Faro Mine Closure
Fermeture de la mine Faro

Options for Closure of the Faro Mine Complex

Prepared for:

Indian and Northern Affairs Canada | **Affaires indiennes et du Nord Canada**

and

Yukon Government

Prepared by:

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Project Reference Number
SRK 1CY001.011

February 2008

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Indian and Northern Affairs Canada (INAC)

and

Yukon Government, Assessment and Abandoned Mines

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SRK Project Number 1CY001.011

February 2008

Executive Summary

This document discusses options for the closure of the Faro Mine Complex. It is intended to support further evaluation of closure options by communities and governments, and selection of a preferred set of closure options by the Federal, Territorial and First Nation governments.

Background

The Faro Mine Complex consists of three main areas: the Faro Mine area, the Tailings area, and the Vangorda/Grum area. The Faro Mine area, located approximately 15 km north of the Town of Faro, includes the Faro Pit, waste rock dumps and the former ore processing facilities. The adjacent Tailings area includes a series of dams and impoundments located below the mine in the Rose Creek valley. The Vangorda/Grum area, located approximately 9 km northeast of the Town of Faro, includes the Vangorda and Grum Pits and waste rock dumps, as well as water treatment facilities.

The site includes over 300,000,000 tonnes of waste rock, which is rock that was mined to expose the ore, and over 50,000,000 tonnes of tailings, which are the finely ground rock residue from processing of the ore. (That’s enough waste material to completely fill BC Place Stadium more than seventy times!). The waste rock and tailings are acid generating, meaning that they release contaminants at accelerating rates the longer they remain exposed. Other concerns that need to be addressed in a closure plan include public and worker safety, contamination of water, risks from severe events (i.e. floods and earthquakes), contamination of air and land by dust, and possible direct contact of humans and animals with the metal-rich waste materials. All of the closure options discussed in this report are designed to address those issues.

Project Framework

In 2003, the Federal and Yukon Governments accepted responsibility for remediation of the Faro Mine Complex. In early 2004 Canada, Yukon, Selkirk First Nation and the Ross River Dena Council (on behalf of the Kaska Nation) endorsed a partnership agreement in which they committed to work cooperatively to develop a closure plan for the Faro Mine Complex. This role has been exercised through the creation of the project Oversight Committee, comprised of senior representatives from these four parties.

After an extensive program of public and stakeholder consultation, the Oversight Committee formulated five overarching objectives for the closure of the Faro Mine Complex:

1. Protect human health and safety;
2. Protect and, to the extent practicable, restore the environment, including land, air, water, fish and wildlife;
3. Return mine site to an acceptable state of use that reflects pre-mine land use where practicable;
4. Maximize local and Yukon socio-economic benefits; and
5. Manage long term site risk in a cost effective manner.

Canada and Yukon have dedicated internal resources to the development of a closure plan, creating the Faro Project Management Team. They have also provided resources to both First Nations to establish community offices for the closure planning project, including full-time coordinators in each First Nation community. A coordinated Technical Advisor team provides technical advice to the Faro Project Management Team. An Independent Peer Review Panel, comprised of nine international experts in fields relevant to the closure and remediation of the Faro Mine Complex, reviews major technical reports and supporting studies.

Development of Closure Options

Options for closure and remediation of the Faro Mine Complex have been under consideration for over 25 years. Several closure plans for the site or portions of it were developed during operations. The current closure planning process began in April 2002 with a series of technical workshops that included identification and screening of closure options.

Following the final closure planning workshop in January 2005, SRK Consulting Inc. was asked to lead the development of "example alternatives" to represent the range of options that the prior work had shown to be technically reasonable. Work on the example alternatives continued through mid-2006. Between September 2006 and March 2007, the Independent Peer Review Panel reviewed the example alternatives and the supporting technical documentation. This report incorporates recommendations arising from the 2006-2007 IPRP review as well as their subsequent review of a draft "options report."

Closure Options Recommended for Further Consideration

Common Elements

The options that are recommended for further consideration have many common elements:

- Covering of Waste Materials. Any remaining exposed waste rock or tailings will be covered with soil.
- Upgrade of Dams and Diversions. Remaining dams and diversions will be upgraded to meet conservative design criteria.
- Long-term Groundwater Collection. Contaminated water arising from contact with waste materials will be captured for treatment. It is expected that in all cases water treatment will be required for hundreds of years.
- Long-term Water Treatment. Contaminated water will be stored in the pits and then treated in a new water treatment plant.
- Risks to Water Quality in Creeks. There will always be a risk that contaminant concentrations in uncaptured seepage will increase to a level that will impact local creeks.

- Long-term Site Presence. Given the above requirements and risks, the site will require long-term (hundreds of years) supervision, including security, inspections, maintenance, and environmental monitoring.
- Adaptive Management. An “adaptive management plan” that describes uncertainties and the future changes that might be needed to address them, will be required in all cases.

Faro/Rose Creek Options

For the Faro Mine area, a single option is recommended for further consideration. For the Rose Creek tailings area, three options remain, Stabilize in Place, Complete Relocation and Partial Relocation. The Faro mine area and Rose Creek tailings options are combined into three “Faro/Rose Creek” options to simplify further assessments.

In the Faro Mine area, all of the waste rock would be regraded, covered with soil, and revegetated. The covers would be designed to reduce the amount of water that reaches the underlying waste. Water that becomes contaminated by seeping through waste materials will be collected and stored in Faro pit prior to treatment. The Faro Creek diversion would be upgraded in a stable location to continue routing clean water around the site in the long term.

The dry cover option for the Tailings area would leave all of the tailings in their current location, and cap them with a soil cover. The dams containing the tailings would be upgraded to withstand the maximum credible earthquake. The Rose Creek Diversion Channel, which carries Rose Creek around the tailings, would be upgraded to pass a 500-year flood. The channel would be configured so that any larger floods would pass over the covered tailings to a widened spillway on the north side of the valley. That arrangement would allow even the probable maximum flood to pass through the area without allowing any release of tailings.

The complete relocation option for the Tailings area would move all of the tailings into the Faro pit. The tailings relocation would require about fifteen years of seasonal work using hydraulic mining of the tailings and pumping of the resulting slurry up to the pit. Lime would need to be added to counteract the existing acidity in the tailings. The tailings relocation would be followed by excavation of contaminated footprint soils and many years of collecting and treating any impacted groundwater. Rose Creek would be restored to its original location only after completing the groundwater cleanup, estimated to be 10-20 years after the tailings relocation is finished.

The partial relocation option would move only the downstream half of the tailings to the pit. The methods used would be the same as those for the complete relocation option. The first half of the Rose Creek Diversion Channel, which wraps around the remaining tailings, would be upgraded to pass the probable maximum flood. The lower half would ultimately be redirected into the valley floor following soil and groundwater cleanup.

Vangorda/Grum Options

For the Vangorda/Grum area, two options are recommended for further consideration, the Stabilize in Place option and the Backfill Vangorda Pit option. For both options, the activities on the Grum side of the area are the same. The Grum waste rock pile would be regraded, covered with soil and revegetated. Contaminated water from the waste rock pile would be collected. The Grum Pit would serve as a storage reservoir for contaminated water prior to treatment.

The significant differences between the two options are on the Vangorda side. In the Stabilize in Place option, the Vangorda waste rock pile would be regraded and capped with a soil cover. In the Backfill Pit option, the Vangorda waste rock would be moved into the Vangorda pit where it would be covered. In the former option, Vangorda Creek would be moved to a new, more stable diversion somewhere uphill of its current alignment. In the latter option, Vangorda Creek would be routed over the backfilled pit in a constructed channel that approximates the creek's original alignment.

Initial Evaluation

A multi-attribute analysis method was developed and applied to examine the similarities and differences among the options. The analysis considered the performance of each option against eight objectives in both the short and long term, and under both expected and risk conditions. The eight objectives were re-statements of the five overarching objectives specified by the Oversight Committee:

- Maximize public health and safety;
- Maximize worker health and safety;
- Maximize restoration, protection and enhancement of the environment;
- Minimize restriction on traditional land use;
- Minimize restrictions on local land use;
- Maximize local socio-economic benefits;
- Maximize Yukon socio-economic benefits; and
- Minimize cost.

The analysis of the Faro Mine/Tailings options showed no significant difference in worker health and safety or Yukon socio-economic benefits. There were differences in the following categories:

- Public health and safety. The tailings relocation options scored slightly lower in the short-term, largely as a result of the increased highway truck traffic that would be required to bring lime to the site.
- Environmental restoration and protection. In general all options scored similarly under expected conditions. The dry cover option scored slightly higher in the short term, because it would allow final reclamation to be achieved many years sooner than the other options. The

complete relocation option was scored as having slightly less risk in the long term. The reason is that, although both the dry cover and partial relocation options can be designed to meet the highest level of stability criteria, there was concern that a loss of funding over the long term would lead to decreased maintenance and non-negligible risks of tailings releases.

- Local socio-economic benefits. The tailings relocation options scored slightly higher, largely because of the higher expenditures involved. However, detailed analysis showed that the bulk of the expenditures go to material purchases, so the differences in local socio-economic opportunities are much less than the differences in total expenditures.
- Traditional land use and Local land use. In both of these categories, the tailings relocation options scored slightly lower in the short term, due to the prolonged time before complete reclamation of the valley is achieved. The dry cover option was judged to have slightly higher risk in the long term.
- Cost. There are significant differences in cost. Implementation of the dry cover option is estimated to cost about 340 million dollars, the partial relocation option about 436 million dollars, and complete relocation about 560 million dollars. Long-term costs are estimated at 3.5 million per year for the dry cover option, 2.8 million per year for partial relocation, and 1.4 million per year for complete relocation. Taking uncertainties into account and expressing the total costs as net present values (calculated at a discount rate of 3%), the ranges are:
  - Dry Cover $380M – $500M
  - Partial Relocation $450M – $620M
  - Complete Relocation $530M – $770M

The analysis of the Vangorda/Grum options showed no significant differences in terms of worker health and safety, local socio-economic benefits or Yukon socio-economic benefits. There were differences in the following categories:

- Public health and safety. The backfill pit option scored slightly lower in the short term, largely as a result of the increased highway truck traffic associated with bringing lime to the site.
- Environmental restoration and protection. Both options are expected to perform well in the short and long term, but both have a risk that a loss of funding could lead to releases of contaminated water. The backfill pit option has a slightly wider range of expected performance. In the best case it could lead to complete restoration of the Vangorda side of the property, but in the worst case it could lead to greater problems if Vangorda Creek were to fail during the backfilling operation.
- Traditional Land use and Local land use. The backfill pit option scored slightly higher in both of these categories, because the entire Vangorda side of the property would eventually be reclaimed and available for traditional or local uses.
- Cost. There are significant differences in cost. Implementation of the Stabilize in Place option is estimated to cost about 57 million dollars, and the backfill pit option about 95 million dollars. Long-term costs are estimated at 0.9 million per year for the Stabilize in Place option, and

0.8 million per year for the backfill put option. In terms of total NPV costs, calculated at a discount rate of 3% and including uncertainties, the ranges are:

- Stabilize in Place $ 70M – $ 90M
- Backfill Pit $100M – $130M

Conclusion

The Technical Advisor Team, the Independent Peer Review Panel and the Faro Project Management Team all agree that the short-listed options represent the range of reasonable options for closure of the Faro Mine Complex, and that sufficient technical information is available to support the selection of a preferred option.

The differences among the options' performance with respect to the project objectives have been examined and documented. Further discussion of the options can now focus on the importance of those differences to each of the affected communities and stakeholders.

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1 Introduction

This document discusses options for the closure of the Faro Mine Complex. It is intended to provide a basis for further evaluation of closure options by communities and governments, and for selection of a preferred set of closure options by the federal, territorial and First Nation governments.

The remaining sections of the document present:

- An overview of the Faro Mine Complex;
- A description of the closure planning framework;
- A summary of the development of "example alternatives", their analysis, independent peer review, and recommendation of options for further consideration; and,
- An initial evaluation of short-listed options.

Seven attachments provide additional details about the alternatives and the initial assessment. Further information is available in several supporting documents listed in the references section.

2 Site Background

2.1 Overview

The Faro Mine Complex consists of the Faro Mine and Tailings areas, located approximately 15 km north of the Town of Faro, and the Vangorda/Grum area located approximately 9 km northeast of the Town of Faro. A 12 km haul road connects the two sites. The Faro Mine area includes the Faro Pit, waste rock dumps and the former ore processing facilities which have been retrofitted for water treatment purposes. The Tailings area includes a series of dams and impoundments located below the mine in the Rose Creek valley. The Vangorda/Grum area includes the Vangorda and Grum Pits and waste rock dumps, as well as water treatment facilities. All ore from Vangorda/Grum area was processed at the Faro Mine, so there are no processing or tailings in the Vangorda/Grum area.

The mine sites are located in the watersheds of two tributaries of the Pelly River. The Faro Mine and Tailings areas are in the Rose Creek watershed, which drains to the Pelly River via Anvil Creek. The Vangorda/Grum area is in the Vangorda Creek watershed, which joins the Pelly River at the Town of Faro.

The entire complex falls within the traditional territory of the Ross River Dena Council. Before mine development, people from Ross River utilized the area around the mine extensively for traditional activities. Details of this use are described in "*Just Like People Get Lost: A Retrospective Assessment of the Impacts of the Faro Mining Development on the Land Use of the Ross River Indian People*" (Weinstein, 1992). The Pelly River downstream of the mine site bisects the traditional territory of the Selkirk First Nation and is integral to the life and health of its people.

Figure 2.1 provides an overview of the Faro Mine Complex. For closure planning purposes, the Complex was divided into the three areas shown in Figure 2.1, namely the Faro Mine area, the Tailings area, and the Vangorda/Grum area. Each of these areas is described below. These short descriptions are only intended to provide an orientation that will prepare the reader for the subsequent discussions of closure options. Descriptions of the site components and environmental conditions were compiled in "2004-2008 Water Licence Renewal – Environmental Assessment Report" (Gartner Lee Ltd., 2003). Technical reports describing subsequent studies, investigations and designs provide additional detail about specific components and are referenced below where appropriate.

2.1.1 Faro Mine Area

Figure 2.2 provides an overview of the Faro Mine Area which includes the Faro Pit, Faro waste rock dumps, Faro Creek Diversion, ore stockpiles, the mill and other ancillary facilities.

Mining at the Faro Mine Complex began along the northwest side of the Faro Pit. The pit was expanded to the west and south until it reached its current size of roughly 1700 m long and 1000 m wide. The pit was allowed to flood in the 1990s, after the economically extractable ore was mined, and now contains a water body that is commonly referred to as the Faro Pit lake. The walls of the pit contain significant pockets of mineralized rock. Above the water level, this rock continues to release contaminants into the pit lake. Much of the south and east walls of the pit are covered by waste rock that also release contaminants into the water. The northeast pit wall is physically unstable, and is gradually ravelling downwards into the pit.

A second pit to the southeast, known as the Zone 2 Pit, was mined in the 1970's and 1980's. The Zone 2 pit was subsequently backfilled with waste rock and is no longer visible on surface. There is, however, a continuing need to extract contaminated water from the backfilled pit. Underground mining areas were also developed to the southwest of the main pit, through a portal that is now submerged by the pit lake.

Waste rock was deposited in a series of dumps that surround the pit. There is now a total of about 260 million tonnes of waste rock in the Faro dumps, and they cover roughly 335 ha of surface area. There are roughly 30 separate dumps, each with a unique history and composition.

