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Appendix A(Draft)
Technical Memorandum, Review of Heap Leach Pad and Waste Rock Dump Design,Carmacks Copper Project

To:	Peter Healey, SRK	**Date:**	16 Feb 06
cc:		**From:**	Terry Mandziak
Subject:	Technical Review of Carmacks Copper Heap Leach Pad	**Project #:**	1CY001.06

SRK Consulting (Canada) Inc (SRK) had conducted a technical review of the Carmacks Copper Heap Leach Pad and Waste Rock Dump Designs, submitted by Western Silver Corporation (WSC). This technical memorandum presents our comments and recommendations.

1 Heap Leach Pad and Event Ponds

1.1 Heap Leach Pad Size and Configuration

The heap leach pad has been designed as a valley leach pad, which involves the preparation and placement of leach ore behind a confining embankment (Pad Embankment). Leaching of the ore is performed with subsequent lifts progressing upslope. Ore will be placed on about 31.5 hectares of lined area. The heap leach pad will be surrounded by a two metre high perimeter berm on the north and west sides and a perimeter bench on the east side. The Pad Embankment will for the lower limits of the heap leach pad, with a crest elevation of 780 metres, 22 metres high and 350 metres long. Solution will be collected from the pad area in a network of solution pipes within a free draining overliner layer, and will flow via gravity to an external Events Pond, which is located downstream of the heap leach pad. Diversion channels will be constructed around the perimeter of the pad to divert upgradient surface water.

References used in this study are as follows:

- Access Consulting Group, Project Description and Environmental Assessment Report-Carmacks Copper Project, June 2005
- EBA, Heap leach Pad Liner Design –Carmacks Copper Project near Williams Creek, YT, May 2005
- Clear Water Consultants, Carmacks Copper Project – Heap Leach Facility Water Balance Design Memorandum CCL-CC4, December 1998
- Knight Piesold Ltd., Report on Updated Detailed Design of the Heap Leach Pad and Events Pond, April 1997.
- Kilborn SNC Lavalin, Report on Evaluation of Mineralogy of a Sample of Carmack Acid Leach Residue and Report on Pilot Scale Column Testing of the Williams Creek Oxide Deposit, October 1996.

1.2 Site / Material Characterization

1.2.1 Foundation Conditions

A terrain analysis was performed for the site, resulting in the heap leach pad being relocated from the northwest side of the open pit to the southwest side of the open pit. The analysis indicated shallower moraine soils overlying bedrock on the southwest side.

Geotechnical programs were performed by KP in 1992, 1995 and 1996. SRK reviewed the 1996 field program. Four test pits were excavated adjacent to the heap leach pad to assess local borrow sources and five drillholes were drilled in the area of the heap leach pad to confirm depth to bedrock. The results of the program indicated that the soils in the area under the heap leach pad consist of moraine soils (well graded silty gravely sand) with sufficient ground ice to possibly cause unacceptable settlement (1.2m) or loss of shear strength as they melt. The density of the foundation soils was not provided in the reference documents. Foundation soils with moisture contents greater than 17 percent was used as the basis for determining potentially thaw unstable foundation material.

1.2.2 Foundation Design and Preparation

Prior to construction of the heap leach pad, the area will be cleared and grubbed of any surficial soil, and the surface inspected prior to any fill placement. Test holes will be drilled in a 50 metre grid pattern through the soil cover to either the top of bedrock or to the base of permafrost, estimated to be 25 metres, whichever is shallower. In the test holes, the upper 1.5 metres will be sampled continuously to check for moisture content and suitability for Soil Liner. Below 1.5 metres, samples will be collected every 1.5 metres, or as required by material changes, and tested for moisture content. Samples will be taken, and the subgrade soils will be classified as follows:

- Soil Liner Fill, or material with a permeability less than 10^{-6} cm/sec;
- Random Fill, or material with a permeability greater than 10^{-6} cm/sec; or
- Waste.

Where the soils are determined to be unfrozen, or frozen with moisture content less than 17 percent, construction may proceed without any special foundation treatment. Where there are frozen soils with a moisture content greater than 17 percent within 5 metres of the ground surface, the soils will be excavated and backfilled with durable rock. Areas with frozen material in excess of 17 percent moisture content and deeper than 5 metres will not be over-excavated and will be evaluated on a case by case basis.

