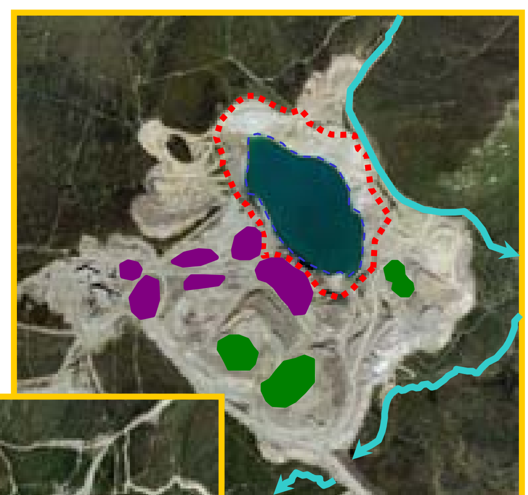
REVIEW OF REMEDIATION ALTERNATIVES FOR THE ANVIL RANGE MINE COMPLEX FINAL REPORT

Prepared by:

The Independent Peer Review Panel

Prepared for:

Deloitte and Touche Inc.
Faro Mine Closure Planning Office (FMCPO)
Indian and Northern Affairs (INAC)
Yukon Government
Selkirk First Nation at Pelly Crossing
Kaska Tribal Council represented by the Ross River Dena Council



April 2007

Mr. Wes Treleaven, Senior Vice President, Receiver
April 1, 2007
Deloitte and Touche, Inc.
79 Wellington Street West
Suite 1900, P. O. Box 29 TD Centre
Toronto, Ontario M5K 1B9

Dear Mr. Treleaven:

In October 2006 the technical experts listed below were commissioned to serve as the Independent Peer Review Panel to review remediation alternatives for Anvil Range Mine Complex located in the Yukon Territory. As required by our Terms of Reference, the review has included an assessment of whether or not:

1. the proposed closure alternatives provide a full and reasonable span of possible closure alternatives for consideration in the selection process, and
2. the individual alternatives are described in a manner that is complete, rigorous, and appropriate for comparing options in a subsequent selection process.

The Panel is satisfied the technical aspects of the remediation evaluation and example alternatives have been properly assessed and with some recommendations believe the process toward finalization of a preferred closure plan can proceed in an expedient manner.

Respectfully Submitted By:

Dr. Laurie Chan, Professor
University of Northern British Columbia

Mr. Kenneth Raven, P.Eng., P. Geo.
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Dr. Kenneth Froese,
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I Introduction

The legacy of twentieth century mining is often characterized by significant environmental, social, and cultural degradation. Scores of abandoned base and precious metal mines exist throughout North America on both public and First Nations' lands. These mines are typically characterized by their physical scars, geotechnical stability issues, and long standing water quality impacts. In particular, significant impacts arise from acid rock drainage and metal leaching from inadequately managed waste rock and tailings.

The largest orphaned site located in Yukon Territory is the Anvil Range Mine Complex (ARMC) consisting of the Faro, Vangorda, and Grum Mines along with the Rose Creek Tailings Facility (RCTF). Mining at the ARMC commenced in the late nineteen sixties and carried on with some interruption until the late nineteen nineties. Associated with these mines are hundreds of millions of tonnes of waste rock and tailings containing sulfides capable of producing very poor quality drainage characterized by low pH and high metals and total dissolved solids content.

In the Yukon, remediation programs related to abandoned and orphaned sites are administered through Indian Northern Affairs Canada (INAC) in association with the Yukon Government (YG), First Nations, and a range of other interests. The firm of Deloitte and Touche, Inc. was appointed Interim Receiver of the ARMC pursuant to an order of the Ontario Court (presently the Superior Court of Justice) in April 1998. The Interim Receiver's mandate is to receive, preserve, and protect the assets of the ARMC. As a result, the Interim Receiver has overseen the care and maintenance program of the ARMC under terms of the Water License granted by the Yukon Water Board. The Interim Receiver has worked closely with INAC, YG, the town of Faro, the Ross River Dena Council, and other stakeholders to manage programs required to protect the receiving environment.

To aid in management of individual remediation studies and the overall program for the ARMC, the Yukon Type II Mines Project Office (YTMPO) established the Whitehorse-based Faro Mine Closure Project Office (FMCPO). The FMCPO reports to the Oversight Committee, which is comprised of representatives of the YG, INAC, the Selkirk First Nation and the Kaska Tribal Council represented by the Ross River Dena Council. Additional interests that have been engaged include industry, non-governmental organizations, and other federal regulatory departments.

In 2002 and after recognition the mines would not be re-opened, the YTMPO initiated a multi-interest review directed toward development of a final closure and remediation plan and implementation strategy. Beginning in 2003, a series of workshops were held between representatives of the various interests, technical experts and consultants to formulate a plan to move the remediation process forward through design and completion of multiple engineering and scientific studies. As a result, and building on the large technical information base that has been generated since mine inception in the 1960s, a number of technical studies have been subsequently conducted to advance overall site knowledge relevant to closure requirements.

Listed below are the broad remediation objectives previously identified by the Oversight Committee in July 2006 and were based on discussions of the perceptions and expectations of the stakeholders regarding the overall remediation program:

- *Protect human health and safety;*
- *Restore to the extent practicable the air, land, and water environments including protection of fish and wildlife;*
- *Reclaim the land to pre-mining uses where practicable;*

- *Maximize both local and territorial socio-economic benefits; and*
- *Manage long term environmental and engineering risks in a cost effective manner.*

A team of technical experts were assembled and contracted through the Interim Receiver, Deloitte & Touche Inc., to serve as an Independent Peer Review Panel (the Panel). The Panel was tasked with reviewing and commenting on a report and supporting documentation prepared by SRK Consulting (SRK). This draft report (the Example Alternatives Report) describes a range of technical alternatives for remediation of the ARMC. Ultimately, the Panel will present its findings in a report to a committee of technical advisors reporting directly to the Oversight Committee.

In general terms, the Panel was asked to review the description of alternatives contained in the draft SRK report to ensure that it reflects the best possible information base for making an informed decision about the preferred course of action to implement. Specifically, the FMCPO asked the Panel to:

1. *Assess whether or not the proposed closure alternatives provide a full and reasonable span of possible closure alternatives for consideration in the selection process.*
2. *Identify whether or not the individual alternatives are described in a way that is complete, rigorous, and appropriate for comparing options in a subsequent selection process.*
3. *Identify any information gaps that should be addressed or work that should be undertaken prior to embarking on selection of the preferred management approach.*

The members of the Panel were selected on the merits of their individual experience and expertise in various technical areas to mine operations and closure, creating a team of senior professionals with a sufficiently broad background to comprehensively address the interrelated and complex environmental, engineering, and economic aspects of the ARMC remediation project. The members of the Panel include:

- Dr. Laurie Chan, Professor University of Northern British Columbia
- Dr. Kenneth Froese, Golder Associates Limited
- Dr. Anthony Hodge, P. Eng., Anthony Hodge Consultants Inc.
- Mr. Randy Knapp, P.Eng., SENES Consultants Limited (Retired)
- Mr. Kenneth Raven, P.Eng., P.Geo., Intera Engineering Limited
- Dr. Terry Mudder, CHCM, IPRP Chairman, TIMES Limited
- Dr. Bill Price, Natural Resources Canada
- Dr. Andrew Robertson, P. Eng. Robertson GeoConsultants Inc.
- Dr. Leslie Smith, Professor University of British Columbia

The Panel convened for the first time October 1 to 7, 2006. At that time, the Panel and representatives from SRK, the YG, Deloitte & Touche, and associated sub-contractors traveled to Faro and conducted four days of site visits and meetings. A comprehensive tour of the entire ARMC was conducted with frequent observational stops accompanied with informational discussions.

Subsequent to the initial site visit, the Panel has conducted ongoing internal conversations and communications leading up to a full panel meeting with the stakeholders in Vancouver, British Columbia December 19 and 20, 2006. The Panel has met on multiple occasions with representatives of the First Nations, staff from the FMCPO, the YG, INAC, SRK and/or members of the Oversight Committee.

During this process, members of the Panel have requested and reviewed scores of documents, and have had numerous communications amongst themselves and with closure staff and the consultants. A bibliography has been compiled for this report to reference the primary documents the Panel examined during its review.

II Human Health and Ecological Risk

The human health and ecological risk assessment prepared by SENES Consultants Limited (SENES) in 2006 concluded that the current risks and impacts associated with the ARMC are low for resident aquatic life, terrestrial wildlife, and humans. Taken collectively, the observations from the site visit, the risk assessment, and engineering information presented to the Panel indicate the current situation is contained and the site is being managed properly. However, future conditions will likely change due to the hundreds of millions of tonnes of mineral wastes containing sulphides placed on the land surface during several decades of mining. The mass of potentially soluble weathering products is steadily increasing in the tailings and waste rock and the neutralization potential is being depleted. The water storage capacity of the waste rock and metal attenuation capacity of the peat beneath the tailings is also being depleted. Left without further human intervention and management, the geotechnical, geochemical, and water quality conditions at the site will deteriorate dramatically over the next several decades leading to widespread environmental impacts lasting for several centuries. The development of a closure plan that addresses the future concerns of impacts to the off-site environment and human health is critical.

The remediation goals include protection of environmental and human health, along with restoration of traditional practices and land uses. In order to achieve the desired remediation goals and implement preferred alternatives, there are only a few generic categories of options available:

- Divert clean water
- Capture seepage
- Water treatment
- Relocate sulphidic materials
- Cover sulphidic materials

Fundamental to the evaluation and selection of a preferred remediation alternative is determination of the level of aquatic and terrestrial ecological protection desired and the appropriate water quality objectives to be applied. Associated with selection of numerical and narrative standards is the level of protection realistically achievable within Rose Creek, Anvil Creek, and/or the Pelly River. There are existing water quality impacts within Rose Creek, resulting from a combination of historical mining activities and natural phenomena. These impacts have resulted in zinc and other constituent concentrations approaching, and at times slightly exceeding, the generic CCME (Canadian Council of Ministers of the Environment) guideline. Nonetheless, the water quality has improved to some extent since cessation of mining.

Based on the review of current and expected water quality within Rose Creek, the Panel believes the generic CCME guidelines for zinc cannot be obtained continuously regardless of the individual technologies selected and remediation alternatives that may be implemented. As a result, the derivation and application of site-specific water quality objectives may be appropriate for this particular surface water ecosystem. It is important to note, however, that estimates of future seepage chemistry, groundwater capture, and treatment efficiencies and discharge water quality do not indicate measurable impacts within the Pelly River after a successful remediation alternative is implemented.

The human health and ecological risk assessment conducted by SENES evaluated potential adverse effects on the ARMC watershed and terrestrial environment including Rose, Anvil, and Vangorda Creeks and their main stem the Pelly River. The Gartner Lee site assessment and SENES risk assessment relied upon generally accepted industry practices and protocols and serve the purpose of defining the boundaries of acceptable risks for the initial selection of remediation alternatives. The Future 1 that SENES used presents a whole series of quantitative data showing that zinc and other metals release at current rate pose minimal risk to the aquatic system. However, adverse impacts to both environment and human health are expected over time if nothing is done at the ARMC as presented in the scenario of Future 3.

The SENES risk assessment focused on potential impacts to the aquatic ecosystem, terrestrial environment, and human receptors assuming the geochemistry would deteriorate over time to a condition termed Future 2. There is a general consensus the geochemistry and water quality will deteriorate from its current condition to that of at least Future 2. It is the understanding of the Panel the proposed remediation alternatives will achieve better results than the hypothetical remediation used in the risk assessment exercise, i.e. Future 2. However, it does appear likely certain proposed remediation alternatives will not achieve a lower residual ecological risk than the hypothetical scenario. A further comprehensive risk assessment of the residual effects and ecological and human health risks is needed when the preferred remediation alternatives have been selected.

In the case of potential risks to the aquatic ecosystem the primary concern is the Pelly River, together with its tributaries Anvil, Rose and Vangorda Creeks. These receiving waters are impacted by anthropogenic and natural sources. The most important components of these aquatic ecosystems are the fisheries and concerns regarding impacts on reproduction and accumulation of metals. From a terrestrial environment standpoint, there are ongoing concerns related to the lesser potential for direct toxicity to and accumulation of metals within several important animal species and traditional food sources.

The SENES risk assessment assumed the remediation alternatives within the SRK report would provide a better outcome than the theoretical one employed in their calculations. There are two distinct observations associated with this assumption. First, the remediation alternatives proposed are not equal in their effectiveness or overall engineering or ecological risk. In some instances the engineering and ecological risk assessment did not adequately portray the level of comparative risk such as the potential impacts associated with the stabilization in place or relocation of tailings. For example, implementation of a minimum construction approach with thinner covers allows for more infiltration and creation of poor quality seepage, thereby relying more heavily on treatment.

Second, when one examines the water quality estimates generated with the use of a series of mass load spreadsheets prepared by SRK specifically for the Panel, one finds even a small decrease in groundwater capture of a percent or more increases the metal mass load dramatically in Rose Creek far overshadowing any benefit from advanced water treatment. It does appear some of the alternatives would not provide a better outcome than the risk scenario put forth at the original site meeting in October, 2006. The Panel recommends the risk rating process and the ecological/human risk assessments that have been completed to date, be integrated into the process that will be undertaken for assessing the relative merits of options against closure objectives.

III Geochemical Conditions

The underlying cause of the long term environmental concerns at ARMC is the geochemical conditions in the hundreds of millions of tonnes of sulphidic tailings, waste rock and mine walls exposed to the air and water by the over 30 years of mining. Without adequate remediation, the release of potentially toxic elements and acidity from sulphide minerals in the mined rock will cause environmental impacts for hundreds of years or more.

As part of closure planning, geochemical studies have been conducted to estimate the geochemical composition of the mined rock and predict the future seepage quality.

The mined materials with the highest concentration of sulphide minerals and thus of greatest environmental concern are the sulphide tailings (55 million tonnes) and massive sulphide waste rock (32.4 million tonnes), all of which are capable of producing extremely acidic and highly toxic drainage. The other major geochemical hazard is the more than two hundred million tonnes of lower sulphide waste rock and the mine walls, much of which will produce lower strength, acidic, and metal containing drainage. Approximately half of the lower sulphide rock will produce acidic drainage in the future and the other half will remain acid consuming.

The surfaces of sulphide minerals have been oxidizing (rusting) for the past 30 years and much of the seepage from the tailings, waste rock and pits already contains toxic trace element concentrations and has to be collected and treated prior to discharge. However, the majority of the sulphide minerals are yet to be oxidized. With continued exposure of the sulphidic mined rock to air and water and as geochemical conditions continue to evolve, the mass of soluble contaminants stored in the wastes will increase, more of the drainage will become acidic and concentrations of acidity and potentially toxic elements in the seepage will dramatically increase.

Three different geochemical scenarios were created to show the potential future seepage chemistry for the waste rock. Future 1 was based on the average contaminant concentration of current seepage. Future 2 was based on the maximum contaminant concentration of the current seepage. Future 3 was a prediction of the future worst case seepage chemistry. The Future 2 geochemical scenario has been advanced by SRK as the most probable conditions. Future 3 is the predicted maximum contaminant concentrations occurring with time. The Panel agrees Future 2 seepage chemistry is not only likely but probable and given the large mass of sulphidic rock, Future 3 seepage chemistry or worse is quite possible and should be given consideration in the ongoing assessment of closure alternatives.

The Panel considered the estimates of future seepage quality were based on generally accepted methodologies and reasonably conservative assumptions and were sufficiently accurate to conceptually assess the various remediation alternatives. Given the long time scales and complex properties and processes, some uncertainty regarding the future seepage chemistry and the extent of sulphide oxidation is typical at most mine sites. At ARMC, there is additional uncertainty due to the heterogeneous nature of the various sulphide bearing mineral wastes and the lack of operational material characterization.

Consequently, it is possible the maximum seepage chemistry may be worse and the speed of the deterioration may be faster than predicted. Although additional studies may be required to address this uncertainty in future phases of the project, they are unlikely to significantly alter the list of remediation alternatives

Ongoing sulphide oxidation and leaching will increase remediation difficulties and costs and the Panel supports moving forward with implementation of remedial actions in as expedient manner as practical. Recommended actions while the process of selecting the preferred remediation alternatives moves forward, include continued monitoring of seepages from different site components, conducting additional test work to better estimate the magnitude of the neutralizing potential (NP) and the time to the onset of acidity, developing interim measures to prevent wind erosion of tailings and ensuring there is adequate capacity for the collection and treatment to handle a faster than predicted deterioration in dump and tailings seepage.

IV Groundwater Capture Approaches and Efficiencies

A central and critical feature of any remediation alternative selected will be the reliable and efficient collection of contaminated seepage and runoff generated in the sulphidic waste rock, tailings, ore, pits and underground workings. Due to the anticipated degradation of the seepage water quality in the future, a highly effective groundwater capture system at the ARMC is needed. Even if a small volume of contaminated seepage escapes capture, the load associated with that volume would likely cause a measurable and undesirable increase in metal concentrations in Rose Creek and Vangorda Creek and possibly further downstream.

Based upon experience, groundwater capture efficiencies approaching 100% are only achievable for very well characterized groundwater systems where adaptive management programs have resulted in the phased implementation of collection systems such as permeable walls, barrier walls, recovery wells and other secondary and tertiary recovery technologies for which continuous monitoring programs are in place and sufficient backup systems exist.

The Panel believes there is sufficient information on hydrogeological conditions at the Faro Mine waste rock dumps (WRDs), the Rose Creek Tailings Facility, and the Grum and Vangorda WRDs to proceed with the evaluation of the closure alternatives that consider groundwater load capture.

The groundwater capture systems proposed for the priority areas of the Faro Mine WRDs draining to North Fork of Rose Creek (NFRC) and Rose Creek Valley have the potential for contaminant by-pass via bedrock migration pathways and due to limits on available drawdown created by thin saturated overburden thicknesses. This possibility has been recognized by SRK, and is one of the primary reasons for moving forward within the framework of an adaptive management system. Even if the proposed groundwater capture systems for the three higher priority areas downstream of the Faro Mine WRDs operated at 100 % efficiency, contaminant loading to the NFRC and Rose Creek Valley will likely not be eliminated due to loading from other diffuse sources of acidic and metals containing seepage emanating from the Faro Mine WRDs. That observation notwithstanding, there is merit in intercepting the subsurface contaminant load from the priority areas of the Faro Mine WRDs (ETA, S-Cluster, Zone 2 Pit Outwash) for reasons of ease of collection, overall load reduction and preventing surface water contamination.

There is a need to explicitly recognize in conjunction with any adaptive management program for groundwater collection, lining of the NFRC will likely become necessary to ensure protection of water quality in NFRC and Rose Creek. Since lining of NFRC will likely be necessary, a groundwater load collection alternative proposed by the Panel is to consider all areas down-gradient of the Faro Mine WRDs and the Rose Creek Tailings Facility (RCTF) as a single contaminant load collection zone and to emphasize contaminant load collection efforts for this zone in the area down-gradient of the Rose Creek Tailings Facility.

The prospects of achieving very high groundwater load capture efficiencies at Faro Mine are judged by the Panel to be greatest downstream of the Rose Creek Tailings Facility, where groundwater flow is naturally focused into a small area that is well defined and the hydrogeology is reasonably well characterized. This is a fortuitous circumstance as groundwater load collection in this area is critically important because it provides final backup collection for Faro Mine WRDs seepage that may bypass the proposed groundwater collection systems in the three higher priority areas. However, the local bedrock in the area downgradient from the RCTF and elsewhere at both Faro and Grum/Vangorda Mine sites, has not been fully investigated and will need to be further characterized and monitored to ensure high load capture efficiencies are achieved.

To provide greater certainty of achieving very high groundwater load capture efficiency at the RCTF, the Panel has proposed a groundwater capture option that relies on surface pumping from a permeable recovery trench or horizontal drain with fully penetrating relief wells near the Cross Valley or Intermediate Dams and a down-gradient cut-off wall installed into bedrock as necessary.

This modified groundwater capture option would include an emergency storage pond to address inevitable pumping system malfunctions and breakdowns and up-gradient cut-off walls to minimize the amount of clean groundwater entering the aquifer beneath the RCTF. The modified groundwater capture option proposed by the Panel is presented on Figure I.

Contaminated seepage and groundwater capture plans are much less developed for the Grum and Vangorda Mine WRDs, primarily because the presence of finer grained soils at the Grum and Vangorda Mine sites lead to slower rates of groundwater flow and contaminant migration.

Additional down-slope investigations of the Grum Mine WRDs and to a lesser extent the Vangorda Mine WRDs will be necessary as part of the adaptive management plan (AMP) process to design and optimize groundwater load capture systems at these sites.

With sufficient site characterization effort, good engineering design, reliable backup systems and rigorous application of adaptive management, the Panel believes it should be possible to achieve the target capture efficiencies of 90 to 99% for the priority areas of the Faro Mine WRDs, for the RCTF and potentially for the Grum and Vangorda Mine WRDs.

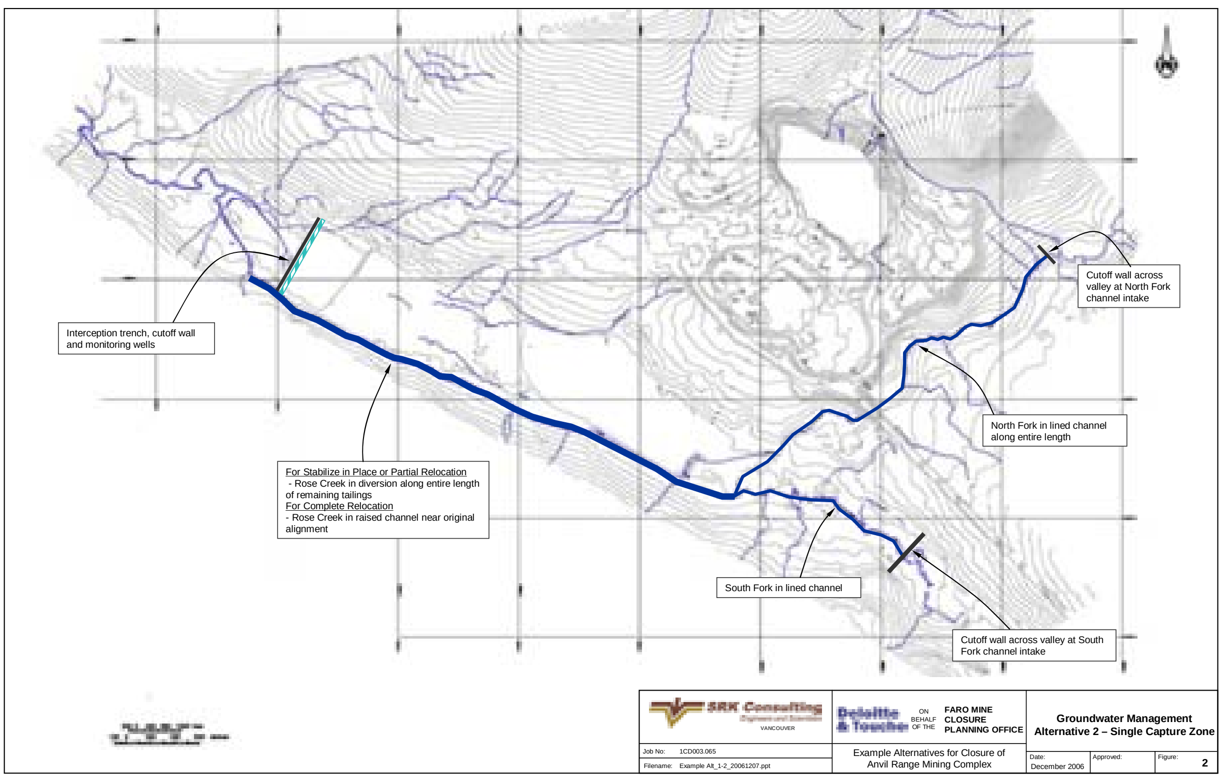

Figure I Proposed Single Groundwater Capture Option

V Soil Covers for Waste Rock and Tailings

Soil covers play a key role in the final closure plan for the ARMC as they are included in each of the four alternatives.

The Panel cannot envision a closure scenario that does not include some type of a “store and release” soil cover on the waste rock piles and a soil or water cover on any tailings left in place within Rose Creek Valley. The concept that it would be possible to place and maintain an impervious barrier cover over all waste rock has been discarded in the alternatives analysis, a technical decision supported by the Panel.

The soil covers described in the Example Alternatives Report are based on conceptual designs that provide the basis for linking performance requirements with cost estimates; this level of information is sufficient at this stage of the alternative selection process. The Panel rejects the cover alternatives that are based on minimum construction efforts as they disregard many elements of best engineering practices employed in the international mining industry today.

For the evaluation of closure alternatives, the three conceptual designs presented in the Example Alternatives Report (rudimentary, low infiltration, very low infiltration covers) provide an adequate representation of the range in cover performance that can reasonably be anticipated for the ARMC.

The cover test trials now underway at the Vangorda Mine site are critical to the selection of a final cover design. If a soil cover is selected for any tailings left in place, a similar test trial will be required to finalize that design. It is sensible to carry forward two options for the very low infiltration covers on the oxide fines and low grade ore stockpiles; one that incorporates a geosynthetic barrier and the other that reduces infiltration only using site soils.

The long-term performance of the low infiltration covers is dependent upon establishing a viable community of plant species on the covers. Consequently a vegetation management plan is needed for the soil covers.

There appears to be a sufficient supply of soils with suitable engineering and environmental properties to construct each of the covers described in the Example Alternatives Report. The single largest source of material is the Grum Mine overburden dump. Long haul distances to the Faro Mine site will quickly increase the cost of covers depending upon their design thickness; therefore the cover designs must be as efficient as possible to minimize haulage of materials. Soil covers at ARMC should be planned to function for thousands of years. They are not “walk-away” solutions as ongoing care and proactive maintenance will be required to maintain their design function. If there were a significant degradation in the covers there is the potential for a metal release rate from an accumulated reservoir of secondary mineral precipitates that could exceed that occurring in the absence of a cover placement.

There are presently many unknowns and challenges, and the mining industry has limited experience with proactive cover maintenance (e.g., do not wait until the cover leaks and discharge increases to make repairs). Challenges include predicting repair costs, difficult in detecting leaks, predicting future settlement of the underlying waste rock and monitoring changes in buried layers within the cover.

VI Long Term Water Treatment

It is inevitable long term treatment of seepage, groundwater, and open pit waters will be required, possibly as long as 500-1000 years, a situation amounting to “perpetual care”. This will be the case regardless of the remediation alternatives implemented at any mine site within the ARMC.

The Panel believes the high density sludge (HDS) process is most appropriate as the primary treatment technology employed at the ARMC both presently and in the future due to its proven reliability, performance, and minimal sludge production compared with other similar processes.

As an alternative to conventional chemical treatment, in-situ biological treatment has been evaluated in a full scale field trial within the Grum Mine open pit for the past three years and for half a summer season in 2004 within the Faro Mine open pit. The decision to pursue biological processes laid in the hope it could become a primary treatment technology to lower metal loads and potentially allow direct discharge of contaminated solution from the open pits into the local surface waters.

It is important to note biological treatment in this and most applications is not passive and would require extensive ongoing care and maintenance provided by highly trained individuals. After the three year trial period several observations and conclusions can be made. First, the biological treatment process remains unproven as a primary technology for metals removal at the ARMC. Biological treatment was not successful in achieving discharge effluent quality.

To date the in-situ addition of phosphorus to the open pit lakes in order to stimulate primary biological production and uptake of metals through adsorption has not yielded sufficient improvements in water quality to allow direct discharge to the environment. It is only appropriate for seasonal treatment and is not entirely passive as presented. On a cost comparison basis there is no advantage of biological versus chemical treatment using the HDS process. As a result, the Panel does not support the pursuit of biological process as a primary water treatment technology.

The excessive algal growth within the open pit lakes hampered the conventional treatment system currently being operated to the point it had to be terminated on a short term basis. The issue related to the effect of the algal cells on the ability to settle the chemical sludge produced through lime precipitation. There are other potential operational issues including residual phosphate, TDS, metals, and other nutrients in the effluent such as ammonia.

The draft SRK Example Alternatives Report does not include an explicit description of the manner in which untreated drainage or off-spec effluent would be stored in the short term, and copious quantities of chemical treatment sludge would be managed in the long term. Preliminary costs for long term sludge management were prepared in a supporting document. The open pits are seen as potentially the preferred option for storage of drainage and disposal of the massive volumes of chemical sludge generated in the long term. There are concerns the continued emphasis upon biological treatment as a primary technology may overshadow the use of the Faro Mine open pit as a long term viable sludge disposal and water management feature. The manner in which sludge is disposed of would likely be unique and not identical for all remediation alternatives.

Large storage facilities for contaminated untreated drainage and potentially off-spec effluent are a crucial part of pro-active, cost-effective, long-term water management and treatment programs with a goal of continuous compliance. Storage of treated effluent will be needed during upset conditions which are likely to occur periodically due to a variety of operational and mechanical reasons. There will be periods when the treatment facility must be shut down for routine maintenance, emergency repairs, or other situations associated with influent flow variations or extreme contaminant loadings. Excessive flows or mass or loads that exceed design capacity of the treatment plant may result from underestimation of extreme meteorological events or drainage chemistry. The ability to store off-spec effluent rather than directly discharge it into the environment is needed. Storage of untreated and effluent for varying periods may allow for more consistent treatment performance or a controlled paced release of effluent into the receiving environment.

Sludge disposal must constitute a major aspect for consideration within the design and selection of individual alternatives. The final disposition of these large quantities of sludge was not discussed in detail in the SRK Example Alternatives Report. In conjunction with any remediation alternative contemplating the relocation of waste rock or tailings to an open pit, there should be an assessment of the ability to accommodate treatment plant sludge within that pit along with the need to store untreated seepage and effluent not meeting water quality objectives.

Due to the need to attain a very high effluent quality there may be a need to incorporate additional unit operations and processes to enhance the removal of a select group of metals (e.g., copper, cadmium), in particular sulphide addition and filtration.

VII Long Term Management Considerations

Understanding the Long Term Context

Alternatives need to be assessed against the potential future physical and social conditions which they may face. In addition to seismic and hydrologic conditions that are part of standard engineering practice and have been included in analyses to date, the following factors need consideration:

- Variations and instabilities in the nature of society and various institutions including the capacity for knowledge transfer, the availability of needed human resource capacity, and the potential evolution of science and technology.
- Variations in environmental conditions such as gradual geomorphologic change and/or extreme episodic and long term climate change.
- Variations in the management of the closure plan addressing such issues as citizen participation in decision-making.

The capacity of various alternatives to address these variations will be a factor in the assessment of alternatives and thus such a scenarios analysis should be undertaken as part of the overall process of assessing alternatives that will now take place.

Key Management Issues

Specifically the following issues need addressing for the full project life cycle:

- Ensuring the availability of trained and experienced personnel for site operation through the full project life cycle predicted to be several hundred years.
- Financial surety for site operation, for project regulation and oversight, and for dealing with unforeseen problems.

  Financial surety is essential: (1) to avoid continued deterioration of the physical and chemical conditions at the site, which if left unchecked would lead to more severe adverse environmental impacts; (2) to support the implementation of adaptive management which demands a capacity to adjust in a timely manner to avoid significant problems that are discovered through the learning process; and (3) to achieve the societal goal of minimizing costs imposed on future generations related to current activities.
- Management of post-mining changes in land use.
- Surety of transportation systems, power supply, supplies of needed materials and services.
- Contingencies for addressing fire and other potentially traumatic events.
- Clarification of the role of various interests in closure plan implementation.

These factors are important to the performance and success of whatever preferred alternative is chosen, and must be addressed in the next phase of the design process and in development of the overall remediation management strategy. There may be differences in these issues between alternatives that are important in the ultimate selection process.

Climate Change

The Panel is of the view potential climate change does not invoke concerns that require design modifications at this time. However, this is an area where a degree of uncertainty exists. This uncertainty underlines the need to use a system of adaptive management in moving forward monitoring and adjusting if performance criteria are not achieved.

Furthermore, the issue of climate change and how it may affect closure is not adequately described in the description of alternatives. As a result, there is the impression the issue has not received due attention, which is not the case. This is a limitation in the current alternatives report and should be addressed.

Risk Rating

The collaborative risk rating that has been undertaken to date has been undertaken as a means to ensure that all interests understand what might go wrong with the various closure alternatives from a technical and cost perspective. It is intended as a contributor to but not driver of the process of assessing options for their relative merit in achieving closure objectives. As a means of collaboratively identifying what might go wrong, it is a useful exercise.

The Panel is concerned on three fronts: (1) the current risk rating appears to unfairly penalize in-valley tailings options while underestimating risks related to tailings relocation; (2) if the rating methodology was to drive the assessment of relative merits of each option there would be some significant methodological concerns; and (3) because the purpose of the current risk rating is not articulated and because the overall process for assessing the relative merits of options against closure objectives is not mapped out, the context of what is currently contained in the SRK report is missing. Both elements of this context need to be explicitly described prior to public discussion of the alternatives.

In now moving forward with a comprehensive assessment of the relative merits of the alternatives: (1) the full range of attributes – positive and negative – need to be considered; (2) the relative implications of all attributes must be accurately portrayed; and (3) some form of multi-interest, collaborative comparison using a “multi-objective” or “multi-criteria” assessment methodology is essential to ensure that all contributing factors are explicitly considered and that the scaling, weighting, and aggregating process are transparent for all to see.

Cost Estimates

A review of the details underlying the cost estimates was not included in the terms of reference for the Panel. As a result, their accuracy cannot be verified at this point in the process. As alternatives are refined and narrowed, a detailed confirmation of cost estimates must be undertaken by qualified professionals. A sensitivity analysis should be undertaken as part of the net present value calculations demonstrating the implications of a range of discount rates on cost estimates. A clear rational for the preferred discount rate should be provided. Net present value calculations are needed for estimating and comparing the financial requirements today of each alternative.

In addition, undiscounted cash-flow profiles over the full project life cycle should be included in the description of alternatives. These are needed to identify, assess and anticipate the technical and social implications for both Yukon and Canada over the long term.

