



TO
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Bud McAlpine

FROM
DE

Jack Nickel

SECURITY - CLASSIFICATION - DE SÉCURITÉ
OUR FILE/NOTRE RÉFÉRENCE
YOUR FILE/VOTRE RÉFÉRENCE
DATE 30 July 1981

007544

SUBJECT
OBJET

Cyprus Anvil Abandonment Plan

1. The main ^{BODY} lobby of the report (p.39) establishes a 3m minimum water depth over the tailings for plan 2. Appendix VII of the report states that a 5m depth was used for calculation (p.21) and refers to a predicted depth of 7 m (p.20). Was 5m or 7m used in the calculations? Why were these depths used for prediction when the design depth is 3m?
2. On P.25 of the main body waste rock seepage is identified as a source of contamination. No reference is made to the inclusion of waste rock contribution to the ionic equilibrium other than drawing 114. Will isolation eliminate waste rock leaching? How will high sulphide rock be separated in existing dumps? Where are the results of the ionic calculations? YES
3. Appendix VIII p.8 states that the synergistic effect of metals can lead to enhanced toxicity, particularly in the winter. Further, it states that an overwintering habitat other than the tailings area should be provided. This has not been included in the abandonment design. 105
4. Environmentally acceptable zinc concentrations (p.27 main body) are proposed using an application factor between 0.1 and 0.05 based on literature LC50 data for rainbow trout. This seems to be in conflict with the U.S. E.P.A.'s publication 'Water Quality Criteria, 1972' which recommends an application factor of 0.005 and further recommends that a 26 hour LC50 be determined using the receiving water in question and the species in the locality (grayling).
5. Page 49 states 'seepage through the tailing must be controlled to obtain acceptable water quality' for scheme 2. No cost has been estimated for placement of an impermeable cap. Is it assumed slimes will be properly deposited to reduce infiltration? Drawing 111 shows three areas of capped tailings sands. Why were these not costed? Will slimes be deposited on the old tailings which have been deposited without regard to distribution?
6. In the discussion of scheme 3(p.51) it is stated 'The effluent from scheme 3 tailings storage is expected to have a significant effect on the water quality of Rose Creek.' On p.22 of Appendix VII the author

588



MEMORANDUM

NOTE DE SERVICE

TO
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FROM
DE

SECURITY - CLASSIFICATION - DE SÉCURITÉ
OUR FILE/NOTRE RÉFÉRENCE
YOUR FILE/VOTRE RÉFÉRENCE
DATE

SUBJECT
OBJET

-2-

states 'Undoubtedly, this alternative (scheme 3) would be acceptable from environmental considerations.' What is meant by the first statement?

- 7. The hydrological model for chemical analysis shown in Drawing 114 has four calculation nodes. Only the pH and zinc values for surface waters at three nodes were reported. The inputs and outputs for all nodes should be presented.



Recopied -
confirmed 3:10 p.m.
August 19/81

Northern Affairs Program
200 Range Road,
Whitehorse, Y.T. Y1A 3V1
13 August 1981

Dr. Vinod Garga,
Klohn Leonoff Consulting Engineers,
10180 Shellbridge Way
Richmond, B. C. V6X 2W6

Your file Votre référence

Our file Notre référence

Re: Water Quality Modelling
Cyprus Anvil Abandonment Plan

Dear Dr. Garga:

I would like to clarify the request made under point #7 of Mr. Jack Nickel's July 30, 1981 memo given to you at the Water Board mining subcommittee meeting of July 31, 1981. Our interest is to be able to follow your calculation process. The theory developed in the report leaves many links unexplained. For example, do you assume ΣI^+ on p.12 of App. VII to be a certain value (background), then solve for a new H^+ , then recalculate ΣI^+ based on the resultant H^+ value, then recalculate H^+ , etc? What is the method of iterative solution for H^+ ? Given you calculate a value for ΣI^+ , is it assumed it is comprised of Fe, Zn and Pb solely? What is the distribution? Do the tailings leachate values (p. 16 of App. VII) confirm the solubility limit expressions presented on p. 12? Do the leachate values confirm the ionic equilibrium predicted values? These and other questions may be trivial and might best be answered by detailing a sample calculation as outlined in Figure VII-1. That, plus the noted initialization, input and output data should clarify your assumptions and process, as well as allow other data to be tested in the model.

The other point discussed at the meeting involved a plan for verification of the model. The details provided should be specific enough to allow construction of the pilot facility, selection of the site and include the monitoring program that accompanies it, including sampling frequency, analysis parameters, sampling techniques, site location and verification calculation process. You should also state the mechanism by which the model software will be available for use during the years required for verification.

Yours Truly,

W. G. Whitley
Controller of Water Rights

cc: Dr. Jeno Scharar,
Senes Consultants

cc: N. G. Cornish, C.A.M.C.



Curragh
Resources

117 Industrial Rd.
Whitehorse, Yukon Y1A 2T8
Tel: (403) 668-3578
Telex: 036 8359

January 19, 1987

Dr. A. Mac G. Robertson, P. Eng.
President
Steffen, Robertson and Kirsten
801 - 1030 West Georgia Street
Vancouver, B.C.
V6E 2Y3

Dear Andy;

It took me a little longer than expected to compile everyone's comments on report 60602. However, here they are.

Attached is a copy of Gary Webster's comments. I am in agreement with them and they should be incorporated. Note that he suggests that section 6 be deleted for the time being. This is not to say that further modeling will not be required, just that Curragh is not committed to carrying it out by itself. Whereas, if worse comes to worse, we may have to carry out the rest of the program without any outside assistance. Of course, without the assistance of governments, etc. the scale and schedule may be different. If you have any questions on Gary's comments I suggest you contact him directly.

Roy Bourke has reviewed the report and discussed it with Kurt Forgaard. He offered the following comments:

The report should make the point that a qualified project manager must be hired. Curragh would need assistance in locating such an individual.

The report should emphasize that a high degree of quality control, and the establishment and adherence to proper procedures are essential to obtaining meaningful results.

The Faro laboratory should be utilized as much as possible to ensure local involvement and minimize cost. Provision of lab services would be seen as part of Curragh's contribution to a cost shared arrangement.

The possible sources of funding sections of the report should be expanded as per Gary's comments. Universities such as Waterloo and U.B.C. could be of assistance including the provision of research personnel.

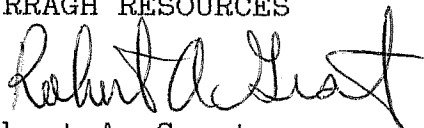
The report contains several typographical errors. These should be corrected in the final copy.

As I previously mentioned, a government briefing is set for February 17. It is hoped that we can distribute copies of this report prior to that meeting. If you have any questions on these points please do not hesitate to contact me.

I noted from a copy of a letter to Keith Ferguson that you sent him a copy of report 60602. As this report will be revised, could you ensure that no further copies are distributed and that Mr. Ferguson is informed that he has a first draft which has not been approved by Curragh and should not be circulated or copied.

Yours truly,

CURRAGH RESOURCES



Robert A. Grant

attachment

cc: Gary Webster
Roy Bourke



INTERNAL CORRESPONDENCE

To ..Robert..Grant...(Curragh..Whitehorse)..... Date1987..01..07.....
YEAR MONTH DAY

..... From ..Gary..Webster.....

..... Env. Engineering.....
DEPARTMENT AND LOCATION

..... File8..12..0.....

Re: Suggestions on SRK Tailings Abandonment Plan Development Program

I have the following suggestions for your considerations:

1. In Executive Summary after paragraph four (prior to "A program"), a paragraph should be added stating "To enhance usefulness of this program it is essential that regulatory agencies support the program and actively participate in quality assurance/quality control programs in the analytical testing."
2. Expand last paragraph of Executive Summary to include RATS program, support by U.B.C. (possibly use COOP students), Canadian Mining Association (if Curragh is a member), Yukon Chamber of Mines, DIAND Non-Renewable Resources, Environment Canada, Yukon Government, Federal Department of Manpower, Government of B.C. (Faro similar to prospect once owned by Cyprus Anvil in North Central B.C.), Government of Ontario, Government of Quebec, etc. etc.
3. Would a list of abbreviations used be helpful.
4. All drawings show Curragh Resources Corporation.
5. Page 7, line 12, remove first "the".

Page 8, second full paragraph last sentence replace "is" with "are", add a sentence "Curragh does not place much faith in the concept of modelling, but this study will provide better confidence in the rates of reaction should government wish to study modelling in more detail".

Page 9, section 1.4 paragraph 7 line 2, delete "will" replace with "can" (....program can be used...).

Page 10 b) delete "Vegetation will be planted on the cover" as this adds another factor into the equation.

Page 11, section 1.6.1 modify first paragraph to say "background and detectability limit value are so close".

Page 13, line 5 "will be undertaken", line 23 USCM/USDA (develop abbreviations table).

Page 14, section 1.7 Either here or in covering letter, clearly state that Curragh will use existing Scharer Model only, if new models come along that are better, then government may want to pay for work or tendering may be approved at that time (this is a bargaining posture that you may have to back away from eventually).

Focus section 1.7 on what program will do to clarify existing model.

Page 15 shouldn't surface water baseline investigation occur in year 2 so we have more than 1 or 1 1/2 years data?

Page 18 Figure 2.2 - Is this a new meteorological station? If so, can't we relocate one at gate house?

How do you plug back hole after Shelby sample is taken? (see also pg. 23 last paragraph section 2.3.4)

Page 20 line 20, hydraulicity? I'm not going to pick out all typos.

Page 21 section 2.2.3 delete last sentence.
section 2.3.1 clarify last sentence (once during a high and once during a low or twice each?)

Page 23 Paragraph 3 after 6 inches per time 3 times per year x 3 times. This gives a 36" "hole", how do you keep from collapsing or being a conduit?

Paragraph 4 how do you back fill to prevent contamination in a vertical hole?

Page 24 section 2.4.3 please clarify sentence 3.

Page 25 section 3.2.1 how and how often do you measure evaporation?

Page 27 Figure 3.1 SRK, 1986?

Page 28 Significant number of typos
-last paragraph of section a) Should the samples be allowed to freeze prior to analysis?

Page 29 add ICP, AAS & FES to abbreviations
- typos

-3-

Section 3.4.2 paragraph 4 please clarify what is meant by "in the field". It's not clear to me if "in the field" in point two is the same as in point three.

Page 30 third last line (ADD)?

Page 33 section 5.1 should emphasize desirability of government conducting surface water quality testing and performing AQ/AC function.

paragraph 3, point 1 background site has an access problem.

paragraph 3, point 2 why not use mill water supply.

Page 34 cyanide line one "preserved "not" present" metals - copper lead, zinc and manganese (extractable). The point made here could be strengthened to have government provide "exact" extraction procedure".

Page 37 delete section 6 leave this for negotiations.

Page 42 renumber to section 6 throughout.

Page 43 renumber to section 7 throughout.

Environment Canada Northern Technology Centre
Possibility of Alaska Dept. of Env. Conservation
U.S. E.P.A.
University of Alaska.

Page 48 number 6(a) check math.


GAN/pb

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers



STEFFEN, ROBERTSON AND KIRSTEN (B.C.) INC.
Suite 801, The Burrard Building
1030 West Georgia Street
Vancouver, B.C., Canada V6E 2Y3
Tel. (604) 681-4196 Telex 04-352578

March 2, 1987

Curragh Resources
117 Industria Road
Whitehorse, Yukon

Attention: Mr. Robert Grant

RECEIVED MAR 9 1987

Dear Sirs:

Re: FARO TAILINGS AND MINE ABANDONMENT PLAN PROGRAM

Herewith:

- (i) Notes I made during the Technical Session on February 17, 1987.
- (ii) Addendums A to D as follows:
 - A. Inclusion of Fisheries Investigations in the Faro Mine Tailings Abandonment Program
 - B. Inclusion of Abandonment Measures for the Open Pits, Waste Dumps, Roads and Reservoirs in Faro Mine Abandonment Plan
 - C. Inclusion of a Program to Investigate Period Available for Abandonment Plan Development
 - D. Inclusion for the Development of a Contingency Abandonment Plan Early in the APDP

The effect of including these additional programs in the APDP are summarized in the attached table.

I would welcome the opportunity of answering any questions you may have.

Yours truly,

STEFFEN ROBERTSON & KIRSTEN (B.C.) INC.

Dr. A. MacG. Robertson, P.Eng.
President

cc. Mr. Gary Webster, Dome Petroleum, Calgary

REVISED COST ESTIMATE FOR ABANDONMENT PLAN DEVELOPMENT PROGRAM

	Year 1	Year 2	Year 3	Year 4	Total
Previous Cost Estimate	425,000	164,000	164,000	319,000	1,072,000
A. Fisheries Program		5,500	20,500	10,000	36,000
B. Pits, Dump, Roads, Prog.			25,000	25,000	50,000
C. Period Available	49,000	38,000	(8,000)	(8,000)	71,000
D. Contingency APDP		36,000			36,000
	<u>474,000</u>	<u>243,500</u>	<u>201,500</u>	<u>346,000</u>	<u>1,265,000</u>

Project 60601 - CURRAGH RESOURCES TAILINGS ABANDONMENT PLAN

Notes by A. Robertson on Technical Session, February 17, 1987.

The following are the questions and answers as I recall them:

A. CONSERVATION SOCIETY

Q.A1 Curragh were late in submitting the report on the tailings abandonment plan study. How will Curragh ensure that the proposed Abandonment Plan Development Program (APDP) is completed on schedule?

Q.A2 The Conservation Society expressed concern about the management of the APDP.

R. by Roy Bourke to Q1 and Q2.

Curragh were a few months late in completing the study because of the coordination required with the various agencies in setting the workscope for the study. This was further delayed when SRK came up with the recommendation for the APDP to allow SRK to develop the proposed APDP.

Curragh recognizes the need for good management with a competent technical person in charge. To this end Curragh will seek a full time project manager - Ph.D candidate in groundwater contaminant migration, or equivalent, in a full time or at least substantial part time capacity.

B. DIAND

Q.B1 Clarity was sought as to whether Curragh considered the APDP to be the "Abandonment Plan" as required by the Yukon Water Board.

R. by Roy Bourke:

Curragh did not consider the APDP to be the "Abandonment Plan" but a program to develop the "Abandonment Plan".

Q.B2 Concern was expressed that the statement on page 8 of Report 60602 - "Curragh does not place much faith in the concept of modelling, but this study will provide better confidence in rates of reaction, should government wish to study modelling in more detail." Did this indicate that Curragh would not accept modelling results when they were finally undertaken towards the end of the APDP?

R. by R. Bourke:

Curragh wished to convey that they did not place much faith in modelling using the currently available data and therefore in the results of any modelling which could be completed at this time. The APDP was aimed specifically at obtaining more accurate data which would enable more realistic and meaningful modelling to be undertaken in the last year of the APDP. Nevertheless, modelling inherently suffers from considerable limitations and must be applied with due caution.

Q.B3 How would the comments and contributions made at this meeting (Technical Session) change Curragh's position and how will this be communicated to the other attendees at the meeting?

R. by Robert Grant.

Curragh would circulate notes on the questions and answers to all attendees prior to the Yukon Water Board Hearing on the 11th March 1987.

Q.B4 Has Curragh considered or prepared any instruments for the provision of long term funding of reclamation at Faro?

R. by R. Grant:

Curragh have previously communicated their willingness to set aside 25c for every ton of concentrate shipped, in a fund for reclamation of the Faro property. It is anticipated that this provisional fund would be drawn against for the funding of the APDP. This set aside has not been formalized and no additional instruments have been considered.

C. ENVIRONMENT CANADA

Q.C1 Concern was expressed about what reclamation work could be implemented technically and within the fiscal limits of Curragh's resources if Curragh were to shut down prematurely. Could alternative D be implemented?

R. by A. Robertson:

Technically, all the alternatives were implementable. The effectiveness of the various alternatives in achieving the desired environmental protection, without maintenance and in the long term was in doubt until the APDP was completed. Since Curragh reopened the Faro operations with substantial loan funds, the fiscal ability of the company to implement abandonment measures, if it were to shut down tomorrow, would be limited. These limits are expected to reduce as Curragh generates capital reserves as a result of successful resource recovery.

Q.C2 Why have the mine pits and waste dumps not been considered in the study or APDP?

R. by A. Robertson:

An evaluation of the pits, waste dumps, roads and reservoirs were not included in the study scope covered in reports 60601 and 60602. It is recognized that they must be included for in the final Abandonment Plan and provision will be made for this in an amended APDP which will be circulated with the notes on this meeting.

Q.C3 Concern was expressed regarding the short time frame of the test plots (4 years). Was this sufficient?

R. by A. Robertson

The time frame for the APDP was determined by the shortest period during which sufficient data could be gathered to develop a realistic APDP. Three years of trial plot monitoring was considered to be this minimum. Monitoring of the test plots could continue beyond this period, and probably would, but this was beyond the Phase 1 program which is described in Report 60602.

Q.C4 Concern was expressed regarding the long period (4 years) which would lapse while the APDP was completed. During this period chemical oxidation of the tailings would continue. Would this continued chemical oxidation, and the consequential contaminant plume, advance to a stage that unacceptable impacts on Rose Creek were inevitable? How soon could Curragh determine the extent and rate of acid product migration?

R. by A. Robertson:

Insufficient data exists on the extent of contaminant plume development to estimate the extent of plume development and the consequential impact of Rose Creek as a result of 4 more years of tailings surface oxidation. Current groundwater monitoring, while very sparse, does not indicate substantial contamination as a result of acid drainage. The determination of the extent of acid product migration, and an estimate of the effects of the next few years of oxidation on the environment, would require an acceleration of the tailings and groundwater baseline investigation and an additional modelling effort. This baseline work would be rescheduled to year one of the APDP and an additional provision made for the cost of the additional modelling. The proposed revisions to the program would be circulated with the notes on this meeting.

Q.C5 What were the fiscal limits of Curragh with regard to implementation of an Abandonment Plan?

R. by R. Bourke: Curragh have made provision in their financial planning for the 25 cents per ton of concentrate set aside for reclamation. Fiscal capability and commitment beyond this have not been considered.

Q.C6 Question 4 above was repeated with the added question as to what contingency measures could be considered? Should cover placement be started immediately?

R. by A. Robertson:

While the placement of covers (other than water) could be started immediately, it is not known which if any, cover types would be sufficient or effective. Placement of an inappropriate cover would represent the expenditure of financial resources which would then not be available for implementing the appropriate cover once this has been determined in the APDP. Other contingency measures, such as the implementation of interceptor wells and pumpback, or the flushing of lime solutions onto the surface of the tailings, may be more cost effective.

Q.C7 Environment Canada indicated that they had little or no funds for support of the APDP. Other sources of funds such as DRIE were suggested.

D. DEPARTMENT OF FISHERIES AND OCEANS

Q.D1 Abandonment Plan should include waste dumps, pits, roads and reservoirs.

R. by R. Bourke, see reply to Q.B2.

Q.D2 What studies have been done to ensure fish protection, and what is proposed in the APDP to determine appropriate levels of contaminant containment?

R. by Robert Grant:

Potential long term impacts were not included in the workscope for the studies reported in 60601 and 60602. It is recognized by Curragh that a study on the impact of fisheries of contaminant migration and the effects of the alternative abandonment schemes would be appropriate prior to setting Abandonment Plan impact criteria. Curragh proposes to expand the APDP in its 4th year to include appropriate fisheries studies to enable appropriate objectives and criteria to be established. A description of the proposed program expansion will be circulated with the meeting notes.

Q.D3 What are Curragh's plans to develop fiscal capability to implement Abandonment Plan measures?

R. by R. Bourke:

Refer reply to question Q.C5.

E. DEPARTMENT OF RENEWABLE RESOURCES

Q.E1 Why only 4 years of test plot study?

R. by A. Robertson:

See reply to Question C3.

Q.E2 Curragh states that many of the options for tailings containment that may be applicable to a new project are not applicable at Faro. What are they?

R. by A. Robertson:

Because containment structures and their location at Faro are a fait accompli, many options available to a new project are not applicable, such as site selection to avoid Rose Creek erosion; obtain better foundation conditions for seepage control; construct less permeable and more stable containment embankments; and provide for easy economical flooding.

Q.E3 Will Abandonment Plans be provided for other mine development such as the pits, dumps, roads and reservoirs?

R. by R. Bourke:

See reply to Question C2.

F. MR. MILOS STEPANEK

Q.F1 What changes in tailings containment technology can be anticipated in the next 10 to 20 years? Can a plan not be developed on current technology?

R. by A. Robertson:

The effectiveness of soil covers, particularly special covers such as covers with saturated or frozen zones incorporated, are very poorly understood. Thus the only secure current technology to prevent acid generation is water cover. At Faro, water cover has been demonstrated to have a number of potentially adverse impacts. There is therefore not an obvious secure economic solution to acid generation control based on current technology. A considerable amount of research is proposed by industry and regulatory authorities alike on acid generation in the next few years, as demonstrated by the RATS program amongst others. This research should add considerably to the technology in the understanding of the effectiveness of alternative covers and in acid generation and contaminant migration modelling.

Q.F2 Was the long term stability of the existing embankment structures considered?

R. by A. Robertson:

The stability of the existing embankment structures were not evaluated to any significant depth by SRK. Detailed stability evaluations will be undertaken for the structures that will remain as part of the Abandonment Plan developed by the APDP.

ADDENDUM A: INCLUSION OF FISHERIES INVESTIGATIONS IN THE FARO MINE TAILINGS ABANDONMENT PROGRAM

The APDP requires a more complete assessment of the impact of water quality and the stabilization measures on fisheries resources in Rose Creek than was provided for in Report 60602. A fisheries program is proposed which is intended to examine both the potential impacts of the Abandonment Plan on Fisheries Resources and to establish appropriate levels of contaminant concentration and load release limits. The proposed program will be undertaken in the second, third and fourth year of the abandonment program. The following outlines the fisheries component of the program to be undertaken.

