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Scoping Studies for Final Closure and Reclamation Plan Faro Mine, Yukon

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SCOPING STUDIES FOR FINAL CLOSURE AND RECLAMATION PLAN, FARO MINE, YUKON

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EXECUTIVE SUMMARY

This report presents the results of scoping studies related to closure and reclamation of the Anvil Range Mining complex. The studies were completed by a team made up of engineers from SRK Consulting Inc., Gartner Lee Ltd. and BGC Engineering Inc. It is the intent of the Interim Receiver that the studies will provide input to further closure planning, specifically for planning meetings in 2003 and the implementation of more detailed studies in the years 2003 and 2004.

There have been several previous efforts at closure planning for the Faro and Vangorda/Grum sites. The following documents were reviewed and closure-related information was summarized in table form:

- 1996 ICAP (Faro, Vangorda, Grum)
- 1991 Down Valley Tailings Impoundment Decommissioning Plan (Faro tailings)
- 1988 Curragh Abandonment Plan (Faro site not including the tailings) combined with the June 1989 Curragh Other Facilities Abandonment Plan
- 1981 Klohn Leonoff Abandonment Plan (Faro site)
- 1996 Proposed Modifications to the Grum Waste Dump
- 1990 Review of Alternative Abandonment Plans
- 1989 Vangorda Plateau Development Water Licence Application
- 1989 Vangorda Plateau Development, Initial Environmental Evaluation.

Available maps of the site were collated in electronic form, and gaps identified. Additional mapping was arranged, but weather conditions in late summer 2002 prevented completion of the air photos.

A simplified water and load balance was developed for each mine area and used to estimate contaminant concentrations and water treatment requirements associated with various closure options. The calculations were set up to consider current water quality, a "best engineering judgement" of future water quality, and "practical worst case" future water quality.

The stability of the Faro, Vangorda and Grum Pits walls was evaluated, and the possibility of developing a flow-through configuration for final closure was evaluated for each pit. While the risk of pit wall failure resulting in a breach of a diversion structure is shown to be low for the Faro and Vangorda pits, progressive sloughing and ravelling of pits walls in the area of major faults is a consideration in the design of permanent diversion structures. More detailed engineering and alternative studies of both the Faro and Vangorda diversions were initiated, based on the scoping study, and designs and costs are presented in other reports. For the Faro and Vangorda open pits, a flow-through or "clean pit" option may be attainable with

considerable ancillary measures to control chemical loading to the pit waters. The Grum pit may reach acceptable flow-through water quality with little intervention.

Simplified methods to estimate water collection and treatment costs were developed and calibrated against current costs. Current annual costs for water treatment are $0.6 million at Faro and $0.4 million at Vangorda. These costs could be as high as $1.1 million for Faro and $0.7 million at Vangorda under the "practical worst case" zinc concentrations. The cost models were also used to estimate water collection and treatment cost associated with various closure options.

The cost and feasibility of upgrading surface water management works were examined. Preliminary cost estimates were prepared for upgrades to the Faro Creek Diversion, the Vangorda Creek Diversion, the Rose Creek Diversion, the Intermediate Dam spillway and the Cross Valley Dam spillway. A preliminary estimate for breaching the Rose Creek Rock Drain was also developed. More comprehensive studies reported elsewhere have further developed many of those estimates.

A cost model was developed and used to estimate costs for re-sloping and covering of the waste rock dumps. Total costs are estimated at $8 million to $31 million for covering of the Faro dumps, $1 million to $3.5 million at Vangorda, and $3 million to $11 million at Grum. Covering of the Faro tailings is estimated to cost between $3 and $20 million. The use of basic covers on all of the waste rock dumps is estimated to decrease long-term water treatment by approximately $17 million. Excellent covers on all of the waste rock dumps could decrease long-term water treatment costs by an estimated $29 million.

Industry experience with tailings relocation was reviewed and cost estimates were developed for relocating the Faro tailings to the Faro Pit. Unit costs for relocating of the Faro tailings are estimated at $0.90 per tonne for hydraulic monitoring, $1.73 per tonne for dredging, or $4.05 per tonne for conventional truck and shovel. However, the neutralizing of the acidity stored in the tailings and pumping the tailings slurry to the Faro Pit would add an estimated $1.50 per tonne to relocation costs.

Industry experience with the backfilling of waste rock to pits was reviewed and cost estimates developed for relocation of each of the major Faro, Vangorda and Grum dumps. Experience at other sites has shown the benefit of neutralizing stored acidity during the relocation of waste rock. The costs of adding lime or limestone to the waste rock was therefore included in the backfilling cost estimates. Costs for backfilling the open pits with a combination of tailings and waste rock (selecting the most reactive rock for backfilling) are estimated at up to $127 million for Faro, $39 million for Grum and $22 million for Vangorda.

The results of the scoping studies can be used to draw inferences about possible closure plans. The report reviews the implications of the studies for preliminary closure variants developed at an earlier (April 2002) workshop, for waste rock closure measures, and for alternatives for decommissioning the Faro tailings system.

One outcome of the scoping studies is the identification of key uncertainties related to each of the individual closure issues or closure measures. It is important to address those uncertainties in a prioritized manner. In experience elsewhere, iterations of investigation and option review have proven to be very effective at directing investigation efforts to (only) high priority items. The scoping studies presented herein can be considered as one of those iterations, and hopefully will provide the tools needed for future reviews.

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SCOPING STUDIES FOR FINAL CLOSURE AND RECLAMATION PLAN, FARO MINE, YUKON

1. INTRODUCTION

The Anvil Range Mining Complex, located near Faro, Yukon, ceased operations in January 1998 when Anvil Range Mining Corporation filed for creditor protection under the Companies' Creditor Arrangement Act. Deloitte & Touche Inc. was appointed Interim Receiver of Anvil Range Mining Corporation ("Interim Receiver") on April 21, 1998. The Interim Receiver has overseen the management of the property under the terms of two water licences since that time.

In 2002, the Interim Receiver initiated the process of developing a Final Closure and Reclamation Plan. One element of that process was a series of scoping studies to assess the feasibility and estimate the costs and benefits for closure methods that might come under consideration.

This document presents the results of scoping studies completed by a team made up of engineers from SRK Consulting Inc., Gartner Lee Ltd. and BGC Engineering Inc. The scoping studies are summarized in the main body of the report, and details are presented in the appendices. It is the intent of the Interim Receiver that the compilation presented herein will serve as input to further closure planning, specifically for planning meetings in 2003 and the implementation of more detailed studies in the years 2003 and 2004.

2. COMPILATION OF PREVIOUS CLOSURE STUDIES

2.1 Investigation and Design Reports

A list of documents related to the Faro Mine, Vangorda/Grum and Rose Creek areas has been compiled and is included in Appendix A. Copies of most of the documents are now available from SRK's Vancouver office. However, as noted in the appended list, there are a few documents for which the copies are located elsewhere.

2.2 Maps and Photos

2.2.1 Existing Maps

The available mapping for the Faro Mine, Vangorda/Grum and Rose Creek areas has been compiled. Maps of individual areas were found to have been developed using a variety of different methods over an extended time period, i.e. late 1960's to present. The resultant map database is a "collage" that covers discrete areas at a variety of scales, units and contour intervals. The use of digital technology has added complexity to the map database because base maps have occasionally been modified to suit a specific objective.

At the regional level, a National Topographic System (NTS) map, produced at a scale of 1:250,000, provides the project location and select features, such as water courses and lakes. The next level is the 1:50,000 NTS maps, of which there are four that provide topographic information at a contour interval of 30.5 m (100 feet) over the site and the confluence of its drainages with the Pelly River. Figure 2.1 shows the location of the four NTS maps superimposed on part of the 1:250,000 map sheet. The aerial photographs on which the 1:50,000 maps were based were taken in 1967/68, which pre-dates mining at the site. These contours were converted from paper format, based on UTM NAD 27, to digital format, based on UTM NAD 83, between 1998 and 2000, inclusive.

The local mapping is summarised on Figure 2.2, which has been prepared using two 1:50,000 NTS maps (105 K/3 and 105 K/6) that, for consistency with local site mapping, have been converted back to UTM NAD 27. The local map areas are summarized in Table 2.1, which includes the base scale (estimated in some cases), the contour interval, the date of the mapping and comments. The latest activities at the Vangorda and Grum areas post-date the most recent mapping in this area.

Table 2.1
Summary of Local Mapping

Area	Site	Scale	Contour Interval (ft)	Contour Interval (m)	Date	Comments
A	Faro Mine	1:10,000	10	3.05	09/1990	UTM NAD27, by Orthoshop
B	Faro Mine	1:20,000	25	7.62	1967 (?)	UTM NAD27
C	Rose Creek	1:2,000	3.28	1	12/1999	Tailmast.DWG
D	Fresh Water Supply Reservoir	1:5,000	1.64	0.5	07/2001	UTM NAD83 Zone 8, by YES
E	Vangorda/Grum	1:2,000[1]	6.56	2	1988 (?)	UTM NAD27, by Orthoshop? missing portions of pits & dumps
F	Vangorda/Grum	1:5,000	16.4	5	1988 (?)	UTM NAD27, Curragh Resources
G	Little Creek Dam	1:2,000	3.28	1	1990 (?)	Mine Grid Survey, Lemerton Assoc.
H	Vangorda and Grum Pits, Grum Waste Dump	1:2,000*	3.28[2]	1[2]	03/1996	- CAD files from Robertson GeoConsultants - Edge of slopes from GPS
I	Vangorda Waste Dump	1:2,000	3.28	1	1994	UTM NAD 27, surveyed & tinned

Note 1: assumed base scale.
Note 2: Toes and crests are surveyed; slope is assumed to be uniform between crest and toe.

2.2.2 Proposal for Additional Mapping

Due to irregularities with the scales and contour intervals of the existing mapping and the fact that some changes at the site post-date the most recent mapping, i.e. the later stages of mining and dumping of waste from the Grum pit, a comprehensive re-mapping is recommended.

Three different options have been considered: conventional aerial photographs, satellite imagery and LIDAR (scanning laser with digital imaging and inertial GPS). The option of obtaining ortho-rectified images of the site has also been explored.

