TECHNICAL MEMORANDUM

TO: Mr. Mike Nahir, INAC Technical Manager

FROM: Independent Peer Review Panel (Panel)

DATE: August 15, 2010

RE: COMMENTS ON DRAFT 4A OF THE PROJECT DESCRIPTION FOR THE FARO MINE COMPLEX CLOSURE AND REMEDIATION PLAN

EXECUTIVE SUMMARY

At the request of Indian and Northern Affairs Canada and the Yukon Government, the Independent Peer Review Panel (IPRP) has undertaken a review of Draft 4A of the Project Description for the Faro Mine Complex Closure and Remediation Plan (Draft 4A) dated March 2010. The Draft 4A document together with a myriad of supporting reports were placed on SharePoint in electronic format for download by the IPRP. This draft of the Project Description is an update of Draft 3 dated May 2009 originally reviewed by the IPRP in June 2009. The Terms of Reference (ToR) as set out in the Call-Up notification from INAC to the IPRP were as follows:

- *Peer review of the Project Proposal report is required. The Project Description would include site characterization, project definition, project objectives, the preferred remediation option, conceptual design, human health and environmental risk assessments, environmental impact assessment, implementation strategy, remediation schedule, cost estimates, and all supporting documentation.*
- *Provide technical, scientific and engineering reviews of the final Project Proposal report and supporting documents and identify any technical risks that may be advanced to the next phase of the remediation process involving pre-engineering design issues;*
- *Identify any additional outstanding specific technical information gaps associated with the preferred remediation option requiring clarification or completion prior to final submittal of the project proposal;*
- *Recommendations as to refinements or modifications to components of the final Project Proposal report or their proposed implementation sequence;*
- *Participate in meetings with the Project Authority via telephone or teleconference as and when required. A kick-off meeting would be coordinated between the Project Authority and the IPRP to provide more detailed instructions and specific terms of reference regarding the peer review; and,*
- *After completion of the review submit a written document including findings, conclusions and recommendations of the IPRP to the Project Authority.*

A Letter of Transmittal received by the IPRP from Yukon Energy, Mines and Resources, Assessment and Abandoned Mines branch stated that Draft 4A described the conceptual design of the proposed remediation plan for the Faro Mine Complex. The review by the IPRP did not include Socio-economic Assessment (SEA) but did include the Human Health and Ecological Risk Assessment (HHERA) along with the various technical and engineering components of the remediation plan.

Detailed design of a final remediation plan is awaiting development of a project governance and management structure to be determined between the federal government, the Yukon Government, and the affected First Nations. Only after the respective roles and responsibilities of these entities have been determined would a design team be engaged to further advance Draft 4A of the Project Description to the Project Proposal phase in preparation for submission under the Yukon Environmental and Socio-economic Assessment Act (YESAA). The IPRP has been requested to provide comments to aid in guiding the detailed design team in the next phase of project planning. Our review examined several key technical areas associated with the remediation, including the following:

- *Groundwater cut-off walls and stream diversions*
- *Tailings, waste rock, and associated materials covers*
- *Seepage groundwater collection systems*
- *Surface water management and treatment*
- *Water quality modeling*
- *Risk assessments*
- *Adaptive management plans*
- *Other technical issues*

Draft 4A did incorporate new technical concepts, some of which were recommended by the IPRP in previous reviews. Overall, the remediation program proposed in Draft 4A represents the preferred approach for achieving and maintaining improved surface water quality in the future by integrating the following key components:

- *Implementation of year around groundwater capture at key locations,*
- *installation of the down gradient cut-off wall in Rose Creek Valley to increase groundwater collection efficiency ,*
- *relocating streams into isolated channels through contaminated groundwater zones in order to keep clean water clean,*
- *selection of sequentially lower infiltration cover designs,*
- *recognizing the critical importance for a comprehensive surface water management plan,*
- *upgrading and enhancing water treatment facilities and processes, and*
- *developing a more robust and reliable adaptive management plan to monitor progress and modify the remediation program as deemed appropriate in the future.*

In general, the IPRP supports the sequential implementation of the core remediation components and accompanying schedules. Construction and operating costs were not reviewed in detail. However, the IPRP notes that efficiency of design is very important as the cover costs and materials handling approach half of the overall remediation expenditures. The IPRP also notes the long-term cost benefits are highly sensitive to increased initial capital expenditures for items such as lower permeability covers compared with increased costs of long-term treatment, if less efficient covers are installed. Long-term protection of downstream water quality would be reliant on water treatment regardless of the capital costs of source controls for all practical options at the Faro mine complex.

There were two recommendations made previously by the IPRP that were not addressed in Draft 4A. The first recommendation relates to consideration of abandoning biological and chemical treatment at the Grum and Vangorda mine sites in favor of seasonally pumping contaminated water from the open pits to the Faro open pit, thereby relying on a single new water treatment facility and sludge disposal option. The second recommendation not addressed was the installation of a groundwater cut-off wall on the South Fork of Rose Creek (SFRC) upstream of the Rose Creek tailings storage facility. The cut-off wall would be needed as groundwater flow in the SFRC alluvial channel could become contaminated by groundwater seepage from the North Fork Rose Creek (NFRC) alluvial channel. Without it additional volumes of groundwater would require collection and treatment in the long-term.

Some concerns remain regarding the reliability and applicability of the GoldSim modeling and related water quality estimates, due not only to the very complex interrelationship between the efficiencies achievable through groundwater capture, cover designs, and/or water treatment plant performance, but also to the uncertainty in delineating their advantages and disadvantages. The probability distribution derived within GoldSim to characterize the possible range in the zinc concentration in the downstream surface water may have placed too large a weight on higher zinc concentration values if the remediation plan is implemented as proposed with a downstream cut-off wall in Rose Creek valley.

The human health and ecological risk assessments which were based on results of the GoldSim water quality modeling predicted moderate impacts to aquatic life following implementation of the remediation plan. The IPRP felt the modeling study over estimated metal levels and in turn aquatic life impacts, and that further water quality refinements and engineering assessments would be possible to aid and enhance the remediation decision making process.