REVIEW OF EXISTING INFORMATION

All relevant fisheries information pertaining to the study area drainage will be compiled and assessed prior to October 1988. Information will be gathered from government and private sources in sufficient detail to ensure that the existing fisheries resources are characterized to the extent of present knowledge of the area and so that programs can be altered if necessary. Study area drainages will include Rose and Anvil creeks and the Pelly River near the mine area. A letter report will be submitted on the findings. Initial indications are that salmon do not utilize Rose Creek, and no angling or food fishery occurs in the drainage.

This aspect of the study may require meetings with government agencies in Whitehorse and Vancouver.

ON-SITE FISHERIES INVESTIGATIONS

Two site visits would be conducted, one in the spring and the other in the summer of 1989. Fisheries studies would concentrate on assessing the fisheries values in the project area. Fish population characteristics (i.e., length, weight, age, growth, species) will be determined by fish sampling. In addition, detailed habitat assessments will be conducted which will include population estimates (fish densities) in various habitat types upstream and downstream of the tailings area. Study area streams will be evaluated for their spawning, rearing and overwintering capabilities, and areas found to support spawning and rearing will be identified. An evaluation will be made of the impact on fisheries resources of different levels of contaminant concentration and loading releases. This will be based on available data in the literature and a limited number of bio-assay, mortality tests.

During the on-site fisheries investigations it would be advisable to assess fish habitat in other areas outside the specific study area. These areas would be chosen for potential stream enhancement work should compensation be identified as desirable in the abandonment plan. Fish population and habitat studies would be conducted in areas with the most cost effective potential for enhancement. Present fish utilization will be determined to establish whether the selected areas are underutilized and, therefore, suitable for enhancement procedures. Enhancement concepts would also be developed for potential stream sites.

DATA EVALUATION

A final report will be prepared by March 1990. An evaluation of the fisheries information collected during 1989 will be presented. In addition, an evaluation of the effect of predicted contaminant loading from the abandoned tailings area will be developed and presented. An assessment will be made of contaminant loadings on fisheries resources with a view to making recommendations as to appropriate criteria for contaminant release concentrations and loadings.

STUDY COST ESTIMATE

An estimate of the costs for the fish studies are summarized on Table A1.

TABLE A1

Review and Assessment of Existing Information (1988)	\$ 5,500
On-Site Fisheries Investigations (1989/90)	
a) Population and Habitat Studies	\$10,000
b) Assessment of Potential Enhancement Sites	\$ 3,500
Evaluation of appropriate contaminant release limits	\$10,000
Reporting/Data Evaluation	<u>\$ 7,000</u>
Total	<u>\$36,000</u>

ADDENDUM B: INCLUSION OF ABANDONMENT MEASURES FOR THE OPEN PITS,
WASTE DUMPS, ROADS AND RESERVOIRS IN FARO MINE ABANDONMENT PLAN

It is recognized that a comprehensive Abandonment Plan must provide for the appropriate decommissioning of the Faro open pits, waste dumps, roads and reservoirs. Since the APDP described in Report 60602 provides only for the preparation of abandonment measures for the tailings impoundment, this addendum is added to include for the preparation of abandonment plans for these additional mine facilities.

The requirements of an abandonment plan for the pits, dumps and roads will depend on when mining and milling is discontinued. At least two ore bodies, in addition to the Faro deposit are under investigation and planning. The nature and extent of their development will depend on future economic conditions, detailed ore and mineralogical constraints and regulatory requirements, the exact nature of which cannot be determined at this time.

Provision is made for the development of general abandonment measures for the pits, waste dumps, roads and reservoirs, within the context of the proposed mine development, during year 4 of the APDP (1990). The generalized Abandonment Plan will provide for:

- (i) Staged reclamation such that facilities are reclaimed once their useful purpose has been served and they are no longer needed. Thus the Faro pits, waste dumps and roads will be reclaimed once the Faro pit is mined out.
- (ii) Waste dumps:
 - (a) The long term acid generating potential of the various waste dumps will be assessed, based on the source and acid generating potential of the waste contained in them as well as the quality of drainage issuing from them. It is anticipated that non-acid generating conditions will be demonstrated. Should acid generating conditions be encountered then alternatives will be evaluated to establish the most appropriate control measures.
 - (b) The waste dumps will be contoured to suitable slopes and shapes to provide long term stability against erosion, earthquake forces, and weathering.
 - (c) Drainage around and through the dump will be evaluated and provision made for the canalization or diversion of flows, where appropriate, to prevent undesirable long term erosion or leaching.
 - (d) Topsoil placement, seeding preparation and seeding programs will be proposed where this is considered appropriate.
- (iii) Pits:
 - (a) The effects of long term acid generation and leaching on the quality of waters from the pits will be assessed based on an estimate of the flooded depth of the pits and the quality of the seepage from above the flooded levels. It is anticipated that adequate water quality conditions will be demonstrated. Should unacceptable water quality conditions be indicated then alternatives will be evaluated to establish the most appropriate control measures.
 - (b) It is not intended that any rock slope stabilization measures will be undertaken in the abandoned pits.

(c) Drainage around and from the pits will be evaluated and provision made for the canalization or diversion of flows, where appropriate to prevent undesirable long term erosion.

(iv) Roads:

Methods for the abandonment preparation of the roads will be described. This may include such items as removal of culverts and other structures which may block drainages or creeks, flattening slopes and scarifying and seeding road surfaces to encourage the re-establishment of vegetation.

(v) Reservoirs:

Plans for the abandonment preparation of reservoirs will be prepared. This may include methods for the safe breaching of dams and embankments, re-establishment of the drainage channel through the reservoir, and seeding of the reservoir basin.

An estimate of the costs for the development of these generalized abandonment plans have been made and are summarized in Table B1.

TABLE B1

(i)	Waste Dumps		
	Field work and laboratory testing	\$17,000	
	Data evaluation and plans preparation	<u>\$ 8,000</u>	
			<u>\$25,000</u>
(ii)	Pits		
	Field work and laboratory testing	\$ 7,000	
	Data evaluation and plans preparation	<u>\$ 6,000</u>	
			<u>\$13,000</u>
(iii)	Roads		\$ 6,000
(iv)	Reservoirs		<u>\$ 6,000</u>
			<u>\$50,000</u>

ADDENDUM C: INCLUSION OF A PROGRAM TO INVESTIGATE PERIOD AVAILABLE
FOR ABANDONMENT PLAN DEVELOPMENT

The surface of the tailings in the Original and Second Tailings Impoundments have been exposed to the atmosphere for periods ranging from approximately 4 years to in excess of 10 years. The investigation reported in Report 60601 indicated that the neutralization front (of acid generated products) has penetrated to a depth of about 2 m after a period of 4 years; a penetration rate of about 0.5 m per year in the tailings. At the edges of the tailings impoundment, this neutralization front will have encountered the foundation soils. The physical transportation and chemical buffering conditions effecting the progression of the neutralization front in the foundation soils will be effected by parameters which differ substantially from those effective in the tailings. Thus, the rate of contaminant migration, within the foundation soils, is not known.

Concern has been expressed regarding the volume of acid generation products that have been produced, and will be produced during the period of the APDP, and what the short and long term impacts of these products will be on Rose Creek. It was requested that consideration be given to an early determination of the quantity of acid products generation and the rate of migration of these, from the edges of the tailings impoundment towards Rose Creek. In particular, it was considered necessary to determine whether a 4 year delay in implementing an emergency cover placement would have a material short or long term impact on the quality of seepage to Rose Creek.

A program is proposed, starting in Year 1 of the APDP to determine the quantity of acid product generation and its rate of migration towards Rose Creek to a level sufficient to establish if a 4 year delay in the implementation of a cover placement will have an unacceptable impact on Rose Creek.

A program is proposed in two phases:

Phase 1 - Investigation at Impoundment Edges (Summer of 1987)

During Phase 1 a number of test pits will be dug with a large backhoe along the outer edges (northern edge) of the tailings impoundment to investigate:

- (i) the quantity and rate of acid product generation, and
- (ii) the penetration of the neutralization front into the foundation soils.

This test pitting program will also allow sampling of oxidized and unoxidized tailings and foundation soils.

Samples of tailings water will be obtained by sampling from piezometers in the tailings and from the fresh tailings discharge. Groundwater samples will be collected from the existing groundwater monitoring wells.

The samples of tailings and foundation soils underlying the tailings will be analyzed, chemically, to establish the depth of penetration and migration of the neutralization front. If the neutralization front has not penetrated far into the foundation soils (as is anticipated) then Phase 2 of the investigation program may not be required.

A laboratory test program will be undertaken to determine the buffering capacity of the tailings and foundation soils solids, and interstitial water. This will include both batch and column leach tests.

Using the results of this sampling and testing program the rate of acid generation product production will be estimated and simple one dimensional equilibrium contaminant transport modelling performed to evaluate the rate of neutralization front migration.

Should the neutralization front migration rate be found to be very slow (relative to 4 years) in the foundation soils then Phase II of the investigation may not be required. Should it be significant then Phase 2 will be carried out during the winter of 1987/88 when access can be gained into the tailings impoundment.

Phase II - Investigation of Central Portion of Impoundment (Winter 87/88)

Phase II is designed to:

- (i) drill and sample tailings and foundation soils under deeper portions of the tailings impoundment (3 boreholes are provided for)
- (ii) extend the evaluation of modelling of the contaminant plume development and prediction of impact on Rose Creek.

Essentially, Phase 2 will extend the data base for impact assessment into zones covered with deeper deposits of tailings and closer to Rose Creek. In particular, it will investigate the depth of neutralization front development in those areas of the tailings impoundment where the tailings surface has been exposed for 10 years or more (western portion of Original Tailings Impoundment).

The modelling will be extended to include the larger data base but will remain essentially simplistic.

An estimate of the costs for both phases of the program have been developed and are summarized in Table C1. Of this amount, only about \$16,000 would be of direct relevance to the previously proposed APDP resulting in a cost increase of approximately \$71,000.

TABLE C1

Phase 1 (Summer 87)

Field work	\$12,000	
Chemical Testing	\$15,000	
Attenuation Testing	\$ 6,000	
Simple modelling	\$ 8,000	
Analysis and report preparation	<u>\$ 8,000</u>	
		<u>\$49,000</u>

Phase 2 (Winter 87/88)

Field work	\$14,000	
Chemical Testing	\$ 8,000	
Simple Modelling	\$ 8,000	
Analysis and report preparation	<u>\$ 8,000</u>	
		<u>\$38,000</u>
		<u>\$87,000</u>

ADDENDUM D: INCLUSION FOR THE DEVELOPMENT OF A CONTINGENCY
ABANDONMENT PLAN EARLY IN THE APDP

It has been requested that Curragh develop, early in the program, a contingency abandonment plan that can be implemented in the case of early mine shut down.

Should the mine be shut down within the next few years its fiscal capabilities would limit its ability to implement abandonment measures to aspects of Alternative D as described in Report 60601.

Reference is made to Table 8.8 on page 143 of Report 60601. Should early shut down occur it will not be necessary to raise Intermediate Dam, saving \$8.84 (items 7 and 8) of the indicated abandonment cost. The cost of installing a concrete spillway (item 12) would be considerably reduced by the reduced elevation of the Dam. Indeed the cost of a spillway could be eliminated if Rose Creek is maintained in its present channel. Thus the cost of implementing Alternative D within the next few years would involve a capital cost expenditure of about \$3 million.

Should the measures proposed for Alternative D prove to be inadequate, it will become necessary to install groundwater interceptor wells and a chemical treatment facility. The cost of the groundwater interceptor and pump system will be small by comparison with a water treatment and sludge disposal facility.

Thus, the implementation of interceptor wells and a pumpback system is a cost effective viable alternative during the period of mine operations. During this period an effective water treatment plant is in operation in the tailings pond, as a consequence of the lime neutralization available in the tailings water and the large settling facility in Cross Valley Dam.

After mill closure, the groundwater treatment must be provided by lime addition and mixing, and the same or alternative settling pond facilities must be maintained. The cost of treatment plant construction as well as the cost of operation of the interceptor wells, treatment plant and settling ponds would be high.

Allowance had not been made in the APDP for the investigation of groundwater treatability or for the capital and operating costs of a groundwater interceptor system, water treatment plant and settling pond.

The cost of developing a contingency Abandonment Plan early in 1988 has been estimated as summarized in Table D1.

TABLE D1

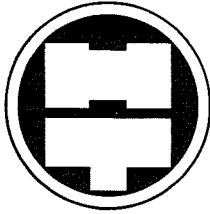
Pumpback System

(i) Conceptual well system evaluation and design	\$ 3,000
(ii) Conceptual pumpback system design	\$ 3,000

Water Treatment System

(i) Treatability evaluations	\$10,000
(ii) Conceptual plant design	\$ 5,000

Development of Contingency Abandonment Plan based on Alternative D	<u>\$15,000</u>
TOTAL	<u>\$36,000</u>



Hardy BBT Limited

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

322401

March 31, 1987

Mr. Robert Grant
117 Industrial Road
Whitehorse, Yukon Territories
Y1A 2T8

Dear Mr. Grant:

RE: MINE ABANDONMENT PLANNING

Pursuant to our recent conversation, I have enclosed several brochures outlining Hardy BBT's capabilities and services in the area of Environmental Sciences and Engineering.

As you are interested in mine abandonment planning, I have also briefly outlined our capabilities in this area.

Hardy BBT is a multidisciplinary company with a full range of capabilities for mine reclamation and abandonment planning. In the area of environmental sciences these include expertise in:

- soil and vegetation inventory,
- overburden characterization,
- soil reconstruction techniques and development processes,
- revegetation strategies,
- soil-plant relationships,
- environmental chemistry (soil, water, air),
- design of field and laboratory studies, and
- design and implementation of monitoring programs to track reclamation success and/or environmental impacts.

Within the engineering disciplines, we have expertise in geotechnical engineering, rock mechanics, geological engineering and hydrogeology.

The Environmental Division consists of ten senior specialists in soil and plant science and analytical chemistry, many of which have worked together for over ten years. Together with our engineering staff we bring many years of varied experience to a job. In terms of a mine abandonment plan, this could translate into:



- Identifying overburden strata most suitable for capping materials, strata which should be buried at depth for environmental protection or a mixture of overburden strata to neutralize acid generating potential.
- Liason with on-site mining engineers to develop a materials handling plan to achieve optimum placement of materials to ensure stability and to enhance reclamation.
- The innovative use of on-site materials for soil reconstruction, i.e. salvaged surface soil complemented with selected overburden strata, the substitution of surface soil with suitable overburden strata or the use of organic materials (trees, muskeg) to condition soil constructed of overburden.
- The design of tailings impoundment structures, the use of capping and/or chemical treatments to cope with acid generation in mine tailings.
- An assessment of regional and local groundwater conditions, the potential effect of mine operations on water quality and recommendations for safe operation.
- A site-specific revegetation plan which is suited to the needs of the site (surface stabilization, aesthetic value) and the climate of the area and which strikes a balance between initial inputs and ongoing maintenance.

Hardy BBT have been involved in various aspects of mine planning and mine reclamation in the Yukon, N.W.T and the western provinces over the past ten years. An annotated list of work experience related to environmental aspects of mining planning and abandonment in the north is appended to this letter. A summary of related engineering experience can be found in the accompanying booklet entitled "Geotechnical Engineering Services for Mining and Transportation Projects".

We believe that Hardy BBT have a seasoned team of well-qualified professionals to service mining projects of any size and complexity. We would welcome the opportunity to discuss the



capabilities of our company with you, particularly as they relate to your needs. For further information contact the undersigned or Brian Dowse, Manager of the Geotechnical Division.

Yours truly,

HARDY BBT LIMITED

Per:

Harvey E. Martens, M.Sc., P.Ag.
Senior Plant Ecologist
Reclamation Planning and Research
Environmental Division

HEM: sak/6.79
Attachment



ENVIRONMENTAL DIVISION EXPERIENCE RELATED TO
PREPARATION OF ABANDONMENT PLANS FOR NORTHERN MINES

<u>Client</u>		<u>Description</u>
Department of Indian Affairs and Northern Development Canada (DIAND)	1987	Development of a reclamation manual for northern Canada.
	1984	Evaluation of selected reclamation studies at 75 sites in Yukon and NWT in preparation for reclamation manual.
Pine Point Mines Ltd.	1985	Abandonment Plan for existing and future rock waste dumps utilizing minimal soil materials and native rock.
Elsa Mines Ltd., Yukon	1985	Conceptual abandonment plan for tailings ponds.
Noranda Mines	1982	Develop reclamation plan for tailings pond and rock waste piles for heavy metal mine on Admiralty Island, Alaska.
Interprovincial Pipe Line (NW) Ltd.	1979-80	Develop revegetation specifications for the Norman Wells Pipeline.
	1985	Norman Wells Pipeline shrub cuttings trial.
	1984-85	Winter revegetation supervision; summer helicopter remedial revegetation.
	1984-87	Revegetation monitoring, Norman Wells Pipeline.
Energy Mines and Resources	1975-76	Inventory and assessment of coal mine spoils along the Eastern Slopes regions of Alberta to develop reclamation guidelines for the Pit Slope Manual.

ENVIRONMENTAL DIVISION RELATED EXPERIENCE, (Continued)

<u>Client</u>		<u>Description</u>
Various		Sulphur Studies.
- Shell Canada Resources Ltd.		Integrated environmental
- Alberta Environment		monitoring program (soil,
- Chevron Standard Ltd.		vegetation, groundwater and
- Esso Resources Canada		surface water quality) design
		of remedial measures including
		liming.
Department of Public Works	1979	Assessment of natural reveget-
Shakwak Highway Project		ation potential along the route
		and preparation of reclamation
		guidelines and a reclamation
		design manual for the Shakwak
		Highway, Y.T.
		Preparation of conceptual
		reclamation plan for Canadian
		segment of Shakwak Highway.
Foothills Pipe Line	1981	Determine the feasibility of
(Yukon) Ltd.		natural revegetation as a
		reclamation technique by field
		studies along the Dempster
		lateral.
Department of Indian and	1980	Assess fish and wildlife habitat
Northern Affairs		of abandoned Placer Mine
		operations and develop reclama-
		tion guidelines, Y.T.
Yukon Territory Water Board	1977	Development of stabilization
		reclamation guidelines for
		asbestos tailings near Clinton
		Creek, Y.T.
	1978	Development of stabilization and
		reclamation guidelines for
		Placer Mine operations near
		Dawson, Y.T.

ENVIRONMENTAL DIVISION RELATED EXPERIENCE, (Continued)

<u>Client</u>		<u>Description</u>
Denison Mines Ltd.	1981	Soil, overburden and vegetation survey and development of conceptual reclamation plan for Quintette property.
Canadian Arctic Gas	1972-77	Test species and seed mixes in lab and field; test various erosion control procedures; test tundra stripping and replacement procedures; study impacts of snow road construction and use, and methanol pressure testing fluids on native vegetation; monitor studies and prepare reclamation plans.
Chevron Ltd.	1976	Assessment of impacts on native vegetation from the use of sulphur foam insulation in Dempster Highway road construction.
Gulf Canada Resources Ltd. Well Site and Access Road Reclamation Study	1978-79	Development and implementation of reclamation procedures for over 30 abandoned well sites and several access roads.
Town of Inuvik	1975	Establish test plots and prepare recommendations for revegetation of the town gravel pit.

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers



STEFFEN, ROBERTSON AND KIRSTEN (B.C.) INC.
Suite 801, The Burrard Building
1030 West Georgia Street
Vancouver, B.C., Canada V6E 2Y3
Tel. (604) 681-4196 Telex 04-352578

May 25, 1987

Vice President Engineering
Curragh Resources
117 Industrial Road
Whitehorse, Yukon
Y1A 2T8

Attention Mr. Marve Pelly

Dear Sirs:

RE: FARO PIT AND AREA - INTERIM CLOSURE PLAN

This letter serves as a proposal for the development of:

- an abandonment scheme for Faro pit and area and
- conceptual plans to stabilize the physical aspects of the Rose Creek diversion ditch and the tailings in the event of an interim closure.

These plans are intended to satisfy the requirements of Curragh Resource's commitment at the Yukon Water Board Hearing March 25, 1987. It is intended that the plans will satisfy the 'Short Term Abandonment Plan Criteria' as recommended by Dr. C.O. Brawner in his letter to the Yukon Water Board dated May 14, 1987, as well as the other major concerns raised by the interveners at the hearings.

A: ABANDONMENT SCHEME FOR FARO PIT AND AREA

A comprehensive Abandonment Plan is required for the appropriate decommissioning of the Faro pits, waste dumps, roads and reservoirs. This plan will provide for the staged reclamation of the Faro facilities once their useful purpose has been served and they are no longer needed.

TASK A1: FARO PITS

- (a) The effects of long term acid generation and leaching on the water quality will be assessed based on an estimate of the flooded depth of the pits and the quality of the seepage from above the flooded levels. This will involve the following subtasks:
 - (i) Review of the pit geology and evaluation of the acid generation potential of the wall rocks. Identification of the various zones of potentially acid and non-acid generating rocks.
 - (ii) Selection of appropriate core from the various zones for laboratory testing purposes and submission of these to a laboratory for acid generation testing. Review of laboratory results and evaluation of the acid generation potential of the the final pit wall rocks.

- (iii) Review of historic data on seepage into the pit as well as any other geohydrological data. Estimation of the inflow and outflow from the pits after abandonment. Estimation of the final pit water levels and inflow water qualities.
- (iv) Evaluation of acid generating potential in the pit walls above the flooded level in the pits. Estimation of the water quality of the seepage water and surface runoff into the pits from above the water table. Evaluation of the resulting water quality in the pits. Estimation of the discharge water quality from the pits.