Other key conclusions arising from the geotechnical investigation, design analysis and the proposed foundation preparation are as follows:

- The thickness of the overburden soils is typically thinnest at the upgradient end of the heap leach pad (in the order of 3 metres), increasing in thickness in the area of maximum heap leach height (about 27 metres). The varying thickness in overburden depths, along with layers of thaw unstable material will result in differential settlements across the heap leach pad.
- There are soils that may meet the Soil Liner Fill specification for permeability, based on remolded permeability tests performed to 500 kPa confining pressure. These samples were located outside of the limits of the heap leach pad, and SRK does not have the data to comment on samples taken from within the heap leach pad.
- Interface shear strength testing was performed on
    - 60 mil smooth HDPE geomembrane to PN3000 geonet, with reported peak shear strength of 12.7 degrees and no cohesion;

- 60 mil smooth HDPE geomembrane to Soil Liner, with reported peak shear strength of 27.3 degrees and no cohesion

1.2.3 Pad and Event Pond Embankment Design

There will be no “in heap” solution storage of Pregnant Leach Solution (PLS). PLS will be collected at the low point of the heap leach pad, and be conveyed through a pipeline that penetrates the heap leach pad liner system to the solvent extraction-electrowinning process or SX/EW Process via a Collection Pipeline. Excess solution from extreme storm events will be diverted and contained in the Events Pond via a synthetically lined spillway.

The Pad and Events Pond Embankments will be constructed as engineered earth and rockfills. Unsuitable surficial soils will be removed with the limits of the embankments, and a drainage blanket installed. The majority of the embankments will be constructed with Structural Random Fill. The downstream face will be covered with a non frost susceptable fill, while the upstream face will have a filter material between the finer Soil Liner and coarser Structural Random Fill. The embankments will be constructed with a 3H:1V slope of the upsteam face and 2H:1V on the downstream face.

Liner Design and Liner Leakage Rates

KP, 1997 had selected the liner configuration following consideration of the State of Nevada regulations, location to water resource, climatic conditions, height of ore placed on liner, construction methods, hydraulic head and life of facility. KP reported that the allowable leakage rate for each of the 34 individual pad cells into the Leak Detection and Recovery System (LDRS) was 100 litres per day (L/day) averaged over a twelve month period, with a maximum of 300 L/day averaged over a three month period.

EBA, 2005 used these recommendations and proposed three different liner configurations for the heap leach pad: Upper, Lower and Trench Liner Configuration.

- Upper Liner configuration (above elev 830 m within the heap leach pad). In this area, the foundation grades exceed 7:1, and the hydraulic heads are expected to be low:
  - High permeability ($k>10^{-2}$ cm/sec), durable overliner cushion layer with solution piping;
  - 60 mil textured HDPE upper geomembrane;
  - Triplanar geocomposite Leak Detection Collection Recovery System (LDCRS ($k>10^{-2}$ cm/sec);
  - 60 mil textured lower geomembrane.
  - Subgrade

- Lower Liner configuration (below elev 830m within the heap leach pad). The hydraulic heads are expected to approach 1.0m and there is a potential for increased leakage.
  - High permeability ($k>10^{-2}$ cm/sec), durable overliner cushion layer with solution piping;
  - 60 mil textured HDPE upper geomembrane
  - Triplanar geocomposite LDCRS ($k>10^{-2}$ cm/sec)
  - 60 mil textured lower geomembrane
  - Compacted Soil liner ($k<10^{-6}$ cm/sec)
  - Subgrade

- Trench Configuration
  - High permeability ($k>10^{-2}$ cm/sec), durable overliner cushion layer with solution piping;
  - 60 mil textured HDPE upper geomembrane.
  - 12 ounce nonwoven geotextile.
  - Crushed ore, sand or gravel drainage layer ($k>10^{-2}$ cm/sec).

- Triplanar geocomposite LDCRS ($k>10^{-2}$ cm/sec).
- 12 ounce nonwoven geotextile.
- 60 mil textured lower geomembrane).
- Subgrade.

The liner system for the Events Pond was designed with the following:

- 60 mil textured HDPE upper geomembrane.
- Triplanar geocomposite Leak Detection collection Recovery System (LDCRS) ($k>10^{-2}$ cm/sec).
- 60 mil textured lower geomembrane.
- Subgrade.

EBA, 2005 reviewed liner leakage criteria to develop the liner design. EBA, 2005 reported that the allowable leakage rate for the heap leach pad was 100 litres per day (L/day) averaged over a twelve month period, with a maximum of 300 L/day averaged over a three month period, with no mention of pad cells. Therefore, the liner configurations and liner leakage rates reported by EBA, 2005 are different than the liner leakage rates presented by KP, 1997.

In order to protect the Soil Liner portion of the heap leach pad composite liner system from frost damage, the liner will be covered with at least 4.5 metres of overliner and ore prior to winter.