Table 2.2 summarizes the cost of each of these items. Further details are provided below.

Table 2.2
Options Considered for the Development of Comprehensive Mapping

Option	Contour Interval	Lowest Cost	Provider	Comments
Air photos	2 m	$25,100	Orthoshop	Includes 1m pixel orthophoto
Satellite	4 m	$39,400	IKONOS	Includes ortho-rectified imagery
Satellite	N/A[1]	$5,000	IKONOS	Cost of images only; no mapping
LIDAR[2]	1 to 2 m	$74,400	LIDAR	0.5m pixel imagery

Note 1: N/A = not applicable.

Note 2: There was a possible $2,000 reduction in cost at the 2m contour interval.

Conventional air photo mapping by The Orthoshop in Calgary was the least expensive option. Their quote was significantly less than three others ($34,800, $61,500 and $76,700), partly because of the existing ground control they have on site. The photos for mapping are based on 1:20,000 photos and those for ortho-rectified imagery are flown at 1:40,000.

Satellite imagery by IKONOS was about 60% more expensive than the air photo option. In addition, the images have lower resolution and the weather constraints are more stringent than for air photos, i.e. conditions must be absolutely clear from space at 11 am daily. The concept of using existing satellite images was explored, but IKONOS has no suitable images in their archives (despite nine unsuccessful attempts in the past two years).

LIDAR is the most expensive option but has higher accuracy and image resolution than air photos and satellite imagery. This technology is understood to be less weather dependent than the other options.

The Orthoshop was authorized in August 2002 to obtain air photos and develop comprehensive topographic maps of the site. However, due to poor weather conditions, air photos could not be taken prior to the deadline of September 22. Beyond this date, the angle of the sun significantly reduces the quality of the photos and resultant topography. The next window of opportunity is June 2003, depending on snow cover and clouds. The price quote will remain the same, subject to changes in third party costs such as fuel.

2.3 Previous Closure Plans

Four closure plans have been prepared for the Faro site:

- 1996 Anvil Range Mining Complex Integrated Comprehensive Abandonment Plan – ICAP;
- 1991 Down Valley Tailings Impoundment Decommissioning Plan (tailings only);
- 1988 Curragh Abandonment Plan (Faro site not including the tailings) combined with the June 1989 Curragh Other Facilities Abandonment Plan; and
- 1981 Klohn Leonoff Abandonment Plan.

Planning for closure was included in the project design and permitting for the Vangorda and Grum sites and described in the Initial Environmental Evaluation and the Water Licence Application documents. Subsequent to these submissions, a more detailed evaluation of alternatives was completed in 1990, followed by the ICAP in 1996. The major documents related to closure of the Vangorda and Grum sites include:

- 1996 ICAP;
- 1996 Proposed Modifications to the Grum Waste Dump;
- 1990 Review of Alternative Abandonment Plans;
- 1989 Vangorda Plateau Development Water Licence Application; and
- 1989 Vangorda Plateau Development, Initial Environmental Evaluation.

The technical aspects of the closure measures from each of these documents are tabulated in Appendix B of this report. Also noted are the level of engineering and costing, and the drawings that relate to each proposed measure.

In general, the closure planning in the above documents was at a conceptual level. However, more detailed engineering and costing was completed for measures that were incorporated into the construction and operation of the site. Basic or detailed engineering, costing, and for some structures "as-built" and annual inspection reports, are available for the following:

- Vangorda water treatment plant and Little Creek Dam;
- Surface water diversion systems for both Grum and Vangorda Creeks;
- Vangorda dump water drainage collection system;
- Vangorda dump segregation and till cover (test section); and
- Stabilization of the Rose Creek Diversion for temporary closure.

The following sub-sections provide an overview of each of the previous closure plans. Appendix B includes tables describing the closure measures proposed for each site component in each plan.

Anvil Range Mining Complex Integrated Comprehensive Abandonment Plan (ICAP) (Robertson Geoconsultants Inc., November 1996)

This is the most comprehensive and most recent closure plan prepared for the Faro, Vangorda and Grum sites. The ICAP comprises:

- characterization of the components of the sites, particularly the hydrological and geochemical aspects of each;
- conceptual definition of two or three alternative closure measures for each component;
- costing for the selected closure option for each component (based on conceptual designs); and
- schedule for decommissioning and monitoring.

In most cases, the closure alternatives include those that have been considered in earlier plans and thus the ICAP provides a useful summary of earlier closure plans. It also incorporates the closure commitments in the Water Licence for Vangorda/Grum. The evaluation of closure measures was based on environmental protection and long-term stability, and on costs. At the time, Anvil Range Mining Corporation was responsible for closure of the Faro Vangorda and Grum sites.

The ICAP was reviewed in the September 16, 2002 “Interim Receivership Project Description Supplement” document. Key aspects of the selected closure measures are:

1. The Faro, Vangorda and Grum open pits would be flooded and used as contaminated water storage reservoirs.
2. Water treatment would be required in the long term for drainage from each of the Faro, Vangorda and Grum waste dumps. Two treatment plants would be

operated; the existing Vangorda treatment plant and a new HDS plant to be built at Faro.

3. The Vangorda Creek diversion would be upgraded but would continue to operate.
4. The Faro Creek diversion would be re-routed and upgraded to continue to divert water around the pit.
5. The Faro Rose Creek tailings would be partially mined out and reprocessed and the remaining tailings flooded *in-situ*. Rose Creek diversion would be removed.

Strengths and weaknesses of the ICAP are discussed in more detail in the “Interim Receivership Project Description Supplement” document.

Down Valley Tailings Impoundment Decommissioning Plan Report 60635, (Curragh Resources Inc. and Steffen, Robertson and Kirsten (B.C.) Inc., April 1991)

In this report, five alternatives for decommissioning of the Faro Rose Creek tailings facility (also called the Down Valley Tailings Impoundment) and associated water management structures were evaluated. Conceptual engineering designs and costs were prepared for two alternatives. For the selected alternative, a more detailed plan, decommissioning schedule and program for monitoring and maintenance was prepared.

The five alternatives evaluated were variations on two main approaches:

1. Stabilization of the tailings in-place, or,
2. Removal and reprocessing of some or all of the tailings.

Evaluation of the alternatives was based on both environmental protection and the long-term safety and stability. Clearly though, costs were also a consideration in the evaluation of the options as, at that time, Curragh Resources Inc. was responsible for the costs of closure. The selection of the alternative to reprocess and cover the remaining tailings was based to a large extent on the premise that Curragh Resources could incorporate the rehandling of the tailings into the operation of the mine. The alternative of establishment of a water cover over the tailings provided significant control of water quality in the long term, however, there are concerns with respect to long-term physical stability of water management structures.

This plan was submitted by Curragh Resources to the Yukon Territory Water Board in compliance with the requirements of their Water Licence IN98-001 for a comprehensive plan for decommissioning of the Down Valley Tailings Impoundment.

Curragh Resources Inc. Faro Mine Abandonment Plan, (Curragh Resources, R. McLenehan and J. Gowers, April 1988)

This preliminary closure plan was prepared by Curragh site personnel. It provides a good summary of the site facilities and water quality data at the time, and of the management plans for operation to reduce the liabilities at closure. A schedule and preliminary cost estimate was provided for the major tasks. Overall cost for closure was estimated to be $2.72 million in 1988 dollars.

The issues for closure identified at the time remain the major issues; physical measures for water management and ARD water quality concerns. Most of the proposed measures are still under consideration for closure. Key features of the plan were:

- Water quality from dumps and pits was the major closure concern. The intention was to manage rock during operations and with short-term treatment so that long-term requirements would be minimal.
- The Faro pit was to be allowed to flood and discharge if water quality was acceptable. However, the assumption was that some treatment would be required in the short term.
- Faro Creek was to be diverted into the open pit, and acid generating portions of Faro Valley dumps would be removed.
- Diversions downstream of the pit were expected to buffer or dilute the pit/dump drainage such that there would not be a water quality problem.
- During operations, the waste rock management program would include segregation and isolation of sulphide waste rock, combined with covers of compacted phyllite waste rock. No long-term maintenance or water management would be needed for dumps.
- Tailings closure was not addressed as a separate plan for tailings decommissioning was required by the water licence.

A useful component of this document is the detailed list of studies and site monitoring recommended to assess the issues for closure. It acknowledges the uncertainties associated with prediction of ARD and metal leaching, which were significant at the time, and the need to monitor water quality and track waste rock distribution on site during operation. Many of these programs were implemented, providing information on changes in water chemistry and water flows over 15 to 20 years in some areas.

Faro Mine Tailings Abandonment Plan, (Klohn Leonoff Consulting Engineers, 1981)

This was the first comprehensive closure document prepared for the Faro site. At the time, the level of understanding of both the problems of ARD and the effectiveness of closure measures was limited. Subsequent documents incorporate many features of this document.

Proposed Modifications to the Grum Waste Dump, (Anvil Range Mining Corporation, May 1996)

This document was submitted to the Water Board to address Anvil Range's proposed changes to the design of the Grum waste dump from the design in the Water Licence. The key changes with respect to closure measures were; the sulphide cell would be larger than the original design and the intermediate till covers between lifts of sulphides would not be placed.

Vangorda Plateau Development Initial Environmental Evaluation Stage II Report, Curragh Resources Inc., (Steffen Robertson and Kirsten Inc. July 1989)

Vangorda Plateau Development Water Licence Application, Curragh Resources Inc., (Steffen Robertson and Kirsten Inc. December 1989)

The Initial Environmental Evaluation (IEE) and the Water Licence Application presented a conceptual abandonment plan for the Vangorda and Grum sites. Both documents were submitted for permitting prior to the start of mining at Vangorda.

Key closure plan components of outlined in these documents (and subsequent clarifications provided to the Water Board: included:

- Vangorda Creek would be allowed to flow into the flooded pit. It was considered that the final pit water quality could be acceptable for discharge, but measures were proposed for consideration if operational monitoring indicated a longer term water quality problem. These measures comprised the combination of covers and flooding that was later included in the ICAP.