It is anticipated that adequate water quality will be demonstrated. Should unacceptable water quality conditions be indicated, then alternatives will be evaluated to establish the most appropriate control measures.

- (b) It is not anticipated that any rock slope stabilization measures will be undertaken in the abandoned pits.
- (c) Drainage around and from the pits will be evaluated and provision made for the canalization or diversion of flows, where appropriate, to prevent undesirable long term erosion. The following will be included:
 - (i) Hydrology calculations for the pit and pit areas to determine average and maximum flood flows.
 - (ii) North Fork Creek Diversion around Faro Pit: Provide for erosion control, side slope stability and stream channel control.
 - (iii) Mine access road drainage: Provide for control of surface water intercepted by ditches along the mine access and mine roads.
 - (iv) Drainage channel from the pits (if required). Determine the need for a drainage channel from the pits and design same.

TASK A2: FARO WASTE DUMPS

- (a) The long term acid generating potential of various waste dumps will be assessed, based on the source and acid generating potential of the waste contained in them as well as the quality of the drainage issuing from them. This will involve the following tasks:
 - (i) Review of the mine geology and the sources of waste to identify waste types, mining schedule and probable destination in waste dumps. Identification of potential acid and non-acid generating waste volumes.
 - (ii) Review of acid generating testing completed to date and selection of samples for laboratory testing to complete waste characterization for acid generation and leaching potential.
 - (iii) Review of all test results and assessment of acid generation potential of the various waste dumps at Faro.

It is anticipated that non-acid generating conditions will be demonstrated. Should acid generating conditions be encountered then alternatives will be evaluated to establish the most appropriate control measures.

- (b) Measures for the long term stabilization of waste dumps will be defined to allow for long term erosion, earthquake forces and weathering.
- (c) Drainage around and through the dumps will be evaluated and provision made for for the canalization or diversion of flows, where appropriate, to prevent undesirable long term erosion or leaching. Particular attention will be given to the flow through or across the mine access road embankment crossing of the North Fork of Rose Creek.
- (d) Topsoil placement, seeding preparation and seeding programs will be proposed where this is considered appropriate, if any.

TASK A3: MILL SITE CLEANUP

- (a) Plans will be prepared for the clean-up or protection of all mill and mine site facilities and storage sites, to ensure spills or contamination do not occur.
- (b) Abandonment measures to provide for making the mine and mill facilities safe, or secure against public access, and to return the site area to a suitable state, will be described.

TASK A4: ROADS

Methods for the preparation and abandonment of roads will be described. This may include such items as removal of culverts and other structures which may block drainages or creeks, flattening slopes and scarifying and seeding abandoned road surfaces to encourage re-establishment of vegetation. Roads which may be required by the Territorial Administration for future access will not be reclaimed but handed over for their further maintenance and care.

TASK A5: RESERVOIRS

Plans for the abandonment preparation of reservoirs will be prepared. This may include methods for the safe breaching of the dams and embankments and re-establishment of the drainage channel through the reservoir.

B: STABILIZATION OF TAILINGS DAMS AND ROSE CREEK FOR INTERIM CLOSURE

A stabilization and maintenance plan will be prepared to ensure the stability of tailings facilities and the Rose Creek diversion in the event of interim closure of the Faro mill. These stabilization measures are the minimum measures that should be implemented in the event of an interim closure (before acceptance of the abandonment plan to be developed in the Abandonment Plan Development Program as proposed in SRK Report 60601).

TASK B1: CROSS VALLEY DAM STABILIZATION

Stabilization measures for the Cross Valley dam will include the following:

- (i) Provision of flood erosion control of the top and downslope of the dam in the event of a serious flood (greater than that which can be passed by the Rose Creek diversion).
- (ii) Provide stability control of the downstream slope of the dam.
- (iii) Provide surface erosion control of the downstream slope.
- (iv) Control development of piping of the toe or downstream slope of the dam.

- (v) Monitor settlement of the dam.

TASK B2: OLD TAILINGS DAM ALONG ROSE CREEK DIVERSION

Stabilization measures for the old tailings dam will include the following:

- (i) Provision of erosion control stability and piping control of the downstream slopes.
- (ii) Provision of erosion control against flood flow in Rose Creek diversion.

TASK B3: ROSE CREEK DIVERSION

Stabilization measures for Rose Creek Diversion will include the following:

- (i) Provision of erosion control along the Rose Creek diversion.
- (ii) Provision for slope stability along Rose Creek diversion.
- (iii) Maintenance of stream flow data.

TASK B4: NORTH VALLEY SURFACE INTERCEPTOR DITCH

- (i) Stabilization measures to control erosion and embankment stability will be provided.

TASK B5: PROVISION FOR INSPECTION, MONITORING AND MAINTENANCE

It is recognized that during temporary closure that the interim closure measures will require inspection, monitoring and maintenance. Provision will be made for these including:

- (i) Definition of surveillance requirements, methods and staff, together with the authority and resources to institute an emergency warning and stabilization measures during problem periods.
- (ii) Maintenance of the sampling and monitoring programs at appropriate levels.
- (iii) Provision of periodic reports as required by the license.
- (iv) Provision to maintain the security deposit in full effect.

C: PROJECT TEAM, COST ESTIMATE AND SCHEDULE

- (a) Project Team

The project team which will undertake the development and writing of the Abandonment Scheme and Stabilization for Interim Closure Scheme will be:

- (i) Dr. A. MacG. Robertson, Project Manager and technical lead in all aspects of the project.
- (ii) Mr. Barton-Bridges, Geotechnical engineer who will be responsible for detailed stability analyses and definition of physical stabilization requirements.
- (iii) Dr. Jim Mallick, of Norecol, who will be responsible for any environmental impact evaluations and the vegetation aspects of any reclamation.

CURRAGH RESOURCES INC.

INTER-OFFICE MEMORANDUM

DATE: February 2, 1988

TO: FILE

FROM: Joan Eamer

SUBJECT: Meeting with Environmental Protection, Jan 21/88, in Vancouver (offices of SRK) to discuss Faro Pit and Vangorda abandonment

Present:

Curragh Resources: Gregg Jilson
Joan Eamer

SRK Consultants: Andy Robertson
Adrian Smith
Jim Cronin

Environmental Protection: Peri Mehling
Keith Ferguson

The objective of the meeting was to hold an open discussion on abandonment issues in order to determine what approach the EPS will be taking to these plans and to find out what our information requirements are.

The meeting lasted 7 hours--the following is a summary of important points, not necessarily in the order discussed.

FARO PIT ABANDONMENT

Rock types and Faro seep survey data:

Keith: we need to present an hypothesis for the mechanism of acid generation. Alternative hypotheses:

1. Acid generation is occurring in the Faro dumps and the acid is being consumed by the carbonates. If this is so, one would expect the Faro dumps to become more acid generating as the carbonate is depleted. This has been observed at other sites, where dumps have taken 10 years to become net acid generators.

2. Acid generation is occurring in "pockets" in the dumps, with the bulk of the rock being non acid generating. The acid is buffered along its pathway through the rocks. This would result

is this
really
different

? diluted?

in a more stable situation.

Keith indicated we have good evidence for hypothesizing that acid generation occurs in pockets:

-Dumps as old as 20 years that have not turned acid.

-Observations from the seep survey could be taken as a model of what is occurring in the dumps--uncontaminated water flowed through a pocket of acid-generating pit wall rock to become acid water with high Zn and Cu, then flowed into neutral water, was buffered and the Cu dropped out. The resulting neutral, high Zn water is typical of Faro pit and dump seeps. The Faro Valley high-Zn water, which evidently comes from a pocket of acid-generating waste rock, supports this.

-If the carbonate level in the phyllites in the dumps is low, it would be depleted quickly and the old dumps should have reached a stable condition.

Gregg suggested a comparison of the old (SW) dumps with current waste rock. Keith expressed concern about characterizing the old dumps.

amplify →

•Pit walls

Keith: what is our plan for handling stringers of sulphide in the upper pit walls? We need to quantify the loading to pit water over the coming years.

•Sulphide waste dump (Faro)

Feri: Will the sulphide waste dumped back in the pit be under water? (current waste dump plan indicates some will be above water level). Expressed strong concern that it should all be under water.

Waste rock management: we discussed identifying high sulphide waste rock--we must indicate exactly what rock types are "sulphide waste" (ie massive sulphides only, or also other acid-generating types such as white mica envelope); how sulphide waste is distinguished in the pit.

Feri expressed grave concerns about the Faro sulphide waste dump. We are taking a "cell" approach to abandonment of this dump--creating a cell of high acid generation and covering it with low-permeability material. This approach has not been proven to be effective--sufficient water still may penetrate to create problems. Specifics of information required to justify this approach:

Acid generation potential of waste rock

Handling procedures

Construction of dump--suggests internal divisions to further limit water flow

Water budget for sulphide dump area

Carbonate levels in waste rock

What is there now--what it will be like at abandonment.

•Water chemistry at Faro pit

Adrian expressed the opinion that the Zn may be in fine particulate form rather than dissolved. He bases this on the high Fe levels in the Zone 2 pit water--too high to be dissolved.

We have a paucity of Fe data and no dissolved vs total metals.

We can resolve this with: 1) review of any government data on dissolved vs totals, 2) sequential filtering tests on neutral, high Zn water (pits, dumps, Grum adit), 3) add dissolved metals and Fe to regular samples.

This is significant
wrt treatment
as settling
may remove
much of the
zinc - perhaps
explaining
the reduction
in Zn content
as water
traverses the
tailings
pond.

→
• Loading approach to abandonment

Approach taken by Curragh in Zone 2 report: Minimize cumulative loading from the various sources with the objective of keeping loading such that downstream water is of acceptable quality, rather than minimize contaminant concentration in each source with the objective of maintaining effluent standards.

Keith and Peri recognized the logic behind this approach but stated that it does not fall within current abandonment guidelines. Peri stated that there is one (operating) mine in Ontario that is permitted to discharge effluent with non-compliant concentrations, and very low flows. If we continue to take this approach, they emphasized, we must well-define fluctuations in concentrations and flows.

• Abandonment plan requirements:

Peri reminded us to address--cost estimates, how abandonment will be funded, study plan for further work--lab work, seep studies, review of information.

• Bog treatment:

Jim Cronin (SRK, San Francisco): Bog treatment has been used in the San Francisco area to reduce Zn levels in municipal waste from 10-20 mg/L to about .5 mg/L. It appears to be an ion-exchange mechanism, not a biological process. As this is sewage, the organisms are presumably heterotroph bacteria. Peat is generally the active ingredient. We have to look at applicability to: 1) low temperature 2) low nutrient conditions (autotroph bacteria/algae) 3) pH differences. This was introduced to the meeting as a possible long-term passive treatment method that we are considering and proposing studying through RATS. Peri indicated that this is the way research is going. Little is known, but it looks promising.

• Regulatory agencies' approaches to abandonment

Distinguish between existing dumps (Faro) and new dumps, in new developments (Vangorda).

Keith and Peri: in BC they have not yet approved a new dump that they thought would be acid generating. If the Vangorda dump appears to be acid-generating and our approach is to limit water flow through the dump, we will have to overcome this "philosophical" hurdle. We must sell both our philosophical and technical approaches to abandonment in our plans.

Perpetual treatment is regarded as a contingency for operations such as Equity Silver, where there is as yet no alternative (but alternatives are under investigation). It is not a politically saleable abandonment alternative unless the treatment is passive--hence the appeal of wetlands treatment.

There is growing concern because there are 5 acid-generating

mines in BC requiring about \$1 million/year treatment and other abandoned mines with no money for treatment.

If perpetual treatment (or a plan involving a high degree of uncertainty) is proposed, the nature and extent of the financial commitment from the company becomes very important.

VANGORDA ABANDONMENT

-Vangorda pit walls

Discussed doing slaking tests (Andy outlined methodology). Acid generation rate is related to surface area, related to slaking. This will assist us to predict impact of upper pit walls.

Options for abandonment discussed. Peri and Keith suggest: 1) clean out loose material on pit walls above flooding level, 2) cover in carbonate material from Grum, 3) cover in till. This will stabilize the walls, provide some buffering and limit infiltration from direct precipitation to the pit wall area. Interceptor ditches would direct surface flow around pit.

As the worst rock will be along the east wall of the pit, the possibility of building a berm in the pit and flooding the east part of the pit to a higher level was discussed.

-Vangorda waste rock lab results

The four groups of waste rock analysed were discussed:

1. Pyritic and graphitic quartzites, massive sulphides: clearly strongly acid generating
2. Altered phyllite: two samples (rock type 4L0) were much worse than the others.
3. Carbonaceous phyllite: quite high % S and high neutralization potential (NP) indicates that this rock type might take a long time to generate acid.
4. Phyllite: % S and NP low, indicating that this rock type would likely go acid quickly.

Keith said that this data set indicates that all the Vangorda waste rock has the potential to generate acid. However, several variables such as the form the base is in influence the relative rates of acid production and consumption. He recommended further testing in order to better predict what will happen in the dumps.

Humidity cell tests and column leach tests discussed (sampling and test methods). These tests were strongly recommended by government and consultants present. The objective is to look more closely at types 2, 3 and 4 to see if all types will generate acid. These tests take up to six months. If we have low sulphates in the leachate from the humidity cell tests after 4 to 6 weeks, this is a good indication that the rock is not strongly acid-generating.

-Vangorda dump

Points discussed:

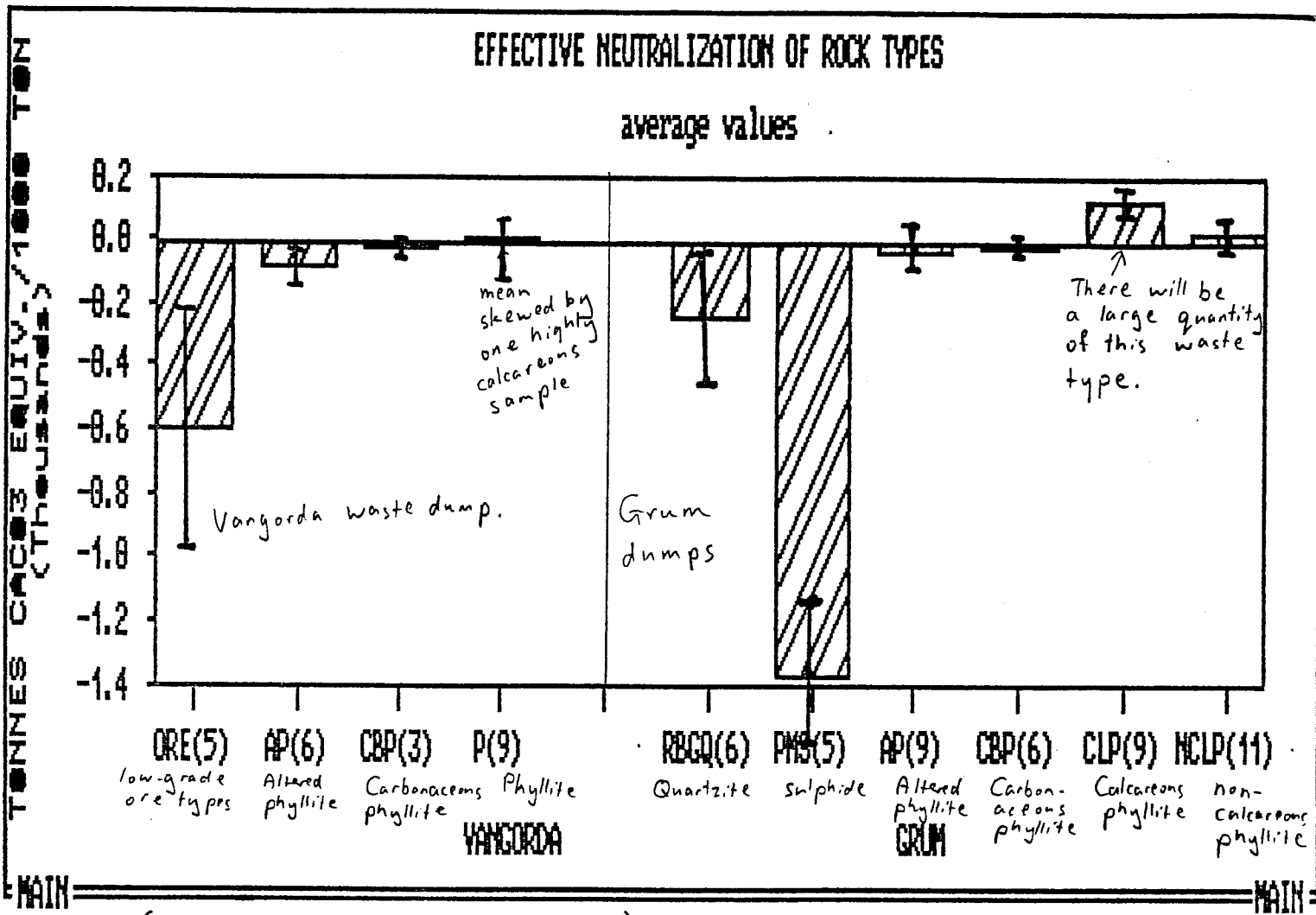
- Internal till layer. Recommended by Keith. Andy questioned this, pointing out that cracking and deformation would occur during dump construction, still allowing oxygen transmission. It is very difficult to make oxygen the limiting factor in dumps because the dumps "breathe" with barometric pressure changes. Keith felt that the added barrier to water penetration would make this worth trying.
- Oxygen trapped in dump during construction. This was raised by Adrian. Studies on another dump showed that oxygen trapped in the dump before a cover was put on resulted in acid mine drainage. Again, our approach is not to limit acid production but to limit its escape from the dump through reduction of water flow.
- Segregation of the worst rock. The low-grade and oxidized ore stockpile was discussed. This is currently planned as part of the dump, near the pit. Keith and Peri indicated that special treatment should be given to the strongly acid-generating rock. Possibilities discussed:
 1. Dump back in pit. By far the most acceptable solution as it is the only one with any certainty of success.
 2. Create a separate dump with additional measures such as complex covers--calcareous rock from Grum, till, synthetic liner. Contaminated runoff could be collected separately for treatment if necessary. Far less acceptable because of the uncertainty involved.
- Approach suggested by Adrian: Exclude worst rock from dump, preferably by dumping back in pit. Demonstrate minimal impact from the remaining dump. A possibility is to direct the flow from the dump as a diffuse flow to near-surface groundwater rather than as a point source to surface water. To demonstrate that this would work, we would need to examine buffering capacities of the till and develop a good model of the hydrology. Adrian suggested a layer (at least one meter) of calcareous rock from Grum over the acid-generating rock, then till. The rain water would pick up alkalinity from the calcareous material, inhibiting the formation of AMD.

Impact assessment

A rough estimate of impact was made based on 50% and 10% infiltration rates, the average annual rainfall on the dump area and dilution. A "worst case" was taken, looking at low flow, year-round average seep flow and seep quality of AMD from the Zone 2 seep. This indicates that, should the entire dump be acid-generating, Vangorda Creek Zn levels could exceed safe levels for aquatic life, especially since the dump is only one of several potential sources of Zn to the creek.

Peri: need to firm up estimates of Zn/Cu concentrations, not just extrapolate from Faro seeps. The humidity cell and column leach experiments could be used for this.

Summary



(sample sizes in brackets)

I 95% confidence intervals.