1.2.4 Ore Material

Various reports reference using haul trucks and conveyors to place the ore in the heap leach pad. SRK understands that the final placement method will be via conveyors to minimize the compaction of the ore material.

Reports developed for the project identifies three different methodologies for producing heap leach ore;

- Crushed and agglomerated to 19 mm minus and conveyed to the heap leach pad using conveyors
- Crushed and agglomerated to 25 mm minus, agglomerated with 5 kilograms of concentrated sulphuric acid per tonne of ore and conveyed to the heap leach pad using conveyors
- Hauled as Run of Mine material (RoM) using off road haul trucks.

Aside from moisture contents that were assumed for the water balance and shear strength numbers assumed for the stability analysis, no other geotechnical characterizations were presented for the ore material.

1.2.5 Design Criteria

Design criteria used in the design are as follows:

- Total capacity of 13.3 million tonnes with an dry density of 1.6 tonnes per cubic metre ;
- Design life of 8 years with a maximum rate of 9,872 tonnes per day;
- Typical 8 metre lifts with an overall 2.5H:1V slope;
- Solution application rate of 0.204 litres per minute per square metre with a total raffinate flow of 540 cubic metres per hour (m^3/hr), and a corresponding 44,118 square metres (m^2)under leach.
- Heap Embankment and Event Pond designed to withstand acceleration from the greater of either 50 percent the Maximum Credible Earthquake (MCE) (0.132 g) with a Factor of Safety (FOS) of 1.0 or greater, or 1000 year return period deterministic event (0.103g) with a FOS of 1.15 or greater.

- The consequence of failure of the Heap Embankment and Event Pond is considered to be "High" per the Canadian Dam Safety Association (CDSA), with required Static FOS of 1.5 and pseudo static FOS of 1.15 (EBA, 2005)

- Material shear strengths:
  - Ore properties: Not reported;
  - Earthfill material properties: bulk density of 2.27 tonnes per cubic metre and shear strength of 0 psf cohesion and 36° friction angle;
  - Soil Liner material properties: bulk density of 1.70 tonnes per cubic metre and shear strength of 0 psf cohesion and 18° friction angle;
  - Composite Liner Interface material properties: bulk density of 1.70 tonnes per cubic metre and shear strength of 0psf cohesion and 12° friction angle; and
  - Foundation material properties: bulk density of 2.27 tonnes per cubic metre and shear strength of 0psf cohesion and 36° friction angle;
- Interceptor Channels and Diversion Channels sized to convey the 200 year storm event
- Sediment Pond spillway sized to convey the 200 year storm event
- Total average annual precipitation of 372 mm, with all snowmelt assumed to occur in April each year. Total snowmelt water equivalent is estimated to be 161 mm.
- Events Pond sized to contain the following:
  - Operating volume;
  - Excess runoff from the 100 year return period;
  - Draindown as follows:
    - 100 percent of the potential heap draindown volume during the first year; or
    - 48 hours of draindown at the full solution application rate.
  - Redundant systems

1.3 Slope Stability

Slope stability analysis were performed for the heap leach pad. KP, 1997 developed the stability model using the critical slope stability section geometry, material shear strengths identified in the Design Criteria and modeled the phreatic surface at the existing ground surface above the Pad Embankment, and at the same elevation as the crest elevation of the Pad Embankment behind the Pad Embankment (representing worse case saturated ore conditions). Static and pseudo-static FOS of 1.7 and 1.3 were calculated, respectively, which met the minimum FOS criteria.

1.4 Hydrology

Unimpacted surface water upgradient of the heap leach pad will be diverted to the North Williams Creek via open flow, gravity diversion channels.

Potentially impacted waters will be collected in gravity interception channels and conveyed to the Settlement Pond. Overflow spillways from the Settlement Pond will drain into Williams Creek. The Sediment Control Pond was designed with a capacity of 14,000 m3, which corresponds to the runoff from the 10 year storm over an upgradient catchment area of 39 hectares.

No information was presented for surface water basin delineation, runoff coefficients, peak surface water runoff flow rates or velocities, or channel sizing. No static or pseudo-static stability analysis was performed on the Sediment Control Dam.

1.5 Hydrogeology

A foundation drainage system (underdrain) will be installed in the major lowpoints or valleys underneath the heap leach pad composite liner system to intercept and remove any near surface and seasonal groundwater flows. A separate underdrain system will be constructed underneath the Events Pond as well. The underdrain will be comprised of a corrugated polyethelene pipe surrounded by drain gravel and wrapped in geotextile. The underdrain will convey collected groundwater via gravity to a drainage collection sump downstream of the embankment. If the water quality of the collected groundwater is acceptable, it will be discharged below the Events Pond, otherwise it will be discharged into the Events Pond.