Adaptive Management

Adaptive management is a formal process of implementing closure with an explicit objective of continuous learning and improvement. It offers an opportunity for building and sustaining public trust while accelerating technical progress. If effectively applied, such an approach can lead to reduced costs.

However, if rationalized simply on the basis of reducing costs and not on the basis of applying best judgment and consciously and carefully putting in place the system and support resources to apply results learned from experience over time, it's use will undermine rather than re-enforce public trust.

A fully developed adaptive management plan (AMP) for the overall ARMC remediation will be required addressing the technical, environmental and human implications over the long term. A general outline of the adaptive management approach for each alternative should be included as part of the assessment process.

As an essential component of the ARMC adaptive management plan, a comprehensive surface water management plan is needed for each remediation alternative remaining following the next phase of review. This aspect was not discussed in any detail in the SRK Example Alternatives Report. The overall objective is to keep uncontaminated surface water clean, which includes primarily runoff during the spring and other precipitation events. As part of this management plan is the recognition that ongoing care and maintenance of water conveyance systems will be needed and the impacts of erosion will be also be ongoing.

VIII Land Form and Land Use Issues

The primary land use and reclamation objectives are to reliably prevent long-term impacts to the aquatic and terrestrial environment and protect human health. Secondary objectives include increasing post-mining site productivity, esthetic considerations and compatibility with neighboring land uses. The Panel recognizes the ability to address these secondary objectives may be constrained by the physical and geochemical features of the mine site and the remediation needed to protect ecological and human health.

The Panel also recognizes the current remediation alternatives have not been developed to the extent necessary to start addressing reclamation issues in any detail. Once remediation approaches have been selected, the closure plan will need to consider reclamation issues such as erosion and drainage control, re-contouring, rooting media and the selection of plant species. Another important component of the reclamation plan will be the long term care and maintenance needed to sustain the land use and esthetic performance and underlying remediation mitigation measures.

The types of reclamation issues and approaches will depend on the site component and the remediation and reclamation objectives. Once the infiltration targets for store and release soil covers become refined, detailed engineering assessments will be required to evaluate and compare alternatives for cover design with emphasis on water management, reducing erosion and sustaining the vegetative growth needed for evapotranspiration.

Historically, the physical reclamation of components at a mining operation including such features as waste rock dumps, open pits, heap leach pads, and tailings impoundments involved a minimalist approach with limited re-contouring and no emphasis on esthetics. Many of the negative connotations associated with mining result from their unnatural visual appearance.

When compatible with overall site objectives, the Panel supports creative approaches to reclamation incorporating esthetic features that are appealing visually and conform to the natural ecology and topography of the area.

The traditional values of First Nations people regarding the ecosystem need to be respected. Even though First Nations are undergoing rapid social and economic change, a profound relationship to the land is maintained and is reflected in the maintenance of many traditional activities and spiritual practices. This connection to the land needs to be captured through a conscious effort to restore the spirit of place even though the physical and biological features may be different than they were pre-mining.

IX SRK and Panel Remediation Alternatives

SRK has presented four example alternatives for each of the three main areas disturbed by mining operations; the Faro Mine site, the Rose Creek Tailings Facility, and the Vangorda and Grum Mine sites. These remediation alternatives are presented in Table I. The Panel believes the range and depth of technical studies conducted to date, along with the range of example alternatives presented by SRK and other technical experts, fulfill the basic information requirements needed to move forward in a process with a reasonable evaluation that allows narrowing the focus for selection of a comprehensive engineering alternative for the ARMC.

Table I Summary of Remediation Alternatives

FARO MINE SITE	ROSE CREEK TAILINGS FACILITY	VANGORDA/GRUM MINE SITE
1. Flow-Through Pit	1. Stabilize in Place	1. Backfill Vangorda Pit
2. Upgrade Faro Creek Diversion	2. Complete Relocation	2. Stabilize in Place
3. Minimize Construction	3. Partial Relocation	3. Minimize Construction
4. Minimize Water Treatment	4. Minimize Construction	4. Minimize Water Treatment
	5. Water Cover	

While the categorization presented in Table I is extremely helpful in presenting and analyzing the range of alternatives that have been considered for each of the three areas, the Panel believes it is important to begin viewing the remediation in a more holistic and integrated format by acknowledging fundamental relationships exist between various mine sites at ARMC. One such example is the relationship that exists between the Faro Mine site and the Rose Creek Tailing Facility, where contaminated groundwater that may bypass the groundwater collection systems at the perimeter of the Faro Mine WRDs would be within the containment system planned downstream of the tailings.

It was this thinking that led the Panel to suggest the groundwater capture approach presented on Figure I in Section IV. In a similar light, the Panel also encourages emphasis on the value of implementing remedial measures based on the principle of “keeping clean water clean”. In Tables I and II noted in light gold is the further option brought forth by the Panel of placing a wet or water cover on the RCTF, which is discussed in Section 8.2 of the report and is illustrated here in Figures II and III. It exhibits the advantages related to prevention of future tailings oxidation and of enabling Rose Creek flood flows to pass over the dam and through a spillway.

The future geochemical conditions are expected to be dramatically different from the current ones. The Panel views Future 2 seepage water quality as probable and recommends that it be viewed as the base case for the assessment and selection of remediation alternatives. It is possible Future 3 seepage water quality or worse could occur and sooner than predicted, at least locally on the site, and therefore it should be given consideration in the ongoing assessment of closure alternatives.

Based on predictions of future geochemistry, there could be a substantial benefit to placing soil covers over the sulphide cells within the Faro and Grum Mine WRDs in as expedient a manner as practical. Placement of an HDPE or bituminous liner beneath the store and release cover would be an effective and prudent measure for eliminating infiltration through these higher hazard mineral wastes for two centuries or more.

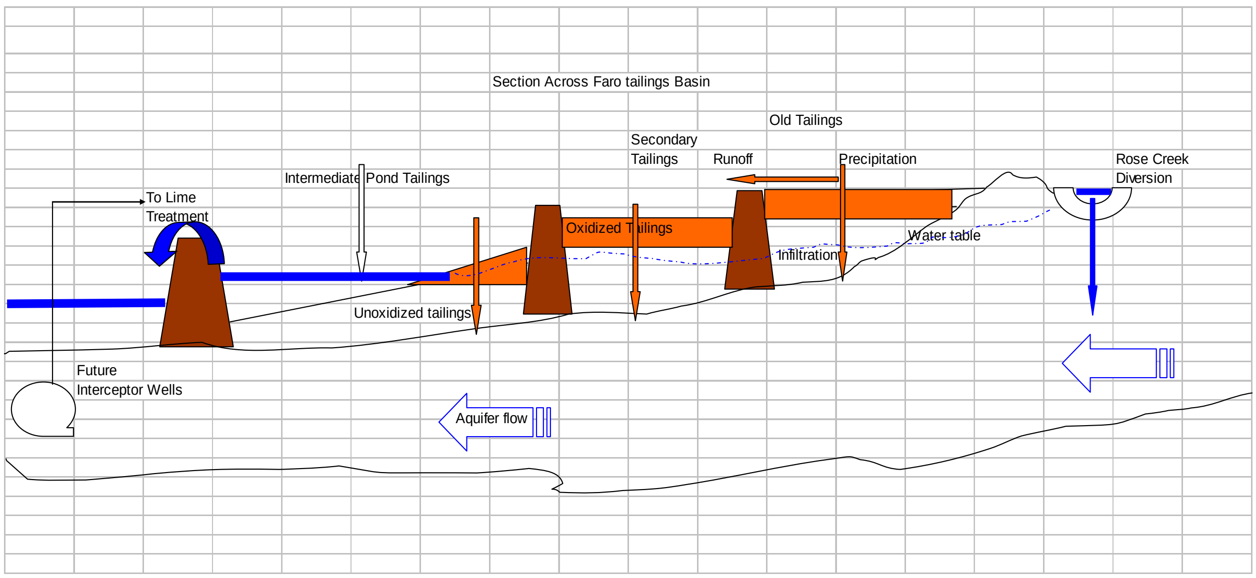

Figure II Existing Rose Creek Tailings Conditions

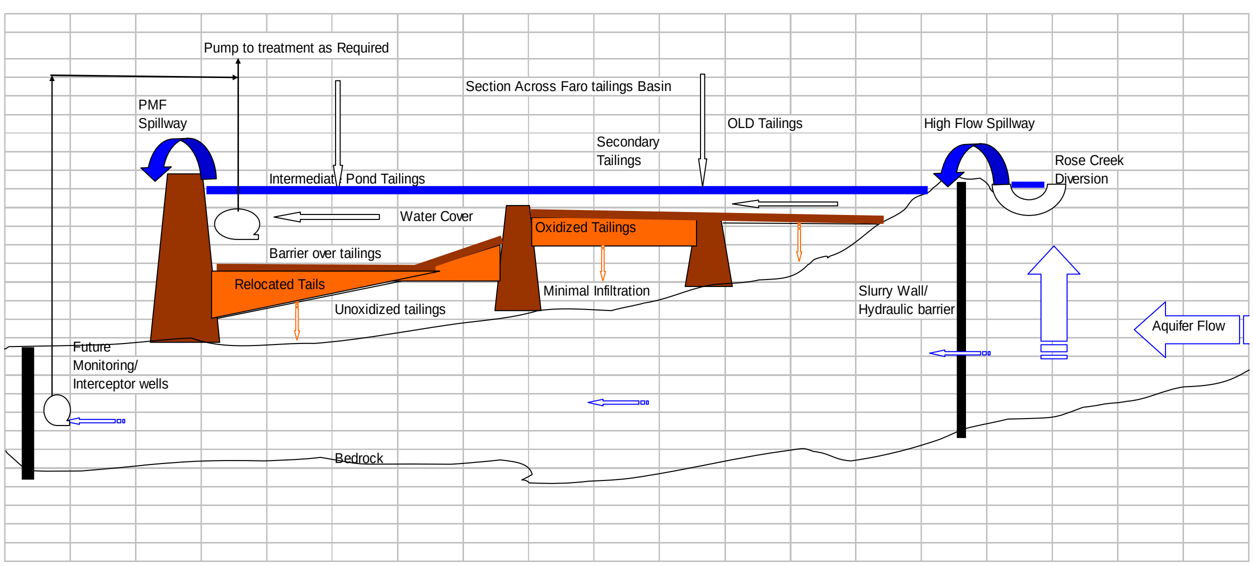

Figure III Proposed Water Cover for the Rose Creek Tailings

Conceptually, the proposed wet cover option for the RCTF is illustrated in Figures II and III. A preliminary cost estimate indicated this option was similar in magnitude to that of the dry cover, although further assessment is needed to provide a more equitable comparison on economic and environmental benefits and impacts.

The initial estimates of costs for the various remediation alternatives are presented in Table II. The Panel has concluded the alternatives developed on the concept of minimizing construction costs, noted in light yellow in Tables I and II, do not meet the current international standards and engineering controls employed by responsible mining companies in the implementation of remediation of their operations. As a result, it is the opinion of the Panel these three Example Alternatives noted in light yellow in Table I should not be included for future consideration.

Table II Summary of Remediation Costs

Example Alternative	Closure	Post-Closure NPV	Total
Faro Mine Area			
Flow-through Faro Pit	$80,900,000	$38,400,000	$119,300,000
Upgrade Faro Creek Diversion	$79,300,000	$36,800,000	$116,100,000
Minimize Up-Front Construction	$35,000,000	$38,400,000	$73,400,000
Minimize Water Treatment	$214,500,000	$36,900,000	$251,400,000
Rose Creek Tailings Facility			
Stabilize in Place	$130,900,000	$52,800,000	$183,700,000
Complete Relocation	$418,500,000	$24,600,000	$443,100,000
Partial Relocation	$253,500,000	$41,800,000	$295,400,000
Minimize Up-Front Construction	$57,000,000	$56,800,000	$113,800,000
Water Cover	$181,000,000	$13,400,000	$194,400,000
Vangorda/Grum Mine Area			
Vangorda Pit Backfill	$86,400,000	$17,200,000	$103,600,000
Stabilize Current Situation	$34,300,000	$30,700,000	$65,000,000
Minimize Up-Front Construction	$12,900,000	$32,200,000	$45,200,000
Minimize Water Treatment	$103,700,000	$18,600,000	$122,300,000

The Panel is not convinced by the existing data that biological treatment can be successfully employed as a primary treatment approach for water treatment in the open pits. Therefore alternatives that employ this approach are not favored. This includes Example Alternative 1 at the Faro Mine site where Faro Creek would be routing through the Faro Open Pit. It is the understanding of the Panel that SRK had earlier removed this alternative, noted in light tan in Table 1, from further consideration.

Exclusion of Example Alternatives 1 and 3 from the remediation options leaves Alternatives 2 and 4 for the Faro Mine site noted in light blue in Tables I and II. Sufficient overlap exists between the engineering components of these two original options to allow consolidation based on an engineering cost benefit analysis, as the review and selection of remediation alternatives moves to the next phase of refinement.

The Panel believes the high density sludge (HDS) process is the most appropriate primary treatment process for the ARMC, both presently and in the future. The open pits are seen as a potential option for the storage of contaminated pretreatment drainage or untreated drainage or long term disposal of the massive volumes of chemical sludge that would be generated at the site over the long time period water treatment is required. Short term storage of contaminated drainage or disposal of sludge in the pits would preclude the possibility of biological treatment in these pits.

Stabilization of the Vangorda Mine WRDs in place is likely to provide an effective control on the generation and containment of contaminated seepage. In contrast, the principal advantage of relocating the Vangorda Mine waste rock to the Vangorda Mine open pit is the reduction of the impacted area for which groundwater collection would be required along with perpetual treatment. Furthermore, sulphide oxidation would potentially cease for the mineral wastes that would be placed below the low water line in the backfilled pit. The key uncertainty in this option concerns the prediction of the chemical quality of the seepage water that may drain from the backfilled pit, as some of the mineralized rock will be above the water line in the pit, and therefore will continue to weather, create acidity, and release metals.

Review of Example Alternatives 1, 2 and 4 for the Vangorda and Grum Mine sites noted in light green in Tables I and II also exhibit overlap amongst their component unit operations including the creek diversion, cover design, and water treatment. The major differences lie in whether or not materials are relocated or covered in place. The Panel believes at this point these individual alternatives can be consolidated through a conventional engineering review into a refined subset of remediation options. An additional mitigation option for the Vangorda Mine waste rock dump that has potential merit is to flood all of the waste rock by backfilling into both the Vangorda and Grum mine open pits.

In the case of the RCTF, although partial or complete relocation is a technically achievable option, the Panel views the environmental, economic, and engineering risks associated with this option have been underestimated, while the engineering risks associated with stabilizing the tailings in place have been overstated. These three original example alternatives noted in light blue in Table I included either stabilization in place with a dry cover or partial or complete relocation for the RCTF noted in light blue in Tables I and II.

The multiple engineering assessments indicate stabilizing the tailings in place is not only feasible but also exhibits an acceptably low risk and can be accomplished with moderate additional cost. The engineering analyses and risk assessments conducted by multiple entities have demonstrated with modifications, tailings and dams would be stable under the maximum credible earthquake (MCE) and probable maximum flood (PMF) events.

As a result, the Panel is of the opinion there is no engineering reason for relocation of the tailings. Stabilization of the tailings in place in conjunction with the provision of upgraded diversion and spillway structures capable of safely passing high flow events is possible.

Partial or complete relocation of the tailings involves a process requiring likely two decades. Although using hydraulic monitoring would likely be the preferred method of moving the tailings, there are many residual environmental and engineering risks associated with the intermittent nature of the process during the course of the year, potential impacts from high precipitation or seismic events, the potential for worker related injuries, and the probable release of metals into Rose Creek during the difficult cleanup of residual tailings in the stream bed.

Although reprocessing offers the hope of offsetting a substantial portion of the relocation costs, the uncertainties related to long term smelter availability and fluctuating commodity prices are not predictable. Therefore, when considering relocation at any level, reliance should not be placed on the economic benefits associated with reprocessing.

1. INTRODUCTION

The legacy of twentieth century mining is often characterized by significant environmental, social, and cultural degradation. Scores of abandoned base and precious metal mines exist throughout North America on both public and First Nations' lands. These mines are typically characterized by their physical scars, geotechnical stability issues, and long standing water quality impacts. In particular, significant impacts arise from acid rock drainage and metal leaching from inadequately managed waste rock and tailings.

The largest orphaned mine site located in Yukon Territory is the Anvil Range Mine Complex (ARMC) consisting of the Faro, Vangorda, and Grum Mines along with the Rose Creek Tailings Facility (RCTF). Mining at the ARMC commenced in the late nineteen sixties and carried on with some interruption until the late nineteen nineties. Associated with these mines are hundreds of millions of tonnes of waste rock and tailings containing sulfides capable of producing very poor quality drainage characterized by low pH, high metals and high total dissolved solids content.

In the Yukon, remediation programs related to abandoned and orphaned sites are administered through Indian Northern Affairs Canada (INAC) in association with the Yukon Government (YG), First Nations, and a range of other interests. The firm of Deloitte and Touche, Inc. was appointed Interim Receiver of the ARMC pursuant to an order of the Ontario Court (presently the Superior Court of Justice) in April 1998. The Interim Receiver's mandate is to receive, preserve, and protect the assets of the ARMC. As a result, the Interim Receiver has overseen the care and maintenance program of the ARMC under terms of the Water License granted by the Yukon Water Board. The Interim Receiver has worked closely with INAC, YG, the town of Faro, the Ross River Dena Council, and other stakeholders to manage programs required to protect the receiving environment.

To aid in management of individual remediation studies and the overall program for the ARMC, the Yukon Type II Mines Project Office (YTMPO) established the Whitehorse-based Faro Mine Closure Project Office (FMCPO). The FMCPO reports to the Oversight Committee, which is comprised of representatives of the Yukon Government (YG), INAC, the Selkirk First Nation and the Kaska Tribal Council represented by the Ross River Dena Council. Additional interests that have been engaged include industry, non-governmental organizations, and other federal regulatory departments.

In 2002 and after recognition that the mines would not be re-opened, the YTMPO initiated a multi-interest review directed toward development of a final closure and remediation plan and implementation strategy. Beginning in 2003, a series of workshops were held between representatives of the various interests, technical experts and consultants to formulate a plan to move the remediation process forward through design and completion of multiple engineering and scientific studies. As a result, and building on the large technical information base that has been generated since mine inception in the 1960s, a number of technical studies have been subsequently conducted to advance overall site knowledge relevant to closure requirements.

Listed below are the set of broad remediation objectives previously identified by the Oversight Committee in July 2006 and were based on discussions of the perceptions and expectations of the stakeholders regarding the overall remediation program:

- Protect human health and safety;
- Restore to the extent practicable the air, land, and water environments including protection of fish and wildlife;
- Reclaim the land to pre-mining uses where practicable;
- Maximize both local and territorial socio-economic benefits; and

- Manage long term environmental and engineering risks in a cost effective manner.

At the request of the FMCPO, a team of technical experts were assembled and contracted through the Interim Receiver, Deloitte & Touche Inc., to serve as an Independent Peer Review Panel (the Panel). The Panel was tasked with reviewing and commenting on a draft report and supporting documentation prepared by a team consisting of SRK Consulting and other consultants (SRK). This draft SRK Example Alternatives report describes a range of technical alternatives for remediation of the Anvil Range Mining Complex (ARMC). Ultimately, the Panel presents its findings in a report to a committee of technical advisors reporting directly to the Oversight Committee.

The Panel was asked to review the description of alternatives contained in the SRK draft report to ensure that it reflects the best possible information base for making an informed decision about the preferred course of action to implement. Specifically, the FMCPO asked the Panel to:

1. *Assess whether or not the proposed closure alternatives provide a full and reasonable span of possible closure alternatives for consideration in the selection process;*
2. *Identify whether or not the various alternatives are described in a way that is complete, rigorous, and appropriate for comparing options in a subsequent selection process; and*
3. *Identify any information gaps that should be addressed or work that should be undertaken prior to embarking on selection of the preferred management approach.*

The members of the Panel were selected on the merits of their individual experience and expertise in various technical areas of mine operations and closure, creating a team with a sufficiently broad background to comprehensively address the interrelated and complex environmental, engineering, and economic aspects of the ARMC remediation project. The members of the Panel are:

- Dr. Laurie Chan, Professor University of Northern British Columbia
- Dr. Kenneth Froese, Golder Associates Limited
- Dr. Anthony Hodge, P. Eng. Anthony Hodge Consultants Inc.
- Mr. Randy Knapp, P.Eng., SENES Consultants Limited (Retired)
- Mr. Kenneth Raven, P.Eng., P.Geo., Intera Engineering Limited
- Dr. Terry Mudder, CHCM, IPRP Chairman, TIMES Limited
- Dr. Bill Price, Natural Resources Canada
- Dr. Andrew Robertson, P.Eng., Robertson GeoConsultants Inc.
- Dr. Leslie Smith, Professor University of British Columbia

The Panel was convened for the first time October 1 to 7, 2006. At that time, the Panel and representatives from SRK, the YG, Deloitte & Touche, and associated sub-contractors traveled to Faro and conducted four days of site visits and meetings. A comprehensive tour of the entire ARMC was conducted with frequent observational stops accompanied with informational discussions. Subsequent to the initial site visit, the Panel has conducted ongoing internal conversations and communications leading up to a full panel meeting with stakeholders in Vancouver, British Columbia December 19, 20 2006. The Panel has met on multiple occasions with representatives of the First Nations, staff from the FMCPO, the YG, INAC, SRK, and/or members of the Oversight Committee.

During this process, members of the Panel have requested and reviewed scores of documents, and have had numerous communications amongst themselves and with closure staff and the consultants. A bibliography has been compiled for this report to reference the documents the Panel examined during its review.

2. CURRENT OPERATIONS AND HISTORICAL STUDIES

SUMMARY OF KEY CONCLUSIONS

The Panel believes the range and depth of technical studies conducted to date, along with the range of example alternatives presented by SRK and other technical experts, fulfill the fundamental information requirements needed to move forward with a reasonable evaluation and selection of a comprehensive remediation plan for the ARMC.

The Panel found the site staff competent and engaged. The physical appearance of the ARMC was adequately maintained and the existing lime precipitation treatment facilities were adequately operated.

2.1 Current Care and Maintenance

In 1998 the Interim Receiver, Deloitte & Touche, was appointed by the Ontario Court to manage the ARMC including the Faro, Vangorda, and Grum Mine sites along with the Rose Creek Tailings Area. The Interim Receiver is responsible for care and maintenance of the complex and seasonal operation of two existing lime precipitation treatment plants. During the first week of October 2006, the Panel and representatives from SRK, the YG, Deloitte & Touche, and associated sub-contractors traveled to Faro and conducted four days of site visits and meetings. A comprehensive tour of the entire ARMC was conducted with frequent observational stops accompanied with informational discussions.

The Panel found the site staff competent and engaged, with the physical aspects of the ARMC adequately maintained, even during extreme weather conditions. The two lime precipitation facilities were being operated adequately and were in general in compliance with numerical and narrative conditions specified in the existing water license. There are ongoing salvage programs to collect and recycle useable materials such as rubber tires and scrap metal.

The human health and ecological risk assessment prepared by SENES Consultants Limited (SENES, 2006) indicate the current risks and impacts are low for resident aquatic life, terrestrial wildlife, and humans. Taken collectively, the observations from the site visit, the risk assessment, and the engineering information available to the Panel indicated the current situation at ARMC is reasonably contained and being managed properly with minimal measurable impacts to the environment and humans.

Although at the moment the impacts to the environment and humans are minimal and the overall risks are low, future conditions will change due to the hundreds of millions of tonnes of mineral wastes containing sulphides that were deposited on the land surface during several decades of mining.

Left without further human intervention and management, the combined geotechnical, geochemical, and water quality conditions at the site will deteriorate dramatically over the next several decades, leading to measurable adverse environmental impacts lasting for several centuries.

2.2 Past Engineering and Scientific Studies

In 2002, the Yukon Type II Mines Project Office began a dialog with various stakeholders directed toward development of a final closure and remediation plan for the ARMC after recognition the mines would not reopen. Beginning in 2003, a series of workshops were held between stakeholders and other technical experts and consultants to formulate a plan to move the remediation process forward through design and completion of multiple engineering and scientific studies. Numerous studies have been conducted in a stepwise manner building on the empirical data obtained during each phase of investigations to advance overall site knowledge.

Central to the design and implementation of an acceptable long term remediation program for the ARMC is the need to minimize deterioration of water quality in the local and downstream receiving waters. This objective can be accomplished by ensuring the physical and geotechnical stability of manmade structures such as waste rock disposal areas and tailings dams and by slowing the geochemical reactions that occur within sulphide containing materials. Central to this remediation approach is the minimization of the metal load released from the sulphide bearing mineral wastes while maximizing the capture and treatment of contaminated seepage or groundwater. The remediation options include either relocation of some of the mine wastes to the open pits and/or stabilization of the wastes in place, combined with a reduction in the infiltration of water into the chemically reactive mineral wastes using soil or synthetic covers. Regardless of the options selected, effective collection of contaminated seepage and water treatment based on the lime precipitation process will be required at ARMC in perpetuity.

The Panel believes the range and depth of technical studies conducted to date, along with the range of example alternatives presented by SRK and other technical experts, fulfill the basic information requirements needed to move forward with a reasonable evaluation and selection of a comprehensive engineering alternative for the ARMC. Certain aspects of the remediation program should be implemented as soon as practical, such as construction of stream diversions and installation of covers. Other actions, such as the installation of groundwater capture systems can be implemented in a timely manner through an adaptive management process. In this report the Panel also presents two other closure concepts that should be considered as the remediation alternatives are finalized. Although data requests from the Panel or the stakeholders may arise, these should not impede progress toward the goal of identifying the preferred remediation alternative.

The future site conditions with respect to water quality impacts and geochemical processes cannot be predicted with high confidence due to the heterogeneous nature of the sulphide bearing mineral wastes and the manner in which they were deposited on the land surface. This uncertainty exists even though the studies conducted to date have been thorough and based on generally accepted methodology. While further geochemical studies may provide a more accurate estimate of the future evolution of the seepage chemistry, they are unlikely to provide substantial new insights into the remediation process or significantly alter the list of example alternatives presented.

An experienced and respected technical team has been assembled on behalf of the stakeholders. The SRK draft Example Alternatives Report provides a range of individual technical and engineering components that have been combined to produce the example alternatives. The Panel views the primary purpose of the SRK report is to provide a range of concepts, the components of which could be recombined to generate additional or modified alternatives with evolution of the combined mine site knowledge. The purpose of the Panel report is neither to provide the final definitive list of distinct remediation options for the ARMC, nor recommend a preferred set of remedial alternatives.

All through the peer review process, the FMCPO, SRK, and the other consultants have provided documents and other materials in a timely and professional manner. The Panel is appreciative of the dedication and efforts of the staffs of these organizations.

3. GEOCHEMISTRY AND FUTURE SEEPAGE QUALITY

SUMMARY OF KEY CONCLUSIONS

The existing geochemical information from laboratory tests and monitoring of seeps provide a reasonable basis for estimating future seepage water quality and is sufficient to conceptually assess different closure alternatives.

A major factor in the generation of low pH seepage containing high levels of metals is the massive sulphides contained within the large volumes of waste rock and tailings located at the ARMC. Concentrations of soluble metals will increase significantly as the pH of the pore water decreases; without adequate mitigation there will be extremely negative, long-term impacts on both the local aquatic and terrestrial environment.

Given the large mass of sulphide in the waste rock, Future 2 seepage quality is probable and Future 3 seepage quality is certainly possible and should also be considered in the assessment of closure alternatives.

Although future worst case seepage chemistry was based on conservative assumptions, uncertainties remain, and the future maximum seepage quality may be worse and the onset of ARD may be faster than predicted.

Ongoing sulphide oxidation and leaching will increase remediation difficulties and costs and the Panel supports moving forward with implementation of remedial actions in as expedient manner as practical.

3.1 Overview of Geochemical Conditions

The underlying cause of the long term environmental concerns at ARMC is the geochemical conditions in the hundreds of millions of tonnes of sulphidic tailings, waste rock and mine walls exposed to the air and water by the over 30 years of mining. Without adequate remediation, the release of potentially toxic elements and acidity from sulphide minerals in the mined rock will cause environmental impacts for hundreds of years or more.

As part of closure planning, geochemical studies have been conducted to estimate the geochemical composition of the mined rock and predict the future seepage quality. The mined materials with the highest concentration of sulphide minerals and thus of greatest environmental concern are the massive sulphide tailings (55 million tonnes) and massive sulphide waste rock (32.4 million tonnes), which are capable of producing extremely acidic and highly toxic drainage. The other major geochemical hazard is the more than two hundred million tonnes of lower sulphide waste rock and the mine walls, much of which will produce lower strength, toxic drainage. Approximately half of the lower sulphide rock will produce acidic drainage in the future and the other half will remain acid consuming.

The surfaces of sulphide minerals have been oxidizing (rusting) for the past 30 years and much of the seepage from the tailings, waste rock and pits already contain trace elements at toxic concentrations and has to be collected and treated prior to discharge. However, the majority of the sulphide minerals are yet to be oxidized. With continued exposure of the sulphidic mined rock to air and water and as geochemical conditions continue to evolve, the mass of soluble contaminants stored in the wastes will increase, more of the drainage will become acidic and concentrations of acidity and potentially toxic elements in the seepage will dramatically increase.

3.2 Geochemical Projections

The purpose in estimating geochemical characteristics and predicting future seepage quality and mass loadings to the environment from the mineral wastes at ARMC was to determine:

- Whether mitigation is required to prevent materials disturbed or moved during mining from exerting adverse impacts on humans and the environment.
- Where mitigation is required, which measures should be implemented to prevent or minimize, in a cost-effective manner, these long term adverse impacts to humans and the environment.

Other geochemical questions requiring investigation included the development of estimates of the time periods over which a particular chemistry would be representative of the quality of the seepage, when significant transitions in the water chemistry may occur, and the probable maximum concentrations and mass loadings the final closure plan will need to accommodate. An area of investigation not yet examined in detail concerns the effectiveness of the various remediation options in mitigating the geochemical processes that control seepage water quality. For example, detailed studies have not been carried out to quantify the extent to which a soil cover may limit the influx of oxygen to the waste rock dumps and slow down the oxidation rate of sulphide minerals. However, field trials of various cover designs are currently underway.

The primary constituents of concern at ARMC include acidity, zinc, and as the geochemical system evolves, other metals and the total dissolved solids. Acidity is important because it will impact the solubility of potentially toxic chemical species and the effectiveness and cost of treatment. Zinc is the chemical species most likely to have a significant environmental impact if drainage from sulphidic materials discharges to the environment. Other constituents of potential concern in the future could include cadmium, manganese, arsenic, lead, and copper.

3.3 Measuring Acid Generating and Neutralizing Potential

Pyrite is the dominant sulphur mineral in the mineral wastes at ARMC and upon oxidation pyrite is a primary source of acidity and soluble iron, two key components of acid rock drainage. The primary source of zinc and cadmium is the sulphide mineral sphalerite. Analysis for sulphate sulphur through typical extraction tests indicated measurable concentrations of leachable sulphate principally in the form of gypsum in neutral and alkaline samples, and jarosite along with zinc sulphates in samples that were acidic. The sulphate sulphur in the Grum and Vangorda waste rock was reported to be in a range from about 1 to 10% of the total sulphur.

Based on the quantity of pyrite or pyrrhotite relative to total leachable sulphate sulphur and the less acid generating sulphides, SRK and other consultants concluded it was reasonable to assume total sulphur reported was entirely pyrite when calculating acid generating potential (AP). This approach allowed the incorporation of data from previous studies for which there were no analyses of sulphate sulphur. The main concern with the use of total sulphur in the calculation of AP, for those waste rock units for which the acid rock drainage (ARD) potential is uncertain, is the potential to overestimate the acid generating potential (AP) and underestimate the neutralization potential ratio (NPR) of the rock units.

The ARMC waste rock contains a large number of reactive and less reactive neutralizing minerals. The rapid reaction of dilute hydrochloric acid with most of the host rocks indicates that the strong neutralizer calcite is common, although typically only in small concentrations. Notable exceptions are the Calcareous Silicate portion of the Faro waste rock and the Calcareous Phyllite portion of the Grum and Vangorda waste rock.

Although the neutralizing potential (NP) in non-calcareous sulphidic material is relatively small, nonetheless, it may be useful in:

- preventing or minimizing ARD in low sulphur materials,
- delaying the onset of ARD, and
- neutralizing seepage from overlying materials.

In the presence of iron and manganese carbonate minerals, which are not net neutralizing under aerobic conditions, estimation of the neutralizing potential based on the carbonate content, or procedures not involving a back titration, may measurably overestimate the NP. The various geochemical studies of SRK and others recognized this fact, and as a result, the Sobek procedure was used in the tailings NP analyses, while the "modified Sobek" method was applied in the estimation of the NP of waste rock.

Although the contribution is much lower than a NP calculated from carbonate measurements, nonetheless, iron and manganese carbonate may also contribute significantly to the NP measured by the Sobek and the modified Sobek NP procedures. The experience of SRK at other sites is that the contribution of Fe and Mn carbonates to the Sobek and modified Sobek NP is insignificant. Quantitative mineralogy on split samples would have provided a site-specific estimate of the contribution of the iron and manganese carbonates to the ARMC Sobek and modified Sobek results.

The other potential overestimation of NP by the Sobek and modified Sobek procedures is the contribution to NP by relatively un-reactive silicates. The use of strong acid in these procedures can cause silicates to react more quickly than occurs in the field. Evidence of the contribution of insufficiently reactive silicates and iron and manganese carbonates to the NP results include:

- Samples with significant modified Sobek NP values that had acidic rinse pH values of 5.6 for Faro materials despite a P5 NP of 22, and a rinse pH of 4.8 despite a P5 NP of 19 kg/t for Vangorda materials.
- The kinetic tests on Faro sulphidic rock that generated acidic leachate despite NP measurements of up to 18 kg/t.