GROUNDWATER CUT-OFF WALLS AND STREAM DIVERSIONS

The proposed remediation design contains components related to the installation of cut-off walls for contaminated groundwater interception and diversion channels to relocate and reroute several streams within the mine complex above the open pits and below the waste rock disposal areas.

Draft 4A incorporated many of the review comments and recommendations provided by the IPRP on earlier drafts of the Project Description. Specifically, the proposed location of the Rose Creek seepage interception system (SIS) including the cut-off wall has been moved downstream from the toe of the Intermediate Dam.

The final location for the SIS and cut-off wall would be selected based on the local hydrological and geotechnical characteristics which would be determined through further field investigations. Currently, placement of the cut-off wall would be bracketed within an area extending from upstream of the existing Cross Valley Dam (CVD) and downstream of the Intermediate Dam (ID). Upon reading of Draft 4A, there was a perception that if groundwater interception systems below the Faro waste rock piles were highly effective the Rose Creek SIS would not be required. It should be clearly stated that the SIS was also designed to intercept contaminated drainage from the tailings impoundment. Once in place it would also serve to intercept contaminated seepage that bypasses the localized interception systems down gradient from the waste rock piles isolated from Rose Creek.

The valley floor immediately upstream of the proposed SIS and cut-off wall is the lowest topographical point at the Faro mine site. It is in essence the combined point source for all contamination farther downstream. Gravity and topography can be relied upon to control all types of drainage when power losses occur disrupting pumping and/or diversion systems. The valley floor between the toe of the ID and the CVD or proposed cut-off wall exhibits the unique potential for serving as a collection point at which all of the surface and groundwater water from the entire Faro mine site drains by gravity.

The description of the Rose Creek SIS in Draft 4A remains conceptual and simplistic, as further geotechnical and hydrological investigations are needed. Although one of the primary functions of the cut-off wall was described in Draft 4A, there was no mention of the provision to allow pumping to maintain a reverse gradient across it. Such a reverse gradient would ensure there would not be a gradient inducing downstream contaminated water seepage across or around the cut-off wall. If seepage did occur it would be a flow of clean water from the downstream side to upstream side of the cut-off wall in the direction of the reversed gradient. This hydrodynamic structure transforms the SIS and cut-off wall into a highly efficient containment system for contaminant releases. The IPRP believes this downstream water collection system would be a highly effective system for final capture of contaminated waters, resulting in considerable reduction in ecological risk for entire remediation plan.

It is recommended the final location selection address the necessity for a large water storage pond upstream of the cut-off wall, as this is the lowest point on the site to which contaminated water would drain by gravity. A pond at this location has the potential of providing a secure and convenient intermittent and seasonal location for accumulations of contaminated groundwater, providing maximum flexibility for site water management and other possible operational disruptions.

Draft 4A retained breaching of the Cross Valley Dam (CVD) early in the project schedule and eliminating its use as a temporary or emergency containment for untreated site waters or treated effluent. The IPRP continues to support the use of the CVD for water storage unless the design of an alternative large capacity storage facility is incorporated into the remediation plan. The current version did not contain such a structure and the rationale for breaching the CVD and removing it was not stated in Draft 4A.

The seismic stability assessments carried out by Klohn Crippen Berger indicated layers of silt, sand and gravel occurring in the dam foundation could liquefy and the dam would likely fail during the maximum 1 in 10,000 year earthquake, but would not liquefy during the maximum 1 in 500 year earthquake. Work to stabilize the dam by lowering of its height, providing further support, or improving the foundation to withstand the Maximum Credible Earthquake (MCE) would include soil densification below original ground level and construction of stabilization berms along the upstream and downstream toes of the dam.

If the CVD is breached to the extent it can no longer impound water, but most of the fill is left in place, the design of a cut-off wall nearby must consider the effect of potential ground movement resulting from a large earthquake. Although water would not be released, the ground movement could disrupt the cut-off wall. If a flow slide did occur, the failure debris could cover infrastructure downstream of the dam

TAILINGS, WASTE ROCK AND ASSOCIATED MATERIALS COVERS

Draft 4A identified sufficient materials for construction of the engineered remediation structures. Optimization of the use of the various sources has potential to reduce the haul distances, fuel usage and ultimately carbon emissions. For example, Draft 4A indicated all of the till used in covering the Rose Creek Tailings would come from the Grum mine site overburden storage area with a haul distance of about 14 km.

Till sources in the Faro mine site area that were identified as the Tailings and the Haul Road Borrow Areas represent nearly one million cubic meters of unallocated material. This material represents about one-third of the till required for construction of the tailings cover and would reduce haul distances A new haul road, identified as a spur road in Draft 4A, would be required to bring the large quantities of material from the Grum mine site to the tailings location. Depending on the point where the new haul road would tie into the existing one between the two mine sites, there could be an opportunity to remove more material from the Rose Creek Rock Drain when it is breached and use this material in the tailings cover, accompanied by a shorter haul distance. Haul road and borrow area construction would create further surface disturbance which must be taken into account in designing surface water management systems.

The conceptual framework presented in Chapter 3 of Draft 4A for cover design and selection was reasonable. In addition, the IPRP considers the range of infiltration rates assumed for each of the three cover types (rudimentary, low infiltration, and very low infiltration) was reasonable and appropriate.

It was acknowledged in Draft 4A that there could be breakthrough of wetting fronts at the base of the store and release covers during wet years, which was an appropriate position to adopt. Experience with long-term cover performance indicates degradation would occur with time.

At the Faro mine complex, the ability to maintain an effective vegetative cover for erosion control and to satisfy transpiration modeling requirements remains uncertain. The IPRP envisions some degree of poor vegetative cover and erosion would occur. The provision included in Draft 4A for ground and surface water protection measures to account for minor cover deterioration was appropriate.

The final cover designs have not been prepared as the collection of site specific performance data at the cover trial experiments on the Vangorda waste rock piles has not been completed. Therefore, it should be recognized the remediation plan could move forward into final design without data upon which to benchmark the assumed range of infiltration rates for the store and release covers. For example, it has not been demonstrated that a very low infiltration cover can be established using only soil media combined with re-vegetation.