1.6 Water Balance

A water balance was performed for the heap leach pad, assuming RoM material being placed in the heap leach pad by KP, 1997, and updated by CCL, 1998. Water balances were modeled for average precipitation events, 20 year dry year and 100 year wet year precipitation conditions.

Results from the KP water balance indicated that there was sufficient capacity to contain water within the Event Pond for Stages I and II, Stage III would require treat and release under wet year conditions, and Stages IV through VI would require treat and release of excess water for dry, average and wet years.
The facility was designed with an event ponds located below the heap leach pad. Based on the results of the water balance, the ponds were sized to contain approximately 160,000 m^3.

CCL, 1998 had performed a revised water balance to confirm the size theof the Events Pond, using updated ore properties and precipitation values.

1.7 Monitoring

The heap leach facility will be monitored on an on-going basis to evaluate overall performance and ensure that design objectives are being satisfied. Instrumentation such as vibrating wire piezometers, survey monuments, water level monitors and flow metres will be installed within the facility

1.8 Closure

Key issues in the closure of the heap leach pad include the following:

- Chemistry of the runoff and drainage;
- Erosion and dust control;
- Establishment of vegetation;
- Decommissioning of the Events Ponds; and
- Water management.

At closure, the heap leach pad will continue to be leached and rinsed following the cessation of mining. An evaporative soil cover will be placed over the resloped heap leach pad and rinsed with water. Effluent from the heap will be treated for release with final solution passing through an infiltration gallery at eventual closure. Carbon based nutrient will be added to the heap after rinsing is complete to enhance immobilization of metals in the infiltration gallery.

WSC has proposed two cover designs. The first was a compacted cap with minimum permeability requirements. However, there are concerns about the impacts of freezing and thawing on hydraulic conductivity. A store and release cover was proposed as a second alternative, in which water would be stored in the soil, with the majority of water released back to the atmosphere through evapotranspiration.

1.9 SRK Comments

SRK has the following comments:

- *General inconsistencies*. Examples of inconsistencies include that the report does not use a consistent heap leach ore dry density (1.6 to 1.9 tonnes per cubic metre), the thickness of the geotextile varies (12 ounce versus 8 ounce), and EBA, 2005 references that the Lower Configuration is adjacent to the Pad Embankment (crest elevation 780 metres), but also references the Upper Configuration begins at elevation 830 metres and above. The design documents should be reviewed and follow a common set of consistent data;
- *Heap Leach Pad Location*. The heap leach pad is within about 100 metres of the ultimate limits of the pit. The pit proximity and impacts that this could have on the pit stability should be considered.
- *Geotechnical Foundation Conditions*. There are three areas that have been identified to date within the heap leach pad limits that have frozen soils at depths greater than 5 metres. Because of their depth, excavation was not feasible. As part of the final design, foundation stabilization options such as using geogrid or constructing a mat of durable rock fill should be evaluated:
- Foundation Preparation and Settlement. There is insufficient data to confirm the settlement calculations performed by KP, 1997. Due to the amount of differential settlement identified, this value should be evaluated, and a liner design developed that will accommodate this magnitude of movement.
- *Materials*. SRK has the following comments on materials identified in the heap leach pad construction:
    - Overliner. The overliner is a key component to minimizing the head on the geomembrane liner and corresponding liner leakage. The material needs to be extremely durable, as it will be exposed to acidic solutions for the life of the project. Any degradation would result in increased head on the liner, which could result in increased liner leakage rates and slope instability. There is no discussion on the source of the rock material or any laboratory testing to demonstrate its geotechnical acceptability (durability, grain size, maximum percolation rate versus normal load, etc.). Also, the text references a maximum thickness of 1.0 metres. There needs to be a discussion on the minimum thickness that will be allowed.
    - Soil Liner: The Soil Liner is a low permeability soil material that is an integral component of the composite liner system. KP has reported that there are soils that may meet the Soil Liner specification for permeability, based on remolded testing performed to 500 kPa confining pressure. WSC should perform permeability tests on remolded samples using an agreed upon confining pressure, such as average or end of first lift normal load conditions. The results presented by KP, 1996 were located outside of the limits of the heap leach pad, and SRK does not have the data to comment on samples taken from within the heap leach pad. EBA, 2005 references that Soil Liner will be placed in 150 mm lifts and stones greater than 10 mm will be removed as part of the Quality Control program. This approach to QC will be difficult to implement and follow in the field, and WSC should consider a 25 mm minus Soil Liner specification.
    - Geomembrane Subgrade: There is no discussion on the quality and preparation of the insitu subgrade materials and the expected performance of the geomembrane.
    - Specifications should be developed that identify gradations, angularity, density, compaction, etc. requirements for each material.
- *Interface shear strength testing*. KP reported interface shear strength testing form peak strength values. The design should be based on lower residual shear strength parameters. The geotextile / Soil Liner interface may be the critical surface, as compared to the HDPE geomembrane / Soil liner interface. Laboratory testing should be done to confirm the critical interface, a literature search to confirm the values used and the stability analysis revised if necessary;
- *Liner Selection*. There is no discussion on the basis for the selection of the geomembrane type and thickness.
    - Geomembrane Type: The report discusses the potential for increased settlements due to thawing of permafrost areas, and the potential for localized settlement. WSC should

