nhc **memorandum**

northwest hydraulic consultants

30 Gostick Place
North Vancouver, BC
V7L 1S6
ph. 604 980-6011
fax 604 980-9264

To:	**John Brodie, FMCPO**	Date:	February 28th, 2006
From:	Barry Chilibeck **(nhc)**	Project:	3-4355
cc:		Pages:	6

Re: RCDC Options Analysis Summary

This memo has been prepared to summarize and present concepts of the Rose Creek Diversion Channel (RCDC) for final design. These were developed from the initial project meeting held at **nhc** offices on November 15th 2005, and subsequent discussions and investigations.

Background

The initial project meeting was held to discuss the previous study results, new information and issues arising from additional work conducted in the intervening period. The approach was to coalesce the issues to identify one or more viable concepts that would allow nhc and BGC to go forward and determine a final concept. These recommendations were based on the review of present data including the **nhc**/BGC 2004 report – *Hydrotechnical Study for Closure Planning, Faro Mine Site, Yukon*. Issues with some of the concepts developed in the 2004 report included:

- Concerns regarding stability of the spillway structures and long-term maintenance issues.
- Stability and long-term water management issues related to an engineered channel across the tailings.
- The use of additional rock drains to attenuate flows and reduce conveyance structure size.
- Elevated dike designs with loadings applied to existing tailings and areas of known prior instability.

Design objectives for the RCDC in closure were discussed, and a recommended course-of-action was proposed. These items include:

- Conveyance for the design PMF – with and without routing through the NFRD – to be determined with ongoing work.
- Accommodate tailings management options including:
    a. complete removal of all dams and tailings,
    b. removal of the Cross Valley Dam only (stabilize in place option), or
    c. removal of the Cross Valley and Intermediate dams and removal of the tailings between the Intermediate Dam and the Secondary Dam.

The direction provided to **nhc** was specifically:

- Use geotechnical and hydrotechnical parameters to be consistent with current and proposed Canadian Dam Association (CDA) standards,
- Provide complete geotechnical solutions for poor foundation conditions in the south slope, under the dike and potentially under the channel,
- A single spillway option at or near the Cross Valley Dam left abutment, as determined by geotechnical and hydraulic considerations,
- Provide fish use and passage for species and lifestages – as required – through the RCDC, and provide opportunities for appropriate aquatic habitat restoration in the overall design,
- Identify and acquire additional data, as required, and
- Identify options to reduce the potential effects of glaciation or aufeis in the channel.

Progress to Date

Since the November meeting, considerable work has been done to better define the underlying geophysical conditions and geotechnical implications to proposed changes to the RCDC. BGC has been requested to provide geotechnical information, as required, on potential options, as well as clarification of previous design issues with the RCDC design. These issues included estimates of depth to bedrock, mapping of geological and surficial materials, and review of as-built reporting. Drilling log data and surficial material data was plotted, and foundation conditions identified along the length of the RCDC. Additional topography was also prepared for areas where an expanded channel section could ultimately daylight beyond existing data.

As-built information suggests that considerable deformations have occurred along the RCDC dike profile. More recent ground survey information was also included that provide better detail along most of the RCDC than the existing air photogrammetry. This data was added to existing topography. Additional survey data collected as part of ongoing care and maintenance work is being reviewed to further characterize dike raising geotechnical issues.

The PMF data was delayed substantially, as has the subsequent analysis required at the North Fork Rock Drain (NFRD). The preliminary PMF estimate provided by WMC (2006) is 674 m^3/s, which is very close to the **nhc** (2004) estimate of 690 m^3/s. As such the conveyance area required in the RCDC will remain relatively unchanged. On recommendation from BGC, re-excavation or deepened excavations into the base of the channel to enlarge or expand hydraulic capacity was not ideal. As-built monitoring and field reports indicate extensive seepage and stability issues. Considerable buttressing, foundation improvement and/or reconstruction of the dike, particularly in the section near to the Intermediate Dam, will be required. A combination of expansion of the diversion north into the slope and raising of the RCDC dike are required along the length of the structure. Measures to address stability of excavated permafrost slopes will also be required.

