium	Be	L	L	L	L	L	0.03
Bismuth	Bi	L	L	L	L	L	5.0
Boron	B	L	L	L	L	L	0.10
Cadmium	Cd	4.30	4.37	4.41	4.32	3.83	0.25
Calcium	Ca	132.	130.	131.	133.	117.	0.10
Chromium	Cr	L	L	L	L	L	0.30
Cobalt	Co	1.25	1.18	1.19	1.16	1.52	0.20
Copper	Cu	129.	119.	119.	133.	189.	0.15
Iron	Fe	4850.	4230.	4530.	5510.	11800.	0.30
Lead	Pb	0.89	0.71	1.00	1.25	4.00	0.80
Magnesium	Mg	413.	412.	421.	428.	382.	0.01
Manganese	Mn	12.6	12.6	12.8	12.9	11.1	0.03
Mercury	Hg	-	-	-	-	-	-
Molybdenum	Mo	L	L	L	L	L	0.40
Nickel	Ni	0.35	0.33	0.37	0.34	0.45	0.25
Phosphorus	PO_4	9.93	4.64	6.14	13.6	46.6	4.0
Potassium	K	60.1	60.5	60.1	49.3	57.8	0.1
Selenium	Se	-	-	-	-	-	-
Silicon	SiO_2	134.	112.	117.	126.	225.	0.8
Silver	Ag	L	L	L	L	L	0.3
Sodium	Na	2310.	3320.	3240.	53.4	2910.	1.0
Strontium	Sr	0.20	0.21	0.22	0.18	0.25	0.01
Tin	Sn	L	L	L	L	L	0.30
Titanium	Ti	0.13	0.11	0.11	0.88	4.57	0.06
Tungsten	W	-	-	-	-	-	-
Uranium	U	-	-	-	-	-	-
Vanadium	V	1.19	0.39	0.50	1.23	5.98	0.10
Zinc	Zn	606.	607.	626.	631.	561.	0.15

All results expressed in parts per million.

L = less than.

Plasma 1

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Spectroscopist

1652-00035

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Report On: Analysis of solution samples

File No.: 0987F

Report No.:

Reported To: C. G. Environmental Engineering
5583 Spruce St.
Burnaby, B.C. V5G 1Y7

P.O. #:

Date: June 20, 1983

Attention: Dr. C. Guarnaschelli, P. Eng.

We have tested the samples submitted by you on June 15, 1983 and report as follows:

SAMPLE IDENTIFICATION:

The samples were submitted in plastic bottles labelled as given on the following Plasma Certificates.

METHOD OF TESTING:

Prior to analysis the samples were digested using an ultra pure nitric acid. The resulting solutions were then analyzed for metals using an Inductively Coupled Argon Plasma Spectrograph.

RESULTS OF TESTING:

See attached Plasma Certificate.

CAN TEST LTD.

Richard S. Jornitz
Supervisor
Trace Metals Laboratory

/cs

Form No. 7L

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1523 WEST 3rd AVENUE, VANCOUVER, B.C. V6J 1J8 • TELEPHONE (604) 734-7276 • TELEX 04-54210

To:
C. G. Environmental Engineering
5583 Spruce St.
Burnaby, B.C. V5G 1Y7

PLASMA SPECTROGRAPHIC ANALYSIS CERTIFICATE

File No. 0987F

Date June 20/83

Attention: Dr. C. Guarnaschelli, P. Eng.

We hereby Certify that the following are the results of plasma spectrographic analysis made on solution samples submitted.

Sample Identification		Composite #1	Supernatant #1 pH 5.5	NaS Supernatant #2			
		Mixture of Bulka & Slidwide	Neutralised with NaOH	After Na_2S added.			Detection Limit
Aluminum	Al	674.	4.48	L			1.5
Antimony	Sb	L	L	L			1.5
Arsenic	As	13.0	L	L			3.0
Barium	Ba	L	0.013	0.36			0.01
Beryllium	Be	L	L	L			0.03
Bismuth	Bi	L	L	L			5.0
Boron	B	4.50	L	L			0.10
Cadmium	Cd	6.20	5.18	L			0.25
Calcium	Ca	119.	106.	57.4			0.10
Chromium	Cr	L	L	L			0.30
Cobalt	Co	L	L	L			0.20
Copper	Cu	154.	4.36	0.080			0.15
Iron	Fe	7260.	5180.	2120.			0.30
Lead	Pb	2.50	L	L			0.80
Magnesium	Mg	394.	346.	185.			0.01
Manganese	Mn	11.4	10.1	5.26			0.03
Mercury	Hg	-	-	-			-
Molybdenum	Mo	L	L	L			0.40
Nickel	Ni	0.29	L	L			0.25
Phosphorus	PO_4	15.3	8.74	L			4.0
Potassium	K	29.4	22.6	16.5			0.1
Selenium	Se	-	-	-			-
Silicon	SiO_2	129.	33.2	16.7			0.8
Silver	Ag	L	L	L			0.3
Sodium	Na	31.6	4140.	4400.			1.0
Strontium	Sr	0.13	0.19	0.10			0.01
Tin	Sn	L	L	L			0.30
Titanium	Ti	1.14	0.12	0.13			2.5
Tungsten	W	-	-	-			-
Uranium	U	-	-	-			-
Vanadium	V	1.02	L	L			0.10
Zinc	Zn	806.	598.	132.			0.15

All results expressed in parts per million.

L = less than.

Plasma 1

CAN-TEST LTD.

Spectroscopist

CH2M HILL
ENVIRONMENTAL LABORATORY
2218 RAILROAD AVENUE, P.O. BOX 2088
REDDING, CA 96001–TELEPHONE (916) 243-5831

Physical
Chemical &
Bacteriological
Analysis

REF. NO. 9230
DATE 6/21/83

SPECIFIC ANALYSIS

REPORT TO RUSKIN DEVELOPMENTS
c/o Monterey Motel
525 Market St.
Redding, Ca. 96001

ATTN: Bill Alderton PHONE:

SAMPLE DESCRIPTION Iron Mountain Mine SAMPLED BY: client

DATE OF SAMPLE 6/14/83 DATE RECEIVED 6/14/83

TESTS	B in=Boulder Ck. Plant Influent	B 1qry out=Boulder Ck. Plant Primary cell eff.	B out=Boulder Ck.Plant effluent
pH (units)	1.20	1.33	1.33
Total Dissolved Solids	57720	59870	55320
Copper	166	13.6	5.17
Total Iron	11,300	13,100	13,200
Ferrous Iron	5160	6520	6670
Zinc	1050	1060	1050 ~~52.3~~
Ferric Iron (by calculation)	6140	6580	6530

COMMENTS: Results are in milligrams per liter unless otherwise noted.

All analyses by EPA or State of California recommended methods, unless otherwise noted

State Approved Water Laboratory for Chemical, Bacteriological, and Bioassay Examinations

REPORTED BY: Brian Gilns

The information shown on this sheet is test data only and *no analysis or interpretation* is intended or implied.

Form 65

CH2M HILL

ENVIRONMENTAL LABORATORY
2218 RAILROAD AVENUE, P.O. BOX 2088
REDDING, CA 96001—TELEPHONE (916) 243-5831

Physical
Chemical &
Bacteriological
Analysis

REF. NO. 9230
DATE 6/21/83

SPECIFIC ANALYSIS

REPORT TO RUSKIN DEVELOPMENTS
c/o Monterey Motel
525 Market St.
Redding, Ca. 96001

ATTN: Bill Alderton PHONE:

SAMPLE DESCRIPTION Iron Mountain Mine SAMPLED BY: client

DATE OF SAMPLE 6/14/83 DATE RECEIVED 6/14/83

TESTS	S in=Slickrock Ck. plant influent	S out=Slickrock Ck. plant effluent
pH (units)	2.59	2.62
Total Dissolved Solids	10490	10130
Copper	122	122
Total Iron	1210	1230
Ferrous Iron	477	474
Zinc	49.1	50.0
Ferric Iron (by calculation)	733	756

COMMENTS: Results are in milligrams per liter unless otherwise noted.

All analyses by EPA or State of California recommended methods, unless otherwise noted

REPORTED BY: Brian Goers

State Approved Water Laboratory for Chemical, Bacteriological, and Bioassay Examinations

The information shown on this sheet is test data only and no analysis or interpretation is intended or implied.

Form 65

1652-00035

THE IRON MOUNTAIN PROPERTY

REPORT ON WORK PROGRESS AND DISCUSSIONS
WITH GOVERNMENT AGENCIES

PAN CANADIAN CONSULTANTS LIMITED
VANCOUVER B.C.

Final Report ~~May~~ August '83

TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

Pan Canadian Consultants Limited were retained by Ruskin in April 1983 to assist them in resolving problems at the Iron Mountain mine at Redding, California. Tasks assigned to Pan Canadian included:

Task 1 - establish good relations with the appropriate government agencies to relieve pressure on Ruskin and to overcome some of the problems created by previous owners of the property.

Task 2 - examine the acid mine drainage (AMD) at Iron Mountain to see if a feasible and economic process could be developed to extract metals values from the AMD.

Task 3 - determine how best the environmental problems at Iron Mountain could be resolved.