evaluate the properties (strain, etc.) for the types of liners currently available on the market, and confirm the most appropriate type for this site.

- Geomembrane Thickness: The report discusses the use of 60 mil HPDE geomembrane. Site specific conditions such as differential settlement and expected strain as well as maximum normal loads should be evaluated to confirm the thickness of liner that would be used for this project.
- Liner Configuration.
  - The KP, 1997 report references an allowable annual average liner leakage rate of 100 litres per day and an allowable quarterly average pf 300 litres per day for each of the 34 cells in the heap leach pad, both values of which appear to be taken from the Brewery Creek Project. EBA, 2005 references the liner leakage rate of 100 litres per day and an allowable quarterly average pf 300 litres per day, but implies that these are for the entire heap leach pad. Liner leakage rates are a function of the permeabilities of the Soil Liner and overliner material, size of defects assumed per hectare of geomembrane and total geomembrane area, all parameters of which are site specific. SRK recommends that site specific liner leakage rates be developed now and that Allowable Limits and Response Plan (ALRP) be developed for the site as part of the final design.
  - The liner configuration presented by EBA, 2005 is different than that presented by KP, 1997. In either case, the liner configuration proposed is similar to that generally specified for hazardous waste landfills. A liner configuration should be developed for the site that represents the Best Available Demonstrated Technology. This would typically consist of a composite liner system in areas with minimal expected head values and a composite liner system with LDCRS in areas where solution ponding (below the elevation of the Pad Embankment for example) could be expected.

- *Pad Embankment*. As the heap leach pad has been designed with an external Events Pond, the Leach Embankment size should not be based on storage capacity. The stability analysis does not present any discussion on variations of the pad Embankment height and FOS. Therefore, it is unclear what is the basis for the Pad Embankment;
- *Ultimate Heap Leach Pad Height*. The report discusses that ore will be placed in 8 metre lifts, but there is no discussion on the maximum ore depth. The maximum height can be related to stability, but is more often related to the ability of the ore to maintain a minimum acceptable percolation rate as a function of normal load and time. EBA, 2005 reported a saturated and unsaturated permeability of $1x10^{-8}$ metres per second for the ore material, which is the same as the permeability of the Soil Liner. Percolation tests should be performed on samples of ore to confirm the maximum height that ore can be stacked, considering such factors as ore durability and unsaturated permeability;
- *MCE and PGA earthquakes*. The design criteria identified that the Heap Embankment and Events Pond would be designed to withstand acceleration from the greater of either 50 percent of the MCE (0.132 g) with a Factor of Safety (FOS) of 1.0 or greater, or 1000 return period deterministic event (0.103g) with a FOS of 1.15 or greater. KP, 1997 reported a FOS of 1.0 for 100 percent of the MCE. In addition to confirming that the criteria and Peak Ground Acceleration (PGA) values represent current seismic requirements and data, the stability analysis should be performed for the PGA noted in the design criteria to determine if an acceptable FOS can be achieved;
- *Stability Analysis*. Per CDSA for a “High” consequence structure, a Static FOS of 1.5 is required for the Leach Embankment. KP, 1997 calculated a static FOS of only 1.4. Therefore, the stability of the Leach Embankment needs to be re-evaluated;
- *Solution Collection Lowpoint and Geomembrane Interface*. PLS from the heap leach pad will be conveyed through the Pad Embankment to the SX/EW via a pipe that penetrates the liner system. While this approach minimizes the volume of solution impounded in the heap leach pad, the pipe boot and embankment penetration have the potential to result in leakage from the heap leach pad due to damage from construction methodology and differential settlement. Considering that KP, 1997 estimated 800 to 1000 mm of settlement in the area of the Solution Collection lowpoint, that will result in a significant

amount of stress on the geomembrane liner in the area of the Solution Collection Manhole and Pipeline and could result in a breach of containment. The pipe inlet design and transfer pipe size will control the rate at which solution can be conveyed into the SX/EW. Therefore these details are not only critical to the performance of the proposed solution recovery conveyance approach, but to the concept of minimizing the head on the heap leach pad liner. This concept and corresponding design details must be developed in more detail;