The cover trial experiments have progressed slowly and have not yet yielded the full data record for which they were originally designed. This finding applies to both the original six covers constructed in 2004 for which soil characteristics but not water fluxes are monitored, and the two trials constructed with lysimeters in 2007 for which water fluxes are monitored. An interpretation report has been released for the original cover trials summarizing the performance observed from 2005 to 2007. This data set has yielded practical qualitative insights into cover performance, but no water balance calculations were reported. The need to incorporate a barrier layer, such as compacted till within the low infiltration store and release cover to manage infiltration from snowmelt into frozen soil has been demonstrated. Because only the data summary reports have been released on the two lysimeter trials, an independent analysis of performance from those trials was not possible.

There have been a number of instrument and logger failures over the duration of the trials, which is expected in this remote and challenging environment. SRK has a system in place for annual maintenance of the trials and in January 2010, SRK recommended monitoring be continued for at least three more years. The IPRP supports continuing the field trials due to the importance of the results in developing effective cover designs.

The locations identified for the placement of low and very low infiltration covers at the mine sites are reasonable and internally consistent. The IPRP recommends a monitoring program be developed for the very low infiltration cover to be placed on the Grum sulphide cell.

Since this would be the first full scale installation of its type at this mine complex, there would be an excellent opportunity to observe early performance which could in turn provide valuable information to be applied in the installation of subsequent very low infiltration covers at the other two mine sites. There would also be a valuable opportunity to observe how cover placement at the Faro mine site modifies the surface discharge from the seeps above the Emergency Tailings Area (ETA). To take advantage of this opportunity following re-sloping and cover placement, it would be necessary to rout buried seeps through a discharge pipe to a flow measurement point.

The plan to cover the Rose Creek Tailings area with a 1.5 m layer of loosely compacted till has not changed from earlier reports. This is considered to be an appropriate design which now includes an underlying trafficable layer to allow access by off road vehicles and other construction equipment, an approach supported by the IPRP. The waste rock layer intended to provide trafficability could be placed in winter and also used for topographic infilling to provide a uniform sloped surface for till cover placement. With appropriate grading selection it could also serve as a drainage layer. These functions were not mentioned in Draft 4A. The placement of till over the tailings in winter could avoid the need for the trafficable layer where it would not be required for the other purposes.

A cost-benefit analysis has been completed to examine the relative merits of placement of the different cover types. This study comparing placement of a more costly low permeability cover over high sulphide wastes instead of a rudimentary cover resulted in the finding that higher long-term water treatment costs would be associated with a higher permeability cover. This conclusion would be valid for the assumed groundwater capture efficiencies.

This same approach also indicated a net benefit for placement of a very low infiltration store and release cover on the sulphide cells at the Faro mine site. A reasonable approach was taken to accommodate the uncertainty inherent in prediction of source loads. If the uncertainty was judged to make a difference in selection of the cover type, a more conservative stance was taken with respect to the upper bound estimate of the source chemistry and infiltration rate through the cover. Similarly, if the ability or cost to intercept contaminated seepage was a major concern, a lower infiltration cover design was chosen.

The IPRP supports the plan to relocate the oxide fines and medium grade ore stockpile to the area of the low grade ore stockpile C. This latter area is expected to be within the groundwater capture zone of the Faro open pit allowing drainage into the pit. There was no detailed discussion of the cost versus benefit of amending this waste with lime or assessment of the geochemical effects on water quality. Considering this option was estimated to cost six million dollars, an analysis to justify the geochemical and economic expenditure would be warranted.

The IPRP continues to support placing rudimentary covers on the waste rock piles located within the Vangorda open pit. From a water treatment perspective regardless of whether or not a plant would remain at the Vangorda mine site, there does not seem to be a need to reduce the mass loading from these piles into the open pit. Treatment efficiency would remain essentially the same over the range of metal concentrations anticipated. Further reductions in mass loading to Vangorda Creek would be achievable by eliminating the discharge from the Grum open pit and the existing treatment facility by seasonally pumping Vangorda open pit water to the Faro open pit for storage and subsequent treatment.

The information presented in Draft 4A indicated there was a sufficient supply of borrow material to implement the project description. The estimates in Table 9.1 of Draft 4A inferred that about 25% of the available borrow material would be unallocated under the current remediation plan. Of this amount, 6% resides in the haul road and the North Fork Rock Drain. The remaining borrow would be essentially clean waste rock. This assessment indicated there would be a sufficient excess over design to cover errors in estimates of in-place materials or borrow demands.

However, it was not clear if the material requirements for rudimentary covers and surface layers of the other lower infiltration covers were based on a conservative value of a 1.0 m or on a 0.3 m thickness, the range noted for the rudimentary covers presented in the report. This range of thicknesses would be a very important aspect of the material balance, in the event the design had been based on the thinner cover but in practice the thicker cover design would be implemented. This design element must be confirmed prior to advancing to the Project Proposal phase of the remediation.

SEEPAGE AND GROUNDWATER COLLECTION SYSTEMS

Given the immediate need for protection of the water quality within the NFRC until it is isolated through construction of an upper cut-off and alternative channel, the IPRP recognizes the need for continued reliance on the existing and possibly additional localized year around groundwater capture systems. The duration of the need as well the number of systems could be extended given the uncertainty of how groundwater seeps could emerge over time until the NFRC is isolated. However, once the down gradient cut-off wall is in place, its performance demonstrated and the NFRC is isolated and its water quality protected, the IPRP believes there would be a distinct advantage in discontinuing or minimizing the need for localized groundwater capture systems in favor of relying upon the single focused groundwater collection point at the proposed cut-off wall down gradient of the Intermediate Dam. This decision comes into focus in relationship to its inclusion within the Adaptive Management Plan.

For example, if monitoring indicated increasing zinc concentrations in the Zone 2 outwash area, it would be more likely than not a local seepage interception system would be needed in that area if the NFRC had yet to be raised and relocated.