We have completed our work as far as we can at this time. Further work will depend on Ruskin's decision whether to proceed with property acquisition or to drop the property.

This brief report summarises our findings to date, and should give Ruskin some guidance on whether it should continue with the property. As discussed in our meeting of 2nd August 1983, and further in this report, continuance with the project will require Ruskin to make a committment to spend considerable sums of money to satisfy the various government agencies.

2. TASK 1 - Government Relationships

We believe that Ruskin has now developed an excellent relationship with the Environmental Protection Agency (EPA) and the Regional Water Quality Control Board (WQCB). Our meetings with these agencies have convinced them that Ruskin is serious about solving the problems at Iron Mountain. The government personnel realize that the problems are no fault of Ruskin's and they have a great deal of sympathy for Ruskin's position.

However, the Iron Mountain environmental problems have continued unresolved for so long that the EPA is not willing to delay its planned studies using "Superfund" money at all. Work is scheduled to commence this month and will be completed in about 12 months. The only way that the government will back-out is if Ruskin and/or IMMI agrees to do the proposed work (or an agreed alternative) itself. The proposed EPA work program is attached as Appendix 1.

The attached work program is to be undertaken by CH_2M-Hill of Redding and will cost about $600,000 (U.S.).* Once the work has been done, the EPA will try to obtain its refund from the "responsible" parties.

We have tried to involve the EPA with Ruskin in a shared cost program, but the EPA is not prepared to do this. The work will be done on an ALL or NOTHING basis i.e. either Ruskin puts up all the money or the EPA will. However, all EPA Superfund monies are claimable back from the responsible party

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*We estimate the cost at about $300,000 (CAN) if Pan Canadian did the work for Ruskin.

2.1 Superfund Program

The attached work program is to be completed by U.S. consultants in the next 12 months, and will cost about $600,000 (U.S.). Once it has been completed, the EPA will seek to recover this money from the responsible parties. Therefore, if Ruskin continues to be involved with the property, it will be held partly liable. If Ruskin does continue with the property, it makes more sense for Ruskin to do the work itself, since it would mean a saving of about $350,000 (CAN).

If Ruskin abandons the Iron Mountain property, it cannot held liable for return of the EPA Superfund money, and this responsibility would revert to IMMI and possibly to previous owners of the property.

The large amounts of money involved with the recent fine imposed on IMMI (Appendix 2) and with the Superfund program, have a significant effect on the feasibility of the entire project, and Ruskin should carefully evaluate whether it wishes to remain involved with the property. Since none of the problems with the property are of Ruskin's making, it would seem that all these costs should be borne by IMMI.

It must be realized that the Superfund work program will be commencing in August 1983, and expenditure will be made at the rate of about $50,000 (U.S.) per month. This expenditure will continue unless Ruskin decides to take over the work program itself. Funds expended, plus additional costs for program administration, interest, etc.,* will be recovered by EPA

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*These extra costs may be substantial.

Since Ruskin does not yet know if it will continue with the project, and since Ruskin does not want to waste money, we suggest that further work be limited to the minimum necessary to retain good relations with the government agencies until Ruskin can make a decision on the property.

3. TASK 2 - Extraction Process.

In our memo of 30th June 1983 (Appendix 3) and in the July proposal to the WQCB and EPA (Appendix 4), we discussed alternative methods for treating AMD to recover saleable metals. We eliminated several potential processes from consideration because of various technical problems. Apart from the cementation process, now used in the Boulder and Slickrock Creek plants to recover copper, we felt that the use of a sulphide preferential-precipitation process showed promise in producing a marketable copper/cadmium sulphide product. Initial laboratory results were encouraging, although iron precipitation was also occurring at the pH value we used for sulphidation (pH 5.5).

More recent tests at lower pH values (pH 3.2, 3.9, 4.2) show that co-precipitation of iron is still a major problem even though theoretically it should not be. The problem is severe enough to rule out the sulphide process as a feasible method for the recovery of saleable metals. The problem occurs because of the very high concentration of dissolved iron (0.5-0.7%) in the AMD compared with the concentrations of other metals. It therefore seems that only the existing cementation process is an economical method of treating AMD for copper removal.

Initially, we were given analyses showing appreciable dissolved gold and platinum in the AMD. Subsequent examination of analyses done by others, and check analyses run by ourselves, show that no such precious metal values occur. Typical values are shown in Appendix 5. The loss of these precious metals removed much of the incentive from our work, since only the gold and platinum seemed to offer a significant opportunity to make a profit. Base metal recovery from AMD is not profitable.

In conclusion, there does not appear to be a suitable economical method for recovering saleable product from the AMD except copper cementation with iron.

4. TASK 3 - Environmental Control.

4.1 Proposed Program

The work program proposed by the EPA (Appendix 1) is designed to produce the most economical solution to the environmental problems caused by Iron Mountain AMD. The ideal solution would be to eliminate all AMD, and this possibility will be examined. However, assuming that AMD continues into the future, treatment will be necessary to reduce the pollution entering the Sacramento River. From our studies, and from work done by many other researchers, we believe the most economical treatment will be neutralisation with lime/limestone and precipitation of the metals as hydroxides. This process is conventional and proven, and has been tested on the Iron Mountain AMD by CH_2M-Hill.

The process will involve directing all AMD to a central point, neutralising with lime/limestone, and settling in large ponds. Clear decant liquor will be discharged to the river. Sludge will be dredged out from time-to -time and buried in a landfill. The plant and pond area likely will be several miles away from the mine site on the flats to the west of the Sacramento River. AMD will be delivered there via a pipeline.

The cost of constructing the plant and settling ponds will probably be $1-1½ million (U.S.). Operating and maintenance costs will be in the order of $500-750,000 (U.S.) per year (1983 dollars). There will be no possibility of any economic return to offset these costs. Treatment, and hence the on-going operating costs, will have to be continuous for as long as AMD is produced from the mine.

Responsibility for constructing and operating the treatment facility will rest with the owner(s) and/or operator(s) of the Iron Mountain Property. This is a cost factor that should be given careful consideration when making a decision on the viability of the Iron Mountain project.

4.2 Alternative Programs.

As discussed in our July proposal (Appendix 4), it may be possible to reduce or eliminate the flow of AMD by a number of methods. These include:

a) reinjecting AMD into the mine workings.
b) intercepting groundwater flows before they can enter the workings.
c) keeping the Brick Flat pit pumped out or at a very low level.
d) preventing surface water from entering the mine.
e) sealing mine openings to prevent AMD discharge.

A preliminary cost estimate of $48,500 was given for a trial of alternative a) in our July proposal. Alternative c) would cost about $15,000 for capital installation plus about $10,000 per year for operating/ maintenance costs. If c) is to be implemented it should be this summer while the Brick Flat pit is dry. No costs have been developed for b) and d); extensive geotechnical studies would be required. We believe that alternative e) has only a slight chance of success, since there are so many potential openings that could drain the mine.

Since these alternatives could cost substantial amounts of money, it does not make much economic sense for Ruskin to implement them unless it is committed to the property.

5. CONCLUSIONS

Until Ruskin makes a decision regarding the feasibility of the Iron Mountain property, it should minimize its expenditures on the environmental aspects. We suggest that a low level of effort be maintained in keeping in touch with the WQCB and with EPA - possibly 1-2 days per month of Mr. Alderton's time. Other expenditures should be held in abeyance until such time as a decision has been made to proceed with acquisition of the property. At that time, Ruskin should advise the agencies that it proposes to do the remedial work itself. If Ruskin decides not to purchase the property, then no cost penalty will be incurred by not doing the work at this time i.e. Ruskin will not be liable for reimbursing the EPA for the money spent under the Superfund program.

APPENDIX 1

This is RI/FS Work Statement that EPA has.

APPENDIX 2

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

CENTRAL VALLEY REGION

-NEWS RELEASE-

100 E. CYPRESS AVENUE • REDDING, CALIFORNIA • 96002

Mr. James Pedri, Supervising Engineer

26 July 1983

** FOR IMMEDIATE RELEASE **

The State of California and the owners of Iron Mountain Mine have reached settlement in their long standing lawsuit.

In a stipulation signed Wednesday by Justice Frances N. Carr sitting in the 3rd District Court of Appeals in Sacramento, Iron Mountain Mines, Inc. agreed to pay the state $500,000.00 for violations of the California Water Code. The Central Valley Regional Water Quality Control Board has maintained that Iron Mountain Mines, Inc. failed to operate existing copper removal facilities according to state standards. The judgment may be reduced to $400,000.00 if Iron Mountain Mines, Inc. begins making payment to the state within 30 days and continues to pay at least $75,000.00 per year for the next five years.

"Although the settlement amount is somewhat less than the original judgment, the $400,000.00 represents the largest settlement for water pollution in this state, and probably the nation, against an abandoned or nonoperating business," said James Pedri, Supervising Engineer with the Board's Redding office. James Pedri also added that, "the judgment is only for past violations of the Board's orders and in no way relieves Iron Mountain Mines, Inc. of their responsibility to clean up toxic discharges from their property."