Notes on rock types, revised classifications

*5% pyrite
 *5-10% pyrite
 *20% banded pyrite and pyrrhotite with some galena and sphalerite
 *35% pyrite plus minor pyrrhotite
 4E0\$ 10-15% very light beige dolomite

 DRILL UPPER LOWER
 HOLE

V26R . 130.0 132.0
 V313 112.0 115.0
 V94R 223.0 225.0
 V35R 177.5 179.5
 V95R 224.0 226.0

10% pyrrhotite with one 2" massive band
 few % fine disseminated pyrite and pyrrhotite
 *2% banded pyrrhotite
 364 stringered, medium grey--transitional to weakly altered wall rock
 364 stringered, medium grey--transitional to weakly altered wall rock
 5% pyrite in bands

V312 175.0 177.0
 V312 197.0 199.0
 V143R 67.0 69.0
 V143R 164.0 166.0
 V35R 97.5 99.5
 V95R 115.0 117.0

*1% pyrite and pyrrhotite

V1R 147.0 149.0
 V28R 148.0 150.0
 V28R 160.0 162.0

[360]
 [36]
 [5862]
 [360]
 may be 580
 may be 580
 [5808]

V27R 128.0 130.0
 V96R 196.0 198.0
 V26R 65.5 67.5
 V20R 162.0 164.0
 V319 65.0 67.0
 V95R 132.0 133.5
 V27R 176.0 178.0
 V96R 130.0 132.0
 V96R 186.0 188.0

very poor 4A, minor pyrite, should be 3642--overlaps with phyllites	A225	59.5	60.3
5% pyrite	A201	139.2	139.8
~1% pyrite--poor 4A--overlaps with phyllites	A207	127.8	128.6
5-10% pyrite	A203	114.5	115.2
~3% pyrite	A204	146.6	147.2
25% pyrite	A211	104.6	105.4

minor coarse galena and sphalerite	A211	128.3	129.2
	A211	131.0	131.6
	A202	173.6	174.2
	A212	147.2	147.7
	A212	153.2	154.0

3-5% disseminated and banded pyrite	A201	167.0	167.5
few % disseminated pyrite	A201	181.5	182.0
minor disseminated pyrite	A075	1070.0	1072.0
~1% pyrite in fractures	A087	1262.0	1264.0
trace of pyrite	A054	253.0	255.0
5% pyrite in bands with up to 50% over 1"	A203	133.5	134.5
minor disseminated pyrite	A050	287.0	289.0
minor disseminated pyrite	A054	244.0	246.0
fine disseminated pyrite	A085	1328.0	1300.0

A085	1023.0	1025.0
A039	58.0	60.0
A221	183.0	183.8
A039	482.0	484.0
A214	17.3	17.7
A218	166.0	166.8

lithon poor
very lithon rich
reclassify as 5D0

A123	29.6	30.7
A125	44.8	45.3
A227	22.2	23.0
A024	53.0	55.0
A059	318.0	320.0
A059	423.0	425.0
A061	383.5	385.5
A087	342.0	344.0
A214	114.3	114.9

[5B0]
originally classified as 5A6
originally classed 3G9(5A6) Some pyrrhotite. Not 5A6.
calcareous [5B0]

A222	98.5	99.5
A039	394.0	396.0
A235	115.0	115.8
A033	380.0	382.0
A087	850.0	852.0
A079	659.0	661.0
A224	82.3	83.0
A227	79.5	80.2
A214	229.0	229.5
A059	482.0	484.0
A039	248.0	257.0

V A N G O R D A			SELECTED INTERVAL	SAMPLED INTERVAL		pH	% S	ACIDITY	NEUTRAL	NEUT/ACID	EFFECT
WASTE ROCK TYPE		DRILL HOLE	MID POINT M	UPPER M	LOWER M					RATIO	NEUTRAL
Ribbon banded graphitic quartzite	4A0	V26R	40.0	39.6	40.2	5.4	5.770	180.0	2.53	0.0	-177.5
Pyritic quartzite	4C9	V94R	68.0	68.0	68.6	6.2	11.100	347.0	5.23	0.0	-341.8
"	4C8	V35R	55.0	54.1	54.7	6.2	18.700	584.0	13.68	0.0	-570.3
Pyritic massive sulphide	4E0	V95R	68.0	68.3	68.9	5.7	28.800	900.0	5.86	0.0	-894.1
						7.6	38.500	1200.0	208.55	0.2	-991.5
				AVERAGE		6.2	20.574	642.2	47.17	0.0	-595.0
				STANDARD DEVIATION		0.8	11.844	369.3	80.78	0.1	311.7
Altered phyllite	4L0	V312	52.0	53.3	53.9	6.6	7.490	234.0	8.30	0.0	-225.7
	4L0	V312	60.0	60.0	60.7	7.4	4.740	148.0	10.47	0.1	-137.5
	4L3	V143R	20.0	20.4	21.0	6.6	1.580	49.4	5.11	0.1	-44.3
	4L6	V143R	50.0	50.0	50.6	8.3	0.527	16.5	14.30	0.9	-2.2
	4L6	V35R	30.0	29.7	30.3	7.7	0.460	14.4	4.87	0.3	-9.5
	4L7	V95R	35.0	35.1	35.7	6.9	2.740	85.6	7.60	0.1	-78.0
				AVERAGE		7.3	2.923	91.3	8.44	0.3	-82.9
				STANDARD DEVIATION		0.6	2.510	78.4	3.24	0.3	78.3
Carbonaceous phyllite	5A0	V1R	45.0	44.8	45.4	8.0	1.730	54.1	41.02	0.8	-13.1
	5A3	V28R	45.0	45.1	45.7	7.8	2.090	65.3	33.50	0.5	-31.8
	5A6	V28R	50.0	48.8	49.4	7.8	1.790	55.9	30.56	0.5	-25.3
				AVERAGE		7.9	1.870	58.4	35.03	0.6	-23.4
				STANDARD DEVIATION		0.1	0.157	4.9	4.40	0.1	7.8
Phyllite	5B05	V27R	40.0	39.0	39.6	8.1	1.230	38.4	13.92	0.4	-24.5
Some weakly calcareous and some not.	5B6	V96R	60.0	59.7	60.4	7.5	0.836	26.1	6.42	0.2	-19.7
	5B6	V26R	20.0	20.0	20.6	7.1	0.728	22.8	4.51	0.2	-18.3
Equivocal as to what formation	5B62	V20R	50.0	49.4	50.0	4.4	0.586	18.3	2.20	0.1	-16.1
	5B62	V319	20.0	19.8	20.4	7.3	0.482	15.1	8.30	0.5	-6.8
	5B7	V95R	40.0	40.2	40.7	7.8	0.302	9.4	9.44	1.0	0.0
	5B7	V27R	55.0	53.6	54.3	7.9	0.619	19.3	13.60	0.7	-5.7
	5B70	V96R	40.0	39.6	40.2	7.2	0.515	16.1	6.88	0.4	-9.2
	5D0	V96R	57.0	56.7	57.3	8.4	0.058	1.8	169.10	93.9	167.3
				AVERAGE		7.3	0.595	18.6	26.04	10.8	7.5
				STANDARD DEVIATION		1.1	0.311	9.7	50.71	29.4	57.0

4/1000

do
alkaline
res (S)

Kim Lepaco - Halifax

G R U M		SELECTED INTERVAL				SAMPLED INTERVAL						
WASTE ROCK TYPE		UPPER LOWER		UPPER LOWER								
		M	M	M	M							

Ribbon banded graphitic quartzite	4A0	A225	59.5	60.2	59.5	60.3	7.6	0.817	25.5	28.82	1.1	3.3
	4A0	A201	132.9	141.9	139.2	139.8	7.6	6.720	210.0	68.68	0.3	-141.3
	4A0	A207	126.2	130.3	127.8	128.6	6.9	9.890	309.0	37.02	0.1	-272.0
	4A0	A203	112.4	126.4	114.5	115.2	6.3	15.600	488.0	33.18	0.1	-454.8
	4A0	A204	142.9	150.1	146.6	147.2	6.0	2.180	68.1	10.73	0.2	-57.4
	4A0	A211	96.3	113.0	104.6	105.4	4.9	16.900	528.0	0.48	0.0	-527.5
						AVERAGE	6.6	8.685	271.4	29.82	0.3	-241.6
						STANDARD DEVIATION	1.0	6.122	191.4	21.60	0.4	196.7
Pyritic massive sulphide	4E0	A211	125.7	128.0	128.3	129.2	5.9	44.900	1400.0	40.61	0.0	-1359.4
	4E0	A211	129.7	134.3	131.0	131.6	5.8	47.700	1490.0	38.92	0.0	-1451.1
	4E0#	A202	173.6	174.7	173.6	174.2	6.6	36.900	1150.0	76.58	0.1	-1073.4
	4E0	A212	147.2	149.2	147.2	147.7	5.4	47.500	1480.0	4.85	0.0	-1475.2
	4E0	A212	153.2	154.7	153.2	154.0	5.7	47.400	1480.0	4.03	0.0	-1476.0
						AVERAGE	5.9	44.880	1400.0	33.00	0.0	-1367.0
						STANDARD DEVIATION	0.4	4.119	129.2	26.92	0.0	152.9
Altered phyllite	4L0	A201	164.7	171.7	167.0	167.5	8.0	1.550	48.4	18.26	0.4	-30.1
	4L0	A201	174.6	186.0	181.5	182.0	7.8	1.670	52.2	25.76	0.5	-26.4
	4L0(4L6, 4L2)	A075	323.4	347.8	326.1	326.7	8.2	0.316	9.9	15.36	1.6	5.5
	4L0	A087	380.7	394.0	384.7	385.3	8.3	1.210	37.8	16.59	0.4	-21.2
	4L07	A054	76.5	84.8	77.1	77.7	8.5	0.154	4.8	45.88	9.6	41.1
	4L2	A203	133.5	137.3	133.5	134.5	6.9	8.710	272.0	16.33	0.1	-255.7
	4L6 WEAK	A050	80.7	90.5	87.5	88.1	7.8	0.778	24.3	26.82	1.1	2.5
	4L67	A054	71.4	76.5	74.4	75.0	7.9	1.880	58.8	35.92	0.6	-22.9
	4L67 9	A085	403.3	418.9	404.8	396.2	8.4	0.596	18.6	10.75	0.6	-7.9
						AVERAGE	8.0	1.874	58.5	23.52	1.6	-35.0
						STANDARD DEVIATION	0.5	2.484	77.6	10.68	2.8	80.8
Carbonaceous phyllite	5A0#	A085	313.2	321.0	311.8	312.4	7.5	1.390	43.4	35.92	0.8	-7.5
	5A1 9 MINOR	A039	15.3	30.2	17.7	18.3	7.3	1.410	44.1	29.23	0.7	-14.9
	5A6	A221	175.3	204.9	183.0	183.8	7.7	2.060	64.4	17.25	0.3	-47.2
	5A6+-1	A039	143.8	173.1	146.9	147.5	7.4	0.997	31.2	27.11	0.9	-4.1
	5A6(5A19)	A214	15.8	23.7	17.3	17.7	7.4	2.370	74.1	33.25	0.4	-40.9
	5A61	A218	164.4	175.3	166.0	166.8	8.4	0.477	14.9	12.21	0.8	-2.7
						AVERAGE	7.6	1.451	45.4	25.83	0.6	-19.5
						STANDARD DEVIATION	0.4	0.629	19.7	8.46	0.2	17.8

relatively minor

5-10%

3-5%

Vangorda formation	5B0	A123	29.6	37.3	29.6	30.7	8.0	0.207	6.5	125.98	19.4	119.5	
calcareous phyllite	5B0	A125	39.6	55.2	44.8	45.3	8.2	0.239	7.5	123.33	16.4	115.8	
	5B0	A227	20.3	27.7	22.2	23.0	7.8	0.539	16.8	26.85	1.6	10.1	
	5B0	A024	10.0	40.8	16.2	16.8	8.8	0.146	4.6	126.94	27.6	122.3	
	5B0(5D0)	A059	96.1	109.2	96.9	97.5	8.5	0.331	10.3	62.19	6.0	51.9	
	5B02MINOR	(5BA059)	128.6	136.1	128.9	129.5	7.9	0.072	2.3	224.23	97.5	221.9	
	5B0 8 MINOR	A061	113.0	125.6	116.9	117.5	8.4	0.392	12.3	156.70	12.7	144.4	
	5B3+-8	A087	104.0	114.5	104.2	104.9	8.3	0.058	1.8	234.89	130.5	233.1	
	5B3+-8	A214	111.2	117.6	114.3	114.9	8.2	0.018	0.6	86.84	144.7	86.2	
							AVERAGE	8.2	0.2	7.0	129.8	50.7	122.8
							STANDARD DEVIATION	0.3	0.2	5.1	64.8	53.7	68.0

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Mt Mye and Vangorda	360	A222	98.2	115.0	98.5	99.5	8.1	0.184	5.8	53.74	9.3	47.9	
formations	360	A039	118.6	143.8	120.1	120.7	7.7	0.741	23.2	16.48	0.7	-6.7	
Non-calcareous phyllite	360	A235	113.1	117.5	115.0	115.8	7.9	0.368	11.5	11.02	1.0	-0.5	
	360+-MINOR	A033	111.9	134.2	115.8	116.4	7.9	0.016	0.5	29.71	59.4	29.2	
	360+-9	A087	257.9	273.3	259.1	259.7	8.4	0.434	13.6	14.69	130.5	1.1	
	360(363)(4LOA079)		192.0	201.9	200.9	201.5	8.2	0.373	11.7	54.58	4.7	42.9	
	5A6	A224	78.3	88.0	82.3	83.0	7.4	0.515	16.1	37.15	2.3	21.1	
	369(5A6)	A227	79.2	90.2	79.5	80.2	7.8	0.410	12.8	12.90	1.0	0.1	
	5B62	A214	228.6	238.1	229.0	229.5	8.3	1.020	31.9	7.09	0.2	-24.8	
	5B6#2 MINOR	A059	145.6	152.7	146.9	147.5	8.0	0.479	15.0	171.54	11.4	156.5	
	5B6 # MINOR	A039	75.2	88.3	75.6	78.3	8.3	0.345	10.8	16.72	1.5	5.9	
							AVERAGE	8.0	0.4	13.9	38.7	20.2	24.8
							STANDARD DEVIATION	0.3	0.3	7.9	44.9	38.5	46.6

1/3

CURRAGH RESOURCES INC.

INTER-OFFICE MEMORANDUMDATE: June 23, 1988

TO: Those present (Curragh representatives)
 Brian Campion
 Glenn Gilchrist

FROM: Joan Eamer

SUBJECT: NOTES FROM MEETING ON FARO ABANDONMENT SUBMISSION,
 APRIL 11, 1988

Place: Westmark Hotel, Whitehorse

Present:

Curragh: Jim Moore, Kresho Galovich, Jack Bowers, Rob McLenehan, Joan Eamer, Gregg Jilson, Andy Robertson

Government: Brian Lendrom (Water Board), Jack Nickel, Bud McAlpine, Al Waroway, Milos Stepanek, Gerry Whitley (DIAND), Ken Wile, Peri Mehling (EPS, Environment Canada), Al von Finster (Department of Fisheries and Oceans)

Yukon Conservation Society: Skeeter Verlaine-Wright

INTERIM ABANDONMENT REPORT

Andy: Summary of Interim Report

- Plan designed to cover abandonment of up to 6 years
- Expanded scope to cover concerns outlined by Brawner
- Philosophy:
 1. Plan should not contribute to costs of reopening
 2. Part of operations, not related to longterm abandonment
 3. Maintenance required. Cannot be engineered out for stabilization for interim closure.

Peri: Sulphide waste dump - what will be the impact during temporary closure?

Andy: Does not form part of this report. Have to give this some thought. Collection and treatment possible--the potential is there for impact.

Bud and Milos: Freshwater reservoir - what provisions for this during temporary closure?

Andy: Not covered.

Milos: Reservoir is not stable. Serious consideration should be given to addressing this. Underseepage and cracks are serious. This should be covered with respect to temporary closure.

Jack: They are still waiting for an action plan to address the concerns in Milos's report (Aug/87).

Further discussion of reservoir dam:

Milos:

- significant chunk of crest affected. This must be addressed in interim closure plan - back up for emergency. Equipment is there.
- Curragh should review the stability of the dam. Factor of safety for segments of downstream slope, about 1.2. Customarily expected factor of safety is 1.5. Also cracks in top. Seepage documented by piezometers is above acceptable limits. Underseepage at toe, adverse conditions.
- Therefore, Curragh needs to ensure greater stability for high seepage conditions.
- An independent review should be done - the design is faulty. Historic data and current state should be reviewed.
- However, there is no indication of catastrophic failure.
- Thorough review especially necessary if the dam is to be left in place in the long term.
- ACRES review of 1984 recommended a toe berm. This was not installed.

Al von Finster:

- Report does not go far enough, does not cover all aspects.
- Favourable hydrologic regime downstream has been created by the operation (referring to the low gradient reach between the reservoir and the tailings). Overwintering habitat in that reach will be affected if the flow regime is not maintained. CAMC maintained this during the shutdown by drawing the reservoir low during the winter.

General agreement by Curragh that this could be done. (This has been added to the report).

Gerry:

- Clean up and contaminant control not addressed in report.
- Spills occur during shutdown and start up (CAMC had problems with this in the past).
- Re section 4.7.5., ensure tanks are empty, reagents tidied up before shut down. Compile a checklist of reagent tanks, things that require cleaning up.

(this has also been dealt with in additions to the report)

Jack:

- Trusteed Environmental Fund (TEF) - he assumes (correctly) that there will be no contributions during shutdown.

Milos:

- Problems at the site change. It should be recognized in the report that whatever maintenance is required would be accelerated to stabilize structures. (Dealt with in revised report).
- Rose Creek Diversion - mud slip area of instability. Not a catastrophic situation, but should be monitored and mitigation taken if required. This is not adequately covered in the report.
- Cross Valley Dam - cracks - monitored and checked. Need a check list for each structure. (This was under development at the mine - John Huntley with Gilchrist - status should be checked).

Jack:

Notes that interim monitoring schedule (Schedule A) is out of date (eg wrt Zone 2). (This should not be a problem, as the report commits to carrying out monitoring as per the schedule, which would be updated in the case of a closure).

Milos and Jack:

Generalize the report more to cover conditions that are prevalent at the time of shutdown, recognize changing conditions and requirements. (This has been incorporated into report)

FARO PLAN

Robert McLenehan presented a summary

Jack:

How would pit discharge be kept from Zone 2?

Skeeter:

Concern that there may be a period of nontreatment. He did not realize that treatment of pit water occurs in the tailings system.

Al von Finster:

- The plan is conceptual and contains no detailed drawings. The preface should state this.
- Concern about perched drainage (pit outflow channel). Will require maintenance. Need detailed design of discharge channels built to avoid erosion and instability due to frost action, settlement, etc. Need energy dissipator down to Rose Creek. The preliminary design should indicate that there

should be no mass movement of sediment in the outflow channel.
How will this be stabilized?

- Concerns re stability of dumps in this area.

Bud: What is the slope in the outflow channel?

Skeeter: Note that dump faces prior to Curragh's takeover not to be changed.

Jack Bowers:

- We will demonstrate stability at angle of repose
- Dumps being built now in lifts - decreasing the angle to 2:1 slope.

Andy:

- Demonstrate no loss of shear strength through slaking tests.
- Toe seepage is the other cause of loss of stability (from groundwater pooling leading to high pore pressures).
- Recognition that under seismic events, may be some creep, not massive failure.
- Slake tests should be added to monitoring and research program.

Milos:

- Freeze-thaw tests are more appropriate for these climatic conditions.

Jack:

- I understand you are seeking to change the design slope in waste dump plan after your assessment (correct)
- Waste dump stability question contains implications to North Fork causeway and outlet channel.

Milos:

- Assumptions of stability are unsupported.
- Just because it was dumped before Curragh, it is not necessarily stable (to quote).
- Factor of safety = 1 when dumped to angle of repose (determined by material friction). With weathering, the factor of safety is reduced to less than one.
- The analysis of safety factor is different for the causeway-pore pressures and slip zones.
- Now there are two slip zones on the east dumps.
- Important to review the stability of the dumps.
- Crucial thing is stability of the toe - toe berms would increase overall stability, dumping on top would decrease stability.

Ken:

- Groundwater. Concern about hydrogeology - how comprehensive is the program? Is it Curragh's intention to expand if necessary? We should expand the seep survey section in relation to contamination from groundwater to the North Fork.

Jack:

- Costs should be compared between south outlet and maintenance of the other (proposed) outlet.

Gerry:

- Concern about length of time sulphides are exposed in the pit. 4 - 8 years exposed.
- Tests required on this (extraction tests).

Jack:

- Not happy with filling the pit as an "experiment". Wants testing and prediction ahead.

Peri:

- Possibility of layers, compaction, blending in sulphides in pit. This has not been adequately addressed.

LUNCH BREAK

Jack:

- Deficiency in the plan - physical stability of tailings impoundment.
- recognizes that confusion existed on this.
- 60601 - favoured plan is to maintain Rose diversion as a perched drainage. Nothing is being done to assess this configuration.
- Concern that Curragh will start working on the physical aspects after 4 years.
- Desire to have total costs and identification of favoured alternative.
- Our program of work (monitoring and research) does not address physical stability.

Al von Finster:

- There is no commitment to monitor after abandonment.
- When planning timing of work, consideration should be given to fisheries.
- Fig. 18: prepared slope, sediment reduction - should be indicated.
- Sediment load in pumphouse pond - should look at extent of it and measures for protection against resuspending it. A possibility is a rock weir.
- Fish in reservoir - need to look at growth and age structure (we are).
- Concerns with lowering dam - how maintain good overwintering habitat, and timing the lowering to reduce fish mortality.

Peri:

- Need flow estimates for treatment.
- Information in treatment report - should be made available.

Gerry:

- Concern re water quality of Zone 2.

Jack:

- Points out that temporary approval only was given for dumping in Zone 2. Are we able to convince the Board that dumping in the pit will not reduce options? What new information or plans are we proposing? (Commitment to longterm treatment)

Milos:

- This plan is conceptual.
- Geotechnical aspects particularly sketchy.
- Acquisition of baseline data essential for waste dumps, reservoir and causeway
- Process of review required.

Peri:

- Acid-base accounting by weight - percentage in dumps - required (i.e. x % of waste in intermediate dumps is rock type y)
- Sulphide dump:
 - First time sulphide waste has been lumped in one location
 - Design based on water control (not control of acid generation)
 - Other aspects have not been examined:
 - minimize acid generation through blending
 - possibility of minimizing air flow, convection
 - possibility of a layer of alkaline rock - (discussion followed; Andy indicated that oxygen control or alkaline rock layer would probably not be effective)
 - possibility of till or synthetic cover
- Dump back in pit - concerns about accumulation of products of oxidation, high initial contaminant load.
- Equity - very contaminated small seeps - trying till covers (dumps). They can collect their seeps well - at Faro more appears to infiltrate, may be difficult to collect and treat if becomes badly contaminated.

Andy

Modelling on dump infiltration needed. Equity only 3/4 m cover. Peri felt that compaction would help (I think this was related to Vangorda)

Peri:

- Fuller static acid-base accounting of rocks needed.
- Need to know mean and variability of rock types, not just those in the haul road.
- Trenching good approach to characterizing old dumps.

General comments:

- Peri: geology unclear, incomplete wrt acid generation potential
- Ken: more attention to groundwater, nothing on treatment

- Jack: physical stability question. Unease with no final plan. Need for a time line - know when certain things will be done, certain information gained.
- Milos - insufficient attention to groundwater. No deadline to review information - need this.