- *Solution Exposure*. An external Events Pond for storage of PLS will require protection for animals and birds. Details on how wildlife be protected from exposure to the PLS should be presented;
- *Climatic Data*. Climatic data was reported for the site from 1994 to 1997. This data should be updated and compared to the values used in the design criteria;
- *Design Storm events*. The closure plan references that the diversions will be designed to convey peak flows for the 100 year return period, while the design criteria suggests that the diversions will be designed to convey the 200 year storm event. This should be resolved.
- *Water Balance*: The report discusses that PLS will gravity drain to the SX/EW, resulting in an empty Events Pond for the majority of the year. This assumes that PLS will flow from the heap leach pad to the SX/EW at a relatively constant and consistent rate, with limited ability to buffer fluctuations in flow capacity. The water balance should be revised to reflect the Events Pond providing surge capacity.
- *Water Balance*: The water balance was based on RoM material, which had an initial water content of 3 percent, a leaching water content of 12 percent and a residual water content of 10 percent. The current report references crushed 19 mm minus ore. The water balance should be updated using data that reflects the properties of crushed ore, including density;
- *Water Balance*. The results of the water balance in Section 4.6 of CCL, 1998 states that "a storage volume of 160,000 m^3 will be provided in the events pond. This volume is 22,000 m3 more than the maximum required solution storage volume calculated using the above criteria presented in the water balance model". Section 3.3 of the same document states that "the system will not require the treatment and release of any excess water during the first three years of ore placement. Average and drier conditions will not require any released until Year 7. Some excess water may require treatment and release during Years 4 to 7 as a result of 100 year wet years". SRK does not understand how the Events Pond can have 22,000 m^3 of excess capacity, but the water balance indicates the need to treat and release up to 200,000 m3 of solution. SRK would recommend that the water balance be performed using agreed upon criteria. Suggested design criteria would be as follows:
    - Defined operating volume.
    - Design storm event. Average annual precipitation, with 100 year snowmelt (from snowfall accumulations of October through end of April) occurring in the month April.
    - Forty eight hours of draindown.

  Sensitivity analyses could then be performed using a set of more conservative design criteria, with treat and release options considered as part of that study; and
- *Monitoring*. Vibrating wire piezometers have been proposed for monitoring the heap leach pad. These can be very unreliable and need to be calibrated on regular intervals after installation. An alternative approach should be incorporated into the design.
- *Closure*.
    - The design concept for breaching the Pad Embankment at closure was revised and replaced with a permanent gravity flow pipeline constructed in the initial phase of construction. This assumes that the pipe integrity will be maintained indefinitely, otherwise water would have to impound to the crest elevation of the Pad Embankment before being able to overflow via the spillway. In the event that the pipe collapsed or failed, solution would have to be impounded to the spillway elevation before it could exit the heap leach pad, resulting in saturation of the ore within the impounded limits and possible impacts to the stability and water quality of the facility. SRK recommend that WSC consider a redundant underdrain be incorporated into the design, that would allow for the solution to be discharged at closure within minimal head on the liner system.

- No method has been proposed to address solution build up in the LDCRS. The redundant rock underdrain proposed above would allow for the discharge of water impounded within the LDRCS as well.
- The store and release cover offers several advantages over a compacted cap, but this assumes that the surficial soil can promote the growth of a vegetative cover. SRK is concerned that surface water runoff can erode the soil surface, concentrating flow, resulting in erosion gulley. Therefore, there is a balance between the size of rock needed to withstand the surface water sheet flow velocities and the size of soil particles needed to support and nurture a vegetative cover. This is particularly relevant in this type of climate where a significant amount of precipitation is generated and is assumed to runoff in a one month period from snowmelt that has accumulated over a six month winter season. SRK recommends a more detailed closure cover design.
- WSC estimated that the seepage entering the heap could be cut in half though the installation of a store and release cover (15,000 to 20,000 m^3), as compared to no cover (35,000 to 45,000 m^3), but no detail is provide on the configuration of the cover. SRK recommends that a sensitivity analysis be performed on the cover design, to identify an optimal thickness.
- No closure information was provided for the Events and Sediment Ponds. It was assumed that any synthetic materials would be removed and the areas regraded and revegetated to match pre-mining conditions and topography. This should be confirmed.
- The heap leach closure plan has been developed assuming that a fresh water rinse will bring the effluent to a pH of near 4, sodium carbonate added to increase the pH to about 7, and the long term release of effluent into a passive infiltration gallery. WSC, 2005 estimates a 2 to 10 year closure period, while the water balance performed for the heap leach pad assumed a three year heap rinsing period (years 10, 11 and 12). The closure plan and water balance should follow the same criteria.