Based on the un-reactive NP measured in samples with acidic pH values, the SRK waste rock study estimated the contribution of relatively un-reactive silicates to the modified Sobek NP results was less than 10kg/t at the Faro Mine site and 15 kg/t at the Vangorda/Grum Mine site. A significant contribution of iron (Fe) and manganese (Mn) carbonates and relatively un-reactive silicates to the modified Sobek NP will result in underestimation of the ARD potential for waste rock and the exposed portions of the pit walls with a lower sulphide content. A significant contribution of Fe and Mn carbonates and relatively un-reactive silicates to the Sobek and modified Sobek NP may also result in underestimation of the rate of onset for acidic weathering conditions in the tailings, waste rock and mine wall materials that are predicted to eventually produce acidic drainage.

The decision not to adjust the NP for the potential contributions of Fe and Mn carbonates and relatively un-reactive silicates was balanced in part by the lack of a correction for the potential contribution of sulphate sulphur to the AP. It is the opinion of SRK the correction for silicate NP would only have a minor effect on the total NP value and the drainage water quality, although the time to peak loading may be reduced if the silicate mineralization was discounted.

Based on their ARD potential, the mineral wastes at ARMC can be segregated into three types:

- Massive sulphide tailings and waste rock: this includes all the tailings and the sulphide rock unit, low grade ore, oxide fines and baritic fines in the waste rock.

- Low sulphide waste rock that will become acidic: this includes the majority of the Faro and Vangorda waste rock.
- Low sulphide waste rock that will remain net acid consuming: this includes the majority of the Grum waste rock.

The criterion used to predict ARD generation in low sulphide waste rock was NP/AP < 1.1. This criterion was based on the results from two humidity cells. The majority of the overburden which will eventually be used in the construction of soil covers appears to be net acid consuming with negligible sulphide.

The Panel concludes that the assessment of the AP, NP and ARD potential is sufficiently accurate to conceptually assess the remediation alternatives. While the process of selecting the preferred remediation alternatives moves forward, a program of supplemental geochemical test work should be initiated to address information gaps.

3.4 Waste Rock Characteristics

The following is a summary of the approximate quantities and characteristics of the waste rock dumps at the individual mine sites within the ARMC. Uncertainty however exists about the exact quantities and composition. In the case of waste rock dumps at the Faro Mine site, the quantity and characteristics included the following:

- About 258,000,000 tonnes covering 368 hectares.
- 11% of the total or about 28,000,000 tonnes of massive sulphide materials covering 37 hectares including the sulphide rock unit, low grade ore, and oxide fines, some of which was already acidic.
- 50% of the total or about 129,700,000 tonnes of low sulphide material, the majority of which are expected to become acidic with time (Schist and Intrusive rock units) although most of it was acid consuming when the studies were conducted.
- 39% of the total or about 100,561,000 tonnes of low sulphide materials, the majority of which are expected to remain net acid consuming (Calcareous Silicate and Overburden rock units).
- The estimated average composition is an AP of 147 kg/t, an NP of 35 kg/t, an NNP of -112 kg/t, an NPR of 0.24, total sulphur of 4.72%, and a solid phase zinc concentration of 2,738 mg/kg or ppm.

Notably, a portion of the Schist and Intrusive rock units are expected to be net acid consuming and a portion of the Calcareous Silicate and Overburden units are expected to become acidic.

In the case of the waste rock piles at the Vangorda Mine site, the characteristics included the following:

- About 8,225,000 tonnes covering 46.3 hectares.
- 34% of the total massive sulphides or about 2,825,000 tonnes covering 10.9 hectares including baritic fines.
- 61% of the total low sulphide rock types, the majority of which are expected to become acidic (Carbonaceous and Non-Calcareous Phyllite).
- 5% of the total low sulphide, the majority of which are expected to remain net acid consuming (Calcareous Phyllite).

- The estimated average composition is an AP of 163 kg/t, an NP of 34 kg/t, an NNP of -129, an NPR of 0.20, a total sulphur content of 5.22%, and a solid phase zinc concentration of 5,542 mg/kg or ppm.

Notably, a portion of the Carbonaceous and Non-Calcareous Phyllite rock units are expected to be net acid consuming and a portion of the Calcareous Phyllite rock unit is expected to become acidic.

In the case of the waste rock piles at the Grum Mine site, the characteristics included the following:

- About 28,000,000 tonnes of materials covering 131.6 hectares.
- 7% of the total massive sulphide or about 2,000,000 tonnes covering 18.5 hectares.
- 15% of the total low sulphide rock types, the majority of which are expected to become acidic (Carbonaceous and Non-Calcareous Phyllite).
- 78% of the total low sulphide materials, the majority of which are expected to remain net acid consuming (Calcareous Phyllite).
- The estimated average composition is an AP of 52 kg/t, an NP of 66 kg/t, an NNP of 14, an NPR of 1.26, a total sulphur content of 1.67%, and a solid phase zinc concentration of 3,751 mg/kg or ppm.

Notably, a portion of the Calcareous Phyllite rock unit is expected to be net acid consuming and a portion of the Carbonaceous and Non-Calcareous Phyllite units are expected to become acidic. Visual observations of the segregation process and the massive sulphide occurring intermittently on the surface of the dump indicate that some massive sulphide rock was dumped in the general dump rather than in the sulphide cell.

In the case of the waste rock used to construct the Vangorda plateau haul road, the characteristics included the following:

- About 7,510,000 million tonnes covering 33.5 ha and has a length of about 7 km
- Constructed from segregated, non-massive sulphide waste rock from Faro mine
- No information about the proportion of predominantly potentially acid producing Schist versus acid consuming Calcareous Silicate rock units.
- Some massive sulphide rock unit encountered in one test pit

3.5 Future Waste Rock Seepage Quality

Three different geochemical scenarios were created to show the potential future seepage chemistry for the waste rock. Future 1 was calculated from the average contaminant concentration of current seepage. Future 2 was calculated from the maximum contaminant concentration of the current seepage. Future 3 was calculated from the maximum contaminant concentration of a current seepage that was considered to represent the future worst case seepage chemistry. For each scenario, seepage types and proportions were assigned to each dump section based upon their estimated proportions and the average AP, NP, and zinc content within each rock type.

The estimated concentrations of acidity and zinc in the various seepages for each future scenario are presented in Table 1. The Panel supports this method as a reasonable approach to develop estimates of the future chemistry of the seepage from the waste rock.

Contaminant concentrations and mass loadings due to seepage from waste rock are increasing with time. Portions of the Faro and Vangorda WRDs already produce acidic drainage with high zinc concentrations. Even with remedial measures in place, oxidation of the sulphide minerals will continue contributing increasing acidity and mass loads to the various seepage sources, with a corresponding deterioration of their water quality. In addition, as shown in Table 1, a dramatic deterioration in water quality will occur in the event the seepage chemistry associated with Future 3 is attained.

Table 1 Summary of Future Seepage Chemistry

Seepage Quality Estimates	Faro Mine Area		Grum Mine Area		Vangorda Mine Area	
	Acidity mg/L as $CaCO_3$	Zinc in mg/L	Acidity in mg/L as $CaCO_3$	Zinc in mg/L	Acidity in mg/L $CaCO_3$	Zinc in mg/L
Future 1	909	257	15	1.0	2,400	1,100
Future 2	3,441	569	50	1.8	6,219	2,684
Future 3	17,501	3,648	1,805	752	7,309	3,138

The massive sulphide waste rock contains 10 to 50 times the amount of sulphur and zinc than other waste rock types. The acid neutralizing capacity of the waste rock down gradient of the massive sulphide cells is negligible when compared with the acid potential of the massive sulphide. This neutralizing capacity will likely be rapidly depleted with the onset of acidic seepage. Even though massive sulphide waste rock represents a relatively small proportion of the mass in each dump, if unmitigated it will disproportionately contribute to the total contaminant loads. Some of the massive sulphide waste rock is already producing acidic drainage with high metal concentrations.

At the later stages in dump construction there was an effort to place the massive sulphide waste rock in cells within the Faro and Grum WRD sites. However, the Panel understands there was no routine operational monitoring of this approach to confirm the effectiveness of the segregation program. Visual observations and test results from the dump characterization work indicated massive sulphide rock was mixed with other rock types.

The future water chemistry due to infiltration through the haul road has not been fully investigated to date and therefore additional evaluation of the tendency for this construction material to generate metal load should be undertaken.

3.6 Rose Creek Tailings Facility

There are 55 million tonnes of sulphide tailings covering 232 hectares in the Original, Secondary and Intermediate Tailings Impoundments within the Rose Creek Tailings Facility. The sulphide sulphur content of the tailings ranges from 20 to 30% by weight.

Only a relatively small proportion of the total, about 11 million tonnes, is estimated to have oxidized thus far. Oxidation is most intense at the surface of the impoundment and it is deepest where the tailings are coarser.

The 2002 SRK study described three acidic fronts of pore water moving downward through the tailings. One acidic front is characterized by elevated iron, a second by elevated zinc, and the third by a near-neutral pH but elevated total dissolved solids (TDS).

The pH values near the surface of the tailings were all less than 2 and below in several instances. The fact the maximum zinc concentrations in the pore water were deeper in the tailings than the pore water with the highest acidity was attributed to a galvanic interaction between sphalerite and pyrite, in which sphalerite suppresses the oxidation of pyrite. Based upon geochemical profiles through the tailings, zinc was only measurably depleted in the upper 50 cm of the tailings (e.g., 1,000 mg/kg versus values greater than 10,000 mg/kg in tailings below 50 cm), indicating the oxidation of pyrite for the entire volume of tailings is not well advanced.

The average and maximum estimated pore water seepage rates are 16 and 26 mm/year through the fine tailings and 34 and 75 mm/year through the coarse textured tailings. Runoff from snow melt and/or direct precipitation that exceeds the infiltration rate of the tailings surface are expected to report to topographic lows within the tailings impoundments and then to the Intermediate Pond. According to work conducted by Robertson GeoConsultants, the only sites where runoff can flow laterally off the tailings are small areas on the edge of the Rose Creek diversion.

As weathering continues, the migration fronts for acidity and zinc will travel farther into the tailings. These fronts will eventually reach the base of the tailings facility, and enter the underlying aquifer in Rose Creek valley. A layer of natural organic material at the base of the tailings facility will retard the migration of dissolved zinc as it moves out of the tailings and enters the native soils. However, it is expected much of the zinc will be remobilized when the lagging front of acidity reaches the base of the tailings. Formation of iron pans may increase seepage rates by diverting drainage towards the coarser tailings and concentrating vertical flow.

In addition to the tailings in the Rose Creek Impoundment, tailings were deposited underwater in the mined-out Faro Pit from 1992 to 1998 and there is a relatively small volume of tailings in the Emergency Tailings Impoundment (ETA). The ICAP report in Section 4.3.2.5 noted 12,300 m^3 of tailings solid and a much larger quantity of slurry were spilled into Rose Creek in 1975 due to a breach in the Original Dam. Most of the spilled tailings were subsequently covered by the Intermediate Tailings. According to Gartner Lee, the tailings downstream of the Cross-valley dam do not appear to be causing water quality impacts, although there is a terrestrial impact (vegetation kill).

3.7 Open Pits and Underground Workings

The pits and underground workings include pit walls, talus, overburden and backfilled waste rock.

- Faro Mine site with the Main Pit (Zones 1 and 3) and backfilled Zone 2 Pit with combined surface areas of 78 hectares.
- Faro Mine Underground Workings.
- Grum Mine Open Pit with a surface area of 28 hectares.
- Vangorda Mine Open Pit with a surface area of 17 hectares.

The majority of the surface area and therefore the majority of the contaminant release is likely to come from stored wastes and talus accumulating on benches above the pit lakes. Continued failure of pit walls will continue to provide fresh sulphides and increase surface area available for weathering. Due to the relatively small surface area, pits and underground workings are a relatively small source of contaminants compared to waste rock and tailings. However, if there are significant inputs of groundwater and upslope runoff in addition to contaminants, the pits may become another large volume of contaminated drainage that requires treatment.

The main value of the pits may lie in flooding some of the high sulphide materials or storing untreated effluent or water treatment plant sludge from the high density sludge (HDS) treatment process. The decision about whether a particular pit is better suited for storing untreated effluent or water treatment plant sludge will depend on the resulting water quality and whether it meets the discharge objectives. For example, the walls of the Vangorda Mine open pit have higher sulphide content than the walls of the Grum Mine open pit.

3.8 Prediction Uncertainties

The prediction of future drainage chemistry from mine wastes is a difficult task due to the:

- large number and complex interactions among properties and processes;
- long time scales;
- many properties and processes in flux;
- many properties and processes cannot be measured accurately; and
- lack of information regarding the accuracy of past predictions.

A number of conservative assumptions were incorporated in the geochemical predictions developed by SRK and others. This approach is an appropriate means of dealing with the inherent uncertainty in predictions of future seepage chemistry.

It is important to recognize there are a number of uncertainties in the data used to calculate Future 2 and 3 seepage chemistry, and predict corresponding maximum contaminant concentrations and mass loads. Many geochemical and biochemical processes are operating within the waste rock and tailings, and the current seepage chemistry used to calculate Future 2 and 3 is unlikely to be indicative of the maximum future contaminant concentrations and mass loads. There are several potential changes in current hydrogeological and geochemical conditions that could increase seepage acidity and contaminant concentrations including the following:

- galvanic Interactions;
- depletion of acid consuming minerals;.
- water no longer enters storage within the waste rock piles;
- reduction in particle size; and
- progressive accumulation and then flushing of accumulated of weathering products.

Due to solubility constraints and limited leaching, seepage only removes a small portion of the annual products of sulphide oxidation. The remainder accumulates as potentially soluble contaminants that may be released in seepage due to an increase in leaching if water is no longer accumulating in the dumps or a decrease in pH if neutralizing minerals are depleted and pyrite oxidation is no longer galvanically suppressed.

The uncertainty associated with the distribution of waste rock types within the various piles clearly magnifies the difficulty in predicting future seepage chemistry. During operations at the ARMC there was no rigorous and systematic recording of the masses of different rock types and where they were placed within the piles. There was also no ongoing sampling and analysis program to provide information on the geochemical variability within the waste rock piles. Furthermore, with the exception of the sulphide cells and low grade ore, there were no drawings indicating placement of specific waste rock types.

Although a number of geochemical studies were conducted during different phases of operations, sampling of waste rock was largely restricted to pile surfaces, which may or may not have been representative of deeper materials.

While the predicted composition of the WRDs is likely generally correct, the actual composition cannot be predicted with a high level of precision. Correcting this deficiency is not practical, due to the impossibility of achieving a representative sampling laterally and with depth from a very large and heterogeneous waste rock pile. Surface excavations and drill-hole samples have confirmed the composition of the waste rock piles is heterogeneous.

The laboratory procedures used likely overestimated the field NP due to the contribution of insufficiently reactive silicates, together with the presence of iron and manganese carbonates, which are not neutralizing under aerobic conditions. The NPR criterion of 1.1 used to identify potentially ARD generating waste rock was based on information from two humidity cells while assuming the AP and NP were measured accurately.

Consequently, there could be an underestimation of the proportion of waste rock producing acidic seepage. The calculated average AP and NP used in the seepage prediction gave equal weight to samples of drill core and bulk waste rock. The use of drill core, which has measurably higher NPR than actual dump samples, may have underestimated the ARD and contaminant leaching potential of some rock types, for example the Faro Schist and Calc-Silicate. The lower NP of the Schist waste rock samples and potential contribution of insufficiently reactive silicates and iron carbonates to the measured NP suggests much of the Schist waste rock could go acidic sooner than the prediction of several decades.

There has been no evaluation of the particle size distribution or surface area, properties that could result in proportional differences in the contribution of the different rock types to the loadings as a whole. Differences in particle size distribution (e.g., fines per tonne) and surface area will impact the rates of both weathering and leaching. According to work conducted by SRK, the massive sulphide is fairly competent and its large crystals make it less reactive than at other lead-zinc mine sites prone to acidic drainage.

The lower sulphide, acid generating schist appeared to be the waste rock type that disintegrates most rapidly and has the highest surface area. Notably, testing of surface samples was undertaken on < 10 mm material, which has a higher S content than the whole samples.

3.9 Conclusions

The existing technical information from laboratory tests and site monitoring provides a reasonable estimate of the geochemical composition of the mineral wastes, future seepage quality, and are sufficient to conceptually assess different mitigation measures and closure alternatives. Ongoing sulphide oxidation and leaching will increase remediation difficulties and costs and the Panel supports moving forward with implementation of remedial actions in as expedient manner as practical.

Nearly all the tailings, waste rock and walls of the open pits and talus slopes at the ARMC contain elevated levels of metals and acid generating sulphide minerals. If allowed to weather, without intervention the water quality of the seepage and surface water drainages would deteriorate dramatically and would exceed generic CCME guidelines and the corresponding receiving environment objectives.

Without adequate mitigation, soluble metal and trace element concentrations will increase sharply as the drainage pH decreases and will exert adverse long term impacts on downstream water quality. Given the large mass of sulphide tailings and waste rock, Future 2 seepage quality is highly likely and Future 3 seepage quality is certainly possible and both should be considered in the assessment of closure alternatives.

Although future worst case seepage chemistry was based on conservative assumptions about future seepage from different wastes, nonetheless, uncertainties remain, and the future maximum seepage quality may be worse and the onset of ARD may be faster than predicted.

Uncertainty regarding future drainage chemistry is the norm at most mine sites. Recognizing and addressing this uncertainty is one of the most important tasks in developing a long term remediation and closure strategy. The three main measures for dealing with the uncertainty are conservative design, adaptive management programs and contingency plans.

The concentration of potential acidity and zinc in the massive sulphide rock is 10 to 100 times more than the other rock types. A portion of the massive sulphide waste rock and tailings is already producing acidic drainage with high metal concentrations. Eventually nearly all of the massive sulphide waste rock and tailings will produce highly acidic and low pH seepage with very high metal concentrations. Unless oxidation and leaching are reduced, the massive sulphide will disproportionately contribute to contaminant loads from the ARMC and is likely to increase contaminant loads coming from other waste rock with lower sulphide contents.

In addition to the emphasis on the impacts of contaminated seepage on surface and groundwater quality, there are also concerns associated with the terrestrial environment. Wind erosion of the massive sulphides and their weathering products exposed on the surface of the tailings and waste rock, has the potential to contaminate the surrounding land and water courses.

In the most favorable circumstance, the deterioration of seepage quality will occur gradually, providing sufficient time for corrective measures to be implemented. Depression of pH may occur initially seasonally and then permanently resulting in seepage with high concentrations of iron, aluminum, zinc, cadmium, sulphate, copper and nickel. However, the crossing of hydraulic or geochemical thresholds could lead to sudden, rapid increases in flow, decrease in water quality and the appearance of additional discharge locations. It would be prudent to develop interim measures to prevent wind erosion of tailings and ensure there is adequate capacity for the collection and treatment of seepage from the waste rock piles and tailings in as timely a manner as practical.

3.10 Recommendations for Additional Information

While the process of selecting the preferred remediation alternatives moves forward, an ongoing program of geochemical monitoring and supplemental test work is recommended to address gaps of significant uncertainty. This work can be undertaken while the process of selecting the preferred remediation alternative moves forward. Monitoring data should be reviewed to ensure there are no significant omissions.

Development is recommended of a program to monitor changes in in-situ geochemical conditions, stored solute, seepage quality and mass loads for discrete well characterized portions or different rock types in the waste rock piles and different particle sizes of tailings. The program should include continuing the existing temperature and oxygen measurements.

Quantitative mineralogy, along with Modified Sobek NP, should be conducted on a representative set of samples for each waste rock type to estimate the magnitude of the contribution of the iron and manganese carbonates and relatively un-reactive silicates to the results of the modified Sobek NP procedure. Detailed quantitative mineralogical analysis could also be used to check assumptions regarding minerals contributing to other test results.

Although there are always site specific differences in hydrogeological, physical, and chemical conditions between sites, in conjunction with ongoing estimates of future seepage chemistry at the ARMC, it may be useful to examine observed rates of oxidation and resultant maximum acidity and metal concentrations in seepages at other closed or existing lead-zinc mining operations with tailings and waste rock containing massive sulphides.

4. ENGINEERING AND ECOLOGICAL RISK ASSESSMENTS

4.1 Surface Water Quality Issues

SUMMARY OF KEY CONCLUSIONS

Based on the review of current and expected water quality within Rose Creek, background conditions equivalent to the generic CCME guidelines cannot be obtained continuously regardless of the individual technologies selected and remediation alternatives implemented.

Zinc concentrations and those of other constituents are likely to increase over time in Rose Creek and downstream surface water, although based upon estimates of future seepage water quality, elevated levels are not anticipated in the Pelly River due to its naturally high flows.

Fundamental to the evaluation and selection of a preferred remediation alternative for the entire mine complex is the consideration of developing and applying site specific standards for protection of aquatic life and the terrestrial ecosystem. This approach is supported by the Panel.

There is a need to recognize that in association with development of site specific standards, realistic goals must be set with respect to the selection of beneficial uses and the points at which compliance with water quality standards will occur.

Fundamental to the evaluation and selection of a preferred remediation alternative for the ARMC is determination of the level of aquatic and terrestrial ecological protection desired and at what location the appropriate water quality objectives will be applied. There is the need to define not only the level of aquatic life protection desirable but also the level of aquatic life protection that is achievable in Rose Creek, Anvil Creek, and/or the Pelly River.

Although minor in comparison with the potential future condition, there are existing water quality impacts within Rose Creek, resulting from a combination of mining activity and natural phenomena. These impacts have resulted in zinc and other constituent concentrations approaching, and at times slightly exceeding, the existing Canadian Council of Ministers of the Environment (CCME) guideline for aquatic life protection. Nonetheless, the interim water quality has improved since cessation of mining, with fish reproduction occurring downstream in Rose Creek.

Based on the review of current and expected water quality within Rose Creek, the Panel believes background conditions equivalent to the generic CCME guidelines may not be obtained regardless of the individual technologies selected and remediation alternatives implemented. However, it does not appear measurable adverse ecological impacts will occur in the Pelly River. As a result, the derivation and application of site-specific waster quality objectives may be appropriate for this particular surface water ecosystem.

A summary of estimated maximum in-stream zinc and other constituent concentrations at various points downstream of the ARMC is presented in Table 2.

Table 2 Estimated Constituent Concentrations Downstream of ARMC

Scenario	Location	Hardness As CaCO3 Mg/L	Cd mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Zn mg/L
Future 1	Vangorda Creek at V27	131	0.0044	0.011	0.126	0.037	0.07
	Vangorda Creek at V8	66	0.0018	0.008	0.079	0.019	0.03
	Pelly River up stream of Vangorda Creek	131	0.0005	0.005	0.021	0.014	0.01
	Pelly River down stream of Vangorda Creek	130	0.0005	0.005	0.022	0.014	0.01
	Pelly River Upstream of Anvil Creek	130	0.0005	0.005	0.022	0.014	0.01
	Rose Creek at X2	102	0.0002	0.005	0.265	0.029	0.03
	Rose Creek at X14	642	0.0027	0.007	0.305	0.028	0.13
	Rose Creek at Anvil Creek	504	0.0020	0.007	0.294	0.028	0.11
	Anvil Creek at Pelly River	254	0.0009	0.006	0.275	0.028	0.06
	Pelly River downstream of Anvil Creek	137	0.0005	0.005	0.035	0.015	0.01
	Pelly River downstream at Pelly Crossing	136	0.0005	0.005	0.033	0.015	0.01
Future 2	Vangorda Creek at V27	140	0.0045	0.012	0.129	0.041	0.08
	Vangorda Creek at V8	75	0.0018	0.008	0.079	0.021	0.04
	Pelly River up stream of Vangorda Creek	131	0.0005	0.005	0.021	0.014	0.01
	Pelly River down stream of Vangorda Creek	130	0.0005	0.005	0.022	0.014	0.01
	Pelly River Upstream of Anvil Creek	130	0.0005	0.005	0.022	0.014	0.01
	Rose Creek at X2	102	0.0002	0.005	0.269	0.030	0.04
	Rose Creek at X14	649	0.0027	0.009	0.438	0.028	0.20
	Rose Creek at Anvil Creek	510	0.0021	0.008	0.392	0.028	0.16
	Anvil Creek at Pelly River	256	0.0009	0.006	0.312	0.028	0.08
	Pelly River downstream of Anvil Creek	137	0.0005	0.005	0.037	0.015	0.01
	Pelly River downstream at Pelly Crossing	136	0.0005	0.005	0.035	0.015	0.01
Future 3	Vangorda Creek at V27	159	0.0045	0.012	0.135	0.051	0.10
	Vangorda Creek at V8	83	0.0018	0.008	0.079	0.024	0.04
	Pelly River up stream of Vangorda Creek	131	0.0005	0.005	0.021	0.014	0.01
	Pelly River down stream of Vangorda Creek	130	0.0005	0.005	0.022	0.014	0.01
	Pelly River Upstream of Anvi Creek	130	0.0005	0.005	0.022	0.014	0.01
	Rose Creek at X2	102	0.0006	0.011	0.500	0.062	0.28
	Rose Creek at X14	670	0.0031	0.027	1.429	0.065	0.65
	Rose Creek at Anvil Creek	525	0.0023	0.021	1.131	0.056	0.49
	Anvil Creek at Pelly River	260	0.0010	0.011	0.591	0.039	0.20
	Pelly River downstream of Anvil Creek	137	0.0005	0.005	0.052	0.015	0.02
	Pelly River downstream at Pelly Crossing	136	0.0005	0.005	0.048	0.015	0.02

These estimates were obtained through personal communication with SRK. The table incorporates all three future scenarios characterizing the quality of the seepage water. The estimates presented in Table 2 apply to a theoretical scenario not examined in the risk assessment, in which the most aggressive remediation alternatives are applied including placement of low infiltration covers on waste rock piles, placement of very low infiltration covers on the tailings and high sulphide materials such as the ore stockpiles, application of maximum treatment efficiency, and finally adopting a 99% load capture efficiency for seepage and groundwater for the entire ARMC.

It is important to recognize that a higher infiltration rate through the soil covers and/or lower capture efficiency dramatically increases the constituent concentrations in the streams, although minimal effects are noted in the Pelly River due to its large volume. These results are presented in Table 3, which presents the estimated zinc concentration at station X14 in Rose Creek for infiltration rates ranging from 2% to 20% and groundwater capture efficiencies ranging from 90 to 99%. The 20% infiltration rate corresponds to a rudimentary cover, while 5% refers to a low infiltration cover, and 2% to a very low infiltration cover.

The results indicate only a small difference in dissolved metal concentrations between the Future 1 and Future 2 geochemical predictions. However, if sulphide oxidation were to create the seepage conditions represented by Future 3, there is predicted to be a sharp degradation in water quality with very limited ability to control the geochemical processes occurring within the various waste materials. It is also important to recognize that even with implementation of the lowest infiltration covers on the high sulphide materials and with the most efficient groundwater capture systems, the CCME guidelines are predicted to be exceeded in Vangorda, Rose, and Anvil Creeks, although the impacts are anticipated to be minimal in the Pelly River.

Table 3 Summary of Estimated Zinc Concentrations at X14 in Rose Creek

Scenario	Allowable Infiltration and Cover Design	Groundwater Capture Efficiency at Each Collection Point	Zinc Concentration at X14 (mg/L)
Future 1	20% and 5%	90%	1.2
	20% and 5%	95%	0.60
	20% and 5%	99%	0.15
	5% and 2%	90%	0.98
	5% and 2%	95%	0.51
	5% and 2%	99%	0.13
Future 2	20% and 5%	90%	1.9
	20% and 5%	95%	0.98
	20% and 5%	99%	0.23
	5% and 2%	90%	1.6
	5% and 2%	95%	0.82
	5% and 2%	99%	0.20
Future 3	20% and 5%	90%	8.9
	20% and 5%	95%	4.6
	20% and 5%	99%	1.1
	5% and 2%	90%	4.4
	5% and 2%	95%	2.3
	5% and 2%	99%	0.65

An exceedence of a generic CCME guideline does not necessarily indicate adverse ecological impacts have occurred or will occur. By definition, the generic numerical CCME values are “guidelines”, which have been conservatively established to protect as broad a range of aquatic species and life stages as possible.

As is often the case with individual receiving systems, there are often local chemical, physical, and biological conditions that warrant application of a modified guideline. Essential to the success of any remediation program selected for the ARMC is the recognition of the existing impacts and the inability to completely remove all contamination, regardless of the capital outlays or state of the art engineering techniques applied.

The example alternatives presented by SRK are based on the assumption of a site specific zinc water quality criterion which is about one order of magnitude greater than the current CCME guideline of 0.03 mg/L total zinc. Site specific water quality criteria have been developed throughout the world, and the Panel supports such a developmental process. Many countries, including the United States and Canada, recognize the fundamental scientific validity of the use of alternative site specific criteria for protection of aquatic life, terrestrial animals, and humans.

There are approved procedures within the regulatory framework of Environment Canada allowing such a process to be implemented. Research is ongoing by consultants for FMCPO to investigate options for developing site specific criteria for zinc and potentially other contaminants of concern. Fundamental to the development of site specific water quality criteria are the establishment of realistic and attainable beneficial uses, which can range from total fisheries reproduction to providing an aquatic habitat suitable for the rearing of a juvenile fish population.

The alternatives assessment has been structured to achieve the lowest water quality objective considered feasible, although from a practical standpoint such a goal may neither be attainable nor warranted, depending on the beneficial uses desired and the point of compliance chosen. The voices of the stakeholders involved, particularly the two local First Nations, should be heard when considering the goals for land use after remediation and hence the associated water quality objectives to be implemented.

4.2 Human Health and Ecological Risk Assessment

SUMMARY OF KEY CONCLUSIONS

While the current site management measures are containing the site, significant adverse impacts to both environment and human health are expected over time if proper remediation is not carried out.

It is important to clarify how the performance of the hypothetical remediation used in the human health and ecological risk assessment relates to the proposed remediation alternatives. It is the understanding of the Panel that the four example alternatives presented by SRK are intended to achieve greater risk reduction than the hypothetical remediation scenario used in the risk assessment exercise. However, after closer evaluation, certain proposed remediation alternatives will not achieve a lower residual ecological risk than the hypothetical scenario.

Further iteration of the risk assessment and an integrated assessment of the engineering risks and human health and ecological risks is required when the preferred remediation alternatives have been selected.

SENES prepared a Tier 2 Human Health and Ecological Risk Assessment (HHERA) of the ARMC using baseline data collected over the period from 2002 to 2005 by Gartner Lee Limited. Exposures were estimated under four different scenarios (Existing, No Intervention, Remediation and Treat All Flows) using the three different projections of seepage chemistry (Future 1, Future 2 and Future 3).

The combinations of remediation scenarios and future seepage chemistry are intended to offer low to maximum risk estimates, capturing a range of conditions among those most likely to be selected as part of a remediation strategy. Results of the SENES HHERA clearly demonstrate the need for remediation. While the existing conditions pose negligible threat to the environment, significant adverse impacts to both environment and human health are expected over time if no action is taken. A further comprehensive risk assessment of the residual effects and ecological and human health risks is needed when the preferred remediation alternatives have been selected. Since there are limitations to the extent of remediation, residual risks will remain of sufficient concern to warrant implementation of institutional controls restricting access to various areas within the ARMC.

The SENES risk assessment focused on potential impacts to the aquatic ecosystem, terrestrial environment, and human receptors assuming the seepage from the mineral wastes would deteriorate over time to Future 2 conditions. There is a general consensus the geochemistry and water quality will deteriorate from its current condition to that of Future 2. In the case of potential risks to the aquatic ecosystem, the primary concern is the Pelly River and its tributary streams: Anvil, Rose, and Vangorda Creeks. These receiving waters are impacted by anthropogenic and natural sources. The most important components of these aquatic ecosystems are the fisheries and concerns regarding impacts on reproduction and accumulation of metals. From a terrestrial environment standpoint, there are ongoing concerns related to the lesser potential for direct toxicity to and accumulation of metals within several important animal species and traditional food sources.

Issues related to human health include wind blown tailings and waste rock with the resultant potential uptake of metals by humans through consumption of contaminated fish and other animals. Another primary concern related to human health and the environment is the ability of the tailings dams to withstand the maximum credible earthquake (MCE) in the region and in estimating the ecological and human health consequences of such an event. These issues were not addressed in the SENES risk assessment as it assumed that the chosen remediation strategies would minimize such risks.

The engineering risk analyses have indicated these engineering structures are stable and exhibit a very low risk of collapse during such seismic events (see Section 7).

The following statements include specific comments regarding the SENES risk assessment:

- This is a comprehensive Tier 2 ecological and human health risk assessment. The objective is to characterize the risks from metal exposure of different biota in the terrestrial and aquatic ecosystem downstream of the mine under the following scenarios: 1) existing; 2) no intervention; 3) a hypothetical remediation scheme; and 4) the best scenario when all water flows are collected and treated.
- Under scenarios 2 through 4, three sub-scenarios were created based on different estimated loadings that reflect uncertainties associated with the future seepage chemistry. The sub-scenarios are termed Futures 1 to 3. Human exposure assessment was based on different land use patterns and typical traditional food use rate for adult, child and toddler.
- The baseline studies reported by Gartner Lee Limited appear to be thorough. This is a good example of comprehensive environmental sampling to support HHERA. Having said this, there are issues with the number of non-detects for some constituents and matrix combinations. Unfortunately, with contract analytical laboratories and various issues surrounding environmental samples from remote locations, non-detects are often unavoidable. Gartner Lee handled non-detects consistently, using one-half reported detection limit as the value to use for further evaluation. While this is fairly typical in ecological risk assessment, there are questions of representativeness in using this approach. Using one-half of the detection limit is usually a conservative approach to handling non-detects but it introduces additional uncertainty.

- There are no direct correlations between the four example alternatives as described in the September 2006 SRK Report and the HHERA Report. We recognize the HHERA report was completed prior to the example alternatives being developed, in part to inform that development process. This was a necessary step in the iterative process of the HHERA informing the remediation planning and vise versa. The next iteration of the HHERA must clearly correlate with the remediation scenarios in the refinement phase of alternatives development. Similarly, the next alternatives report must put into perspective the findings of the HHERA report with respect to their relevancy in the context of the refined alternatives.