ADDITIONAL POINTS FROM ANDY ROBERTSON'S NOTES

- Need to prepare a program for Faro waste dump characterization and testing (wrt acid generation potential).
- Andy prefers the south route - look at what excavation costs would be. Need to cost and eliminate if not used.
- Curragh treats causeway as a haul road, not as a dump-abandoned at angle of repose. Slumping and overtopping.
- Waste dumps - consider small toe berm. Need to look at foundation, potential for flooding of toe. Also program of study - slaking and freeze-thaw tests.
- Cost and maintenance of Faro Creek diversion and of east outlet vs south outlet (Jack Nickel)
- Discuss oxygen transport to acid generating rocks in an open pit where convective transport is not prevented. Not an automatic solution.
- Need for water quality model (Jack N and Peri). Need for determination of loads in oxidized rock waste in pit. Can wastes be mixed to reduce acid product generation?
- treatment - should also address sludge disposal. Need flow estimates.
- What can be done about getting an idea about what will happen in Zone II (must be multilevel to detect layering) (Gerry W)
- Need to cost out double handling of sulphide wastes back into the pit (to indicate it is not feasible)
- Also need to cost synthetic liner on sulphide dump.



Curragh
Resources Inc.

117 Industrial Rd.
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Tel: (403) 668-3578
Telex: 036 8359

August 9, 1988

Ms. Diane Granger
Chairperson
Yukon Territory Water Board
302-4114 Fourth Avenue
Whitehorse, Yukon Y1A 4N7

Dear Ms. Granger:

Enclosed please find the proposed schedule for monitoring and research associated with the Faro Mine Abandonment Plan (Curragh Resources Inc., 1988). In response to comments from the intervenors at the recent hearing, we have added several projects to those originally described in our submission.

We have presented a detailed, project by project schedule and a summary schedule showing the timing of each project up to 1991. Integration of data and presentation of results are tied to Curragh's annual reports to the Water Board.

We ask the Board to consider incorporating the summary schedule as a schedule to Curragh's Water Licence.

Much of the work is of an ongoing nature and the schedule has been left open-ended for many projects. We expect that changes will have to be made to both the timing and content of some of these projects as we learn more about the site.

Yours truly,
CURRAGH RESOURCES INC.

Joan Eamer

Joan Eamer
Environmental Supervisor

cc: Jim Moore, General Manager, Curragh, Faro
Ken Wile, EPS
Jack Nickel, DIAND
Skeeter Verlaine-Wright, YCS
Al von Finster, DFO
Hammond Dick, Ross River Dena Council

enclosure



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**FARO MINE ABANDONMENT PLAN RESEARCH AND MONITORING:
SUMMARY SCHEDULE**

Projects are described in full in "Faro Mine Abandonment Plan Research and Monitoring: Detailed Schedule", Curragh Resources Inc., 1988.

■ data collection and analysis
* results reported in annual report

PROJECT NO.	PROJECT DESCRIPTION	1988	1989	1990	1991
1	Seep surveys	■	■	■	■
2	Waste dump stability assessment				
i)	Assessment by a geotechnical engineer	■			
ii)	Annual inspection		■	■	■
3	Waste rock characterization				
i)	Acid-base accounting of rock types	■			
ii)	Slake and freeze-thaw tests	■			
iii)	Surface geology survey	■	■		
iv)	Trenching program on old dumps		■		
v)	Characterization of weathered sulphide rock	■	■		
vi)	Evaluation of data and further studies		■	■	
4	Groundwater studies				
i)	Installation of wells	■			
ii)	Groundwater monitoring	■	■	■	■
iii)	Test pits to test for shallow groundwater		■		
iv)	Assessment of data		■	■	■
5	Loss of flow in Faro Creek diversion				
i)	Channel preparation	■			
ii)	Flow measurements		■	■	■
6	Compacted phyllite as a dump cover		■		
7	Water quality in the Faro pits				
i)	Sampling of Zone I/III pit water				■
ii)	Sampling of Zone II pit water	■	■	■	■
iii)	Sampling of overflow from pits				
8	North Fork Rock Drain				
i)	Annual inspection	■	■	■	■
ii)	Water quality monitoring	■	■	■	■
iii)	Photographic record	■	■	■	■
9	Freshwater Reservoir annual inspection	■	■	■	■
10	Water quality model	■	■	■	■
11	Hydrology				
i)	Review of data and methodology	■			
ii)	North Fork hydrometric station installation	■			
iii)	Flow records: Rose diversion and North Fork	■	■	■	■
12	Rose Creek water quality	■	■		
13	Fisheries studies				
i)	Fish resources of Rose Creek	■			
ii)	Freshwater Reservoir fish habitat	■			
iii)	North Fork Rose Creek fish habitat	■			
14	Toxicity studies	■	■		
15	Impact assessment	■	■	■	■
16	Setting of abandonment plan design standards		■	■	



Curragh
Resources Inc.

432, 408
✓

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iii)	Surface geology survey	█████	█████		
iv)	Trenching program on old dumps		█████		
v)	Characterization of weathered sulphide rock	█████	█████		
vi)	Evaluation of data and further studies		█████	█████	
4	Groundwater studies				
i)	Installation of wells	█████			
ii)	Groundwater monitoring	█████	█████	█████	█████
iii)	Test pits to test for shallow groundwater		█████		
iv)	Assessment of data		█████	█████	█████
5	Loss of flow in Faro Creek diversion				
i)	Channel preparation	█████			
ii)	Flow measurements		█████	█████	█████
6	Compacted phyllite as a dump cover		█████		
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i)	Sampling of Zone I/III pit water				█████
ii)	Sampling of Zone II pit water	█████	█████	█████	█████
iii)	Sampling of overflow from pits				
8	North Fork Rock Drain				
i)	Annual inspection	█████	█████	█████	█████
ii)	Water quality monitoring	█████	█████	█████	█████
iii)	Photographic record	█████	█████	█████	█████
9	Freshwater Reservoir annual inspection	█████	█████	█████	█████
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14	Toxicity studies	█████	█████		
15	Impact assessment	█████	█████	█████	█████
16	Setting of abandonment plan design standards		█████	█████	

FARO MINE ABANDONMENT PLAN

RESEARCH AND MONITORING

DETAILED SCHEDULE

AUGUST, 1988

CURRAGH RESOURCES, INC.

WHITEHORSE

FARO MINE ABANDONMENT PLAN RESEARCH AND MONITORING:
DETAILED SCHEDULE

OVERVIEW

The research and monitoring program is designed to answer three questions:

1. How will the abandoned minesite affect Rose Creek?

Projects 1 through 10.

Examination of potential sources of structural failure and water contamination following abandonment. The latter culminates in a water quality model that will be used to predict loadings to Rose Creek from all potential sources of contamination, through all pathways, under different abandonment scenarios. This research includes assessments of the effectiveness of different abandonment measures.

2. What are the resources of Rose Creek that could be affected?

Projects 11 through 13.

Assessment of the flow characteristics, water quality and biota of Rose Creek, with emphasis on the fish habitat in the Rose Creek system.

3. How could the abandoned minesite impact those resources?

Projects 14 through 16.

Assessment of impact of potential contaminants on the downstream resources and assessment of the impact of the physical configuration of the abandoned mine on fish habitat. This integrates information from all projects and culminates in an environmental impact evaluation. Recommendations for abandonment plan design standards will be formulated in conjunction with the development of a fuller understanding of the downstream resources and of the options for abandonment.

PROJECTS

1. Seep Surveys

Seeps from the Faro pit and area will be sampled to determine sources and extent of acid mine drainage and metal leaching. Receiving waters will be sampled at points throughout the site to assess impact on streams of seeps, groundwater flow and contact with waste rock. Extensive seep surveys will be carried out for a year, then a seep monitoring program will be developed. The monitoring program will focus on key seeps located during the seep surveys and provide a long term record of the water flow and quality.

Sample locations:

- a. Seeps from upper walls of pits
- b. Seeps from waste dumps
- c. Stream sites:
 - Faro Creek upstream of point of diversion
 - Faro diversion channel 2.2 km downstream of point of diversion
 - North Fork Rose Creek:
 - upstream of Faro Creek (from 1989)
 - downstream of Faro Creek
 - upstream of rock causeway
 - downstream of rock causeway
 - at mine road (X2)

Parameters:

flow (for seeps), temperature, pH, specific conductance, total metals (Zn, Cu, Fe), SO₄, total alkalinity or acidity
Dissolved metals measured when appropriate.

Timing:

September, 1987 to September, 1988: Six full seep surveys.

March, 1989: Mapping and analysis of seep surveys completed and seep monitoring program established. Results presented in 1988 annual report.

Spring, 1989 until final abandonment: seep monitoring program to continue. Results interpreted and the following year's program presented in each annual report.

2. Waste dump stability assessment

- i) Assessment of stability of waste dumps by a geotechnical engineer

Timings: 1988
Results in 1988 annual report.

- ii) Annual inspection of waste dumps for signs of instability

Timings: 1989 until final abandonment.
Results reported in each annual report.

3. Waste rock characterization

- i) Acid-base accounting of representative waste rock types.
Waste rock types will be categorized and representative samples taken from drill core. Samples will be tested for potential to produce and consume acid. Results will be assessed and humidity cell tests done as required to further assess the potential to generate acid.

*Some results
- pH results
- humidity cells*

Timings: 1988
Results in 1988 annual report.

- ii) Slake and freeze-thaw tests of representative waste rock types
The potential for rock deterioration due to slaking and freeze-thaw cycles will be tested using the drill core samples taken for section 3 i). Results will be used in predicting long term acid generation potential of these rock types, as well as assisting in the evaluation of long term dump stability.

Timings: 1988
Results in 1988 annual report.

- iii) Surface survey of old dumps
A map will be produced, by a geologist, of rock types on the surface of the old dumps as well as an assessment of the possibility that the observations are applicable to the dumps as a whole.

look at Wayne's map

Timings: 1988-1989
Results reported in 1989 annual report.

- iv) **Trenching program on old waste dumps**
Trenches will be dug and the rock types categorized as an extension of the surface mapping program. Composite samples may be taken and tested for acid-base accounting.

Timings: 1989
Results reported in 1989 annual report.

- v) **Characterization of weathered sulphide waste rock**
Extraction tests will be performed on samples of sulphide waste subjected to varying periods of exposure. Results will be used in predicting pit water quality and the impact of sulphide waste dump.

Timings: 1988-1989
Results reported in 1989 annual report.

- vi) **Evaluation of data and further studies**
Results from the above waste rock characterization studies, combined with dump seep survey results and an analysis of old mining records, will be evaluated with the objective of producing a qualitative description of the waste dumps. Further testing may be required to fulfil this objective. These tests may include further acid-base accounting tests and/or kinetic tests (such as columns or humidity cells), particularly on mixtures of rocks indicated to be likely waste dump compositions by earlier studies.

Timings: 1989-1990
Results in 1990 annual report.

× 4. Groundwater studies

Groundwater studies are aimed at assessing the potential for transport of metals leached from the pits and dumps via groundwater to Rose Creek.

- i) **Installation of well**
Piezometer nets, consisting of three wells, will be installed for groundwater sampling and piezometric readings:
-South of Zone II
-Southwest of sulphide waste dump

Timings: 1988

combine
with trenching
? Push the PH

- Zone II wells are missing Prec details
- but monitoring
- 2 samples taken last year each set some difficult by in getting samples from dry wells*
- ii) **Groundwater monitoring**
Piezometric readings and sampling of groundwater from wells.
- Timings:** 1988 to final abandonment.
Results reported in each annual report and incorporated into groundwater flow and water quality models.
- iii) **Test pits**
Test pits will be dug with a backhoe along waste dump toes to sample shallow groundwater flow.
- Timings:** 1989
Results in 1989 annual report.
- iv) **Assessment of groundwater data**
A preliminary assessment will be made, sampling adapted as required and a groundwater flow model developed.
- Timing:** 1989: Preliminary assessment of groundwater data.
1990: Development of groundwater model. Results in annual report and incorporated into water quality model.
1991 until final abandonment: refinement of groundwater model as more data become available.
- backhoe along NE dumps - fix up road to NF-16 station*

5. Assessment of the loss of flow from Faro Creek

- i) **Prepare channel sections for metered flow measurements at:**
-Faro Creek at the point of diversion
-Faro Creek diversion channel at:
1. Downstream end of source of seepage to Zone I/III pit through the Faro Valley waste dump.
 2. Downstream end of source of direct seepage to the Faro pits
- Timings:** 1988
- ii) **Carry out monthly flow measurements during ice-free months.**
- Timings:** Spring 1989 until Faro Creek is diverted into pit.

6. Assessment of compacted phyllite as a dump cover

In-situ permeability tests will be conducted on existing compacted phyllite surfaces on dumps in order to estimate the rate of infiltration of precipitation through the cover planned for the sulphide waste dump.

Timings: 1989

Results in 1989 annual report and incorporated into water quality model.

7. Assessment of Water Quality in the Faro Pits

i) Sampling of Zone I/III pit water

As the pit fills, samples will be taken at depth intervals. Water will be analysed to determine if density stratification is occurring and to assess changes in water chemistry.

Timings: Completion of mining of the pit until the pit overflows. Results in annual reports and incorporated into water quality model.

ii) Sampling of Zone II pit water

A groundwater sampling well will be drilled through the waste rock in the low part of the pit. As the pit fills, water level will be measured and samples will be taken to assess changes in water chemistry.

Timings: 1988: Installation of well in backfilled Zone II pit. 1988 until the pit overflows: Sampling from well. Results in annual reports and incorporated into water quality model.

iii) Sampling of overflow from pits

After each pit is full, samples will be taken of the overflow.

Timings: For each pit, from the time overflow occurs until final abandonment. Results in annual reports and incorporated into water quality model.

Samples to be done with homemade apparatus

8. North Fork Rock Drain

- i) Annual inspection
A geotechnical engineer will inspect the drain annually, report on its performance and make recommendations for maintenance, monitoring or modifications.

Timing: 1988 until final abandonment. Results presented in annual reports.

- ii) Water quality monitoring
Water samples will be taken in conjunction with seep surveys upstream and downstream of the rock drain. Suspended solids will be included in the list of parameters.

Timing: 1988 until final abandonment. Results included in annual reports, as part of seep surveys.

- iii) Photographic record
A photographic record will be kept of the extent of the impoundment behind the drain.

Timing: 1988 until final abandonment.

9. Freshwater Reservoir

Annual inspection of the dam

A geotechnical engineer will inspect the dam and provide recommendations for maintenance, monitoring and upgrading, including plans for upgrading to abandonment standard.

Timing: 1988 to final abandonment. Results in annual reports.

10. Development of a water quality model.

A model will be developed to predict water quality of the various components of the Faro pit and area, to predict impact on Rose Creek water quality and to assess abandonment options.

Timing: Preliminary model developed in 1988, results in 1988 annual report.
Model updated annually, results in annual reports.

11. Hydrology

- i) **Review of data and methodology**
Regional and local hydrology studies and data reviewed by a hydrologist with a view to providing updated peak flow estimates for the drainage basins of concern in the Rose Creek system.

Timing: 1988. Results in 1988 annual report.

- ii) **Hydrometric station on North Fork Rose Creek.**
A continuous flow monitoring station will be installed in North Fork Rose Creek above the Faro Creek diversion channel to expand the local data base for flood level estimates (for design of structures) and for stream flow estimates (for impact assessment).

Timing: 1988

- iii) **Operation of hydrometric stations**
The hydrometric station in the Rose Creek diversion canal and the station on North Fork Rose Creek will be operated during ice-free periods. This entails maintenance of flow recording stations, compilation of flow records, periodic updating of flood and streamflow estimates.

Timing: 1988 (diversion canal) and 1989 (North Fork) to final abandonment. Results presented in annual reports and incorporated into design of structures and impact assessment.

12. Assessment of Rose Creek water quality.

Rose Creek water quality and benthic invertebrate data will be compiled and reviewed; additional stream water quality samples will be taken as necessary to provide a more comprehensive data base.

Timing: 1988-1989. Results in 1989 annual report.

13. Fisheries studies

i) Assessment of fish resources of Rose Creek.

A comprehensive study of the existing fish populations and habitat capability of Rose Creek and lower Anvil Creek, from the headwaters of the North and South Forks of Rose to the Pelly River, will be undertaken.

Timing: 1988: spring study.
1988 or 1989: summer study, depending on flow conditions.
Results in 1988 annual report (and 1989 report if summer study is postponed).

ii) Freshwater Reservoir fish habitat assessment and depth survey

A lake survey will be carried out by a fisheries biologist to determine species, abundance and population structure of fish in the reservoir and to assess the reservoir as overwintering habitat.

Timing: 1988. Results in 1988 annual report (may be postponed to 1989).

iii) North Fork Rose Creek fish habitat assessment

An assessment will be made by a fisheries biologist of the habitat capability of the upper North Fork and the extent of the loss of habitat through the construction of the barrier to fish passage.

Timing: 1988. Results in 1988 annual report.

14. Assessment of toxicity of potential contaminants following mine abandonment.

A literature review of metals (especially zinc) toxicity to fish (especially Arctic grayling) will be undertaken. If this review indicates a need, lab or in situ testing of toxicity of zinc to grayling under site specific conditions will be conducted.

Timing: 1988-1989. Results in 1989 annual report.

15. Assessment of impact of Faro Mine following abandonment.

Integration of water quality predictions and toxicity data with baseline information on resources to provide impact assessment. This assessment will be refined as data are acquired.

Timing: Preliminary assessment presented in 1988 annual report. Assessment updated annually.

16. Setting of abandonment plan design standards

Design standards, both for flood and earthquake protection and for protection of downstream water quality, will be recommended by Curragh Resources Inc., following discussions with the Northern Affairs Program and Environmental Protection. These recommended standards will be submitted to the Water Board for approval.

Timing: 1989: Provide recommendations for design standards for protection against failure due to floods or earthquakes.
1990: Provide recommendations for standards to protect downstream water quality.



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Faro Mine
Env
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Schedule

Environmental Protection
225, 308 Main Street
Whitehorse, Yukon
Y1A 2B5

Your file Votre référence

Our file Notre référence

4484-37/A293

1988-08-29

Ms. Joan Eamer
Environmental Supervisor
Curragh Resources Inc.
117 Industrial Rd.
Whitehorse, Yukon
Y1A 2T8

Dear Ms. Eamer:

**Re: Proposed Faro Mine Abandonment Plan Research and
Monitoring Schedule**

Thank you for forwarding a copy of the proposed Faro Mine Abandonment Plan and Schedule. A significant amount of time and effort has been put into the proposed Abandonment Schedule and we wish to acknowledge the company's progress. We have reviewed the proposed plan and have the following comments and questions. Our response will follow the project numbering as outlined in the detailed schedule.

1. Seep Surveys

Does the company plan to continue monitoring of selected seeps after the the initial survey is completed? Will these sites be recommended for licence monitoring stations? Will receiving water sites be established in Next Creek and the North Interceptor Ditch for seeps located below the Northwest Waste Rock Dump sites?

4. Groundwater Studies

In view of the hydrogeological complexity of the site, we question whether the study will greatly improve estimates of groundwater flow patterns. It is expected that the groundwater monitoring will act more to check predictions of quality, and possible flows of acid

.../2

leached contaminants, escaping to the receiving environment over the long term. The most critical area for groundwater contamination and loss is between Zone II pit and the North Fork of Rose Creek, and below the sulphide dump. The siting of the piezometer locations will be important to detect the sub-surface migration of acid contaminants.

4(ii) Groundwater Monitoring

Will the piezometric readings and sampling occur from the existing wells and/or will new wells be installed for this project?

7(ii) Sampling of Zone II Pit Water

Will the groundwater sampling and hydrostatic level monitoring well be a permanent dedicated installation? We are concerned that the existing groundwater sampling techniques are not adequate and may not preclude the collection of representative samples. We would be pleased to discuss sampling procedures with you and your colleagues.

8(iii) North Fork Rock Drain - Photographic Record

The installation of a staff gauge above the impounded water at the rock drain would provide more useful information on quantities than just a photographic record of the site. This staff gauge could also be incorporated with the hydrometric station located in the North Fork of Rose Creek upstream of the Faro Creek diversion.

12. Assessment of Rose Creek Water Quality

Will additional water quality stations be established in the upper Rose Creek drainage and further downstream of the present X-14 station? These stations will provide more comprehensive background and receiving water quality data.

Ms. Joan Eamer
Page 3

14. Assessment of Toxicity of Potential Contaminants
Following Mine Abandonment

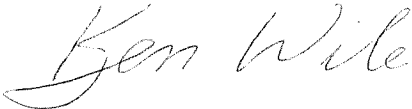
If the literature review indicates a need to conduct toxicity testing, will salmonid species be included in the testing program?

Additional Studies

We recommend that a plan for reviewing Wastewater Treatment options and developing a design for the Faro Treatment plant be incorporated into the proposed Abandonment Plan Research and Monitoring Schedule. The plan should include assessment of the Vangorda Treatment plant and include estimates of flow capacity and anticipated cost of the Faro treatment plant.

If you have any questions or require further clarification regarding our comments, please call the office at 667-3400.

Yours sincerely,



K. Wile
Manager Industrial Programs
EP - Yukon Branch

c.c.: J. Nickel, DIAND
A. von Finster, DFO
K. Nordin, YTWB
S. Verlaine-Wright, YCS
H. Dick, Ross River Dena Council

Andy;

Feb., 1989

Enclosed is an abstract for your review and approval. I provided notes to D. Blowes, and he compiled the draft. I have tentative approval from Gregg, but his approval is conditional on his review of the abstract. (Gregg is in Vancouver somewhere - I'm presently trying to track him down.)

Purpose of abstract:

1: Form basis of presentation for Geological Association of Canada / Symp. on Waste Management / Montreal / May 15/16/17. (NO PAPER REQUIRED.)

2. Form basis for journal submission to either
CIMM (which is holding a tailings symposium
Aug 24/89)

or

Journal of Reclamation Research.

With respect to pt. 1 (Geol. Assoc.), I need both your approval and Gregg's approval by no later than noon tomorrow. (Feb 9, 1989)

J. Cherry's participation is conditional on content and review of first draft.

R. M. Linnell

Fax (604) 687-5532

AN ASSESSMENT OF TAILINGS ABANDONMENT TECHNIQUES AT CURRAGH RESOURCES, FARO, YUKON.