- Waste rock would be segregated in cells in the waste dump and the dump covered with till at closure. It was anticipated that water collection and treatment would not be required once the till cover was placed.
- The Grum open pit would be allowed to flood. Short-term water treatment might be required to treat stored oxidation products in pit walls.
- Covering of the sulphide cell in the Grum dump would control metal leaching and long-term drainage water management would not be required.
- The water treatment plant would need to continue to operate for some time after closure until acceptable water quality was achieved.
- The uncertainties with respect to long-term ARD and metal leaching from the Vangorda pit walls and Grum dumps, and to a lesser extent from the covered Vangorda, were acknowledged. Analysis of operational data was recommended prior to finalizing the conceptual closure measures.

Curragh Resources Inc. Review of Alternative Abandonment Plans and Water Quality Prediction Methods (Steffen Robertson and Kirsten (B.C.) Inc. February 1990)

This document attempted to predict the water quality associated with alternative closure measures for the Vangorda pit and Vangorda waste rock dumps, and the Grum waste rock dumps. While the techniques for water quality prediction have advanced significantly since that time, the document served to highlight the uncertainties for closure of this site, namely, the rate and extent of acid generation and metal leaching.
It was recommended that the approach to abandonment include development of a plan that could accommodate a number of alternatives and could be implemented in stages with each subsequent stage selected based on the results of the monitoring program.

3. PRELIMINARY ENGINEERING STUDIES

This section of the report provides summaries of a series of preliminary engineering studies identified in a meeting in late July 2002. At that meeting, engineers from SRK, Gartner Lee Ltd. and BGC Engineering Inc. prepared summaries and cost estimates for a wide range of closure measures. It was clear that further consideration of some of those closure measures would benefit from a more focused assessment. The preliminary engineering studies were subsequently completed by individuals from the engineering team. In keeping with the "scoping" level of this project, the engineers were instructed to restrict their work to readily available information and experience from other sites, rather than additional investigation or design.

The following sections present key results from the preliminary engineering studies. Technical memoranda and supporting calculations are presented in Appendices C through M. Implications of the preliminary engineering studies for overall closure planning are discussed further in Chapter 4.

3.1 Water Balance and Load Estimates

The effectiveness of many proposed closure measures will be assessed in large part by their effect on water quality. A simple set of calculations to allow prediction of water quality under various closure alternatives was developed in one of the preliminary engineering studies.

This type of calculations is often referred to as "water and load balances", because they estimate the distribution of water flows around a site and the loading of contaminants carried by each flow. Development of the water and load balances for the Faro and Vangorda/Grum sites is described in Appendix C. Briefly, the steps were:

- Major contaminants sources (waste rock dumps, pit walls) were identified and delineated on maps. The plan area of each source was measured and the amount of precipitation that will fall on each source was estimated. Average annual flows from each source were then calculated.

- The water quality measured in recent seep samples from each area was reviewed and characteristic "water types" were defined to represent "acidic water", "neutral water with high zinc", and "neutral water with low zinc".

- Calculations were set up to estimate the resulting average seepage quality from each area and the mixing of flows in pit lakes.

Once the calculations were set up and tested, it was possible to make minor adjustments to simulate future conditions and some of the proposed closure measures. For example, the effect of deteriorating water quality could be simulated by switching source areas from “neutral water” to “acidic water”. To simulate the effects of placing soil covers on the waste rock dumps, the drainage from each area was decreased and/or the water quality improved. A further use of the calculations was to estimate the quality of water that would require treatment under future closure plans. These applications are described where appropriate in the following sections.

3.2 Pit Wall Stability

The stability of pit walls will have significant implications for diversion ditches and for long term water quality in the pit lakes. Although many studies of pit wall stability have been undertaken at the mine, there has been no recent compilation or review. In one of the preliminary engineering studies, the available data regarding wall stability at the Faro and Vangorda pits was reviewed by BGC Engineering Inc. A second study SRK briefly reviewed reports on the stability of the Grum pit. The results of these assessments are presented in Appendices D-1 and D-2, respectively, and summarized below.

3.2.1 Faro Pit

At least one sector of the Faro pit, notably north and south slump areas of the east wall, experienced significant deformation during the active life of the mine. A system of monitoring was installed and the monitoring data were regularly analyzed. The highest rates of movements were associated with seasonal high water pressures during spring thaw and when mining activities were being carried out in close proximity to the toe of the slope. Movement within the north and south slump areas took the form of relatively shallow creep.

Active monitoring ceased when mining ended in 1992. There is no information on current movement rates, although visual inspection indicates ravelling and retrogression of the pit crest is continuing. Eventually, breaching of the Faro diversion channel may take place (Section 3.6.1). Further assessment work is needed, but stabilization options may consist of one or more of the following:

- Prevent seepage losses from the Faro Creek Diversion Channel (cost estimates are being prepared as part of a separate assessment by Golder Associates Ltd.)
- Intercept or divert surface runoff and groundwater from the slope above the pit ($50,000 to $100,000 for monitoring points and groundwater investigations);
- Gravity drainage of the rock mass using “horizontal drains” and/or drainage tunnels ($1.5 to 3.0 million for 1 km of drainage gallery); and
- Overall slope flattening but removing material at the top of the slope or buttressing the toe (insufficient data to cost this option).

3.2.2 Vangorda Pit

The Vangorda pit experienced at least one significant wedge failure and displacements within the overburden. Monitoring systems were installed but no data has been collected since the cessation of mining in 1998. An inspection of the pit slopes by BGC Engineering Inc. in 2000 indicated that widespread ravelling was occurring, but no evidence of large-scale distress was apparent.

There does not appear to be an urgent need to undertake stabilization measures, although regular visual monitoring is warranted and the leaky flume within the Vangorda Diversion Channel should be repaired (it is understood that this repair is planned).

3.2.3 Grum Pit

The western walls of the Grum open pit, where till forms the pit wall, have failed extensively. There have been no large-scale failures through the rock mass in the pit. The Grum interceptor ditch is located to the west of the pit and may be affected by further failures of the pit walls. The Grum overburden dump is located southwest of the pit and a potential risk is that continued pit wall failure may result in dump material being transported into the pit lake.

Inspection of cross sections through the west and southwest walls of the pit showed that pit wall failure would not have a direct impact on the interceptor ditch or the overburden dump. However, over the longer term, the potential exists for the till materials to erode and this may have an impact on the dump and interceptor ditch.

3.3 Flow-through Pit Assessment

Recent experience has shown that *in situ* treatment of pit lakes can result in dischargeable water quality. The feasibility of the "flow-through pit" option for Faro, Vangorda and Grum was therefore re-evaluated. The water and loading balance discussed in Appendix C was used for water quality predictions. A more detailed discussion is provided in Appendix E.

At the time that the ICAP was prepared, the general understanding was that the significant contaminant loads to the Faro and Vangorda pits, from both internal and external sources, would result in high concentrations of metals in the pit lakes for the foreseeable future. Flow-through pits therefore were not anticipated to be feasible. The potential of a "clean pit" option for Vangorda was re-evaluated in 2000, with the conclusion that at the current pit water elevation, the loadings from exposed wall rock and small in-pit dumps were high for both zinc and cadmium. The expectation for the Grum pit was somewhat different, as no significant sulphide exposures had been identified above the final flooded pit elevation for the ultimate pit design.

This preliminary engineering study for this report considered a few key factors that are different from previous assumptions. Specifically, *in situ* water treatment has been demonstrated to reduce the initial concentrations in the pit lakes, and estimated long-term metal loadings to the pit can now be better estimated, based on recent observed site water quality.

The results of the re-evaluation are summarized in Table 3.1 below. The estimates in the table are based simply on dilution calculations and do not account for any *in situ* or active treatment options that may be considered. While the new predictions must be reviewed more rigorously before any decisions are made, the calculations suggest that flow-though pits could be feasible, subject to specific requirements. For the Vangorda pit, the flow-through system would require many ancillary measures, notably maximum in-pit dilution, maximum flooded elevation in pits, cleanup of the dumps and pit walls for the Vangorda pit, and *in situ* water treatment of the initial pit lake. For the Faro pit, a flow-through option may be feasible with the use of additional, *in situ* water treatment measures. The Grum pit may reach acceptable flow-through water quality with little intervention.

The *in situ* water treatment methods being used to remove zinc from the upper layer of the Island Copper pit lake are an example of what might be considered for the

Vangorda and Faro pit lakes. However, the differences in climate and lake physics mean that the application of this method in the Yukon would require rigorous assessment. In any of the pits, the flow-through option would also require construction of spillways and possibly other construction to control surface inflows.

Table 3.1
Predicted Long-term Pit Water Concentrations

Pit	**With Diversions**		**With No Diversions and With Ancillary Measures**	
	Predicted Zinc Conc. (mg/L)	Residence Time (years)	Predicted Zinc Conc. (mg/L)	Residence Time (years)
Faro Main	7	13	2.3	4
Vangorda	7	11	0.3	1
Grum	0.7	12	0.5	8

3.4 Water Treatment Costs

Estimates of future water treatment costs were developed using a combination of current site costs and estimates from previous projects. Estimates were derived for current geochemical conditions and for a hypothetical "high zinc" case, which represents the situation where acid rock drainage is allowed to accelerate, leading to much higher metal levels in the treatment plant effluent. The resulting cost estimates are summarized in Table 3.2. The calculation sheets for each case are attached to Appendix F.

Capital costs were estimated by comparing costs for similar facilities elsewhere with the estimates derived in the 1996 ICAP. This method of estimating can be expected to result in magnitude accuracy only. The operating cost estimates were derived using zero-base methods, with significant unit costs obtained from current operations. The resulting operating cost estimates for current water treatment at Faro and Vangorda agree well with 2001/2002 costs. To estimate operating costs for the "high zinc" conditions, the theoretical lime demand associated with the zinc, iron and copper concentrations shown in the table was calculated. The theoretical lime demand for the "high zinc" cases was found to be approximately five times that of the current cases. It was then assumed that the actual lime demand in the "high zinc" cases would be five times that of the current lime demand. Flocculant and sludge disposal costs in the "high zinc" cases were also assumed to be five times the current values

It is noteworthy that the estimated operating costs in the "high zinc" cases are roughly double the estimated operating costs for current conditions. The difference can be seen as a preliminary estimate of the water treatment costs associated with a significant deterioration in water quality or, conversely, the benefits associated with methods that will prevent future deterioration in water quality.