The Regional Water Quality Control Boards, State Department of Health Services and Environmental Protection Agency are pursuing the use of "Superfund" money to study and clean up the pollution problem. A work plan has recently been approved in Washington to spend over $600,000.00 in the next several months to complete all necessary studies. "We foresee the start of major cleanup activities sometime next summer," said Mr. Pedri. According to federal law, Iron Mountain Mines, Inc. will be responsible for repaying the state and federal government for all costs associated with the Superfund cleanup.

Iron Mountain Mines, Inc. may still be able to avoid high cleanup costs if they are successful in developing an operating mine on their property. Ruskin Developments, Ltd., a canadian mining company, has leased the mineral rights to Iron Mountain Mines, Inc.

If current testing by Ruskin indicates sufficient mineral value, then the mines can again be operated at a profit. Such operation will allow for recovery, treatment or elimination of existing toxic mine discharges.

# # #

APPENDIX 3

Memo to: Tyke Thodos
from: Bill Alderton

Date: 30 June 1983

Subject : Summary of the Iron Mountain Acid Drainage Problem and Possible Methods of Treatment.

The problem

The Water Quality Control Board (WQCB) has identified 18 sources of acid mine drainage (AMD) within the Iron Mountain area. However, they are mainly interested in only 4 major discharges. These are:

1. Richmond portal
2. Lawson portal
3. Slickrock Creek seep
4. Old #8 portal

#1 and 2 are now combined and flow to the Boulder Creek cementation plant via a pipeline and trough. #4 is now collected and directed to the Slickrock Creek plant. #3 discharges into Slickrock Creek untreated, although it could be collected and sent to the plant.

Flow rates are not monitored, although there is a V-notch weir at the outfall from the Boulder Creek plant (this is now calibrated and Frank Foster should be taking readings daily). The WQCB has measured flows from time to time. Based on their results I have assumed that mean annual flows for the above sources are:

1 + 2 = 1000 l/min (220 gpm)
3 + 4 = 800 l/min (180 gpm)

Since flow measurement equipment is just being installed, it is impossible to verify these flows. However, they are a useful starting point for discussion. Flow measurements will be taken on a regular basis in future, so we can check my assumptions.

From numerous WQCB analyses, I have derived an average analysis for Boulder Creek and Slickrock Creek plant influents. These are:

Parameter	Boulder Ck	Slickrock Ck
pH	1.3	2.5
Cu	250 mg/l	150 mg/l
Zn	1300 "	70 "
Cd	10 "	0.5 "
Fe	12000 "	1500 "

I have also assumed that there is a silver content of 0.19 mg/l in both waters, although this is based on only one analysis (D'Appolonia, 1981). More recent analyses by CH_2M-Hill show silver values of only 0.02-0.09 mg/l.

Using the above flows and analyses, the maximum possible metal recovery from the AMD is:

Cu	195	MT/yr	= $300,300 @ 70¢/lb
Zn	713	"	= $533,324 @ 34¢/lb
Cd	5½	"	= $ 7,260 @ 60¢/lb
Fe	6860	"	Zero value
Ag	180	Kg	= $ 88,700 @ $14/oz
Total			$929,584

I assume that there is no market for iron. In practice, the actual $ recovery may be less than $500,000/yr - this depends to some extent on the quality of the extracted metals.

An earlier analysis showed dissolved gold and platinum in the drainage. I am having analyses done to check this out,but discussions with both the WQCB and CH_2M-Hill in Redding tend to discount the possibility of precious metals in the water. You may remember also, that I expressed doubts about this when we first met; gold and platinum do not dissolve readily in water or sulphuric acid.

Apart from the economics of recovering metals values, there is the problem of pollution control and the need to satisfy the WQCB. This must be dealt with even if no economic return is possible. We are examining methods for treating the AMD and you will soon have a copy of a proposal to the WQCB for EPA Superfund \$. We are trying to concentrate the metals so that we can remove them as cheaply as possible.

Some processes are clearly unsuitable or technically unfeasible. Others show promise but need more work. The processes considered are described in the following sections.

Demineralization by Ion Exchange.

Ion exchange demineralizers have been demonstrated to treat successfully a synthetic AMD, and to produce potable water. (Holmes & Kreusch, 1972). Their tests however, used AMD with much lower concentrations of dissolved constituents than occur at Iron Mountain. A comparison of AMD quality is shown below:

	Concentration (mg/l)	
	Holmes & Kreusch	Iron Mountain (Boulder Ck Plant)
Acidity (as $CaCO_3$)	500	Est 20,000
Sulphate	1150	47,000
Ca	200	66
Mg	24	720
Al	15	1,550
Fe	210	8,700
Cu	0	130
Zn	0	1,300

The difference in the total dissolved solids makes the process of ion exchange impossible to justify unless there are ion exchange resins capable of selectively adsorbing Cu, Zn, and Cd in preference to iron and aluminum. At present there do not appear to be such resins. Without these resins, one cubic foot of standard ion exchange resin will treat only about 12 gallons water before it requires regeneration. This is unacceptable since it would make the cost of ion exchange excessive.

Ion exchange demineralisation would be so uneconomic that it cannot be considered any further.

Reverse Osmosis (R.O.)

R.O. is an established technology used widely in the production of industrial process water and drinking water from brackish or sea-water. It has also been demonstrated to treat AMD successfully in the U.S. (Wilmoth,1973).

Use of R.O. would produce one fairly pure stream (permeate) that could be discharged to surface streams without further treatment, and a concentrated stream (reject) that would contain almost all dissolved minerals originally in the AMD. It would thus concentrate the water to allow treatment in smaller facilities and to enhance metal recovery.

We have discussed R.O. with Seagold Industries in Vancouver, and with Fluid Systems Division of U.O.P. in San Diego (U.O.P. makes R.O. units). U.O.P. have a couple of systems working on AMD streams but not as acidic or as concentrated as at Iron Mountain.

U.O.P. advise that their R.O. membranes cannot handle the acidity of the Iron Mountain AMD, and also that they would be concerned about membranes fouling with iron, manganese and gypsum. They suggested neutralising to pH 8-9 to remove iron and manganese before running the neutralised and clarified effluent through a R.O. unit. Since the U.O.P. R.O. units are believed to be more resistant to fouling than other types (because of their construction) we have assumed that other R.O. systems will have even more problems with the Iron Mountain AMD.

The requirement for neutralisation makes the use of R.O. units impractical. At pH 8-9 most of the dissolved solids in the AMD will be removed as hydroxides and gypsum and there would be no need to use R.O. Adding a R.O. unit to treat already neutralised water would cost over $1,000,000 and would not achieve any great improvement. There would be no economic return.

For these reasons, R.O. is not a feasible trearment for the Iron Mountain AMD. No further work is planned.

Neutralisation with lime or limestone

The addition of lime ($Ca(OH)_2$) or limestone ($CaCO_3$) to AMD will neutralise the acidity and result in the removal of dissolved metals as hydroxide precipitates. At pH 8-9 most of the dissolved metals can be removed, leaving about 0.5-1.0 mg/l in the neutralised decant liquid and most of the metals in the precipitated sludge.

Unfortunately, in the case of Iron Mountain, the AMD contains high concentrations of sulphate ion. Addition of calcium ion will give a massive precipitate of gypsum ($CaSO_4$). This will form 60-70% of the final sludge volume. Iron and aluminum hydroxides will form another 30-35% of the final sludge volume. The marketable metals (Cu,Zn,Cd) will only comprise about 5% of the total sludge volume.

This "dilution" by gypsum, iron and aluminum renders the produced sludge unsaleable, and means that neutralisation with lime/limestone is a "throw-away" process involving the continual use of large quantities of chemicals, the continual need to dispose of large volumes of sludge, and the impossibility of ever realising any cost recovery from sale of a product.

The WQCB has contracted a company in Redding (CH_2M-Hill) to study the lime/limestone process. They have just completed their pilot-plant work at the Boulder Creek plant site. Their initial results indicate that a settled sludge volume of about 20% of the original AMD volume is produced. Based on a combined flow rate of 1800 l/min (400 gpm) the annual sludge production will be almost 7 million cubic feet (260,000 cubic yards). CH_2M-Hill are proposing that the sludge be concentrated by evaporation in summer, so that the total solids volume would be reduced. Nevertheless, the volume to be landfilled or ponded is still considerable.

Lime/limestone neutralisation is a proven process that will solve the pollution problem. It has no other redeeming features and must be considered as a last resort if all else fails. This process has not been rejected but is being ignored for the moment while we examine an alternative.

Partial neutralisation and sulphide addition

Metallic sulphides are almost totally insoluble in neutral or alkaline waters. Their solubility increases in acid waters, but is still low at pH 3-5.

Partial neutralisation to pH 3-5 using an alkali plus a sulphide (eg Na_2S) will precipitate most of the metals as sulphides without contaminating them with gypsum. Subsequent neutralisation with lime to pH 8 and aeration will remove most of the iron and sulphates in a separate stage where they will not contaminate the metallic sulphides. The objective of this 2-stage process is to allow the recovery of a fairly pure mixture of CuS, ZnS and CdS for sale to a smelter.

The disadvantage of sulphide precipitation is that the cost of chemicals is higher than lime and limestone. On the other hand, recovery of the metal sulphides offsets these costs and may result in an overall lower treatment cost. Until some more experimental work has been done to optimise the chemical dosages it is impossible to conclude what the costs of sulphidation will be.