McLenehan, Robert E., Curragh Resources, Faro, Yukon, Y0B 1K0; Robertson, Andrew M., Steffan, Robertson and Kirsten (B.C.) Inc., Vancouver, British Columbia, V6E 2Y3; Bloues, David W. and Cherry, John A., Waterloo Centre for Groundwater Research, University of Waterloo Waterloo, Ontario, N2L 3G1.

The Faro Zn-Pb mine located 220 km NNE of Whitehorse, YT, and operated by Curragh Resources Inc., began operation in 1969. The high-sulphide mill tailings (16-45 wt% sulphide) are contained behind a series of elevated tailings dams constructed in Rose Creek Valley. A field-scale evaluation of tailings stabilization and acid-mitigation techniques has been undertaken at the Faro minesite. The objective of this program is to identify techniques that will provide long-term protection to the environment, particularly to Rose Creek, that require minimum maintenance and reasonable financial resources and available technology. Six test pits were constructed, and instruments were installed in each to monitor the pore pressure, and to provide samples of the tailings pore-gas, water and solids. After emplacement of fresh tailings from the mill and initial consolidation, the treatments were installed. Treatment techniques included a 60 cm till cover, a 60 cm water cover, a calc-argillite waste rock cover, a composite cover including waste rock and till, and addition of organic carbon below the water table to induce sulphate reduction and metal sulphide formation. A control plot was left untreated for comparison purposes. After installation of the treatments, the instruments in each test pit were sampled to provide an assessment of the initial conditions.

CURRAGH RESOURCES INC.

Inter-Office Memorandum

TO: Godfrey MacDonald
Vice-President, Metallurgy
Toronto Office

FROM: Gregg A. Jilson
Vice-President, Exploration
Whitehorse Office

cc: Eric Soprovich
Environmental Engineer
Faro Minesite

RE: FARO CLOSURE PLAN

DATE: 02 15 1990

Eric Soprovich and I met recently with Dr. Andy Robertson of SRK to discuss planning for the Faro Closure Plan, due to the Waterboard in March, 1991.

There is much field work to do this season but it appears to be manageable given enough technical support for Eric.

During our discussions on the planning for the preparation of the Closure Plan, the physical plan, assessment of options and impact of selected option on the environment, it became clear that major changes have occurred to the Tailings Deposition Plan since inception of Curragh's closure thinking in 1986.

At that time it was planned to deposit 43 million tonnes of tails in the DownValley scheme, however now it appears the plan is more like 26 million tonnes or less. There are corresponding reductions in height of the Intermediate Dam. If the pit were used for tailings and the next increase were not placed on the Intermediate Dam then the implications for the scale of earthworks and spillways is considerable.

I would like to meet with you and Dr. Robertson and whomever else is relevant in Whitehorse or Faro on 14-16 March or in the following week, 21-23 March.

I would like to have some preliminary conclusions on developing a tailings deposition plan at that time building on Jack Bowers report.

I have included a copy of SRK Report 60601 for your information.

The purpose of the meeting would be to review, in detail, the mine site and the tailing area and modify the Closure Plans in Report 60601 to reflect the expected situation upon closure. As well I want to brainstorm to ensure that any other options are considered; such a reprocessing moss covers, reflectors, permafrost enhancement or taking home in lunchpails and flushing down toilet.

Please advise on your availability and preferred location; as far as location is concerned, I would prefer a concentrated session with minimal interruptions - Faro might not be a good choice.

GAJ*geb

Attachments: SRK Report #60601
Closure Plan Schedule

faro\closure.gaj

RECEIVED APR - 5 1990

RECEIVED MAR 30 1990

CURRAGH RESOURCES INC

INTER-OFFICE MEMORANDUM

FARO OFFICE

Faro Mine
EWR
~~PH tails~~
1023
Julius's 16/3/90

DATE: March 28, 1990

TO: BILL DUNN
CHIEF ENGINEER

FROM: JACK BOWERS
PROJECT ENGINEER

SUBJECT: FARO MINE ABANDONMENT - 1990 CONCEPTUAL PLAN

1. BACKGROUND:

The 1988 Mine Abandonment submitted to the Governmental Agencies did not provide for storage of tailings within the abandoned pit. The in-pit tailings disposal study completed in November 1989 shows this to be the best alternative.

The storage capacity within the pit to the 1988 abandonment plan level of 3920 feet maybe sufficient to contain tailings from the Vangorda, Grum and Dy properties, given the present or reserves. These capacities are based on a storage density of 2.2 tonnes/cubic meter, which is the density of tailings expected at depth (Golders, 1989). Should storage densities be 2.10 tonnes/cubic meter or less, the capacity at 3920 feet would be exceeded.

A minimum water cover of two meters is necessary to prevent AMD and Zinc loading resulting from wave action.

2. THE 1988 MINE ABANDONMENT PLAN

This plan, as submitted to the Government Agencies, called for sulphide waste rock storage in the designated sulphide waste dump and in the mined out "AY" phase of the pit, under water cover. The revised mine plan still requires the 3.1×10^5 tonnes be disposed of. Two sites are available; (A) the existing sulphide waste dump or (B) the south access area of the pit.

Because the reserves of phyllitic rock needed to cap the sulphide waste dump are limited, a decision was made to abandon the sulphide dump now rather than rehandle cap rock. This makes it necessary to store the remaining sulphide waste inside the pit. The required volume of sulphide waste would block off the south dyke and spillway as presently designed.

The introduction of tailings to the pit will result in making it necessary either to treat the discharge water before it can enter North Fork Rose Creek or to pump such water to the tailings area for treatment. If Faro Creek is diverted back into the pit the water volume to be handled will be substantial.

3. THE 1990 MINE ABANDONMENT CONCEPTUAL PLAN

This plan calls for dyking off the south pit access to allow for storage of sulphide waste rock inside the pit limit. By raising the stored water level of 3970 feet, discharge from the pit can be drained to the existing tailings facility for treatment via the west access. Thus the need for a second treatment plant or pumping of pit water is eliminated. The additional 50 feet of water cover will further reduce future AMD potential within the pit. A further benefit is the additional storage capacity for the tailings should mining be extended.


4. COST OF ALTERNATIVES:

4.1 - FOLLOWING THE 1988 ABANDONMENT PLAN:

i) 1990-91 yr. Sulphide waste handling - existing dump 3.1 x 10 tonnes		
incremental haul	(1000 meters)	
cost tonne/km	(\$0.225)	
additional haul cost		\$700,000.00
rehandle cap rock 0.5km 900,000 tonnes, loader, haul costs		\$270,000.00
TOTAL:		\$970,000.00
ii) 2000 yr South Dyke & Spillway	\$640,000	
iii) 2000 yr. West Dyke	\$110,000	
1988 ABANDONMENT PLANS - TOTAL COST		\$1,720,000.00

4.2 1990 MINE ABANDONMENT PLAN CONCEPTUAL

i) 1990 yr. 110,000 c/m Till Dyke-Compacted		\$1,100,000.00
1989 cost \$10.00 c/m in place		
ii) 1993 yr. West Access Ditch		\$ 100,000.00
TOTAL COST		\$1,200,000.00


Jack Bowers
Project Engineer

JB:cc

cc: Gregg Wilson
Leo Hwozdyk
Bill Weymark



STEFFEN ROBERTSON AND KIRSTEN (B.C.) INC. Consulting Engineers

Suite 800, 580 Hornby Street, Vancouver, B.C. Canada V6C 3B6
Phone: (604) 681-4196 Fax: (604) 687-5532

Faro Mine
EW
Closure Plan

July 18, 1990

Curragh Resources Inc.
117 Industrial Road
Whitehorse, Yukon
Y1A 2T8

Attention: Gregg Jilson

Dear Gregg:

RE: 1990/91 PROGRAM FOR ABANDONMENT PLAN DEVELOPMENT

A review of the program for abandonment plan development was made in December 1989 and a copy of the letter summarizing our conclusions and cost estimate at that time is attached.

We have reviewed the workscope and the following revisions are appropriate - Refer Table 1

- i) Our estimate for evaluation work and writing up of the test plot program (item A) is revised downwards from \$60,000 to 30,000. No allowance is made in this estimate for additional data gathering by SRK from the test-pits, it being assumed that the mine will provide such services.
- ii) Our estimate of the cost of Item E - Modelling has been developed with greater precision as described in the attached workscope for project 60626. The estimate increased from \$80,000 to \$90,000 primarily to allow for the input from the acid generation modelling specialist, with \$15,000 in professional services.
- iii) Addition of item G - Overall Impact Modelling which is the spreadsheet model development and application for the entire Faro operation to predict the overall water quality in Rose Creek.

The resultant cost estimate is \$252,000 compared with the estimate of \$242,000 made in 1986. This estimate does not allow for any additional data gathering that may be required, should deficiencies be identified during the program execution. The need for additional information will be indicated to Curragh Resources Inc. and agreement obtained as to the program for such data collection as these needs are identified.



We look forward to your further instructions.

Yours truly,

STEFFEN, ROBERTSON AND KIRSTEN (B.C.) INC.

A handwritten signature in cursive script, appearing to read "A MacG Robertson". The signature is written in dark ink and is positioned above the printed name.

Dr. A. MacG. Robertson, P. Eng.
Principal

AMR/kb
Attach

TABLE 1

Summary of 1990/91 Phase 1 Work
Original and Revised Cost Estimates

Tasks and estimated costs for completion of the 1990/91 program are provided below.

	Original	Revised
A. Test Plot Program	\$ 60,000	\$ 30,000
B. Groundwater Baseline Program	\$ 10,000 *	unchanged
C. Surface Water Baseline Program	\$ 9,000 *	unchanged
D. Tailings & Subsite Soils Characterization	\$ 8,000 *	unchanged
E. Modelling	\$ 80,000	\$ 90,000
F. Preparation of Abandonment Plan	\$ 75,000	\$ 75,000
G. Overall Impact Modelling	*	\$ 30,000
TOTAL	<u>\$ 242,000</u>	<u>\$ 252,000</u>

Not included is any additional costs of further field data collection which may become necessary as a consequence of the compilation and evaluation of existing data.

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December 22, 1989
 Project Number 60602

Curragh Resources Inc.
 117 Industrial Road
 Whitehorse, Yukon
 Y1A 2T8

Attention: Gregg Jilson

Dear Gregg;

We have recently reviewed the Faro mine Tailings Abandonment Plan Development Program (APDP) as described in Steffen Robertson and Kirsten Report 60602 (January, 1987). A summary of the Phase I progress review is provided below. Further, work programs which are scheduled for completion during 1990 are identified and detailed. Cost summaries have been included.

The Faro mine Tailings APDP was designed in four phases of which Phase I is currently being implemented. The four APDP phases include:

- Phase I: Investigation and Basic design of Abandonment Plan.
- Phase II: Implementation of Pre-Close-Out Measures and Re-Evaluation of Abandonment Plan.
- Phase III: Implementation of Final Abandonment Plan
- Phase IV: Monitoring and Maintenance

Phase I was planned as a four year program and was initiated in 1987. Expenditures for each year of the program were estimated as follows:

Year 1	Apr/87 to Apr/88	\$ 425,000
Year 2	Apr/88 to Apr/89	\$ 164,000
Year 3	Apr/89 to Apr/90	\$ 164,000
Year 4	Apr/90 to Mar.91	\$ 319,000
TOTAL		<u>\$1,072,000</u>



The phase I program was further detailed for the four year period by task. The task outline together with estimated task costs are as follows:

A. Test Plot Program	\$ 725,000
B. Groundwater Baseline Program	\$ 68,000 ←
C. Surface Water Baseline Program	\$ 42,000 ←
D. Tailings and Subsite Soils Characterization	\$ 50,000
E. Modelling	\$ 80,000 ←
F. Preparation of Abandonment Plan	\$ 75,000
Contingency	\$ 32,000
TOTAL	<u>\$1,072,000</u>

PHASE I REVIEW

The purpose of the following review is to determine the extent to which Phase I tasks have been completed, delineate deficiencies in task completion, and detail work remaining to be completed. The last scheduled sampling of the test facility is the summer of 1990; thus, all data requirements for the APDP must be satisfied by the fall of 1990. The remainder of 1990 and the first few months of 1991 will be required to establish a data base, evaluate collected data, model the results, and prepare a detailed abandonment plan.

TASK A: Test Plot Program

The testing of five tailings covers was initiated in 1987. The primary objective of this program is to identify appropriate technology and stabilization measures which will ensure the long term protection of the water quality in Rose Creek. Of the five tailings covers being tested, four tests are still considered valid. The fifth tailings cover being tested was a shallow water cover. As the water cover was not continuously maintained, test results for the water cover must be treated with doubt.

In 1987, the tailings as placed into the test facility were chemically analyzed. Subsequent to cover placement, water quality analysis was conducted in the test facility in October, 1988, July, 1989, and October, 1989. Solids sampling and analysis was conducted in October, 1989. Two remaining water quality sampling and analysis events are scheduled: one in July, 1990, and one in October, 1990. One solids sampling and analysis event is scheduled for October, 1990.

*
*

Water quality sampling and analysis has been successfully undertaken to date. One type of sampler, the air/water sampler, has proven to be particularly successful and free from mal-function. The back-up lysimeters, which to date have not been required, have not functioned well. Sample extraction has proven to be difficult, and sample volumes have been small. Small volumes create difficulties in in-situ and laboratory analysis.

Solids sampling was not successful in 1988. The sampler unit had inherent design problems. In July, 1989, efforts were made to modify the sampler. The sampler was subsequently abandoned and a new sampling method introduced. To date, the success of this sampler is not known. Should this sampler also prove to be unsatisfactory, arrangements will have to be made to collect samples from surface using a small hand auger. Changes in solids chemistry is critical to analysis and samples must be collected in 1990. *

Pore water pressure can be monitored by pneumatic piezometers installed at various depths throughout each test pit. Pore water pressures were determined in October, 1988; however, by July, 1989, most of the brass adapter fittings at the end of the instrument leads had cracked. These fittings must be replaced if further pore water pressure readings are to be obtained. *

Temperature profiles can be determined in each test pit through access to thermistor strings. Temperatures were monitored in 1987, in 1988 and several times during 1989. These instruments continue to function well; however, in 1990, the frequency of readings must be increased to once every two weeks throughout the year beginning. *

Oxygen and carbon dioxide gas profiles have not been determined to date. These in-situ tests should be undertaken at monthly intervals through 1990. *

With respect to outstanding tasks scheduled for 1990/ 91, these include up-dating and refinement of the data base, evaluating the data, and reporting on the final results of the tailings covers tests. (Item A.(v): estimated cost = \$ 60,000).

TASK B: Groundwater Baseline Program

The necessary installations to supplement existing instrumentation were completed in September, 1988. A complete sampling of all groundwater monitoring stations was scheduled for 1989. One more sampling event is scheduled for 1990. *

done?
*

The major tasks for 1990/ 91 include developing a data base, evaluating the data and preparing a report which summarizes the findings. (Item B.(iv): estimated cost = \$ 10,000).

TASK C: Surface Water Baseline Characterization

The surface water within the immediate vicinity of the mine site has been monitored regularly since mining began in Faro in 1969. The major task involved with surface water baseline characterization is completing the data base. A data base was partly developed in 1987, and has since been updated on a regular basis. However, data prior to 1987 has not been entered into the computer data base. Results from 1982 to 1987 have been organized for easy access. Data prior to 1982 has not been reviewed in detail.

In addition, sampling above the confluence of Faro and North Fork Creeks should be undertaken monthly. Water quality results from this sample location should help to determine background water quality for the Faro mine area. Sampling should begin as soon as possible, and continue through 1990.

Data entry is the major component of this program. Besides this, the major work remaining for 1990/ 91 are data evaluation and report compilation. (Item C.(iii): estimated cost = \$ 9,000).

TASK D. Tailings and Subsite Characterization

The drilling and sampling was completed in September, 1988. The laboratory analysis was completed by spring, 1989.

In-situ monitoring of oxygen and carbon dioxide gases must be done in 1990. Equipment problems prevented this component of the program to be initialized in 1989. The in-situ investigation program should entail a transect from old to new tailings. Paste pH should also be determined during instrument installation.

In-situ permeability tests should be done in 1990 at locations in the proximity of the CO₂/O₂ monitoring installations.

Samples should be collected in 1990 along a transect from old to new tailings for analysis for the presence of the bacteria, Thiobacillus Ferroxidans. Samples should be taken approximately every 0.3 meters to a depth at which the paste pH is greater than 5.5. Samples taken during 1988 for this purpose were lost in transit.

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Supplementary weather data was collected during 1989 at the tailings facility. Maximum and minimum temperatures, precipitation and evaporation rates were measured. This program should be continued throughout 1990. *

*Check
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do this*

(This investigation has generated a lot of data, which must be entered into a data base, summarized and then evaluated. The data has been organized and presented in SRK Report 60613. This work is scheduled for 1990/ 91. (Item D.(iii): estimated cost = \$8,000 which does not include remaining test work which must be completed).

TASK E. Modelling

The approach to and the type of modelling to be undertaken must be determined in early 1990. Two modelling systems are required: acid-generation modelling and contaminant migration modelling. (Item E.(i & ii): estimated cost = \$ 80,000).

TASK F: Preparation of Abandonment Plan

This task entails evaluating acid abatement options, evaluating stabilization options, and preparing the abandonment plan. Preliminary organizational work should be started early in 1990. (Item F.(i,ii, & iii): estimated cost = \$ 75,000).

SUMMARY OF 1990/ 91 PHASE I WORK

Tasks and estimated costs of completion for 1990/ 91 program year are provided below.

A.	Test Plot Program	\$ 60,000	
B.	Groundwater Baseline Program	\$ 10,000	*
C.	Surface Water Baseline Program	\$ 9,000	*
D.	Tailings & Subsite Soils Characterization	\$ 8,000	*
E.	Modelling	\$ 80,000	
F.	Preparation of Abandonment Plan	\$ 75,000	

} *our staff
could do*

TOTAL \$ 242,000

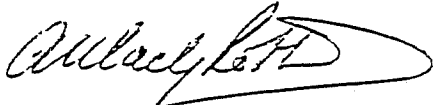
Curragh Resources Inc.
December 22, 1989

Page 6

We would like to emphasize the importance of planning the 1990/ 91 programs, and the importance of an early start date for the remaining work in each of the phase I programs. Should you require any further information, please contact either A. Robertson, R. McLenehan or myself.

Yours very truly,

STEFFEN, ROBERTSON AND KIRSTEN (B.C.) INC.

A handwritten signature in cursive script, appearing to read "Andy MacG. Robertson".

Andy MacG. Robertson, P. Eng.
Principal

AMR/cs

60626

FARO TAILINGS ABANDONMENT PLAN DEVELOPMENT PROGRAM
WORKSCOPE FOR THE MODELLING OF ACID GENERATION AND TRANSPORT

Prepared for:

CURRAGH RESOURCES INC.
117 Industrial Rd.
Whitehorse
Yukon

Prepared by:

STEFFEN ROBERTSON AND KIRSTEN (B.C.) INC.
580 Hornby Street
Vancouver, B.C. V6C 3B6
Canada

JUNE 1990

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LIST OF APPENDICES

1.0 INTRODUCTION

The Faro mine tailings abandonment plan development program (APDP) was described and set out in detail in SRK report 60602, January 1987. The objective of the plan is to determine, design and install abandonment measures to limit the generation of acid drainage from the potentially acid generating tailings, and to minimize or avoid the discharge of contaminants to receiving waters.

The APDP was designed in four phases, of which Phase I is currently being implemented. The four phases include:

- Phase I: Investigation and Basic Design of Abandonment Plan.
- Phase II: Implementation of Pre-Close-Out Measures and Re-Evaluation of Abandonment Plan.
- Phase III: Implementation of Final Abandonment Plan.
- Phase IV: Monitoring and Maintenance.

Phase I was planned as a four year program and was initiated in 1987.

The phase I program was further detailed for the four year period by task. The task outline is as follows:

- A: Test Plot Program
- B: Groundwater Baseline Program
- C: Surface water Baseline Program
- D: Tailings and Subsite Soils Characterization
- E: Modelling
- F: Preparation of Abandonment Plan

Tasks A and D are ~~mostly~~ ^{substantially} complete. Tasks B and C are to be up-dated this summer, and reports detailing baseline conditions must be written. Task E, Modelling, is the subject of this workscope. This task includes the modelling acid generation from the Faro tailings for various cover scenarios, and the predicted contaminant load discharging to the natural environment. Modelling will be based on the data collected in tasks A to D, and will form the basis for task F, the preparation of an abandonment plan. In task E, it is assumed that previous programs are complete and that necessary input data is available.

A workscope for the modelling is given below consisting of a rationale for the modelling, details of

the modelling to be performed and programs to be used, a cost estimate based on the expected input by the project team, a description of the team and a project time schedule.

2.0 RATIONALE FOR MODELLING

The layout of Faro Mine is shown in Figure 1, and shows the location of the tailings ponds in relation to surface drainage and other mine facilities. The tailings ponds are located in a valley previously occupied by Rose Creek, the creek now being diverted around the ponds on the south side.