The geochemistry of the dumps has been studied extensively (SRK 2004a, 2004b, 2006a, 2007a). At the broadest level, it is helpful to distinguish three groupings. The most mineralized material occurs in a series of low grade ore and oxide fines stockpiles. Although that material represents less than 10% of the total volume of waste, it has a high metals content and is therefore a significant source of contaminants. The next most mineralized material is found in three sulphide cells, which are areas where sulphide waste was purposefully segregated during some of the mining. The sulphide cells are not as well delineated as the low grade ore and oxide fines, so volumes are harder to estimate. But the relatively high metal content and acid generating potential of the material suggest that the sulphide cells are also disproportionately large sources of contaminants. The remainder of the waste rock dumps are variable in composition. In general however, there are areas of acidic and metal-leaching waste in most of the dumps, and none of the dumps can be considered completely benign.

Faro Creek initially flowed directly over the Faro Pit area and joined Rose Creek near the middle of the current tailings area. As the pit expanded, it was necessary to re-route the creek into its current alignment. The Faro Creek Diversion captures the water above the northernmost dumps and routes it to the northeast of the pit where it flows into the North Fork of Rose Creek. The diversion has been upgraded several times. However, recent studies have shown that it is not stable for the long term, and specifically further movement of the northeast pit wall will breach the channel if it is left in its current alignment (Golder Associates Ltd., 2004a).

The North Fork of Rose Creek flows below and to the southeast of the Faro mine area. The North and South Forks of Rose Creek join immediately upstream of the tailings area. The North Fork of Rose Creek passes in close proximity to several large waste rock dumps and flows through a rock drain constructed as part of the Vangorda haul road.

Infiltration through waste rock dumps is leading to contamination of groundwater at the Faro Mine Area. This groundwater contamination is causing increasing contaminant levels in some surface waters, though these surface water changes are not ecologically significant at this time. Contamination of groundwater is expected to increase significantly in the future.

Two main areas of groundwater contamination have been identified between the North Fork of Rose Creek and the adjacent waste dumps. The Zone 2 pit groundwater area is located below the Zone 2 pit, and the so-called "S-Well" area is located below at the southernmost extension of the Main Dump, where it branches off to the Vangorda haul road (SRK 2006b, 2007b). These areas are both located close to the North Fork of Rose Creek.

Significant groundwater contamination has also been identified in the Emergency Tailings Area (ETA), which is located below the mill and stockpiles (SRK, 2006c). As the name suggests, the area was used for emergency deposition of tailings, but recent studies have shown that the groundwater contamination arises at least in part from the waste rock located above the tailings. The ETA is also the only point in the Faro Mine area where there is significant surface water seepage from the waste rock. (Other seeps are ephemeral or internal.) Measures to capture the ETA surface and groundwater, and send it directly to water treatment, have recently been completed.

Ore processing took place in the mill complex located just southwest of the mine area. There are a number of structures in the mill area that remain in use, including the office, warehouse and the portions of the mill that have been converted to water treatment. The mill pad appears to consist of a range of rock materials, with hydrocarbon and metal contamination evident in many areas (Gartner Lee Ltd., 2006a).

2.1.2 Tailings Area

Figure 2.3 provides an overview of the Tailings Area which includes four dams (three tailings storage dams and one water polishing pond dam), the Rose Creek Diversion and various ancillary facilities.

Throughout most of the operating periods at the Faro Mine Complex, tailings were deposited in the three impoundments that comprise the Rose Creek tailings facility. The Original Impoundment was used from 1969 to 1975, has a surface area of 41.7 hectares, and holds about 6,300,000 m^3 of tailings. The Secondary Impoundment was used from 1975 to 1982 and again in 1986. It has a surface area of 54.5 hectares and contains about 10,400,000 m^3 of tailings. The Intermediate Impoundment was used from 1986 to 1992, has a surface area of 99 hectares and contains about 11,900,000 m^3 of tailings. (Tailings produced from 1992 to 1998 were deposited in the Faro Pit.)

The impoundments were created by a series of dams and dam raises. The dams that created the Original Impoundment are now almost entirely buried by the secondary tailings, but the Secondary and Intermediate Dams remain in function. The east limb of the Secondary Dam is relatively low, rising only about 4 m above the natural topography. The west limb of the Secondary Dam is higher, rising about 27 m, about half of which is now covered by the intermediate tailings. The Intermediate Dam is about 35 m high at its highest point.

The stability of the dams has been comprehensively investigated. Those studies concluded that the Intermediate Dam would be stable in the Maximum Credible Earthquake (MCE), but that weaknesses in the underlying soils mean that the Secondary Dam would require upgrading in two areas to ensure stability in the MCE (Klohn Crippen 2006a, 2006b). The geotechnical properties of the tailings have also been studied in detail, and the conclusion is that they would be subject to liquefaction and localized movement even in earthquakes that are less strong that the MCE (Golder Associates 2004b, 2006a, 2006b).

The Cross Valley Dam is located about 500 m downstream of the Intermediate Dam. It has a maximum height of about 19 m and creates a polishing pond for water discharged from the Intermediate Impoundment and the mill water treatment system. Studies of the stability of the Cross Valley Dam indicate that the underlying soils could liquefy in the MCE, and that substantial upgrades would be required to ensure stability (Klohn Crippen 2006a, 2006b).

A number of water management structures are also present in the tailings area. The most significant of these is the Rose Creek Diversion Channel, which routes the entire flow of Rose Creek around the tailings impoundments and Cross Valley pond. Recent reviews of the diversion and the local hydrology have concluded that a 1:500 year flood event could pass through the diversion, but that larger floods would spill onto the surface of the Intermediate Impoundment (nhc, 2006). Other water management structures of note include Guardhouse Creek and the North Wall Interceptor Ditch, which divert clean water from the north side of the valley, and the emergency spillways around the Intermediate and Cross Valley Dams.

The tailings contain an excess of acid generating sulphide minerals, and in fact most of the exposed tailings surface is quite acidic, with very high levels of soluble metals. The acidic conditions extend up to 6 m deep in the Original Impoundment. Precipitation passing through the tailings picks up some of the soluble contaminants and transports them down into the underlying tailings and soils.

Extensive groundwater investigations throughout the tailings area have identified an essentially continuous aquifer of sand and gravel outwash below the tailings. Sampling to date has identified increasing trends in concentrations of some contaminants in some areas beneath the tailings. However, this groundwater contamination is limited and is not ecologically significant at this time. One possibility is that the contaminants are being temporarily held up by reactions with the organic soils that lie between the tailings and much of the aquifer. Contamination of the groundwater below the tailings is expected to increase significantly at some time in the future. (Gartner Lee Ltd., 2007, Robertson GeoConsultants 2006, SRK 2006d).

2.1.3 Vangorda/Grum Area

Figure 2.4 provides an overview of the Vangorda/Grum Mine Area which includes the Vangorda Pit, Vangorda Waste Rock, Grum Pit, Grum Waste Rock, Grum Overburden, Vangorda Water Treatment Plant, Little Creek Dam and various ancillary facilities.

The Vangorda pit is about 1150 m long and 350 m across at its widest point. The deepest point in the pit was about 150 m from the crest, but the bottom of the pit is now completely flooded. The southeast half of the pit is narrower and shallower, and includes a ramp and ore and waste stockpiles. The Grum pit is roughly circular with a diameter of about 1000 m from crest to crest. A ramp that was cut as part of the Phase 2 expansion extends a further 300-400 m to the southeast. The north wall of the Grum Pit is a till slope that is gradually sliding into the pit. The pit bottom has been allowed to flood. Pit wall rock and waste rock continue to release contaminants into the water that accumulates in both pits. Water quality in Vangorda Pit is the worst of the three pits on the site (SRK 2006e).

There are three waste rock dumps in the Vangorda/Grum area. The Vangorda Dump contains about 16 million tonnes of material and covers about 40 hectares. The Grum Dump contains about 28 million tonnes of waste covering about 128 hectares. It includes a sulphide cell where most of the Grum sulphidic waste was placed. The Grum Overburden Dump covers about 46 hectares and contains overburden and till that was stripped from the surface of the Grum deposit. There are a number of much smaller waste deposits in the area, for example above the Vangorda Pit ramp and on the ore transfer pad located to the west of the Grum Pit.

Geochemical studies of the Vangorda/Grum waste rock indicate that the Vangorda waste is generally strongly acid generating. The walls of the Vangorda Pit and the in-pit dumps are also strong sources of acidity and metals. The sulphide cell in the Grum Dump also contains strongly acid generating material, but the remainder of the Grum Dump contains only pockets of acidic material (SRK 2004a, 2007a).

The Vangorda waste rock dump includes a seepage collection system and all water collected requires treatment before it can be released. The seepage from the dump is captured by a ditch and stored behind Little Creek Dam prior to transfer to the Vangorda pit and eventually the water treatment plant. Water quality down-gradient of the Grum Dump has also begun to deteriorate, but does not currently require treatment. Groundwater contamination is expected to increase in the future (SRK, 2006f).

The major water management structure in the area is the Vangorda Creek diversion. Prior to mining, Vangorda Creek flowed directly over the Vangorda deposit. The diversion was constructed to capture the creek and route it along the northwest rim of the pit. However, the diversion was designed for only a 1:100 year flood event, and it has required extensive maintenance since mining ceased. Furthermore, the pit wall below the diversion is expected to ravel back over time, and eventually cut off the current alignment of the diversion.

Other water management structures in the area include a water treatment plant and settling pond located above the Grum Pit, which are used to treat water from the Vangorda Pit and Waste Rock. There are also a number of small ditches and sediment ponds around both the Grum and Vangorda pits.

2.2 Site History

A brief review of the history of the Faro Mine Complex is helpful in understanding the current conditions.

Anvil Mining Corporation began operating the Faro Mine in 1969 and continued operations, under the name Cyprus Anvil Mining, until 1982 when economic conditions forced a shut-down. To support tailings disposal, Cyprus Anvil developed three tailings impoundments in the Rose Creek Valley. The second one, constructed in 1974, required an initial diversion of Rose Creek. The third one, developed in the early 1980s, necessitated construction of the existing Rose Creek Diversion Channel and two dams across the Rose Creek Valley.

Operations at the Faro Mine resumed under Curragh Resources Ltd. in 1986. Curragh recognized limited remaining resources in the Faro Pit and began seeking approvals and constructing infrastructure, including the 12 km Vangorda Haul Road, for mining at the Vangorda/Grum Mine. Mining at Vangorda commenced in 1990 and continued, concurrent with mining at Faro Mine, until mid-1992 when resources in the Faro Pit were depleted. Once mining ceased in Faro Pit, Curragh began depositing tailings in the Faro Pit. In late 1992, Curragh sought bankruptcy protection and ceased mining operations.

Operations resumed in 1994 under Anvil Range Mining Corporation who continued mining the Vangorda deposit and proceeded with the development of the Grum Deposit. Stripping of the Grum Pit began prior to the 1993-94 shutdown, but the bulk of the Phase 1 mining occurred from 1994-98. Processing of ore from the Grum deposit began in mid-1995. Anvil Range Mining Corp. terminated mining operations in late-1996 for economic reasons and, following a financial restructuring, restarted in 1997. Mining continued until 1998 when Anvil Range ceased mining operations and sought bankruptcy protection, with Deloitte and Touche Inc. appointed as interim receiver. At the time of closure, an expansion of the Grum Pit was underway and approximately 3-6 years of additional mining was anticipated. The mine has not operated since 1998 and is now considered permanently closed. The Faro Mine Complex remains in care-and-maintenance mode under the control of the Deloitte and Touche Inc.

In 2003, after seeking independent expertise about remaining mineral values at the mine, the federal and territorial governments concluded that the Complex did not have sufficient remaining value to support renewed operation or the costs associated with mine closure and reclamation. At that time, the governments agreed to accept responsibility for closure planning and closure implementation at the Faro Mine Complex.

2.3 Closure Issues

The brief site descriptions provided above mention most of the issues that drive closure planning at the Faro Mine Complex. In general, the key issues relate to public and worker safety, contamination of water, risks from severe events (i.e. floods and earthquakes), contamination of air and land by dust, and possible direct contact of humans and animals with metal-rich waste materials. All of the closure options discussed in this report are designed to address these issues.

Tables 2.1 to 2.3 provide component-by-component summaries of concerns that will need to be addressed by any closure plan.

Table 2.1: Closure Issues – Faro Mine Area

Site Component	Description of Issues
Faro Creek Diversion	The Faro Creek Diversion is located immediately adjacent to the Faro Pit. Flood flows or raveling of the pit wall will eventually breach the diversion causing the clean Faro Creek water to flow into the contaminated Faro Pit. If not corrected, this would lead to release of contaminated water from the pit, causing severe effects on aquatic ecosystems.
Faro Pit	Without pumping/treatment, the Faro Pit would eventually fill with water and overflow because inflows from runoff and seepage exceed outflows. The quality of water in the pit is affected by mineralized rock on the pit walls and by surrounding waste rock. The pit cannot be allowed to overflow because the water quality of the pit water would severely affect aquatic ecosystems if released without treatment. The water would be further contaminated because it would flow through the waste-rock-filled Zone 2 Pit before reaching the environment. Water quality is expected to remain problematic for several centuries.
Oxide Fines & Low-Grade Ore	The oxide fines and low-grade ore stockpiles are strongly mineralized materials and contain significant soluble contaminants. These stockpiles are contaminating groundwater. Without remediation, the level of contamination would increase over the next few decades, continue for several centuries and be sufficient to severely impair aquatic ecosystems. Oxide fines and low-grade ore may be contributing to transport of contaminants by dust.
Waste Rock	Much of the waste rock from the Faro Mine is acid-generating and will leach metals. The leaching process has begun and, without remediation, the contaminant loading from these materials would increase over the next several decades and continue for several centuries. While there are some segregated pockets (i.e. sulphide cells) of strongly acid-generating waste rock, the waste rock at the Faro Mine Site is generally poorly segregated. As a result, all of the waste rock dumps at Faro would release contaminants and could lead to severe contamination of aquatic ecosystems. Waste rock may be contributing to transport of contaminants by dust.
Emergency Tailings Area	Tailings and other materials placed in the old Faro Creek channel are leading to contamination of groundwater in this area. Waste rock dumps upgradient of the Emergency Tailings Area (ETA) are also contributing to the contaminant loads. The old Faro Creek channel likely serves as a conduit for transmission of contaminants into the aquifer in the Rose Creek Valley where, without collection and treatment, they would contaminate Rose Creek (RGC, 2006). If the loads present in the ETA were to reach Rose Creek, they would cause severe effects on the aquatic ecosystem. The ETA may be contributing to transport of contaminants by dust.