2 Waste Rock Storage Area

2.1 Waste Rock Storage Area Size and Configuration

The Waste Rock Storage Area (WRSA) is located immediately north of the open pit on a gentle northeast facing slope. It is sized to contain 60 million tonnes, covers an area of about 70 hectares and will be dumped in 25 metre high lifts at angle of repose with intermediate benches wide enough to maintain an overall slope of 2.25H:1V. Surface water runoff and seepage from the WRSA will be collected in perimeter collection ditches located at the toe of the facility and conveyed in an outlet channel to the Sediment Control Pond.

This particular site was chosen as to minimize the haul distances from the pit and minimize any potential impacts on existing surface drainage courses.

References used in this study are as follows:

- Access Consulting Group, Project Description and Environmental Assessment Report-Carmacks Copper Project, June 2005
- Knight Piesold Ltd., Report on Detailed Design of Waste Rock Storage Area, May 1997.

2.2 Site / Material Characterization

2.2.1 Foundation Conditions and Preparation

The WRSA is situated on potentially thaw unstable permafrost, varying in depth from 10 to 15 metres. No treatment has been proposed for the area. Prior to placement of waste rock material, the footprint area will be cleared and grubbed, and material stockpiled in a designated area. KP 1997 has recommended two field programs that will be implemented during various stages of the operations:

- Pore Water Pressure Monitoring. KP, 1997 has predicted that pore water pressure will increase with time in a thawing soil layer, and developed a stability model based on these estimates. Actual pore water pressures and pore water dissipation rates will be monitored from installed instrumentation to confirm that stability objectives are being met. In the event that conditions are not as anticipated, appropriate design modifications will be implemented.
- Geotechnical Investigations. At approximately year 3 of the mine development, the extent of thaw and other geotechnical conditions will be re-evaluated to determine dump stability prior to placement of waste and the ultimate dump revised as required. Before final closure, WCH will carry out a site investigation to confirm the stability of the waste rock, and address any issues through regrading the slopes or the construction of a key trench, for example.

2.2.2 Design Criteria

Design criteria used in the analysis are as follows:

- Capacity of 60 million tonnes at a dry density of 2.0 tonnes per cubic metre;
- Design life of 8 years with an annual production rate of about 7.5 million tonnes;
- Waste Dump designed to withstand acceleration from the MCE (0.13g);
- Static FOS of 1.3 and pseudo-static FOS of 1.0;
- Material shear strengths:
  - Waste Rock material properties: bulk density of 2.00 tonnes per cubic metre and shear strength of 0psf cohesion and 37° friction angle;
  - Foundation material properties: bulk density of 2.04 tonnes per cubic metre and shear strength of 0psf cohesion and 39.5° friction angle and r_u=0.4.
- Diversion channels sized to convey the 200 year storm event; and
- Sediment control ponds sized to contain the 10 year storm event and a spillway that can convey the 200 year storm event.

2.3 Slope Stability

Slope Stability analysis were performed for WRSA. KP, 1997 developed the stability model using the critical slope stability section geometry and material shear strengths identified in the Design Criteria. Foundation soils were modeled with a pore pressure ratio of 0.4. Static and pseudo-static (0.13g) FOS of 1.7 and 1.3 were calculated, respectively, which met the minimum FOS criteria.

2.4 Hydrology

Unimpacted surface water upgradient of waste rock dump will be diverted to the North Williams Creek via open flow, gravity Perimeter Collection ditch (sized to convey 1.25 m^3 per second) that runs along an 100 metre offset from the WRSA.

Surface Drainage Ditches will be located within the footprint of the WRSA. Initially, the Surface Drainage Ditches will divert surface water, but they will be eventually covered by waste rock and ultimately collect seepage from the WRSA. A Surface Drainage Collection Ditch (sized to convey 0.65 m^3 per second) will collect seepage as well as water from the Surface Drainage Ditches, and convey collected water to the Sediment Control Pond.

The Sediment Control Pond was sized to contain a volume of 65,000 m^3, which is comprised as follows:

- Runoff from 10 year storm event (10,000 m^3);
- Dead Storage (10,000 m^3);

- Surface runoff from WRSA (10,000 m^3);

Stored water will be pumped for use at the Process Plant. Overflow spillways from the Settlement Pond will drain into Williams Creek.