The partial neutralisation/sulphidation process is being examined for its practicability on Iron Mountain AMD. Further small-scale work is continuing and will be reported in future. This process is the subject of our proposal to the WQCB for EPA Superfund money to do some pilot-plant work on site (see proposal for details).

Recirculation of AMD back into the mine

As has been mentioned in your offices, the possibilty of pumping AMD back into the mine may increase the concetration of copper to the point where electrowinning is possible. I think we will find that the volume of water leaving the portals will increase steadily if we do this, but I will come up with some cost estimates for installing the necessary pump, pipeline and well. I have included this option in the proposal to the WQCB for partial financing by the EPA.

Interception of groundwater and pumping

It seems to me that much of the water infiltrating the old workings and causing the AMD originates as ground water - possibly from some distance away from the mine. If this is the case, it should be possible to install water wells and pumps to draw down the water table around the mine area, and to prevent water from entering the mine workings. An alternative would be to re-enter the mine and to seal points where water flows in. I doubt if the mine is safe enough to enter to do this type of work, so it really boils down to intercepting flows before they can reach the mine.

This approach has much to recommend it. Once the initial expense of well/pump installations has been incurred, the operating costs will be relatively low - just power for the pumps. If successful, the AMD would cease totally and there would be no need for any treatment facilities. Of course, there would never be any economic return either.

This alternative would require a major geotechnical investigation of groundwater conditions around the mine. Existing drill holes may provide useful data if piezometers can be installed in them. I do not have a handle on the $ involved with this course of action. I have included it in our proposal only at a preliminary stage, and have suggested that you would want to discuss it with the WQCB.

EPA "Superfund" availability

The EPA has promised about $800,000 to study the Iron Mountain problem. Discussions have already taken place between the EPA, WQCB and the State Department of Health Services to establish terms-of-reference for the study; the contractor will be CH_2M-Hill.

The WQCB is assuming that Ruskin will not go through with the purchase of the Iron Mountain property and that, therefore, the State will have to develop a solution to the problem. If Ruskin was operating the mine, you would be expected to do the work.

The results of the Superfund contract will not necessarily be imposed on Ruskin by the WQCB, but once a process or method has be arrived at, pressure will be put on Ruskin to implement a solution at least equal to the WQCB's.

The importance of the problem and the potential high costs involved make it desirable for Ruskin to keep a close liaison with the authorities in California; in particular the WQCB. It would also be most desirable for Ruskin to have a direct involvement with the Superfund work, by way of doing a joint program with government.

The WQCB suggested that we submit a proposal for Superfund money to study the problem, and to examine the proposed sulphidation process in detail. It will be necessary for Ruskin to propose a joint funding approach because I am sure that the EPA will not agree to 100% funding. The split I have used is 50/50.

The proposed program is described in a separate proposal - you have a copy.

APPENDIX 4

PROPOSAL FOR A STUDY OF THE
FEASIBILITY OF TREATING IRON
MOUNTAIN ACID MINE DRAINAGE

RUSKIN DEVELOPMENTS LTD
VANCOVER B.C.

Proposal submitted to EPA & WQCB.

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Figures

INTRODUCTION.

The Iron Mountain mine at Redding produces large volumes (est. 300 - 500 gpm) of acid mine drainage (AMD) year-round. The AMD has a low pH (1 - 3.5) and contains high concentrations of dissolved copper, zinc, iron and aluminum, together with appreciable quantities of manganese and cadmium. Dissolved sulphate concentrations have been measured as high as 47,000 mg/l.

The origin of the AMD is meteoric water, and possibly groundwater, infiltrating the old workings of the mine and ore bodies via fractures and old adits. Once inside the mine, bacterial activity converts sulphides to sulphuric acid which dissolves the metallic constituents of the ore. The residence time and reaction rate in the mine are unknown. Evidence that vigourous reactions are taking place is provided by a number of old portals that "steam", by the fact that drainage from the Richmond portal is quite warm, and by the extremely high dissolved solids concentrations (over 20,000 mg/l) in the drainage.

At present, drainage from the three largest sources is treated in small cementation plants to remove dissolved copper. These plants use scrap steel to precipitate the copper, while releasing a large concentration of iron into solution. The drainage is then allowed to discharge into Slickrock Creek and Boulder Creek, both tributary to Spring Creek. A number of smaller seeps discharge into the Spring Creek system untreated. Spring Creek flows are regulated by a dam at the Spring Creek Generating Station, and water is discharged into the Keswick reservoir on the Sacramento River.

The Spring Creek discharge has been determined to be detrimental to the water quality of the Sacramento River downstream from the Keswick reservoir, and fish mortality has been recorded (D. Heiman. pers. comm.). Since the Sacramento River is used by spawning chinook salmon, the potential exists for damage to this resource via toxicity from heavy metals dissolved in the river water and from suspended particulate materials, mainly ferric hydroxide, which can interfere with respiration by coating the gills.

As a result of these concerns, Iron Mountain Mines Inc. was required to limit the discharge of copper from its operations and to ensure that receiving water quality in the Keswick reservoir or Sacramento River did not exceed certain specified levels (California Regional Water Quality Control Board Order Nos. 77-225 and 78-152).

Ruskin Developments Ltd. is considering the purchase and renewed operation of the Iron Mountain property. As such, it wishes to resolve some of the past problems associated with this property and is prepared to use its best efforts to limit the extent of AMD production and to develop a process to treat AMD. To meet these objectives Ruskin has engaged a consulting company (Pan Canadian Consultants Limited) to study the problem and to recommend a suitable course of action.

The consultant has studied the alternatives available for treatment of the AMD and reports that only two methods appear feasible. These are:

1. the lime/limestone process currently under investigation by CH_2M-Hill

2. a partial neutralisation/sulphidation process to precipitate metals as sulphides

The second process appears to have the potential to make a partial economic return, while reducing heavy metal levels below those possible with hydroxide precipitation.

The consultant, having done some laboratory-scale experiments, wishes to proceed to a pilot-plant scale to verify that the proposed process does allow preferential precipitation of heavy metal sulphides under larger-scale conditions, and to permit the development of capital and O & M costs for a process.

The consultant has also considered the possibility of preventing the creation of AMD by limiting the inflow of water into the mine workings, and by recirculating AMD back into the mine to develop an in-situ leaching operation. These possibilities are discussed later in this proposal.

Ruskin is willing to enter into a joint funding venture with government to ensure that adequate finances are made available to examine these important potential methodologies for solving the problem at Iron Mountain. Since the proposed treatment methodology has already been examined to some degree by the consultant, and since Ruskin is prepared to match the contribution by government on a 50/50 basis, we believe that the government would obtain a more cost-effective and economical use of its funds by participating jointly on this program with Ruskin. The present consultants for Ruskin would undertake the work, and would report to both parties to the agreement. Details of funding are discussed in a later section of the proposal.

STUDY OBJECTIVES

The objectives of the proposed work are:

1. to develop a feasible method for the removal of heavy metals from AMD

2. to obtain better water discharge quality than can be obtained from other alternative treatment(s)

3. to attempt to obtain a marketable product from the process to offset its operating costs and, if possible, to make an operating profit

4. to add to the knowledge and understanding of AMD treatment technology, and to develop procedures that may be applicable elsewhere

5. to examine the potential for "zero discharge" of mine water by recirculation of AMD back into the workings, or of interception of groundwater flows before they can infiltrate the mine workings.

Ruskin believes that the approach suggested by the consultant is logical and should be examined further. Initial results indicate the potential for high efficiency waste treatment and the discharge of high quality effluent using sulphide precipitation. The potential for closed-loop circulation of AMD back into the mine has not been examined in the same detail but has great merit, since it may solve the problem of AMD discharge at source.

TECHNICAL PROPOSAL

A number of potential processes have been examined to treat the AMD. Those considered are:

Ion exchange

Rejected because of the high TDS of the AMD, the low treatment capacity of available resins (@30 kgr/ft^3, 1 ft^3 of resin will treat only about 12 gallons AMD before exhaustion), and the potential for severe iron and manganese fouling of the resins. Operating costs would be excessive and waste regenerants would pose a significant waste disposal/ treatment problem of their own.

Reverse osmosis

Rejected because of the low pH and the potential for iron, manganese and calcium sulphate fouling. UOP Fluid Systems advised that their spiral-wound membranes would not be able to operate in the low pH conditions at Iron Mountain unless the water was first neutralised to raise its pH and to precipitate iron. Since this would by itself solve most of the problem, the addition of R.O. would then be pointless.

Neutralisation with lime/limestone

This is being researched by CH_2M-Hill under contract with the WQCB. Neutralisation to pH 8-9 with aeration of ferrous to ferric hydroxide will remove metals down to acceptable levels. Disadvantages of the process are that there is no prospect of any economic return, the large areas required for sludge settling ponds, and the fact that metallic hydroxides tend to redissolve under acidic conditions. This process is considered as a "last resort" if the proposed alternative processes and procedures fail to meet our expectations.

The process we propose taking to the pilot stage is discussed in the following sections.