Table 2.2: Closure Issues – Tailings Area

Site Component	Description of Issues
Tailings	There are approximately 57 million tonnes of tailings stored in the Rose Creek Valley, behind three dams. The tailings are strongly acid-generating and those that have been exposed to air contain very high levels of soluble contaminants. These contaminants are moving down through the tailings and into the underlying sand and gravel aquifer (RGC, 2006). Although monitoring indicates that contaminants are not yet causing adverse effects on the aquatic environment, it also shows that some contaminants are mobile in the aquifer. Attenuation appears to be delaying the release of contaminants of concern, but this is expected to be temporary and once breakthrough occurs, the contaminant loads are expected to be sufficient to severely impair the aquatic ecosystem unless contaminated groundwater is collected and treated (SRK, 2006e). The tailings are expected to remain as a source of contaminants for several centuries. Contaminant transport in dust from the exposed tailings surface is causing widespread contamination of the terrestrial environment (GLL, 2006b). Without remediation, continued long-term accumulation of these contaminants in the surrounding environment would lead to adverse effects on the health of species that are of ecological and cultural importance (SENES, 2006).
Rose Creek Diversion	The Rose Creek Diversion which carries Rose Creek around the tailings and tailings dams is located above, and adjacent to, a large portion of the tailings and two major dams. A failure of the diversion during a flood could cause a dam failure and/or erode tailings, leading to severe effects on the downstream aquatic ecosystem. Such a failure would also affect traditional uses by local people, especially Selkirk First Nation citizens who live downstream. The flood routing capacity in the Rose Creek Valley needs to be upgraded because the current diversion does not have sufficient capacity for a probable maximum flood (Water Management Consultants, 2006, Taylor, 2005), the design event considered necessary for this facility. The current facility also requires upgrading to address susceptibility to other failure modes.
Tailings Dams	The tailings dams must provide a stable location for tailings containment because release of tailings to the environment would cause unacceptable long-term ecological effects. To avoid any tailings release, the dams must be capable of withstanding severe floods and earthquakes. The dams must perform satisfactorily for several centuries because the tailings are expected to remain a source of contamination in the long-term. Some dams need upgrading so that they can withstand the Maximum Credible Earthquake – the design event considered necessary for these facilities (Klohn Crippen, 2006a, 2006b).

Table 2.3: Closure Issues – Vangorda/Grum Mine Area

Site Component	Description of Issues
Vangorda Creek Diversion	The Vangorda Creek Diversion is located immediately adjacent to the Vangorda Pit. The Diversion was not designed for long-term service as the initial project plan envisioned re-routing of Vangorda Creek back through the mined-out Vangorda Pit. This is no longer possible due to water quality. The existing diversion requires extensive, ongoing maintenance and repairs to keep it functional. Without an upgraded diversion, flood events will breach the diversion causing clean Vangorda Creek water to flow into the contaminated Vangorda Pit. Storage in the Vangorda Pit is limited and if a diversion failure were not corrected quickly, it would lead to release of contaminated water from the pit, causing severe effects on aquatic ecosystems.
Vangorda and Grum Pits	Without pumping/treatment, the Vangorda and Grum Pits would both fill with water and overflow because inflows from runoff and seepage exceed outflows. The quality of water in both pits is affected by mineralized rock on the pit walls and by surrounding waste rock. The quality of water in Vangorda Pit is currently the worst of all three pits at the Faro Mine Complex. Vangorda Pit is also the smallest pit and would overtop most quickly without pumping and treatment. Water quality in Vangorda Pit is expected to remain problematic for several centuries. Release of this water without treatment would cause severe effects on the aquatic ecosystem. Without treatment, water quality in Grum Pit would also remain problematic at least for decades. The contaminant loads in Grum Pit, though sufficient to impair aquatic ecosystems, are not expected to be as severe as for Vangorda Pit.
Vangorda Waste Rock	The Vangorda Waste Rock dump contains a high proportion of acid-generating materials. Seepage from the Vangorda Waste Rock dump is currently collected and treated. The contaminant load is expected to continue increasing in the next few decades, and the water will likely require treatment for several centuries. Without collection and treatment, contaminant loads would be sufficient to severely impair aquatic ecosystems if not collected and treated.
Grum Waste Rock	The Grum Waste Rock Dump contains a segregated sulphide cell. Monitoring indicates that contaminant loading from the Grum Waste Rock dump is increasing over time. Without remediation, contaminant release from the sulphide cell and the other waste would increase over the next few decades, continue for several centuries and severely impair aquatic ecosystems. The sulphide cell will be the main source of contamination from the Grum Waste Rock.

3 Closure Planning Framework

3.1 Administrative Structure

In 2003, the federal and Yukon Governments accepted responsibility for remediation of the Faro Mine Complex. The Complex is identified as a "Type II Site" in the 2001 "Yukon Northern Affairs Program Devolution Transfer Agreement" (between the Governments of Canada and Yukon). This agreement created requirements for Canada, Yukon Government and affected First Nations, in this case the Selkirk First Nation and the Ross River Dena Council (on behalf of the Kaska Nation), to work cooperatively in addressing the site. The Devolution Transfer Agreement included Canada's acknowledgement of financial responsibility for closure and remediation of the Faro Mine Complex.

The overall project management and administration related to all Type II Sites including the Faro Mine Complex is directed by the Type II Steering Committee, comprised of senior representatives of Canada and Yukon, with Canada represented by Indian and Northern Affairs Canada and Yukon represented by the Department of Energy, Mines and Resources. Each government has established internal capacities to address their closure planning and project management responsibilities.

In early 2004 Canada, Yukon, Selkirk First Nation and the Ross River Dena Council (on behalf of the Kaska Nation) endorsed a partnership agreement in which they committed to work cooperatively to develop a closure plan for the Faro Mine Complex. This role has been exercised through the creation of the project Oversight Committee, comprised of senior representatives from these four parties. The Oversight Committee is tasked with providing overall strategic direction to the closure project, and with recommending a closure option for the Faro Mine Complex. The Committee has agreed that such a recommendation will only be made with the support of all members. On the basis of a consensus recommendation, Canada will seek funding approval for the closure plan development and implementation.

Canada and Yukon have dedicated internal resources to the development of a closure plan. The planning process is guided by the Faro Senior Project Manager and supported by other members of the Faro Project Management Team that includes internal staff as well as external technical consultants. Canada and Yukon have provided resources to both First Nations for the establishment of community offices for the Faro Mine Closure Planning project, including full-time coordinators in each First Nation community. The community offices have resources for technical assistance as necessary. Resources have also been provided to the Town of Faro for community liaison throughout the closure planning process.

A diverse team of technical consultants provides support to the Faro Project Management Team, advising on all aspects of closure planning as well as carrying out studies, investigations and designs. A Technical Advisor team coordinates the work of technical consultants and provides technical advice to the Faro Project Management Team.

The Oversight Committee and the Faro Project Management Team seek input, as necessary to support closure planning, from other groups and agencies. In 2006, the committee endorsed the establishment of an Independent Peer Review Panel (IPRP) comprised of nine international experts in fields relevant to the closure and remediation of the Faro Mine Complex. The IPRP continues to provide advice about the adequacy of the closure planning process and activities. Throughout the closure planning process, the Project Management Team has utilized ad-hoc technical working groups to support and advise on closure planning activities. These working groups have provided opportunities for participation by relevant government agencies.

3.2 Closure Objectives

Early in the closure planning process, the Oversight Committee recognized that reaching agreement about closure options would require a common understanding of what a closure plan needs to achieve. To support this, the Oversight Committee wanted to develop broad closure objectives that would guide the development and selection of closure options.

The development of closure objectives began by seeking input from all four governments involved in the closure planning process. Meetings and workshops were held in both Pelly Crossing (Selkirk First Nation) and Ross River (Ross River Dena Council). Both communities engaged technical expertise to help them develop input for the closure objectives. The closure planning team also sought input from departments in both the federal and territorial governments. At the same time, the governments carried out research to investigate processes for involvement of First Nations in the establishment of closure objectives for other northern mines. By late 2004, the closure planning team had compiled input from various sources and categorized the objectives and interests, with a few exceptions, into four main areas relating to human health and safety, environment, land use and socio-economic benefits. Subsequently, the Oversight Committee recognized that there were five overarching objectives on which all parties could agree.

1. Protect human health and safety;
2. Protect and, to the extent practicable, restore the environment, including land, air, water, fish and wildlife;
3. Return mine site to an acceptable state of use that reflects pre-mine land use where practicable;
4. Maximize local and Yukon socio-economic benefits; and,
5. Manage long term site risk in a cost effective manner.

Within these overarching objectives, each party had different and independent sub-objectives and interests, which were not always convergent. Ultimately, the Oversight Committee approved the five overarching objectives, each with some guiding principles.

The closure objectives approved by the Oversight Committee served as a starting point for the development of evaluation criteria used in the initial options assessment process described in Chapter 5 of this report.

3.3 Community Engagement

The Faro Project Management Team has endeavoured to maintain transparency throughout the closure planning process and seek input from governments, communities, other stakeholders and the public. This has been accomplished through a variety of forums including workshops, information sessions, meetings, open houses, working groups, site tours, home visits and published materials. The community coordinators have played an integral role in disseminating information in communities and in gathering and interpreting community input.

A series of closure planning workshops between 2002 and 2005 helped in scoping of closure issues, identification of closure methods and scoping of study programs. Participants at these workshops varied, but at times included representatives from federal and territorial government departments, First Nations, Town of Faro, regulatory agencies and land claim resource management agencies.

Government agencies, First Nations and communities provided ongoing input and advice related to various technical studies and investigations carried out as part of the closure planning work. This included participation in technical working groups. In some cases, investigators sought direct input from communities about their study programs – i.e. community input related to investigation of potential terrestrial contamination.

To help support community understanding of closure planning issues, the Faro Project Management Team has made many presentations in the communities of Faro, Pelly Crossing, Ross River and Whitehorse. Once technical studies were under way, the Team provided updates about the progress of studies, the findings and the conclusions/recommendations. At subsequent meetings the Team presented the closure alternatives and sought input about those alternatives. The issues and challenges associated with closure planning have been addressed in meetings and during site tours. The refinement of the alternatives into the closure options considered in Chapter 5 has also been discussed at meetings in each community. At all of these phases, the Team has also provided updates to local media.

Since 2004, the closure planning process has included meetings and discussions with the following communities, groups and agencies: Ross River Dena Council (community and leadership), Selkirk First Nation (community and leadership), Town of Faro (community and Mayor/Council), Federal Government Departments, Yukon Government Departments, Yukon Environmental and Socio-Economic Assessment Board, Selkirk Renewable Resources Council, Yukon Salmon Committee, Yukon Chamber of Mines, Yukon Chamber of Commerce, Yukon Conservation Society, Canadian Parks and Wilderness Society, Yukon River Intertribal Watershed Council and Yukon Mineral Advisory Board.

4 Development of Closure Options

4.1 Screening of Options

Options for closure and remediation of the Faro Mine Complex have been under consideration for over 25 years, through a series of processes.

Several studies related to the closure of portions of the site were completed during operations (Klohn Leonoff 1981, Curragh Resources 1988, SRK 1991). Attachment A-1 provides a summary of the options that were considered in those reports. An Integrated Closure and Abandonment Plan or "ICAP", was produced for the site operator in 1996 (RGC 1996). It was reviewed by regulatory agencies and other interested parties but never approved or revised. Attachment A-2 provides a summary of the options that were considered in the 1996 ICAP.

The Interim Receiver initiated a review of the ICAP in 2002, as part of the application for a new Water License (Deloitte & Touche, Inc. 2003a). That work included review of all of the options assessed in the ICAP and the previous closure-related studies. It concluded that there were several options that could no longer be implemented and others that would not meet approval of the broader range of stakeholders that are now involved in the project.

The Interim Receiver therefore organized a series of technical workshops to initiate development of a new closure plan. Over the period April 2002 to January 2005, there were a total of five workshops, each of which included screening of closure options. Attendees at the workshops included specialist consultants in the key technical disciplines, as well as representatives of the federal, territorial and First Nation governments, the town of Faro, Yukon regulatory agencies, Environment Canada, the Department of Fisheries and Oceans, and the Yukon Salmon Committee. The workshop discussions and conclusions are summarized in a series of reports (Deloitte & Touche Inc. 2003b, 2004a, 2004b, 2005).

At each workshop, participants developed lists of methods that could be used to close various parts of the Complex. The methods were reviewed and the technical uncertainties preventing selection of preferred methods were identified. Studies to resolve the critical uncertainties were then designed. Over the years 2003-2006, approximately forty of these studies were undertaken, at a total cost of several million dollars. Attachment A-3 summarizes the closure options that have been considered in the 2003-2006 project reports.

4.2 Example Alternatives

4.2.1 Project Overview

In February 2005 following the final in the series of closure planning workshops, SRK was asked to lead the development of "example alternatives" to represent the range of options that the prior work had shown to be technically reasonable.

SRK prepared an initial list of options and circulated it to other project participants including the federal and Yukon government departments, the Faro Project Management Team, and the Ross River and Selkirk First Nations. The list was then modified based on feedback from the other participants. A number of critical uncertainties about the design of some of the options were also identified, and the project team worked to resolve these over the next several months.

In November and early December, 2005, the "example alternatives" were reviewed by a small team consisting of SRK and Faro Project Management Team staff, and a complete set of sketches and cost estimates was prepared for each of the alternatives. Results from studies of post-closure water quality, ecological and human health risk (SENES, 2006) became available and were integrated into the analysis.

In January and February, 2006, a series of meetings were held to identify and evaluate the risks associated with each example alternative. Participants in the meetings included technical representatives from the Faro Project Management Team, the federal and Yukon governments, the Ross River and Selkirk First Nations, and SRK. Each example alternative was reviewed and major risks identified. The alternatives were then modified to reduce risks, where practicable. New alternatives were also developed to represent a wider range of options. Lastly, the risk identification process was repeated to characterize residual risks, i.e. the risks that are inherent in each alternative even after all reasonable risk mitigation measures are added.

In September 2006, an Independent Peer Review Panel (IPRP), made up of nine of North America's leading experts in the scientific and engineering disciplines underlying mine closure planning, was commissioned to review the example alternatives and the supporting technical documentation. The IPRP produced its final report on the example alternatives in March 2007. One of the significant findings of the IPRP report was that an additional alternative, based on a water cover over the tailings, should be considered.

The following subsections describe the example alternatives for each of the Faro Mine, Tailings and Vangorda/Grum areas. To simplify the presentation, the water cover option proposed by the IPRP is included as an additional example alternative. Other outcomes from the peer review process are discussed in Section 4.3.

4.2.2 Faro Mine Area

Table 4.1 summarizes the four example alternatives for the Faro Mine Area. The upper portion of the table lists the closure methods that would be applied to each component. The lower portions provide estimated costs and residual risks.

Components

All of the four example alternatives require long-term management of contaminated water. There will also be various requirements for long-term inspections, maintenance and repairs of clean water ditches, contaminated water collection system, soil covers and water treatment equipment.

The major differences among the alternatives reflect different approaches to:

- Closure of the Faro Creek Diversion, which was assumed to be either rerouting of Faro Creek into the Faro Pit, or continued diversion of Faro Creek around the Faro Pit;
- Long-term water treatment, which was assumed to be either biological water treatment in the Faro Pit, or chemical water treatment in a treatment plant; and,
- Reducing contaminant loadings from waste rock, which in all cases involves construction and revegetation of soil covers, but with different levels of waste relocation and different cover designs.

Attachment B-1 provides more detailed descriptions of the Faro Mine Area example alternatives. Attachment C provides details on the assumptions related to the design and performance of the soil cover systems.

Estimated Costs

The cost estimates are divided into two categories. The “closure phase total costs” include all of the direct and indirect expenditures to construct the closure measures. “Post-closure costs” are the continuing long-term costs required for running of the water collection and treatment systems and for monitoring, inspection, maintenance and repairs. The post-closure costs will vary from year to year, but for simplicity are shown as an average annual cost in the table.

The table also shows post-closure costs converted to a net present value (NPV). The NPV calculations assume that the post-closure activities will be required in perpetuity, and use a net discount rate of 3%. A simple way to interpret the NPV is that it is the amount of money that would need to be put into the bank today in order to fund perpetual post-closure activities, if the bank provided an interest rate of 3% above the rate of inflation. One advantage of the NPV method is that it allows the closure and post-closure costs to be summed to provide the overall NPV costs for each alternative, which are also shown in the table.