  - Specific attention should be placed on the engineering risks identified in Attachment C of the SRK Report. Engineering and financial risks were evaluated and ranked in a Consequence Severity/Likelihood risk matrix (Attachment C, Figure 3). The effect of the specific consequences on constituents of potential concern and land disturbance should be assessed in the risk assessment process. The response received regarding this matter during the initial site visit and meeting was the risk assessment already encompassed the range of loadings that would be expected from any of the example alternatives. However, this response did not address the question of whether the consequences of various engineering or management failures had been specifically worked through the risk assessment process. To limit the number of iterations of the risk assessment it is recommended to initially complete them for those consequence and likelihood combinations contained in the high risk category.
  - The proposed cover materials for the waste rock piles and the tailings area should be examined through the risk assessment process for potential releases and impacts of contaminants of concern.

- An assessment was not completed for consumers of traditional food only. While this receptor may be an extreme case, it is important from a First Nations stakeholder perspective to include such an individual in the assessment. Intake data for consumers of traditional food only is presented in the HHERA Report, Tables 3.2-4 and 3.2-5. These parameters should be used in subsequent iterations of the assessment.
- The selection of Toxic Reference Values (TRVs) used for human receptors requires further clarity (Table 5.4-1).

  - Non-carcinogenic assessment of arsenic was not completed. This should be included in subsequent iterations of the risk assessment. ATSDR and IRIS databases specify a non-carcinogenic TRV for arsenic of 0.0003 mg/kg/d.
  - The cadmium TRV is listed as 0.008 mg/kg/d and referenced to Health Canada. The Health Canada document lists 0.0008 mg/kg/d. SENES has subsequently confirmed that they used 0.0008 mg/kg/d in the risk calculations.
  - A number of the remaining non-carcinogenic TRVs were significantly less conservative than those provided by ATSDR or IRIS. Using the most conservative value is not necessarily the best from a scientific perspective; however, some regulatory agencies require them. In any case, a brief discussion of the process by which one value was chosen over another is needed to follow the decision path for the risk characterization, particularly if the TRV value chosen was not the most conservative available from the major agencies (e.g. Health Canada, WHO, IRIS, ATSDR, RAIS).

- The risk assessment procedure lacks transparency, particularly with respect to the media contaminant of concern concentrations used in the exposure estimates. Mean, minimum and maximum concentrations are given in the report text with insufficient clarity on which values were used in the exposure calculations and reasoning for the selection.
- To better relate the exposure scenario to the results of geochemistry modeling, an additional table could be provided to describe the loadings of metals used for the risk assessment under different scenarios.
- It is not possible to compare the human health risk under different scenarios as the definitions of the receptors were different. It may be more instructive to estimate the risks across all scenarios of a receptor that has a fixed combination of lifestyle and consumption patterns.
- Instead of assuming all sulphide-containing materials will be covered and therefore there will be no uptake of contaminants by vegetation, it is recommended a sensitivity test be conducted to characterize the risks resulting from different thicknesses of till with varying infiltration rates.
- It would be beneficial to relate the mass loading used for the risk assessment to the target zinc concentration at station X2. Additionally, demonstrate that achieving a numerical water quality objective at the release location will lead to low risk exposure in the ecosystem downstream.
- It is important to clarify how the performance of the hypothetical remediation relates to the proposed alternatives of remediation. The risk assessment assumed the remediation alternatives within the SRK report would provide a better outcome than the hypothetical scenario employed. There are two distinct observations associated with this assumption:
    - The remediation alternatives proposed are not equal in their effectiveness or overall engineering or ecological risk. In some instances the engineering risk assessment did not adequately portray the level of comparative risk, such as the potential impacts associated with relocation of tailings. Implementation of a minimum construction approach with thinner covers allows for more infiltration and creation of poor quality seepage, thereby relying more heavily on treatment. However, when one examines the water quality estimates generated with the use of a series of mass load spreadsheets prepared by SRK specifically for the Panel, one finds even a small decrease in groundwater capture of a percent or more increases the metal mass load dramatically in Rose Creek far overshadowing any benefit from advanced water treatment. Furthermore, the poorer the quality and operation of the covers the worse the seepage chemistry would become, transitioning potentially from Future 2 to Future 3. It does appear some of the alternatives would not provide a better outcome than the risk scenario put forth at the Faro meeting.
    - The SENES risk assessment assumed an instream site specific water quality criterion of 0.24 mg/L for zinc, which has neither been verified nor may be achievable even with implementation of the highest level of treatment, groundwater capture, and control of infiltration. It is likely higher zinc and other metals concentrations could occur in Rose Creek above this yet to be specified site specific criterion.

The result is the risk assessment scenarios evaluated in the SENES HHERA did not reflect a situation of greater residual risk than the example remediation alternatives. Therefore, based on these observations, a further evaluation of residual risks will be required following selection of preferred remediation alternatives. In the next stage of risk assessment, it is also recommended that land use objectives be clearly identified for different areas of the mine site. The relevancy of the receptors to the local populations should also be validated.

4.3 Risk Rating

SUMMARY OF KEY CONCLUSIONS

The SRK Report summarizes the results of a multi-interest, collaborative risk rating process leading to a consensus on residual risks associated with each alternative considered. The risk rating methodology is useful as a qualitative means of identifying what adverse impacts may occur with a particular alternative. The multi-interest collaborative process is effective for incorporating the varied interests of stakeholders and ensuring their concerns are considered in the design process.

However, the purpose and limitations of the risk rating process are not clearly articulated. A full and clear explanation of the purpose and limitations of the risk rating process needs to be added prior to public discussion of alternatives. In the absence of such an explanation, and because it is the only comparative mechanism that is presented, readers of this material may assume it is the sole means being used to undertake a comparative assessment between alternatives. However, this was not the intent of the initial process. Rather, the rating was undertaken to ensure all interests understood the potential adverse impacts associated with each alternative from a technical and cost perspective. It is intended as a contributor to the assessment of alternatives, but by no means the driver of that assessment.

The Panel's review of the risk rating process gave rise to three categories of concern:

1. **Concerns related to the assessed significance of risks. From the perspective of the Panel: (1) some risks appear to be rated too high; (2) some too low; (3) some risks are missing; (4) one option brought forth by the Panel has not been evaluated (flooded tailings). The current risk rating appears to unfairly penalize in-place tailings remediation options while underestimating risks related to tailings relocation.**
2. **Concerns related to the rating methodology. If the purpose of the rating methodology was to drive the final assessment of the relative merits of each option there would be methodological concerns.**
3. **Concerns related to the lack of an overall approach intended for use in assessing the relative merits of alternative closure strategies. The intended process to be used in moving forward for assessing the relative merits of options is not specified. As a result, the role the risk rating methodology will ultimately play within the total assessment process is unclear.**

In moving forward:

1. **A full and clear explanation of the purpose and limitations of the risk rating process needs to be added prior to public discussion of alternatives.**
2. **The intended approach to be used for assessing alternatives in terms of their relative ability to meet closure objectives over the full project time horizon (500 to 1,000 years) needs to be explicitly stated prior to public discussion of the alternatives. The proposed assessment process in fact, would benefit from public review at the same time as alternatives were being reviewed.**
3. **Not only risks but the full range of both positive and negative attributes needs to be included in the assessment process.**
4. **For all attributes, the relative implications must be accurately portrayed.**
5. **Some form of multi-interest, collaborative comparison using a "multiple-objective" or "multiple-criteria" assessment methodology is needed. Such a process is essential to ensure that all contributing factors to the assessment are explicitly considered and that the scaling, weighting, and aggregating process are transparent for all to see.**

4.3.1 Risk Rating

Section 6 and Attachment C of the SRK Example Alternatives Report summarize the assessment of technical and cost-related risks undertaken to date associated with each alternative. Three facilitated workshops were undertaken with representatives of the Faro Mine Closure Project Office, SRK, the Type II Mines Office, the Selkirk First Nation (Pelly Crossing), Ross River Dena First Nation (affiliated with the Kaska Tribal Council), and Environment Canada. For each alternative, various technical and cost-related risks were identified and assessed with proposed mitigation measures offered. Following the modification of alternatives to include the proposed mitigation measures, remaining residual risks were identified and again assessed. The risk rating process involved three components:

1. Assessment of the severity of the consequence for various risks (Consequence Severity Matrix) on a five-part qualitative scale ranging from very-low to minor, moderate, major, and finally critical;
2. Assessment of the likelihood a consequence will be realized (Likelihood Chart) on a qualitative scale ranging from almost certain to likely, possible, unlikely and finally very unlikely; and
3. Development of a combined “risk level” based on development of a matrix that plots Likelihood against Consequence severity and facilitates the assigning of given risks to a cell in the matrix identified as having a risk level that is qualitatively scaled as low, moderate, moderately high, high, or very high.

Risk level plots are thus provided for each of the twelve alternatives. No attempt was made initially to aggregate risks by alternative nor to provide a judgement of which alternative might be considered “less risky.”

4.3.2 Risk Rating Purpose

Through discussions with SRK and the FMCPO, the Panel has come to understand the risk rating process was undertaken to ensure articulation of what potential adverse impacts might occur with each alternative. Taking this approach avoids past experience in which proposed projects were “sold” on the basis of their positive characteristics while leaving many potential negative implications unclear. Thus, the risk rating is intended as a contribution to the ultimate assessment of alternatives, but not a driver of decision-making. The rating that is contained in the SRK Example Alternatives report reflects a consensus of participants in the facilitated workshops described above.

However, the purpose and limitations of the risk rating process are not clearly articulated in the SRK report. In the absence of any explanation, and because it is the only comparative mechanism presented, readers of this material may assume it is the sole means being used to undertake a comparative assessment between alternatives. It should be noted this was not intent of the initial risk assessment process. A full and clear explanation of the purpose and limitations of the risk rating process needs to be added prior to public discussion of alternatives.

4.3.3 Strengths of the Risk Rating Process

In itself, the risk rating process is useful as a means of identifying on a quantitative basis a range of potential adverse impacts associated with any alternative. The collaborative consensus seeking process that was utilized in this case is very effective for involving the varied interests and backgrounds of stakeholders and ensuring their concerns play in the design process.

4.3.4 Concerns Arising

However, three groups of issues with the approach emerged that are of concern to the Panel. These issues are related with one leading to the next.

First, the current rating suggests a “relative” weighting of alternatives that is not consistent with the technical experience of the Panel. In addition, certain options and issues were not adequately addressed:

1. The risks related to physical instability of dam structures and tailings appear overestimated.
2. The issue of sludge management in general and the implications to overall water management, in particular, if the Faro Pit is used for storage of sulphide materials and tailings are not clearly addressed.
3. The risks related to tailings relocation with respect to both environmental harm and human health and safety appear underestimated. From an environmental perspective, these include risks related to the difficulty of cleaning up the footprint and residual contamination in the valley floor while attempting to control terrestrial and aquatic ecological impacts. Risks related to worker health and safety during the tailings relocation process, do not appear to have been addressed.
4. The relative risks related to the water cover option for the tailings have not yet been assessed as this was a remediation alternative brought forth by the Panel during this review.

Added together, the above issues indicate a risk assessment result that was overly optimistic in its assessment of tailings relocation, while unfairly penalizing alternatives that utilize existing dams and in-place remediation of the tailings.

Given the rating process does not aggregate risks and come to an overall assessment of which alternative is least risky, the above observations simply reflect the Panel’s overall qualitative read of the risk rating results. However, if these perceptions are shared by other readers, then the Panel’s concern the results may be misleading would be confirmed.

It is possible the above set of concerns could be resolved with a revisiting of the existing risk assessment. However, the current rating is the result of an extensive multi-interest collaborative process that may not be repeated. As a minimum, it is essential the purpose and limitations of the risk rating are clearly articulated. However, faced with the above concerns, the Panel looked more carefully at the underlying methodology that produced these results initially. Thus, a second set of concerns emerged that are perhaps more fundamental. These concerns relate to the methodology itself and the role the rating might play in ultimately identifying the preferred alternative.

Three concerns of this type emerged:

1. **Scaling**. In this risk assessment methodology, the qualitative scaling process leads to a risk matrix which implies a linear distribution along both axes. In fact, in some areas, particularly towards the corners of the risk assessment matrix, the axes scales may be closer to logarithmic in nature, rather than linear. For example, one “critical, very unlikely” risk may be several orders of magnitude greater or more significant than another because they are being placed together in a single large category.

   Because no numerical scaling is involved, the relative significance of various risk factors is not accurately portrayed throughout. The step-wise general nature of the scale is not concise, transparent, or sufficiently rigorous to provide a full relative assessment of risks.

2. **Addressing Other Attributes.** By design, this risk methodology focuses primarily on technical and cost-related risks. Other attributes also contribute to the assessment of alternatives and in the related decision making process. Many of these attributes relate to benefits that stand to be achieved or opportunities to be realized, and would be included on the positive side of the assessment. Choice of an alternative based solely on minimizing risk would relegate the achievement of these benefits to zero value. In assessing alternatives it is the achievement of benefits that can be the key differentiator.

3. **Linking to Closure Objectives.** As it stands, there does not appear to be an explicit and systematic link between the risks identified and the objectives set out as ultimately driving the overall remediation process as stated at the beginning of the report. In assessing the relative merits of alternatives, it is each alternatives' success at achieving these objectives that must be tested.

All of the above concerns again can be addressed with clarification of the purpose or the risk rating methodology. If its valid purpose is simply to clarify the potential adverse impacts of any alternative, then: (1) accurate scaling is less of a concern, (2) other attributes will not play in this listing by definition; and (3) there is no need to link to the objectives of closure at this stage of the analysis.

However, if the risk rating process was intended to drive the final assessment of alternatives the concerns the Panel has noted would be significant. However, according to discussions with the FMCPO and SRK this was not the intent of the initial risk assessment process.

These observations then lead to the third and overarching concern of the Panel emerging from our review of the risk rating process. Nowhere is there a clear articulation of the decision framework or the analytic and decision making process that will be undertaken to assess the relative merits of the various alternative approaches as the process moves forward into its next phase.

By "alternatives" what is meant is the overall strategy involving the technical approach and the implementation plan that includes how the management issues will be addressed along with the approach to adaptive management discussed herein. The strategy linked to each alternative needs to formulated as to how monitoring will be undertaken, adaptation will be triggered, impacts will be prevented or mitigated, and other benefits and opportunities will be captured.

It is the Panel's view that as the process moves forward a clear strategy and protocol are required laying out the approach that will be taken for assessing the various remediation alternatives. It is the Panel's understanding, the responsibility for this task will fall on a collaborative team comprised of the federal and territorial governments in conjunction with the First Nations. In this instance, five objectives have been articulated for remediation of the ARMC as stated previously. Presumably, the ultimate goal is to select a preferred remediation alternative that best achieves from an environmental and economic standpoint the most objectives. To address this goal, some form of multi-interest, collaborative comparison using a "multiple-objective" or "multiple-criteria" assessment methodology seems essential.

It is the strategy and protocol for undertaking the manner in which the relative merits of alternatives will be assessed that is required for inclusion in the public review of alternatives, not the assessment itself. This later presumably will be informed by the upcoming public review.

4.3.5 Moving Forward

In any case, the risk rating process reported in the SRK report while useful as a means of describing "what can go wrong" does not provide a full foundation for an overall assessment of alternatives in terms of manner in which each alternative could meet the objectives set forth for the ARMC closure.

This conclusion does not contradict the Panel's opinion the information base that has been developed is adequate to move forward with this assessment. Rather, the Panel recommends as the project now moves into a formal assessment phase the following steps should be taken.

1. A full and clear explanation of the purpose and limitations of the risk rating process needs to be added prior to public discussion of alternatives.
2. The intended approach to assessing alternatives in terms of their relative ability to meet closure objectives over the full project time horizon (500 to 1,000 years) needs to be explicitly mapped out prior to public discussion of the alternatives. In fact, the proposed assessment process would benefit from public review at the same time as alternatives were being reviewed.
3. Not only risks, but the full range of positive and negative attributes, need to be included in the assessment process.
4. For all attributes, the relative implications must be accurately portrayed.
5. Some form of multi-interest, collaborative comparison using a "multiple-objective" or "multiple-criteria" assessment methodology will be needed. Such a process is essential to ensure all contributing factors to the assessment are explicitly considered and that the scaling, weighting, and aggregating processes are transparent to the public.

5. ADDRESSING THE LONG TERM HORIZON

5.1 Understanding the Long Term Context

SUMMARY OF KEY CONCLUSIONS

Given the indefinite nature of remediation and the 500 to1,000 year time horizon used in planning ARMC remediation, implementation will have to take into consideration potential variations in the following factors: (1) the nature of society; (2) environmental conditions; and (3) the management of closure plan implementation itself. A long-term scenarios analysis is required to address these considerations. The capacity of various alternatives to address these variations will be a factor in the assessment of alternatives and thus such a scenarios analysis should be undertaken as part of the overall process of assessing alternatives that will now take place.

As noted previously, due to the indefinite need for remediation, the design time horizon for Faro Mine closure is in the order of 500 to 1,000 years, considered in perpetuity in this review. Regardless of which combination of alternatives is chosen, ARMC closure will require active care and maintenance throughout this design life, a situation amounting to "perpetual" care.

As a result, alternatives need to be assessed against both the current conditions in which remediation will proceed as well as the potential future physical and social conditions which they may face during a several hundred year project life. This is a real challenge as various properties and processes controlling the long term conditions cannot be accurately predicted. It is a fact the world will change, although the precise directions this change will take is not predictable.

For typical public works, standard engineering design addresses long term seismic and hydrologic conditions by projecting historic conditions to calculate the Probable Maximum Precipitation (PMP) and from that deriving the Maximum Probable Flood (PMF). Similarly, the Maximum Credible Earthquake is calculated. These are extremely conservative engineering and scientific projections which introduce a large factor-of-safety into the design. In addition to projecting long-term seismic and hydrologic conditions, the following factors also need consideration because given the long project life, they too will affect how the preferred remediation alternative will perform:

- Variations in the nature of society: instability of society and institutions including capacity for knowledge transfer, availability of needed human resource capacity, and the potential evolution of science and technology.
- Variations in environmental conditions including gradual geomorphologic change, extreme episodic and long term climate change.
- Variations in the management of the closure plan addressing such issues as citizen participation in decision-making.

Central to all approaches developed to address these change factors is a realization that accurate prediction is not possible as the range of uncertainty is too great. This uncertainty increases the farther into the future that is being considered.

However, while one cannot know what future society and the future environment *will* look like, one can try to anticipate what they *may* look like by envisioning a broad range of possibilities. This is the approach taken by formal scenarios technique which has emerged over the past 30 years.

Using the insight of a team of individuals drawn from many interests, a range of futures is designed, each of which is plausible according to what we know today. Some of these futures may be more desirable than others but in a scenarios exercise, no attempt is made to either design a desirable future or to predict an expected one. Rather, a range of plausible alternative environments are described in which today's decisions may be played out. The aim is to bracket what eventually occurs, realizing prediction is not possible.

Such scenarios highlight potential risks and opportunities ahead. They serve as a means of testing the robustness of alternative closure options. And by doing so, they facilitate better decision making today. Scenarios evaluation has an added benefit as well. It provides a safe place for varying interests to explore and find common ground when it comes to choosing the preferred alternative. Scenarios evaluation has not yet been undertaken for the ARMC project. As remediation proceeds, the capacity of various alternatives to address the considerations listed above as well as others not yet articulated will play in the assessment of alternatives. Thus, such a scenarios analysis should be undertaken as part of the overall process of assessing alternatives that will now take place.

5.2 Key Long Term Management Issues

SUMMARY OF KEY CONCLUSIONS

The following key management issues need addressing for each alternative for the full project life-cycle. These issues are important to the performance and success of closure implementation and there may be differences in the capacity of various alternatives to address these issues. Thus, they may play in the ultimate selection of closure design and should be addressed in the next phase of developing the overall closure management strategy.

1. **Ensuring the availability of trained and experienced site personnel for site operation through the full project life cycle (in the order of 500 - 1000 years).**
2. **Financial surety for site operation, project regulation and oversight, and dealing with unforeseen problems.**
3. **Management of post-mining changes in land use.**
4. **Surety of transportation systems, power supply, supplies of needed materials and services.**
5. **Contingencies for addressing fire and other potentially traumatic events.**
6. **Clarification of the role of various interests in closure plan implementation.**

A number of key management issues are important to the performance and success of whatever preferred remediation alternative is ultimately chosen. These issues also need consideration for each alternative over the full project life-cycle. There may be differences in these issues between alternatives that are important to the ultimate selection of closure design.

Thus, they will need to be addressed in the next phase of the design process and in development of the overall closure management strategy. The scenarios analysis described in the previous section can also address future implications related to these key management issues.

Key management issues are listed below and detailed in the Table 4, the responsible parties are identified and a comment provided on the link to closure planning.

1. Ensuring the availability of trained and experienced site personnel for site operation through the full project life cycle (in the order of 500 - 1000 years).
2. Financial surety for:
   a. site operation;
   b. project regulation and oversight; and
   c. dealing with unforeseen problems.

   Financial surety is essential to address for the following reasons:

   a. to avoid the continued deterioration of the physical and chemical conditions at the site, which left unchecked, would lead to more severe adverse environmental impacts;
   b. to support the implementation of Adaptive Management. Adaptive Management in the absence of financial surety makes no sense because it demands a capacity to adjust in a timely manner to avoid significant problems that are discovered through the learning process; and
   c. to achieve the societal goal of minimizing costs imposed on future generations related to current activities is to be achieved.
3. Management of post-mining changes in land use.
4. Surety of transportation systems, power supply, supplies of needed materials and services.
5. Contingencies for addressing fire and other potentially traumatic events.
6. Clarification of the role of various interests in closure plan implementation.

Table 4 Key Management Issues

Management Issue	***Responsibility***	***Link to Closure Plan being Prepared by the FMCPO***
1. <u>Ensuring the Availability of Trained and Experienced Site Personnel.</u> Successful long term operation of the site will require properly trained and experienced staff.	Faro Mine Closure Planning Office or implementing agency that is established	An important aspect of the closure plan is the issue of provision of support infrastructure and services (housing, food, medical services, education, recreation services etc.) needed by site personnel. Presently these people live in the town of Faro. Thought needs to be given to the cost of maintaining the basic services of the town of Faro (e.g., water, schools and sewage), whether this is sustainable and what other arrangement or additional costs may be required.
<u>2a. Surety of Financial and Human Resources for the Site Operation.</u> The large costs, high degree of uncertainty and the large amount of staff time and required expertise make sustaining adequate environmental protection and reclamation a difficult and expensive task for any organization. Factors potentially resulting in reduced resources to prevent environmental impacts and limit the public liability and environmental risks at government owned mine sites include: ⇨ The money, data storage and personnel required by government to manage closed mines will increase in the future as the number of mines that fall to government responsibility increase;	Governments of Canada and Yukon	If a commitment for ensuring financial surety is not forthcoming: (1) the choice of alternatives will be pushed toward those least dependent on the availability of resources in the future, something that itself will likely greatly increase overall costs; (2) the potential for applying Adaptive Management will be undermined as will the capacity for developing and maintaining public trust.

⇨ Political changes may result in the shifting of resources to areas that directly impact more voters; ⇨ Mines like Faro are very complex and when staff retires or leaves, there is a significant reduction in the institutional knowledge of the site.		
2b. Surety of Resources for Project Regulation and Oversight. In addition to the organization conducting the work, there needs to be an independent organization that ensures that the site is meeting present performance objectives, properly managing the future liability and limiting future environmental and public risks.	Governments of Canada and Yukon	As above in terms of ensuring resources are available to support this function. It is up to government to establish the oversight mechanism.
2c. Surety of Resources for Dealing with Unforeseen Problems. Experience at other closed mines of this type (e.g., Equity Silver and Sullivan Mines) indicates that there will be a number of unforeseen problems that occur due to factors such as the difficulty of site characterization, difficulty in predicting the future performance of the large number of properties and processes in flux and over such a long time period, and the lack of long-term experience with many of the required mitigation measures.	Governments of Canada and Yukon	As above in terms of ensuring resources are available to support this function. Contingencies for dealing with the unexpected should be factored into the Closure Plan. Adoption of a process of Adaptive Management is essential.
3. Management of Post-Mining Changes in Land Use. Post-mining changes in land use may alter who is exposed to contamination from the site and how results are interpreted. This is an issue both for the site and tailings spilled downstream.	Faro Mine Closure Planning Office in cooperation with the Government of Yukon	The closure plan should identify where caveats are required for on-site and off-site land use to ensure that future activities are compatible with the environmental protection needs and activities and do not increase risks to fish and wildlife and human health.
4. Surety of Transportation and Storage for Power, Supplies, etc. Successful long term environmental protection and reclamation will require power and supplies such as lime.	Faro Mine Closure Planning Office	The closure plan needs to outline the required transportation and storage capacity for power and supplies, and the resources required to build and sustain them, both during normal operating and extreme climate or upset conditions.
5. Contingencies for Addressing Fire and Other Potentially Extreme Traumatic Events.	Faro Mine Closure Planning Office	The closure plan needs to ensure that potentially traumatic natural and anthropogenic events, such as fire, will not adversely impact the performance of remedial measures required for environmental protection (e.g., power poles and vegetation required for erosion protection and evapotranspiration from soil covers).
6. Clarification of the Role of the Various Interests in Closure Plan Implementation	Faro Mine Closure Planning Office	The closure plan should clearly lay out how ARMC closure implementation will include ongoing involvement of various interests including the Selkirk First Nation (Pelly Crossing), Ross River Dena First Nation (affiliated with the Kaska Tribal Council), Town of Faro, non-government organizations, and various elements of government. It is key to effective application of Adaptive Management and the development and maintenance of public trust.

5.3 The Role of Adaptive Management

SUMMARY OF KEY CONCLUSIONS

Adaptive Management is a formal process of implementing closure with an explicit objective of continuous learning and improvement. Adaptive Management offers an opportunity for building and sustaining public trust while accelerating technical progress. If effectively applied, Adaptive Management can lead to improved performance and reduced costs.

However, if rationalized simply on the basis of reducing costs and not on the basis of (1) effectively and openly tracking and reporting performance against specific criteria, and (2) using best judgment to adjust actions as and when needed, its use will undermine rather than re-enforce public trust.

A fully developed Adaptive Management Plan for Closure will ultimately be needed that addresses the technical, environmental and human implications over the long term. A general outline of how Adaptive Management would be implemented for each alternative should be included as part of the preparation for the formal comparative assessment process.

Although implicit in aspects of the draft SRK Example Alternatives Report, it does not include a formal detailed discussion of "Adaptive Management" and how such a concept would be applied in implementation of a closure plan for the ARMC.

However, in discussions with the FPMCO, it was clear Adaptive Management would likely be a driving concept for whatever alternative was ultimately implemented. A good example of the road map which always underlies an adaptive management plan is presented in the March 2006 SRK report describing the implementation of the groundwater capture system proposed for the S-Cluster area.

In general terms, "Adaptive Management" is a formal process of conceiving and carrying out a program as an experiment, so that learning from experience becomes an explicit objective. More specifically, "Adaptive Management" is a systematic approach to engineering design and related policy choices that recognizes uncertainty, embraces surprise, expects unexpected developments and puts in place the mechanisms that ensure that learning takes place and appropriate adjustments to an implemented system can be made.

The term was invented by Canadian ecologist C.S. Holling in 1978. This discussion is drawn from Kai (2003) who provides a succinct overview of what it means and how it might be applied in long-run engineering projects.

Application of Adaptive Management requires specifying expectations in a concrete systematic fashion through a crisp definition of specific performance targets for all aspects of the closure system. Monitoring is then put in place to track actual behaviour and establish whether or not targets are being met and if not, why not. The idea is to look for surprises that might highlight incorrect assumptions. Thus, adaptive management is a kind of organized skepticism that is created specifically to facilitate learning and adjustment.

Kai points out:

> *Small surprises lead to better understanding, and this better understanding improves the likelihood that catastrophic failures can be prevented. Over time, confidence in the . . . waste management system should then increase, even if there are unanticipated outcomes. The conceptual model, explained in terms accessible to the lay person, is the centerpiece of the safety case: a periodic public discussion of how safe management and isolation of . . . wastes is being pursued.*

Seen in this way, an adaptive approach to closure of the ARMC provides an opportunity for the FMPCO to build and sustain public trust while accelerating technical progress. For some, adaptive management has been raised as a means of implementing the least costly alternative first and only moving to additional expenditures when the first step is demonstrated to be ineffective.

This kind of thinking is not consistent with Adaptive Management as intended by the originators of the concept. Rather, decision-making at any point in time should be driven by doing what best professional judgment deems as appropriate. It is true that if effectively applied, Adaptive Management can lead to reduced costs. However, if rationalized simply on the basis of reducing costs and not on the basis of (1) effectively and openly tracking and reporting performance against specific criteria, and (2) using best judgment to adjust actions as and when needed, its use will undermine rather than re-enforce public trust.

A fully developed Adaptive Management Plan (AMP) will ultimately be needed that addresses the full spectrum of technical, environmental and human implications over the long term. At this stage, a general outline of how Adaptive Management would be implemented for each alternative should be included as part of the preparation for the formal comparative assessment process.

5.4 Cost Estimates

SUMMARY OF KEY CONCLUSIONS

As alternatives are refined and narrowed, a detailed confirmation of cost estimates should be undertaken by a qualified third party

A sensitivity analysis should be undertaken as part of the net present value calculations demonstrating the implications of a range of discount rates on cost estimates. A clear rational for the preferred discount rate should be provided.

Net present value calculations are needed for estimating and comparing the financial requirements today of each alternative. In addition, undiscounted cash-flow profiles over the full project life cycle should be included in the description of alternatives. These are needed to identify, assess and anticipate the technical, social, and economic implications for both Yukon and Canada over the long term.

Cost estimates are summarized in Section 7 of the SRK Example Alternatives Report and detailed supporting tables are provided in Attachment E. Cost estimates of the various alternatives have been developed using a deterministic model with allowance for unknown contingencies. This is consistent with standard industry practice. Summary estimates for each alternative are reported as a sum of closure costs in 2006 dollars and net-present value post-closure costs calculated using a 3 % discount rate.

The Panel was not required to review the details underlying the cost estimates and cannot comment on their accuracy. For a project of this magnitude it is recommended an independent third party review these cost estimates as the alternatives selection process proceeds. Thus, as alternatives are refined and narrowed, a detailed confirmation of cost estimates should be undertaken by qualified professionals.

While the time horizon included on the tables contained in Attachment E extend out 20-23 years, page 71 of the SRK Example Alternatives Report notes that the post-closure phase was assumed to include construction and perpetual operation of the water treatment facilities, as well as inspection, maintenance and repairs of other components constructed during remediation of the ARMC. In practice, the SRK project team informed us this translates to a consideration of costs over the first 100 years of the project in the net present value (NPV) calculations. In such calculations, the future value of money is discounted with the result that eventually future value goes to zero. The point which it goes to zero depends on the discount rate and in this case the choice of a 100 year time frame ensures all significant present valued costs are captured.

Estimated costs are reported in terms of net present value and calculations are based on the following two assumptions: (1) operating and maintenance costs will be required in perpetuity; and (2) a 3% net discount rate. Notably, the 3% net discount rate exceeds the rate currently available from Government of Canada real return bonds which suggests a lower discount rate may be more appropriate, at least in the short-term. There is literature spanning many decades that describes the debate about the choice of appropriate discount rate for various applications. In this case: (1) a sensitivity analysis should be undertaken that shows the implications of a range of discount rate; and (2) a clear rationale should be provided for the “preferred” rate to be used. Both of these steps will have to be taken in preparation of the final remediation plan.

Estimating financial requirements using discounted cash flow totals is standard industry practice. Such estimates are required to generate an estimate of what is required in today’s dollars to cover project costs. However, for the following reasons, undiscounted cash-flow profiles in addition to net present value calculations should be included in the description of each management approach:

1. Because discounting causes future dollars to go to zero after some period of time, used on their own, discounted cash flow calculations can mask the fact various alternatives will involve major future allocations of resources.
2. By showing the projected timing and repeat cycles of investments associated with closure implementation, undiscounted cash-flow profiles provide a means for better understanding the potential distribution of benefits to various interests at any point in time and across generations through project implementation.
3. They are needed to identify, assess and anticipate the technical, social, and economic implications for both Yukon and Canada over the long term.

5.5 Climate Change

SUMMARY OF KEY CONCLUSIONS

Potential climate change does not invoke concerns that require design modifications at this time. However, this is an area where uncertainty exists. This uncertainty underlines the need to use a system of Adaptive Management in moving forward – monitoring and adjusting if performance criteria are not achieved.

The issue of climate change and how it may affect closure is not adequately described in the description of alternatives. As a result, readers may receive an impression that the issue has not received due attention – which is not the case. This limitation in the current descriptions should be addressed.

Concerns about climate change have led to significant efforts to explore the potential implications of a warming climate for the Yukon and other regions of northern Canada, where the impacts are projected to be greater than in more southern locations of Canada. According to work commissioned by the Faro Mine Closure Planning Office, climate change could affect estimates of: (1) probable maximum precipitation (PMP); (2) cover performance; (3) mass loading and its implications for water management and treatment systems; and (4) geotechnical stability of constructed works and upstream terrain. This work is summarized in a technical memorandum prepared by John Brodie to Roger Payne and Bill Slater, October 8, 2006 with subject heading "Global Warming-Faro Mine Closure."

Experts commissioned to estimate the Probable Maximum Precipitation (PMP) and the linked estimate of Probable Maximum Flood (PMF) have reviewed the implications of potential climate change and concluded that further refinement of PMP is not warranted. Expert opinion on the affect of climate change on PMP varies. A recent Environment Canada commissioned paper suggests annual precipitation could rise by between five to twenty percent. This position was reviewed by an expert working group aside from the Panel commissioned by the Faro Mine Closure Office who reached the following conclusions in the case of Faro:

- There appears to be a reduction in extreme intensity storms associated with climate change over the past 50 - 80 years.
- From a theoretical perspective, warmer air holds more moisture; however a warmer climate will yield lower temperature gradients and thus reduce storm dynamics. These factors may be offsetting with respect to PMP.
- The Alberta hydrology guidelines stated that there is no solid basis for increasing PMP estimates based upon historical data.