Concepts

With or without routing by the NFRD, the RCDC will require upgrading to convey the PMF in closure. The amount of upgrade work required for the RCDC depends on the tailings management options and ultimate location of the spillway as required safeguard remaining stored tailings. As such, the tailings management options then direct what hydrotechnical options are possible. Analysis of the tailings options tend to collapse the hydrotechnical options to two designs. The three tailings management scenarios are:

1. Complete Tailings Removal:
   Complete tailings relocation will require removal or breach of both the Cross Valley and Intermediate Dams. Short-term actions would include maintaining the RCDC in current configuration until groundwater remediation complete, then return Rose Creek to the valley floor is some stable channel configuration. The RCDC would then be sealed off and decommissioned. This option is not part of current **nhc** scope of work.
2. Stabilize in Place:
   Remove the Cross Valley Dam and upgrade the RCDC to convey the PMF. Construct a new flood spillway starting at mid-point between the existing Cross Valley and Intermediate dams, or upgrade the existing spillway to convey PMF flows. Fish passage upgraded and maintained in modified version of existing RCDC.
3. Partial Tailings Removal:
   Remove Intermediate and Cross Valley dams and tailings behind Intermediate Dam. Construct new spillway below Secondary Impoundment dam, and upgrade RCDC from inlet to new spillway to convey the PMF. Fish passage upgraded and maintained in existing RCDC.

Stabilize in Place

In-place stabilization of the tailings would require upgrading of the RCDC along its entire existing length to convey the PMF. As discussed earlier, this involves expanding the channel by raising the dike on the right bank, excavating the slope on the left bank or both, while addressing the geotechnical issues identified above. The proposed freeboard for the channel is 0.5 m at the PMF to address potential aufeis, slope failure blockage, wind and wave run-up which will be evaluated as part of the final design.

A new spillway structure would be required downstream of the Cross Valley Dam left abutment. A new fish passage channel would be required or the remaining downstream RCDC would be upgraded. The most practical option would involve use of the existing RCDC below the Intermediate dam to convey flood flows up to the 100 to 500-year level, and excess flows from more extreme floods up to the PMF would be spilled through a new steeper channel which crosses the Cross-valley dam and pond, as shown in Figure 1. .

Another spillway option would involve upgrading the RCDC along its entire length – including

the current steep section at the downstream end – to PMF conveyance capacity. The furthest downstream reach of the RCDC where the slope increases from less than 0.2% to nearly 5% would be improved to convey the flow and provide fish passage under normal flow regimes. Upgrading the channel – based in bedrock – would remove the requirement of constructing a new spillway on the left valley wall near the Cross Valley Dam. It is recognized that the depth to bedrock will make this a difficult and costly option to implement.

Partial Tailings Removal

Partial tailing removal will require removal of the Cross Valley and Intermediate Dams. Spillway locations suitable to convey flows to the valley floor for the partial tailings removal option are approximately half way between the existing Secondary and Intermediate Dams. In this area, a spillway on bedrock is possible and the channel would be well away from groundwater collection areas.

The hydrotechnical design is similar to the stabilize in place scheme. The existing lower RCDC channel downstream of the spillway would be upgraded to improve fish passage conditions and ensure channel stability. In mine closure, this channel will convey flood flows up to the 100 to 500-year level, and excess flows from more extreme floods to the PMF would be safely routed down a spillway. This spillway would be situated about 500 m downstream of the Secondary Dam.

Channel and Spillway Stability

The design constraints – hydrology, geology, and topography – pose a difficult problem for the PMF spillway. Previous work has shown that a rip-rap lined channel would be subject to erosion in an extreme flood event which could regress upstream and compromise dam and tailings stability. A concrete spillway could be designed to pass the flood without erosion, but it would require continuous maintenance and repair work. A spillway founded entirely on competent bedrock is not possible. Consequently, a low maintenance solution cannot be achieved. In recognition that an ideal solution cannot be readily and cost-effectively achieved, our focus has been applied to how to best minimize maintenance while ensuring stability and integrity of the structures.