Residual Risks

The residual risks shown in Table 4.1 include all of the high or very high risks identified through the evaluation process described in Section 4.2.1. The risks are grouped into four categories that appeared repeatedly in the evaluations.

One, all of the Faro mine area alternatives carry some level of risk that the covers and groundwater collection systems will not perform as well as expected, or that the seepage water chemistry will be worse than estimated. However, the amount of risk varies from one alternative to another.

- Under the Minimize Construction alternative, almost any combination of poor cover performance, poor groundwater collection, and/or contaminant concentrations above the estimates would lead to long-term contamination of Rose Creek.
- Under the Flow-Through Pit and Upgrade Faro Creek Diversion alternatives, only the S-Well groundwater collection system, which requires a high capture efficiency in difficult ground conditions, presents a high risk. The other risks are also present in these alternatives, but are less than in the Minimize Construction case.
- Under the Minimize Water Treatment alternative, the improved control of the contaminant sources reduces all of these risks. However, because the collection of contaminated water will be required even in this alternative, the risks are not completely eliminated.

Two, all of the alternatives have roughly equal levels of risk related to failure of the contaminated water collection and treatment systems. Good maintenance and repair policies can reduce the risk of equipment failures. To reduce these risks over the very long term, however, will also require good management, funding and project control systems.

Three, Alternative 1, which relies entirely on in-pit biological treatment, is at risk of water treatment system failures. The in-pit biological method is not yet proven, and in any case will only work seasonally, meaning that large freshet inflows of water may need to be released without complete treatment.

Four, cost increases are a risk with any project of this scale. The alternatives with less robust water treatment systems (Alternative 1) and less robust soil covers (Alternative 3) are at greater risk of unexpectedly high operating and maintenance costs.

More details of the risk evaluation process and results are provided in Attachment D.

Table 4.1: Faro Mine Area Example Alternatives

	Alternative 1 Flow-Through Pit	Alternative 2 Upgrade Faro Creek Diversion	Alternative 3 Minimize Construction	Alternative 4 Minimize Water Treatment
Components and Closure Methods				
Surface Water Diversions	Re-route Faro Creek to pit. Raise North Fork as needed to prevent contamination by seepage or contaminated groundwater.	Upgrade Faro Creek Diversion now. Raise North Fork as needed to prevent contamination by seepage or contaminated groundwater.	Upgrade Faro Creek Diversion in future as needed Raise North Fork as needed to prevent contamination by seepage or contaminated groundwater.	Upgrade Faro Creek Diversion now. Raise North Fork as needed to prevent contamination by seepage or contaminated groundwater.
Contaminated Water Management	Collect contaminated groundwater in ETA, S-well and Zone II areas. Store water in pit for seasonal biological treatment.	Collect contaminated groundwater in ETA, S-well and Zone II areas. Store in pit for seasonal treatment in High Density Sludge plant.		Collect contaminated groundwater in ETA, S-well and Zone II areas. Store in pit for seasonal treatment in High Density Sludge plant with possible future switch to biological treatment in pit.
Waste Rock				
Oxide Fines/ Low-Grade Ore	Consolidate with plastic cover	Consolidate with plastic cover	Cover with 0.5 m soil and revegetate	Relocate to Pit with lime
Sulphide Cells	Cover with 2 m soil and revegetate	Cover with 2 m soil and revegetate	Cover with 0.5 m soil and revegetate	Consolidate with 2.5m soil cover
Faro Valley Dump	Cover with 0.5 m soil and revegetate	Cover with 0.5 m soil and revegetate	Cover with 0.5 m soil and revegetate	Relocated to sulphide cell with 2.5m soil cover and revegetate
Other Waste Rock	Reslope and cover with 0.5 m soil and revegetate	Reslope and cover with 0.5 m soil and revegetate	Cover flat areas with 0.5m soil and revegetate. No resloping	Reslope and cover with 2 m soil and revegetate
Faro Pit	Store contaminated water for in-pit biological treatment. Discharge water each year after treatment is effective.	Construct berm around pit rim to reduce risk of inadvertent access. Use pit for storage of contaminated water.		
Emergency Tailings Area	Relocate tailings and collect groundwater	Relocate tailings and collect groundwater	Leave as is	Relocate tailings and collect groundwater
Estimated Costs				
Closure Phase Total Cost	$80,900,000	$82,000,000	$38,400,000	$217,300,000
Average Annual Post-Closure Cost	$1,150,000	$1,110,000	$1,150,000	$1,130,000
Post-Closure NPV	$38,400,000	$33,300,000	$35,000,000	$34,100,000
Closure + Post-Closure NPV	$119,300,000	$115,300,000	$73,400,000	$251,400,000
Residual Risks				
Performance of Covers & Groundwater Collection Systems	Combinations of higher than estimated contaminant loadings, poor soil cover performance, or ineffective groundwater capture could lead to significant increases in contaminant levels in Rose Creek and Anvil Creek. Alternatives that include better soil covers generally have lower risks.			
Operation of Groundwater Collection System	Short-term failures, e.g. two week upsets due to mechanical or power supply problems, could result in significant but temporary increase in contaminant levels in Rose Creek and Anvil Creek. Longer term failures, e.g. loss of funding for several years, would result in fish kills in Rose Creek and Anvil Creek, but are very unlikely to affect Pelly River. All of the alternatives require diligent operation of a water collection and treatment system, and therefore all have these types of residual risk.			
Performance of Water Treatment System	In-pit biological treatment is not proven, and is only effective seasonally leading to significant risk that incompletely treated water will need to be discharged at some time.	High Density Sludge treatment method is well proven and low risk.		
Cost Increases	Closure phase costs may be higher than estimated, due to inflation and/or locally high demand for construction equipment and operators. Long-term maintenance and repair costs may also be higher for the same reason. Alternatives with less robust covers (Alt. 3) may also have higher than estimated repair and maintenance requirements. Alternatives that rely on biological treatment (Alt. 1) may experience much higher treatment costs if that method proves infeasible over the long term.			

4.2.3 Tailings Area

Components

Table 4.2 summarizes the example alternatives for the tailings area. The initial example alternatives were developed around the following concepts:

- Leaving the tailings in place with a soil cover;
- Relocating all of the tailings to the Faro Pit; and,
- Relocating some of the tailings and covering the remainder in place.

A fourth alternative, where the tailings were left in place without a soil cover was added to expand the range of considerations. The IPRP subsequently recommended a fifth alternative. The so-called “water cover” alternative has now been more fully assessed and is also included in Table 4.1.

As Table 4.1shows, the differences in the broad concepts lead to different requirements for almost every component of the tailings area. The biggest distinction is whether tailings remain in place or are relocated. Alternative 2, which completely relocates the tailings to the Faro Pit, will require 10-15 years of relocation activities followed an estimated 10-20 years of groundwater cleanup. All of the other alternatives leave at least some of the tailings in the valley, and will therefore require long-term management of contaminated water.

The “leave in place” alternatives differ in how they would deal with the Rose Creek Diversion. Alternatives 1 and 4 include upgrading of the entire Rose Creek Diversion to enable it to pass the Probable Maximum Flood (PMF). Alternative 3 includes relocation of the tailings below the most hazardous sections of the Rose Creek Diversion, so that the creek can eventually be routed back to the valley floor over those reaches. Alternative 5 also takes to creek out of the most hazardous sections of the diversion, but in this case routes it over the tailings pond to a new spillway on the north side of the valley.

The “leave in place” alternatives also differ in how they would manage the tailings surface. Alternatives 1 and 3 include soil covers to limit infiltration and prevent dust release or direct uptake of tailings by animals. Alternative 5 includes a water cover to limit further tailings oxidation and prevent dust and direct uptake. Alternative 4 would not control infiltration or oxidation, and would rely on dust suppressant and fences to prevent dust release and direct uptake. All of the alternatives include relatively simple geotechnical modifications to make the dams stable, even in the Maximum Credible Earthquake (MCE).

Attachment B-2 presents further details on Alternatives 1 through 4, and Attachment B-3 presents further detail on Alternative 5.

Costs

There are wide differences in the costs of the tailings area alternatives. Some of the high costs associated with tailings relocation (Alternatives 2 and 3) will be recovered in the form of lower long-term costs. But the complete relocation option (Alternative 2) is still much more costly, overall, than any of the "leave in place" options.

Residual Risks

The alternatives that leave some or all of the tailings in place present risks that more water will infiltrate the tailings surface (with or without a cover), that the resulting groundwater contamination will be more severe, and/or that the long-term groundwater collection system will not perform as well as predicted. Any of these risks could result in significant increases in contaminant levels in Rose Creek and Anvil Creek. The Complete Relocation alternative does not leave tailings in the valley and therefore does not have significant risks of this type.

As was the case for the Faro Mine area, temporary failure of the groundwater collection system could also lead to downstream contamination. Again, only the alternatives that leave some or all of the tailings in place have significant risks of this type; the Complete Relocation alternative does not.

As long as there are tailings remaining behind a dam, there is at least some risk of the dam breaching in a flood, resulting in the release of tailings to Rose Creek, Anvil Creek and possibly the Pelly River. There are significant differences in how the alternatives address these risks:

- In the Stabilize in Place alternative and Minimize Construction alternatives (Alternatives 1 and 4), the Rose Creek Diversion remains above the tailings over much of its length. Failure of that channel, for example due to poor maintenance coupled with a severe flood, could cause a breach of the Intermediate Dam and a very significant outflow of tailings.
- The Partial Relocation alternative (Alternative 3) eliminates the more hazardous portion of the Rose Creek Diversion. The Secondary Dam could conceivably still fail, but there is much less potential for a significant amount of tailings to be flushed downstream.
- The Water Cover alternative (Alternative 5) also eliminates the more hazardous portion of the Rose Creek Diversion, but does so by creating a new channel over the tailings surface. There would be risks associated with maintaining such a broad, low gradient channel. In particular, the channel would be prone to blockage by ice.

The two groups of cost-related risks are also common to the tailings area alternatives. There is a risk that implementation costs will be higher than expected in all cases. These risks are higher for the Complete Relocation alternative, due to the extended duration of the relocation work and the exposure to changes in third party prices such as for lime and power. The four "leave in place" alternatives have higher risks associated with long-term operating, maintenance, or repair costs. Two examples are the risk that a significant earthquake could damage the tailings covers, and the risk that maintenance costs for the Rose Creek Diversion will be higher than estimated.

Table 4.2: Tailings Area Example Alternatives

	Alternative 1 Stabilize in Place	Alternative 2 Complete Relocation	Alternative 3 Partial Relocation	Alternative 4 Minimize Construction	Alternative 5 Water Cover
Components and Closure Methods					
Surface Water Diversions	Upgrade entire length of Rose Creek Diversion to pass Probable Maximum Flood (PMF).	Keep Rose Creek in channel during relocation and for roughly 20 years of groundwater cleanup, then re-route it to the valley floor.	Upgrade Secondary Dam portion of Rose Creek Diversion to PMF. Re-route remainder to valley floor after tailings relocation and groundwater cleanup.	Upgrade entire length of Rose Creek Diversion to pass Probable Maximum Flood (PMF).	Upgrade Secondary Dam portion of Rose Creek Diversion to PMF. Route remainder over tailings surface to new spillway on north side of Intermediate Dam.
Contaminated Water Management	Install well system along toe of Cross Valley Dam. Collect contaminated groundwater. Store in pit for seasonal treatment.	Collect contaminated groundwater from tailings footprint for estimated 10 to 20 years. Store in pit for seasonal treatment.	Install well system along toe of Secondary Dam to collect contaminated groundwater from tailings. Also collect groundwater from footprint of relocated tailings. Store in pit for seasonal treatment.	Install well system along toe of Cross Valley Dam. Collect contaminated groundwater. Store in pit for seasonal treatment.	Construct cut-off wall through Intermediate Dam to reduce seepage rates through tailings. Install well system along toe of Cross Valley Dam. Collect contaminated groundwater. Store in pit for seasonal treatment.
Tailings					
Original & Secondary	Construct 2 m thick rock/soil cover. Revegetate.	Complete a 10-15 year project to hydraulically mine and pump all tailings to the Faro Pit, with lime addition to neutralize acidity.	Construct 2 m thick rock/soil cover. Revegetate.	Fence tailings and apply dust suppression measures annually.	Partially relocate to Intermediate tailings to create level surface and cover with pond.
Intermediate			Relocate to Faro Pit		Cover with relocated Secondary tailings and cover with pond.
Dams					
Cross-Valley	Remove (Breach)				
Intermediate	No Action	Remove (Breach)	Remove (Breach)	No Action	Raise and Construct new spillway
Secondary	Upgrade to MCE	Remove (Breach)	Upgrade to MCE	Upgrade to MCE	Upgrade to MCE
Original	No Action	Remove (Breach)	No Action	No Action	No Action
Estimated Costs					
Closure Phase Total Cost	$136,100,000	$421,900,000	$257,400,000	$62,300,000	$238,900,000
Average Annual Post-Closure Cost	$1,730,000	$990,000 (35 years only)	$1,440,000	$1,910,000	$1,680,000
Post-Closure NPV	$47,600,000	$15,200,000	$37,900,000	$51,500,000	$47,900,000
Closure + Post-Closure NPV	$183,700,000	$437,100,000	$295,300,000	$113,800,000	$286,800,000
Residual Risks					
Performance of Covers & Groundwater Collection Systems	Poor soil cover performance or ineffective groundwater capture could lead to significant increases in contaminant levels in Rose Creek and Anvil Creek.	Covers are not needed and groundwater collection is only planned for 10-20 years, so risks are low.	Poor soil cover performance or ineffective groundwater capture could lead to significant increases in contaminant levels in Rose Creek and Anvil Creek.	With no covers in place, this alternative would be subject to high risks that contaminant loadings could increase, and risks related ineffective performance of groundwater capture.	Cut-off wall would reduce rate of groundwater flow, but not level of contaminant loadings, so this alternative remains at risk from ineffective groundwater capture.
Operation of Groundwater Collection System	See Alternatives 3, 4, 5	Short-term failures are possible during the 10-20 year period of groundwater cleanup.	Short-term failures could result in significant but temporary increase in contaminant levels in Rose Creek and Anvil Creek. Longer term failures, e.g. loss of funding for several years, would result in fish kills in Rose Creek and Anvil Creek, but would be very unlikely to have any effect on the Pelly River.		
Dam Failure or Breach and Tailings Release	Risk of Rose Creek Diversion being blocked, leading to dam breach and tailings release.	Dam failures only a risk for 10-15 years.	Dam failures only a risk for 10-15 years.	Risk of Rose Creek Diversion being blocked, leading to dam breach and tailings release.	Risk of cross-tailings channel being blocked by ice, leading to breach and tailings release.
Other Maintenance Failures	Failure of North Wall Interceptor would erode tailings into streams.	North Wall Interceptor failure a risk only for 20-35 years.	Failure of North Wall Interceptor would erode tailings into streams.	Failure of North Wall Interceptor would erode tailings into streams. Failure to apply dust suppressant would lead to contamination of surrounding land.	Failures of North Wall Interceptor or cross tailings channel would erode tailings into streams.
Cost Increases	Common to all alternatives. Alternatives involving tailings relocation are generally more at risk of cost increases.				

4.2.4 Vangorda/Grum Area

Components

Table 4.3 summarizes the example alternatives for the Vangorda/Grum area.

The major differences among Alternatives 1 and 2 arise from a decision either to place the Vangorda waste rock back in the Vangorda Pit (SRK, 2006g), or to stabilize it in place. Alternatives 3 and 4 represent further expansion on those two approaches.