Overall, the climate review group concluded that further refinements or adjustments to the PMP were not considered warranted at this time. Importantly, a very conservative approach has been taken with respect to developing engineering safety factors for the Rose Creek diversion channel. Based on the recommendation of Northwest Hydraulic Consultants a freeboard of about 1.0 m has been designed for the Rose Creek diversion channel. Having this freeboard provides an additional safety factor in the event the PMP increases slightly due to climate change.

Climate change could result in an increase in Mean Annual Precipitation or MAP. If this were to occur the volume of water to be treated in the pits would increase, as would the volume of water sent to treatment plants at the Faro and Vangorda/Grum sites. Increased temperatures and precipitation could increase the volume of infiltration entering the sulphide wastes and accelerate the geochemical processes occurring within those materials. Although the volume of treated water discharged would increase, nonetheless it would be partially offset by greater dilutive flows in the receiving waters.

Furthermore, there may be a shift in the winter/summer (snow/rain) distribution of precipitation. Freshet would likely occur earlier in the year. Groundwater collection systems would not likely be affected by changes in MAP, as they could be expanded if necessary to contain any additional volumes of subsurface flow. The warmer ambient conditions may improve the effectiveness of biological treatment if it were employed at some point in the future.

Given the long time horizon over which the covers must remain effective, it is important to consider how decadal and longer changes in the local climate may affect cover performance. If the climate in the central Yukon Territory becomes warmer and wetter, there may be competing factors at play that will modify the percolation rate at the base of the covers.

Higher rainfall will promote higher rates of infiltration, but a warmer climate suggests higher rates of evapotranspiration over a longer growing season. A greater number of frost-free days at the leading and trailing ends of the winter period when vegetation will be dormant will contribute to higher infiltration rates through the soil covers.

Changes in the seasonal distribution and intensity of rainfall events will also affect the infiltration rates to the covers. Mathematical models are potentially of some help in understanding how these factors may interact. An alternative approach may be to examine store and release covers at existing installations at mine sites in southern Canada, where the current climate may foreshadow conditions that could develop farther north.

With respect to the sulphide-bearing materials, several types of covers are being considered for closure of the Faro mine. Very low infiltration covers (HDPE, bitumen) are proposed for the low grade ore stockpiles and oxide fines. The leakage, runoff control and maintenance and repair of these covers is likely to be affected to some extent by an increase in MAP or PMP. The low infiltration (2 meters in depth) and rudimentary covers (0.5 meters in depth) are designed to perform as storage and release covers. An increase in MAP due to climate change would likely result in more water to manage, but also greater evaporation potential due to the longer and warmer summer season. Additional modeling could be undertaken to evaluate this effect, although the calculations are unlikely to prove definitive.

The simple contingency to address the lower infiltration covers is to provide long-term monitoring of cover performance and erosion effects. In the event of increasing MAP, an evaluation of the benefits of increasing the thickness of the constructed covers should be undertaken.

Climate change manifesting itself through global warming would likely lead to a reduction in the extent of permafrost. Thawing of overburden within Rose Valley could result in the release of sediment to the creeks. A terrain assessment of the North Fork of Rose Creek identified colluvium, till and coarse glacio-fluvial materials as the predominant soil types. Similar soils are located within the South Fork Rose Creek watershed and the Vangorda watershed.

Adverse clogging of ditches and diversions is not expected to be a problem should global warming result in thawing of permafrost. None of the engineered components of the closure alternatives rely upon frozen conditions for performance.

Ultimately, on the Faro side of the ARMC, the groundwater capture system downstream of the Rose Creek Tailings Facility provides the safeguard in a climate change scenario where greater infiltration occurred through the store and release cover on the waste rock piles. The increased seepage of contaminated water should still be captured there with a properly functioning and maintained containment system. It would be useful to examine if a similar condition could be met in the Vangorda watershed. Groundwater capture is discussed in Section 6.2 of this report.

In summary the Panel concludes:

- Any potential climate change-induced variations in the water balance and related water treatment requirements are expected to fall within design capacity.
- Behaviour of storage and release covers under climate change induced increases of Mean Annual Precipitation or Maximum Probable Precipitation is a complex issue that is difficult to project with confidence.
- The appropriate contingency to address the store and release covers is to provide long-term monitoring of cover performance and erosion effects. In the event of increasing MAP, an evaluation of the benefits of increasing the thickness of the constructed covers should be undertaken.

The Panel is of the view that potential climate change does not invoke concerns that require design modifications at this time. The Panel recognizes this is an area where a degree of uncertainty exists. This uncertainty underlines the need to use a system of Adaptive Management in moving forward - monitoring and adjusting if performance criteria are not achieved.

In addition, the Panel also finds the issue of climate change and how it may affect closure is not adequately described in the alternatives report. As a result, readers may receive an impression that the issue has not received due attention which is not the case. This limitation in the current descriptions should be addressed.

6. COMMON ENGINEERING & REMEDIATION COMPONENTS

6.1 Introduction

Although there are technical issues and engineering solutions specific to various components within the ARMC, there are nonetheless generic approaches and underlying processes common to these components as well. In advance of evaluating the individual remediation alternatives for the ARMC component sites, the Panel felt a discussion of these common factors should be presented to aid the stakeholders with an understanding of the overall remediation process. Therefore, comments are presented in this section on topics relevant to the technical studies conducted and example alternatives presented for the entire ARMC, which is comprised of three component sites including the Faro Mine, the Rose Creek Tailings, and the Vangorda/Grum Mines.

6.2 Groundwater Capture Efficiencies

SUMMARY OF KEY CONCLUSIONS

Seepage from the Faro Mine waste rock dumps (WRDs) has the potential to bypass the proposed groundwater collection system due to bedrock flow pathways, limits on available drawdown and the presence of diffuse sources beyond the high-priority areas at the Emergency Tailings Area, S-Cluster and Zone 2 Pit Outwash. There is merit in collecting contaminant load from these areas for reasons of ease of collection, overall load reduction and prevention of new areas of surface water contamination. The potential for bypass will need to be addressed during subsequent engineering design studies and adaptive management programs.

There is a need to explicitly recognize early in the adaptive management process for groundwater collection that lining of the North Fork of Rose Creek (NFRC) will likely be necessary to protect water quality in NFRC and Rose Creek.

The prospects of achieving very high load capture efficiencies are greatest downstream of the Rose Creek Tailings Facility (RCTF) where groundwater flow is naturally focused into a small well-defined area. Characterization of bedrock flow pathways will be required to ensure high capture efficiencies in this area.

An alternate groundwater capture option for the Faro Mine suggested by the Panel, is to focus capture of groundwater loads from the Faro WRDs and Tailings downstream of the RCTF with surface pumping using a recovery trench or drain with fully penetrating relief wells, together with upstream and downstream cut-off walls to isolate groundwater within the Rose Creek aquifer below the Rose Creek tailings.

Groundwater capture plans are less developed for the Grum and Vangorda WRDs, primarily because the presence of finer grained soils, which lead to lower rates of contaminant migration, and reduces the need for immediate action.

With sufficient site characterization effort, good engineering design, reliable backup systems and rigorous application of adaptive management plans (AMP), it should be possible to achieve the target capture efficiencies approaching 100% for the higher priority areas of the Faro WRDs, for the RCTF, and potentially for the Grum and Vangorda WRDs.

There is sufficient information on hydrogeologic conditions at the Faro WRD, Rose Creek Tailings and Grum/Vangorda WRD sites to proceed with the evaluation of closure alternatives considering groundwater load capture.

With time, water with low pH and carrying metals generated through sulphide oxidation of materials deposited throughout the ARMC will enter the local groundwater system. This groundwater, together with the visible seepage, will require collection and treatment. If the current situation is left unattended the water quality will deteriorate dramatically resulting in severe impacts to nearby and downstream receiving waters. Consequently, collection of contaminated seepage from the Faro and Grum/Vangorda Mine sites is a common and important component of all example alternatives for closure of the ARMC. In conjunction with various tailings relocation, waste site cover and water treatment alternatives, collection of contaminated seepage is essential to mitigating future contaminant loading and adverse effect in surface water. Understanding achievable groundwater capture efficiencies is therefore central to the evaluation of the example alternatives.

The example alternatives have been presented in the SRK reports on the basis of the assumption that a site specific water quality objective could be derived and approved for compliance purposes at monitoring station X14 in Rose Creek at Faro Mine site, and at stations V27 and V8 in Vangorda Creek at Grum/Vangorda Mine site. Furthermore for purposes of evaluation of example alternatives, it was assumed that the current seepage chemistry would deteriorate over time, eventually taking on the estimated Future 2 characteristics. To meet the water quality objectives in each of the four example alternatives that SRK has analyzed, high groundwater capture efficiencies are indicated.

Achievement of very high groundwater capture efficiencies, approaching values greater than 99%, is possible for well characterized and well defined hydrogeologic settings. In these situations, well engineered and well maintained primary, secondary and possibly tertiary collection and backup systems have been shown to perform effectively and reliably over the long term However, for complex hydrogeologic settings with limited site characterization, and where backup collection and monitoring systems are incomplete or unreliable, achievement of very high groundwater capture efficiencies will be difficult to maintain over extended periods of time.

The Panel's assessment of achievable groundwater capture efficiencies for the ARMC is based on the descriptions of the proposed groundwater recovery systems and the level of hydrogeologic understanding provided in the SRK documentation and presentations to the Panel. The Panel's assessment recognizes that adaptive management plans are proposed for these groundwater collection systems and also that adaptive management plans must be built on a comprehensive hydrogeologic understanding.

6.2.1 Mixing Cell Model and Groundwater and Load Capture Efficiencies

The evaluation of the four example alternatives uses contaminant collection efficiency as an adjustable primary variable in a water flow and load balance (mixing cell) model to estimate future metal concentrations in surface water of Rose Creek and Vangorda Creek. The mixing cell models, which the Panel endorses as valuable and important tools for assessing closure alternatives, have also been used to estimate contaminant collection efficiencies necessary to meet target metal concentrations in surface water at and downstream of the ARMC. These models also allow the project to examine closure alternatives (e.g., numeric values for groundwater capture efficiency, soil cover efficiency) to aid in better understanding of the tradeoffs that may be possible in formulating a cost-effective site closure plan.

On one hand, it is important to understand the mixing cell models used in the alternatives report do not specify or consider the groundwater pathways by which contaminant load from the WRDs and Rose Creek Tailings reaches Rose Creek and Vangorda Creek. In simple terms the mixing cell model mixes the contaminant load created by source area infiltration (area x rate) and the assumed source concentrations with surface water flows to yield a resultant surface water concentration. On the other hand, knowledge of groundwater pathways is essential for the successful design of an interception system intended to capture the groundwater load prior to discharge into surface water.

For almost all of the ARMC waste sites, contaminant collection efficiency is equivalent to groundwater collection efficiency as groundwater interception, recovery and treatment will be the principal means of preventing discharge of contaminated seepage from mine waste sites to surface water. However, as the contaminant collection efficiency is a load-based parameter, it considers both the concentration and flow rates of contaminated seepage. Thus when examining the capture of zinc released from ARMC WRDs or the tailings, one needs to think in terms of the capture efficiency of the total zinc load, not simply the groundwater capture efficiency in discrete areas.

The concept underpinning the mixing cell models works best if the groundwater discharge points are focused in readily identified zones, such as the valley downstream of the Rose Creek Tailings. In that case, it will likely be feasible to implement a groundwater capture system with relatively high capture efficiency, subject to managing the complexity of local site conditions and addressing system maintenance and operation issues. If the discharge is more diffuse, as it may eventually be around the perimeter of the Faro WRD and perhaps Grum and Vangorda WRDs, high capture efficiencies would require groundwater collection over a significant portion of the perimeter of the dumps.

6.2.2 Uncertainty in Water Quality Predictions

Uncertainty in predictions of surface water quality will arise from uncertainty in predictions of contaminant seepage concentrations and uncertainty in seepage flow rates, including both infiltration rates through cover materials and groundwater collection efficiencies. It is also apparent that higher concentrations of metals in groundwater will require higher groundwater collection efficiencies to meet the same surface water quality target for fixed waste site seepage or groundwater flow estimates. Uncertainties in future seepage concentrations (i.e., Future 1, 2 and 3 seepage chemistry scenarios) are much greater than uncertainties in groundwater flows or achievable groundwater capture from interception/recovery systems.

Thus it is likely that the uncertainty in future zinc concentrations in Rose and Vangorda Creeks will be driven more by the uncertainty in future water quality in the Faro and Grum/Vangorda WRDs and in the Rose Creek Tailings, than they will be by the uncertainty in the ability to capture a certain percentage of the groundwater flow in these areas. Consequently, a caution is required in adopting capture efficiency as a planning tool for evaluation of the example alternatives to closure of the ARMC waste sites. It is important to recognize that because of the uncertainty in predicting the zinc and other metal loads released from the entire perimeter of the waste sites in future years, it may not be meaningful to base decisions on closure alternatives solely on the assumption that it is possible to differentiate between capture efficiencies of say, 95 vs. 99% at the ARMC priority areas such as the Emergency Tailings area or the S-Cluster area.

6.2.3 The Faro Mine Site

At the Faro Mine site, target contaminant capture efficiencies have been defined for different example alternatives and for identified broad areas of groundwater contamination (sources above North Fork Rose of Creek, sources above Emergency Tailings Area, and Rose Creek Tailings) for assumed base case assumptions of cover performance (20% and 5% of MAP for rudimentary and low infiltration covers) and future seepage water chemistry (Future 2). Although calculations of contaminant capture efficiencies have been performed by SRK for other assumptions of cover performance and future seepage water chemistry, only the results from the base case assumptions are discussed here.

The groundwater capture efficiencies presented in the SRK documentation are based on achieving a yet to be approved site specific water quality objective for zinc of 0.24 mg/L in the primary receiving system (Rose Creek) downstream of the Tailings Facility (as defined by sampling location X14).

As part of the assessment of residual risks, the required groundwater capture efficiencies presented in the SRK report range from 80 to >99% for tailings stabilized in place, and 70 to >99% for tailings completely relocated. The highest required groundwater capture efficiencies are 98 to >99% are for the area downstream of the Rose Creek Tailings Facility. These capture efficiencies are summarized in Table 5.

Table 5 Contaminant Collection Efficiencies Needed to Meet Proposed Site Specific Zinc Water Quality Criteria

Remediation Alternative	Percentage of Contaminant Needing to be Collected					
	Tailings Stabilized in Place			Tailings Completely Relocated		
	Sources above North Fork	Sources above ETA	Tailings	Sources above North Fork	Sources above ETA	Tailings
Flow-Through Pit	>95%	>99%	>99%	>95%	>99%	n/a
Upgrade Faro Creek Diversion	96%	99%	99%	90%	95%	n/a
Minimize Construction	99%	99%	99%	95%	99%	n/a
Minimize Water Treatment	80%	93%	98%	70%	80%	n/a

It is important to note the required contaminant collection efficiencies listed in Table 5 are defined at the scale of the entire Faro Mines site, but groundwater collection systems at the Faro Mine site have only been identified and conceptually designed at the scale of individual contaminated groundwater sites.

Consequently, evaluation of the ability to achieve site-wide load capture efficiencies listed in Table 5 requires evaluation of the completeness of the identification of all contaminated groundwater migration pathways that may contribute loading to surface waters now and in the future. This includes contaminated groundwater migration pathways in overburden and bedrock beyond the influence of the collection systems currently proposed at the individual sites.

6.2.4 Groundwater and Seepage Loading Pathways at Faro Mine Site

The pre-mining surface topography of the natural slopes above Rose Creek Valley is likely the dominant factor in determining the locations of focused seepage initially emerging from the Faro WRDs. The location of the higher priority seepage sites around the Faro WRDs (i.e., Emergency Tailings Area, S-Cluster Area and Zone No. 2 Pit Outwash Area) is consistent with this interpretation. However, as the Faro WRDs are likely still accumulating water, it is probable future areas of contaminated seepage may not coincide solely with current ones.

Information on the spatial distribution and quantities of sulphides in the Faro WRDs is surprisingly detailed, given these historic stockpiles date from the 1970's. The larger piles all have large quantities of sulphides (10-20% by weight). Some of the smaller piles are devoid of sulphides, others contain sulphide cells where calcium silicate rocks were draped over sulphide-rich waste rock, and many contain dispersed sulphides placed by random dumping.

There are also low-grade ore stockpiles never processed remaining on site. It is reasonable to expect a number of the segmented piles within the larger Faro WRDs have the potential to eventually release some zinc load to the environment throughout most of their footprint area.

At the Faro Mine site, groundwater collection systems have been proposed at four areas of identified groundwater contamination: Zone No. 2 Pit Outwash Area, S-Cluster Area, Emergency Tailings Area (ETA), and Rose Creek Tailings Facility. The Zone No. 2 Pit Outwash Area and the S-Cluster Area are the two identified contaminated groundwater areas that drain to the X2 surface water monitoring point upstream of where the North Fork joins the South Fork of Rose Creek. Groundwater collection systems for these two areas represent about 10% or less of the perimeter length of the groundwater discharge area from the waste rock piles to the area above the North Fork.

It is not possible with current information to reliably identify all potentially important current and future groundwater loading pathways at the Faro Mine site. The most relevant review document for current conditions for this issue is the July 14, 2004 Memorandum by Christoph Wels. The 1996 ICAP report also reviews this subject. The Wels memo reviews the available water quality results for historical monitoring wells and identifies and prioritizes areas for further investigation and assessment. As such the identification of current potential groundwater contaminant migration pathways is limited to sources and pathways (mostly overburden and toe seeps) defined by existing monitoring wells. Sulphate increases in groundwater monitoring wells outside of these collection areas (e.g., wells BH14A, P96-6 and P96-7) over the last few years indicate that loading via groundwater pathways beyond proposed collection areas may be a concern at Faro Mine site.

The bedrock migration pathway is not well characterized and monitored at the Faro Mine site. There is unevenness in the limited characterization of the bedrock pathway and the manner in which this pathway is dealt with in the proposed groundwater collection systems at the four priority collection areas.

Where this pathway has been considered, the depth of concern appears to be limited to a few meters to address mostly the weathered bedrock horizon. Based on the hydrogeologic setting and available hydraulic and water quality data for the bedrock (which in places show a range of moderate bedrock hydraulic conductivity (K) values to depth and shallow impacted water quality), migration through the deeper (> few m) fractured bedrock is a pathway of concern.

For some of the investigation areas (Rose Creek Tailings Facility, Zone No. 2 Pit Outwash Area, S-Cluster Area), bedrock has not been characterized and is implicitly assumed to be of low K at about 10^{-7} m/s, much lower than values measured in some packer tests on site (10^{-6} to 10^{-4} m/s), suggesting that migration in this pathway may be locally underestimated. The very limited bedrock characterization at and outside of the four priority groundwater collection areas does not allow one to discount the current or future groundwater loading to surface water through these pathways at the Faro Mine site.

It is probable the bedrock below the large and elevated Faro WRDs will receive recharge from precipitation with some of this water moving into the deeper bedrock and migrating within the bedrock beneath the proposed groundwater capture systems to surface water receptors. Insufficient information exists about the bedrock flow system to eliminate it as a contaminant migration pathway at this time. Available borehole data have indicated generally low bedrock permeability, with higher values occurring locally. During open pit operations, reports indicated there was limited groundwater entering the pit from the deeper bedrock. Although groundwater flow rates through bedrock will be much lower than through more permeable overburden, if migration is more widespread in the underlying bedrock than assumed, then this bedrock loading may be important at the mine site scale. This observation is particularly important as only a minor release of zinc load escaping capture will result in a measurable increase in metal concentrations within Rose Creek.

6.2.5 Groundwater Collection System - S-Cluster Area

The proposed groundwater interception/recovery system for the S-Cluster Area is a permeable trench and a cut-off wall excavated into the weathered bedrock, which is assumed to be about 1.5 m thick. While it is acknowledged the actual thickness of the weathered bedrock will be determined from supplementary investigations, there is potential for underflow and by-pass of the collection system as currently described, principally via deeper bedrock groundwater flows

There are also groundwater recovery concerns at this site related to operational challenges imposed by the constraints on available groundwater drawdown caused by the limited saturated thickness of the surficial deposits. If soil covers are placed on the upgradient WRDs which then reduce the net infiltration and cause a water table decline at the perimeter of the pile, difficulties in attaining a high capture efficiency using pumping wells could be compounded.

It is anticipated that these concerns would be addressed in subsequent engineering design studies that would be based on deeper bedrock investigations and in application of adaptive management plans for optimizing groundwater load capture at this area.

6.2.6 Groundwater Collection System - Zone 2 Pit Outwash Area

The proposed groundwater interception/recovery system for the Zone 2 Pit Outwash Area is a permeable trench with recovery wells penetrating into bedrock, although the depth of bedrock recovery wells is not defined. This appears to be an appropriate system for this site given the observation that bedrock hydraulic conductivity is moderate (2×10^{-6} m/s) to depths of at least 46 m based on packer testing in BH10 and pumping test responses in interval BH-10A/B.

It is unfortunate that there are no recent groundwater quality data available for the bedrock at this site. Without information on bedrock groundwater quality and the proposed depths of the bedrock recovery wells, one cannot discount the potential for underflow in the bedrock at the Zone 2 Pit Outwash Area. However, as for the S-Cluster Area, it is anticipated that these concerns would be addressed in subsequent engineering design studies that would be based on additional bedrock investigations and in application of adaptive management plans for optimizing groundwater load capture at this area.

6.2.7 Groundwater Collection System - Emergency Tailings Area

The proposed groundwater interception/recovery system for the Emergency Tailings Area (ETA) is a slurry cut-off wall with up-gradient pumping wells screened in the overburden and bedrock, including sections of permeable trench. Groundwater monitoring would be multi-level and include overburden, shallow and intermediate depth bedrock. The proposed primary interception/recovery system and monitoring program appears to be comprehensive considering that the ETA tailings are to be removed, the bedrock appears tight and clean, and that any system by-pass will be directed to the Rose Creek Tailings Facility.

Similar to the S-Cluster Area, there are groundwater recovery operational challenges at this site due to constraints on available drawdown. Again, it is anticipated that groundwater load capture concerns would be addressed in subsequent engineering design studies that would be based on additional multi-level bedrock investigations and in application of adaptive management plans for optimizing groundwater load capture at this area.

6.2.8 Groundwater Collection System - Rose Creek Tailings Facility

The investigation and assessment of overburden groundwater interception systems for the Rose Creek Tailings Facility appears to be comprehensive and complete.

The hydrogeologic interpretation and quantitative assessment of groundwater interception/recovery system is the most thorough of all the four areas investigated and reported to date at Faro Mine site. The decision to emphasize the Rose Creek tailings site is appropriate given the importance of groundwater interception/recovery at this most downstream location at the Faro Mine site. The groundwater interception/recovery system is a series of high capacity pumping wells installed in the permeable sand and gravel deposits with target well drawdowns of 4 to 5 m. Recent modifications to this system prompted by the Panel and evaluated by SRK have included recovery trenches, drains and cut-off walls.

The Rose Creek valley site has both favourable and unfavourable characteristics for operation of a groundwater recovery/collection system. Because groundwater discharge is naturally focused into a small area with a well-defined permeable sand and gravel aquifer system below the Cross Valley Dam, high groundwater capture efficiencies are theoretically easier to achieve at this single, well-characterized site. However, because of the permeable setting, large quantities of groundwater are moving through the sediments in the Rose Creek valley and these high natural flows mean that failure of the pumping system would rapidly result in discharge of contaminated groundwater to surface and Rose Creek downstream of the Cross Valley Dam.

Furthermore, the nature of the glacial fluvial deposits in the valley, with heterogeneous and anisotropic hydraulic properties due to silt and clay layers and lenses, requires the use of fully-penetrating pumping or relief wells to ensure collection of groundwater at depth. Passive recovery trenches are unlikely to achieve the required high groundwater capture efficiencies at this location, particularly at depth.

There is very limited characterization of the bedrock underlying the Cross-Valley dam site considering the hydrogeologic setting and strategic importance of groundwater collection at this location. Shallow bedrock hydraulic conductivity values are cited from 1980 and 1981 investigations of the intermediate and cross valley dams (K range of 4×10^{-8} to 4×10^{-6} m/s). Without more recent information on bedrock hydraulic properties, hydraulic heads and groundwater quality, one cannot discount underflow and migration within the underlying bedrock.

For high capture efficiencies at the Rose Creek Tailings Facility, it will be necessary to better define the bedrock pathway (both beside and below the Cross Valley Dam or Intermediate Dam depending on where the groundwater recovery systems will be established), and to evaluate options for interception of these flows. This will require additional monitoring wells in the bedrock with completion zones below the shallow weathered bedrock zone.

Given the physiographic setting of the tailings facility within the Rose Creek Valley, there is potential for the presence of bedrock structural features and hence deeper bedrock migration pathways that should be investigated and monitored. The Panel anticipates that groundwater load capture concerns downstream of the Rose Creek Tailings would be addressed in subsequent engineering design studies that would be based on additional multi-level bedrock investigations and in application of adaptive management plans for optimizing groundwater load capture at this area.

6.2.9 Summary Comments on Groundwater Capture Efficiencies at Faro Mine Site

Design to a particular value of capture efficiency is inherently uncertain. This uncertainty can be managed in two ways: (1) over pumping relative to the “best-estimate” design, or (2) implementation of an adaptive management plan (AMP) that permits sequential improvements in the capture efficiency. Because of limitations at the Faro Mine site on the available drawdown at several of the high priority areas, the proposed adaptive management plan is the more viable approach and is endorsed by the Panel for use at this site.

However, for AMP methods to be successful there must be monitoring of all potentially important groundwater by-pass pathways at identified high priority capture areas. The Panel believes that such investigation and monitoring of important groundwater migration pathways can be achieved through rigorous application of AMP at the identified Faro Mine high priority areas.

The qualitative description of designs for groundwater and load capture systems at the three high priority areas adjacent to the Faro WRDs, suggests that it will be possible to attain quite high capture efficiencies approaching 90%, with little difficulty based on current hydrogeological understanding. To move to higher capture efficiencies will require additional site characterization and modeling at each of the priority areas before such capture efficiencies could be considered a reasonable expectation. The Panel believes that with sufficient site characterization effort, good engineering design, reliable backup systems and rigorous application of AMP, it should be possible to achieve the capture efficiencies of 95 to 99% for these three priority areas.

Capture of 95 to 98% of the Faro WRDs contaminant load from reaching the North Fork Rose Creek as listed in Table 4.5.3 may be very difficult to achieve if diffuse sources of contamination exist within the Faro WRDs and seepage occurs outside of the two priority groundwater collection areas of S-Cluster and Zone 2 Pit Outwash. It is the Panel's understanding SRK and their consultants expect that it will be necessary to line the North Fork of Rose Creek during the period of active site remediation. Since lining of NFRC will likely be necessary, a groundwater load collection alternative proposed by the Panel is to consider areas down-gradient of the Faro WRDs and the Rose Creek Tailings Facility (RCTF) as a single contaminant load collection zone and to emphasize contaminant load collection efforts for this zone to areas down-gradient of the RCTF. Section 8.3 provides additional description of this alternate groundwater capture option.

Although successful operation of groundwater capture systems at the three priority areas of ETA, S-Cluster and Zone 2 Pit Outwash, may not preclude metal loading to North Fork Rose Creek and Rose Creek, there is merit in operating groundwater capture systems in these areas for reasons of ease of collection, overall load reduction and prevention of new areas of surface water contamination.

The prospects of achieving very high groundwater load capture efficiencies (e.g., 95 to 99%) are judged by the Panel to be greatest downstream of the Rose Creek Tailings Facility, where groundwater discharge is naturally focused into a small area that is reasonably well defined and hydrogeologically characterized. This is a fortuitous circumstance as groundwater load collection in this area is critically important because it provides final backup collection for Faro WRD seepage that may bypass proposed WRD groundwater collection systems.

Any groundwater collection system proposed for the Rose Creek Tailings Facility will need to operate at efficiencies approximating 98 to 99%. Such high capture efficiency requires that the groundwater collection and recovery system functions as designed for 98 to 99% of the time.

Breakdown of the proposed groundwater recovery system for a week would result in groundwater discharge to surface and direct loading to Rose Creek within a day or two. Over the long term, these performance targets may only be achievable with extensive back-up systems to address the expected mechanical upsets and failures of submersible pumps and piping, electrical system failures and well efficiency deterioration due to chemical precipitation and bio-fouling of well screens and aquifers adjacent to the well screens.

Provided such backup systems are established, capture efficiencies approximating 98 to 99% should be achievable for the Rose Creek Tailings with additional bedrock characterization and rigorous application of AMP. To provide improved certainty of achieving 98 to 99% groundwater load capture efficiency at the Rose Creek Tailings Facility, the Panel has proposed the alternate groundwater capture option that relies on surface pumping from a permeable recovery trench or drain with fully penetrating relief wells near the Cross Valley or Intermediate Dams and a down-gradient cut-off wall installed into bedrock as necessary.

This alternate capture option would include an emergency storage pond to address inevitable pumping system malfunctions and breakdowns and up-gradient cut-off walls to minimize clean groundwater from entering the Rose Creek Aquifer. Section 8.3 provides additional description of this alternate groundwater capture option.

6.2.10 Grum/Vangorda Mine Site

A similar approach for defining necessary groundwater load recoveries was followed at the Grum and Vangorda WRD sites based on protection of water quality in Vangorda Creek at sampling locations V27 and V8. However, detailed quantitative or qualitative analysis of groundwater capture systems at individual high priority areas have not been undertaken at the Grum/Vangorda Mine site to date, as significant zones of contaminated seepage have not yet been identified. Only conceptual groundwater load capture systems have been described for the Grum and Vangorda WRDs.

Data on groundwater conditions down-gradient of the Grum and Vangorda WRDs are sparse due to the very limited drilling and monitoring well investigations. Information on the nature and extent of contaminated seepage are derived principally from shallow test pits and surface seep surveys. These limited data suggest that groundwater quality has not been appreciably degraded to date, although there is evidence to indicate some impact (e.g., sulphate concentrations). The absence of significant groundwater contamination is likely largely reflective of the fact that the overburden deposits beneath the waste rock piles are generally finer grained and less permeable at Grum/Vangorda than at the Faro Mine site.

Mixing cell model calculations for Future 2 chemistry with low infiltration covers (5% of MAP) for sulphide cells, and rudimentary covers (20% of MAP) for the remainder of the Grum and Vangorda waste rock piles indicate contaminant load collection efficiencies of about 90% are necessary for protection of water quality at V8 in Vangorda Creek to 0.24 mg/L zinc.

The presence of thick layers of low permeability glacial till below and around the Vangorda WRD suggests that the proposed seepage collection system of an upgraded perimeter drain, with groundwater pumping wells could achieve the necessary contaminant load collection efficiencies of about 90%. However, as Vangorda WRD is recognized as having a high future ARD risk and the WRD is still accumulating water, supplementary investigation and monitoring of the deeper bedrock and overburden as part of an AMP process, is considered necessary to provide confidence in the proposed groundwater load capture system. Limited drilling of the soils surrounding the Grum WRD indicates a complex layering of fine-grained glacial till and medium-grained glacial fluvial sands are present, which may provide both confined and unconfined groundwater pathways for contaminated seepage migration from the Grum WRD.

Based on these conditions, the proposed groundwater contaminant load collection system for the Grum WRD is conceptualized as a linear set of groundwater collection wells and cut-off wall along the southeast perimeter of the WRD. The cut-off wall which is conceptualized as being up-gradient of the groundwater collection system would be more effective if placed down-gradient of the collection wells.

Because of the potential for future migration of contaminated seepage in the permeable soils as the Grum WRD continues to accumulate water, additional hydrogeologic investigations of the soil and underlying bedrock will be necessary as part of the application of AMP for design and optimization of groundwater load capture systems at this site.

Assuming these AMP activities are followed, the proposed Grum WRD perimeter groundwater collection systems should be able to achieve the necessary load collection efficiencies of 90% if the bulk of the contaminated seepage from beneath the Grum WRD is focused in a limited number of areas. Consequences of upsets in groundwater collection system performance at the Grum and Vangorda WRD sites are likely to be minimal due to the relatively slow groundwater flow rates in overburden at these sites. These low permeable soils allow for more time for the application of AMPs to these contaminated groundwater collection areas.

6.3 Soil Covers for Waste Rock and Tailings

SUMMARY OF KEY CONCLUSIONS

Soil covers are an integral element of the closure plan, the Panel cannot envision a closure plan that does not include a "store and release" soil cover on waste rock and a soil or water cover on any tailings left in place.

For the evaluation of closure alternatives, the three conceptual designs described in the alternatives report (rudimentary, low infiltration, very low infiltration covers) provide an adequate representation of the range in cover performance that can reasonably be anticipated for ARMC.

The Panel rejects the cover alternatives based on minimum construction efforts as they disregard many elements of best engineering practice employed in the international mining industry today.

For the low infiltration covers, establishing a viable community of plant species on the cover is an integral element of the design.

The soil cover test trials that are underway on the Vangorda dump are critical to selection of a final cover design.

Based on the predictions of future seepage chemistry, there may be a substantial benefit to placing soil covers over the sulphide cells within the Faro and Grum waste rock piles in as expedient a manner as practical.

Soil covers are expected to play a key role in the final closure plan for the ARMC; they are included in each of the four example alternatives. For the WRDs, the example alternatives include four different soil cover designs. In two of the three alternatives where tailings are left within Rose Creek Valley, a soil cover is also placed over the tailings. Two of the design alternatives for the Faro mine area include very low infiltration covers placed over the oxide fine and low grade ore stockpiles. In these specific cases, the possibility of incorporating a "plastic cover" (HDPE or bituminous liner) within the soil layer has been included in the design.

In each case, the principal function of the soil cover is to reduce metal loading at the base of the waste rock piles or tailing disposal facility by reducing the downward flux of water. Soil covers also serve the additional functions of isolating the mineralized wastes from the biosphere, keeping any surface runoff from the waste piles and tailings clean, reducing the volume of water that must eventually be treated when captured, and providing protection from erosive processes and wind blown materials.

The soil covers may also limit oxygen transfer into the interior of the piles and slow down the geochemical reactions releasing acidity and metals, although the magnitude of this effect has not been quantified for the ARMC dumps.. Based on predictions of future geochemistry, there could be a substantial benefit to place soil covers over the sulphide containing materials (sulphide cells, oxide fines, low-grade ore) in the Faro and Grum WRDs in as expedient a manner as practical.