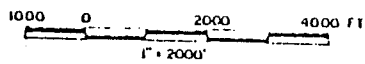
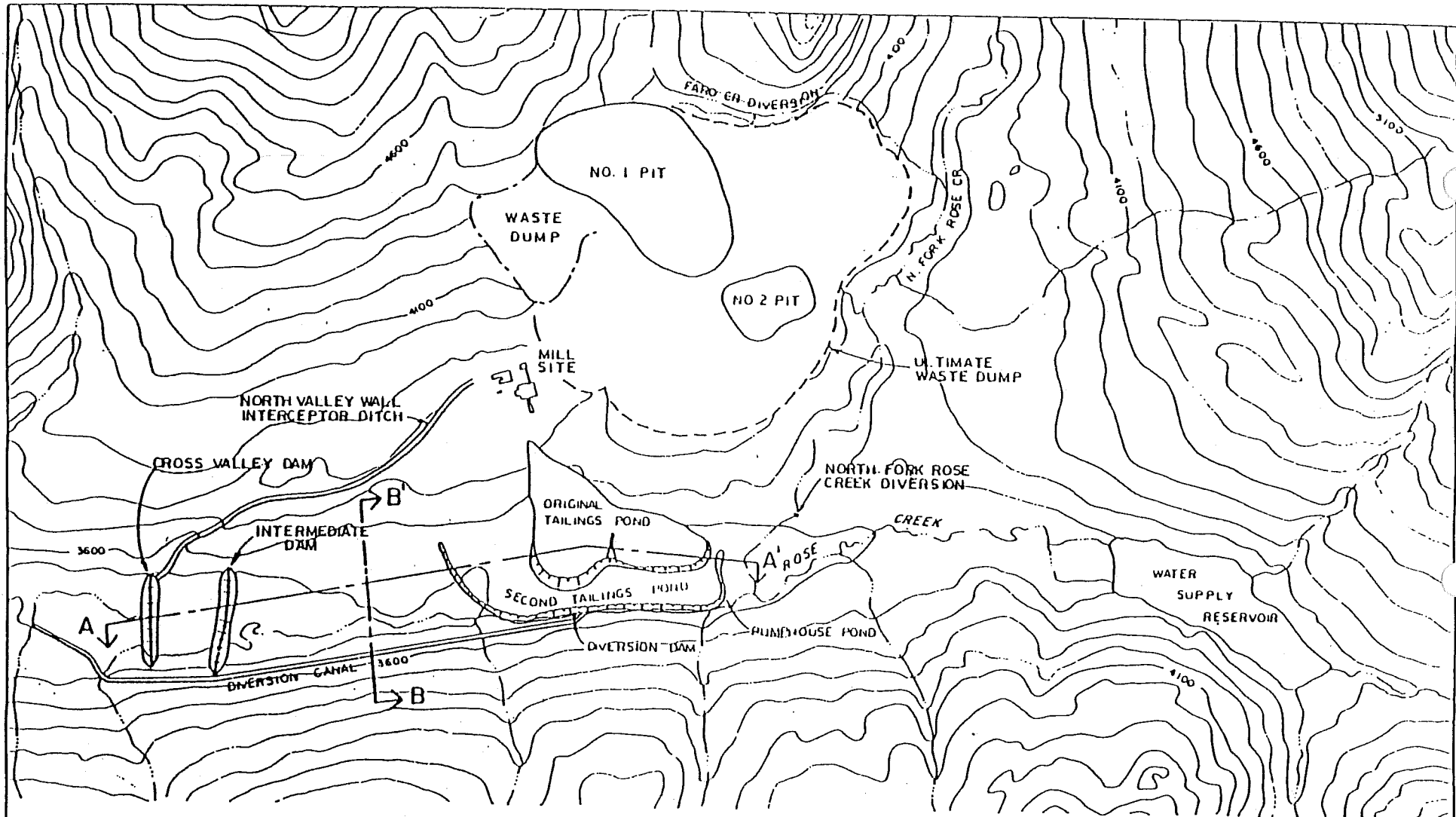
The tailings pond system consists of a number of surface and groundwater inputs, flows within the system prone to chemical change, and a number of discharges at some point below the impoundments in Rose Creek. The chemical changes that occur in water flowing through the system will primarily be a function of:

- . the displacement of tailings pore water containing process residues
- . the generation of acidity and metal leaching resulting from the oxidation of sulphides

The prediction of water volume and quality discharging from the tailings impoundments after abandonment will be based on, but not limited to, assessments of the following:

- The quality of background surface and groundwater entering the tailings system
- the volumes of recharge and through-flow in the tailings for various abandonments scenarios
- the quality of pore-water displaced, and the quality generated by the acid generation process
- the buffering effect that sub-site materials (attenuation reactions) and water (equilibrium reactions) have on migrating tailings leachates, both of which may serve to reduce contaminant concentrations
- the number, volume and quality of discharges from the tailings system which ultimately merge in Rose Creek

The tailings system is considered to include all water inputs and outputs. Flows in Rose Creek above the tailings impoundments, and surface run-off diverted around the dams, are not considered part of the system. However, these surface water flows will have to be considered to assess the impact of the release of contaminants from the tailings on receiving water quality. Surface water flows and receiving water quality are to be assessed in a separate investigation in which all potential discharges from the Faro Mine



CURRAGH RESOURCES		DATE
FARO ABANDONMENT PLAN EVALUATION		PROJ. NO.
FARO MINE LAYOUT		APPROVED
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		NO. <i>AD</i>

operation, the tailings dams being one, are included. Hence, receiving water quality will not be addressed in this workscope.

A number of models will be generated to perform or incorporate the assessments listed above. The potential for acid generation from the tailings will be modelled utilizing state-of-the-art codes. The object of this modelling will be to determine acid generation as a function of various types of cover for the tailings, each cover imposing different hydraulic and chemical constraints on the acid generation process.

Acidity and dissolved salts produced during sulphide oxidation will migrate to the phreatic surface within the tailings, and then undergo saturated solute transport. To account for the change in chemical states of dissolved contaminants, which in turn may lead to changes in pore water quality, we propose to use an equilibrium model. This step would follow acid generation, but would precede solute transport in the groundwater below the tailings.

Groundwater flow into the system, flow through the tailings profile including the covers, and the transport of solutes from generation to discharge will be modelled using a two-dimensional finite element solute transport code. The code will incorporate the effects of sub-site attenuation mechanisms with respect to contaminant concentrations. The end result will be the prediction of discharges from the tailings system which will ultimately flow into Rose Creek, and how these are affected by different abandonment solutions.

3.0 ELEMENTS OF TAILINGS SYSTEM MODELLING

3.1 Databases

Three elements for tailings system modelling are identified:

- acid generation and leaching in the tailings
- chemical equilibrium of leached contaminants
- groundwater flow and solute transport

Each element requires the generation of a database to facilitate modelling. This activity follows the previous collection and assimilation of site data, and consists essentially of the definition of model input parameters. As stated above, this workscope implicitly assumes that site data corresponding to tasks A through D will have been completed and written up prior to this modelling phase.

Model databases will be constructed using established physical and chemical properties, and drawing from the data collected on site since initial mine development began, and that generated from the tailings disposal test plots and monitoring systems established in 1987. The modelling of acid generation will require the analysis and application of the following data:

- tailings physical properties
- tailings chemical properties
- location specific saturation and gas conditions
- location specific pore water quality
- various types of tailings cover and the physical and chemical controls these exert

The modelling of chemical equilibrium controls requires site data on the likely chemistry of tailings pore water before and during acid generation, and the chemistry of surface and groundwaters in the tailings system with which tailings pore waters will contact. Redox conditions measured on site are also input, while chemical controls on speciation are already built-in the model.

A relatively large database is needed for the modelling of groundwater flow and solute transport. Physical properties of sub-site materials and of the tailings has been determined. This, together with historical water-level data, is needed to define and calibrate flow systems. Model boundaries also have to be assessed, as variations of these during or after mining activities may significantly change simulation controls and results. Background groundwater quality will have been established, and sub-site attenuation potentials from previous testing are available. This data will be compiled in a model-ready format.

3.2 First Estimates

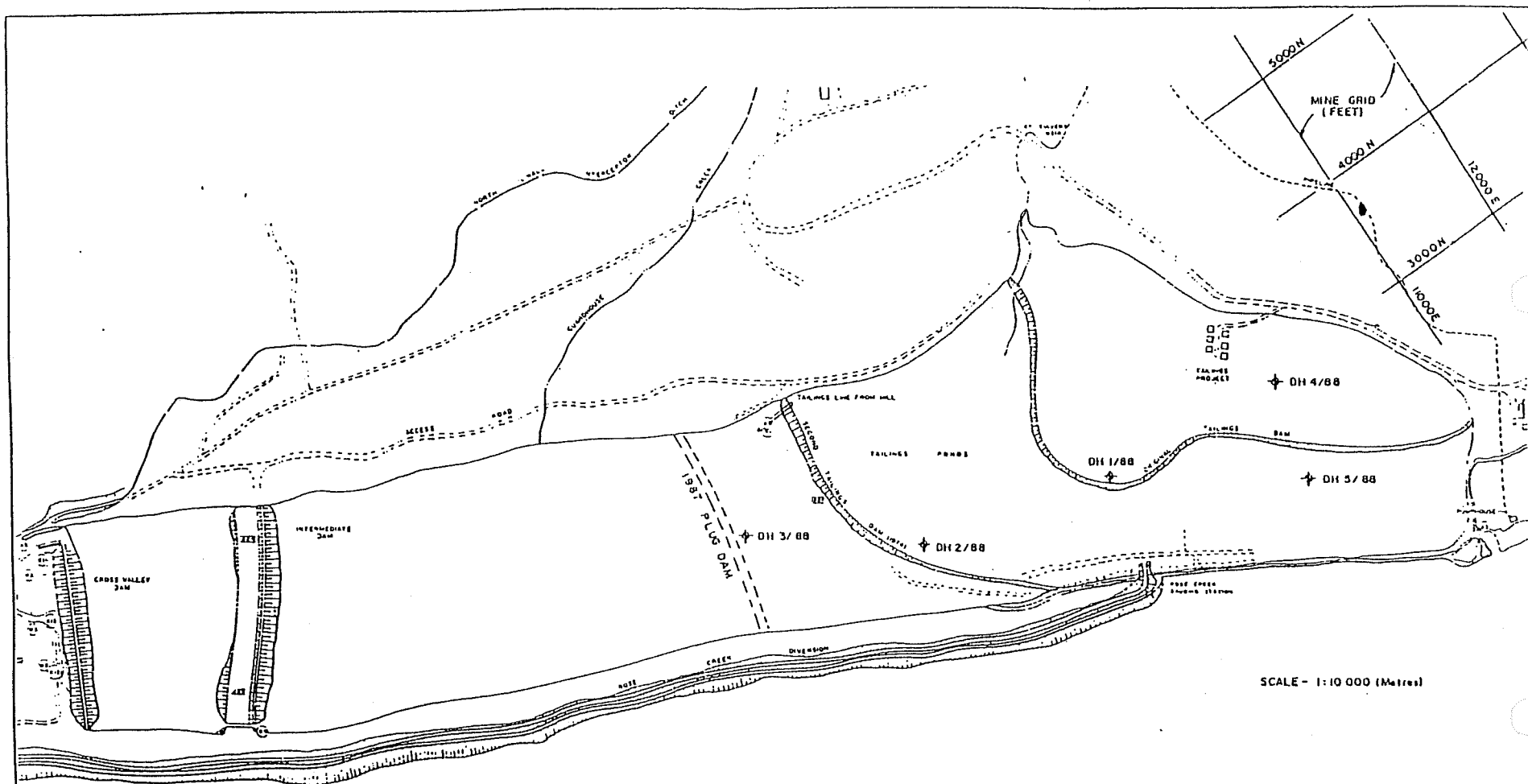
Following the analysis and reduction of data for model database construction, and prior to detailed modelling, it is recommended that first estimates of likely model results be made. This will serve a number of functions:

- indicate which portions of the modelling give the most sensitivity in terms of predicted contaminant discharge, and in so doing, direct the detailed analysis to follow
- provide a first estimate of potential contaminant discharge
- any data requirements previously overlooked can be addressed

The estimates are intended to direct model activities at an early stage to improve the efficiency of the modelling exercise. Because of the assumptions that will be made, the estimates will not be a reliable indication of potential discharges, and no design work should be based on them.

3.3 Acid Generation

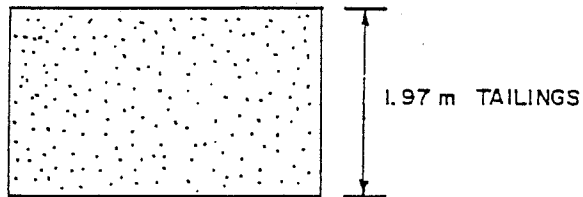
The generation of acid drainage from the tailing^s will be the most difficult of the modelling functions to perform. This is because the processes controlling acid generation are currently the subject of on-going researched, and predictive capabilities are at an early stage of evolution. The tailings test plot program will provide useful data with which to attempt model calibration. However, only three to four years of test plot data will be available compared with acid generation processes which may take



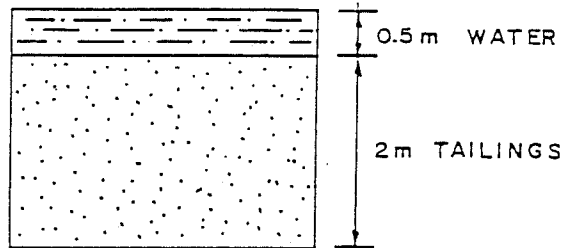
LEGEND

⊕ DH 2/88 1988 DRILL HOLE
(Approx. location)

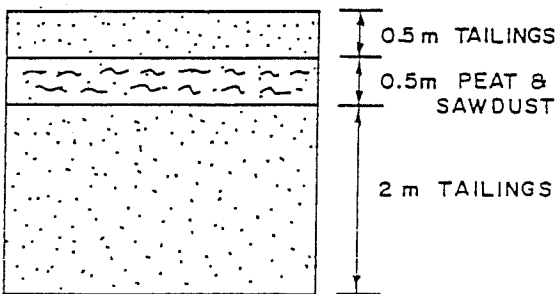
CURRAGH RESOURCES - FARO MINE		DATE OCT 1988
FARO MINE TAILINGS IMPOUNDMENT AREA		PROJ NO 60606
		APPROVED
		FIGURE 2



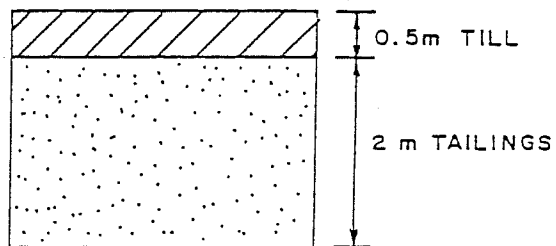
TEST PIT # 3



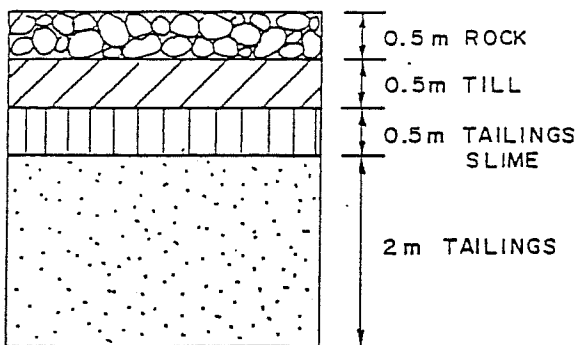
TEST PIT # 6



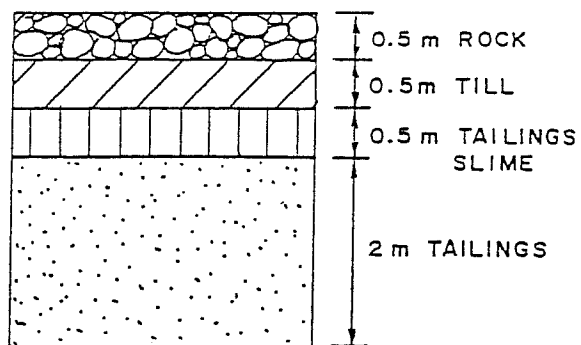
TEST PIT # 2



TEST PIT # 5



TEST PIT # 1
(Saturated)



TEST PIT # 4
(Unsaturated)

CURRAGH RESOURCES - FARO MINE

DATE OCT. 1988

PROJ. NO. 60606

APPROVED

NO.

TAILINGS TEST FACILITY
SCHEMATIC OF VERTICAL PROFILES
OF TAILINGS AND COVERS IN TEST PITS

FIGURE *MS*

3

decades to develop properly.

There are two computer codes which are currently available for the simulation of acid generation:

- the RATAP model developed by SENES-BEAK and funded by CANMET
- a model developed by Marie Collin *at ORN in Sweden*

The RATAP model is believed to be currently the most appropriate for the modelling of acid generation processes, although the effects of different cover types and geometries are not well accommodated. The Marie Collin model is perhaps less strong on the acid generation processes, but is probably the best available in simulating the changes in acid generation as a function of ~~material~~ ^{potential for} saturation, and thus is more applicable for an assessment of cover types. A decision will be made on which code to use, although the Marie Collin model is currently preferred.

As both of the above codes have only recently become available for external use, it is proposed that the developer of the selected code will be invited to assist in datafile generation and with initial simulations. This will enable a merger of site knowledge with code knowledge, and should be the most efficient approach.

The acid generation modelling will consider the three Faro tailings ponds to be abandoned as individual items. The ponds are shown on Figure 2, and are numbered 1, 2 and 3 from east to west. A variety of tailings covers are being evaluated in the field in the test plot program (see Figure 3.). The covers ultimately to be selected for the ponds may not be the same. Various cover conditions for the ponds will be evaluated in the modelling, and this will include the effects imposed by potential abandonment structures.

An important control on the acid generation process is the degree of saturation in the partially saturated tailings, and the elevations of phreatic surfaces. The degree of water percolation from surface through covers will probably be the main control on tailings saturation and acid generation. The selected acid generation model should account for this. In addition, a one-dimensional partially saturated solution is already linked in the solute transport model recommended. This may assist in the knitting and overlap of model simulations.

Fig 2

3.4 Acid Equilibrium

Acid drainage from the tailings will probably have two routes of flow:

- embankment seepage entering the surface water directly below the Cross Valley Dam
- percolation to the groundwater followed by sub-surface flow and discharge to surface water downstream via base-flow

In both instances, acid drainage containing dissolved metals will contact water with a different chemistry, and the resultant blend will likely lead to a change in metal stabilities and may result in precipitation. This process should be accounted for as a step between the acid generation modelling and surface water discharge or groundwater flow. Contaminants will potentially be removed from solution in flow systems, and may not ever reach the groundwater or receiving waters. The model PHREEQ is suggested for use to assess contaminant equilibrium conditions in the mixing environments considered, and the potential for the precipitation of contaminants.

3.5 Groundwater Flow and Solute Transport

A two-dimensional areal solute transport model will be constructed for the tailings system, extending east to the Faro water supply reservoir, and west to the final point of groundwater discharge to Rose Creek. Appropriate north and south boundaries will also be selected. The model will simulate inflowing groundwater, and point and non-point recharge to and discharge from the system. The main recharge source will be the infiltration of precipitation. A quality will be assigned to the recharge to simulate the supply of acid generation contaminants to the groundwater. Changes in tailings system hydraulic conditions as a result of different abandonment covers and structures will also be simulated. Model results will consist of the predicted volume and quality of discharge to Rose Creek.

The computer code SUTRA is recommended for this modelling. The code was originally developed by the USGS, and has been extensively tested and verified. The code is suitable for this application as it incorporates one-dimensional partially saturated flow linked to a two-dimensional saturated flow regime, and includes the simulation of sub-site attenuation mechanisms in solute transport.

The constructed model will be of a scale suitable for the simulation of solute transport from the tailings system, and will simulate the majority of flows adequately. However, two areas of detail may require additional numerical simulation:

- flows through tailings covers in the partially saturated zone
- flows between tailings ponds which are influenced by steep and variable hydraulic gradients

The object of assessing these flows in detail is to ensure that the main model simulates prevailing

TASK	FEES							DISBURSEMENTS		
	Andy Robertson	Adrian Smith	Dave Harpley	Robert McLenehan	Support Engineer	Drafting	Typing	Computer Costs	Printing	Tel/Fax
Project Initiation	1		2	1						
Complile Databases			10	3	3					
First Estimates	1	1	2	1	1					
Acid Generation	1	2	12	5				17000		
Acid Equilibrium		1	2	5				400		
Groundwater and Solute Transport		1	16	1				1500		
Meetings/Liaison	2	1	3	1						500
Review	3	2								
Reporting	3	2	11	4	1	6	6		1000	
Total Days	11	10	58	21	5	6	6			
Rate/Day	960	1000	560	480	440	380	320			
Costs (\$)	10,560	10,000	32,480	10,080	2,200	2,280	1,920	18900	1000	500
Total Costs (\$)	69520							20400		
	89920									

conditions adequately.

The main areal model will be constructed from existing data, and will be calibrated against the same database. Allowance will also be made for potential changes in system boundaries up to and after tailings impoundment abandonment.

4.0 COST ESTIMATE

A cost estimate for this workscope is given in table 1.

5.0 PROJECT TEAM

6.0 PROJECT SCHEDULE

conditions adequately.

The main areal model will be constructed from existing data, and will be calibrated against the same database. Allowance will also be made for potential changes in system boundaries up to and after tailings impoundment abandonment.

4.0 COST ESTIMATE

A cost estimate for this workscope is given in table 1. Fees are based on the inputs indicated, and assume 8 hour days. The \$17 000 item for computer costs for acid generation modelling is intended to cover the acquisition and use of the selected model, and the professional fees billed by the model's author. This figure may vary as this function has not been finalised.

The total estimate is currently \$89 920.

5.0 PROJECT TEAM

Dr. Andy Robertson, P.Eng., President of SRK (BC), will serve as project principal and would perform the function of overall technical direction and review. Dr. Robertson has over 20 years of experience in the design of mine waste facilities and has developed particular interest and expertise in the field of acid mine drainage. He is involved in a number of key western Canadian AMD projects as well as projects in the USA and Norway.