The IPRP agrees with the proposed two-stage strategy for protection of water quality in the NFRC, that being upgrading the area by Zone 2 initially and then monitoring performance of the collection system at the S-wells area before determining whether it would be necessary to place the NFRC in an isolated channel in the region between the rock drain and its confluence with the SFRC. Of particular concern to the IPRP is the potential for contaminated groundwater seepage bypassing the local interception systems in the reach of the NFRC below its cut-off wall and confluence with the SFRC.

The contaminated drainage entering the NFRC alluvial channel would mix with the groundwater flowing in the SFRC alluvial channel at their confluence. Some groundwater could surface resulting in contamination of the creek before it enters the channel. To avoid contamination of groundwater flows in the SFRC alluvial channel, the IPRP recommended evaluation of the installation of a cut-off wall to raise the SFRC into the alternative channel and avoid additional contamination of clean fresh water. The groundwater flow within the SFRC alluvial channel and the groundwater recharge/discharge conditions in the area of its confluence with NFRC have not been defined sufficiently to appropriately evaluate the cost and water quality protection benefits of a cut-off wall in the SFRC.

However, if the down gradient cut-off wall was in place and the NFRC and SFRC were isolated, the IPRP anticipates the water quality of the streams would be protected, even if the efficiency of the groundwater collection systems did not achieve their anticipated goals. The IPRP observes at that time there could be a distinct advantage in discontinuing or minimizing localized groundwater capture systems in favor of the single focused groundwater collection point at the proposed cut-off wall down gradient of the Intermediate Dam.

The design of the aquifer cut-off wall below the Rose Creek Tailings has not been advanced beyond previous drafts of the Project Description and was presented only in general terms. The schedule for installation of this cut-off wall indicated it would follow the upgrade of the Intermediate Dam. It was acknowledged that the cut-off wall could be constructed earlier than the dam upgrade if groundwater monitoring indicated it was warranted. The IPRP supports this approach, but it should be noted that the cut-off wall is a key component of the long-term groundwater collection and surface water protection plan, and therefore, geotechnical evaluations to identify the final location should be begin as soon as practical.

Draft 4A deferred detailed comment on an upgraded collection system below the Vangorda waste rock piles until monitoring indicated it would be needed to reduce loading into Vangorda Creek. The waste rock in this area is located on lower permeability till and the difficulty in operating a long-term robust groundwater capture system relying on wells could be underestimated.

In addition, it would be advantageous to construct a seepage interception system below the Grum sulphide cell prior to placement of the very low infiltration cover in case disturbance during cover construction leads to elevated releases of zinc to the groundwater system.

Although in-depth discussion of passive treatment outside of the Grum open pit has not taken place, there could be an opportunity to incorporate organic sulphate reduction trenches or permeable reactive barriers as supplemental treatment measures in locations of small groundwater discharges where the hydrogeology would be favorable. This treatment alternative, although not passive in the long-term, could be a simple and effective alternative to the management of water quality from small flows of contaminated groundwater. If hydrogeological conditions are suitable, such treatment trenches or reactive barriers could be effectively incorporated as a series of treatment gates within a low permeability cut-off wall.

The IPRP recommends consideration of this passive in-situ biochemical technology and if deemed potentially suitable for this application, a field trial should be designed and conducted to examine its viability over a multiple season cycle. The field trials are essential to evaluate the effects of temperature. A similar technology is currently being field tested at the United Keno Hill Mine Complex to treat acidic mine adit drainage. This technology has been employed at numerous sites in North America and Europe, some of which have been operating for as long as two decades.

WATER MANAGEMENT AND TREATMENT

Regardless of the effectiveness of the cover designs, groundwater collection systems, and geochemical predictions, long-term water management and treatment would remain the cornerstone of a successful site remediation program. The combined water management and treatment systems must be flexible and reliable to accommodate highly variable quantities and qualities of various site waters. The results of multiple studies over the past few years have highlighted zinc as the most important constituent of potential concern (COPC) for causing adverse impacts within the local aquatic ecosystems. Secondary water quality concerns are associated with cadmium and copper.

Valuable advances have been made in component design and overall strategy of these technical areas in Draft 4A. The water balance for the site was discussed along with water treatment in Chapter 8, while water management was discussed in Chapter 12. The water balance was developed in conjunction with the estimation of future groundwater and surface water quality with the aid of GoldSim modeling software.

The range of site waters that would be treated include contaminated groundwater collected from wells underlying or down gradient of waste rock piles or tailings, groundwater day lighting as seeps, and surface runoff arising from direct precipitation or snow melt. The list of constituents of concern included total suspended solids as well as metals.

The control and removal of entrained suspended solids in runoff would be of major importance for many years as the numerical values for the constituents of concern in the eventual water license would be based on their total and not dissolved concentrations.

The stringency of those numerical values would dictate the level of suspended solids removal and advanced water treatment required. To date the final numerical effluent limitations have not been specified leaving the issue of advanced treatment unresolved. However, it has been noted in conjunction with the ecological risk assessments that total suspended solids levels should be held to less than 25 mg/L in any surface waters discharged from the mine sites for protection of aquatic life.

Surface Water Management

It was noted in the Draft 4A that highly variable flows would occur periodically, requiring collection and transport to temporary storage or directly to treatment. The highest of these flows would come with snow melt during the freshet and coincidental or intermittent summer rain events that could come in close succession. Therefore, collection and routing of runoff would be an important operational consideration both in the short and long-term as more areas become disturbed while being re-contoured, covered, and re-vegetated. Routing of surface runoff from areas under physical remediation can be controlled in part with short-term structures such as earthen berms, silt fences, straw bales, sand bags, and sediment collection features. These structures, although considered best management practices (BMPs) during active remediation, would not be suitable as permanent long-term strategies for collection of runoff and control of sediment.