Partial neutralisation and treatment with sulphides.

Chemical background

The basic premise behind the proposed process is that metallic sulphides are much less soluble than metallic hydroxides. Typical solubility products for metallic compounds (Ref 1) are:

CuS	1×10^{-40}	$Cu(OH)_2$	6×10^{-20}
ZnS	1×10^{-23}	$Zn(OH)_2$	1×10^{-17}

MnS	1×10^{-16}		$Mn(OH)_2$	4×10^{-14}
CdS	1×10^{-28}		$Cd(OH)_2$	1×10^{-14}
FeS	1×10^{-22}		$Fe(OH)_2$	1×10^{-15}
			$Fe(OH)_3$	1×10^{-38}

(these values are not quoted as being precise but are of order of magnitude).

Equally as significant as the low solubility of the metallic sulphides is the fact that they are insoluble at relatively low pH levels. Thus, at pH 4, solution concentrations of CuS, ZnS and CdS would not exceed 0.10 mg/l. By comparison, most hydroxides require a pH of 8-9 for effective removal. ($Zn(OH)_2$ has a minimum solubility at pH 9-10; $Cd(OH)_2$ has a minimum solubility at pH 11). Furthermore, metal hydroxides will redissolve readily when the pH is lowered, as can occur in tailings ponds over time. The amount of metal redissolving increases with decreasing pH.

The ability to precipitate metal sulphides at low pH permits the selective separation of metals. Neutralisation with soda ash or caustic will limit the precipitation of calcium sulphate or ferric hydroxide and will retain a fairly clear solution. Addition of a sulphide (BaS, Na_2S, NaHS) will selectively precipitate the heavy metal sulphides as a dense sludge which can be reclaimed, dewatered and sold.

Following heavy metal removal, the solution can be aerated to remove excess sulphide ion and treated further with lime or limestone with aeration to precipitate iron as $Fe(OH)_3$ and aluminum. After settling, the supernatant liquid would be discharged to surface waters. The ferric and aluminum hydroxides/calcium sulphate sludge could be ponded or possibly filtered to dry-haul to a disposal site.

The process has been demonstrated by numerous researchers (Ref 2,3,4) and in the laboratory by our consultants. They are now at the stage where pilot-scale work is needed to optimise the treatment process.

Pilot study

It is proposed to operate a pilot-plant at the Boulder Creek plant site. The unit would comprise 2-3 reaction vessels and a number of settling tanks. The reactors would each be 50-100 gallons capacity. Initially the pilot-plant would operate batch-wise to establish parameters for optimum operation (pH, sulphide concentration, reaction times, settling rates etc) but would subsequently be arranged to operate continuously for short periods.

The first reaction vessel would be for initial pH adjustment. The second reactor would be for sulphide addition. The contents of the second reactor would be drained into a settling tank after sulphide addition. The third reactor would be used for final neutralisation and aeration.

The pilot study will concentrate on establishing and optimising basic parameters for a full-scale plant. These include:

- the minimum pH level for initial neutralisation to permit complete removal of heavy metals in the second stage without contamination with $Fe(OH)_3$
- optimisation of sulphide dosage
- sludge settling rates, composition and filterability
- effectiveness of aeration for sulphide removal
- decant neutralisation and aeration for ferric hydroxide precipitation

- ferric hydroxide/calcium sulphate sludge settling rate, composition, dewatering characteristics and filterability

Pilot-plant work is proposed to lead to a second stage study at a small plant scale.

Small plant scale study

Initial study of the existing Boulder Creek cementation plant indicates that the concrete cells could be cleaned out and converted to a sulphide precipitation plant with minor modifications. This preliminary evaluation is dependent on the conclusions reached during the prior pilot-plant work, but we believe that there is some evidence to show that the heavy metal sulphides will precipitate rapidly and that the Boulder Creek plant cells have the capacity and residence time to permit their complete separation and removal.

Post-sulphide neutralisation and ferric hydroxide precipitation may also be possible; this will be examined during the pilot-plant study.

A possible conversion of the Boulder Creek plant and an operational flowsheet is shown on Figure 1. Conversion will involve the cutting of some channels to interconnect cells, the installation of mixers, feeders, small chemical feed tanks, aerators, pumps and a small filtration unit.

Cell dimensions, volumes and residence times for a 150 gpm flow are given below:

Initial neutralisation cell;	5' x 10' x 35' 1750 ft^3 Residence 87 minutes

Rapid mix cell;	6' x10' x4' 240 ft^3 Residence 12 minutes.
Sulphide settling basin;	30' x 35' x 4' 4200 ft^3 Residence 209 minutes
Neutralisation/aeration cell(each); Flow 75 gpm/cell x 2 cells	5' x 8' x 33' 1320 ft^3 Residence 132 minutes
Sludge settling basins(each); 50 gpm/cell x 3 cells	5' x 8' x 33' 1320 ft^3 Residence 197 minutes

In the event that the 2-stage neutralisation/sulphidation process is found to be unfeasible or excessively costly to operate, the Boulder Creek plant may be convertible to a neutralisation/aeration plant with copper removal via iron cementation. This alternative is shown on Figure 2. Brief discussions with CH_2M-Hill personnel, and the data presented in the CH_2M-Hill progress report dated May 6, 1983, indicates that the metallic hydroxide/calcium sulphate sludge from lime/limestone neutralisation settles freely and is essentially completely settled after 2 hours. The existing plant cells will provide settling times of this order.

<u>Recirculation of AMD to the mine workings.</u>

The consultant is examining the possibility of collecting AMD from the Richmond and Lawson portals, pumping it through a pipeline up the mountain, and reinjecting the water through a well into the mine workings.

A location for the well site is presently under review. The objective of this particular course of action will be to try to concentrate dissolved metals in the AMD to a point where electrowinning of economic amounts of copper are possible. Ultimately, there is the possibility that AMD discharge could be halted entirely. The consultants will be developing cost estimates for this process in the near future. Costs presented in this proposal are preliminary.

Interception of groundwater flows

The Brick Flat pit has been pumped out, yet there has been no decrease in the quantity of AMD flowing from the Richmond and Lawson portals. The decline in AMD discharge over the past several months seems to relate more to the fact that the weather is drier, and little rainfall has occurred. The Slickrock Creek discharge from the Old #8 portal continues unabated.

These observations may be an indication that most water inflow to the mine workings originates as groundwater, possibly from aquifers some distance from the mine site. If this is the case, it may be possible to intercept groundwater flows with wells and to pump them before they can reach the workings. The supposition that the water source may be groundwater is not in disagreement with observed AMD flows, since the regional water table will be elevated during the winter rainy season and would tend to discharge more water into the mine. Conversely, the dry summer weather will lower the water table, and the amount of water that can invade the workings will be less.

This is an aspect of AMD control that Ruskin would like to explore further with government, since the implications of massive pumping of groundwater are considerable. No costs have been developed for this possible course of action. Ruskin is prepared to discuss similar conditions as for the other actions.

COST PROPOSAL

Ruskin Developments proposes entering into an agreement with the appropriate government agencies to provide 50% of the funds required to undertake the work outlined in this proposal. It is proposed that the work would be undertaken by Pan Canadian Consultants Limited personnel, and invoices, progress reports, draft and final reports would be submitted by the consultant to the WQCB for approval. Invoices and progress statements would be submitted monthly. Following approval, payment would be divided equally between Ruskin and government. Total cost for the work would not exceed that given in this proposal without prior approval by both parties.

Ruskin is prepared to enter into a formal agreement to legalise the arrangement.

COST ESTIMATE

a) Pilot-plant work

Material and equipment purchase	$ 5,000
Equipment rental	$ 5,000
Professional fees (est. 120 MD)	$25,000
Travel, accommodation, misc. expenses	$ 4,000
Sub-total - pilot-plant work	$39,000

b) Plant-scale work

Plant alterations	$ 8,000
Equipment Purchase	$15,000
Equipment rentals	$10,000
Chemicals and consumable supplies	$ 1,500
Professional fees (est 180 MD)	$38,000
Travel, accommodation, misc. expenses	$ 5,000
Sub-total - Plant-scale work	$77,500

TOTAL ESTIMATED COST (a+b)	$116,500

Preliminary cost estimate - recirculate AMD to mine:

Pump purchase and installation	$12,000
Pipeline (est 2000' @ 2" O.D.)	$15,000
Well drilling/casing	$ 8,000
Valves and fittings	$ 5,000
Professional fees (est 20 MD)	$ 6,500
Expenses	$ 2,000
Estimated cost	$48,500

PROJECT SCHEDULE

The work proposed under cost items a) and b) will be performed as shown on the attached schedule. The recirculation of AMD into the mine would commence about two weeks after delivery of the equipment, and would continue for 2 months.

