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Stanley

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007543

Curragh Resources Corporation
c/o Dome Petroleum Limited
12th Floor, 630 - 3 Street S.W.
Calgary, Alberta
T2P 2H8

Attention: Mr. Gary Webster

Dear Sir:

Reference: Determination of Chemical Stability of Ore, Waste Rock and Tailings for Development of an Abandonment Plan

Due to the magnitude of the Faro mining operation and the type of waste material generated, development of a final abandonment plan is essential to provide an economical environmentally sound means of final abandonment. A number of technical questions must be addressed initially to allow abandonment planning to be incorporated into ongoing mill site operations. Stanley Associates is pleased to present this proposal to conduct the above mentioned study related to materials chemical stability.

In preparation of this proposal we have assembled a team of experts from Stanley Associates, Beak Associates, Thurber Consultants and the University of Alberta to address a number of specific questions. We are able to offer the service of any individuals from throughout the Beak organization because of our operating agreement with them. The study team identified in the proposal consists of geochemists, hydrogeologists, microbiologists, geotechnical engineers and chemists all of whom have the necessary qualifications to undertake a project of this magnitude and significance.

The study team offers a factor which will be of interest to Curragh. Members of the study team are without association with this mine and are therefore free of incumberances defending previous work. We are free to assess the past and look to the future with no conflict of interest. This will ensure a quality product. point

We look forward to your approval to proceed and are available to discuss this proposal at your convenience.

Yours very truly,

STANLEY ASSOCIATES ENGINEERING LTD.

R.P. Innes, P.Ag.
Senior Environmental Scientist

RPI/tlz

DOME

INTERNAL CORRESPONDENCE

To K. Forgaard (Faro), R. Visagie (Toronto), M. Pelly (Whitehorse), R. Sultan (Toronto), J. van der Linden (D-30)

Date 86-03-18 (YEAR MONTH DAY)

From Gary Webster

Environmental Services (DEPARTMENT AND LOCATION)

File 8.22.0

AWARD OF ENVIRONMENTAL PREDICTION/FLOODED-
NONFLOODED TAILINGS ABANDONMENT OPTION
TO STEFFEN, ROBERTSON & KIRSTEN (SKR)

I recommend that prior to you reviewing this memo any further that you read the attached submission from SKR focussing on the three issues:

1. the concept of modelling the "acid production" of the Anvil tailings in the nonflooded abandonment scenario;

2. the concept of designing the tailings deposition to minimize surface area and at the earliest possible time to complete mining from Zone 1 pit to allow use of the exhausted Zone 1 pit as a tailings repository for tails produced from the Vangorda Plateau;

3. the concept of going from an "effluent parameter" based water licenced to the concept outlined in the SKR third alternative to a "receiving water" based licence.

It was my recommendation that SKR be chosen to conduct the studies as their proposal was the one that best addressed the issues and problems facing Curragh. I recommend that you seriously consider awarding the contract to SKR on the basis of Alternative 2 of doing work on Tasks 1, 2 and 3 through 8, but cutting back on Task 2, to allow $500 to review the geochemical data to determine if it has potential value in the overall problem assessment.

Before I recommend Curragh go for the receiving water criteria (as described in Alternative #3), it is important to assess the results of the modelling of nonflooded abandonment and its "worst case" impact on Rose Creek and to understand its risks as well as its positive aspects. Once this has been assessed internally, the concept then has to be developed, marketed and sold to the parties concerned.

GAW/lr
Attach.

7/11

3. ALTERNATIVE #1: CRC-RFP, TASK-BY-TASK PROPOSAL

This section of the proposal identifies the technical approach, work scope, manpower and cost estimates for the eight groups of tasks given in the RFP, together with an additional task of data collection by a site visit to the mine. Each group of tasks is described and costed individually, on a task-by-task as specified in the RFP.

Profiles of the individuals who are proposed for these tasks are given collectively in Section 6 (manpower and management) of this proposal and are common to all three alternative approaches. Their resumes are included in Appendix 1.

3.1 Task 1: Model Review and Suitability Assessment

Objective

The objectives of Task 1 are:

- to review available chemical models which predict acid generation from mine waste, including the model of Halbert and Scharer (1983) used in the Klohn Leonoff, 1981 study;
- to assess the extent to which site monitoring data confirms existing model predictions;
- to comment on the suitability of all currently available, alternative models to predict acid generation;
- to recommend a suitable model for acid generation prediction; and
- if acid generation is predicted, assessment of buffering capacity of receiving water to combat such acidity.