Draft 4A proposes the design of these temporary runoff collection and sediment control structures be based on the ten-year peak daily flow. No information was provided as to the methodology employed to arrive at this value. Typically, the sizing of these structures for which there are severe consequences for failure is based on an assessment of the dynamic water balance for a particular site with the resultant design criteria accommodating higher flows than the ten year peak event. In the absence of specific supporting design criteria and considering that the consequences of failure could results in a major ecological impact, verification of design specifications is needed, preferably through collection of empirical data at the mine sites.

In addition, the configuration, placement, and sizing of sediment control structures and settling basins are critical design considerations selected to attain a specific removal efficiency and effluent concentration for total suspended solids. Draft 4A presented specific design criteria for the settling basins including removal of particle sizes down to 5 microns in basins no larger than 20 hectares allowing bypass of flows through spillways exceeding the 200 year precipitation event. Again no details or references were provided in Draft 4A as to the underlying assumptions used to develop these design criteria, such as the relationship between size fractions and total suspended solids levels or the selection of the bypass flow.

There remains the related question as to where the bypass flows would be routed or if they would simply be released to the local surface waters. Based on the limited data and criteria provided, further validation of the underlying specifications is needed prior to final design of the comprehensive surface water management system.

Although dividing the surface areas into Reclamation Land Units for remediation is a plausible basis for planning purposes, it would be the sequencing of remediation and coordination of collection, routing, and storage of surface water runoff that ultimately becomes the controlling factor in design and the major operational challenge in the field on a daily basis.

The GoldSim water quality modeling applied 10% of the seepage water chemistry to represent the surface water runoff chemistry prior to covers being placed and set it equal to the background water quality once they are in place. Although an estimate of runoff water quality was needed to establish this model variable and provide an input, the proper approach to determining the runoff water quality and the sizing of sedimentation basins for the purpose of removing total suspended solids and associated metals, would best be determined empirically through collection of surface flows at various points throughout the mine sites during freshet and precipitation events and conduct bench scale column settling tests. At a minimum a rationale should be provided for the choice of the 10% value including for example actual field data supporting this design criterion.

In this manner the total versus dissolved fractions of the metals could be analyzed along with their association with the particular particle size fractions comprising the suspended solids. Again there was no specific technical justification provided for the setting of surface water quality.

The IPRP fully supports an operational approach that routs all surface water flows to centralized collection points for transfer to the open pits for storage prior to treatment. This approach alleviates the concerns associated with sizing of conveyance systems and intermediate settling basins as long as the channels and pumping systems are appropriately sized to accommodate very large short-term peak flows. However, much of the contaminated surface flow does not flow by gravity to the open pits and must be collected in intermediate storage ponds and pumped into them. There would be potential for the storage capacity and pumping capabilities of smaller intermediate storage facilities to be exceeded during extreme precipitation events and as a consequence of other factors such as power failures. There would be advantages to maintaining a large water storage pond located at the lowest elevation on the site below Intermediate Dam into which drainage could be conveyed by gravity during such episodes.

The large storage capacity of the open pits allows maximum flexibility with respect to managing flows and providing adequate lead time for making critical and informed decisions regarding the need for further treatment capacity or processes.

Previous studies have indicated there would be sufficient capacity for chemical sludge generated from treatment to be deposited in the Faro open pit for centuries. The bulk of suspended solids associated with runoff would be removed within the open pits. This would constitute an important operational advantage versus construction of multiple settling ponds to accommodate large and highly variable flows with the need to periodically remove the accumulated solids.

In order to achieve the highest reliability with respect to capture of surface runoff, a robust but relatively simple conveyance system should be contemplated. One approach to alleviating some unpredictability related to the design and performance of settling basins would be to rely more on designing and constructing conveyance systems to rout high flows directly into the open pits or a large temporary storage facility from which pumping can be controlled. Depending on the final location of the down gradient cut-off wall, a substantial volume of storage could be provided upstream of it. If the cut-off would be placed below the existing Cross Valley Dam, then this dam could remain in service after lowering or strengthening it to allow its continued safe use.

As the final Project Proposal moves forward with more design details, it would become necessary to closely integrate and coordinate the remediation of a particular Reclamation Land Unit (RLU) at the three mine sites with the site-wide short and long-term water management plan to ensure appropriate capture, conveyance, and storage facilities are provided particular during high flow events and periods.

During the initial stages of remediation the most likely water quality impacts would arise from runoff containing high levels of total suspended solids and associated metals escaping capture and making its way into local surface waters of Rose and Vangorda Creeks.

Water Treatment

At present, the proposed primary treatment systems would be based on dual stage lime precipitation known as the high density sludge or HDS process. The IPRP supports the decision to use this process due to its proven reliability, effectiveness, and relative ease of operation. If treatment beyond lime precipitation is needed to further reduce residual metal loadings to surface water, then one or more advanced treatment processes such as sulfide addition or pressure filtration would be needed as noted in Draft 4A. The decision regarding the need for advanced treatment would be determined as part of the aquatic ecosystem and other water quality monitoring programs associated with the Adaptive Management Plan.

The underlying assumptions used in estimating current and future flows of various site waters were not verified in conjunction with this review. It was stated in the Project Description that both of the existing water treatment facilities with minor equipment upgrades were capable of accommodating the anticipated flows over the next few years. The IPRP has previously recommended completion of a detailed engineering review of the treatment facilities to determine their maximum capabilities, but it is not known if it has been completed.

Increasing treatment plant capacity over time in stages is a prudent approach supported by the IPRP. The IPRP is aware of and supports the proposed design equipment upgrades being considered for the two existing water treatment facilities in the short-term.

The IPRP supports the option for seasonal treatment due to the extreme climactic conditions at the mine sites and the ability and capacity to safety store water in the open pits for multiple years if necessary.

The IPRP also supports the decision for long-term disposal of chemical sludge from lime precipitation in the open pits due to the available storage volume, the added acid neutralizing capacity, and the lack of other environmentally acceptable options. There were discrepancies noted between the lime dosages reported in Draft 4A needed for treatment and some data from past studies and reports that should be revisited and verified. As a result, further evaluations on a bench or pilot scale are recommended to confirm the chemical dosages for various waters.