The Vangorda waste rock and pit are significant sources of contaminated water, so the decision about backfilling the waste rock into the pit constrains selection of a water treatment methodology. If the Vangorda waste rock is relocated to the Vangorda Pit, biological treatment in the Grum Pit could be the primary and possibly the only water treatment method (SRK, 2006h). If the Vangorda waste rock is stabilized in place, long-term chemical water treatment will certainly be necessary.

In addition to the above components, all closure alternatives for the Vangorda/Grum area include long-term groundwater collection and covers for the Grum waste rock.

Attachment B-4 provides further detail on the example alternatives for the Vangorda/Grum area.

Costs

Estimated costs for the four Vangorda/Grum alternatives are shown in Table 4.3. Again there is a clear difference between the two alternatives that include backfilling of the Vangorda pit and the two that do not. The difference reflects the high cost of the Vangorda waste neutralization and relocation. Other cost differences among the alternatives are largely attributable to differences in the cover design.

Residual Risks

All of the Vangorda/Grum alternatives have risks associated with performance of the waste rock covers and groundwater collection systems, and uncertainty in the water quality predictions. However, there are significant differences among the alternatives:

- Under the Backfill Vangorda Pit, Stabilize Current Situation, and Minimize Water Treatment alternatives, the high risks are those associated with the Grum Dump. In particular, if the Grum Dump becomes more acidic than is currently predicted, the requirements for cover performance and groundwater collection would increase.
- The Minimize Construction alternative shares the risks associated with the Grum Dump, and heightens them because of the relatively poorer cover and groundwater collection system. In addition, the poorer covers on the Vangorda Dump, which is already acidic, create additional risks.

Unlike the Faro Mine area and the tailings area, short-term failures of groundwater collection in the Vangorda/Grum area are less likely to lead to significant environmental impacts. The reason is that the contaminated groundwater in this area moves more slowly. Only the Minimize Construction alternative has a significant risk in this group, and it arises because of the possibility that a delay in detecting the escape of groundwater contamination could allow some of it to pass beyond the zone from which it could be re-captured.

Risks associated with the failure of, or damage to, the Vangorda Creek diversion also differ among the four alternatives. In alternatives where Vangorda Pit is backfilled (Alternatives 1 and 4), Vangorda Creek would be returned to its original alignment. The Stabilize in Place alternatives include relocation and upgrading of the diversion, but there would remain a possibility of failure in future. The Minimize Construction alterative does not include relocation or major upgrading of the diversion, and therefore would carry a higher risk of diversion failure. If the diversion were to fail during a flood, water would fill the Vangorda pit within one or two weeks, and release of the very contaminated pit water would result.

The Backfill Vangorda Pit alternative has a risk that implementation costs will be higher than expected, due principally to uncertainty in the amount and cost of lime that would need to be added to the waste rock prior to backfilling. Risks of increased operating, maintenance and repair costs are common to all of the Vangorda/Grum alternatives. The primary risks are those arising from uncertainties in groundwater collection costs at the Grum Dump, and the possibility that the Grum Pit passive water treatment system might need to be replaced by an active treatment system.

Attachment D provides further discussion of the risk evaluations.

Table 4.3: Vangorda/Grum Area Example Alternatives

	Alternative 1 Backfill Vangorda Pit	Alternative 2 Stabilize in Place	Alternative 3 Minimize Construction	Alternative 4 Minimize Water Treatment
Components and Closure Methods				
Surface Water Diversions	Re-route Vangorda Creek in erosion protected channel over backfilled pit. Maintain Grum Creek diversion.	Upgrade Vangorda Creek Diversion now. Maintain Grum Creek diversion.	Upgrade Vangorda Creek Diversion in future as needed. Maintain Grum Creek diversion.	Re-route Vangorda Creek in erosion protected channel over backfilled pit. Maintain Grum Creek diversion.
Contaminated Water Management	Collect contaminated groundwater below Grum Dump. Store in Grum Pit for biological treatment. Include contingencies for collection of Vangorda Pit groundwater and HDS treatment of Grum Pit water.	Collect contaminated groundwater below Grum Dump and Vangorda Waste. Store in Vangorda Pit for periodic extraction and chemical treatment in High Density Sludge (HDS) plant.	Collect contaminated groundwater below Grum Dump and Vangorda Waste. Store in Vangorda Pit for periodic extraction and chemical treatment in High Density Sludge (HDS) plant.	Collect contaminated groundwater below Grum Dump. Store in Grum Pit for biological treatment. Include contingencies for collection of Vangorda Pit groundwater and HDS treatment of Grum Pit water.
Waste Rock				
Vangorda Waste Rock	Relocate to Vangorda Pit. Add lime to neutralize acidity. Compact during backfilling to reduce permeability.	Cover with 2 m soil and revegetate	Cover with 0.5 m soil and revegetate	Relocate to Vangorda Pit. Add lime to neutralize acidity. Compact during backfilling to reduce permeability.
Grum Sulphide Cell	Cover with 2 m soil and revegetate	Cover with 2 m soil and revegetate	Cover with 0.5 m soil and revegetate	Consolidate with 2.5m soil cover
Other Grum Waste Rock	Reslope and cover with 0.5 m soil and revegetate	Reslope and cover with 0.5 m soil and revegetate	Cover flat areas with 0.5m soil and revegetate. No resloping	Reslope and cover with 2 m soil and revegetate
Ore Transfer Pad	Relocate ore to Vangorda Pit and cover remainder with 0.5 m soil and revegetate	Relocate ore to Grum Sulphide cell and cover remainder with 0.5 m soil and revegetate	Cover with 0.5 m soil and revegetate	Relocate ore to Vangorda Pit and cover remainder with 2 m soil and revegetate
Vangorda Pit	Backfill with neutralized Vangorda waste rock to cover all pit walls.	Construct berm around pit rim. Use pit lake for storage of contaminated water.	Construct berm around pit rim. Use pit lake for storage of contaminated water.	Backfill with neutralized Vangorda waste rock to cover all pit walls.
Grum Pit	Construct berm around pit rim. Use pit lake for storage and biological treatment of contaminated water.	Construct berm around pit rim.	Construct berm around pit rim.	Construct berm around pit rim. Use pit lake for storage and biological treatment of contaminated water.
Estimated Costs				
Closure Phase Total Cost	$86,400,000	$37,000,000	$16,800,000	$110,100,000
Average Annual Post-Closure Cost	$610,000	$950,000	$970,000	$670,000
Post-Closure NPV	$17,200,000	$28,000,000	$28,300,000	$12,200,000
Closure + Post-Closure NPV	$103,600,000	$65,000,000	$45,100,000	$122,300,000
Residual Risks				
Performance of Covers & Groundwater Collection Systems	Combinations of higher than estimated contaminant loadings, poor soil cover performance, or ineffective groundwater capture could lead to significant increases in contaminant levels in Vangorda Creek.			
Operation of Groundwater Collection System	Short-term failures, e.g. two week upsets due to mechanical or power supply problems, are unlikely to cause environmental problems. Longer term failures, e.g. loss of funding for several years, would result in fish kills in Vangorda Creek.			
Vangorda Creek Risks	New alignment of creek would be designed for energy dissipation and erosion protection. Low risk.	Failure of diversion would lead to rapid filling of Vangorda Pit and discharge of contaminated water.	Failure of diversion would lead to rapid filling of Vangorda Pit and discharge of contaminated water.	New alignment of creek would be designed for energy dissipation and erosion protection. Low risk.
Cost Increases	Closure phase costs may be higher than estimated, due to inflation and/or locally high demand for construction equipment and operators. Long-term maintenance and repair costs may also be higher for the same reason. Alternatives with less robust covers (Alt. 3) may also have higher than estimated repair and maintenance requirements. Long-term water collection and treatment costs could increase if Grum Dump becomes more acidic than expected.			

4.3 Independent Peer Review

The Independent Peer Review Panel (IPRP) reviewed the example alternatives and the supporting technical reports, and made several comments and recommendations (IPRP, 2007). Some of the comments and recommendations relate to the options evaluation process, and others relate to details of technical studies. Those types of comments and recommendations are being addressed in other work. The discussion herein is confined to IPRP comments and recommendations that relate directly to the closure options.

Within that group, the following themes can be distinguished:

- Clarifications of the example alternatives;
- Suggested modifications of the example alternatives; and,
- Recommendations that some example alternatives be dropped from consideration.

As noted above, the IPRP also recommended a new example alternative. The tailings “water cover” alternative option was added to the Section 4.2.3 above in response to that recommendation.

In clarifying the example alternatives, the IPRP pointed out that the predicted contamination at the Anvil Range complex means that there are no closure measures that could keep the local receiving water in compliance with Canada-wide freshwater aquatic life criteria. In other words, some effect on the water quality of Rose Creek, Anvil Creek and Vangorda Creek is inevitable under all of the example alternatives, and site specific water quality guidelines need to be developed. The IPRP also agreed however, that the Pelly River is unlikely to be adversely impacted.

The IPRP agreed that long-term water collection and treatment would be part of any closure plan for the site, and emphasized that long-term management issues, such as the availability of trained personnel many decades in the future, represented risks to all of the closure alternatives. Technical uncertainties also represent risks for long term. The IPRP agreed with the project team that an “adaptive management” approach would be needed to deal with both types of long term risks, and suggested that adaptive management be more clearly communicated in future discussions of closure options.

Several points of clarification related to water treatment were raised by the IPRP. These included the need for long-term management of water treatment sludge, the potential for future changes in geochemical conditions to necessitate additions to the water treatment system, the need for pre-treatment and post-treatment water storage, and the fact that any biological treatment system would require intensive management. These points had not been adequately emphasized in the descriptions of the example alternatives.

The most significant recommendations for modification of the example alternatives related to the management of contaminated groundwater in the Faro mine and tailings areas. The IPRP recommended an integrated approach that would include placing both the North Fork and South Fork into lined channels to remove any potential for contamination by groundwater, and developing a completely robust collection system at the down-gradient end of the integrated management area, *i.e.* in the Rose Creek Valley. Specific suggestions for the latter included using trenches or sumps, rather than wells, and making the cut-off wall across the Rose Creek Valley part of the initial construction, rather than a contingency. The IPRP felt that this integrated and more robust approach would allow a very high proportion of the known groundwater contamination to be captured, and would also allow contamination from any new or unexpectedly increasing sources within the management zone to be captured.

Another modification recommended by the IPRP related only to the tailings “Stabilize in Place” alternative. The IPRP expressed concern about the risk of floods escaping from the raised portion of the Rose Creek Diversion, where it passes above the Intermediate tailings. The recommendation was to consider a flood channel over the tailings, leading to a widened spillway on the north abutment of the Intermediate Dam.

The IPRP recommended that four example alternatives be dropped from any further consideration. Three of those were the “Minimize Construction” alternatives in each of the Faro mine, tailings and Vangorda/Grum area. The IPRP was of the opinion that these alternatives are not expected to meet objectives for the receiving environment and that they disregard a number of key elements of mine remediation best practices.

The other alternative that the IPRP recommended dropping from further consideration was the Faro Mine area “Flow-Through Pit” option. The analysis of the example alternatives had already proven that a truly “flow-through” pit would not be feasible. The IPRP expressed additional concern about the use of biological treatment even in the “flow-in, pump-out” mode that was eventually adopted for that alternative.

Finally, the IPRP identified many similarities among the Faro mine area and Vangorda/Grum alternatives, and suggested that the use of combinations and variants could lead to a further reduction in the number of alternatives being considered.

4.4 Options Recommended for Further Consideration

On the basis of evaluations completed to date, as well as results of the initial public consultation and independent peer review, several of the example alternatives can be dropped from further consideration, and others can be combined to simplify the further consultation and evaluation processes.

Table 4.4 presents the resulting short list of alternatives for further consideration. The following bullets summarize the reasoning for recommending alternatives for further consideration:

- Alternatives 2 and 4 for the Faro Mine area, Upgrade Faro Creek Diversion and Minimize Water Treatment, are both feasible and both provide similar performance against the objectives put forward by stakeholders. A single combined alternative can be carried forward for further analysis. The combined alternative should include a range of possible cover and relocation variants, and the groundwater management improvements recommended by the IPRP. Once the ongoing field tests of waste rock covers have advanced to the point that more precise cover designs can be formulated, standard engineering cost-benefit analyses would then be sufficient to make the final choices as to what will be covered, what will be relocated, and the appropriate types of covers.
- Alternative 1 for the Rose Creek Tailings, Stabilize in Place, mitigates most of the risks associated with the tailings facility, using well-proven methods. The remaining risks of concern to many stakeholders are those associated with a dam breach or tailings release due to failure of the Rose Creek Diversion and those associated with the groundwater collection system. The former group of risks can be further reduced by a re-design of the Rose Creek Diversion, specifically replacing the raised portion of the diversion by routing extreme floods over the tailings to a PMF spillway at the Intermediate Dam (as recommended by the IPRP for the Water Cover alternative). The latter group of risks can be further reduced by adopting the groundwater management measure recommended by the IPRP.
- Alternative 2 for the Rose Creek Tailings, Complete Relocation, also mitigates most of the risks associated with the tailings. One modification is required. As noted above, it is recommended that the IPRP's suggestions for groundwater management improvements in the Faro Mine area be adopted. The IPRP suggestions include recognizing that, if mine area capture systems are not completely effective, the Rose Creek aquifer can be used as a more robust collection point. That possibility will remain even if the tailings are relocated, meaning that the long-term groundwater management measures for the tailings area need to be added to this alternative as a contingency measure.
- Alternative 3 for the Rose Creek Tailings, Partial Relocation, remains of interest because it deals with the major risks in a way that is very different from Alternatives 1 and 2. Specifically, it removes the risks associated with flood-induced dam failures by relocating all of the tailings that lie below the Rose Creek Diversion.

- Alternatives 1 and 4 for the Vangorda/Grum area, Backfill Vangorda Pit and Minimize Construction, differ from each other in the same limited way as Alternatives 2 and 4 for the Faro Mine area, and they should be considered together for the same reasons (see the first bullet above).

Alternative 2 for the Vangorda/Grum mine area, Stabilize in Place, differs from Alternatives 1 and 4 in how it deals with the Vangorda part of the site. Specifically, it keeps all of the features constructed during mining in place, whereas Alternatives 2 and 4 relocate waste rock to fill the pit and allow Vangorda Creek to be returned to its original alignment. Those differences have implications for physical stability and water management. Reasons for not recommending further consideration of the other alternatives are as follows:

- The Minimize Construction alternatives (Alternative 3 for the Faro Mine and Vangorda/Grum areas, and Alternative 4 for the Rose Creek Tailings) do not meet the standard of good mine closure practice. The minimal covers proposed for the mine areas would leave many areas exposed, and would have excessive maintenance requirements. The lack of a cover on the tailings would present a high risk of future dust releases and direct contact by animals.
- Alternative 1 for the Faro Mine area, the Flow-Through Pit, has been thoroughly examined. Despite many attempts at revision and improvement, it is clear that a true flow-through system is not feasible, and that the in-pit biological treatment system will not be sufficient on its own. At best the in-pit treatment system should be considered a possible add-on to a more conventional treatment method. It is not a sufficient basis for an entire alternative.
- Alternative 5 for the Rose Creek Tailings, the Water Cover alternative, is similar to the Stabilize in Place alternative, but with higher costs and risks than the Stabilize in Place option. The one feature of the Water Cover alternative that is attractive is the routing of large floods over the impoundment to reduce reliance on the Rose Creek diversion. However, that feature could also be implemented in other options, and is in fact recommended above for the revised Stabilize in Place alternative.