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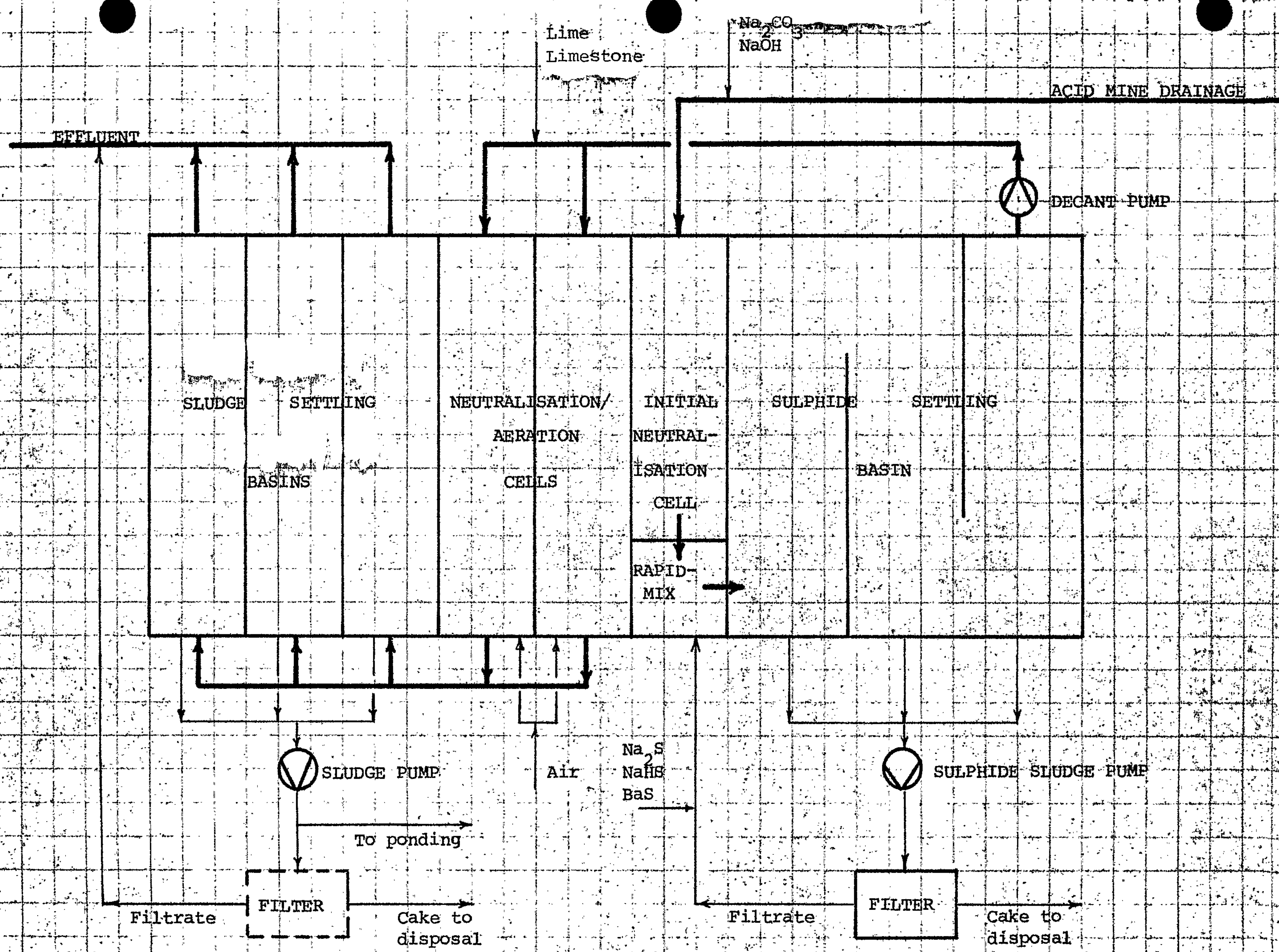
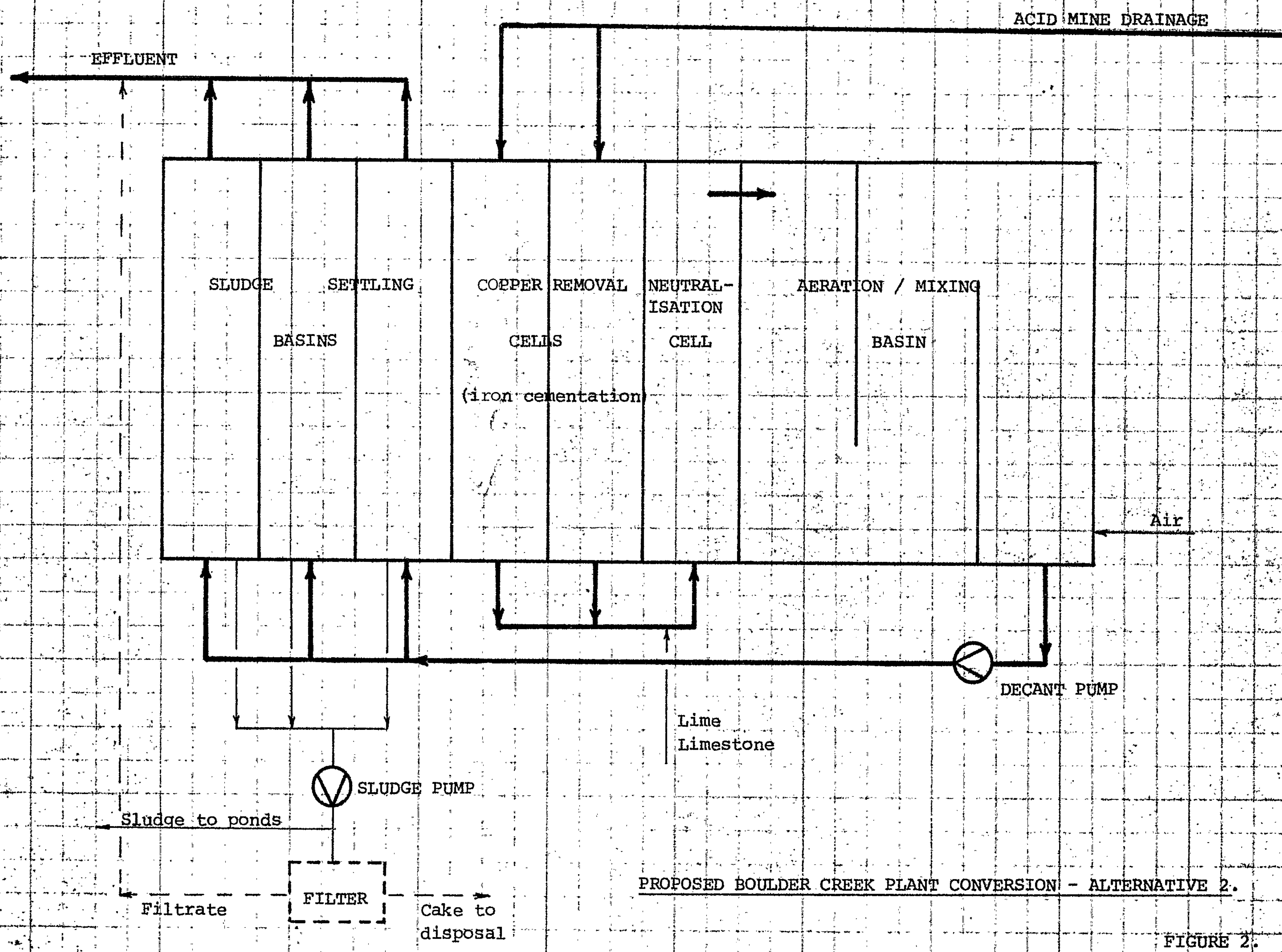