There was one specific water treatment strategy not addressed in the Project Description that was put forth by the IPRP in previous discussions and reviews. This strategy would involve eventual elimination of the water treatment facility at the Vangorda and Grum mine sites accompanied by a new pipeline to convey accumulated waters to the Faro open pit on a seasonal basis. Only one large, new multi-stage treatment facility would be built at the Faro mine site. There are several reasons for recommending a more detailed evaluation of this strategy.

First, although Draft 4A continued support for the in-situ biological treatment concept being examined in the Grum open pit on a full scale basis, the long-term water quality monitoring program has not demonstrated its effectiveness in achieving a dischargeable level of zinc on a continuous seasonable basis. The evaluation has been conducted for a sufficient length of time to demonstrate the effectiveness and reliability of this treatment technology. Second, due to the dynamics of the Grum open pit limnology, re-suspension and re-solubilization of zinc and other metals is possible. Third, there would be a reduction in overall maintenance and personnel at the Grum and Vangorda mine sites on a continuous basis as remote sensing could be employed for routine monitoring and operational activities. Fourth, no economic advantage of pursuing biological versus chemical treatment has been realized during the multi-year evaluation conducted in the Grum open pit. Fifth, there are lingering concerns regarding the potential adverse impact of residual nutrients in the discharge to Vangorda Creek.

It has been proposed the biological treated overflow from the Grum pit would be conveyed through a wetland area prior to discharge into Vangorda Creek. However, during freshet and after for some period of time there would be minimal contribution of the wetland area to treatment as the ground would be frozen and the biochemical processes still inactive. This is a well known limitation of the use of wetlands in cold climates.

The remaining zinc concentration and the load from the Grum open pit following biological treatment would be quite large compared with that associated with the treated effluent from the lime precipitation process. By eliminating the metal loading associated with discharge from Grum open pit a substantial improvement in overall water quality would be realized in Vangorda Creek, which in turn would be further enhanced with the elimination of the Vangorda chemical treatment facility. The reduction in metals concentrations and loading would lower the potential for adverse impacts to aquatic life in Vangorda Creek.

The IPRP recommends a detailed evaluation be undertaken of the advantages of installing and maintaining a pipeline to the Faro open pit be compared with those of continuing to manage the in-situ biological process and the cost of designing, building, operating, and maintaining a new water treatment facility at both the Faro and Vangorda mine sites. With the treatment plant eliminated there would remain a need to allow access to the pipeline for maintenance. There would be sufficient time to evaluate this alternative treatment strategy since the water balance studies conducted for the Grum open pit indicated there was at a minimum several years of storage capacity remaining prior to a surface discharge occurring at the spill point.

The IPRP believes that as a guiding principle, no primary treatment process should be proposed or pursued which cannot achieve at a minimum the same level of removal and effluent quality as the conventional HDS process, particularly when there would be no operational or cost advantages. At this point, the empirical evidence from the field has not supported the continued pursuit of in-situ biological treatment in the Grum open pit as either a primary or supplementary treatment process due to the inability to achieve low residual zinc levels for a period sufficiently long to allow meaningful discharge of accumulated water. There would also be concerns about the potential for natural processes to disrupt treatment routinely and unpredictably thereby rendering it unreliable.

Draft 4A indicated placement of the new water treatment facility below the Faro open pit near the Rose Creek tailings. Although placement of the actual treatment facility would not be critical to its operational efficiency, placement of it nearer the open pit would allow for the partial use of gravity for disposal of sludge into the lower portion of the open pit and discharge of treated effluent to Rose Creek. Pumping of collected site waters into the open pit would be the only requirement versus placement of the treatment facility below waste rock and mine which would require pumping of both the untreated water and sludge up gradient into the open pit.

As with the qualitative and quantitative characterization of the runoff with respect to suspended solids and metals, further bench scale investigations are recommended of the various potential advanced treatment processes including filtration and sulphide addition for removal of either residual suspended solids and/or total and dissolved metals.

In conjunction with these treatability tests, an examination of various coagulants and flocculants is needed to identify potential filtration and settling aids. This information would be necessary at some point if it is determined lime precipitation alone cannot meet the required standards for discharge of treated effluent into Rose Creek.

WATER QUALITY MODELING

Initially, water quality predictions were generated using separate versions of the Rose Creek tailings and Faro waste rock geochemical models. These models were eventually consolidated into a single EXCEL spreadsheet to allow estimation of future in-stream metal concentrations.

The spreadsheet model allowed variable inputs for seepage chemistry, groundwater capture efficiency, and cover infiltration rates. The outputs from the model were used as the basis for preparing both short and long-term preliminary human health and ecological risk assessments (HHERA) for the three mine complex.

There was a desire to refine those water quality estimates in a narrower quantitative range to reflect the important differences in resultant surface water qualities that arise from seemingly small and subtle variations in input variables such as groundwater capture efficiency and cover infiltration rates. To that end the site wide water quality modeling effort was revisited employing the well recognized GoldSim software to not only apply a more powerful stochastic analysis but also to incorporate more recent upgrades to the overall remediation plan to examine resultant future surface water quality.

The updated and revised site wide water quality model was developed to provide predictions for periods of decades to as much as two centuries, of solute concentrations in surface water downstream of the Faro mine complex assuming final implementation of the final remediation plan. The primary solutes included several metals and sulphate. The IPRP considered the overall framework of the water quality model and the methodologies used to make the calculations are sound. The model was structured to account for the following principal factors determining solute concentrations in surface water:

1. the rate of solute release from the various regions of the waste rock piles with different sulphide mineral content,
2. the change in the rate of solute release as the system matures geochemically and the natural neutralization capacity of the waste rock is depleted,
3. the seasonal variations in stream flow, and
4. the effects of mitigation measures.

The mitigation measures were intended to reduce the rate at which solutes were flushed from mine wastes by infiltration of precipitation, to intercept contaminated water before it intercepts the surface water system, and/or to physically isolate surface flows from contaminated groundwater.