The preferred cover designs for the waste rock piles and tailings are based on “store and release” concepts. The competing alternative, where the intent is to create a hydrologic barrier over mineralized wastes, has been largely discarded. The Panel views this approach as sensible given that the covers are required to function for many hundreds of years without recourse to anything more than reasonable ongoing care and maintenance. There would be difficulties in maintaining a hydraulic barrier in the sub-Arctic climatic conditions of the central Yukon Territory. Furthermore, the available soils near the site do not have a sufficient fines fraction to easily yield “barrier-type” values of hydraulic conductivity relative to the expected rates of infiltration into the cover.

Covers described in the example alternatives are based on conceptual designs that provide a basis for linking performance requirements and cost estimates. The Panel views this level of information as sufficient at this stage of the alternative selection. When the final closure plan is formulated, it will be necessary to consider a number of factors not discussed in the Example Alternatives Report, including landscape aesthetics. Soil cover design must be integrated with the site water management plan where, for example, efforts are taken to maximize the diversion of clean water around the covered waste rock piles, uncontaminated surface runoff from the covers is preserved in a clean state, and a plan is in place to clean and repair diversion ditches. At the ARMC, this latter element includes the removal of ice buildup in any diversion ditches prior to spring runoff.

6.3.1 Supply of Cover Materials

The reports indicate the Anvil Range Mining Complex has a sufficient supply of glacial sediments with suitable properties to construct each of the covers in all four alternatives.

This is a fortunate circumstance, as there are numerous mine sites where cover materials are not available in sufficient quantities within a reasonable distance of the mine. The single largest source of cover material is the Grum overburden dump.

The main issue which must be considered is the long haul distance to the Faro Mine area from the Vangorda/Grum Mine areas where the majority of the cover material resides. Therefore, efficiency in cover design is an important factor to consider, as a thinner but effective soil cover could dramatically reduce remediation costs for the ARMC.

A preliminary assessment of the material and hydrologic properties of the glacial sediments has been completed in 2003 (6 samples for laboratory tests, with a limited number of field permeability tests). The tills have a grain size distribution that provides an adequate capacity to retain water for store and release covers.

A concern has been noted, based on cover trials in the early 1990’s at the Vangorda Mine WRD, of potentially large increases in the hydraulic conductivity of the cover materials over time of up to 2 orders of magnitude, relative to values that could be achieved at initial placement. An increase in hydraulic conductivity will lead to a degradation of cover performance.

6.3.2 Infiltration through Uncovered Waste Rock Piles

Estimates of current infiltration into the uncovered stockpiles and waste rock piles are based on the application of a state of the practice hydrologic model (Cold Regions Hydrology Model - CRHM).

This physically-based model is used to estimate infiltration by formulating a water balance for the surface of the Faro, Grum and Vangorda WRDs. The Panel views this effort as an important component of the site characterization program. The reliability of the infiltration estimate is dependent on the quality of the field data used to calculate spatially-distributed estimates of rainfall, snow melt equivalent, infiltration into and evaporation from bare rock surfaces, and surface runoff from rainfall and snow melt. The CRHM model is based on dividing the waste rock piles into hydrological response units defined by surface texture and slope aspect. It includes modules that take account both snow accumulation and infiltration into frozen soils. On the basis of this comprehensive model analysis, the estimated infiltration rate for the 2004 - 2005 water year range from 53 - 57% of the annual precipitation for the three main waste rock disposal areas. It was noted that this water year was significantly warmer and wetter than average, these values may be greater than long-term average infiltration.

There has been neither independent confirmation of the recharge estimates by direct measurement (lysimeters), nor is it possible to evaluate the reliability of the infiltration estimate by comparing the estimated inflow to the top of the piles, with the estimated outflow at the base of the rock piles. It seems that in each of the three main WRDs, water is continuing to accumulate in a significant fraction of the total rock volume. A dynamic equilibrium may not yet have been reached where the outflow volume largely matches the inflow volume, except for changes in water storage that can be attributed to annual variations in total precipitation (see comments on the water balances for the WRDs, below).

The model-based infiltration estimate of approximately 55% of MAP (mean annual precipitation) for the wet year in 2004/2005, with a long term average of 45% of MAP is consistent with the expectation of the peer review panel, given the character of the waste rock surfaces and the climatic regime at ARMC.

Janowicz et al. (2005) estimated that for 2004/2005, on the Faro WRD, infiltration of rainfall exceeded that from spring snowmelt by a factor of almost two. The potential exists for a greater amount of infiltration from snowmelt if meteorological conditions are such that the surfaces of the waste rock piles are relatively dry in the preceding autumn, at the onset of sub-zero temperature conditions and the start of snow accumulation.

6.3.3 Soil Covers in the Example Alternatives

The design thickness of the different cover types is based on the water retention capacity of the tills at the site, and the cover thickness needed to retain a given percentage of the mean annual precipitation. The eventual establishment of a viable community of plant species on the covers is an important element of the design concept. The Example Alternatives Report considers three different soil covers for the waste rock piles:

- Rudimentary covers (50 cm of lightly compacted till) where the intent is to reduce infiltration to 15 - 25% of MAP.
- Low infiltration covers (150 cm of lightly compacted till above 50 cm of compacted till) where the intent is to reduce infiltration to 3 - 8% of MAP.
- Very low infiltration covers (either 150 cm of lightly compacted till above 100 cm of compacted till or 100 cm of till above a geomembrane placed on a compacted subgrade) where the intent is to reduce infiltration to less than 2% of MAP.

The performance of the low infiltration covers is based on the concept that while frost action may eventually reduce the density of the compacted layer, there will be sufficient time for vegetation to be established so the transpiration can supplement the loss of water holding capacity in the cover due to frost heave.

A vegetation plan will need to be developed that considers species selection and compatibility with long-term performance requirements, and considers the management of both natural plant colonization and invasion of undesirable plant species. It is sensible to carry forward in the alternatives assessment two options for the very low infiltration covers; one that incorporates a synthetic barrier, and the other that reduces infiltration using only the site soils.

The infiltration rates assumed for the different cover types are based on simple calculations and professional judgment, in the absence of results from the cover test trials now underway (see below). The Panel considers these three conceptual designs to be an adequate representation of the range in performance that can reasonably be anticipated for different levels of effort in cover construction. Rudimentary covers are less robust than the thicker soil covers, due to their greater sensitivity to material variability, construction deficiencies, erosion, frost action and root penetration. They are, however, a viable option to consider in the evaluation of the example alternatives.

The Panel agrees with the view it will not be sufficient to simply place a layer of coarse rock on top of the tailings impoundment to create a cover that prevents wind blown transport of tailings, and disturbance by animals. This design has the potential to cause an increase in the infiltration of water into the tailings pile relative to the current condition, which is likely quite low where the tailings are fine grained. To control the infiltration rate, it is also necessary to place a soil cover above the coarse rock to serve as a store and release layer that promotes evaporative losses of water.

Uncertainty in the range in performance that can be expected of the covers appears to be a less influential factor in the alternatives assessment that either the projection of the geochemical trajectory of the seepage water quality or the load capture efficiency. For example, the assumed range in performance for the low permeability cover on the sulphide cells in the Faro WRDs (3- 8% of MAP) has little effect on changing the zinc concentration at X14.

The “minimum construction” alternative proposes all waste rock be covered with a rudimentary cover, and no soil cover be placed on tailings remaining in Rose Creek Valley. When judged solely from the perspective of cover design, the Panel views this alternative as unacceptable as it disregards many elements of best engineering practices employed throughout the world. The standard of practice widely adopted by the international mining community today is built on an ethic that, by adopting best management practice, reduces the potential for contamination to a value as low as is reasonably possible. The Panel assumes that closure of the ARMC should be held to this same standard.

A facility that is closed within the framework of best practice is inherently more robust in being able to meet the performance goals in the presence of prediction uncertainties and changing environmental conditions, and can give rise to the condition where each element of the design contributes to a reduction in the geochemical load without placing excessive reliance or pressure on any single component (e.g., groundwater capture).

For example, current practice would suggest at least the placement of a “terrestrial cover” on the tailings disposal facility, although loading calculations indicate that without some reduction in the infiltration through the tailings, this option is not acceptable. A rudimentary cover on the waste rock piles ignores the benefits of greater infiltration control above the sulphide cells that are present within both the Faro and Grum WRDs.

The degree to which the cover designs may reduce air circulation within the WRDs, and limit oxygen re-supply to the interior of the piles, has not been evaluated. Field data suggest that thermally-driven convective air circulation is re-supplying oxygen to the interior of the Faro WRDs, while the Grum WRDs may be a diffusively-controlled system.

There is a brief mention of the concept that if the covers retain sufficient water, they could function as an oxygen barrier. SRK is of the view the piles have already oxidized to the extent there may be no benefit in incorporating oxygen barriers as an element of cover design. The example alternatives take no direct credit for modifying the circulation of air within the piles, which may have some potential for reducing the rate of oxidation of sulphides within the pile, and thus reducing the risk of reaching Future 3 water chemistry.

Soil covers at ARMC will be required to function for many hundreds of years. They are not a walk-away solution; some level of ongoing care will be required to maintain their design function. A proactive maintenance plan must be put in place to detect, prevent, and/or repair deterioration of covers from settlement, weathering, desiccation, freeze-thaw, erosion, root penetration, and/or animal or human activity. Should a cover degrade to the point where there is a significant increase in the rate of infiltration into the waste rock, the potential exists for mobilization of a large reservoir of secondary mineral precipitates that would have accumulated inside the piles during the period of time when the cover was functioning properly. The possibility exists if a cover fails, there may be a period of time during which metal loads at the base of the water rock pile would be greater than that occurring in the absence of a cover placed on top of the pile. Cover performance and maintenance have been considered in the cost estimates and residual risk ranking of the example alternatives

6.3.4 Cover Test Trial Experiments

The FMCPO initiated a test cover trial in 2004 that should provide important insight to the percolation rates through soil covers that are constructed using nearby glacial till and glaciofluvial materials.

The experimental plots do not mimic the layer thicknesses adopted in the example alternatives report, but they are sufficiently similar so that the field data will be of direct value in advancing the final cover designs. The Panel was impressed by the instrument layout and data acquisition system for the soil cover trials.

SRK anticipates it will be possible to compute reliable estimates of the percolation rate into the underlying waste rock from these trials using water balance calculations. SRK holds the view direct measurement of percolation using one or more types of lysimeters emplaced beneath the covers will not provide reliable estimates of the infiltration. There will be a divergence of opinion in the community on this point, with other groups favouring methods of direct measurement in addition to the water balance estimates. The Panel recommends the project consider the possibility of retro-fitting one or more of the cover trials with a lysimeter system to provide a more robust experimental data set.

The cover design for the tailings deposit was updated for the Example Alternatives Report when it was recognized that it will be necessary to achieve a substantial reduction in the metal loading at the base of the tailings in order to meet a site specific water quality objective at X14. The initial design proposed a “terrestrial cover” where the primary intent of the cover was to prevent wind erosion, limit access to the tailings by humans or animals, and inhibit the establishment of vegetation on the cover. Field trials on this earlier design were carried out in 2004 and 2005 to examine the consolidation characteristics of the tailings beneath an emplaced cover, and to investigate construction issues. The cover design in the alternatives report is now based on the goal of reducing infiltration into the underlying tailings, using a store and release till layer atop a capillary barrier created by a layer of clean waste rock.

If the final closure plan includes the option where a soil cover is placed on any tailings left within Rose Creek valley, field trials of cover performance will be needed that are similar in scope to the trials already underway on the Vangorda WRD. To move forward with the example alternatives analysis, the Panel is satisfied that numeric values of infiltration through a low infiltration cover on the tailings that have been adopted are reasonable (a base case of 10% of MAP, with a sensitivity range from 5 to 20% of MAP).

6.3.5 Water Balances for the Waste Rock Dumps

There is evidence to suggest significant portions of the Faro, Grum, and Vangorda WRDs have yet to reach a dynamic equilibrium between the volume of water that infiltrates through the surface of the dumps and the drainage that is estimated to discharge beneath the dumps or as perimeter seeps. Substantially greater volumes of water are estimated to enter the piles than is known to discharge as toe seeps. In this case, the dumps may still be accumulating water, with the implication they are continuing to evolve both hydrologically and geochemically.

It is essential to understand the extent to which this is the case to place current conditions in context and to predict future states. The SRK report and other consultants have considered several possibilities that might explain the accumulation of water inside the WRDs including:

- the volume of water needed to reach residual saturation before drainage can begin;
- freezing of water inside the dumps; and
- the formation of perched water bodies above interior pavement surfaces.

If water is not accumulating within the WRDs, the simplest explanation of the difference between the estimated inflow and observed outflow would be substantially greater releases of water to the deeper bedrock than is currently envisioned by the project. If the pile as a whole is still accumulating water, drainage that currently emerges from the piles would reflect infiltration into thinner sections of the pile, infiltration through the side slopes of the piles, and flow along preferential flow paths that could cross the entire vertical extent of a pile. The current flows would be on an upward trajectory to an eventual dynamic equilibrium.

The possibility also exists that higher metal concentrations are associated with the segments of the WRD that have yet to fully contribute to seepage leaving the waste rock piles. This hypothesis would be difficult to quantify without extensive drilling and sampling within the WRDs.

In summary, the WRD water balance calculations have not yet been closed. It is important to note the predicted metal concentrations at X14 are not influenced by the transfer of water to storage inside the dumps, the relevant loadings for evaluation of the example alternatives are computed using the estimated infiltration to the piles, not the known discharges from the piles. The lack of closure in the water balance probably has its greatest impact when making the assessment of load capture efficiencies for drainage from the WRDs, due to uncertainty created in defining the fluid pathways beneath the rock piles.

6.4 Water Treatment and Sludge Disposal

SUMMARY OF KEY CONCLUSIONS

It is inevitable treatment of seepage, contaminated groundwater, and open pit waters will be required essentially in perpetuity at the ARMC.

The Panel believes the HDS process is most appropriate as the primary treatment technology employed at the ARMC both presently and in the future.

To date the in-situ addition of phosphorus to the open pit lakes in order to stimulate primary biological production and uptake of metals through adsorption has not yielded sufficient improvements in water quality to allow direct discharge to the environment.

The draft Example Alternatives Report does not include an explicit description of how copious quantities of treatment sludges will be managed in the long term. Costs for long term sludge management were prepared in supporting document but were not included as part of the treatment costs in the review of alternatives. There are concerns the continued emphasis upon biological treatment as a primary technology may overshadow the use of the Faro open pit as a long term viable site for sludge disposal and water management.

Due to the need to attain a very high effluent quality there may in future be a need to incorporate additional unit operations and processes to enhance the removal of these constituents, in particular sulphide addition to enhance copper and cadmium removal and filtration.

It is inevitable treatment of seepage, groundwater, and open pit waters will be required indefinitely at the ARMC. The primary constituents of concern will include acidity and metals, principally zinc and iron. Other metals that may be of concern in the future include cadmium, copper, and manganese. Under worst case conditions additional constituents such as sulphate may become of importance.

The traditional approach to treatment for these water types involves neutralization and precipitation with an alkali, usually lime. The modern version of this technology is referred to as the high density sludge (HDS) process which has been in use for more than 30 years. The Panel believes the HDS process is most appropriate as the primary treatment technology employed at the ARMC both presently and in the future.

In recent years, there has been a desire and trend to move away from this traditional form of treatment which relies heavily on manpower and machines to more passive forms. Ideally, a passive treatment system would be preferable as it reduces the need for ongoing care and maintenance which is particularly useful in more remote regions and areas difficult to access during winter weather.

Passive treatment for acidic mine waters most often involves some form of biological process. There is a general misunderstanding of biological processes often considering them fully passive and cheaper to design and operate. There are specific applications in which passive biological treatment in the mining industry has been highly successful. These include the use of algae to uptake and remove metals and nutrients and the use of sulphate reducing bacteria to consume acidity and precipitate metals.

To date the in-situ addition of phosphorus to the open pit lakes at ARMC in order to stimulate primary biological production and uptake of metals through adsorption have not yielded sufficient improvements in water quality to allow direct discharge to the environment. Furthermore, when pit lake water was removed and pumped to the lime precipitation treatment system there was a substantial increase in sludge production and the algal biomass created other mechanical handling problems within the plant resulting in a temporary shut down of the treatment plant.

In the absence of in-situ biological treatment with the open pits, the Panel believes storage of excess contaminated water and/or disposal of water treatment sludge within the Faro Mine open pit remains a viable option. There has been a considerable effort to evaluate treatment plant requirements and costs. The cost for construction and operation of the plants is appropriate however the costs presented in the alternatives report do not include an allowance for long term management of the potentially copious volumes of treatment sludge. Furthermore, explicit management plans for sludge have not been finalized.

The draft SRK Example Alternatives Report does not include an explicit description of the manner in which untreated drainage or off-spec effluent would be stored in the short term, and copious quantities of chemical treatment sludge would be managed in the long term. Preliminary costs for long term sludge management were prepared in a supporting document. The open pits are seen as potentially the preferred option for storage of drainage and disposal of the massive volumes of chemical sludge generated in the long term. There are concerns the continued emphasis upon biological treatment as a primary technology may overshadow the use of the Faro Mine open pit as a long term viable sludge disposal and water management feature. The manner in which sludge is disposed of would likely be unique and not identical for all remediation alternatives.

Large storage facilities for contaminated untreated drainage and potentially off-spec effluent are a crucial part of pro-active, cost effective long-term water management and treatment programs with a goal of continuous compliance. Storage of treated effluent will be needed during upset conditions which are likely to occur periodically due to a variety of operational and mechanical reasons. There will be periods when the treatment facility must be shut down for routine maintenance, emergency repairs, or other situations associated with influent flow variations or extreme contaminant loadings. Excessive flows or mass or loads that exceed design capacity of the treatment plant may result from underestimation of extreme meteorological events or drainage chemistry. The ability to discharge the treated drainage into storage ponds rather than directly to the environment will prevent discharge of off-spec effluent. Storage of untreated drainage and effluent for varying periods may allow for more consistent treatment performance or a controlled paced release of effluent into the receiving environment.

The long term disposal of chemical sludge from the HDS process is a major concern given the potential to produce millions of cubic metres of sludge over the treatment period. Capital and operating costs have been developed for the continued use of freeze densification cells followed by disposal in purpose built storage cells at the site.

This requires new waste management areas to be developed for sludge disposal. The location of these cells and the total area occupied by these cells over the treatment period was not assessed. The estimated costs for sludge disposal at ARMC were estimated to be in the range of 1 to 3% of the total treatment costs for the site. These costs would appear to be quite low and may need to be revisited. The review of sludge management options report (Task Report 14 (f)) does consider storage of the sludge in the pits but discounts this option because of potential for sludge remobilization should the pits become acidic. Given the great depth and capacity of the Faro pit and the fact that the pit already contains sludges and tailings, it is the Panel’s opinion that the pit would be an acceptable long term repository for sludges.

The only costs for use of the pit would be pumping to the pit. This option does not require the operation of the freeze densification cells or the development of new in purpose built sludge storage cells at the site. Some dissolution of the sludge may occur however this should not have a material impact on water treatment plant performance or costs.

There are concerns the continued emphasis upon biological treatment as a primary technology may overshadow the use of the Faro Mine open pit as a long term viable sludge disposal and water management feature.

Finally, there are concerns related to the effectiveness of lime precipitation treatment with respect to removal of not only zinc but also other potential constituents of concern including copper, cadmium, and manganese. From the studies completed, there is no indication additional treatment would be warranted. However, based upon experience at other sites, metals levels may in future be elevated and require additional polishing to minimize downstream water quality impacts. Should this occur, additional unit operations and processes to enhance the removal of these constituents, in particular sulphide addition and filtration could be required.

Sulphide addition would be implemented to enhance copper and cadmium removal with filtration potentially being needed since numerical effluent limitations are promulgated as total and not dissolved metals as this point. The final issue relates to the future need to control non-regulated parameters such as sulphate. Should this ever occur, treatment costs would increase by several fold.

6.5 Land Form and Land Use Issues

SUMMARY OF KEY CONCLUSIONS

When compatible with overall site objectives, the Panel supports creative approaches to reclamation incorporating esthetic features that are appealing visually and conform to the natural ecology and topography of the area. In conjunction with this approach, First Nation values and perspectives of the Land should be respected.

The Panel is aware the current remediation alternatives have not been developed to the extent necessary to start addressing reclamation issues in any detail. Once remediation approaches have been selected, the closure plan will need to consider reclamation issues such as erosion and drainage control, re-contouring, rooting media and the selection of plant species that are compatible with the reclamation objectives.

A detailed engineering assessment is required to evaluate and compare alternatives for cover design with emphasis on water management, reducing erosion and sustaining the vegetative growth needed for evapotranspiration, both of which can represent major difficulties in long term care and maintenance.

The closure plan should include a commitment to conduct the long term monitoring and maintenance required to sustain the performance of constructed remediation measures and the desired ecological land form and uses.

The primary land use and reclamation objectives are to reliably prevent long-term impacts to the aquatic and terrestrial environment and protect human health. Secondary objectives include increasing post-mining site productivity, esthetic considerations and compatibility with neighboring land uses.

The Panel recognizes that the ability to address these secondary objectives may be constrained by the physical and geochemical features of the mine site and the remediation needed to protect ecological and human health. Site productivity and esthetic objectives may also be restricted by hazards such as pit walls in the ARMC post-mining landscape.

The Panel recognizes that the current remediation alternatives have not been developed to the extent necessary to start addressing reclamation issues in any detail. Once remediation approaches have been selected, the closure plan will need to consider reclamation issues such as erosion and drainage control on soil covers, re-contouring to create more natural landforms, rooting media to sustain productive vegetation and the selection of plant species that are compatible with the reclamation objectives. Another important component of the reclamation plan will be the long term care and maintenance needed to sustain the land use and esthetic performance and underlying remediation mitigation measures. The reclamation plan for ARMC will need to include a commitment to conduct the long-term monitoring and maintenance of the various remediation measures and reclamation features on the site, and identify the resources required and provide the necessary access.

The types of reclamation issues and approaches will depend on the site component and the remediation and reclamation objectives. For example, once the infiltration targets for store and release soil covers become refined, detailed engineering assessments will be required to evaluate and compare alternatives for cover design with emphasis on water management, reducing erosion and sustaining the vegetative growth needed for evapotranspiration, all of which can represent major difficulties in long term care and maintenance.

Historically, the physical reclamation of components at a mining operation including such features as waste rock dumps, open pits, heap leach pads, and tailings impoundments involved a minimalist approach with limited re-contouring and no emphasis on esthetics. Many of the negative connotations associated with mining result from their unnatural visual appearance. The Panel supports efforts to incorporate more pleasingly esthetic land forms in the post mining landscape. The more abrupt lines associated with waste rock dumps are the result of physical restrictions, safety concerns and the emphasis on minimizing costs during operations. When feasible during the process of re-contouring the waste rock piles for cover placement, efforts should be undertaken to create esthetic features that are appealing visually and conform to the natural ecology and topography of the area.

The traditional values of First Nations people regarding the ecosystem need to be respected. Even though First Nations are undergoing rapid social and economic change, a profound relationship to the land is maintained and is reflected in the maintenance of many traditional activities and spiritual practices. This connection to the land needs to be captured through a conscious effort to restore the spirit of place even though the physical and biological features may be different than they were pre-mining.

7. THE SRK EXAMPLE REMEDIATION ALTERNATIVES

7.1 Introduction

SUMMARY OF KEY CONCLUSIONS

Conceptual remediation plans to prevent impacts from drainage, direct contact, plant uptake, and soil and wind erosion must demonstrate they can reliably meet discharge limits and achieve receiving environment objectives.

Any closure alternative that does not include a sustainable system for collection and active chemical treatment of contaminated drainage that reliably meets discharge limits should be eliminated from further consideration on the grounds that it does not meet minimum standards of environmental protection and therefore does not constitute industry best practices.

Any closure alternative that does not include adequate covers to prevent significant risks to ecological and human health and soil and wind erosion should be eliminated from further consideration on the grounds that it does not meet minimum standards of environmental protection.

7.1.1 Remediation Objectives

The SRK Example Alternatives Report puts forth twelve example remediation alternatives, four for each area of the ARMC (Rose Creek Tailings Facility (RCTF), Faro Mine site, Vangorda/Grum Mine sites). In preparing these draft example alternatives SRK has assumed there are a number of critical elements common to all of them, which did not need to be addressed in the evaluation of each alternative. The Panel believes it is important to now begin viewing the site remediation in a more integrated format by understanding the fundamental relationships that exists between various facets of the ARMC. One such example is the relationship that exists between the Faro Mine site and the RCTF. Examples of components which in concept apply to the various example alternatives but would differ in their individual implementation include water management and treatment, the locations and maintenance of ditches, storage of seasonal flood flows, and the approaches to sludge disposal. Some alternatives did not adequately address the options available for site wide water management and disposal of sludge in an open pit. Additional examples are the relationship between the source of construction materials for covers located at the Vangorda/Grum Mine and the massive requirement for these materials at the Faro Mine site.

The remediation objectives are to prevent impacts from contaminated seepage, direct contact, plant uptake, and soil and wind erosion. The conceptual remediation plans must demonstrate they can reliably reduce contaminant levels sufficiently to meet discharge limits and achieve receiving environment objectives. This includes demonstrating the required process understanding, technical capability, functioning of major design components, site capacity, resources and intent.

Potential mitigation strategies for individual mine components should also be evaluated in terms of their contribution to the cumulative risk and costs for the entire mining complex. Achieving the required level of understanding is an important part of risk reduction.

Where significant risk or uncertainty is identified, additional mitigation and/or contingency prevention measures will be required. Where it does not compromise the goals of meeting receiving environment objectives and minimizing risk, the remediation plans should return disturbed land and watercourses to productive use.

Diversion of clean drainage is a crucial aspect of remediation at the ARMC in part because it will be the only significant dilution volume for the treated mine drainage and in part because diverting clean water reduces the volume of water to be stored and treated.

7.1.2 Preventing Impacts from ARMC Seepages

The Faro and Vangorda WRDs and the Rose Creek Tailings all contain large masses of partially weathered massive sulphide and other potentially acidic waste rock or tailings capable of producing drainage with over 10,000 mg/L acidity and 1,000 mg/L zinc. The only mitigation strategy capable of reliably preventing significant environmental impacts in this situation is a system that includes perpetual collection and active chemical treatment of contaminated drainage and the diversion of clean water.

Mitigation measures, such as biological treatment and dry covers, may increase the cost effectiveness of the remediation plan, improve site reclamation and reduce some of the risks, but without collection and chemical treatment these mitigation measures are not capable of preventing long term adverse environmental impacts. Flooding some portions of the waste may eventually reduce the need for collection and treatment, but since there has already been significant sulphide oxidation, in the short-term flooding may increase collection and treatment requirements.

Consequently, it is the opinion of the Panel that any remediation alternative that does not include a sustainable system for the collection and active chemical treatment of contaminated drainage that will reliably meet discharge limits could be eliminated from further consideration on the grounds it does not meet minimum standards of environmental protection and therefore does not constitute industry best practices. Active chemical treatment using the high density sludge (HDS) lime process has proven at other mine sites with a similar geochemistry to the ARMC to be a robust and reliable method for quickly treating large volumes of highly acidic drainage with high contaminant concentrations. Diversion of the clean drainage is a crucial part of collection and treatment at the ARMC in part because it will be the only significant dilution volume for the treated mine drainage.

The required capacity of the system for collecting and chemically treating contaminated drainage and diverting clean water will depend on:

- the geochemistry and hydrogeology defining flows and load from the contaminant sources and the surrounding land and water courses, and
- the minimum effectiveness of supplemental mitigation measures, such as soil or water covers.

The selection of supplemental mitigation measures should be based on their reliability and cost effectiveness in reducing overall environmental risks and costs for the site.

There are some mineral wastes on site containing relatively low masses of massive sulphide and other acid generating rock, and/or with significant potential attenuation and dilution, where the concentrations and resulting loads of contaminants is predicted to be low and the collection and active chemical treatment of contaminated drainage and clean water diversion may not be required. These site components include the Grum WRD, outside the zone influenced by the sulphide cell, and the various pits and overburden stockpiles.

Considerations in the review of remediation options for these areas include:

- uncertainty about their composition and future seepage quality and loadings, and
- the contribution to the cumulative risk and liability of the entire mining complex if additional mitigation measures are needed to respond to future changes in the ARD conditions.

For the Grum WRD, there is some uncertainty concerning the effectiveness of operational separation and segregation of the massive sulphide rock from other non-acid generating material during the period of Grum Mine deposit mining. This is expected to have resulted in some contamination of designated non-acid generating zones. Dr. Robertson, a Panel member, during routine visits to the mine site in years prior to cessation of mining, observed substantial contamination of the ‘clean’ zones of this waste rock disposal site by the presence of high sulphide materials. One consideration in the use of biological treatment for contaminated drainage in the pits is that it precludes use of the pit(s) as components of the collection and treatment system for the highly acidic drainage, potentially increasing the risks and costs for other site components.

7.1.3 Preventing Terrestrial Impacts

The only mitigation strategy that will reliably prevent significant contact, plant uptake and soil and wind erosion from the large mass and area of sulphidic mineral wastes (tailings, waste rock, mine workings and other areas of disturbance) are soil covers. The required extent, design and maintenance of these covers will depend on the ecological and human health assessment and the potential for soil and wind erosion.

The Panel is of the view any closure alternative that does not include adequate covers to prevent significant risks to ecological and human health and soil and wind erosion should be eliminated from further consideration on the grounds that it does not meet minimum standards of environmental protection.

7.2 Faro Mine Remediation Alternatives

SUMMARY OF KEY CONCLUSIONS

Alternative 1 involving a flow through option for the Faro Mine open pit has been previously eliminated on the grounds biological treatment alone is insufficient to meet the water quality objectives.

Alternative 3 does not meet the engineering standards considered standard professional practice and is below the minimum guidelines presently considered acceptable in the mining industry worldwide.

A more detailed assessment of the ecological risks and cost benefits is recommended for a range of intermediate cover designs between Alternative 2, which includes low infiltration covers and Alternative 4 with potentially limited relocation and very low infiltration covers on sulphide ores.

The Faro Mine area is characterized by several distinct features including hundreds of million of tonnes of waste rock, massive sulphide cells, low grade ore and oxide fines, and an Emergency Tailings Area (ETA) along with an open pit which is filling. Four example alternatives have been presented in the SRK report for this area: the flow-through pit, the upgrade of the Faro Creek, the minimization of construction, and the minimization of water treatment alternatives.

As seen on Figure 1, on one hand the lower sulphide waste rock piles account for 331 hectares or nearly half of the total disturbed surface of the area but only a small portion of the total mass load of zinc unless the Future 3 geochemical scenario is attained. On the other hand, the sulphide cells, oxides fines, and low grade ore (LGO) stockpile account for only about 5% of the total disturbed area but the majority of the mass load of zinc in the Future 1 and 2 Scenarios. On Figure 2 the projected mass load contributions for zinc from various sources at the Faro Mine site are presented in relation to the three future scenarios.

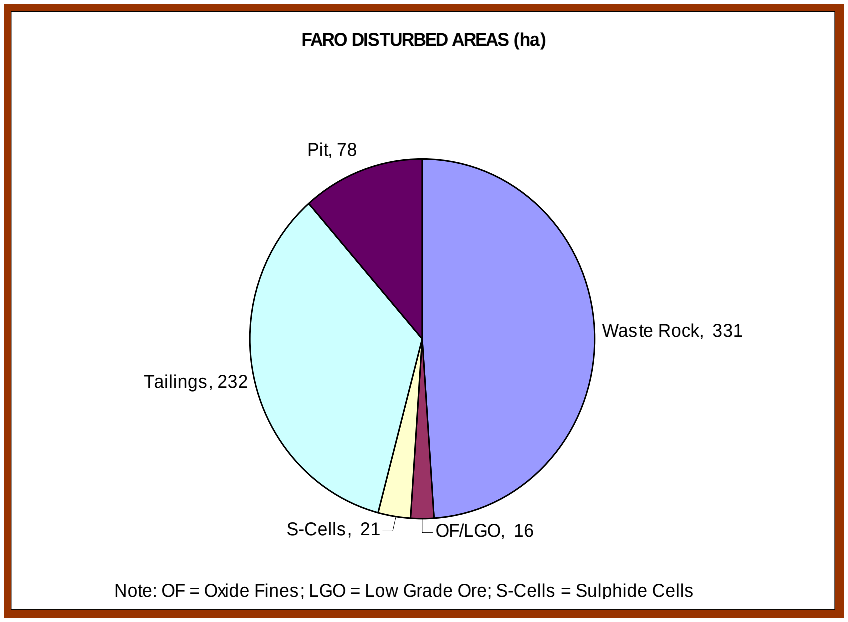

Figure 1 Disturbed Areas Associated with the Faro Mine Site

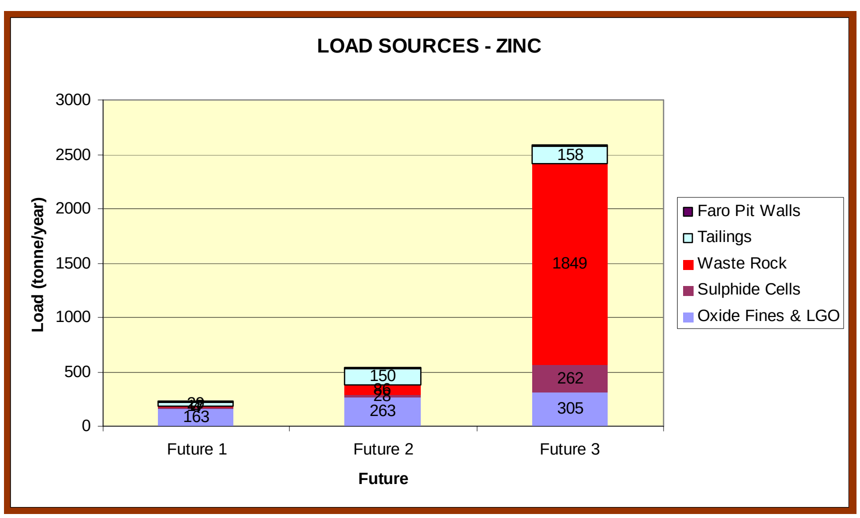

Figure 2 Contribution to the Estimated Mass Load of Zinc over Time

Several observations can be drawn from these figures. First, there is a dramatic rise in the mass load of zinc exiting the Faro Mine WRDs if the Future 3 geochemical scenario becomes a reality.