Technical Approach and Workscope

A review will be presented of currently available models and their usefulness with respect to accuracy for prediction of acid generation from mine wastes. This review will include relatively simple static models through to the more complex models based on kinetics, mineral and solution phase equilibria. (A basic discussion of the use of such models is given by Ferguson, 1985). The 1981 Klohn Leonoff model will be included in this review.

Based on this review, comments will be made on the advantages or otherwise of these models and their applicability to the Faro mine wastes for the prediction of acid generation will be appraised. Comparison will then be made with the current, 1981 model. From the comparison, a specific recommendation will be made as to the most appropriate model for CRC to use.

(2)

When consideration is made of the applicability of the present model, its success in predicting acid generation and consequent water quality will be measured by comparison with available monitoring data: i.e., pore water quality data from the tailings mass and water quality monitoring data, as defined in the water licence and its attached documents.

Should it be shown that the present model or an alternative, recommended model predicts acid generation and hence trace metal mobilization from the tailings, then the "loading" from the tailings will be assessed in terms of the buffering capacity of the receiving waters (surface water and near-surface groundwater). The evaluation will focus on the rate of acid generation and trace metal release, as the rate determines the loading. Clearly, it may be possible for some acid generation to occur (with its metal release) as long as the total buffering capacity of the receiving waters is sufficient to limit or nullify the impact such generation has on downstream water quality. The relative impact is a time dependent, mass loading problem, and, therefore, this approach will be used in the problem assessment. Changes in receiving water discharge and chemistry (hence buffering capacity) with time and season will be addressed as acid generation may be acceptable during one season when the total buffering capacity is high and no longer acceptable during another time period.

Manpower

Model review and assessment	Mr. Ab Bruynsteyn
Geochemistry and hydrochemistry	Dr. Adrian Smith
Impact assessment and criteria	Dr. Jim Malick

Cost Estimate

Professional costs	$ 7500.00
Disbursements*	$ 2000.00
Total for Task 1	$ 9500.00

3.2 Task 2: Review of Geochemical Data

Objective

Review of the use of exploration geochemical data to predict chemical stability of the ore.

(Note: In all task cost estimates the term "disbursements" includes engineering assistance, technician, drafting and secretarial costs, as well as direct costs.)

Discussion and Technical Approach

In their 1981 study, Klohn Leonoff Ltd. considered three abandonment plans:

(i) unsaturated tailings;

(ii) summerged tailings; and

(iii) in-pit disposal.

They recommended the adoption of submerged tailings, largely because of the advantages it had with respect to controlling:

(i) oxidation and acid generation in the tailings

(ii) erosion of the tailings surface along the Rose Creek channel

There are very significant advantages. However, the scheme also has a number of disadvantages. These include:

(i) questionable long term stability of the throughflow spillway;

(ii) high hydraulic heads, causing a relatively high seepage (and therefore leaching) flow through the tailings;

(iii) poor flexibility, if the impoundment had to be abandoned early; and

(iv) high costs.

Because of these disadvantages it is appropriate that nonflooded alternatives be evaluated. The object of such a review is to identify alternative abandonment measures which can be implemented which would result in a nonflooded impoundment sufficiently low environmental impact on Rose Creek in the long term such that it will be accepted by the regulatory authorities. Crucial to this review of alternative abandonment measures is the establishment of the criteria for acceptable long term environmental impact of Rose Creek. Abandonment measures can then be designed which will achieve the necessary criteria. Many of the required actions may have large cost implications and a successful design depends on the identification and implementation of that combination of abandonment measures, which together achieve the criteria at the lowest cost. Some of the potential measures are discussed below.

(i) Managed Tailings Discharge

(a) Control of surface geometry

The shape of the tailings surface determines the long term runoff and impoundment of water. The shape that exists at the time when tailings discharge is terminated is dependent on where and how the tailings were discharged. Reshaping by moving the tailings is extremely costly. The development of a suitable surface profile on the tailings can be achieved during impoundment operation by using appropriate discharge locations and techniques. In the review, consideration will be given to alternative tailings discharge arrangements to develop a surface profile which allows rapid water runoff towards a drainage system and on which ponding can be prevented. This will minimize the cost of tailings re-shaping:

(b) Control of surface characteristics

It is desirable to achieve a tailings surface with the following properties:

- low permeability to limit infiltration and air entry;

- good drainage to allow trafficability;

- gentle uniform slopes to limit erosion; and

- optimize conditions for vegetation growth.