Table 3.2
Summary of Water Treatment Cost Estimates

Case	Annual Treatment Volume (m^3/yr)	Zinc (mg/L)	Iron (mg/L)	Copper (mg/L)	Capital Cost	Annual Cost	Unit Cost ($/$m^3$)
Faro Current	2,100,000	20	0.1	0.1	$15,200,000	$551,000	$0.26
Vangorda Current	750,000	40	0.1	0.1	$6,500,000	$391,000	$0.52
Faro "High Zinc"	2,100,000	40	30	20	$15,200,000	$1,047,000	$0.50
Vangorda "High Zinc"	750,000	80	30	20	$6,500,000	$727,000	$0.97

3.5 Water Treatment Pumping Costs

A simple engineering study was completed to compare the costs estimated in the ICAP for pumping water to the water treatment plant to new estimates based on recent site experience. The results are presented in a technical memorandum presented in Appendix G.

Key results are summarized in Table 3.3, which shows pumping cost estimates from the ICAP and the current work (in 1996 and 2002 dollars, respectively). The new estimating methods more accurately predict current costs and are expected to provide a good basis for predicting future pumping costs for various closure alternatives.

Table 3.3
Estimated Operating Costs – Pumping for Water Treatment

Plant	**Annual Pumping Cost**		**Cost per m^3 Treated**	
	1996 Estimate $ per year	2002 Estimate $ per year	1996 Estimate $/$m^3$	2002 Estimate $/$m^3$
Vangorda	**$38,500**	**$136,000**	**$0.05**	**$0.15**
Faro	**$26,000**	**$158,000**	**$0.01**	**$0.06**

3.6 Surface Water Management Upgrades and Costs

The need to upgrade diversions and ditches throughout the mine and tailings areas has been recognized in all previous closure plans. There is, however, considerable disagreement as to the level of upgrading that is required. That issue is being addressed in other work. The preliminary engineering studies therefore focused on preparing rough estimates of the costs of upgrading ditches and diversions to arbitrarily selected standards, generally the 1:500, half-PMF and PMF flows. Results of the studies are provided in Appendix H and summarized in the following sections.

It should be noted that estimates of flood flows vary over a wide range, particularly for low return periods and the PMF. This variation is a result of the limited duration of meteorological and hydrological records for the Yukon, which typically only span an interval of tens of years. There is, therefore, considerable uncertainty in any estimates of floods with return periods greater than, say, 100 years.

3.6.1 Faro Creek Diversion

- BGC Engineering Inc. completed an evaluation of the cost of upgrading the Faro Creek Diversion Channel (Appendix H-1). The evaluation considered the 1 in 500 year flood, the half-PMF (probable maximum flood) and the PMF.

The results are summarized in Table 3.4. A more detailed assessment of alternatives for relocating the Faro Creek Diversion Channel was recently completed by Golder Associates.

Table 3.4
Summary of Costs for the Upgrade of the Faro Creek Diversion Channel

Parameter	**Design Flood**		
	1 in 500	**½PMF**	**PMF**
Flood flow rate	27 m^3/s	75 m^3/s	150 m^3/s
Flow depth	0.6 m	1.2 m	1.8 m
Cost of upgrade	$537,000	$634,000	$711,000

3.6.2 Vangorda Creek Diversion

The existing Vangorda Creek Diversion Channel was designed to handle the 1:100 year event, with an estimated peak flow of 10 m^3/s. A quick assessment of the options and corresponding costs for upgrading the Vangorda Creek Diversion was undertaken by SRK (Appendix H-2). More detailed studies are underway in another project.

Three options were considered in the preliminary engineering:

- Option 1: Re-diverting the creek back along the alignment of the original creek bed and constructing an open channel within a partially backfilled Vangorda Pit;
- Option 2: Realigning Vangorda Creek in an open channel located above the Vangorda Pit over to Dixon Creek to the south.
- Option 3: Upgrading the existing flume diversion in an open channel using the same alignment, removing the drop box structure, excavating through the existing haul road and relocating the plunge pool (the ICAP alternative).

The resulting cost estimates are summarized in Table 3.5. Note that the cost for Option 1 does not include backfilling of the Vangorda pit. As discussed in Section 3.10 below, the backfilling would cost an additional $22,100,000.

Table 3.5
Summary of Costs for the Vangorda Creek Diversion Options

Option	**Design Flood and Corresponding Cost**		
	1 in 500	**½PMF**	**PMF**
Option 1	$459,000	$1,020,000	$1,779,000
Option 2	$1,591,000	$2,267,000	$3,536,000
Option 3	$1,188,000	$1,430,000	$1,730,000

3.6.3 Rose Creek Diversion

The existing Rose Creek Diversion Channel was designed to handle the 1:100 year flood event, with a peak flow of 48 m^3/s. BGC Engineering Inc. completed an evaluation of the cost of upgrading the Rose Creek Diversion (Appendix H-1) to both half-PMF and the PMF. The following assumptions were made:

- The channel would be developed entirely in rock;
- A robust section dam would be required to block up the current spillway channel and ensure that all water flow will enter the new channel; and
- An energy dissipater would be required at the downstream end to transition the flow from the channel into the natural creek section.

The results of the evaluation are summarized in Table 3.6.

Table 3.6
Summary of Costs for the Upgrade of the Rose Creek Diversion

	Design Flood and Corresponding Cost		
	1 in 500	**½PMF**	**PMF**
Flood flow rate	135 m^3/s	740 m^3/s	1480 m^3/s
Capital cost	$45,000[1]	$16,815,000	$27,846,000

Note 1: for survey and evaluation of channel capacity.

3.6.4 Rose Creek Rock Drain

BGC Engineering Inc. completed an evaluation of the cost of constructing a notch through the location where the haul road embankment linking the Faro and Vangorda/Grum areas crosses the North Fork of Rose Creek (Appendix H-3).

The evaluation considered both the half-PMF and the PMF and assumed the following:

- Side slopes along the excavation will be 2H:1V;
- The diameter of the rock fill near the base of the embankment is 1.0 m;
- The notch will be sized so the rock fill can be used as rip rap.

The results are summarized in Table 3.7.

Table 3.7
Summary of Costs for Notching the Rock Drain

Item	**Half-PMF**	**PMF**
Flood flow rate	460 m^3/s	920 m^3/s
Notch width	30 m	60 m
Flow Depth	2.1 m	2.1 m
Flow Velocity	6.4 m/s	6.7 m/s
Excavation Quantity	798,000 m^3	996,000 m^3
Excavation Mass	2.07 million tonnes	2.59 million tonnes
Total Cost	$3,439,000	$4,293,000

3.6.5 Seepage Collection Ditches

The need for seepage collection ditches at the Faro, Vangorda and Grum waste dumps was evaluated based on the information in the ICAP and recently collected seepage data as discussed in Appendix H-4.

Site water quality monitoring since the ICAP continues to show very little flow or contaminant migration from the toes of the dumps at Faro. However, at some time in the future, flow and loading from the dumps could increase. That could in turn require construction of a series of ditches, as shown in Figure 3.1, to collect drainage from around toes of the Faro dumps. For cost estimating, it was assumed that these ditches would be unlined, excavated to till or bedrock with sumps for pumping water to the treatment plant or open pit. Three areas were considered:

- Around the toe of the Northeast and Intermediate Waste dumps to the haul road, with the ditch located between the dump toe and Rose Creek. A sump would be constructed near the existing monitoring wells. Because of the topography and ground conditions, ditch construction is expected to be more difficult in this area, lining may be required, and costs have been increased accordingly.
- Two ditches around the toe of the Intermediate and Main Rock dumps, also with a sump for pumping to the treatment plant reservoir.
- Around the Northwest waste rock dumps and stockpile area, again requiring a collection sump and pumping facility.

The Vangorda waste dump was designed and constructed with a dump seepage collection system. No additional ditch construction is considered necessary at this time.

The Grum dump was originally designed with a covered sulphide cell which was considered sufficient to control water quality in dump seepage. Recent seep data indicate that sulphides are distributed throughout the dump and that dissolved metal levels are increasing in some dump seeps.

Cost estimates were therefore developed for construction of a ditch, excavated in colluvium and unlined, along the south/east side of the Grum main dump as indicated in Figure 3.2. There is currently a small ditch and sediment collection pond which could be incorporated into the long-term system. The location of any required treatment plant and the method for conveying the Grum water to the plant (and over Vangorda Creek) would need to be considered before a final design is made.

3.7 Re-sloping Costs

The costs of re-sloping each of the waste dumps in the Faro, Vangorda and Grum areas were estimated using methods developed in previous SRK projects (Appendix I).

The method calculates the time required for a dozer to re-slope dump faces from angle of repose to the selected final slope, and then multiplies the dozer time by a unit hourly cost.

In general, waste rock dumps are re-sloped for three reasons:

- To correct slope stability problems;
- To spread the finer waste rock from the dump crest along the slope, in order to enhance possibility of revegetation; and
- To allow the construction of soil covers.

Re-sloping to final slopes of 2H:1V is sufficient for the first two purposes. However, the construction of soil covers requires slopes at least as flat as 2.5:1. To cover both possibilities, estimates were completed for final slopes of 2H:1V and 2.5H:1V.

The calculations can be done for any size of dozer. For these calculations, it was assumed that D11N dozers would be contracted for the work, at an all-found cost of $400 per hour. D11 dozers are known to be heavy enough for efficient re-sloping of waste rock.

The cost estimating method is quite rapid, but it requires the time-consuming measurement of the length and height of each slope from topographic maps. Therefore, estimates were completed for only the main dumps in each mine area.
Results are summarized in Table 3.8.

Table 3.8
Summary of Dump Re-Sloping Cost Estimates

Dump	**Cost Estimate**	
	Final slope 2H:1V	**Final Slope 2.5H:1V**
Faro Main & Intermediate Dumps	$1,400,000	$2,070,000
Vangorda Dump	$390,000	$650,000
Grum Waste Rock Dump	$620,000	$940,000
Grum Overburden Dump	$100,000	$140,000

3.8 Cover Costs

Cost estimates were developed for the construction of soil covers on waste dumps at the Faro, Grum and Vangorda areas, and on the Rose Creek tailings (Appendix J).