The water quality model was used to compute estimates of soluble constituent concentrations at specified points in the surface water system and, using a conventional statistical method, derive a range of possible concentrations which reflected uncertainties in the determination of source concentrations in the mine wastes and the efficiency of the mitigation measures.

The range in predicted solute concentrations developed from the water quality model formed the basic input to the most recent and updated HHERA. The Monte Carlo simulation program that exists in the site wide water quality model has the capability to not only examine the interplay of the multiple factors which determine the potential range in solute concentrations in surface water, but also to examine tradeoffs amongst the various mitigation measures in terms of probable effects on downstream water quality. However, minimal advantage was taken of these opportunities within the supporting document that details the construction and application of the water quality model.

The IPRP recommends that the water quality modeling program and its documentation in the supporting document be expanded to provide greater clarity on the manner in which individual elements in the project description were incorporated in the model structure. This clarification is critical to allow users and reviewers to envision how management of site components through time and space can affect the downstream outcomes. Examples of the changes to documentation, clarification of inputs, and/or extensions of the current modeling would be materially useful are as follows:

- It was unclear how the effects of isolating the North Fork of Rose Creek were introduced in the spreadsheet used to compute solute concentrations.
- It was not intuitive that a uniform probability distribution best represented the range in capture efficiency for seepage discharging from each segment of the waste rock piles and the tailings deposit. A triangular distribution could be more appropriate since based on engineering experience the extremes of the range were substantially less likely to occur than were values well within the range. In any case, the supporting document needs to explain the choice of the range and distribution for each variable that was considered by referencing existing data and/or engineering estimates of performance that had been empirically tested for other relevant mine sites.
- For each area of the mine site, different bounds could be appropriate for estimating the capture efficiency in the model. For example, while a range in capture efficiency between 95% and 99% could be appropriate at the S-wells area, at the downstream cut-off wall in Rose Creek Valley, a higher mean capture efficiency and a narrower range would be more realistic, given the level of effort to attain the highest capture efficiency at this structure. This would be important because the capture efficiency assumed for the downstream cut-off wall would exert a dominant influence on the predicted mean and range of solute concentrations at surface water station X14.
- In the current version of the water quality model, no uncertainty was considered in the long-term performance of the very low infiltration covers. This assumption needed justification because it was inconsistent with the fundamental modeling approach. At this time, the documentation of infiltration associated with the very low infiltration covers has not been finalized, and so the IPRP assumed there was uncertainty in the performance.

- The IPRP is skeptical that the range in downstream solute concentrations was adequately characterized by 25 sets of realizations drawn from the probability distributions, as standard practice for Monte Carlo simulations, even for a complex system with many steps such as this, would be to run at least 100 and more likely several hundred realizations in order to establish acceptable estimates of the percentiles..
- Much greater advantage could have been taken of the methodology to conduct sensitivity studies to gain insight into the factors controlling the range in solute concentrations predicted in the downstream waters. In the IPRP's view, the major limitation of the model was the fact that it's capacity to test engineering alternatives in support of the remediation design has not been taken advantage of insofar as the IPRP can determine from review of the water quality modeling report.
- The potential load reduction in Vangorda Creek by eliminating both biological and chemical treatment at the Vangorda and Grum mine sites in favor of pumping water to the Faro open pit was not evaluated as this water management option had not been reviewed in Draft 4A.

In the opinion of the IPRP, the probability function assigned too low of a capture efficiency for the Rose Creek SIS that was not appropriate for the technology and experience noted with systems of this type. Thus, the risks of contaminant effects presented in Draft 4A resulting from bypass seepage would likely be overestimated on a probability basis. It is recommended that the risk assessment be based on probability functions which have been reassessed taking into account the efficiencies associated with seepage interception systems of this type.

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

The water quality estimates from the GoldSim analysis were in turn employed in the revised HHERA. The results of the HHERA stated that implementation of the final remediation plan as proposed would not impart adverse effects on either humans or the terrestrial ecological receptors. In the case of the aquatic environment and receptors, it states that only minor impacts from zinc and cadmium to sensitive algal species (i.e., phytoplankton) and benthic organisms would be anticipated in both Rose and Vangorda Creeks following implementation of the remediation plan.

The water quality projections from the GoldSim evaluation adopted in the revision of the HHERA included over 2,200 monthly data points covering nearly two centuries of estimates following completion of remediation past the year 2200, which were used to develop a log-normal distribution along with calculated geometric means, geometric standard deviations, and minimum and maximum concentrations. Although the projected metals concentrations varied considerably through time, the water quality estimates used in the HHERA were based on the mean and 95th percentile concentrations derived over nearly 200 years, potentially missing subtle adverse impacts related to smaller time increments. In the conclusions of the HHERA it was stated that fewer exceedances of CCME water quality guidelines would be expected after the remediation plan had been implemented versus the current conditions.

But it was also noted the estimated in-stream concentrations of copper, cadmium, and zinc would ultimately be higher than current concentrations in the local streams. This conclusion was based upon an assumption that as oxidation progressed within the waste rock and tailings, the increased metal load within the contaminated seepage escaping capture would contact and contaminate local surface waters.

However, it was not known whether this analysis and its conclusion took into account the entire conceptual approach based on a combination of cut-off walls and stream relocation to maximize groundwater capture and protection of surface water. In addition, the potential load reduction associated with abandoning biological and chemical treatment at the Vangorda and Grum mine sites was not evaluated. As noted in the discussion regarding the GoldSim modeling, this conclusion appeared to reflect earlier versions of the remediation plan that did not take into account all of the additional most recent remediation concepts.

In reviewing the draft Chapter 8 of the Project Proposal and Appendix A of the HHERA containing the water modeling data, higher metals concentrations were projected in local streams during the first ten years of remediation. It is not known to what extent the projected increase could be related to the intense physical reclamation and ground disturbance associated with the initial stages of remediation, and the resultant impacts arising from contaminated surface runoff escaping capture and entering local streams.