Dave Harpley will be responsible for project management, administration and coordination. He will be responsible for the compilation of model methodology and construction, and predictive analyses. He is a senior hydrogeologist with 10 years experience principally in groundwater contamination related to the disposal of mine tailings/rock waste. He has led many waste disposal projects requiring site investigation, waste and site characterisation, contaminant transport modelling, control measures and monitoring installations.

Dr. Adrian Smith will act as a technical specialist and will be responsible for review functions related to hydrogeochemistry. The latter encompasses the geochemistry of the acid generation process, the hydrochemistry and hydrogeology of tailings, contaminant equilibrium, and solute transport mechanisms.

Rob McLenehan, P. Eng., will assist in the acquisition of model data, the generation of model databases,

and the modelling of acid generation and contaminant equilibrium reactions. Rob is a project engineer with 3 years experience in environmental engineering, and a total of 7 years experience in environmental consulting. Since joining SRK, he has been involved with many ARD projects including the Faro, Mt. Hundere, Vangorda and Grum Deposits for Curragh Resources, as well as Ruttan Mine for the Hudson Bay Mining and Smelting Company.

6.0 PROJECT SCHEDULE

The anticipated project schedule is shown in table 2. This shows that we estimate -- weeks are required for the completion of the project. This assumes no impediment to project progress resulting from data or acid generation model availability for example.

TASK	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Initiation	—													
Compile Databases		—												
First Estimates			—											
Acid Generation				—										
Acid Equilibrium					—									
Groundwater and Solute Transport							—							
Meetings/Liaison	—				—				—					—
Review				—					—					—
Reporting										—				—

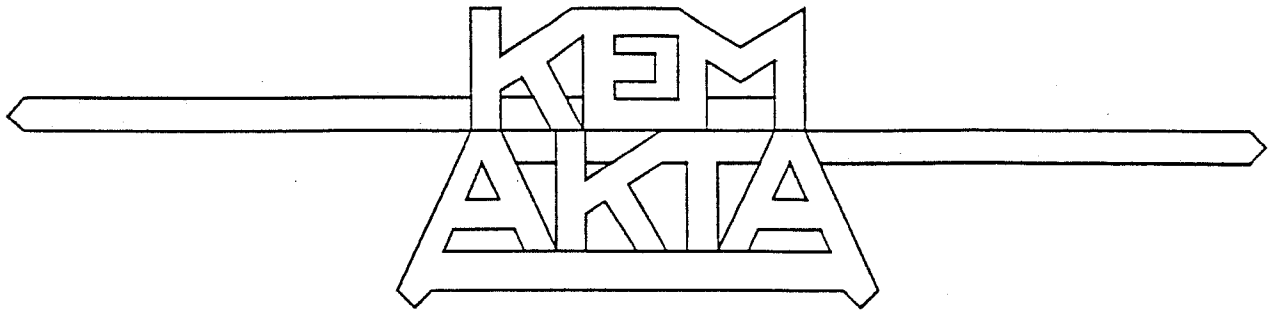
Table 2: Project Schedule

98 09/26 11:12

604 687 5532

SRK UCR

04



KEMAKTA Consultants Co is a Swedish company specialising in investigations and mathematical modelling of physical and chemical phenomena in the environment and in industrial processes. In order to be able to treat these problems, the company has developed an expertise in scientific computer programming. KEMAKTA is owned by its employees and is located in Stockholm. It was founded in 1975 and has a scientific staff of about 30 people, mainly chemical and civil engineers, biologists and mathematicians. INTAKTA France, located in Paris, is a wholly owned subsidiary, presently staffed with chemists and hydrogeologists. Most of the activities of KEMAKTA/INTAKTA are focussed on safety analyses, in particular of the disposal of radioactive waste from nuclear power production. The clients are industrial and governmental organisations both in Sweden and abroad.

KEMAKTA has the ambition to maintain a high level of scientific competence in order to be able to serve as a link between basic scientific knowledge and its applications to real problems. This is achieved by, in addition to using highly trained staff (doctors and masters of science), also by involving academically engaged professionals both as advisors to the company and directly in the projects.

At present KEMAKTA's major clients are:

- Swedish Nuclear Fuel and Waste Management Co, SKB
- Swedish Nuclear Power Inspectorate, SKI
- Swedish National Institute of Radiation Protection, SSI
- Swiss National Cooperative for Radioactive Waste Disposal, NAGRA
- French Radioactive Waste Management Agency, ANDRA

In addition to these clients, contracts have also been carried out for other organisations such as the Swedish Environmental Protection Board, the Swedish National Board for Spent Nuclear Fuel, the Taiwan Power Co (in cooperation with SKB), the Finnish Industrial Power Co (in cooperation with SKB), the UK Nirex Ltd, and the German Reactor Safety Co.

KEMAKTA Consultants Co
Pipersgatan 27, S-112 28 Stockholm, Sweden
Telephone xx46 - (0)8 54 06 80, Telefax xx46 - (0)8 52 16 07,
Teletex 2401-8106328=KEMAKTA, Telex 156 60 KEMAKTA S

MAJOR PROJECTS

Radioactive Waste Disposal

- Modelling of radionuclide transport through the geological barrier in the KBS 1, 2 and 3 studies, 1976-1983 (SKB, Sweden)
- Modelling of ground-water flow for the KBS 3 study, 1982-1983 (SKB, Sweden)
- Modelling of ground-water flow and radionuclide transport for the Swedish repository for radioactive waste from reactor operation, SFR, 1986-1987 (SKB, Sweden)
- Investigations regarding the impact of the chemical conditions in the waste and the near-field on the safety of SFR, 1981-1983 and 1987 (SKB, Sweden)
- Assistance in the preparation of the Preliminary Safety Analysis Report, PSAR, 1981-1983, and the Final Safety Analysis Report, FSAR, 1987, for SFR (SKB, Sweden)
- Modelling of the radionuclide transport in the near-field in a WP-Cave repository, 1987-1988 (SKB, Sweden)

- Principal Investigator of the international INTRACOIN study for testing models and computer codes for radionuclide transport through the geological barrier, 1981-1986 (SKI, Sweden)
- Principal Investigator of the international HYDROCOIN study for testing models and computer codes for ground-water flow calculations, 1984- (SKI, Sweden)
- Principal Investigator of the international INTRAVAL study for evaluating and validating models for radionuclide transport through the geosphere, 1987- (SKI, Sweden)

- Assistance in the preparation of the safety-analysis documentation for the LLW/ILW repository in Projekt Gewähr, 1985 (NAGRA, Switzerland)
- Modelling of radionuclide transport in the near-field of an LLW/ILW repository at Oberbauenstock, 1981-1985 (NAGRA, Switzerland)
- Modelling of the ground-water flow at Oberbauenstock for Projekt Gewähr, 1984-1985 (NAGRA, Switzerland)
- Investigations regarding the stability of concrete barriers in a repository for LLW/ILW at Oberbauenstock, 1986 (NAGRA, Switzerland)
- Investigations regarding effects of chemical changes and gas formation in an LLW/ILW repository; Detailed studies of mechanisms and consequences of gas transport in the engineered barriers and in the host rock for an LLW/ILW repository, 1982-1987 (NAGRA, Switzerland)
- Near-field modelling of an LLW/ILW repository, comprising near-field hydraulics, barrier degradation, radionuclide chemistry, and radionuclide transport, 1986- (NAGRA, Switzerland)

- Modelling of ground-water flow and radionuclide transport in the unsaturated zone at Centre de la Manche, 1986- (ANDRA, France)
- Modelling of water uptake and radionuclide transport in bitumenised waste, 1986- (ANDRA, France)

- Peer review of the Nirex Safety Assessment Research Programme, 1988- (UK Nirex Ltd, United Kingdom)
- Participation in the Taipower Back-End-Study coordinated by SKB; compilation of the projected radioactive waste inventory and evaluation of options for disposal of low and intermediate level waste from reactor operation and decommissioning, 1986-1987 (TPC, Taiwan)

Ecological Transport

- Modelling of the interface between the geosphere and the biosphere, discharge through a lake sediment layer, 1985 (SSI, Sweden)
- Calculation of radiation doses from a surface disposal of uranium containing industrial waste, 1986 (ABB-ATOM)
- Correlation of the radioactivity content in algae and in the water in the Biotest basin at Forsmark nuclear power station to that in the discharged cooling water, 1986 (SSI, Sweden)
- Modelling of the interface between the geosphere and the biosphere, discharge through a soil layer, 1988 (SSI, Sweden)
- Coordination of the International Biospheric Model Validation Study - BIOMOVS, 1984- (SSI, Sweden)

Safety of Transportation of Radioactive Materials

- Safety assessment of the transportation of radioactive materials in Sweden, 1978-1979 (SKI, Sweden)
- INTERTRAN - A model for world-wide risk assessment of the transportation of Radioactive materials, 1980-1983 (SKI, Sweden)
- Consequences of a ship accident involving spent nuclear fuel, 1981 (SKB, Sweden)
- Consequences of an airplane crash involving UO_2 , UF_6 , and fresh nuclear fuel, 1988 (SKI, Sweden)

Safeguards of Nuclear Material

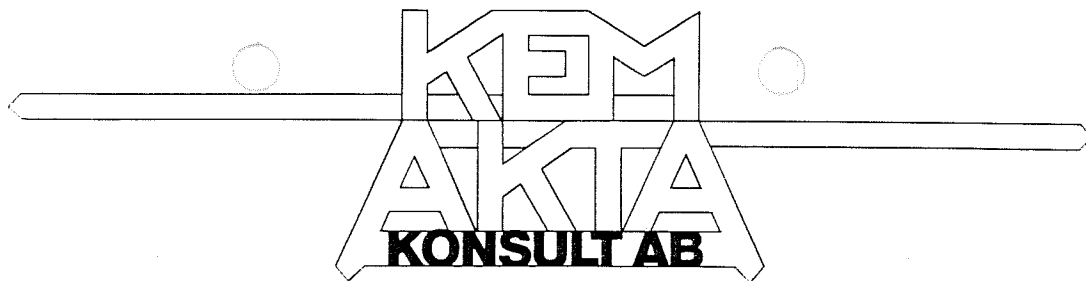
- Analysis of the content of safeguards inspections of the International Atomic Energy Agency (IAEA), 1987-1988 (SKI, Sweden)
- Modelling and programming the Book Audit Part of IAEA's Inspection Field Support System, 1988- (SKI, Sweden)
- Programming a system for calculation of uncertainty in Materials Unaccounted For (MUF) at the ABB-ATOM nuclear fuel fabrication plant, 1987-1988 (SKI, Sweden)

Other Safety Related Issues

- Consequences of release of UF_6 from a storage cylinder, 1977 (ABB - ATOM, Sweden)
- Review of the FILTRA concept for filtered ventilation of off-gases from major nuclear reactor accidents, 1982 (SKI, Sweden)
- Calculations of atmospheric dispersion for releases from the ABB - ATOM nuclear fuel fabrication plant, 1983 (ABB - ATOM, Sweden)
- Calculation of aerosol formation and transport during major reactor accidents, 1982 (OKG, Sweden)
- Review of a verification program for a system of venturi scrubbers for cleaning the off-gases from a core-melt, 1987- (SKI, Sweden)

Other Projects

- Evaluation of alternatives to satisfy SKI's needs for computing capacity for the research in the radioactive waste management area (SKI, Sweden)
- Development of a computer model describing the effects of different levels of tourism on employment and taxes in different areas, 1988 (Swedish Tourist Board)
- Model calculation of the effect of moraine covers on the weathering rate for sulfide containing mine tailings, 1988 (Boliden AB, Sweden)
- Review of the state-of-the-art of contaminant transport modelling for the unsaturated zone; Organisation and chairmanship of a workshop on contaminant transport in the unsaturated - saturated zones, 1988 (Environmental Protection Board, Sweden)



Steffen Robertson and Kirsten (B. C.) Inc
Suite 800
580 Hornby Street
Vancouver
B. C.
Canada

Attention: A. MacG. Robertson

George for

Maanda

Proposal

Formal proposal - month

July 2, 1990

Dear Andy:

RE: Modelling work and transfer of modelling technology

Thank you for your letter of May 28. I have sent an offer to Björn Södermark at the Swedish Environment Protection Board (SNV) on the conversion of my computer programs and the writing of manuals in English. He has in principal accepted the scope and costs. As a matter of fact the work to convert the programs started four weeks ago and a great deal of that part of the work is ready. Hans Lindberg, who is doing the programming part, is now on four weeks vacation but he will continue the work as soon as he is back. The entire project is planned to be completed by November 1, but the program conversion part will probably be ready much earlier.

About the two projects outlined in your letter I certainly agree with you that it would be preferable if ii) (technology transfer) could be completed before i) (Faro tailings). However, I suggest that the Faro tailings cover is used as the main example when training someone in your organisation (SRK). I think this would be an efficient way of getting the work done but it might not be possible to have it ready in November. How tight is your schedule for the Faro project? Could you please send some more information about the project. You visualize about two weeks work for me in Vancouver. Including traveling costs, but no substantial work made here in Stockholm before or after the tripp, this would cost about 79 000 SEK (CAN\$ ca 15 200). If an APEX ticket (must be ordered at least 3 weeks in advance) cannot be used the cost will increase with about 11 000 SEK (CAN\$ 2 100).

About the technology transfer project I am not sure I have understood your plans correctly. Do you mean that this project should consist of two different parts:

- 1) Setting up the programs and training someone at SRK (about two weeks work for me in Vancouver)
- 2) A "public" two day workshop organized by MEND to introduce the model to others in Canada.

A third part would then perhaps be: Setting up the programs and training someone at Noranda.

The cost for part 1 would be the same as for the Faro tailings project plus costs for some minor work made in Stockholm by me and my colleagues (say about 11 000 SEK or CAN\$ 2 100). However, some time could perhaps be saved by combining this part with the Faro tailings project.

I assume that MEND (or someone else in Canada) does all the practical arrangements and does the invitations. However, I think we, including Keith Ferguson, should sketch out a program as soon as possible. What is the goal for the workshop? What kind of people will attend it? How detailed should my model be described? What else should be included and by whom? As you understand, the time I need for preparations (and thereby the costs) will very much depend on the program content.

At this early stage I would like to give you a warning. If you want to model the water transport for more complex situations using the TRUST code (which is a part of my model) you will probably need a larger computer than a PC/AT. The DSI-machines we use at Kemakta are Unix machines with PC:s at the front. These machines have substantially larger active memory and makes calculations about 5 times faster than PC:s. More complex situations are e. g. two dimensional flow in layered media, layered media with very large differences in hydraulic conductivity or problems with many changes in infiltration and evaporation rates. If you have a computer with a Fortran 77 compiler available it should not be a large problem to install my converted programs on it because the programs will be ANSI Fortran 77 and all input and output is made on files.

Both my firm and I are very pleased with the results of my visit in Canada and we are very interested in continued cooperation. I enclose some information about our firm. Unfortunately, the list of major projects is not up to date so I would like to add three very interesting project:

- Mathematical modelling of water and gas transport in layered soil covers for coal ash deposits. 1989 (Swedish State Power Board)
- Release of contaminants from sediments as compared to remedial actions involving dredging and land disposal. 1990 (Swedish Environment Protection Board)
- TRUST + TRUMP: Coupling the TRUST and TRUMP codes for simulation of simultaneous unsaturated transport of solute and water. 1990 (Swedish Nuclear Power Inspectorate)

I have been told that the next issue of KEMAKTA News will be partly about our environmental projects. It is planned to be ready in the beginning of the autumn and I will put you on the mailing list.



Mr A. Mac G. Robertson
 Steffen, Robertson and
 Kirsten (BC) Inc
 Suite 800
 580 Hornby Street
 Vancouver, B.C. V6C 3B6
 CANADA

Dear Mr Robertson,

Re: AMD Research cooperation

Once more I want to thank you and your colleagues for making our time in Vancouver so enjoyable and for all your kind help and hospitality.

Referring to your letter of May 28th I want to inform you about the situation.

- i) As you have already heard from Marie Collin I have asked her to convert our program to an IBM compatible PC and to prepare a users manual. She has promised to finish this work before the end of October.
- ii) At the same time she and Anders Rasmuson will study your proposal to MEND on the development of a methodology for waste rock modelling and give their opinion about your approach as a background for our decision concerning a future participation.
- iii) Also, as you already know, I have asked Ann Marie Fällman at SGI to act as editor/contributor for Sweden to the International Mine Waste Management News. Hopefully, we will be able to use her as a Swedish information coordinator in the future.
- iv) Finally about the ARD short course. It seems to be a great interest for a course like this in Sweden. The financing, the time and the outline will be discussed more in detail after the summer holidays. Lars-Åke will keep you informed.

Concerning some background documentation to this course, we discussed a short version of "your" technical guide, as I recall it. Would it be possible for me to have a copy.

Yours truly

Björn Södermark

Environmental Protection
Conservation and Protection
Environment Canada
3rd Floor, Kapilano 100, Park Royal
West Vancouver, B.C. V7T 1A2

Our file: 4780-1

July 13, 1990

Dr. A. Robertson, P. Eng.,
Steffen Robertson and Kirsten
800-580 Hornby St.
Vancouver, B.C.
V6C 3B6

Dear Andy:

Re: Kemakta Konsult Proposal for Modelling of AMD

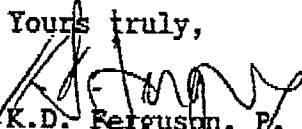
I have reviewed the letter from M. Collin of Kemakta Konsult AB of Sweden to you outlining a proposal to transfer their modelling technology for acid mine drainage (AMD) to Canada. As we discussed at the recent tailings modelling workshop, we believe this model is one of the important tools for examining the factors that control acid production in tailings, and evaluating means to reduce the release of contaminants. The model approach appears to be practical and technically sound, and should be directly applicable to several proposed and operating mines in Canada. As your firm is very active in designing AMD control approaches for several mines, SRK is a logical choice to develop and lead the technology transfer program in Canada.

I am also pleased that the proposal includes a workshop to transfer this technology to a wider audience in the mining industry, consulting companies, and government agencies. I believe this is necessary to maximize the benefits of this new technology.

Both the provincial B.C. Acid Mine Drainage Task Force and national Mine Environment Neutral Drainage Program (MEND) should be very interested in this proposal. As chairman of the Prediction Committees for both task forces, I would be prepared to support the proposal, should you decide to submit it to the task forces for approval.

Please keep me apprised of developments in this important project. Call me at 666-2399 to discuss any aspect of this matter.

Yours truly,


K.D. Ferguson, P. Eng.,
Manager, Mining and Metallurgy Program



Environment
Canada

Environnement
Canada

Canada



⇒ Keith
 Andy?
 R10
 Gemen?
 RBS?

IRAP - The Industrial Research Assistance Program of the National Research Council

Small- and medium-size firms are one of the main driving forces of the Canadian economy. Success in these firms is achieved not only by desire, hard work and business skills, but also by effectively adapting technologies to the firms' needs. Canada has substantial scientific and engineering expertise in government laboratories, specialized research centres, universities and consulting engineering companies which these firms may be able to utilize. There are even larger pools of technology abroad.

Through IRAP, the National Research Council aims to help Canadian firms put this technical expertise to work. Technology can stimulate their productivity, profitability and international competitiveness. IRAP assists manufacturing, resource, construction and service industries. Vital linkages between companies and sources of appropriate technology and expertise are provided through the IRAP Technology Network.

A Canadian firm can access the family of services offered by IRAP and the entire IRAP Technology Network through one of over 180 IRAP Industrial Technology Advisors located across Canada. The various modes of IRAP assistance are outlined below.

Field Advisory Service (IRAP-C)

With the resources of the IRAP Technology Network, the IRAP Advisor can assist a firm to: define its technical needs; identify technical opportunities; obtain technical information and assistance; solve product and production problems; access or acquire technology and expertise from Canadian or foreign sources; access financial assistance programs and refer the firm to other assistance.

International Technology Service (IRAP-I)

The NRC IRAP program provides assistance to firms to locate and make use of technology from foreign sources.

We will apply for technology transfer under this program

Projects employing students (IRAP-H)

Some short-term projects for product or process development can utilize the skills of a university- or college-level engineering or science student dedicated to the task. IRAP covers most of the student's salary and the services of Project Technical Counsellors as required. These counsellors monitor the technical progress of the project and provide technical guidance where necessary.

Short-term Projects (IRAP-L)

A firm may need specialized help from outside facilities for projects involving product testing, product or process design or development, or engineering feasibility studies. IRAP can contribute up to \$5,000 (or 65%, whichever is lower) for such projects provided they are less than \$12,000 in total cost.

Medium-term Projects (IRAP-M)

IRAP can contribute up to \$100,000 towards the salaries of technical personnel, from the firm or subcontracted, for specific projects to develop new or improved products and processes.

Long-term Projects (IRAP-R)

For a project with high risk but high potential benefits IRAP can contribute funds to help a firm team up with experts in Canadian federal, provincial or university laboratories or with international resources to pursue the development of promising new technologies for commercial exploitation.

FOR INFORMATION AND APPLICATION FORMS FOR THESE IRAP PROGRAMS, CONTACT THE NEAREST IRAP ADVISOR.

THE ADVISOR'S TELEPHONE NUMBER IS LISTED IN THE YELLOW PAGES UNDER TECHNOLOGY-ASSISTANCE.

Distribution and Flow of Water in
Unsaturated Layered Cover Materials
for Waste Rock

Marie Collin

Anders Rasmuson



Royal Institute of Technology
Department of Chemical Engineering
S - 100 44 Stockholm
Sweden

MATHEMATICAL MODELLING OF WATER AND OXYGEN
TRANSPORT IN LAYERED SOIL COVERS FOR DEPOSIT
OF PYRITIC MINE TAILINGS

Marie Collin

Licentiate Treatise

April 16, 1987