The estimates took into consideration the cost of excavating borrow material, trucking it to the cover area, and dumping, spreading and compacting the material in the cover area. Supervision costs and camp costs were also included. Costs for mobilization, demobilization, and decommissioning of the borrow area were not included.

Estimates were completed assuming a 990 series excavator and 769 series trucks. It was assumed that till would be used to cover the waste dumps. For the Faro area dumps, the till borrow source was assumed to be the surficial deposit located below the haul road. For the Grum dumps, the till was assumed to be sourced from the Grum Overburden Dump. For the Vangorda dump, the till was assumed to be sourced from a deposit located just east of the Vangorda Pit. Till was selected because it will provide the lowest permeability cover and the best medium for revegetation. However, it should be noted that conditions at the site are far from ideal for construction with till. Till is very sensitive to moisture content and therefore during construction one can expect substantial weather delays.

Three types of covers were considered. A “Basic Cover” was assumed to require a single 30-cm layer of soil. Such a cover would not restrict infiltration but would provide a basis for re-vegetation. An “Intermediate Cover” was assumed to require a 40-cm compacted layer overlain by a 60-cm uncompacted layer. It would provide some restriction of infiltration and oxidation. An “Excellent Cover” was assumed to require three layers of lightly compacted material, each 50-cm thick, with an uncompacted 50-cm thick surface layer which is scarified for revegetation. In the case of the tailings facilities, one of the three compacted layers would comprise till. The “Excellent Cover” design would provide further restriction of infiltration and oxidation.

Two construction materials were considered for the tailings. The first was sand and gravel, which was assumed to be sourced from a deposit located about 3 km downstream from the Cross Valley Dam. The second was till, sourced from the surficial deposit located between the plant site and the tailings impoundment. The “Basic” and “Intermediate” tailings covers were assumed to consist only of sand and gravel . The “Excellent” tailings cover was assumed to include three 50cm layers of sand and gravel and one 50cm layer of till. It should be noted there is not sufficient till in the known borrow areas at Faro to cover the tailings in a thicker layer of till, nor would there be enough to cover both tailings and waste rock. For such cases, till would need to be obtained from more distant sources, at commensurately higher cost.

The assumed cover "designs" represent the range of covers in common use at other mines. However, this simple approach to assessing the costs and effects of various types covers is only appropriate in scoping studies. Extensive further investigations would be required before site specific designs and performance estimates would be possible.

Table 3.9 summarizes the estimates of cover costs. The estimates include the cost of re-sloping the dumps to 2.5H:1V, the minimum that will allow soil cover construction. Table 3.10 shows the unit costs for the cover construction (i.e. not including regrading costs). The wide range of unit costs indicates the strong influence of the borrow source location. Longer haul distances and uphill grades lead to higher unit costs (e.g. Faro Valley Dumps) than short hauls over flat or downhill grades (e.g. Vangorda Dump).

Table 3.9
Estimated Costs of Cover Construction

Site	Component	Resloping Cost	Total Cost = Cover Cost + Resloping Cost		
			Basic Cover	**Intermed. Cover**	**Excellent Cover**
Faro	Faro Valley Dumps	$200,000	$400,000	$900,000	$1,700,000
Faro	Main & Intermediate Dumps	$2,100,000	$3,800,000	$7, 800,000	$13,400,000
Faro	Ranch Dump	$100,000	$100,000	$300,000	$400,000
Faro	Northwest Dump	$1,000,000	$2,100,000	$4,700,000	$8,300,000
Faro	Northeast Dump	$1,000,000	$1,900,000	$4,100,000	$7,200,000
Grum	Main Dump	$900,000	$1,500,000	$3,000,000	$5,000,000
Grum	Southwest Dump	$1,000,000	$1,700,000	$3,400,000	$5,700,000
Vangorda	Main & Barite Dumps	$700,000	$1,100,000	$2,100,000	$3,500,000
Rose Creek	Tailings	n/a	$3,500,000	$11,600,000	$18,600,000

Table 3.10
Summary of Soil Cover Unit Costs

Site	Component	Borrow Source	Unit Cost (per m^3)
Faro	Faro Valley Dumps	Haul Road Till	$3.66
Faro	Main & Intermediate	Haul Road Till	$3.01
Faro	Ranch Dump	Haul Road Till	$3.01
Faro	Northwest Dump	Haul Road Till	$3.66
Faro	Northeast Dump	Haul Road Till	$3.33
Grum	Main Dump	Grum O/B	$2.69
Grum	Southwest Dump	Grum O/B	$3.01
Vangorda	Main & Barite Dumps	East of Vg Pit	$2.69
Rose Creek	Tailings	Sand and gravel	$4.92
Rose Creek	Tailings	Tailings Till Borrow	$3.97

3.9 Tailings Relocation Costs

Experience with tailings relocation elsewhere was reviewed (Appendix K) as a basis for estimating the costs of relocating the Rose Creek tailings to the Faro pit. Three primary methods have been used elsewhere to relocate tailings:

- Dredging, using a suction dredge that floats on a pond;
- Hydraulic mining (monitoring), using water cannons to re-liquefy the tailings; and
- Mechanical excavation using, for instance, conventional truck and shovel operations.

The typical range of relocation costs in the available literature is summarized in Table 3.11. Actual relocation costs depend on site-specific conditions and factors such as the quantity of tailings to be relocated.

Table 3.11
Typical Range of Tailings Relocation Costs[a]

Relocation Technique	**Monitoring**		**Dredging**	**Truck & Shovel**		
Source	**Anvil (1996)**	**Goode (1993)**	**Goode (1993)**	**Nuna Logistics (2002)**		**Durango Mine (1991)[d]**
Total tonnage (x 10^6)	43.5	40.0	8.0	12.0[b]	50.0[c]	3.7
Total cost (x 10^3)	$ 23,249	$ 35,873	$ 13,836	$ 48,000	$150,000	$ 14,876
Total unit cost/tonne	$ 0.53	$ 0.90	$ 1.73	$ 4.00	$ 3.00	$ 4.05

Notes:

a. All rates have been converted to 2002 Canadian Dollars.
b. This rate is for excavating "soupy" overburden at Diamond mines in the Northwest Territories.
c. This rate is an estimate for excavating wet tailings at large scale, in remote locations.
d This rate is inclusive of the complete tailings rehabilitation, i.e. construction and capping of the new tailings facility.

These results indicate that the lowest cost of tailings relocation is associated with hydraulic mining (monitoring), in the range of $0.50 to $1 per tonne. Dredging costs are somewhat higher and mechanical excavation would be approximately 3 to 8 times more costly.

Using the scenarios identified in the ICAP, the volume of tailings to be relocated would be either 43 million tonnes, if tailings were excavated to the 1042 m elevation (i.e. relocation of most of the tailings, so remnant tailings could be flooded) or 57 million tonnes if all the tailings were relocated. The estimated range of hydraulic monitoring costs for these volumes are summarized in Table 3.12.

The costs in Table 3.12 do not include pumping of the tailings slurry from the tailings area to the Faro Pit. Assuming that the tailings would be pumped as a 15% slurry, the pumping would cost an additional $1.00 per tonne (of tailings). Calculations of the acidity stored in the tailings indicate that up to an additional $0.90 per tonne would be required for lime addition. However, that figure does not allow for the alkalinity that might be present in some of the tailings. An alkalinity addition cost of $0.25 per tonne is a more reasonable average. The total relocation cost adopted for the calculation presented in Chapter 4 below was $2.25 per tonne, which includes hydraulic monitoring, pumping to the pit, and lime addition.

Table 3.12
Projected Range of Tailings Relocation Costs

Description	Unit Cost	Partial relocation (to 1042 level only)[1]	Total relocation (all tailings)[2]
Total tonnage		43,053,000	57,200,000
Monitoring - low end	$0.53/tonne	**$22,818,000**	$30,316,000
Monitoring - high end	$0.93/tonne	$40,039,000	**$53,196,000**

Note 1. Partial relocation to elevation 1042 m would allow for the remainder of tailings to receive a permanent water cover (Robertson Geo-Consultants, 1996)

Note 2. Total relocation implies removal of all tailings in the facility (Robertson Geo-Consultants, 1996)

3.10 Waste Rock Backfilling Costs

Cost estimates were also developed for the relocation of waste rock dumps into the nearest pits (Appendix L). There are two recent examples of the backfilling of waste rock into pits. The Lichtenberg Pit near Ronneburg Germany is currently being backfilled as part of the WISMUT closure project; and Kennecott Minerals backfilled waste rock into a pit during the 1998-1999 closure of the Flambeau Mine in Wisconsin. In both projects, alkalinity was added to the rock during the relocation in order to neutralize acidity and prevent groundwater contamination. The estimates in Appendix L therefore have two components: an estimate of the costs of excavating, loading, hauling, dumping, spreading and compacting the waste; and an estimate of the costs of adding lime to neutralize any acidity contained in the waste.

3.10.1 Relocation Costs

To estimate the earth-moving costs, it was assumed that the relocation would be accomplished by a fleet consisting of a 992D loader and 777D haul trucks, or equivalent. The fleet also included a D9 dozer for spreading the waste in the pit, a 14G grader for spreading lime, and CS-563C compactor for compacting the waste. Caterpillar equipment was used in the cost estimate to allow the use of a consistent set of performance specifications. Equivalent equipment from other manufacturers would also be capable of the same work.

The fleet used in the cost estimate is not the same as was used in either the Flambeau or the WISMUT projects. At Flambeau, belly scrapers were used for the relocation. At WISMUT, much larger loaders, haul trucks and dozers are being used. However, the fleet assumed in the cost estimate should be capable of doing the job, and is likely to be available from Yukon-based contractors.

It became apparent that relocation of even one of the dumps will require several months of work – they will essentially be small-scale mining operations. Therefore, the costs of full-time supervision, as well as accommodation and meals for all staff were added. Mobilization and demobilization were not included.