Second, due to the disproportionate share of mass load contributed by the mineral wastes placed in the sulphide cells, designing and installing soil or soil-geomembrane composite covers over the cells in an expedient manner seems reasonable and warranted. Soil covers on the remainder of the Faro WRDs could be scheduled at a later date in the remedial operation. Third, the Faro Mine open pit would contribute only a minor portion of the total mass load of zinc, suggesting a more beneficial use such as sludge disposal or water storage should take precedence over the use of biological treatment.

Although the flow-through pit nomenclature has been retained, this alternative has since been modified to allow the pit to fill, with the excess water being pumped to a conventional lime precipitation treatment plant. This alternative may or may not include in the future the initial removal of a portion of the mass load through in situ biological treatment in the pit lake. Biological treatment in this case involves nutrient addition in the form of phosphate to stimulate the growth of an algal biomass onto which metals are adsorbed. As noted previously, to date the field trials of biological treatment have not proven fully successful.

It was prudent to investigate the potential of using some form of biological treatment; nonetheless, the results of the field trials indicate it is unlikely to produce a water quality within the pit lake suitable for direct discharge into the environment. Regardless of the success of biological treatment, conventional HDS lime treatment will nonetheless be required in perpetuity at this site.

There are a number of fundamental observations that can be drawn regarding the remediation of the Faro Mine area. First, biological treatment alone will not produce an effluent quality sufficient for direct discharge without supplemental treatment relying upon lime precipitation. Second, covers that minimize the infiltration of incident precipitation will greatly reduce contaminant mass loadings because the surface topography and the presence of the pit will likely limit groundwater inputs to the ARMC dumps. Upslope interception ditches will be required in locations where upslope seepage may result in significant groundwater inputs. Third, while covers will slow air entry and therefore the rate of sulphide oxidation and the deterioration in geochemical conditions, the reduction in oxidation and impact on drainage chemistry cannot be accurately predicted. Although loadings will be reduced, unless there is a significant dilution and attenuation, some of the seepage chemistry may become as bad as that predicted for uncovered dumps.

Assuming these observations are correct the first remediation alternative which relies on biological treatment only and does not contemplate traditional chemical treatment should be eliminated from further consideration unless a marked improvement in performance is realized in the next two seasons.

Although all of the proposed remediation measures are based on the same goal, the relative risks presented in the appendices to the SRK Example Alternatives Report indicated adoption of a thinner rudimentary waste rock cover is in the high risk category with respect to anticipated rates of infiltration. It is imperative that sulphide oxidation and the deterioration of the seepage chemistry be slowed down and leaching and loadings be reduced as soon as possible regardless of the cover design.

Furthermore, based upon experience with mine closure throughout the world, Example Alternative 3 does not meet the engineering standards now considered to be the minimum in the industry worldwide. Based upon the overwhelming influence of seepage chemistry and required groundwater capture efficiencies needed to minimize impacts to Rose Creek, installation of minimal covers places an unreasonable reliance upon the ability of treatment to accommodate high future flows.

There are good reasons to be proactive in preventing seepage through the sulphide cells in the Faro WRDs. In addition to its large reservoir of zinc, the large amounts of acidity and ferric iron in the seepage draining from the cell will blind the neutralizing minerals and increase the rate of sulphide oxidation, and acidity, and the contaminant load from mineral wastes encountered farther along the flow path. The Panel suggests consideration be given to placing a conventional HDPE geomembrane or bituminous liner beneath the store and release cover above the sulphide cells. A liner slightly larger than the area of the cell would be required. Thought should be given to designing a monitoring system at discrete points along the edge of the synthetic liner, to provide runoff data useful in demonstrating the long-term performance of the store and release soil cover.

Placement of a synthetic liner, as noted in the minimize water treatment alternatives, is an effective and prudent measure to essentially eliminate any infiltration of water through the sulphides cell. It can be expected the synthetic liner would function as a barrier for two centuries or more. There may be advantage in considering a natural material such as bitumen as used in Coletanche liners for even longer periods, though root penetration is a concern. Note the store and release cover is still viewed as the primary element for long term control of the metal load migrating out of the sulphide cells into groundwater. The range of costs associated with cover designs increases sharply between the first three alternatives and fourth alternative.

A more detailed assessment of the ecological risks, ability to conduct proactive maintenance, and cost benefits is recommended for a range of intermediate cover designs between Alternative 2 which includes upgrading the Faro Creek diversion sooner than later and Alternative 4 which includes partial relocation of high sulphide materials and very low infiltration covers. These two remaining example alternatives could be further consolidated through engineering and cost analysis during the next phase of evaluation. Furthermore, a detailed program should be developed to initiate sequential cover installation on the most reactive, smaller volume, high sulphide mineral wastes.

7.3 Rose Creek Tailings Remediation Alternatives

SUMMARY OF KEY CONCLUSIONS

Based on an assessment of the stability of the dams subjected to extreme seismic events, the dams are either currently or can be made stable to standards nationally and internationally accepted for the design and construction of high hazard dams.

The routing of floods over the dam by structures such as the Rose Creek Diversion or a spillway requires long term monitoring and maintenance of these structures. While the Rose Creek Diversion can be upgraded to meet national and international safety standards of performance, a relatively high level of monitoring and an adequate but low level of maintenance is required. In contrast re-routing of Rose Creek over the tailings dam and through a spillway can be done to national and international standards and should be included in the alternatives analysis.

The remediation of the Rose Creek Tailings Facility (RCTF) is driven first and foremost by a decision on whether or not a portion or all of the tailings are relocated to the Faro open pit or stabilized within the RCTF. A related issue is the stability of the Rose Creek stream diversion channel in the event the tailings remain in place.

There is concern among stakeholders and interested parties about the long-term stability of the Faro tailings dams under seismic loadings and failure of the Rose Creek diversion. The stability of these dams has been investigated thoroughly by appropriate investigations of their foundations and structures, as well as an assessment of the potential maximum credible earthquake (MCE). The MCE associated with the nearest active fault forming the Tintina Trench was determined.

Of the dam structures it was determined the Intermediate Dam (ID) and West Second Dam (WSD) were not on liquefiable foundations and were stable. East Second Dam (ESD) and Cross Valley Dam (CVD) were partially on foundations that could liquefy but remediation measures such as foundation densification could be applied to stabilize these dams.

The Rose Creek Diversion (RCD) has been determined to be capable of safely passing flood events up to the 1 in 500 year event. However, it is noted this assumes the RCD channel will be continuously monitored and maintained to preserve its flow capacity which may be impaired by sedimentation, glaciation (ice accumulation) or sidewall collapse. The need for constant but low level maintenance represents a relatively high risk to failure, post closure. While the RCD can be upgraded to safely pass the probable maximum flood (PMF), there remains the need for constant and vigilant maintenance.

The Panel recognizes reliance on constant vigilance and proactive maintenance of the Rose Creek diversion will be a difficult undertaking and represents a substantial long-term risk. The Panel therefore proposes for consideration that, as an alternative to relying on RCD to pass flood flows, these flows be allowed to flow over the tailings and be discharged over an appropriately designed spillway at the ID or CVD (depending on which is retained). A dam spillway would not be subject to the impairment by sedimentation or glaciation or sidewall collapse that applies to RCD. This concept for conducting the flows over the tailings impoundment is considered further in Section 8.

A variant of this option is to maintain the RCD at its 1 in 500 year capacity but upgrade the flow path over the tailings dam so that in the event of a breach at the fuse plug of the RCD (caused by any of the afore mentioned events) then the flow can be safely passed. This has the advantage that Rose Creek can be diverted with only very infrequent occurrences of flow over the tailings. With this variant the high level of risk associated with RCD monitoring and maintenance is avoided.

As is discussed previously in Section 4.3, Risk Rating, the Panel is concerned that the current assessment appears to unfairly penalize in-valley tailings options while underestimating risks related to tailings relocation.

Regarding the tailings relocation alternative, the overall significance of the following risks, though identified in the rating process, appears to be under-estimated:

- The relocation and reclamation process is completed over a period of 20 years in a region of extreme climate. The normal hazards of large earthworks in this climate apply. This item is not explicit in the risk rating but is addressed implicitly;
- Seismicity and static liquefaction during hydraulic relocation poses a hazard to workers and the environment (risk 5H in the risk rating);
- Tailings dust inhalation poses a health hazard to workers disturbing the tailings both with hydraulic and mechanical relocation (risk 8H in the risk rating);
- The tailings effluent during relocation is contaminated with ARD. Spills and seepage to groundwater are a hazard (risk 1 in the risk rating);
- Contaminated water used in hydraulic monitoring will enter groundwater in the Rose Creek alluvial aquifer is expected during this period (risk 17E in the risk rating);

- Rose Creek Diversion has to be maintained for 20 more years with a potential for failure into the tailings area (risk 15C in the risk rating);
- Because of vegetation and valley slope constraints on hydraulic mining a very large percentage of tailings relocation and valley alluvial floor clean-up will have to be done mechanically (risk 23C in the risk rating); and
- On completion, it may be expected the Rose Creek alluvial aquifer would be contaminated (risk 17E in the risk rating).

Although reprocessing offers the hope of offsetting a substantial portion of the relocation costs, the uncertainties related to smelter availability and fluctuating commodity prices are not predictable. Therefore, when considering relocation at any level, the economic benefits associated with reprocessing should not be relied upon. Due to the geochemical makeup of the tailings there are only a few smelters capable of and likely willing to consider processing the poor quality mixed concentrate that can be recovered from tailings.

These smelters are located outside North America most likely in China, where the regulatory and contractual conditions are not equivalent to Western standards. There is a real concern of disruption of the smelter contract during the course of relocation would leave the partially relocated tailings in a situation more unstable geotechnically and at a greater risk of causing environmental impacts.

Another issue relates to base metal prices. While current prices are above the economic breakpoint, current consensus amongst experts indicates zinc prices will decline, potentially sharply over the next few years. This decline could easily render the reprocessing unprofitable, requiring a large infusion of capital to complete relocation of the tailings which cannot be left in this condition long term.

In the overall assessment of alternatives that lies ahead (see our earlier discussion of this in Section 4.3) it will be important to ensure that the full range of attributes – positive and negative – over the full project life cycle are considered with relative implications accurately portrayed.

The Panel believes that stabilizing and covering the tailings in Rose Creek Valley to be an appropriate alternative to consider. The Panel is of the opinion there is no engineering reason for relocation of the tailings. To achieve stabilization with the minimum raising of a dam, consideration could be given to relocating a limited volume of tailings from the Original and potentially the Second tailings impoundment to behind either Cross Valley or Intermediate Dams. The stability of the tailings and dams were compared with engineering standards for stability for equivalent high hazard dams employed both in Canada and internationally. The potential for instability noted in the assessments could be overcome with upgrades employing well proven engineering practices for a cost small in proportion to the anticipated overall cost of remediation. In contrast, partial or complete relocation involves a process requiring one to two decades to complete at very high costs.

Based on the assessments presented to the Panel, the current and/or upgraded engineering designs would meet the national standards for dam safety. In Section 8 of this report, the Panel provides an alternative concept for closure of the RCTF and the upgrade of the Rose Creek diversion channel. The concept is based on placing a water cover over the tailings, and creating a hydraulic cage in the vicinity of the tailings facility using low-permeability barrier walls both upstream and downstream of the site. In this way, the downward hydraulic gradient across the tailings could be minimized.

7.4 Vangorda/Grum Mine Site Remediation Alternatives

SUMMARY OF KEY CONCLUSIONS

It does not appear that biological treatment will perform as hoped and thus it is not viewed as the primary treatment method for the Vangorda and Grum Mine sites.

There is considerable merit in placing a low infiltration cover over the sulphide cell in the Grum WRD. Inclusion of a synthetic liner beneath a store-and-release soil cover would be a prudent and effective measure to eliminate infiltration through the sulphide cell for two centuries or more.

Stabilization of the Vangorda Mine WRD in place is likely to provide an effective control on the generation and containment of contaminated seepage. The principal advantage of relocating the Vangorda Mine waste rock to the Vangorda Mine open pit is the footprint of the impacted area requiring perpetual care would be reduced. The key uncertainty in this option concerns the prediction of the chemistry of the seepage exiting the backfilled waste rock.

The Vangorda Creek diversion should be retained in the closure plan and upgraded in a timely fashion. In the example alternative where the Vangorda Mine open pit is backfilled, the strongest technical option would be to maintain the current diversion of the creek where the channel is cut into stable rock. The Panel recommends this variant to be included in future deliberations.

A summary of the disturbed area and mass load contributions of zinc for the Vangorda and Grum Mine sites are presented in Figures 3 to 6. Under the Future 1 and future 2 scenarios, the Vangorda and Grum Mine sites are estimated to contribute comparable mass loads of zinc as does the Faro Mine site. At the Vangorda Mine site, by far the largest zinc load will originate from the WRD.

The walls of the Vangorda Mine open pit contribute only a small portion of the total mass load of zinc. At the Grum Mine site, the sulphide cell contributes a major proportion of the mass load of zinc, although it represents a relatively small part of the disturbed area. The overburden material which would be used in the construction of covers for the waste rock and other sulphide containing materials are benign and contribute an insignificant portion of mass load of zinc.

At the Vangorda Mine site, the four Example Alternatives can be separated into essentially two options with different overall strategies for remediation:

- The first would involve re-location of the Vangorda WRD to the Vangorda pit. (Alternative 1 - Backfill Vangorda Pit; Alternative 4 - Minimize Water Treatment).
- The second option would stabilize the Vangorda WRD by placement of a soil cover on the pile, with the commitment to ongoing collection of surface seepage, capture of contaminated groundwater, and maintenance of a low infiltration cover (Alternative 2 - Stabilize in Place; Alternative 3 - Minimize Water Treatment).

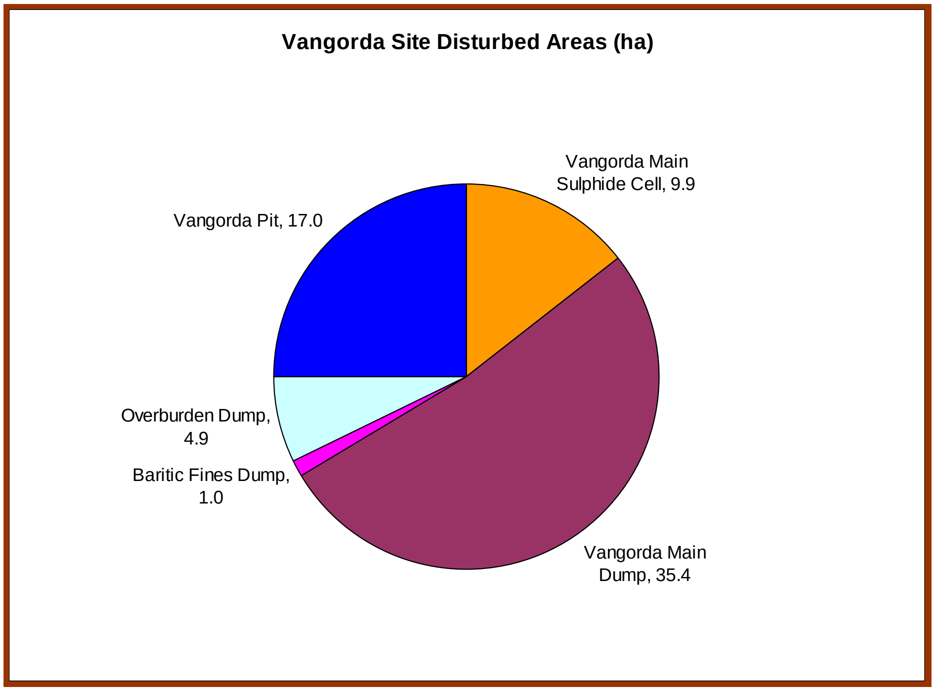

Figure 3 Summary of Vangorda Mine Disturbed Areas

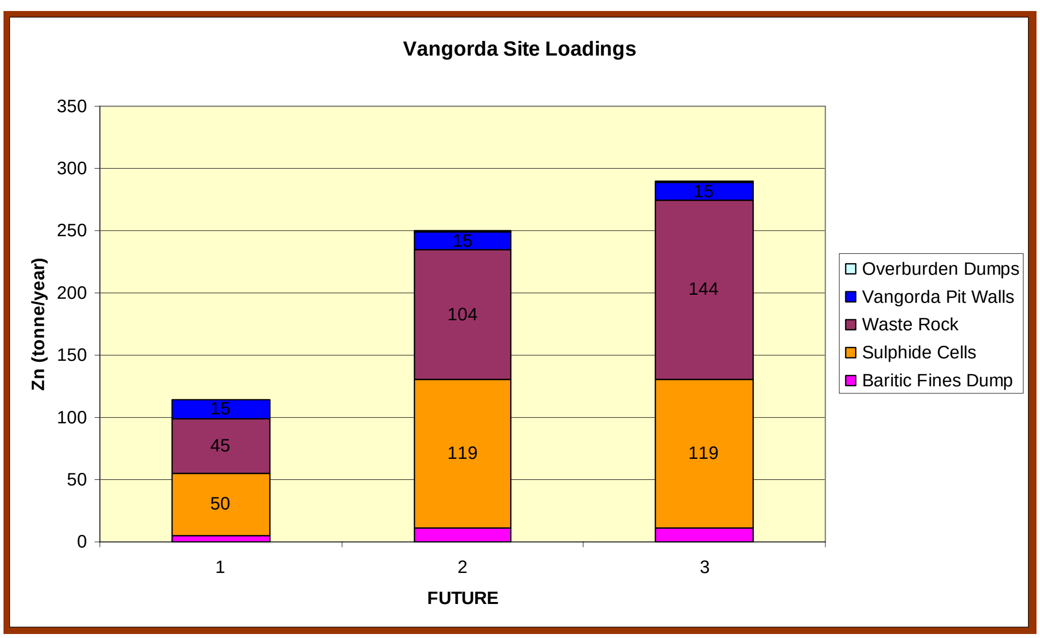

Figure 4 Mass load Contributions for Zinc at the Vangorda Mine Site

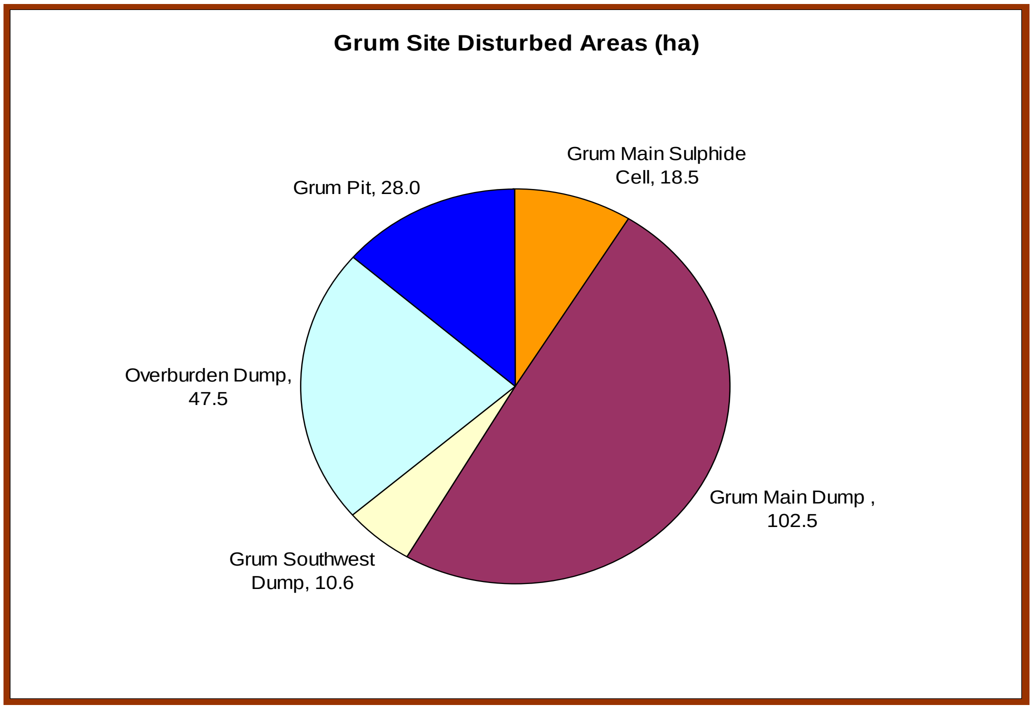

Figure 5 Summary of Disturbed Areas at the Grum Mine Site

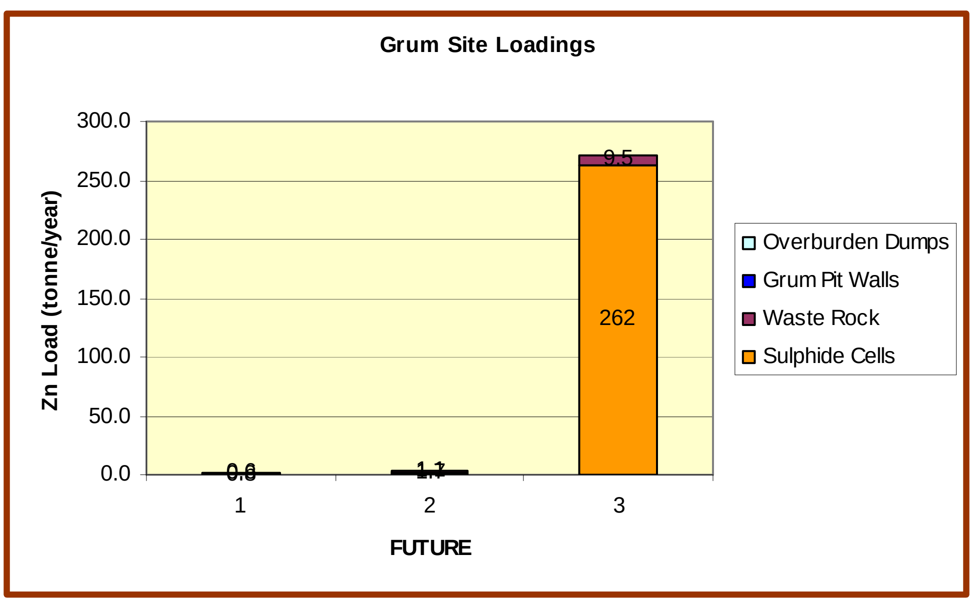

Figure 6 Zinc Mass Load Contributions from the Grum Mine Site

The technical challenges and engineering risks associated with excavating and moving the Vangorda Mine WRD are not comparable to those raised by the Panel in conjunction with relocation of the Rose Creek Tailings Facility. Following transfer of the waste rock pile to the Vangorda Mine open pit, cleanup of the foundation material would be a relatively straightforward engineering activity. Because of the lower permeability soils upon which the Vangorda Mine waste rock was located, it is likely that there would be minimal residual contamination of the foundation materials.

At the Grum Mine site, all four example alternatives emphasize the placement of soil covers on the waste rock piles. In two of the alternatives, however, some of the waste rock left at the ore transfer pad is relocated to either the Vangorda mine open pit if it were to be backfilled, or to the sulphide cell in the Grum Mine WRD. The remaining waste rock would be placed under a store and release soil cover.

It does not appear at present biological treatment will perform as hoped and will not become the primary treatment method for the Vangorda and Grum Mine sites. The difficulties are the same as discussed earlier in connection with biological water treatment in the Faro pit. As a result, it does not appear Example Alternative 1 that relies on biological treatment should be considered further unless a substantial improvement in the ongoing field test is realized.

As argued earlier in this report, the minimum construction alternative for the massive sulphide waste rock at the Vangorda and Grum Mines (Example Alternative 3) should be eliminated from further consideration as it is not expected to meet the objectives for the receiving environment and disregards a number of key elements of remediation best practices adopted today in the mining industry for sites where massive sulphides have been placed in WRDs.

For example, given the sulphide content and reactive characteristics of the Vangorda Mine waste rock, it is inconceivable placement of a simply rudimentary cover would be viewed as an acceptable management strategy that would significantly reduce the ongoing sulphide oxidation, reduce contaminant loadings, and be protective of the environment over the long term.

In each of the three remaining example alternatives (Alternatives 1, 2, and 4), it is proposed the sulphide cell in the Grum WRD be covered by at least a two metre thick low-infiltration cover. The Panel agrees this is a sound plan for reducing the rate of release and the overall contaminant load. There are good reasons to be proactive in preventing seepage through the sulphide cell. In addition to its large reservoir of zinc, the large amounts of acidity and ferric iron in the seepage draining from the cell will blind the neutralizing minerals and increase the rate of sulphide oxidation, and acidity, and the contaminant load from mineral wastes encountered farther along the flow path. The Panel suggests that consideration be given to placing a conventional geomembrane or bituminous liner beneath the store and releases cover above the sulphide cell. The footprint of this cell is a relatively small 18.5 hectares. A liner slightly larger than the area of the cell would be required.

It is recommended thought be given to designing a monitoring system at discrete points along the edge of the synthetic liner, to provide runoff data useful in demonstrating the long-term performance of the store and release soil cover. Placement of a synthetic liner is an effective and prudent measure to essentially eliminate any infiltration of water through the sulphide cell. It can be expected the liner would function as a barrier for two centuries or more. Note that the store and release cover is still viewed as the primary element for long term control of the metal load migrating out of the sulphide cell into groundwater. Additional issues with the Grum waste rock pile should be addressed through adaptive management and contingency plans include the uncertainty regarding the impacts of massive sulphides occurring intermittently in the rest of the waste rock pile and the costs of cover maintenance and repair.

Of the three major WRDs at the ARMC, the Vangorda WRD incorporated the best measures to contain and collect the low quality drainage that emerges from the pile. The perimeter seepage collection system appears well designed. The pile itself sits on top of native soils with low permeability, which creates a barrier at the base of the pile to promote lateral drainage to the perimeter of the pile, rather than infiltration into the bedrock flow system. It is expected to be stable over the long term. Given its setting, size, and geometry, it should be possible to meet a groundwater load capture target of 90%, if required in the future. Thus, the Panel sees merit in the example Alternative 2 that has the Vangorda WRD stabilized in place.

The Panel views the principal advantage of relocating the Vangorda Mine waste rock to the Vangorda Mine open pit is the footprint of the impacted area requiring perpetual management would be reduced. SRK is of the opinion that the primary advantage of backfilling the pit is that it provides a more stable location for the Vangorda Creek channel than the current diversion. A secondary advantage noted by SRK is the walls of the Vangorda Mine open pit expose reactive rock, and backfilling the pit may provide a means of better managing this source of acidity and metals.

The relative merits of closing the Vangorda WRD in place or relocating the pile to the Vangorda Mine open pit is largely dependent on an assessment of the zinc load that would need to be managed from the backfilled pit. The backfilling operation would proceed by first dewatering the pit, with appropriate treatment, and then placement and compaction of the waste rock within the pit. Given the internal composition of the Vangorda WRD, it is not feasible to segregate the massive sulphide and lower sulphide waste in the pile.

During placement, lime would be added to waste rock to neutralize and control the acidity. Some of the waste rock placed back in the pit would be located above the long-term position of the water table, and subject to ongoing oxidation. A cap would be placed on top of the backfilled rock to limit infiltration into that area. SRK is of the opinion the water quality emerging from the backfilled pit may be of sufficient quality so there would be no need to collect this groundwater. As a contingency in the event the zinc load in groundwater must be intercepted, it is proposed that groundwater wells be placed into this zone to create in inward hydraulic gradient, thereby ensuring containment and subsequent treatment.

For the backfill option to move forward, additional testing and evaluation is needed of the acidity, pH, and zinc loads that could emerge from the region of the backfilled pit, and the cost effectiveness of supplemental mitigation measures. A detailed assessment is needed of the likely seepage rates through the compacted backfill that would be placed in the pit. There is considerable uncertainty regarding the future chemistry of the seepage. The Panel is skeptical the zinc concentrations will be low enough to permit free drainage from that zone. It seems more likely the groundwater would need to be collected and treated, even if additional mitigation measures are put in place during backfill such as the placement of a reactive barrier in the zone immediately beneath the water table. If long term treatment is required, then the merits of moving the pile are less clear, when compared to the collection system now in place at the Vangorda WRD sites. Because it is not possible to separate the massive sulphide component, the Panel sees little long term synergy in a partial relocation of the Vangorda waste rock, to a height that would not rise above the elevation of the seasonal low water table in the backfilled pit.

An additional mitigation option for the Vangorda Mine WRDs that has potential merit is to flood all of the Vangorda waste rock by backfilling into both the Vangorda and Grum Mine open pits. This variant has the potential advantage of avoiding placement of reactive waste rock above the long-term water table in a backfilled Vangorda pit. Should there be a case for placing Vangorda waste rock only below the surface of a flooded pit, a possible alternative to amending the waste rock with lime could be placement of a composite cover consisting of an organic layer to create reducing conditions, a mineral soil layer to form a diffusion barrier and an upper layer of unreactive rip rap for the dissipation of energy from waves and focused discharge from the walls of the pit.

The Panel is of the opinion the Vangorda Creek diversion needs to be upgraded in a timely fashion. Even if a closure alternative is selected that includes backfilling Vangorda pit, the Panel does not recommend that channel be relocated over the backfilled pit, along its pre-mining pathway. Because the Panel anticipates there will be differential settlement within the backfilled waste rock, it is concerned that the security of the channel as it crosses the backfilled pit might be compromised. Cracking in the bed of the channel would lead to leakage of water into the underlying waste rock that could be difficult to control without a substantial and long-term maintenance program. This raises the likelihood of additional infiltration into the waste rock and a potentially massive release of the weathering products that would have accumulated in the aerated, acidic waste rock beneath the cover, should the channel leak water into the ground. This concern should be weighed against the expectation that even a perfect Vangorda diversion would not preclude runoff and seepage toward a backfilled Vangorda pit.

However, any relocation of waste rock or tailings throughout the ARMC should be accompanied by an evaluation of the volume needed to sludge disposal and storage of untreated seepage and/or off spec effluent over a period of several hundred years. These are critical design and operational elements that did not receive in the opinion of the Panel the attention they deserved in the development of remediation alternatives.

8. OTHER REMEDIATION ALTERNATIVES AND VARIATIONS

8.1 Introduction

Although the SRK draft report provides a thorough review of the various remediation options, there are nonetheless potential refinements to those presented that may be of interest and should be considered. Two such engineering refinements have been postulated for the Rose Creek Tailings remediation to potentially improve their in place stabilization and integrity of the Rose Creek diversion, while lowering the minimal risk further.

8.2 Water Cover for Rose Creek Tailings

One of the preferred best engineering practices for control of acid generation in tailings or waste rock is sub-aqueous disposal. Burial of reactive material below water effectively impedes oxygen transfer and minimizes sulphide oxidation and acid production. In previous reclamation plans for the Rose Creek Tailings, flooding was presented as a preferred option which was shown to be cost effective when used in combination with partial relocation of the tailings and long term water treatment. Based upon our understanding, flooding was not included because:

- Flooding would not prevent the release of the inventory of acid salts and pore water in the tailings basin. This release of this historic inventory of metals and acidity is a prime driver in the need for long term treatment of the tailings basin drainage.
- There were also likely issues regarding long term dam stability and the higher potential for tailings to be mobilized in the event of a failure. (Recent studies have shown that the Intermediate Dam is stable under the Maximum Credible Earthquake).

Flooding has been applied or proposed as a management option for reactive wastes at sites throughout the world. It is our understanding at sites where this remediation approach has been applied sulphide oxidation can be controlled effectively. This includes tailings which may be in advanced stages of acid production. In these cases, basins were limed after relocation and no further acid release to the pond was observed. In order that acidic salts are not released, the tailings seepage gradients must be controlled and this may be achievable at the Faro Mine site if slurry walls were constructed in the aquifer upstream and downstream of the tailings. A potential flooding option could consider as shown in simplified format on Figures 7 and 8:

- The relocation of a portion of the tailings from the old and secondary tailings to the intermediate tailings basin. These tailings could be relocated in the dry (mechanical) or wet (hydraulic) and all tailings covered with a barrier.
- The Intermediate dam would be raised to flood the tailings.
- Seepage cut-off walls would be installed in the aquifer up gradient and down gradient of the tailings impoundment to isolate the stored acidity and metals in the basin. With minimal seepage, there will be minimal gradient to remove the stored acid inventory from the basin.
- Rose Creek would be diverted in a channel over the tailings
- A new PMF spillway constructed to accommodate the Rose Creek diversion.