The short-listed options are discussed in more detail in Section 5.2 below.

Table 4.4: Summary of Recommendations for Example Alternatives

Alternative	Recommended for Further Consideration?
Faro Mine Area	
Alternative 1 Flow-Through Pit	No
Alternative 2 Upgrade Faro Creek Diversion	Yes, in combination with Alternative 4 and the groundwater management improvements recommended by the IPRP
Alternative 3 Minimize Construction	No
Alternative 4 Minimize Water Treatment	Yes (see Alternative 2)
Rose Creek Tailings	
Alternative 1 Stabilize in Place	Yes, with modifications to the Rose Creek diversion design and the groundwater capture system
Alternative 2 Complete Relocation	Yes, with modifications to the groundwater capture system
Alternative 3 Partial Relocation	Yes, with modifications to the groundwater capture system
Alternative 4 Minimize Construction	No
Alternative 5 Water Cover	No
Vangorda/Grum Mine Area	
Alternative 1 Backfill Vangorda Pit	Yes
Alternative 2 Stabilize in Place	Yes
Alternative 3 Minimize Construction	No
Alternative 4 Minimize Water Treatment	Yes, in combination with Alternative 1

5 Initial Assessment of Short-Listed Options

5.1 Multi-Attribute Assessment Process

The complete assessment of short-listed options for closure of the Anvil Range Mining Complex will ultimately involve a variety of participants, including but not limited to several Federal and Yukon government departments and the Selkirk and Kaska First Nations. Some of those stakeholders are expected to develop and apply their own assessment processes. To facilitate those assessments and to provide a common basis of information, the Faro Project Management Team commissioned an initial options analysis. The results of the initial analysis are reported herein.

Following the advice of the IPRP, the initial options analysis used a technique known as multi-attribute utility analysis. Multi-attribute utility analysis is a well recognized method to assess options that involve a wide range of objectives, and in particular when some of those objectives cannot easily be expressed in monetary terms. The initial analysis was facilitated by two individuals with extensive experience the method, Dr. Anthony Hodge and Dr. Lee Merkhofer. Their complete report is included in Attachment E.

The complete report provides more details about the basis of the multi-attribute analysis. Briefly, the method requires that the project goals be re-stated in terms of specific performance objectives, and that each option be assessed against each objective. In theory, the method allows the individual assessments to be weighted and then “added up” to indicate overall preferences. That last step was not completed in this case, because the initial analysis was only intended to collate information and develop insights that would support the examination of overall preferences by other stakeholders.

To ensure that the initial assessment took into account a range of perspectives and expertise, a number of participants were invited to take part. The resulting team included participants from the federal and Yukon governments, the Selkirk First Nation and the Ross River Dena Council, First Nation technical advisors, the project technical advisor team, and the Independent Peer Review Panel.

The project facilitators led the team through a series of steps that included:

- Definition of the short-listed options;
- Re-statement of the five overarching project objectives developed by the Oversight Committee (see Section 3.2 above) in terms of eight specific objectives
  - Maximize public health and safety;
  - Maximize worker health and safety;
  - Maximize restoration, protection and enhancement of the environment;
  - Minimize restriction on traditional land use;
  - Minimize restrictions on local land use;

  - Maximize local socio-economic benefits;
  - Maximize Yukon socio-economic benefits; and,
  - Minimize cost.
- Development of 1-10 scoring scales for each re-stated objective;
- Development of memoranda to summarize the results of previous studies regarding the likely performance of the short-listed options; and,
- Individual and group scoring of each option’s performance with respect to each objective in the short term, defined as Years 1-40, and the long term, defined as 500-1000 years in the future.

As noted, the complete report on the multi-attribute analysis is included in Attachment E. The following sections describe the short-listed options, present the assessment results, and analyze those results to derive insights for the further consideration by the federal, territorial and First Nation governments.

5.2 Short-Listed Options

5.2.1 Common Elements

The options that were recommended for further consideration in Section 4 have many common elements that will need to be part of any closure plan. It is useful to review these common elements before presenting the differences among the short-listed options.

All combinations of the recommended options will include the following:

- Covering of Waste Materials. Any remaining exposed waste rock or tailings will be covered with soil to prevent dust release and direct uptake by animals, and to reduce infiltration. Attachment C summarizes the current thinking on soil cover designs. The selection of a specific design for each waste area will be based on cost-benefit analyses, with the more reactive wastes generally receiving thicker covers. The covered areas will be revegetated, and maintenance will be required until the vegetation stabilizes. Surface water channels on the covered areas will require continued maintenance over the long term.
- Upgrade of Dams and Diversions. Remaining dams and diversions will be upgraded to meet conservative design criteria. The Vangorda Creek and Faro Creek diversions will be moved to stable locations and upgraded to pass their respective 1:500 year floods. Except in the complete tailings relocation option, the Rose Creek Diversion and tailings pond will be upgraded to pass a Probable Maximum Flood. Any remaining tailings dams will be upgraded to ensure they remain stable under the Maximum Credible Earthquake and the Probable Maximum Flood, which are the most rigorous design standards in any Canadian or international dam classification system. Long-term maintenance of all remaining diversions will be required.
- Long-term Groundwater Collection. Despite the soil covers, waste relocation, and surface water diversions, some water will continue to reach the waste materials and become contaminated. That water will need to be captured, probably as groundwater, and treated. Efficient

groundwater capture systems will be required in all cases. In the Faro area, the north fork of Rose Creek will be placed in a lined channel to keep it separated from any contaminated groundwater, which will be captured in a series of wells. The groundwater collection system will extend if necessary as far as the downstream toe of the tailings, which is expected to be the best location for a highly efficient collection system.

- Long-term Water Treatment. Contaminated water will be stored in the pits and then treated. Long-term water treatment will certainly be required on the Faro side of the property, and will be at least a contingency on the Vangorda/Grum side. Water treatment requires construction of new treatment plants, long-term supply of labour, power, and lime, regular maintenance and equipment replacement, and a system and location for disposing sludge.
- Risks to Water Quality in Creeks. There will always be a risk that contaminant concentrations in uncaptured seepage from the remaining waste rock and tailings will increase to a level that will impact local creeks. Rose Creek, Anvil Creek and Vangorda Creek, in particular, will remain at risk. However, the contaminant concentrations will remain below levels that could threaten the Pelly River.
- Long-term Site Presence. Given the above requirements and risks, the site will certainly require long-term supervision, including security, inspections, maintenance, and environmental monitoring. A stable source of long-term funding and governance will be required.
- Adaptive Management. The current level of knowledge of the site is at a level commensurate with good mine closure and environmental protection practices elsewhere in the world. However, there remain many uncertainties that no amount of additional studies will resolve. It will therefore be necessary to modify elements of any closure plan as the site matures. An “adaptive management plan” that describes uncertainties and the changes that might be needed, will be required in all cases.

5.2.2 Specific Components

Tables 5.1 through 5.3 list the specific components of the recommended options for each of the Faro Mine, Tailings, and Vangorda/Grum areas. In all cases, the components are either taken directly from the analogous example alternatives, or they represent combinations of components from the example alternatives with the recommendations from the IPRP.

Figures 5.1 through 5.6 present the recommended options in graphical form. Appendix F presents detailed cost estimates.

It should be noted that work is continuing on the design of specific remediation measures, such as the optimal combination of material relocation and covering in some of the mine areas. Other remediation measures, such as for example groundwater collection systems, water treatment systems, and sludge management plans, will require further investigation before more detailed designs can be prepared.

Table 5.1: Combined Option for Faro Mine Area

Component	Combined Option
Surface Water Diversions	
Faro Creek	Upgrade diversion
North Fork Rose Creek	Construct channel to isolate creek from contaminated groundwater.
South Fork Rose Creek	If seepage escapes along North Fork and contaminated groundwater reaches South Fork, construct channel to isolate South Fork Rose Creek from contaminated groundwater.
Contaminated Water Management	
Groundwater Collection	Construct and operate local collection systems at ETA, S-wells, the Zone II pit and the Zone II outwash area. Install monitoring wells and additional collection wells where needed in other areas.
Water Treatment	Store water in pit. Extract water for treatment in HDS treatment plant (combined with tailings area water treatment). Continue for long term.
Waste Rock	
Oxide Fines/ Low-Grade Ore	Consolidate and construct low infiltration or very low infiltration covers, or relocate to pit with lime.
Sulphide Cells	Construct low or very low infiltration covers. Consolidate isolated pockets to larger cells.
Faro Valley Dump	Construct low infiltration cover.
Other Waste Rock	Reslope and construct rudimentary or low infiltration covers. Include surface water runoff swales and ditches.
Faro Pit	Construct berm around pit rim to reduce risk of inadvertent access. Use pit lake for storage of contaminated water prior to treatment.
Emergency Tailings Area	Relocate tailings and construct groundwater collection system.

Table 5.2: Recommended Options for Tailings Area

Component	Option 1 Stabilize in Place	Option 2 Complete Relocation	Option 3 Partial Relocation
Surface Water Diversions			
Rose Creek Diversion	Upgrade section along Secondary Dam to PMF. Upgrade remainder to 1:500 or 1:1000 year flood. Enhance fuse plug to allow floods greater than channel capacity to flow over tailings to improved spillway.	Re-route to valley floor after tailings relocation and groundwater cleanup are complete.	Upgrade section along Secondary Dam to PMF and re-route remainder to valley floor after tailings relocation and groundwater cleanup are complete.
North Wall Interceptor	Upgrade and maintain	Allow return to natural channel after tailings relocation and groundwater cleanup are complete.	Allow return to natural channel after tailings relocation and groundwater cleanup are complete.
Contaminated Water Management			
Groundwater Collection	Install cut-off wall and trench or drain system along the toe of either the Cross Valley or Intermediate Dam. Collect contaminated groundwater from tailings and any escaped seepage from mine area.	After tailings are relocated, install local groundwater capture systems where aquifer is contaminated. Operate for at least 20 years. Include contingency for long-term collection of escaped mine area seepage.	Install cut-off wall and trench or drain below toe of Secondary Dam. After tailings are relocated, install local groundwater capture systems where aquifer is contaminated. Operate for at least 20 years. Include contingency for long-term collection of escaped mine area seepage.
Water Treatment	Store water in pit for seasonal treatment or treat year-round in HDS treatment plant. Continue for long-term.	Store water in pit for seasonal treatment or treat year-round in HDS treatment plant. Continue for 20 years. Include contingency for long-term treatment of escaped mine area seepage.	Store water in pit for seasonal treatment or treat year-round in HDS treatment plant. Continue for long-term. Include contingency for long-term treatment of escaped mine area seepage.
Tailings			
Intermediate	Construct 2m rock/soil cover. Construct armoured areas where extreme floods would flow on to tailings cover.	Relocate to Faro Pit with lime addition to neutralize acidity	Relocate to Faro Pit with lime addition
Original & Secondary			Construct 2m rock/soil cover
Dams			
Cross-Valley	Remove, breach or modify to create small polishing pond	Remove, breach or modify to create small polishing pond	Remove, breach or modify to create small polishing pond
Intermediate	Expand spillway to pass PMF.	Remove or breach	Remove or breach
Secondary	Upgrade to MCE	Remove or breach	Upgrade to MCE
Original	No Action	Remove or breach	No Action

Table 5.3: Recommended Options for Vangorda/Grum Area

Component	Option 1 Backfill Vangorda Pit	Option 2 Revised Stabilize in Place
Surface Water Diversions		
Vangorda Creek Diversion	Re-route into lined and erosion-protected channel over backfilled Vangorda Pit. Design and construct channel to pass 1:500 year flood.	Relocate upslope to stable location and upgrade to pass 1:500 year flood.
Grum Creek	Maintain diversion for long-term.	Maintain diversion for long-term.
Contaminated Water Management		
Groundwater Collection	Install groundwater collection system below Grum waste rock. Include contingency system to collect contaminated groundwater, if any, from backfilled Vangorda Pit.	Install groundwater collection system below Grum waste rock. Include contingency system to collect escaped contaminated groundwater, if any, from Vangorda waste rock pile.
Water Treatment	Store contaminated water in Grum Pit. Use biological method to pre-treat water in Grum Pit. Discharge pre-treated water directly if contaminant concentrations are low enough. If not, periodically extract and treat water using active HDS plant and discharge.	Direct contaminated water to Vangorda Pit for storage. Periodically extract contaminated water from Vangorda Pit and possibly Grum Pit and treat using active High Density Sludge plant.
Waste Rock		
Vangorda Waste Rock	Relocate to Vangorda Pit, with lime addition to neutralize acidity. Compact during deposition to minimize hydraulic conductivity and settlement.	Cover with low infiltration or very low infiltration soil cover.
Grum Sulphide Cell	Cover with low infiltration or very low infiltration soil cover.	Cover with low infiltration or very low infiltration soil cover.
Other Grum Dump	Cover with rudimentary or low infiltration soil cover.	Cover with rudimentary or low infiltration soil cover
Ore Transfer Pad	Relocate part to Vangorda Pit. Cover remainder with rudimentary soil cover.	Relocate part to Grum Sulphide Cell. Cover remainder with rudimentary soil cover
Overburden Dump	Use part for cover construction. Re-vegetate remainder.	Use part for cover construction. Re-vegetate remainder.
Pits		
Vangorda Pit	Backfill with waste rock to cover all exposed highwalls.	Construct berm around pit rim to reduce risk of inadvertent access. Use pit lake for storage of contaminated water prior to treatment.
Grum Pit	Construct berm around pit rim to reduce risk of inadvertent access. Use pit lake to store and pre-treat contaminated water.	Construct berm around pit rim to reduce risk of inadvertent access. Use pit lake to store contaminated water prior to treatment.

5.2.3 Option Combinations for Initial Assessment

Early in the process of developing the initial options analysis, it was noted that it was easier to assess the Faro mine area and tailings area options when they were combined. The resulting "Faro/Rose Creek" options are straightforward combinations, but to avoid any confusion they were:

- "Dry Cover" – Combination of the Faro mine area option from Table 5.1 with the tailings Stabilize in Place option from Table 5.2;
- "Partial Relocation" – Combination of the Faro mine area option from Table 5.1 with the tailings area Partial Relocation option from Table 5.2; and,
- "Complete Relocation" – Combination of the Faro mine area option from Table 5.1 with the tailings area Complete Relocation option from Table 5.2.

The two short-listed options for the Vangorda/Grum were adopted, but with slightly simpler names:

- "Backfill Pit" – the Backfill Vangorda Pit option from Table 5.3; and
- "Stabilize in Place" – the revised Vangorda/Grum Stabilize in Place option from Table 5.3.

5.2.4 Implementation Scenario

In order to assess some of the effects and risks of the options, it was necessary to define assumptions about implementation of the work. The assumptions provide a reasonable basis for evaluating options but are not meant to represent a final implementation strategy. The following points summarize the key assumptions. Attachment E provides further details.

- Selected options for the Faro/Rose Creek and the Vangorda/Grum areas would be combined to comprise a single project. Implementation of the project would extend over roughly a fifteen-year period, regardless of the options chosen.
- There would be a two or three year phase-in period to allow the development of local capacity. Thereafter work would be scheduled to provide continuity of expenditures and employment over the remainder of the implementation period.
- The implementation period would be followed by long-term care and maintenance. There would be roughly a 25-year transition period where adaptive management is expected to be intensive, before the site care and maintenance settle down to a long-term equilibrium.
- Appropriate financial arrangements would be in place to provide adequate funding for the implementation phase, for long-term care and maintenance, and for responses to any future emergencies.
- About 60 workers would be directly employed during the fifteen-year implementation phase, with peak employment of 70-85 workers. In addition there would be approximately ten professional, technical and management positions.