3.10.2 Alkalinity Addition Costs

In both the WISMUT and Flambeau projects, alkalinity was added to the waste rock during relocation. The dose of alkalinity was chosen to neutralize the acidity created by oxidation of sulphide minerals during the time the rock was on surface. In both projects, a sophisticated program was developed to sample the rock during relocation, test it, and establish appropriate alkalinity dosages. To arrive at a reasonable estimate of possible alkalinity requirements for the Faro, Vangorda and Grum dumps, the estimates of stored acidity derived in the 1996 ICAP were used. It was assumed that the alkalinity addition rate would be at 2x the estimated acidity (factors of safety applied in the WISMUT and Flambeau projects varied depending on the uncertainty in the testing and regulatory requirements).

It was assumed that lime would be used as the alkalinity addition. Lime was used as the alkalinity source in the WISMUT project, but crushed limestone was used in the Flambeau projects. Both materials have advantages and disadvantages that can only be established by testing.

3.10.3 Results

Tables 3.13 and 3.14 show the results of the cost estimate calculations. Table 3.13 shows estimated relocation and lime addition costs for each of the dumps. Table 3.14 shows the estimated costs to just fill each of the three pits, using rock from the surrounding dumps.

Table 3.13
Dump Relocation Costs

	Location	Volume (m^3)	Portion to be relocated	Volume to be relocated (m^3)	Load-Haul-Dump Unit Cost (per m^3)	Lime Addition Unit Cost (per m^3)	Total Unit Cost (per m^3)	Total Cost
Faro	Faro Valley	2,060,608	100%	2,060,608	$2.16	$1.14	$3.30	$6,800,000
Faro	Main & Intermediate	83,645,762	25%	20,911,441	$2.16	$0.82	$2.98	$62,300,000
Faro	Ranch Dump	1,091,072	100%	1,091,072	$1.78	$2.52	$4.30	$4,700,000
Faro	Northwest Dump	12,806,966	100%	12,806,966	$2.16	$0.44	$2.60	$33,400,000
Faro	Northeast Dump	30,411,663	100%	30,411,663	$2.16	$0.55	$2.70	$82,200,000
Grum	Main Dump	16,994,978	100%	16,994,978	$2.16	$0.38	$2.54	$43,200,000
Grum	Southwest Dump	6,601,719	100%	6,601,719	$2.54	$0.12	$2.66	$17,600,000
Vang.	Main & Barite	32,450,000	100%	32,450,000	$2.16	$0.86	$3.02	$98,100,000

Table 3.14
Pit Backfilling Costs

Pit	Fill with	Volume (m3)	Average Unit Cost (per m3)	Total Cost
Faro	Waste rock	37,000,000	$3.18	$ 117,500,000
Faro	Tailings and waste	37,000,000	$3.44	$ 127,200,000
Faro	Hydraulic tailings and waste	37,000,000	$3.04	$ 112,500,000
Grum	Waste rock	15,000,000	$2.60	$ 39,000,000
Vangorda	Waste rock	7,300,000	$3.02	$ 22,100,000

4. COMPARISON OF CLOSURE METHODS AND ALTERNATIVES

4.1 Comparison of Closure Workshop Alternatives

During the April 2002 Closure Workshop, a number of preliminary closure plans were developed and compared by workshop participants. The various plans represented complete "alternatives", *i.e.* they included individual "methods" for each of the major components of the site. Three of the plans were relatively comprehensive and therefore provide the most useful basis for assessing the significance of the findings presented in the previous chapter and the supporting appendices. Those plans are referred to as Alternatives 7.1, 7.2 and 7.3 in the Workshop report:

- Alternative 7.1 was intended to lead to acceptable environmental protection at the minimum overall cost, taking into account both short-term and long-term costs;

- Alternative 7.2 was intended to lead to a minimum requirement for long-term management of the site, and therefore allowed for aggressive (and expensive) methods in the short term;

- Alternative 7.3 was intended to provide an optimum balance between environmental protection and costs, *i.e.* to represent a "middle of the road" approach.

Table 4.1 compares the cost estimates derived at the April 2002 Workshop for each alternative to estimates prepared with the benefit of the information presented in the preceding chapter. Two things are clear from the comparison. First, the initial estimates were consistently above the current estimate. Second, and more importantly, there are significant differences among some of the component costs.

Tables 4.2 through 4.4 provide more detail for each estimate and allow the sources of the differences to be identified. For consistency, the cost of closing the mill area has been set to $10,000,000 in all cases, and a 20% uncertainty factor has been applied to all estimates. Long-term costs are shown as net present values (NPV), based on a discount rate of 4%. The remaining significant differences are as follows:

- In Alternative 7.1, the current estimates of water treatment operating costs are lower than the estimates derived in April 2002. The current cost estimates for backfilling waste rock and covering tailings are lower than the respective April

2002 estimates. In all cases, the differences are attributable to the better calculation methods used in the current estimates.

- In Alternative 7.2, the biggest difference is in the relocation cost for tailings. The previous estimates were $3 per tonne for relocation and $0.10 per tonne for lime addition. The current estimates are approximately $2.00 per tonne for relocation and $0.25 per tonne for lime addition. The difference in relocation costs is attributable to the selection of hydraulic monitoring for the current estimate. Waste rock relocation unit costs are slightly higher in the current estimate. In the Faro estimate, that difference is compensated for by the fact that new calculations show that the volume available for waste rock (after the tailings are relocated to the pit) will be less than was previously thought.

- In Alternative 7.3, the currently estimated overall costs are much less than those estimated in April 2002. The differences are due to much lower water treatment costs in the current estimates and slightly lower relocation and covering costs in the current estimate for Vangorda/Grum.

The intent of the April 2001 workshop was not to develop definitive closure plans, but rather to explore the range of possibilities. The results shown in Tables 4.1 through 4.4 should therefore be viewed in the same light. The cost totals are not definitive, but they do show the range of possibilities. The individual costs are rough estimates only, but they do give some indication of which closure measures will dominate overall costs and therefore should receive more attention as the closure planning proceeds.

Table 4.1

Comparison of Cost Estimates for Alternatives 7.1, 7.2 and 7.3

Alternative		Cost Estimate Basis	Cost Estimates (Capital + NPV Operating)				
			Faro	**Vangorda Grum**	**Tailings**	**Other**	**Total**
7.1	Minimal cost with acceptable environmental risk	April 2002	$80,000,000	$53,500,000	$34,000,000	$13,400,000	$217,100,000
		Scoping Studies	$53,900,000	$46,900,000	$20,900,000	$13,400,000	$162,000,000
7.2	Minimized requirements for long-term care	April 2002	$154,750,000	$65,500,000	$182,000,000	$10,000,000	$494,700,000
		Scoping Studies	$102,300,000	$56,400,000	$136,000,000	$10,000,000	$365,700,000
7.3	Optimized incremental benefit / cost	April 2002	$127,800,000	$45,100,000	$47,500,000	$10,000,000	$276,500,000
		Scoping Studies	$68,300,000	$38,200,000	$34,900,000	$10,000,000	$181,700,000

Table 4.2a Cost Estimates for Alternative 7.1 from April 2002 Workshop

FARO	COSTS ($M)	VANGORDA / GRUM	COSTS ($M)	TAILINGS	COSTS ($M)	OTHER	COSTS ($M)
Minimize seeps (intercept)	0.3	Including concurrent in-situ treatment		Upgrade Rose Creek Diversion (Risk based design criteria)	5	Remove Rock Drain & Other Crossings on Haul Road	3.4
On going water treatment (and pumping)	69	Backfill with sulphide waste rock and cover	34	Cover with Composite Soils	25	As before, re Mill area	10
Relocate Faro Creek Diversion up hill (long term)	4	Relocate Vangorda Creek Through a lined Channel Across the back-filled pit	2	Lower Intermediate Dam & Buttress with Valley Dam Material (COST INCLUDED ABOVE)		INDIRECTS 20%	36.18
Build new water treatment plant	6	Balance of Waste Rock at Vangorda - Recontour and Cover	1	Breach Cross Valley Dam	2		
Waste rock collect & treat seeps	0.3	Allow Grum pit to Flood and Release untreated to the environment if feasible		Breach Fresh Water Dam	2		
Minimize run-off through Faro Creek Valley Dump	0.4	Recontour Grum waste rock	0.5	Transfer Emergency Tailings to Tailing Area (included above)			
		Operate WTP = 3years	16				
TOTAL	**80**	**TOTAL**	**53.5**	**TOTAL**	**34**	**ALTERNATIVE TOTAL**	**217.1**

Table 4.2b Revised Cost Estimates for Alternative 7.1

(Note: See Appendix M for further details on the calculation of the costs)

FARO	COSTS ($M)	VANGORDA / GRUM	COSTS ($M)	TAILINGS	COSTS ($M)	OTHER	COSTS ($M)
On going water treatment (and pumping)	32	Backfill with sulphide waste rock and cover	15.5	Cover with Composite Soils	18.6	As before, re Mill area	10
Minimize seeps (intercept)	1.9	Including concurrent in-situ treatment	4.6	Upgrade Rose Creek Diversion (Risk based design criteria)	0.1	Remove Rock Drain & Other Crossings on Haul Road	3.4
Relocate Faro Creek Diversion up hill (long term)	0.7	Relocate Vangorda Creek Through a lined Channel Across the back-filled pit	3.5	Lower Intermediate Dam & Buttress with Valley Dam Material (COST INCLUDED ABOVE)	0.1	INDIRECTS 20%	27.0
Build new water treatment plant	15.2	Balance of Waste Rock at Vangorda - Recontour and Cover	2.1	Breach Cross Valley Dam			
Waste rock collect & treat seeps WITH PUMPING	4	Allow Grum pit to Flood and Release untreated to the environment if feasible		Breach Fresh Water Dam	2		
Minimize run-off through Faro Creek Valley Dump	0.1	Recontour Grum waste rock	0.9	Transfer Emergency Tailings to Tailing Area (included above)	0.1		
		Operate WTP & PUMPS LONG TERM	20.2				
TOTAL	**53.9**	**TOTAL**	**46.8**	**TOTAL**	**20.9**	**ALTERNATIVE TOTAL**	**162.0**