Key to the design of closure at Faro mine is stability of hydrotechnical structures and facilities. Safety and stability of the tailings and remediation facilities must be ensured. In the conceptual design of the RCDC, we propose to ensure adequate capacity for the PMF, that the bed and side slopes are hydraulically stable, and geotechnical requirements are integrated into the upgrade plans. Contingencies will be incorporated to address potential side slope failures, permafrost degradation, channel blockages, ice and sediment.

At transitions between the hydraulic structures – spillways and flow control structures – the stability of the RCDC channel would be ensured with a large keyed section of mass reinforced concrete. These will be set below finished grade which will provide protection from

environmental degradation of freeze-thaw and spalling. The key sections would be located above the spillway sections, at the flow control structures and the transition to the steep channel. The keyed sections would entail excavation to bedrock and re-building with thick-walled (1 - 2 m) mass concrete structure to ensure the channel could not degrade or back cut and destabilize the remaining RCDC and tailings. Keying and footing to bedrock also provides bearing and lateral resistance for the expected hydraulic forces on these structures during the PMF.

Steep sections of the channel and spillways will be constructed of large diameter (1 - 2 m dia.) rip rap installed and founded to bedrock where possible, and of sufficient mass and quantity to resist scour and erosion, uplift and plucking. It is anticipated that some of this rip rap will be sourced from the base of the North Fork Rock Drain.

At the PMF, some movement and loss of material in the spillway is expected (as was identified in previous RCDC designs), and lower sections of the spillway would likely be damaged and eroded material relocated into the spilling basin. However, the integrity of the RCDC and the dams would be ensured as erosion can not progress upstream due to the buried key concrete sections. Reconstruction of the spillway after a PMF would be required, but it would be relatively minor and part of a monitoring and maintenance program associated with the overall closure plan..

The lower steep section of the existing RCDC will function up to 500-year events with limited maintenance (e.g. replacement of fish passage roughness and weirs) and would discharge the flows approaching the PMF in a controlled manner with minor movement of riprap. Resulting in a requirement for some repairs, managed in the same manner as the spillway.

With the inclusion of keyed concrete structures and redesign of the RCDC channel and spillways, a stable PMF conveyance can be assured with some movement of the rock lining in the spillways and steep channel sections, and would preclude any potential for erosion progressing upstream towards the Intermediate Dam or tailings. The widened RCDC will incorporate a pilot channel to reduce the effects of glaciation or aufeis. Even with a pilot channel, winter conditions may still result in glaciation of the RCDC in some winters. Periodically, excavation of accumulated ice may be required. Some regular maintenance and clearing of debris will be required to ensure that the pilot channel remains open. However, velocities should be sufficient to ensure fine sediments do not aggrade in the channel and are mobilized over the expected range of flows.

Summary

The hydrotechnical options for upgrading of the RCDC for closure involve improvements to the channel to convey the PMF safely and design of a ramp spillway to convey the flows to the valley floor. The location of the spillway and length of upgraded RCDC is a function of the closure tailings option selected. The risks lie predominantly in the design and construction of the spill structure capable of conveying flows in excess of the RCDC capacity (up to 550 m^3/s), the likelihood and ramifications of material movement, and potential failure of these structures on the remaining RCDC and remaining tailings.

We suggest that the critical section hydraulic design using large rip rap and keyed reinforced mass concrete control structures ensures stability of the RCDC and remaining tailings and minimizes any potential long-term risk to the remaining tailings. Upgrades to the RCDC can be made to ensure fish passage and remain stable during the PMF with limited movement of erosion protection. The repairs would be minor and infrequent, and accomplished at minimal cost as part of overall closure monitoring and maintenance.

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Please contact us if you have any questions or comments regarding the outlined design criteria.

Prepared by:

Barry Chilibeck, P.Eng.

Attachments:

Conceptual Upgrade Options Sheets 1-4