- After the implementation phase, direct employment would drop to about ten workers, five of whom would be year-round and five of whom would be seasonal. Both groups would include technical and managerial positions to provide project oversight.
- A Socio-Economic Participation Agreement would be negotiated among the federal, Yukon and First Nations governments, and would include requirements that the project provide employee assistance programs, training, education and succession planning, and monitoring of socio-economic conditions. Employment policies will support continuity of traditional activities, such as seasonal fishing, hunting and gathering.
- To the extent feasible, business and indirect employment opportunities would be geared towards local capacity, with commitments to be spelled out in a Socio-Economic Participation Agreement.
- Long-term care and maintenance would be carried out by a First Nation/Private Sector contractor subject to terms and conditions specified by water licenses. Yukon regulatory agencies would oversee compliance with the water license requirements. Yukon and federal agencies would provide financial control and oversee compliance with the Socio-Economic Participation Agreement.
- A system of regional land use planning and management would be put into place to ensure that reclaimed areas are returned to other uses where feasible.

5.2.5 “Do Nothing” Option

To facilitate the assessment of the short-listed options, it was helpful to define a base case. The base case was assumed to be complete abandonment of the site in its current condition, with no future maintenance or water management. Clearly that is not a realistic option, but the so-called “do nothing” case allowed a baseline to be set by which the benefits arising from the short-listed options could be measured. The “do nothing” option is further described in Attachment E.

5.3 Results of Initial Assessment

Tables 5.4 and 5.5 summarize the results of the multi-attribute assessment of the short-listed options. The tables show the scoring of each option’s expected performance against each objective in both the short term (years 0-40) and long term (beginning after year 40 and extending until 500-1000 years in the future). Table 5.4 shows the scoring of the combined Faro/Rose Creek options, and Table 5.5 shows the scoring of the Vangorda/Grum options.

Attachment E presents a complete explanation of the scoring process. The key points are that, for each option and objective, individuals were asked to estimate all of the following:

- Upper bound and lower bound scores under expected conditions;
- Upper bound and lower bound scores under risk conditions; and,
- Upper and lower estimates of the probability that the risk conditions would arise.

Each individual's scores were reported to the group and discussed, after which individuals were allowed to modify their scores. Each individual's final scores were then recorded and converted to a probability distribution. The probability distributions were combined to generate an overall group scoring, which was then reviewed and discussed by all participants. The median, 1st percentile, 10th percentile and 90th percentile scores shown in Tables 5.4 and 5.5 represent the overall scoring agreed to by the group.

One way to read the tables is to say that the initial assessment group expects that performance of each option against each objective in the specific time period is 50% likely to be better or worse than the median score. The 1st percentile and 10th percentile scores represent adverse performance outcomes that the group believes are 1% and 10% likely to occur. The 90th percentile scores represent more favourable performance outcomes that are 10% (i.e. 100% minus 90%) likely to occur.

Figures 5.7 through 5.22 present the scoring results in a more complete manner. Each figure presents the scoring of options against one objective.

- The left side of each figure re-produces the scale used by each individual in developing the initial scores. The scales also allow the final group scores to be interpreted.
- The graphs in each figure plot the group estimates of the median, 1st percentile, 10th percentile and 90th percentile scores against the total estimated option cost.
- The first graph in each figure shows the scoring of short-term performance and the second shows the scoring of long-term performance.

This presentation spreads the options out across the page in a fashion similar to simple bar graphs. The use of total cost estimates on the x-axis facilitates comparisons of the options on the basis of cost effectiveness, rather than cost minimization. (The former was the term used in the objective statement from the Oversight Committee.) The "do nothing" option is also included in the plots in order to facilitate cost-benefit analyses. Figures 5.7 through 5.14 show the results for the combined Faro/Rose Creek area options. Figures 5.15 through 5.22 show the results for the Vangorda/Grum options.

It is clear from the figures that some of the differences among the options are very small. Tables 5.6, and 5.7 highlight cases where the difference between the maximum and minimum scores is greater than 0.3. The choice of 0.3 as a cut-off is arbitrary, and it could be argued that differences of 0.2 or 0.1 could also be significant in some cases. However, the intent is only to highlight objectives for which there are clear differences among the options. Close examination of the tables shows that the objectives identified as having significant differences would be the same if lower cut-offs were chosen.

Tables 5.6 and 5.7 illustrate that the initial assessment group expects there to be relatively few significant differences in the performance of the options against objectives. Review of the reasoning behind the individual and group scores, as captured in the complete report (Attachment E), shows that the significant differences can be explained by an even smaller number of causal factors. The following points refer to the colour coded and numbered groups shown on the tables.

The main differences among the Faro/Rose Creek options can be explained as follows.

1. Differences in worker and public health and safety scores during the short term relate primarily to safety risks arising from trucks going to and from the site. Options with tailings relocation require more truck trips (hauling lime) and therefore present a higher risk of accidents. For the long term-scoring, the reasoning is similar but the ranking is reversed because the tailings relocation options lead to lower long-term lime demands.
2. Differences in environmental and land use scores during the short term arise from the duration and the risk of activities during the implementation phase. In the short term, risks of dam failure, tailings release or environmental contamination are greater for options that include tailings relocation. The long period of time needed to complete the relocation and clean up groundwater in the valley after tailings relocation would restrict traditional or local land use.
3. Differences in environmental and land use scores in the long term reflect concerns about long-term risks associated any tailings that are left in place. Land use risks may include possible problems with long-term funding or management leading to dam failure. Environmental risks also include failure of groundwater treatment arising from the same root causes.
4. Variations in short-term socio-economic scores are due to the differences in expenditures. The more costly tailings relocation options provide a potential for greater socio-economic benefits.
5. Variations in long-term socio-economic scores reflect the very slight differences in the amount of long-term activity at the site.

The differences between the Vangorda/Grum options can also be explained in terms of common factors.

1. Variations in health and safety scores for the short term relate primarily to safety risks arising from trucks going to and from the site. The option with waste rock relocation requires more truck trips (hauling lime) and therefore present a higher risk of accidents.
2. Variations in environment scores for the short term reflect opposing factors. Backfilling of the pit will ultimately provide greater environmental protection, but there will be risks during the short-term period when the pit is partially filled and the creek not yet re-established. The backfill pit option is also at greater risk if funding ceases.
3. Variations in land use scoring for both the short term and long term arise because the backfilled pit will allow greater traditional and local uses of the area. Specifically, the pit itself will be reclaimed, making the Vangorda area as similar to the pre-mining conditions as possible, and restrictions related to pit wall safety will not be needed.

Table 5.4: Group Scoring of Faro/Rose Creek Options

		Short Term Scores			Long-Term Scores		
		Dry Cover	Partial Relocation	Complete Relocation	Dry Cover	Partial Relocation	Complete Relocation
Worker Health & Safety	**Median**	**6.51**	**6.18**	**5.70**	**7.66**	**7.74**	**7.87**
	1st Percentile	4.93	4.37	4.11	5.07	5.07	5.07
	10th Percentile	5.50	4.94	4.80	5.86	5.86	5.86
	90th percentile	7.88	6.98	6.66	8.50	8.65	8.95
Environmental	**Median**	**7.43**	**6.87**	**6.59**	**6.91**	**6.94**	**6.89**
	1st Percentile	3.73	4.10	3.39	3.34	3.56	3.85
	10th Percentile	5.90	5.71	5.64	5.43	5.73	5.42
	90th percentile	8.00	7.82	7.46	7.88	7.90	7.96
Public Health & Safety	**Median**	**7.90**	**7.73**	**7.64**	**7.70**	**7.70**	**7.70**
	1st Percentile	6.53	6.53	6.50	6.40	6.40	6.40
	10th Percentile	7.00	7.00	7.00	6.95	6.95	6.95
	90th percentile	8.46	8.21	7.96	8.40	8.40	8.40
Traditional Land Use	**Median**	**4.94**	**4.63**	**4.32**	**6.11**	**6.24**	**6.12**
	1st Percentile	2.82	2.72	2.82	1.58	2.02	2.30
	10th Percentile	3.96	3.98	3.93	3.25	4.26	4.26
	90th percentile	5.94	5.49	4.95	7.37	7.37	7.37
Local Land Use	**Median**	**6.42**	**6.08**	**5.65**	**7.07**	**6.98**	**6.98**
	1st Percentile	3.77	3.81	3.44	4.73	4.74	4.73
	10th Percentile	5.20	5.05	4.61	5.70	5.59	5.73
	90th percentile	7.42	7.19	6.96	7.96	8.08	8.32
[1]Local Socio-Economics	**Median**	**7.49**	**7.45**	**7.48**	**7.55**	**7.39**	**7.32**
	1st Percentile	5.43	5.53	5.34	6.56	6.27	6.09
	10th Percentile	6.15	6.48	6.37	7.00	6.77	6.58
	90th percentile	8.45	8.24	8.32	8.29	8.08	7.96
[1]Yukon Socio-Economics	**Median**	**7.35**	**7.59**	**7.81**	**6.98**	**6.95**	**6.83**
	1st Percentile	6.22	6.47	6.72	5.60	5.60	5.60
	10th Percentile	6.97	7.30	7.50	6.00	6.00	6.00
	90th percentile	7.98	8.13	8.43	7.55	7.33	7.05

Shading indicates rankings:

Highest
Second
Third
No difference

Notes to Table 5.4:

1. The socio-economic scores reported in Attachment E are for combinations of Faro/Rose Creek and Vangorda/Grum options. The scores shown here were decomposed to show the effects of each option independently. For example, the Median score assigned to the Dry Cover option for short-term Local Socio-Economics was the average of the scores that Attachment E assigns to the two combinations “Dry Cover - Backfill Vangorda Pit” and “Dry Cover - Stabilize in Place”.
2. The scores for the “minimize cost” objective are not shown. The cost estimates used in the assessment are presented in Attachment F, along with the complete estimate details, and are summarized in Table 5.8.
3. Scores are shaded even in cases where differences are insignificant. See Table 5.6 for significant differences.

Table 5.5: Group Scoring of Vangorda/Grum Options

		Short Term Scores		Long-Term Scores	
		Stabilize in Place	Backfill Pit	Stabilize in Place	Backfill Pit
Worker Health & Safety	**Median**	**7.57**	**7.37**	**7.81**	**7.84**
	1st Percentile	6.47	5.48	5.07	5.07
	10th Percentile	7.00	6.00	5.86	5.86
	90th percentile	8.36	8.40	8.64	8.92
Environmental	**Median**	**7.71**	**8.01**	**7.39**	**7.48**
	1st Percentile	5.81	4.94	4.34	4.50
	10th Percentile	6.50	6.67	6.50	6.52
	90th percentile	8.49	8.96	8.00	8.13
Public Health & Safety	**Median**	**8.15**	**8.15**	**8.00**	**8.00**
	1st Percentile	6.69	6.69	6.40	6.40
	10th Percentile	7.50	7.50	6.95	7.00
	90th percentile	8.96	8.96	8.90	8.90
Traditional Land Use	**Median**	**5.25**	**5.53**	**6.32**	**6.55**
	1st Percentile	2.95	2.95	2.80	2.80
	10th Percentile	3.98	3.97	4.41	4.72
	90th percentile	6.44	6.94	7.70	7.92
Local Land Use	**Median**	**6.23**	**6.65**	**7.18**	**7.49**
	1st Percentile	4.44	4.37	5.23	5.37
	10th Percentile	5.50	5.72	6.09	6.23
	90th percentile	7.42	7.88	7.96	7.96
[1]Local Socio-Economics	**Median**	**7.44**	**7.50**	**7.38**	**7.45**
	1st Percentile	5.37	5.50	6.21	6.31
	10th Percentile	6.26	6.40	6.74	6.78
	90th percentile	8.32	8.35	8.18	8.11
[1]Yukon Socio-Economics	**Median**	**7.57**	**7.59**	**6.90**	**6.93**
	1st Percentile	6.39	6.54	5.60	5.60
	10th Percentile	7.25	7.27	6.00	6.00
	90th percentile	8.14	8.22	7.25	7.37

Shading indicates rankings: Highest / Second / No difference

Notes to Table 5.5:

1. As in the previous table, the socio-economic scores have been decomposed to show the effects of each option independently. For example, the Median score assigned to the Stabilize in Place option for short-term Local Socio-Economics was the average of the scores that Attachment E assigns to the three combinations "Dry Cover - Stabilize in Place", "Partial Relocation – Stabilize in Place", and "Complete Relocation – Stabilize in Place".
2. The scores for the "minimize cost" objective are not shown. The cost estimates used in the assessment are presented in Attachment F, along with the complete estimate details, and are summarized in Table 5.9.
3. Scores are shaded even in cases where differences are insignificant. See Table 5.7 for significant differences.

Table 5.6: Significant Differences in Initial Assessment of Faro/Rose Creek Options

		Short Term				Long-Term			
		Dry Cover	**Partial Relocation**	**Complete Relocation**	**Max-Min**	**Dry Cover**	**Partial Relocation**	**Complete Relocation**	**Max-Min**
Worker Health & Safety	**Median**		6.18	5.70	0.81	7.66	7.74	7.87	0.21
	1st Percentile		4.37	4.11	0.82	5.07	5.07	5.07	0.00
	10th Percentile		4.94	4.80	0.70	5.86	5.86	5.86	0.00
	90th percentile		6.98	6.66	1.22	8.50	8.65		0.45
Environmental	**Median**	7.43	6.87	6.59	0.84	6.91	6.94	6.89	0.05
	1st Percentile	3.73	4.10	3.39	0.71	3.34	3.56	3.85	0.51
	10th Percentile	5.90	5.71	5.64	0.26	5.43		5.42	0.31
	90th percentile	8.00	7.82	7.46	0.54	7.88	7.90	7.96	0.08
Public Health & Safety	**Median**		7.73	7.64	0.26	7.70	7.70	7.70	0.00
	1st Percentile	6.53	6.53	6.50	0.03	6.40	6.40	6.40	0.00
	10th Percentile	7.00	7.00	7.00	0.00	6.95	6.95	6.95	0.00
	90th percentile		8.21	7.96	0.50	8.40	8.40	8.40	0.00
Traditional Land Use	**Median**	4.94	4.63	4.32	0.62	6.11	6.24	6.12	0.13
	1st Percentile	2.82	2.72	2.82	0.10	1.58	2.02	2.30	0.72
	10th Percentile	3.96	3.98	3.93	0.05	3.25	4.26	4.26	1.01
	90th percentile	5.94	5.49	4.95	0.99	7.37	7.37	7.37	0.00
Local Land Use	**Median**	6.42	6.08	5.65	0.77	7.07	6.98	6.98	0.09
	1st Percentile	3.77	3.81	3.44	0.37	4.73	4.74	4.73	0.01
	10th Percentile	5.20	5.05	4.61	0.59	5.70	5.59	5.73	0.14
	90th percentile	7.42	7.19	6.96	0.46	7.96	8.08	8.32	0.36
Local Socio-Economics	**Median**	7.49	7.45	7.48	0.04	7.55	7.39	7.32	0.23
	1st Percentile	5.43	5.53	5.34	0.19	6.56	6.27	6.09	0.47
	10th Percentile	6.15	6.48	6.37	0.33	7.00	6.77	6.58	0.42
	90th percentile	8.45	8.24	8.32	0.21	8.29	8.08	7.96	0.33
Yukon Socio-Economics	**Median**	7.35	7.59	7.81	0.46	6.95	6.85	6.90	0.10
	1st Percentile	6.22	6.47	6.72	0.50	5.60	5.60	5.60	0.00
	10th Percentile	6.97	7.30	7.50	0.53	6.00	6.00	6.00	0.00
	90th percentile	7.98	8.13	8.43	0.45	7.55	7.30	7.10	0.45