2.5 Hydrogeology

KP, 1997 reported that the activities associated with the construction of the WRSA would initiate the thawing of permafrost. And that seepage generated from the thawing of the soils would flow downslope and be intercepted by drains along the toe of the WRSA. KP concluded that the seepage losses into the groundwater would be an insignificant amount and seepage losses to North Williams Creek would not be of concern.

2.6 Monitoring

The waste rock dump will be monitored on an on-going basis to evaluate overall performance and ensure that design objectives are being satisfied. Instrumentation such as vibrating wire piezometers, survey monuments and flow weirs will be installed within the facility, along with an annual review and inspection program.

2.7 Closure

Key issues in the closure of the WRSA include the following:

- Chemistry of the runoff and drainage;
- Erosion control;
- Establishment of vegetation; and,
- Water management.

WSC has proposed the following reclamation approach:

- Surface water collection ditches will be maintained to collect and control surface drainage
- Slopes and benches will be maintained with no regrading of slopes. The benches will be capped with 300 mm of overburden material and revegetated with natural species.
- The final surface of the WRSA will have material stockpiled to imitate a rolling landform

When long term reclamation monitoring has indicated that runoff and seepage are of suitable quality for direct release to the environment, the surface water runoff ditches and Sediment Control Pond will be decommissioned.

2.8 SRK Comments

SRK has the following comments:

- *MCE and PGA earthquakes*. The minimum static and pseudo-static FOS values are different than that developed for the heap leach pad. In addition to confirming consistent design criteria across the site, the PGA values should be evaluated to determine if they represent current seismic requirements and data. SRK suggests that reference be made to the a May 2004 report prepared by Gail Atkinson on the "Seismic Hazard Assessment for Faro, YK" The stability analysis should then be performed for the PGA noted in the design criteria to determine if acceptable an acceptable FOS can be achieved;
- *Stability Analysis*. KP, 1997 incorporated a shear strength of 39.5° for the foundation soils, which is higher than the value used for the waste rock. The shear strength should be based on lower residual shear strength parameters. This should result in a shear strength less than that assumed for the waste rock, which would then change the critical slope surface from a circular failure to a wedge failure, which would result in lower FOS values. Therefore, the stability analysis should be performed with more appropriate foundation shear strength values.

- *Foundation conditions*. The majority of geotechnical investigations in the WRSA have involved only test pits, and there is little data on the depth to bedrock. The test pits show that permafrost is relatively close to surface, and that the majority of the WRSA footprint will be situated over permafrost soils. It is unclear as to the short and long term impact that the WRSA will have on the permafrost area.
- *Hydrogeology*. KP, 1997 assumed minor impacts to the local hydrogeological regime. This should be evaluated in further detail.
- *Monitoring*: Vibrating wire piezometers have been proposed for monitoring the waste rock dump. These can be very unreliable and need to be calibrated on regular intervals after installation. An alternative approach should be incorporated into the design.
- *Closure.* The current closure plan is somewhat dated, and implies that the stockpiled rock will be generally neutral and that there would be relatively minor water quality impacts. It also does little to address the aesthetics of the stockpile. A more current closure plan should be developed.

    - No closure information was provided for the Sediment Ponds. It was assumed that the areas be regraded and revegetated to match pre-mining conditions and topography. This should be confirmed.
    - Because of potential water quality issues, low grade material was identified that may be stored in a stockpile separate to the WRSA and heap leach pad. A conceptual closure plan for the LGO should be developed which addresses the volume of the material, the stockpile location and the overall approach to operating and closure.
    - The WRSA should be regraded, covered and revegetated in a manner to match pre-mining topography.
    - Based on the limited testing performed to date, WSC has based their closure approach on the belief that ARD would not be generated and seepage would be able to be discharged into the environment without treatment. SRK recommends that kinetic or column leach testing be performed on a sufficient number of representative samples. A contingency should also be developed in the event the site monitoring during operations indicated water quality issues.
    - WSC states that the “reclamation and revegetation will be ongoing so that in the event of suspended operations or a premature closure, revegetation will be well in advanced of disturbance”. Of the open pit (29.5 ha), WRSA (69.6 ha), heap leach pad (37.2 ha) ,plant and ancillary facilities (13.3 ha), and access and haul roads (12.3 ha), only a few hectares of the WRSA (the 7 metre wide bench at every 25 metre high lift) would actually be reclaimed. WSC should identify what concurrent reclamation activities could occur during operations