The surface characteristics of the tailings can be substantially varied by different discharge and beach management techniques. These include:

- using distributed discharges, such as numerous spigots or distribution bars;

- placing thickened discharge;

- discharging in rotating panels; and

- limiting and controlling the pool location and size

The cost of these measures are small compared with the placement of cover layers. Additional measures can be implemented for the top meter or so of tailings such as:

- addition of imported bentonite or local clays to reduce permeability; and

- addition of excess lime to provide a chemically active layer to infiltrating water or emerging seepage.

Alternative measures will be reviewed to identify those that would limit infiltration and oxidation and be most cost effective.

(ii) <u>Control of infiltration</u>

Because of the high permeability of the foundation soils (sandy gravels), the seepage from an unflooded impoundment will be determined by the rate of infiltration. Control of the total volume of infiltration therefore controls the volume of contaminated seepage.

(a) Control of surface drainage

Good surface drainage reduces both the time during which infiltration occurs and the hydraulic head. This is achieved by having a good slope on the tailings to defined drainage channels. Water accumulation in depressions must be avoided. Since the tailings continue to settle after abandonment, depressions can develop with time. This is prevented by anticipating the zones and amount of settlement and designing the abandonment surface profile to allow for settlement. All surfaces and drainages must be stable in the long term. Sheet, rill and surface erosion can disrupt the designed drainage system. This is substantially avoided by appropriate layouts.

(b) Control of surface permeability

The surface permeability can be controlled at the time of abandonment by:

- controlling tailings characteristics;
- using additives in the last meter or so of tailings; and
- placing a low permeability cover layer.

Cover layers could be designed to different degrees of complexity, i.e., incorporating such ion breaker layers, etc. However, such covers are very costly and should be avoided, if possible.

Because of the relatively low permeability of the tailings they have considerable potential as a sealing layer themselves. One potential may be to dredge slimes from the pond area and hydraulically place a layer of this on the coarser tailings.

The long term stability of this cover is important. Vegetation and root action will change the surface permeability. Front heading and pingo formation may be very rapid in the silt sized tailings. These aspects have all been examined in detail in the CANMET studies and appropriate avoidance measures identified.

(iii) Control of Leachate Quality

The total seepage impact on Rose Creek will be determined by both the quantity and quality of the seepage. There are a number of measures which can be evaluated for the control of the quality of the seepage.

(15)

(a) Control of oxidation

The oxidation of the tailings to produce acid is highest in the unsaturated tailings above the water table. Thus the amount of oxidation can be reduced by limiting the volume of tailings located above the phreatic surface in the tailings impoundment. The location of the phreatic surface will be controlled by the level of the spillway and the drainage channel across the tailings to the spillway. By optimizing the level of these facilities relative to the remainder of the tailings the unsaturated zone may be minimized. It is possible that with the good underdrainage existing in the valley, the phreatic surface may fall below the invert of the drainage facilities and this potential will be assessed.

Oxidation in the partially saturated zone is dependent on the rate at which oxygen becomes available for oxidation. This can be controlled to some degree by achieving or installing a low permeability cover. Ice lensing which may have been, or could deliberately be, incorporated into the tailings mass in the beach areas could potentially be a large inhibitor of oxygen entry and oxidation. The thermal stability of such ice lenses over the long term would have to be considered.

(b) Control of acidity

Some measure of acidity control can be achieved by installing chemically active layers. The incorporation of lime into the cover layer or its injection into the foundation gravels would provide some measure of pH control. The long term effects of such measures are always questionable due to continual leaching and must be assessed.

(iv) Control of Erosion

Wind erosion can be controlled by either vegetation and/or rip-rap or desert pavement type solutions.

Sheet erosion is also soluble in the long term by available techniques for which design guidelines have been proposed in the CANMET study.

Gulley erosion on the tailings will require careful design and evaluation. Slope control (by tailings discharge techniques) and use of durable rock waste (readily available) to develop hydraulic energy control points.

Stream channel and spillway erosion are a major concern. The development of a large (50 m wide by 10 m deep say) durable rock water lined stream channel over the tailings impoundment appears to be technically feasible. Control of velocities in this channel can be achieved by a very stable hydraulic control at the spillway crest. Such a channel is too wide to block and would accommodate the maximum probable floods. The two most important aspects of its feasibility will depend on:

- appropriate pre-planning and designing to make its construction feasible. Some under water excavation (dredging) and water rock placing (from a barge) may be required; and

- the achievement of a secure hydraulic control at the spillway crest.