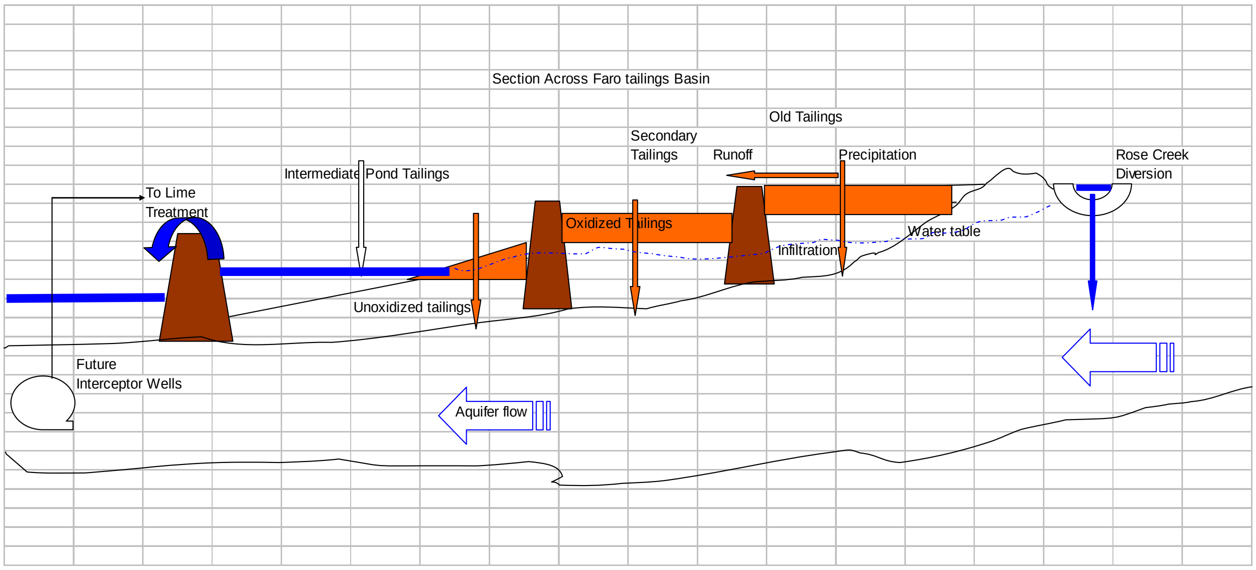

Figure 7 Existing Conditions at the Rose Creek Tailings Facility

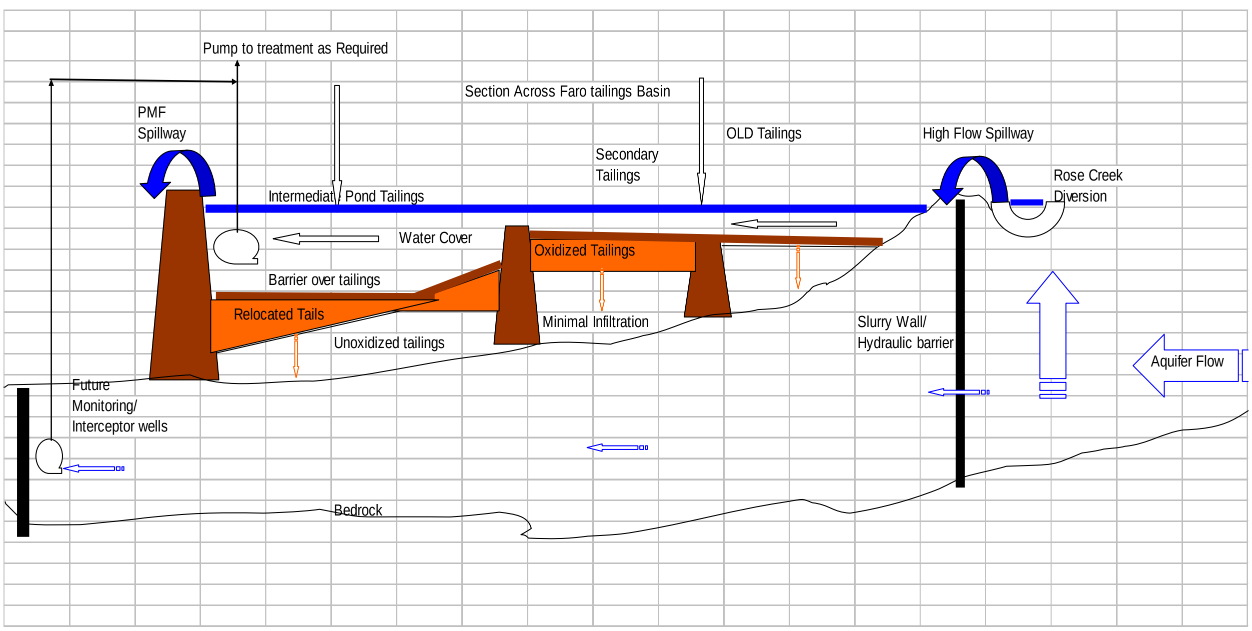

Figure 8 Water Cover Concept for the Rose Creek Tailings

If the tailings are flooded, much of the Rose Creek diversion could be designed for a lesser design storm and higher floods allowed to breach the Rose Creek Diversion at the fuse plug and pass over the flooded tailings area. It would be necessary to prepare the surface of the tailings impoundment to route floods from Rose Creek across the surface of the tailings.

It may be necessary to maintain Rose Creek in its existing state with its existing capacity for as long as required. In the event the existing capacity is exceeded, the Creek would spill to the tailings pond and only the final discharge spillway for the tailings pond would be designed to pass the PMF. Once it can be demonstrated that the flooded tailings pond contains clean water, there will be no requirement to maintaining the Rose Creek channel across the tailings and at that time, the creek would spill directly to the flooded pond. In the event it is decided a dry cover is desirable for the tailings then it would be possible to maintain the current Rose Creek Diversion but provide for short term flooding in the event that Rose Creek breaches the fuse plug. Such an event will occur very seldom as the existing Rose Creek channel is adequate for at least the 1 in 500 year flood event.

The issues related to this option include its cost, performance, and risk need to be evaluated. There are technical challenges including the construction of the deep slurry walls which may be problematic. It was noted in the summary spreadsheet prepared by Bill Slater indicated this option had been investigated to some level and rejected primarily for the reasons noted above.

8.3 Groundwater Capture Approach

8.3.1 Faro Mine Waste Rock Dumps

The Faro Mine WRDs are a source of contaminated drainage. Infiltration into the dumps picks up contaminants and drains vertically to the base of the dump. At the base of the dump this contaminated water continues infiltrating vertically until it reaches the groundwater table in the bedrock and then flows with groundwater in the direction of groundwater migration. Groundwater migration routes are influenced by the natural topography which the groundwater surface tends to mimic. This results in drainage towards the Faro Mine open pit, North Fork of Rose Creek and Rose Creek between the confluence of the North Fork and Intermediate Dam.

The Faro Mine open pit is filling and is nearly full at this time, and the hydraulic gradient and flow towards the North Fork have increased significantly. This will result in increased contaminated seepage towards the North Fork. Some shallow contaminated seepage is detected along the right flank of North Fork.

Some waste rock drainage is currently discharged to the small creek adjacent to the concentrator upstream of the emergency tailings area which drains towards the tailings pond area in Rose Creek upstream of Intermediate Dam. The ARD from the waste dumps as well as the dump drainage conditions are still maturing and it is predicted that there will be substantial increases in the contaminant concentration in dump seep water with time (Future 2 and 3). The seepage paths are also changing with the increase of water level in the Faro Mine open pit and maturing dump drainage and flow pathway conditions.

Both the shallow and deep groundwater flow paths are poorly defined but it is anticipated that contaminated seepage towards North Fork and Rose Creek will increase substantially with time. Interception of this groundwater to a very high degree of efficiency is required to achieve reasonable water quality objectives downstream of Cross Valley Dam (CVD).

8.3.2 Rose Creek Tailings

The tailings contain massive sulphides and are highly acid generating. These are placed in deposits behind dams in Rose Creek valley over alluvial valley fill with a high heterogeneity and a high horizontal to vertical permeability. Longitudinal gravel channels form preferred flow paths in the valley stream flow direction. The upper layer of the tailings is oxidized and acidic and the acidic front is migrating downwards.

The front has not yet progressed into the alluvial channel, but is expected to do so with time. It is anticipated that with time there will be substantial discharge of contaminated drainage from the tailings to the Rose Creek alluvial channel. Interception of this groundwater, to a very high degree of efficiency, is required to achieve reasonable water quality objectives downstream of CVD.

8.3.3 Assumed Global Groundwater Conditions

Based on the available information, it appears that the North Fork, together with its alluvial channel, is a gaining stream from the confluence of the diverted Faro Creek (DFC) to the confluence with Rose Creek (RC), and that Rose Creek also is a gaining stream from the confluence of the North Fork (NF) to below the CVD. It appears in the absence of any groundwater control, all contaminated drainage from the Faro Mine open pit, dumps, mill site and tailings would discharge to the alluvial aquifer or surface streams of Rose Creek between the confluence of the diverted Faro Creek and Intermediate Dam (ID).

8.3.4 Basis for Contaminated Surface and Groundwater Control

To protect Rose Creek water quality it is necessary the groundwater and any surface waters originating from the Faro Mine site and entering the Rock Creek drainage between the DFC and the ID be securely isolated from surface flows, collected and treated before discharge. Source control, such as covers, is not discussed here. It is assumed that source control will be applied in accordance with the options under consideration.

All the proposed closure options under consideration involve the installation of interception well systems upstream of the right bank of NF and interception wells downstream of CVD. These well interception systems are installed in highly heterogeneous flow systems and must intercept groundwater flowing along gradient. The potential for well bypass is high. Also uncontaminated water is drawn towards the wells from the downstream side of the interception system, considerably increasing the pumped water yields that must be treated. Achievement of the required efficiencies of groundwater capture would be extremely difficult.

An alternative approach is to use the alluvial valley infill in NF and RC down to the ID as a very efficient surface and groundwater collection system, and then to recover contaminated water from this aquifer for treatment. For such a system the alluvial channels of NF from DFC to the RC confluence and from there to the CVD would be isolated from upstream and downstream clean surface and groundwater flows.

8.3.5 Measures for Surface and Groundwater Control

A control system of this nature would comprise the following:

1. Maintain DFC diversion

2. Install a diversion on the right bank of NF from the confluence of DFC to RC, into which all surface and alluvial valley fill aquifer groundwater flow would be directed.

   The NF diversion will discharge to the RC diversion. Any clean surface water (after remediation) draining from the covered Faro Mine waste rock piles could be canalized and discharged to the NF diversion.

3. Install a cut-off wall across NF immediately downstream of the DFC confluence to cause all surface and groundwater from upstream to be discharged into the NF diversion (NF cut-off).

4. Install cut-off (likely a plastic concrete wall) through the RC alluvial valley fill immediately upstream of the confluence of the NF valley fill aquifer. This cut-off will divert all upstream RC surface and groundwater flows into the existing RC diversion channel (Upper RC cut-off).

5. Install a cut-off wall downstream of CVD or ID if CVD is removed. This would prevent any groundwater discharge to RC valley alluvium downstream of CVD (Lower RC cut-off).

6. Maintain the valley reach from NF cut-off to the Lower RC cut-off as a contaminated ground and surface water collection zone. Install a contaminated water collection trench immediately downstream of the Upper RC cut-off (on the contaminated water side).

   Pump contaminated water from this trench for treatment. The water level in this trench should be maintained 2 m below (say) the water level upstream of the cut-off. This ensures that there will always be a positive head on the clean water side of the cut-off wall. Thus no contaminated seepage can flow upstream to contaminate RC ground or surface water.

7. Install a contaminated water collection trench on the contaminated water side of the Lower RC cut-off. Pump contaminated water from this trench for treatment. The water level in this trench should be maintained a few metres below the water level on the clean water side of the cut-off. This ensures that there will always be a positive head on the clean water side of the cut-off wall. Thus no contaminated seepage can flow outwards to contaminate RC ground or surface water. If necessary seepage relief well (or pumping wells should the need arise) could be installed through the base of this collection trench to ensure that the lower hydraulic head is maintained on the contaminated water side of the cut-off wall to its full depth. Pumping systems suited for the trench operation must be developed during the detailed design phase of remediation.

8.3.6 Observations Regarding Approach

This system essentially 'keeps clean water clean'. The vast majority of the RC catchment is diverted around the 'containment facility' without potential for becoming contaminated.

The release of contaminated water from the 'containment facility' is limited to treated water (and its residual contaminants) and seepage that bypasses the Lower RC cut-off wall. It is anticipated that with a positive inward head across the cut-off the contaminated water outward seepage escape could be reduced to negligible.

The cut-off walls and diversions reduce the amount of water that can become contaminated hence ultimately reduces the amount of water to be treated. If the water treated is to the same concentration this outcome would minimize the load of contaminants discharged resulting in the lowest possible impact to the downstream receiving environment and water quality.

The system can likely be implemented with a few high capacity surface pumps installed at only a few (3 or 4) locations. With surface pumping the problems of well and well pump maintenance for pumping acidic groundwater with high iron precipitation is avoided. This minimizes pumping and well replacement costs, power and access provision and maintenance costs.

A large pond can be provided for seepage water collection at the cut-off wall collection points. This provides water retention capacity for a substantial period in the event of power failures (enough to allow pump replacement and provision of portable power.

9. SUMMARY

SRK has presented four example alternatives for each of the three main areas disturbed by mining operations; the Faro Mine site, the Rose Creek Tailings Facility, and the Vangorda and Grum Mine sites. These remediation alternatives are presented in Table 6. The Panel believes the range and depth of technical studies conducted to date, along with the range of example alternatives presented by SRK and other technical experts, fulfill the basic information requirements needed to move forward in a process with a reasonable evaluation that allows narrowing the focus for selection of a comprehensive engineering alternative for the ARMC.

While the categorization presented in Table 6 is extremely helpful in presenting and analyzing the range of alternatives that have been considered for each of the three areas, the Panel believes it is now important to begin viewing the remediation in a more holistic and integrated format by acknowledging fundamental relationships exist between various mine sites at ARMC. One such example is the relationship that exists between the Faro Mine site and the Rose Creek Tailing Facility, where contaminated groundwater that may bypass the groundwater collection systems at the perimeter of the Faro Mine WRDs would be within the containment system planned downstream of the tailings. It was this thinking that led the Panel to suggest the groundwater capture approach outlined in Section 8.3 of this report. In a similar light, the Panel also encourages emphasis on the value of implementing remedial measures based on the principle of "keeping clean water clean". Note that in Table 6 the Panel has added the option of placing a wet or water cover noted in light gold on the Rose Creek Tailings Facility, which is discussed in Section 8.2 of this report.

Table 6 Summary of Remediation Alternatives

FARO MINE SITE	ROSE CREEK TAILINGS FACILITY	VANGORDA/GRUM MINE SITE
1. Flow-Through Pit	1. Stabilize in Place	1. Backfill Vangorda Pit
2. Upgrade Faro Creek Diversion	2. Complete Relocation	2. Stabilize in Place
3. Minimize Construction	3. Partial Relocation	3. Minimize Construction
4. Minimize Water Treatment	4. Minimize Construction	4. Minimize Water Treatment
	5. Water Cover	

The future geochemical conditions are expected to be dramatically different from the current ones. The Panel views Future 2 seepage water quality as probable and recommends that it be viewed as the base case for the assessment and selection of remediation alternatives. It is possible Future 3 seepage water quality or worse could occur and sooner than predicted, at least locally on the site, and therefore it should be given consideration in the ongoing assessment of closure alternatives.

Based on predictions of future geochemistry, there could be a substantial benefit to placing soil covers over the sulphide cells within the Faro and Grum Mine WRDs in as expedient a manner as practical. Placement of an HDPE or bituminous liner beneath the store and release cover would be an effective and prudent measure for eliminating infiltration through these higher hazard mineral wastes for two centuries or more.

Based on a review of the current and expected water quality in Rose Creek, the Panel believes conditions equivalent to the generic CCME guidelines may prove difficult to achieve regardless of the individual technologies that may be selected and remediation alternatives selected. However, the control option most likely to achieve such conditions would require the implementation of the ground and surface water control system described in Section 8.3. Since the attainment of generic CCME guidelines may not be possible, derivation and application of site specific water quality objectives may be appropriate for this surface water ecosystem.

The human health and ecological risk assessment that has been completed focused on potential impacts to the aquatic ecosystem, terrestrial environment, and human receptors assuming the seepage from the mineral wastes would deteriorate over time to Future 2. It is important to clarify how the performance of the hypothetical remediation adopted in the risk assessment relates to the example alternatives. It is the understanding of the Panel that the proposed alternatives will achieve better results than the hypothetical remediation used in the risk assessment exercise. However, it does appear likely certain proposed remediation alternatives will not achieve a lower residual ecological risk than the hypothetical scenario. A further comprehensive risk assessment of the residual effects and human health risks is needed when the preferred remediation alternatives have been selected.

The Panel has come to understand that the risk rating that has been completed was undertaken as a means to ensure that all interests understand what might go wrong with the various closure alternatives from a technical and cost perspective. It is intended as a contributor to but not driver of the process of assessing options for their relative merit in achieving closure objectives. As a means of collaboratively identifying what might go wrong, it is a useful exercise.

With respect to the risk ranking, the Panel is concerned on three fronts: (1) the current risk rating appears to unfairly penalize in-valley tailings options while underestimating risks related to tailings relocation; (2) if the rating methodology was to drive the assessment of relative merits of each option there would be some significant methodological concerns; and (3) because the purpose of the current risk rating is not articulated and because the overall process for assessing the relative merits of options against closure objectives is not mapped out, the context of what is currently contained in the SRK report is missing. Both elements of this context need to be explicitly described prior to public discussion of the alternatives.

In now moving forward with a comprehensive assessment of the relative merits of the alternatives: (1) the full range of attributes – positive and negative – need to be considered; (2) the relative implications of all attributes must be accurately portrayed; and (3) some form of multi-interest, collaborative comparison using a “multi-objective” or “multi-criteria” assessment methodology is essential to ensure that all contributing factors are explicitly considered and that the scaling, weighting, and aggregating process are transparent for all to see.

The design time horizon for closure of the ARMC is on the order of 500 to 1000 years. Regardless of which combination of remediation alternatives selected, ARMC will require proactive and sustained care and maintenance throughout this design life, a situation amounting to perpetual care. A long-term scenario analysis is needed to address such issues as the changing nature of society, environmental conditions, and management of the implementation of the closure plan itself. This analysis should be undertaken as part of the overall process of assessing alternatives that will now take place. The Panel outlines in Section 5 a series of long-term management and financial surety issues. These factors should be addressed in the next phase of developing the overall closure management strategy.

Proactive adaptive management is expected to play a key role in the implementation of the remediation plan at ARMC. The Panel strongly endorses this concept. A fully developed Adaptive Management Plan will ultimately be needed that addresses the technical, environmental, and human elements of site closure in this context.

The initial estimates of costs for the various remediation alternatives are presented in Table 7. The Panel has concluded the alternatives developed on the concept of minimizing construction costs do not meet the current international standards and engineering controls employed by responsible mining companies in the implementation of remediation of their operations. As a result, it is the opinion of the Panel these three Example Alternatives noted in light yellow in Table 6 should not be included for future consideration.

The Panel is not convinced biological treatment can be successfully employed as a primary treatment approach for water treatment in the open pits; the alternatives that employ this approach are not favored. This includes Example Alternative 1 at the Faro Mine site where Faro Creek would be routing through the Faro Open Pit. It is the understanding of the Panel that SRK had earlier removed this alternative also noted in light tan in Table 6 from further consideration.

Table 7 Summary of Remediation Costs

Example Alternative	Closure	Post-Closure NPV	Total
Faro Mine Area			
Flow-through Faro Pit	$80,900,000	$38,400,000	$119,300,000
Upgrade Faro Creek Diversion	$79,300,000	$36,800,000	$116,100,000
Minimize Up-Front Construction	$35,000,000	$38,400,000	$73,400,000
Minimize Water Treatment	$214,500,000	$36,900,000	$251,400,000
Rose Creek Tailings Facility			
Stabilize in Place	$130,900,000	$52,800,000	$183,700,000
Complete Relocation	$418,500,000	$24,600,000	$443,100,000
Partial Relocation	$253,500,000	$41,800,000	$295,400,000
Minimize Up-Front Construction	$57,000,000	$56,800,000	$113,800,000
Water Cover	$181,000,000	$13,400,000	$194,400,000
Vangorda/Grum Mine Area			
Vangorda Pit Backfill	$86,400,000	$17,200,000	$103,600,000
Stabilize Current Situation	$34,300,000	$30,700,000	$65,000,000
Minimize Up-Front Construction	$12,900,000	$32,200,000	$45,200,000
Minimize Water Treatment	$103,700,000	$18,600,000	$122,300,000

Exclusion of Example Alternatives 1 and 3 from the remediation options leaves Alternatives 2 and 4 for the Faro Mine site noted in light blue in Tables 6 and 7. Sufficient overlap exists between the engineering components of these two options to likely allow consolidation into a single option as the review and selection of remediation alternatives moves to the next phase of refinement.

The draft SRK Example Alternatives Report does not include an explicit description of the manner in which untreated drainage or off-spec effluent would be stored in the short term, and copious quantities of chemical treatment sludge would be managed in the long term. Preliminary costs for long term sludge management were prepared in a supporting document. The Panel believes the high density sludge (HDS) process is the most appropriate primary treatment process for the ARMC, both presently and in the future.

The open pits are seen as potentially a preferred option for the short term storage of contaminated drainage or the long term disposal of the massive volumes of chemical sludge that will be generated at the site over the long time period water treatment is required. Short term storage of untreated drainage or off-spec effluent, and long term disposal of sludge in the open pits would preclude the possibility of biological treatment in these pits.

There are concerns the continued emphasis upon biological treatment as a primary technology may overshadow the use of the Faro Mine open pit as a long term viable sludge disposal and water management feature. The manner in which sludge is disposed of would likely be unique and not identical for all remediation alternatives.

Large storage facilities for contaminated untreated drainage and potentially off-spec effluent are a crucial part of pro-active, cost effective long-term water management and treatment programs with a goal of continuous compliance. Storage of treated effluent will be needed during upset conditions which are likely to occur periodically due to a variety of operational and mechanical reasons. There will be periods when the treatment facility must be shut down for routine maintenance, emergency repairs, or other situations associated with influent flow variations or extreme contaminant loadings.

Excessive flows or mass or loads that exceed design capacity of the treatment plant may result from underestimation of extreme meteorological events or drainage chemistry. Storage of untreated drainage and effluent for varying periods may allow for more consistent treatment performance or a controlled paced release of effluent into the receiving environment.

Stabilization of the Vangorda Mine WRDs in place is likely to provide an effective control on the generation and containment of contaminated seepage. In contrast, the Panel views the principal advantage of relocating the Vangorda Mine waste rock to the Vangorda Mine open pit is the reduction of the impacted area for which groundwater collection would be required along with perpetual treatment. Furthermore, sulphide oxidation would potentially cease for the mineral wastes that would be placed below the low water line in the backfilled pit. The key uncertainty in this option concerns the prediction of the chemical quality of the seepage water that may drain from the backfilled pit, as some of the mineralized rock will be above the water line in the pit, and therefore will continue to weather, create acidity, and release metals.

Review of Example Alternatives 1, 2 and 4 for the Vangorda and Grum Mine sites noted in light green in Tables 6 and 7 exhibit considerable overlap amongst their component unit operations including the creek diversion, cover design, and water treatment. The major differences lie in whether or not materials are relocated or covered in place. The Panel believes at this point these individual alternatives can be consolidated through a conventional engineering review into a refined subset of remediation options.

All of the example alternatives incorporate groundwater interception systems to capture and treat contaminated groundwater before it discharges to the surface water drainages. Groundwater capture efficiencies approaching 100% are achievable for well-characterized sites, with the use of rigorous adaptive management plans and with sufficient backup plans in place in case of system upsets.

The proposed groundwater capture systems for the Faro Mine priority areas (ETA, S-Cluster, Zone 2 outwash) have the potential for contaminated water to bypass the collection systems through bedrock pathways, or because of difficulties related to limited available drawdown. This possibility will need to be evaluated with further hydrogeological investigation, engineering design, and application of an adaptive management plan. Even if the proposed groundwater capture systems for the three priority areas at the Faro Mine WRDs operate at 100% efficiency, contaminant loading to the North Fork of Rose Creek, and Rose Creek, will not be eliminated due to diffuse sources around the perimeter of the WRDs.

The prospects of achieving high groundwater capture efficiencies are greatest downstream of the Rose Creek Tailings Facility where contaminated groundwater discharge is naturally focused into a relatively simply, well-defined hydrogeologic zone. Additional studies will be required there to better understand the bedrock pathways. This site is the key groundwater collection area at the Faro Mine in that it provides backup capture for loads that may bypass the collection system around the Faro dumps. However, there is sufficient information on the hydrogeologic conditions at the Faro, Rose Creek Tailings Facility, and the Grum and Vangorda sites to proceed with the evaluation of the closure alternatives.

Soil covers play a key role in the example alternatives that stabilize the mineral wastes in place. Soil covers are an integral element of the closure plan, the Panel cannot envision a closure scenario that does not include some type of soil cover on waste rock and any tailings left in place.

The cover designs presented in the SRK Alternatives Report have been carried forward only to conceptual design, which the Panel feels is an acceptable strategy for the purpose of establishing performance requirements and cost estimates in the alternatives assessment. The cover trials at Vangorda, which should provide data required for final design of the covers, are an integral part of the program going forward. The Panel considers the three conceptual designs in the alternatives report to be an adequate representation of the range in performance that can reasonable be anticipated at ARMC. It must be recognized that monitoring of cover performance, and the commitment to a long-term proactive maintenance plan, are fundamental elements to address in evaluating store and release soil covers. The Panel encourages an emphasis on creative reclamation to incorporate esthetic land forms that capture the spirit of the land.

In the case of the Rose Creek Tailings Facility, although partial or complete relocation is a technically achievable option, the Panel views the environmental, economic, and engineering risks associated with this option have been underestimated, while the engineering risks associated with stabilizing the tailings in place have been overstated. These three example alternatives including either stabilization in place with a dry cover or partial or complete relocation for the RCTF noted in light blue in Tables 7 and 8. The multiple engineering assessments indicate stabilizing the tailings in place is not only feasible but also exhibits a low risk and can be accomplished with only moderate additional cost.

The engineering analyses and risk assessments conducted by multiple entities have demonstrated that with minor modifications, tailings and dams would be stable under the maximum credible earthquake and probably maximum flood events. Therefore, there is no engineering reason for relocation of the tailings. Stabilization of the tailings in place in conjunction with the provision for upgrading diversion and spillway structures capably of safely passing high flow events along the Rose Creek diversion is quite possible.

Partial or complete relocation of the tailings involves a process requiring one to two decades. Although using hydraulic monitoring would likely be the preferred method of moving the tailings, there are many residual risks associated with the intermittent nature of the process during the course of the year, the impacts from high precipitation or seismic events, and the probably release of metals into Rose Creek during the cleanup of residual tailings in the stream bed. Although reprocessing offers the hope of offsetting a substantial portion of the relocation costs, the uncertainties related to smelter availability and fluctuating commodity prices are not predictable.

10. BIBLIOGRAPHY

Brodie, John, Faro Mine Closure Office, 2006. Memo to Roger Payne regarding Global Warming - Faro Mine Closure, October.

Chapman, J. and Day, S. of SRK Consulting (Canada) Inc., 2004. Water Quality Estimates for Anvil Range Waste Rock, July.

Chapman, J. of SRK Consulting (Canada) Inc., 2006. Anvil Range Geochemistry, Water and Load Balance, and Attenuation Processes. Power point presentation made in association with the ARMC site visit by personnel from SRK Consulting, the Faro Mine Project Closure Office, and the Independent Peer Review Panel, October.

Dinardo, O. and Price, W. A., CANMET Mining and Mineral Services Laboratory, 2003. Treatment of Pit Lake Waters, A Review of Treatment Process, report to SRK Consulting, December.

Faro Mine Closure Planning Office, 2006. Faro-Vangorda-Grum Mine Problem Description, July 12.

Faro Mine Closure Office, 2006. Site-specific Water Quality Objectives Faro Mine Rose and Vangorda Creeks. Technical Memorandum prepared by Bill Slater to the Oversight Committee Working Group, December.

Faro Mine Closure Office, 2006. Faro Mine Closure Planning Background Paper Receiving Water Quality Guidelines for Zinc. Report prepared by Bill Slater, December.

Gartner Lee Limited, 2006. Anvil Range Mine, 2005 Groundwater Monitoring Report (GLL 40692) prepared for Deloitte & Touche Inc., July.

Gartner Lee Limited, 2006. Anvil Range 2003 Project 18b, Assessment of Tailings Outside the Containment, Draft Report prepared for Deloitte & Touche Inc., December.

Gartner Lee Limited, 2002. 2001 Rose Creek Tailings Facility Hydrogeological and Geochemical Investigation, March.

Janowicz, J., Henderson, N. and Granger, R., 2006. Investigation of Anvil Range Mining Corporation (Faro) Waste Dump Water Balance, Final Water Balance, Report prepared for SRK Consulting Inc., August.

Kai, N., 2003. Adaptive Management in the Canadian Nuclear Waste Program. Nuclear Waste Management Organization Background Paper 1-3.

Laberge Environmental Services, 2005. Biological and Sediment Monitoring Program at Rose and Anvil Creeks, Faro, Yukon.

Laberge Environmental Services, 2005. Selkirk First Nation-Pelly River Aquatic Effects Assessment.

Laberge Environmental Services, 2003. Pelly River Water Quality Surveillance Survey.

Laberge Environmental Services, Access Consulting Group and White Mountain Environmental, 2005. Pelly River Aquatic Effects Assessment-2004. Report to the Selkirk First Nation.

Robertson GeoConsultants Inc., 2006. Design of Groundwater Interception System for Rose Creek Tailings Storage Facility, Draft Report No. 118004/1 prepared for Deloitte & Touche Inc, July.

Robertson GeoConsultants Inc., 2006. Memo to Independent Peer Review Panel regarding Groundwater Management Alternative, December 12.

Robertson GeoConsultants Inc., 2005. Water and Load Balance Study for Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory, with SRK memorandum attached as Appendix B, September.

Robertson GeoConsultants Inc., 2004. Initial Review of Groundwater Quality Downstream of Faro, Grum, and Vangorda WRDs, Yukon Territory, Memorandum from C. Wels to D. Hockley, July 14.

Robertson GeoConsultants Inc., 1996. Anvil Range Mining Complex - Integrated Comprehensive Abandonment Plan, Report No. 033001/3, prepared for Anvil Range Mining Corporation. (Selected parts reviewed).

SENES Consultants Ltd., 2006. Anvil Range Mine Tier 2 Ecological and Human Health Risk Assessment of Remediation Scenarios, April.

SRK Consulting (Canada) Inc., 2006. Anvil Range Pit Lakes - Evaluation of In-Situ Treatment 2004/05, Task 14c, Report prepared for Deloitte & Touche Inc., March.

SRK Consulting (Canada) Inc., 2006. 2005 Seepage Investigation at the S-cluster Area Below the Faro Waster Rock Dump, Draft Report prepared for Deloitte & Touche Inc., March.

SRK Consulting (Canada) Inc., 2006. Sludge Management Requirements for the Anvil Range Site, Task 14f, Report prepared for Deloitte & Touche Inc., March.

SRK Consulting (Canada) Inc., 2006. 2005 Seepage Investigation at the Emergency Tailings Area, Draft Report prepared for Deloitte & Touche Inc., May

SRK Consulting (Canada) Inc., 2006. Task 20e, 2005/06 Seepage Investigation at the Grum Dump Area, Draft Report prepared for Deloitte & Touche Inc., June.

SRK Consulting (Canada) Inc., 2006. Task 20e, Continued Seepage Investigation, Zone 2 Pit Outwash Area, Draft Report prepared for Deloitte & Touche Inc., June.

SRK Consulting (Canada) Inc., 2006. Anvil Range Mining Complex, Rose Creek Tailings Deposit, Assessment of Zinc Attenuation, 2005/06 Task 22h(ii), Report prepared for Deloitte & Touche Inc., July.

SRK Consulting (Canada) Inc., 2006. Anvil Range Mining Complex 2005 Waste Rock and Seepage Monitoring Report, July.

SRK Consulting (Canada) Inc., 2006. Anvil Range Mining Complex-Tailings Relocation 2005/06 Task 22a, Report prepared for Deloitte & Touche Inc., July.

SRK Consulting,(Canada) Inc., 2006. Memorandum prepared by S. Schulz and D. Hockley to FMCPO regarding Reprocessing of Tailings to Recover Lead and Zinc, September 29.

SRK Consulting (Canada) Inc., 2006. Example Alternatives for Closure of the Anvil Range Mining Complex, Draft Report for Peer Review (with Attachments B though E), Prepared for Deloitte & Touche Inc., September.

SRK Consulting (Canada) Inc., 2006. Memo to Faro Mine Closure Planning Office regarding DRAFT Modeling of Additional Groundwater Control Options for Rose Creek Tailings Facility, Faro Mine, YT, December 12.

SRK Consulting (Canada) Inc., 2006. Groundwater Management Alternative. Technical Memorandum prepared by Daryl Hockley and Christoph Wels for the Faro Mine Closure Planning Office, December 12.

SRK Consulting (Canada) Inc., 2006. Memo to Independent Peer Review Panel regarding Groundwater Management Alternative, December 12..

SRK Consulting (Canada) Inc., 2006. Tailings Water Cover, Technical Memorandum prepared by Daryl Hockley and Peter Mikes for the Faro Mine Closure Office, December 14.

SRK Consulting (Canada) Inc., 2005. Water Treatment Requirements for the Anvil Range Site, Report SRK 1CVD003.54, Task 14e, prepared for Deloitte & Touche Inc., May.

SRK Consulting (Canada) Inc., 2004. Design Options for Seepage Collection, Grum Waste Rock Dump, Report SRK 1CVD003.37 prepared for Deloitte & Touche Inc., June.

SRK Consulting (Canada) Inc., 2004. Water Treatment Costs, Report SRK 1CVD003.32 Task 12c, prepared for Deloitte & Touche Inc., June.

SRK Consulting (Canada) Inc., 2004. Geochemical Studies of Waste Rock in the Anvil Range Mining Complex, June.

SRK Consulting (Canada) Inc., 2004. Water Quality Estimates for Anvil Range Waste Rock, Draft Report SRK 1CVD003.50 prepared for Deloitte & Touche Inc., November.

SRK Consulting (Canada) Inc., 2003. Geochemical Assessment of Vangorda/Grum Water Treatment Sludge, Report SRK 1CG008 to Gartner Lee Limited, October.

Steffen Roberston and Kirsten (Canada) Inc., 1994. Groundwater Investigation North Fork of Rose Creek Faro Mine, Yukon Territory, Report No. A114101 prepared for Anvil Range Mining Corporation, December.

Type 11 Mines Project Office, 2004. Report on Anvil Range Mining Complex- Closure Planning Technical Workshop held on Feb. 16-19.

Whitefish Mountain Environmental Consulting, 2005. An Assessment of Fish Habitat and Fish Utilization within North Fork, Rose Creek.

White Mountain Environmental Consulting, 2005. Aquatic Life Sampling and Testing Program for the Anvil Range Mine Site, Rose and Vangorda Creek Watersheds, Faro, Yukon.

White Mountain Environmental Consulting, 2005. North Fork, Rose Creek Rock Drain, Winter Fish Utilization Assessment.