Table 4.3a Cost Estimates for Alternative 7.2 from April 2002 Workshop

FARO	COSTS ($M)	VANGORDA / GRUM	COSTS ($M)	TAILINGS	COSTS ($M)	OTHER	COSTS ($M)
Relocate AG waste and excavate cut (35M tonnes)	88	Relocate 16M tonnes of Vangorda PAG waste to Vangorda and Grum pits	44	Relocate 55x106t QS3/t	165	As before, re Mill area	10
Create Plug Dam	2	Cap pits with low permeability till	3	Remediate Faro Valley Breach Dams (allow)	12		
Cap PAG Dumps	15.75	Add lime	5	Add lime to tailings (allow)	5	INDIRECTS 20%	82.45
Recontour and vegetate Non-PAG	10	Cap / vegetate the Grum dump	10.5				
Seepage Collection	2	Reclaim site / restore drainage	3				
Lime Addition into materials when pit is being filled	5						
Misc. Clean up	5						
New treatment Plant	2						
Operating Costs	25						
TOTAL	**154.75**	**TOTAL**	**65.5**	**TOTAL**	**182**	**ALTERNATIVE TOTAL**	**494.7**

Table 4.3b Revised Cost Estimates for Alternative 7.2

(Note: See Appendix M for further details on the calculation of the costs)

FARO	COSTS ($M)	VANGORDA / GRUM	COSTS ($M)	TAILINGS	COSTS ($M)	OTHER	COSTS ($M)
Relocate AG waste and excavate cut (ONLY 10M TONNES)	33.0	Relocate 16M tonnes of Vangorda PAG waste to Vangorda and Grum pits	48.	Relocate 57 Mtonnes of tailings and add lime	128	As before, re Mill area	10
Create Plug Dam	2	Cap pits with low permeability till	2.2	Remediate Faro Valley Breach Dams (allow)	8		
Cap PAG Dumps	15.1	Add lime (INCLUDED ABOVE)				INDIRECTS 20%	61.0
Recontour and vegetate Non-PAG	5	Cap / vegetate the Grum dump	3.2				
Waste rock collect & treat seeps WITH PUMPING	4	Reclaim site / restore drainage	3				
Lime Addition into materials when pit is being filled (INCLUDED ABOVE)							
Misc. Clean up							
New treatment Plant	15.2						
Operating Costs	28						
TOTAL	**102.3**	**TOTAL**	**56.4**	**TOTAL**	**136**	**ALTERNATIVE TOTAL**	**365.7**

Table 4.4a Cost Estimates for Alternative 7.3 from April 2002 Workshop

FARO	COSTS ($M)	VANGORDA / GRUM	COSTS ($M)	TAILINGS	COSTS ($M)	OTHER	COSTS ($M)
Move Faro valley dump into Faro Pit (4.1M tonnes)	10	Cover main dump	4.2	Cap Tailings (1.5 m thick)	20.4	MILL AREA	10
Contour & Cover main/Intermediate dump	17.3	Contour main dump	0.6	Remove Hotspots	2		
Toe collection system for the main/Intermediate dump	0.2	Move (not "push") sulphide dump into Vangorda pit	1.1	Upgrade Rose Creek Channel (to Intermediate dam)	8.5		
Move low-grade ore stock pile into Faro Pit	21	New WTP	5.5	Notch dams (CV and Int) & new water channel	2.4	INDIRECTS 20%	46.08
Pump Faro Pit dirty water to WTP at mill location (Replace Plant)	5.5	New collection pipe to WTP	1.5	Rehabilitate FWSD to PMF	3.5		
Move Faro Creek into new tunnel or ditch	5	Covering and slot cut at Grum Pit	5	Well water collection and treatment	1.2		
No change to North Fork Rose Creek Rock Drain	0	Vangorda Creek Diversion to shrimp Creek (pipe & dam)	1	Upgrade Intermediate Dam	2		
Zone II Pit water treatment	0	Ore Transfer Pad Material to Vangorda Pit	1.2	Operating ($0.3M/a)	7.5		
Water Treatment and Pumping	68.8	Water Treatment system	25				
TOTAL	**127.8**	**TOTAL**	**45.1**	**TOTAL**	**47.5**	**ALTERNATIVE TOTAL**	**276.5**

Table 4.4b Revised Cost Estimates for Alternative 7.3

(Note: See Appendix M for further details on the calculation of the costs)

FARO	COSTS ($M)	VANGORDA / GRUM	COSTS ($M)	TAILINGS	COSTS ($M)	OTHER	COSTS ($M)
Move Faro valley dump into Faro Pit (4.1M tonnes)	6.8	Contour and cover Grum Dumps	6.3	Cap Tailings (2.0 m thick)	18.6	MILL AREA	10
Contour & Cover main/Intermediate dump	7.8	Contour and cover remaining Vangorda Dump	2.1	Remove Hotspots	6		
Toe collection system for the main/Intermediate dump	1	Move (not "push") sulphide dump into Vangorda pit	3.0	Upgrade Rose Creek Channel (to Intermediate dam)			
Move low-grade ore stock pile into Faro Pit	4	New WTP	6.5	Notch dams (CV and Int) & new water channel		INDIRECTS 20%	30.3
Pump Faro Pit dirty water to WTP at mill location	4	New collection pipe to WTP and PUMPING	2.3	Rehabilitate FWSD to PMF	2		
Move Faro Creek into new tunnel or ditch	3.5	Covering and slot cut at Grum Pit	0.4	Well water collection and treatment			
No change to North Fork Rose Creek Rock Drain		Vangorda Creek Diversion to shrimp Creek (pipe & dam)	1.6	Upgrade Intermediate Dam	0.8		
NEW WTP	15.2	Operate WTP & PUMPS LONG TERM	1	Operating ($0.3M/a)	7.5		
Operating Water Treatment and Pumping	26	Operating Water Treatment system ($1.0M/a)	15				
TOTAL	**68.3**	**TOTAL**	**38.2**	**TOTAL**	**34.9**	**ALTERNATIVE TOTAL**	**181.7**

4.2 Comparison of Waste Rock Closure Methods

Several of the scoping studies addressed closure measures that could be applied to the waste dumps. The previous chapter and the supporting appendices describe designs and cost estimates for waste dump relocation (with alkalinity addition), re-sloping, and covering. Those results can be used to draw inferences about which methods are likely to be most applicable.

Table 4.5 compares the cost of dump relocation to the cost of dump covering. It is immediately clear that constructing even an “Excellent” cover is generally much less expensive than total relocation of a dump. The inference is that total relocation of a dump should only be considered when there are additional benefits to be gained. For example, relocation of the Faro Valley Dump may be cost effective because it will significantly reduce the discharge of contaminated water to the Faro pit, and relocation of the Vangorda waste may be cost-effective if it allows a less costly alignment of Vangorda Creek. Taken only on its own merits, however, relocation of dumps appears to be a poor option.

Another inference from Table 4.5 is that any further work on relocation should focus on partial relocation of the most problematic material. The currently ongoing geochemical studies will help to determine whether areas of “problematic” material can be identified and, equally importantly, whether the remaining material can truly be considered benign.

Tables 4.6 and 4.7 look in more detail at the cost and benefits of covering waste rock dumps. The “benefits” considered in the tables are the reduction in long-term water treatment costs that can be attributed to each level of cover. The water treatment cost reductions were estimated by combining the water balance and load estimates from Section 3.1 and Appendix C with the water treatment cost calculations described in Section 3.4 and Appendix F. As shown in Table 4.6, the water treatment costs were estimated for cases where the waste rock dumps are uncovered (first three rows) and the cases where they are covered with “Basic”, Intermediate” or “Excellent” covers (middle three rows).

As shown in the last two columns of the table, the difference between treatment costs with and without covers is accounted for as the “benefit” associated with the cover. There are “Best Engineering Judgement” (BEJ) Benefits” and “Practical Worst Case” (PWC) Benefits” to reflect the current uncertainty in future water quality. The ongoing geochemical studies should narrow the range of uncertainty, but at the moment a wide range of future conditions must be taken into consideration. If the future water quality is what the BEJ estimates in Appendix B suggest, the savings in water treatment costs will be less than if the water quality reaches the PWC levels.

One additional uncertainty is the effects of the covers on the progress of acid rock drainage. It is known from work elsewhere that properly designed and constructed covers can significantly reduce oxidation rates, leading to long-term improvements in drainage water quality. However, it is not known whether the materials and climate in the Faro area will allow for such improvements. The last three rows of Table 4.6 therefore consider cases where the covers lead to additional reduction in zinc concentrations. Comparison of the "benefits" of these cases with the preceding three cases shows the importance of such an effect.

Table 4.7 compares the estimated "benefits" of each cover to the construction costs estimated in Section 3.8 and Appendices I and J. (It is important to note that the "benefits" column does <u>not</u> show net benefits. To get "net benefits" it would be necessary to subtract the "costs" column from the "benefits" columns.) The comparison suggests that the benefits, with respect to water treatment costs alone, generally will not justify the costs of completely re-sloping and covering the dumps. However, if the risks of much poorer water quality and the added benefits associated with revegetation are taken into consideration, the basic covers look more attractive. It might also be cost effective to cover the most "problematic" material with better covers. An example would be covering the sulphide dumps with high quality covers. In that case a relatively small investment in covers could lead to a disproportionately large savings in water treatment costs. As discussed above, the ongoing geochemical investigations will determine whether well-defined "problematic" areas can be identified.

As mentioned in Section 3.8, more detailed site-specific work will be needed before cover design and accurate performance estimates can be made. The additional work will include sampling and testing of available construction materials, modeling of cover performance, and probably field-scale trials. If the decision to build covers hinges on an accurate estimate of the benefits, such as shown in Table 4.7, field-scale trials will certainly be required.