PROPOSED BOULDER CREEK PLANT CONVERSION - ALTERNATIVE 1

FIGURE 1

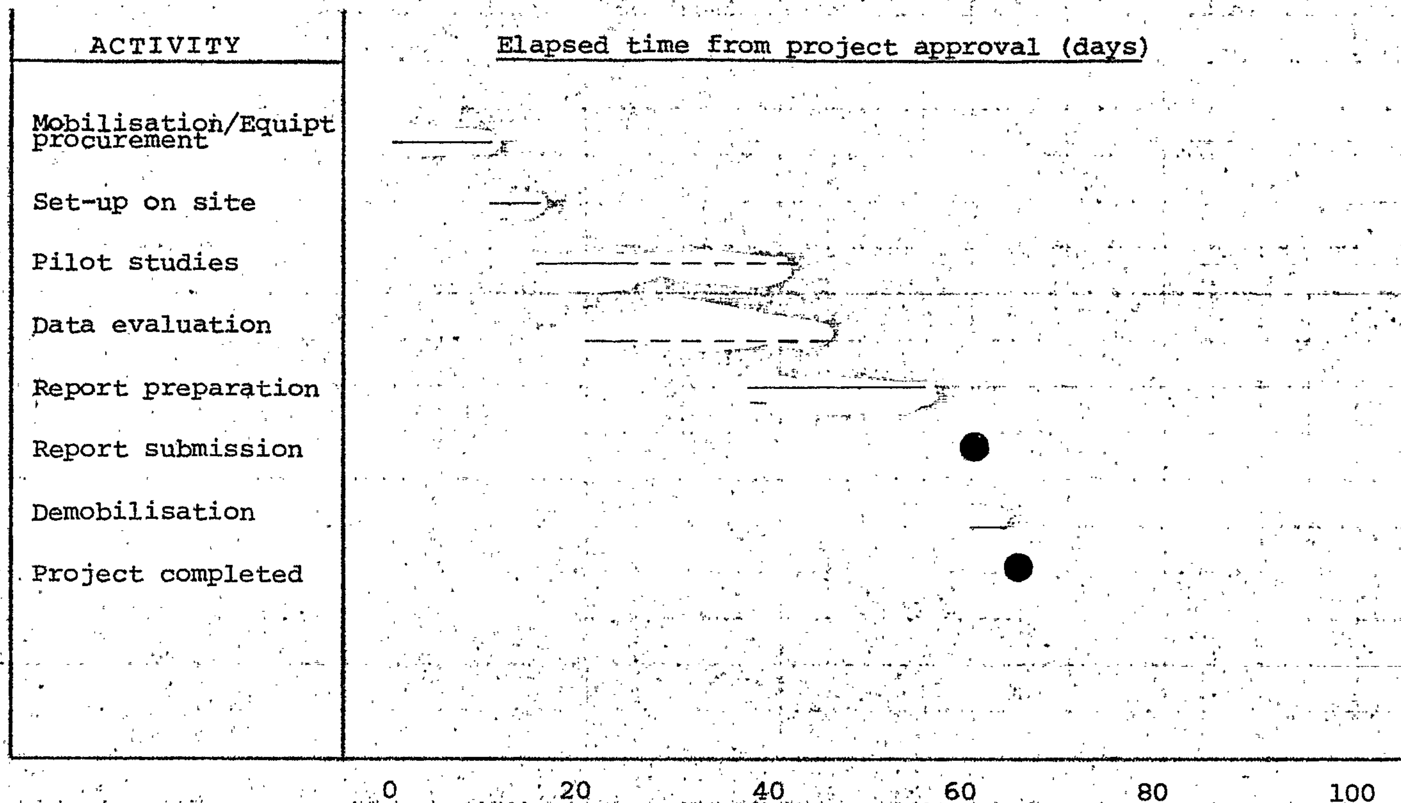


PROPOSED BOULDER CREEK PLANT CONVERSION - ALTERNATIVE 2.

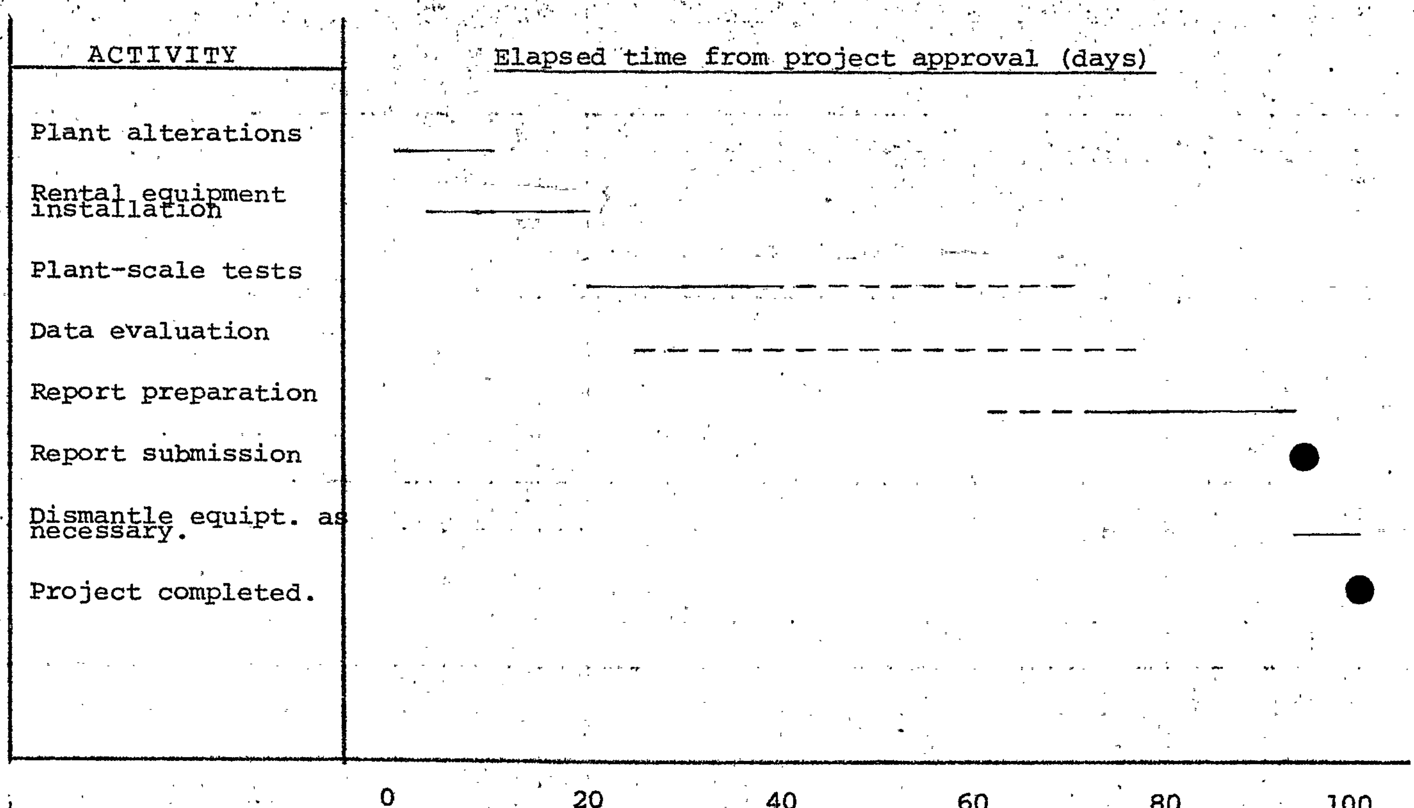
FIGURE 2.

PROJECT SCHEDULES

a) Pilot study



b) Plant study



APPENDIX 5

ANALYTICAL RESULTS (Chemex Labs)

a) Slickrock Creek Plant

	Water analysis	Assay equivalent
Ag	< 0.10 mg/l	< 0.00035 oz/ton
Au	< 0.01 mg/l	< 0.000035 oz/ton

b) Boulder Creek Plant

	Water analysis	Assay equivalent
Ag	0.10 mg/l	0.00035 oz/ton
Au	0.10 mg/l	0.00035 oz/ton

c) Copper concentrate assay

Cu	58.3 %	
Ag	28.1 g/ton	1.0 oz/ton
Au	0.2 g/ton	0.007 oz/ton
Pd	< 0.1 g/ton	< 0.0035 oz/ton

Copper sludge removed from Boulder Creek cementation plant.

Pan Canadian Consultants Limited

Suite 1040 – 999 West Hastings Street
Vancouver
British Columbia V6C 1M3
(604) 688-8618

Environmental and
engineering consultants
to industry
and government

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A REGION IX
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12 October 1983

United States Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, CA 94105
U.S.A.

Attn: Mr. Harry Seraydarian,
Director, Toxics & Waste Management Division.

Dear Sir,

We were requested recently by Mr. C. N. Thodos, President of Ruskin Developments Ltd., to provide you with copies of data we had collected during the project work we undertook for Ruskin on the Iron Mountain property. Some of the paperwork in our files is not relevant to your investigation, so we have sorted out the information that may be useful.

The enclosures are:

- our final report to Ruskin (which contains much earlier data in the appendices)

- copies of chemical analyses on acid mine drainage, and on treated water samples (after our tests).

We do not possess any other information that would be useful to your investigation. We understand that Ruskin will be asking their geological consultant to forward data relating to the geology of the area.

Please confirm that you have received this information.

Yours truly
PAN CANADIAN CONSULTANTS LIMITED

W. B. Alderton, P.Eng.,
President.

test ltd.
1523 WEST 3rd AVENUE, VANCOUVER, B.C. V6J 1J8 • TELEPHONE (604) 734-7276 • TELEX 04-54210

Report On Analysis of solution samples

File No. 1298F

Report No.

Reported To C. G. Environmental Engineering
5583 Spruce St.
Burnaby, B.C. V5G 1Y7

P.O. #

Date July 26, 1983

Attention: Dr. C. Guarnaschelli, P. Eng.

We have tested the samples submitted by you on July 18, 1983 and report as follows:

SAMPLE IDENTIFICATION:

The samples were submitted in plastic bottles labelled as given on the following Plasma Certificates.

METHOD OF TESTING:

Prior to analysis the samples were digested using an ultra pure nitric acid. The resulting solutions were then analyzed for metals using an Inductively Coupled Argon Plasma Spectrograph.

RESULTS OF TESTING:

See attached Plasma Certificate.

CAN TEST LTD.

Richard S. Jornitz
Supervisor
Trace Metals Laboratory

/cs

Form No. 7 L

can test ltd.

1523 WEST 3rd AVENUE, VANCOUVER, B.C. V6J 1J8 • TELEPHONE (604) 734-7276 • TELEX 04-54210

To: C. G. Environmental Engineering
5583 Spruce St.
Burnaby, B.C. V5G 1Y7

Attention: Dr. C. Guarnaschelli, P. Eng.