Colours indicate groupings for discussion of underlying issues in text:

1	Health & safety	4	ST socio-economic
2	ST environmental & land use	5	LT socio-economic
3	LT environmental & land use		

Differences are assumed to be significant when Max - Min > 0.3

Table 5.7: Significant Differences in Initial Assessment of Vangorda/Grum Options

		Short Term			Long-Term		
		Stabilize in Place	Backfill Pit	Max-Min	Stabilize in Place	Backfill Pit	Max-Min
Worker Health & Safety	**Median**	7.57	7.37	0.20	7.81	7.84	0.03
	1st Percentile		5.48	0.99	5.07	5.07	0.00
	10th Percentile		6.00	1.00	5.86	5.86	0.00
	90th percentile	8.36	8.40	0.04	8.64	8.92	0.28
Environmental	**Median**	7.71		0.30	7.39	7.48	0.09
	1st Percentile		4.94	0.87	4.34	4.50	0.16
	10th Percentile	6.50	6.67	0.17	6.50	6.52	0.02
	90th percentile	8.49		0.47	8.00	8.13	0.13
Public Health & Safety	**Median**	8.15	8.15	0.00	8.00	8.00	0.00
	1st Percentile	6.69	6.69	0.00	6.40	6.40	0.00
	10th Percentile	7.50	7.50	0.00	6.95	7.00	0.05
	90th percentile	8.96	8.96	0.00	8.90	8.90	0.00
Traditional Land Use	**Median**	5.25	5.53	0.28	6.32	6.55	0.23
	1st Percentile	2.95	2.95	0.00	2.80	2.80	0.00
	10th Percentile	3.98	3.97	0.01	4.41	4.72	0.31
	90th percentile	6.44	6.94	0.50	7.70	7.92	0.22
Local Land Use	**Median**	6.23	6.65	0.42	7.18	7.49	0.31
	1st Percentile	4.44	4.37	0.07	5.23	5.37	0.14
	10th Percentile	5.50	5.72	0.22	6.09	6.23	0.14
	90th percentile	7.42	7.88	0.46	7.96	7.96	0.00
Local Socio-Economics	**Median**	7.44	7.50	0.06	7.38	7.45	0.07
	1st Percentile	5.37	5.50	0.13	6.21	6.31	0.10
	10th Percentile	6.26	6.40	0.14	6.74	6.78	0.04
	90th percentile	8.32	8.35	0.03	8.18	8.11	0.07
Yukon Socio-Economics	**Median**	7.57	7.59	0.02	6.90	6.93	0.03
	1st Percentile	6.39	6.54	0.15	5.60	5.60	0.00
	10th Percentile	7.25	7.27	0.02	6.00	6.00	0.00
	90th percentile	8.14	8.22	0.08	7.25	7.37	0.12

Colours indicate groupings for discussion of underlying factors in text:

1	Health & Safety
2	Environmental
3	Land use

Differences are assumed to be significant when Max - Min > 0.3

5.4 Summary of Initial Options Assessment

Overall, the initial assessment of options found that:

- All of the options are estimated to perform similarly with respect to achievement of most objectives.
- There are a few significant differences in the estimated performance of the options. These differences are generally easy to interpret and understand.
- The differences between the closure options are minor in comparison to the improvement between the "do nothing" case and any of the closure options.

The numeric scores derived in the multi-attribute assessment and presented in the preceding section show some clear patterns. To further clarify the significant findings with respect to each objective Tables 5.8 and 5.9 translate the numerical scores back to the plain English terms used as the basis for the scoring scales. Table 5.8 summarizes the findings for the Faro/Rose Creek options, and Table 5.9 summarizes the findings for the Vangorda/Grum options.

The interpretations provided in the tables reflect the overall findings of the initial options assessment. Consistent with the purposes of the initial assessment, the findings are intended to provide a concise, accessible, common base of information for those who are conducting options assessments on behalf of their respective governments or other stakeholder groups.

Table 5.8: Summary of Initial Assessment of Short-listed Options for Faro Mine & Tailings Areas

Objective	Dry Cover	Partial Relocation	Complete Relocation
Maximize worker health and safety	No significant differences amongst the options. All options could perform well if project health and safety is managed to the high standards common in well-run projects elsewhere, and all could perform poorly in the event of project management failures. There are minor differences in the short-term scoring due to the different amounts of work involved in implementation of the options, specifically the trucking of lime to the site for use in tailings relocation.		
Maximize public health and safety	Minor differences amongst the options, with dry cover ranked best, partial relocation next, and complete relocation third. The difference is almost entirely attributable to short-term differences in traffic risks, with the greater number of trucks required for the relocation options leading to greater risks of traffic accidents on the public roads. All options will minimize the risk of public exposure to contaminants. All options will present long-term safety risks related to snow machines and ATV's driving over exposed pit walls.		
Maximize restoration, protection and enhancement of the environment	All options are expected to show fair performance in the short and long term, with only localized short-term impacts, generally self-correcting in 1-10 years. But there are slight differences in the expected short-term performance and in long-term risks.		
	Dry Cover generally performs better in the short term because it leads to the tailings area being returned to post-closure conditions faster than the options involving tailings relocation.	Partial Relocation is intermediate between the two other options in the short term.	Complete Relocation performs slightly less well, but still "fair", in the short term due to the longer time needed to reach stable conditions in the Rose Creek valley.
	Dry Cover presents slightly higher environmental risks in the long term due to the possibility that a loss of funding would compromise maintenance and lead to a breach of the tailings dam.	Partial relocation substantially removes the risk of dam failure. There remains risk that a loss of funding would lead to release of contaminated water from the mine area or the remaining tailings.	Complete Relocation has lower environmental risks in the long term, because the risks of a dam breach are completely removed. There remains a risk that a loss of funding would lead to release of contaminated water from the mine area.
Maximize local socio-economic benefits	Minor differences only. All options are expected to provide significant local socio-economic benefits if they are implemented with due consideration of socio-economic effects. But none of the options will satisfy everybody in the region, and all of them could lead to problems if commitments to socio-economic benefits are not respected. Slight differences among the options arise because options that spend more money present a slightly greater potential for socio-economic benefits. However, detailed analysis of the expenditures shows that the bulk of the differences in costs go to the purchase of materials, rather than labour, meaning that the differences in socio-economic benefits are much less than the differences in total cost.		
Maximize Yukon socio-economic benefits (i.e. outside the project region)	All options are expected to provide significant socio-economic benefits to other areas of the Yukon. The options involving tailings relocation could provide slightly greater benefits and present slightly fewer problems, due to the higher total expenditures. The differences among the options are greater for "Yukon socio-economics" than for "local socio-economics" because the purchase of project materials, in particular lime, could be focused elsewhere in the Yukon.		

Table 5.8: Summary of Initial Assessment of Short-listed Options for Faro Mine & Tailings Areas (con't)

<table>
<tr><th>Objective</th><th>Dry Cover</th><th>Partial Relocation</th><th>Complete Relocation</th></tr>
<tr><td rowspan="3">Minimize restrictions on traditional land use</td><td colspan="3">All options will require continued restrictions on traditional land uses in the project area, and those restrictions will impair the overall traditional use of the region. The effects could be limited by good management of the project, or could be significant and persistent if the implementation is poor. There are differences in the expected short-term performance and long-term risks.</td></tr>
<tr><td>The Dry Cover option could lead to traditional uses of the Rose Creek valley being restored more quickly in the short-term.</td><td>The Partial Relocation option is intermediate between the two other options in the short term.</td><td>The Complete Relocation option will require intensive management of the Rose Creek valley during fifteen years of implementation and another 25 years of groundwater treatment, restricting traditional uses for the short term.</td></tr>
<tr><td>The possibility of a breach of the tailings dam, arising from a failure of funding and maintenance, leads to a risk that traditional uses of the entire Rose Creek and Anvil Creek areas could be critically impaired in the long term.</td><td>Partial Relocation reduces the risk of tailings breaches in the long term, but still presents risks of permanent and major limitations on traditional land use.</td><td>Complete Relocation removes any risk of dam breaches in the long term. But other failures of site management, and the possible loss of traditions during the long implementation phase, could lead to permanent and major limitations on traditional land use.</td></tr>
<tr><td rowspan="3">Minimize restrictions on local (i.e. non-traditional) land use</td><td colspan="3">All options are expected to require localized and short-term restrictions on non-traditional land use. Poor management of any of the options could lead to restrictions being more persistent and widespread. There are differences in the expected short-term performance and long-term risks.</td></tr>
<tr><td>The Dry Cover option is expected to lead to non-traditional uses of the Rose Creek valley being restored more quickly.</td><td rowspan="2">The Partial Relocation option is intermediate between the two other options.</td><td>In the Complete Relocation option, the extended period before restoration of the Rose Creek valley is expected to restrict non-traditional uses in the short term.</td></tr>
<tr><td>Continued maintenance of the Rose Creek diversion and operation of the tailings groundwater collection system could restrict non-traditional uses, such as recreational hunting and fishing, in the long term.</td><td>Complete Relocation of the tailings will provide the opportunity for more non-traditional uses of the reclaimed valley in the long term.</td></tr>
<tr><td rowspan="4">Minimize cost</td><td colspan="3">There are differences among the short-term costs of the options. All options will require long-term funding for site maintenance and operation of water collection and treatment systems. The long-term costs also differ, but much less than short term costs.</td></tr>
<tr><td>Implementation of the Dry Cover options will cost about $344,000,000 NPV over fifteen years.</td><td>Implementation of the Partial Relocation option will cost about $436,000,000 NPV over fifteen years.</td><td>Implementation of the Complete Relocation option will cost about $560,000,000 NPV over fifteen years.</td></tr>
<tr><td>Long-term costs will be about $3,500,000 per year.</td><td>Long-term costs will be about $2,800,000 per year.</td><td>Long-term costs will be about $1,400,000 per year.</td></tr>
<tr><td>Factoring in uncertainties of -10%/+20%, the Dry Cover option will cost between $380,000,000 and $500,000,000 NPV in total.</td><td>Factoring in uncertainties of -10%/+25%, the Partial Relocation option will cost between $450,000,000 and $620,000,000 NPV in total.</td><td>Factoring in uncertainties of -10%/+30%, the Complete Relocation option will cost between $530,000,000 and $770,000,000 NPV in total.</td></tr>
</table>

Table 5.9: Summary of Initial Assessment of Short-listed Options for Vangorda/Grum Area

Objective	Stabilize in Place	Backfill Pit
Maximize worker health and safety	No significant differences between the options. Both options could perform well if project health and safety is managed to the high standards common in well-run projects elsewhere, and both could perform poorly in the event of project management failures. There is a minor difference in the short-term scoring due to the different amounts of work involved in implementation of the options.	
Maximize public health and safety	Minor differences amongst the options in the short-term, with stabilize in place ranked slightly better. The difference is almost entirely attributable to short-term differences in traffic risks, with the greater number of trucks required for the backfill option leading to greater risks of traffic accidents on the public roads. Both options will be protective of public health and safety in the short term and long term. Both options minimize the risk of public exposure to contaminants. The site will continue to have steep slopes in the pit areas, which could be a hazard to snowmobilers or ATV-riders.	
Maximize restoration, protection and enhancement of the environment	Both options are expected to have at most only minor exceedances of environmental standards in the short term, and only localized impacts that are self-correcting.	
	Stabilize in Place has a slightly smaller range of short-term performance, i.e. the best performance could be not quite as good and the worst not quite as bad as Backfill Pit.	Backfill Pit has the potential to be slightly better in the short-term, because the entire Vangorda side is reclaimable. But it also has a risk of poorer short-term performance due to the possibility that Vangorda Creek could breach its diversion during the period when the pit if partially filled with waste rock.
	Both options are expected to perform well in the long term, but both have a risk that a loss of funding could lead to release of contaminated water.	
Maximize local socio-economic benefits	No significant differences.	
Maximize Yukon socio-economic benefits (i.e. outside the project region)	No significant differences.	

Table 5.9: Summary of Initial Assessment of Short-listed Options for Vangorda/Grum Area (con't)

Objective	Stabilize in Place	Backfill Pit
Minimize restrictions on traditional land use	Both options will limit traditional land uses in the project area, and the limitations could impair the overall traditional use of the region. The effects could be limited by good management of the project, or could be significant and persistent if the implementation is poor.	
	Stabilize in Place will place slightly more limitations on traditions land use, because the Vangorda side of the property will remain actively managed.	Backfill Pit has the potential to place slightly less limitations on traditional land use in both the short and long-term because the entire Vangorda side of the property will be reclaimed, including the area of the Vangorda Pit.
Minimize restrictions on local (i.e. non-traditional) land use	Both options will require continued restrictions on non-traditional land uses in the project area. The effects could be limited by good management of the project, or could be significant and persistent if the implementation is poor.	
	Stabilize in Place will place slightly more restrictions on local land use, because the Vangorda side of the property will remain actively managed.	Backfill Pit has the potential to be slightly less restrictive in both the short and long-term because the entire Vangorda side of the property will be reclaimed, including the Vangorda Pit.
Minimize cost	There are differences among the short-term costs of the options. All options will require long-term funding for site maintenance and operation of water collection and treatment systems. The long-term costs also differ, but much less than short term costs.	
	Implementation of the Stabilize in Place option will cost about $57,000,000 NPV over fifteen years.	Implementation of the Backfill Pit option will cost about $95,000,000 NPV over fifteen years.
	Long-term costs will be about $930,000 per year.	Long-term costs will be about $800,000 per year.
	Factoring in uncertainties of -10%/+20%, the Stabilize in Place option will cost between $70,000,000 and $90,000,000 NPV in total.	Factoring in uncertainties of -10%/+20%, the Backfill Pit option will cost between $100,000,000 and $130,000,000 in total (NPV).

5.5 Recommendations

For the Faro Mine area, a single option is recommended for further consideration. For the Rose Creek tailings area, three alternatives remain, Stabilize in Place, Complete Relocation and Partial Relocation. The Faro mine area and Rose Creek tailings area options can easily be combined into three Faro/Rose Creek options to simplify further assessments.

For the Vangorda/Grum area, two options are recommended for further consideration. The significant differences are on the Vangorda side, specifically whether the Vangorda pit is left open or backfilled and whether Vangorda Creek is stabilized near its current alignment or routed over the backfilled pit.

The initial assessment of the short-listed options has clarified that all of the options will perform similarly with respect to most of the objectives set by the project Oversight Committee, that there are relatively few differences in the expected performance, and that those differences are generally easy to understand.

The Technical Advisor team recommends the use of the options descriptions presented in Tables 5.1 through 5.3, and the initial assessment results presented in Tables 5.6 through 5.9, as a basis for further assessment of closure options. Figures 5.1 through 5.6 illustrate the short-listed options, and Figures 5.7 through 5.22 present the initial assessment scoring in a concise form.

The IPRP has also considered the short-listed options, initial assessment process, and the discussion of its results. The IPRP's support of the findings presented herein is expressed in a memorandum dated February 1, 2008, which is included as Attachment G.

This report, "**Options for Closure of the Faro Mine Complex**", has been prepared by SRK (Canada) Consulting Inc.

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