The spillway crest and spillway to this channel will be the major engineering challenge. However, there is ample durable rock waste available to build an appropriate spillway geometry. Note that the total spillway energy dissipation requirements will be considerably less for a nonflooded impoundment than for a flooded impoundment, since the spillway crest is at a lower elevation. We anticipate that even with a very favourable spillway geometry, some erosion resistance will have to be built into the spillway. We are of the opinion that this could probably be achieved with a limited depth of in-situ cement/concrete grouting in the critical erosion zones. Based on our current understanding, we believe it will be possible to construct a stable long term spillway using a combination of spillway geometry, durable waste and in-situ cement/concrete grout.

Workscope

The workscope for task 8 is described into 3 sections, as detailed below:

Task 8.1 Data Collection and Review

Collect and review available data on the existing tailings impoundments to obtain a thorough understanding of the following:

- tailings properties and their in-situ characteristics in the impoundment;

- soil, rock and foundation conditions;

- available construction materials from the mine (waste) and borrow sources;

- groundwater and seepage conditions, including the potentials for geochemical retardation;

- hydrology condition and extreme events to be designed for;

- permafrost conditions and earthquake hazard;

- tailings impoundment construction and operating records and practices;

19

4. ALTERNATIVE #2: INTEGRATED PROJECT TEAM FOR ORIGINAL CRC TASK PROPOSAL

The concept of alternative proposal #2 is to integrate the task-by-task technical requirements discussed in Alternative #1, section 3, and provide a combined project team to perform the program. Therefore, the technical approach and scope are essentially the same as alternative #1: The description of these items will not be repeated here. However, the combination of the tasks together makes for efficiency in the removal of repetition of some aspects of individual tasks. It will, therefore, be more efficient by requiring less individual project management, project coordination and control, and cost to CRC.

The following efficiencies can be effected both in terms of time and cost, by integrating alternative #1 into a single group of tasks:

- buffering capacity of the receiving waters, required in tasks 1, 3 and 8 need only be assessed once, and avoids the potential for differences arising between separate groups;
- the basic understanding of and data review for tasks 4 and 5 are similar and cost savings can be made by their combination;
- the monitoring aspects of task 3 can be integrated with the review of monitoring in task 7;
- groundwater flow and geochemistry evaluated in task 3 can be used directly in task 8;
- minor savings in the estimation of toxicity units because of integration of aquatic biologist in tasks 7 and 8;
- a single site visit ~~to~~ by one member of the project team to collect all the data. w/o

The cost estimate for alternative #2 is given in Table 7.2 and is assessed to be $71,500.00.

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5. ALTERNATIVE #3: SRK/NORECOL TECHNICAL APPROACH FOR INTEGRATED PROJECT EVALUATION

5.1 Overview

As a result of our review of the existing data to us, particularly the 1981 Klohn Leonoff report and the various EPS documents and CRC's RFP, we believe it is appropriate to "step back" and clarify the objectives of any study in terms of its real benefit to CRC. CRC's objective is, presumably, to formulate a tailings facility abandonment scheme which will be acceptable to the regulatory authorities in terms of its impact on Rose Creek but be cost effective (i.e., a lesser cost than the 1981, $50 million current abandonment scheme).

If this is the objective, we suggest that it may be best approached by understanding what discharge can be made to Rose Creek without significantly impacting the water quality or the aquatic biota. Once this is established, then a set of design criteria for the tailings facility, on abandonment, can be established and alternative abandonment designs can be evaluated against these criteria. Clearly, the release rate of seepage and the seepage chemistry will change with time, as will the capacity of the receiving water (Rose Creek) to accept that seepage; the design criteria will, by necessity, have to incorporate this variability. Fundamentally, this is a mass loading problem, which is time dependent.

At present, CRC will require a modification of their Water Licence if the regulatory authorities accept an alternative to the current abandonment plan. At the same time, it is our opinion that CRC should attempt to have receiving water standards as their criteria for effluent seepage, particularly on abandonment. With time, it is likely that the seepage volumes for the tailings will decrease, but its quality will deteriorate and will never meet the current effluent standards (Part B, 2(F) Water Licence). In any case, in terms of impact at Rose Creek, it can be argued that receiving water standards are a better measure of any impact.