PLASMA SPECTROGRAPHIC ANALYSIS CERTIFICATE

File No. 1298F

Date July 26/83

We hereby Certify that the following are the results of plasma spectrographic analysis made on solution samples submitted.

Sample Identification		10/Supernatant 3.2	10/supernatant 3.9	1/supernatant 4.2	Compsite (As received)	ppt 3.9	
Neutralised with NaOH to pH →		3.2	3.9	4.2	Original Sample	Sludge from pH 3.9.	Detection Limit
Aluminum	Al	742.	556.	594.	763.	2030.	1.5
Antimony	Sb	L	L	L	L	L	1.5
Arsenic	As	L	L	L	L	L	3.0
Barium	Ba	0.10	0.067	0.027	0.020	0.36	0.01
Beryllium	Be	L	L	L	L	L	0.03
Bismuth	Bi	L	L	L	L	L	5.0
Boron	B	L	L	L	L	L	0.10
Cadmium	Cd	4.30	4.37	4.41	4.32	3.83	0.25
Calcium	Ca	132.	130.	131.	133.	117.	0.10
Chromium	Cr	L	L	L	L	L	0.30
Cobalt	Co	1.25	1.18	1.19	1.16	1.52	0.20
Copper	Cu	129.	119.	119.	133.	189.	0.15
Iron	Fe	4850.	4230.	4530.	5510.	11800.	0.30
Lead	Pb	0.89	0.71	1.00	1.25	4.00	0.80
Magnesium	Mg	413.	412.	421.	428.	382.	0.01
Manganese	Mn	12.6	12.6	12.8	12.9	11.1	0.03
Mercury	Hg	-	-	-	-	-	-
Molybdenum	Mo	L	L	L	L	L	0.40
Nickel	Ni	0.35	0.33	0.37	0.34	0.45	0.25
Phosphorus	PO_4	9.93	4.64	6.14	13.6	46.6	4.0
Potassium	K	60.1	60.5	60.1	49.3	57.8	0.1
Selenium	Se	-	-	-	-	-	-
Silicon	SiO_2	134.	112.	117.	126.	225.	0.8
Silver	Ag	L	L	L	L	L	0.3
Sodium	Na	2310.	3320.	3240.	53.4	2910.	1.0
Strontium	Sr	0.20	0.21	0.22	0.18	0.25	0.01
Tin	Sn	L	L	L	L	L	0.30
Titanium	Ti	0.13	0.11	0.11	0.88	4.57	0.06
Tungsten	W	-	-	-	-	-	-
Uranium	U	-	-	-	-	-	-
Vanadium	V	1.19	0.39	0.50	1.23	5.98	0.10
Zinc	Zn	606.	607.	626.	631.	561.	0.15

All results expressed in parts per million.
L = less than.

CAN TEST LTD.

Spectroscopist

Plasma 1

can test ltd.
1523 WEST 3rd AVENUE, VANCOUVER, B.C. V6J 1J8 • TELEPHONE (604) 734-7276 • TELEX 04-54210

Report On Analysis of solution samples

File No. 0987F

Report No.

Reported To C. G. Environmental Engineering
5583 Spruce St.
Burnaby, B.C. V5G 1Y7

P.O. #

Date June 20, 1983

Attention: Dr. C. Guarnaschelli, P. Eng.

We have tested the samples submitted by you on June 15, 1983 and report as follows:

SAMPLE IDENTIFICATION:

The samples were submitted in plastic bottles labelled as given on the following Plasma Certificates.

METHOD OF TESTING:

Prior to analysis the samples were digested using an ultra pure nitric acid. The resulting solutions were then analyzed for metals using an Inductively Coupled Argon Plasma Spectrograph.

RESULTS OF TESTING:

See attached Plasma Certificate.

CAN TEST LTD.

Richard S. Jornitz
Supervisor
Trace Metals Laboratory

/cs

Form No. 7 L

test ltd.

1523 WEST 3rd AVENUE, VANCOUVER, B.C. V6J 1J8 • TELEPHONE (604) 734-7276 • TELEX 04-54210

To:

C. G. Environmental Engineering

5583 Spruce St.

Burnaby, B.C. V5G 1Y7

Attention: Dr. C. Guarnaschelli, P. Eng.

PLASMA SPECTROGRAPHIC ANALYSIS CERTIFICATE

File No. 0987F

Date June 20/83

We hereby Certify that the following are the results of plasma spectrographic analysis made on solution samples submitted.

Sample Identification		Composite #1	Supernatant #1 pH 5.5	NaS Supernatant #2			
		Mixture of Bruller & Slidwode	Neutralised with NaOH	After Na_2S added.			Detection Limit
Aluminum	Al	674.	4.48	L			1.5
Antimony	Sb	L	L	L			1.5
Arsenic	As	13.0	L	L			3.0
Barium	Ba	L	0.013	0.36			0.01
Beryllium	Be	L	L	L			0.03
Bismuth	Bi	L	L	L			5.0
Boron	B	4.50	L	L			0.10
Cadmium	Cd	6.20	5.18	L			0.25
Calcium	Ca	119.	106.	57.4			0.10
Chromium	Cr	L	L	L			0.30
Cobalt	Co	L	L	L			0.20
Copper	Cu	154.	4.36	0.080			0.15
Iron	Fe	7260.	5180.	2120.			0.30
Lead	Pb	2.50	L	L			0.80
Magnesium	Mg	394.	346.	185.			0.01
Manganese	Mn	11.4	10.1	5.26			0.03
Mercury	Hg	-	-	-			-
Molybdenum	Mo	L	L	L			0.40
Nickel	Ni	0.29	L	L			0.25
Phosphorus	PO_4	15.3	8.74	L			4.0
Potassium	K	29.4	22.6	16.5			0.1
Selenium	Se	-	-	-			-
Silicon	SiO_2	129.	33.2	16.7			0.8
Silver	Ag	L	L	L			0.3
Sodium	Na	31.6	4140.	4400.			1.0
Strontium	Sr	0.13	0.19	0.10			0.01
Tin	Sn	L	L	L			0.30
Titanium	Ti	1.14	0.12	0.13			2.5
Tungsten	W	-	-	-			-
Uranium	U	-	-	-			-
Vanadium	V	1.02	L	L			0.10
Zinc	Zn	806.	598.	132.			0.15

All results expressed in parts per million.

L = less than.

Plasma 1

CAN-TEST LTD.

Spectroscopist

CH2M HILL
ENVIRONMENTAL LABORATORY
2218 RAILROAD AVENUE, P.O. BOX 2088
REDDING, CA 96001—TELEPHONE (916) 243-5831

Physical Chemical & Bacteriological Analysis

REF. NO. 9230
DATE 6/21/83

SPECIFIC ANALYSIS

REPORT TO RUSKIN DEVELOPMENTS
c/o Monterey Motel
525 Market St.
Redding, Ca. 96001

ATTN: Bill Alderton PHONE:

SAMPLE DESCRIPTION Iron Mountain Mine SAMPLED BY: client

DATE OF SAMPLE 6/14/83 DATE RECEIVED 6/14/83

TESTS	B in=Boulder Ck. Plant Influent	B 1ary out=Boulder Ck. Plant Primary cell eff.	B out=Boulder Ck. Plant effluent
pH (units)	1.20	1.33	1.33
Total Dissolved Solids	57720	59870	55320
Copper	166	13.6	5.17
Total Iron	11,300	13,100	13,200
Ferrous Iron	5160	6520	6670
Zinc	1050	1060	1050 ~~52.3~~
Ferric Iron (by calculation)	6140	6580	6530

COMMENTS: Results are in milligrams per liter unless otherwise noted.

All analyses by EPA or State of California recommended methods, unless otherwise noted

REPORTED BY: Brian Geller

State Approved Water Laboratory for Chemical, Bacteriological, and Bioassay Examinations

The information shown on this sheet is test data only and no analysis or interpretation is intended or implied.

Form 65

CH2M HILL
ENVIRONMENTAL LABORATORY
2218 RAILROAD AVENUE, P.O. BOX 2088
REDDING, CA 96001—TELEPHONE (916) 243-5831

Physical
Chemical &
Bacteriological
Analysis

REF. NO. 9230
DATE 6/21/83

SPECIFIC ANALYSIS

REPORT TO RUSKIN DEVELOPMENTS
c/o Monterey Motel
525 Market St.
Redding, Ca. 96001

ATTN: Bill Alderton PHONE:

SAMPLE DESCRIPTION Iron Mountain Mine SAMPLED BY: client

DATE OF SAMPLE 6/14/83 DATE RECEIVED 6/14/83

TESTS	S in=Slickrock Ck. plant influent	S out=Slickrock Ck. plant effluent
pH (units)	2.59	2.62
Total Dissolved Solids	10490	10130
Copper	122	122
Total Iron	1210	1230
Ferrous Iron	477	474
Zinc	49.1	50.0
Ferric Iron (by calculation)	733	756

COMMENTS: Results are in milligrams per liter unless otherwise noted.

All analyses by EPA or State of California recommended methods, unless otherwise noted

State Approved Water Laboratory for Chemical, Bacteriological, and Bioassay Examinations

REPORTED BY: Brian Geers

The information shown on this sheet is test data only and *no analysis or interpretation* is intended or implied.

Form 65