The IPRP has concerns related to the projected higher in-stream zinc concentrations during the first ten years and the possible impact on primary production. The IPRP acknowledges that Rose and Vangorda Creeks are inherently low-productivity streams, and therefore a healthy phytoplankton population is essential to the fundamental productivity in these streams. Therefore, IPRP recommends a reassessment of the ecological risk of these potential short-term impacts and their severity on the long-term health of aquatic ecosystem resulting from the actual remediation period covering the first fifteen years or more.

The HHERA is nearly one thousand pages in length with an ecological assessment comprised of a very complex web of pathways using a combination of log-normal, triangular and uniform distributions to estimate exposure for different receptors. Draft 4A and the HHERA did not appear to present all of the detailed rationale for the selection of the calculation model including the probabilistic method, number of realizations, output treatment and interpretation, which if true would constitute an omission warranting attention.

The Aboriginal Peoples living on the land typically rely on traditional food more frequently than when residing in the community. The dietary information used for the community may have underestimated the differential intake, since the community average including non-consumers was used as the central tendency as noted in Table 3.5 of the HHERA. The likely intake scenario would have been more appropriately represented by the data in Table 3.7, which were derived from the research of Receveur and co-workers, which presented 24-hr recall data for the consumers reflecting the typical range of daily serving sizes.

However, Table 3.7 apparently presented the sum total of all the meat and fish species reported in the Receveur research. Noting that individuals do not consume all species on a daily basis, the total consumption appeared too high and should be reexamined.

It was not clear the basis for the utilization of the triangular distribution of traditional food intake reported in Table 3.10 of the HHERA. The estimate of local fish intake appeared low and since fish had been a major contributor to the estimated intake of a number of metals noted in Figures 4.1 and 4.2, the IPRP recommends recalculating the estimated human health exposure based on a higher consumption rate to verify a similar conclusion would have been reached.

The IPRP recommends revising the water quality projections and ecological risk assessment to examine multiple time periods including during remediation and after completion, taking into account the variability in constituent concentrations and the most recent concepts for stream relocation and seepage and groundwater interception systems. For the Project Proposal itis recommended that additional clarification be provided regarding the underlying assumptions and mathematical approaches employed in a more simplified summary format.

ADAPTIVE MANAGEMENT PLAN

In principle, the IPRP supports the strategy put forward for development and implementation of the Adaptive Management Plan (AMP) associated with the comprehensive remediation program for the three mine complex. In essence the plan relies almost exclusively on a systematic ground and surface water quality monitoring program with annual reviews of the data accompanied by a statistical analysis to identify trends useful in highlighting a need to modify the remediation program. It is important that the AMP distinguish between routine environmental monitoring and routine maintenance and actual modifications of the remediation plan to accommodate the host of likely and unforeseen changes that would occur over a period of decades or centuries.

There was only a limited discussion of how the review of these data would be integrated into a comprehensive quantitative assessment of the degree of success being realized in comparison with the original remediation plan as derived from the lengthy geochemical assessments, implementation of cover designs and the prediction of surface water quality.

Adaptive management is necessary for successful, cost effective environmental protection and reclamation given the uncertainty about many aspects of site performance and remediation and the long-term nature of the project. The IPRP vigorously supports an adaptive management process that includes a site specific approach, focusing on proactive monitoring to provide early warning of potential problems employing both environmental and statistical numerical triggers that ensure timely implementation of effective responses and corrective actions to protect the environment.

It cannot be assumed that the original geochemical predictions and associated decisions regarding the choice of remediation options are completely accurate. If that were the case there would be no need for adaptive management as the future success and impacts of the remediation would already be known.

The need for an adaptive management plan arises from the reality that goals may change and predictions are only estimates based on many informed but imperfect assumptions and limited observations which are not infallible.

One area of low predictability would be the effectiveness and durability of a specific cover once constructed. In comparison one area of high predictability and reliability would be treatment plant performance.

Therefore, as part of the AMP, the IPRP supports developing a rigorous evaluation protocol to monitor the physical integrity and hydrological performance of the covers. As mentioned previously, the IPRP supports continued field trials of cover performance for at least the next few years.

The IPRP believe it is sensible to continue year around collection at the three major seep areas at Faro, at a minimum until Rose Creek is raised and relocated. Once the creek has been raised, and the Rose Creek cut-off walls have been constructed and their performance demonstrated, an informed decision could be made as to the need to continue the localized capture systems. In addition to visual field examinations to identify seeps as potential new sources of contamination, the ultimate early detection system for identifying impacts would be ongoing in-stream monitoring of the aquatic ecosystems including aquatic insects, benthic organisms, algal species, and numbers and age classes of different fish species.

The adaptive management plan needs to recognize that although changes could occur gradually with sufficient time for implementation of corrective actions, this is not always the case. Unforeseen changes could occur rapidly for example related to geotechnical failures arising from natural events. Crossing hydraulic or geochemical thresholds could in some instances lead to rapid increases in contaminant concentrations and loadings as well as new discharge locations.

The closure and remediation plan needs to specify how the project would respond to periodic adverse natural events, such as fires or extreme temperature or precipitation events from adversely impacting the performance of remedial measures required for environmental protection. These events would most acutely affect the water management system including ground and surface water collection, routing, and storage.

The other important technical issue is the need to create a repository of site information, such as-built construction designs, results of field studies, and environmental monitoring data in a secure, accessible, and transparent manner which is continuously updated to allow tracking of changes to key remediation components and aid in guiding program modifications and management decisions.

ADDITIONAL TECHNICAL ISSUES

The following list includes additional technical issues previously raised by the IPRP for which there was no detailed discussion presented in Draft 4A:

- Draft 4A provided no additional information on the stability of the Grum Pit Wall. Comments provided on the previous draft of the Project Description related to individuals working the pit lake beneath an actively moving pit wall have not been addressed.

- There was no indication whether or not an evaluation has been completed to support the decision to leave the hydrocarbon contaminated soils at Faro and Grum in place for another 13 years before land farming scheduled to begin.

- No further advancements were noted in the design of either the Vangorda or Faro Creek diversion structures, both of which have been supported by the IPRP in previous reviews for early completion within the remediation plan.