Table 4.5
Waste Rock Covering vs. Relocation

Site	Component	Relocation Cost	Cover Cost (incl. Re-sloping)		
			Basic Cover	Intermed. Cover	Excellent Cover
Faro	Faro Valley Dumps	$6,800,000	$400,000	$900,000	$1,700,000
Faro	Main & Intermediate Dumps (25%)	$62,300,000	$3,800,000	$7,800,000	$13,400,000
Faro	Ranch Dump	$4,700,000	$50,000	$250,000	$350,000
Faro	Northwest Dump	$33,400,000	$2,100,000	$4,700,000	$8,300,000
Faro	Northeast Dump	$82,200,000	$1,900,000	$4,100,000	$7,200,000
Grum	Main Dump	$43,200,000	$1,500,000	$2,900,000	$4,900,000
Grum	Southwest Dump	$17,600,000	$1,700,000	$3,400,000	$5,700,000
Vangorda	Main & Barite Dumps	$98,100,000	$1,100,000	$2,100,000	$3,500,000

Table 4.6
Water Treatment Costs for Various Waste Rock Covers

Scenario	Faro NPV	Vangorda Grum NPV	Total NPV	BEJ Benefits	PWC Benefits
No Covers, Current Zinc	$29,900,000	$20,600,000	$50,500,000		
No Covers, BEJ Zinc	$37,100,000	$25,000,000	$62,100,000		
No Cover, PWC Zinc	$42,000,000	$27,400,000	$69,400,000		
Basic Covers, BEJ Zinc	$35,700,000	$23,700,000	$59,400,000	$2,700,000	$10,000,000
Intermediate Covers, BEJ Zinc	$30,100,000	$20,300,000	$50,400,000	$11,700,000	$19,000,000
Excellent Covers, BEJ Zinc	$25,600,000	$17,600,000	$43,200,000	$18,900,000	$26,200,000
Basic Covers, BEJ Zinc/2	$31,800,000	$21,100,000	$52,900,000	$9,200,000	$16,500,000
Intermediate Covers, BEJ Zinc/4	$26,600,000	$18,000,000	$44,600,000	$17,500,000	$24,800,000
Excellent Covers, BEJ Zinc/5	$23,600,000	$16,400,000	$40,000,000	$22,100,000	$29,400,000

Table 4.7
Waste Rock Cover Benefits vs. Costs

Cover	Total Cost	Benefits (Reductions in Treatment Cost)		
		Expected	Minimum	Maximum
Basic Covers	$12,500,000	$9,200,000	$2,700,000	$16,500,000
Intermediate Covers	$26,100,000	$17,500,000	$11,700,000	$24,800,000
Excellent Covers	$45,000,000	$22,100,000	$18,900,000	$29,400,000

4.3 Comparison of Tailings Area Closure Alternatives

Sections 3.6.3, 3.8 and 3.9 discuss closure methods applicable to the Rose Creek tailings area, (diversion improvements, covers and relocation, respectively). Table 4.8 below presents a compilation of the cost estimates presented in those sections.

The table also includes rough estimates for upgrading of the Fresh Water Supply Dam. As discussed in other reports, any upgrading of the FWSD will require remediation of the low-level pipe. That will in turn require lowering of the spillway to a level that happens to be sufficient to pass the PMF. The costs of upgrading the FWSD to the 1 in 500, half-PMF or PMF are therefore all the same. Costs for breaching the FWSD were estimated at roughly $2,000,000, but could be higher if a two-stage lowering of the water level is required.

Table 4.8 can be used as a "menu" from which methods can be chosen and combined to create complete closure alternatives for the Rose Creek tailings area. Table 4.9 present five example alternatives:

- Under Option 1, the Fresh Water Supply Dam would be breached and the Rose Creek Diversion upgraded to pass the Probable Maximum Flood (PMF).

- Under Option 2, the Fresh Water Supply Dam would be breached but any flood flow would be allowed to overtop the Rose Creek Diversion and pass across the tailings in a riprap channel. Improvements to the Intermediate Dam and Cross Valley Dam spillways would be required.

- Under Option 3, the FWSD would be upgraded to withstand the PMF, i.e. the spillway would be lowered and the low-level pipe remediated. The resulting flow would be routed through the Rose Creek, which would need to be upgraded. However, the Rose Creek diversion upgrade in this case would not be as difficult as in the preceding case, because the FWSD would act to attenuate the flood.

- Under Option 4, the FWSD would again be upgraded to withstand the PMF. In this case however, the resulting flow would be allowed to overtop the Rose Creek Diversion and pass across the tailings in a riprap channel. The riprap channel could be smaller than in Case 2 because of the attenuation of the flood by the FWSD. Improvements to the Intermediate Dam and Cross Valley Dam spillways would be required.

- Under Option 5, the tailings would be completely relocated and other structures breached.

All of the above options are expected to result in similarly low long-term risks. It is therefore reasonable to compare the options on the basis of cost. As shown in Table 4.9, the estimated costs for the options range from roughly $20,000,000 to roughly $125,000,000. As was the case with the waste rock dumps, complete relocation (Option 5) is far more expensive than the other approaches. The other options are more similar in cost, with the two options where floods are directed over the tailings in a riprap channel appearing to be significantly less costly than those where the Rose Creek Diversion is upgraded. However, further analysis will be required before such conclusions can be firm.

Table 4.8
Rose Creek Closure Methods

Upgrade FWSD		
a	Lower spillway to pass PMF	$2,000,000
b	Breach	$2,000,000
Upgrade Rose Creek Diversion		
a	1 in 500	$100,000
b	80% of PMF	$22,400,000
c	PMF	$28,000,000
Upgrade Intermediate and Cross Valley Ponds		
a	1 in 500 Spillways	$100,000
b	Half-PMF Spillways	$300,000
c	PMF Spillways	$800,000
d	Construct PMF Channel[a]	$9,700,000
e	Construct 80% PMF Channel[b]	$7,700,000
Cover or Remove Tailings		
a	Relocate All[c]	$123,800,000
b	Relocate Half[d]	$61,900,000
c	Basic Cover	$3,500,000
d	Intermediate Cover	$11,600,000
e	Excellent Cover	$18,600,000

Notes:

a. Channel width 150 m, depth 3.3 m
b. Channel width 115 m, depth 3.3 m
c. 55,000,000 tonnes @ $2.25 per tonne
d. 27,000,000 tonnes @ $2.25 per tonne

Table 4.9

Rose Creek Closure Alternatives

Option 1 - Breach FWSD and Upgrade RCD for PMF			
FWSD	b	Breach	$2,000,000
RCD	c	PMF	$28,000,000
ID/CVD	a	1 in 500 Spillways	$100,000
Tailings	d	Intermediate Cover	$11,600,000
			$41,700,000
Option 2 - Breach FWSD and Run PMF over Tailings in Channel			
FWSD	b	Breach	$2,000,000
RCD	a	1 in 500	$100,000
ID/CVD	c	PMF Spillways	$800,000
	d	Construct PMF Channel	$9,700,000
Tailings	d	Intermediate Cover	$11,600,000
			$24,200,000
Option 3 - Keep FWSD and Upgrade RCD for PMF			
FWSD	a	Lower spillway to pass PMF	$2,000,000
RCD	b	80% of PMF	$22,400,000
ID/CVD	a	1 in 500 Spillways	$100,000
Tailings	d	Intermediate Cover	$11,600,000
			$36,100,000
Option 4 - Keep FWSD and Run PMF over Tailings in Channel			
FWSD	a	Lower spillway to pass PMF	$2,000,000
RCD	a	1 in 500	$100,000
ID/CVD	b	Half-PMF Spillways	$300,000
	e	Construct 80% PMF Channel	$7,700,000
Tailings	d	Intermediate Cover	$11,600,000
			$21,700,000
Option 5 - Remove Tailings			
FWSD	b	Breach	$2,000,000
RCD	a	1 in 500	$100,000
ID/CVD	a	Relocate All	$123,700,000
			$125,800,000

5. CONCLUSIONS

One objective of the scoping studies presented herein was to develop a set of tools for further closure planning. In the immediate future, the most useful tools in this particular "toolbox" are expected to be:

- The compilation of information from previous plans (Section 2);
- The initial water and load balance, which can be used to estimate the effects of closure measures on water quality and/or water treatment needs (Section 3.1);
- Consistent, calibrated methods for estimating costs of water collection and treatment (Sections 3.4 and 3.5); and,
- Consistent methods, as yet calibrated only to experience elsewhere, for estimating the costs of major earthworks such as re-sloping, construction of soil covers, tailings relocation, and waste rock backfilling (Sections 3.7-3.10).

Most of these tools can and should be further improved as the closure planning progresses. For example, the water treatment cost estimates should be re-calibrated after each season of treatment. For items where there is no direct site experience, it may be useful to work with local contractors to develop better estimates. However, the basic structure and estimating method should be applicable for any level of planning up to and including alternative selection. More detailed cost estimating methods would require basic engineering design.

A number of the other "tools", such as the assessments of pit walls and diversions (Sections 3.2 and 3.3) provide a useful compilation of available information, and are already being superseded by ongoing studies.

A second objective of the scoping studies was to provide a check on previous estimates of overall closure costs. The estimates presented in Section 4.1 show that earlier estimates were in the correct order of magnitude. It is reasonable to talk about a total closure cost of several hundred million dollars. Uncertainties about a small number of high cost items dominate the range. The priorities for narrowing the overall cost range are to establish whether the tailings will be relocated or covered in place, and to identify the combination of relocation, re-sloping, covering and or perpetual water collection and treatment that is best for each mine area.

A third objective was to draw inferences, where possible, about which closure measures might be preferred. One must be very cautious about drawing inferences from scoping level studies, but some patterns appear to be clear. For example, Section

4.2 shows that total relocation of waste rock piles is much more costly than covering, so any further work on waste rock relocation should perhaps be limited to identifying target areas for partial relocation. Similarly, the cost associated with covering all of the dumps with a highly engineered soil cover do not appear to be recoverable in terms of water treatment benefits, so further work should focus on simpler covers or perhaps on identifying "problematic" areas that might justify better covers. The comparisons in Section 4.3 show that total relocation of the tailings is much more expensive than other reasonable options. The inference is that the emphasis should be on determining whether those other options can indeed meet all stakeholder expectations.

A final objective of the scoping studies was to identify priorities for further investigation. The key uncertainties related to each of the individual closure issues or closure measures are identified in the relevant sections and appendices. However, it is important to address those uncertainties in a prioritized manner. In experience elsewhere, that process has been effectively coordinated by iterations of investigation and option review. The scoping studies presented herein can be considered as one of those iterations, and hopefully will provide the tools needed for future reviews.

This report, **1CD003.13 – Scoping Studies for Final Closure and Reclamation Plan, Faro Mine, Yukon Territory**, has been prepared by:

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