5.2 Technical Approach

Our technical approach would be as follows:

- o assess the "acceptable" mass loading to Rose Creek by taking the range of chemical variation in the seepage (pore water) composition and simulating its seepage volume variation with a range of discharge/chemical conditions of Rose Creek;
- o from this analysis, develop design criteria for acceptable seepage/flow losses from the tailings mass and acceptable chemical composition in these discharges; and

August 14, 1986

File: 60601

MEMORANDUM

TO: DR. ANDY ROBERTSON, SRK

FROM: ADRIAN SMITH, ASCI

RE: CURRAGH RESOURCES CORPORATION: TAILINGS ABANDONMENT REPORT
TASK 7: GROUNDWATER MONITORING PROGRAMME

This memo addresses my further review of the issues related to groundwater quality monitoring, with respect to the above. As you know, I was not entirely satisfied with my previous report in terms of the depth of my previous review and I have reconsidered a number of the issues related to groundwater quality.

In particular, I have re-examined the following:

- 1982, 1983, 1984, 1985 annual reports on monitoring;
- Environmental and Water: Tailings report file - 1976-1980;
- Environmental summary sheets: 1981-1982;
- 1983 water quality sheets;
- transmittals to the Controller of Water Rights, 1981-1982; and
- Klohn-Leonoff/Senes and Golder Associates data and reports.

From this re-examination, I have found nothing that contradicts or fundamentally changes my comments and recommendations in section 7.3 - groundwater monitoring- of our initial report. There are a couple of items which bear further comment and I have addressed these below.

I would be grateful if you could inform Curragh that the extra time and costs associated with this re-examination are not for their account.

Background Water Quality

Both in sections 7.3 and in Task 1 of the report, the problem of background water quality was discussed. I believe that the previously held premises of what is background are not correct and this, perhaps, should have been stated a little more positively. Specifically:

- well X-20 was considered to be background "as this well is on the backslope side of the diversion canal", (CAMC, 1983 water licence annual report).

  The chances of this actually representing background quality are small. It will be cyclically affected by the recharge due to freeze, thaw and flooding. It is not up hydraulic gradient of the system. In essence, it probably represents a melange of water qualities and is not a good well on which to base impact.

- DH81 - K4, K5, K6 are suggested to be background because they show "no signs of contamination", even though they are in a position to be impacted by poor quality water. As the difference between, say 0.05 and 0.005 ppm will make a substantial difference in impact and compliance analysis, and both might be considered by the casual observer to be background, how can there be any confidence in the supposition of a background well?

- the interlaboratory analytical evaluation (CAMC/Chemex/Can Test) reported in the Klohn Leonoff, 1981 document, indicated much of the data collected prior to 1981/1982 could be high by an order of magnitude. Conversely, improper sampling/handling of water samples for trace metal analysis can lead to low results by, say, an order of magnitude. In view of the extreme importance of background levels in determining impacts due to release from the Faro tailings, the data base is critical and is, in my opinion, questionable at best.

The above should not be taken as outright criticism. It is difficult to a simple and analyse for trace metals at the low levels required for background monitoring. It is also difficult for any assay lab, used to doing ore analysis at the percent level, to do trace metal analysis in water. This has been proven on numerous occasions.

Sample Volumes

Throughout the annual reports and the data sheets, there is mention of "no sample", "little" sample or "insufficient" sample on numerous occasions. Yet analyses for trace metals have been made on very small, turbid samples containing a large proportion of suspended matter. Despite careful handling and filtration, these analyses most likely represent an estimation of the metal contents of suspended material in the water in the 0.2 to 0.45 micron range at best, and a larger size, at worst.

There is, in my opinion, no point in analyzing such samples. The results are misleading to the Company and can be harmful to their case when presented in annual reports to the regulatory authorities.

Monitoring Program

The comments made on both the location of sampling wells and frequency (i.e., the change from bi-monthly to quarterly) are considered valid. One issue on monitoring that should be addressed is what data might Curragh themselves need to gain an understanding of how their system is functioning, as opposed to the need to satisfy the regulatory authorities and conform to their license conditions. The following would be of value in this regard, in addition to the present/proposed monitoring system:

- one or two uphydraulic gradient, groundwater monitoring wells; and
- a series (two or more) of nested or multilevel piezometers or lysimeters in the tailings from near-surface to depth covering the oxidized ozone, through the intermediate zone down into the reduced zone of the tailings. The object would be to evaluate the time dependent, geochemical evolution of the tailings.

(It should be noted that I have problems with the normal lysimeter installation and operation procedures. This system would require very careful design and installation).