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Ketza River Mine Project Adequacy Review

Water Resources
Yukon Dept. of Environment

February 2012
SLR Project No.: 201.88448.00

KETZA RIVER MINE PROJECT ADEQUACY REVIEW

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February 13, 2012

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Final Report

Distribution: 1 electronic copy – Water Resources

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1.0 INTRODUCTION

SLR Consulting (Canada) Ltd. was retained by Yukon Environment, Water Resources Branch, to complete an external adequacy review of selected components of the YESAA Executive Committee Project Proposal, Ketza River Project – Ross River Yukon (henceforth referred to as the "Project Proposal").

The objectives of the adequacy review were to identify any missing/inadequate information and make recommendations on information needed to fill the identified data gaps.

The review completed by SLR consisted of a high level review of the following components of the Project Proposal:

- Groundwater (baseline, model, prediction of impacts and proposed mitigation measures and monitoring);
- Geochemical characterisation program [acid rock drainage (ARD)]; and,
- Surface water quality (baseline, prediction of impacts, proposed mitigation measures and monitoring).

1.1 Information Reviewed

The documents reviewed by SLR were posted on the YESAB ftp site (Project No.: 2011-0218, Project Title: Ketza River Mine) and included the following:

Doc No	Description	Section reviewed (if applicable)
060-1	Project Proposal (Single File)	Section 4.9, Section 4.11, Section 6.4, Section 8.7 and Section 8.9
031-1	Appendix G – Surface Water Quality Sampling Results	
032-1	Appendix H – Detailed Hydrogeological Assessment (Part 1 of 3)	
033-1	Appendix H – Detailed Hydrogeological Assessment (Part 2 of 3)	
034-1	Appendix H – Detailed Hydrogeological Assessment (Part 3 of 3)	
038 -1	Appendix K – Acid Rock Drainage (Part 1 of 2)	
039-2	Appendix K – Acid Rock Drainage (Part 2 of 2)	

2.0 SUMMARY OF REVIEW COMMENTS

The available groundwater baseline data presented in the Project Proposal was considered to be generally adequate for a project submission.

The geochemical (ARD) characterisation program was based on single samples for the tailings and ore material portion of the assessment which was considered to be insufficient for a defendable assessment.

The surface water baseline data provided in the Project Proposal was presented in a format not considered to be adequate for a project submission. Generally, the statistics used to describe the baseline data were incomplete and the raw surface water quality data was not provided in Appendix G of the Project Proposal.

The assessments of impacts on groundwater and surface water were considered to lack sound, defendable mathematical models (water quantity) or to lack quantitative assessments entirely (water quality).

At present, the Project Proposal assumes that there will be little if any contaminated seepage to the underlying groundwater from the Waste Rock Dump (WRD) sites, Run-of-Mill (ROM) ore storage area and the Tailings Storage Facility (TSF) and therefore, does not provide a very detailed assessment of impacts to groundwater (and surface water through groundwater discharge) from these areas. There is insufficient information provided to support this assumption and the information provided suggests that contaminated leakage from these facilities is a possibility. Therefore, a more comprehensive assessment of groundwater quality impacts is recommended.

For this assessment, it is recommended that the available data be incorporated into a site-specific numerical groundwater flow and transport model to assess the single and cumulative environmental impacts arising from a multitude of mine voids and mine residue deposits. Given the noted depth of groundwater levels in the bedrock, the selected model code should preferably be capable of simulating unsaturated flow and transport from the WRD sites and TSF towards the saturated zone, as well as saturated flow and transport.

The post-closure assessment should address potential decanting from underground mine voids and establish final pit lake water levels (if any) and the timing of water level recovery in the pits using water balance approaches.

A mass balance model should be used to predict surface water parameter concentrations in downstream receiving water bodies (in accordance with YESAB Water Information Requirements for Quartz Mining Project Proposals, December 2011). The mass balance should include effluents and contact and non-contact areas and should be run for conditions critical to aquatic life such as minimum low flow and maximum flow. The surface water impact assessment should be updated once this information becomes available.

More detail should be provided on the proposed mitigation measures. For example, details are needed about the engineered liners proposed to prevent leachate seepage from the WRD sites and ROM area into the groundwater. The information presently provided is very general and lacks sufficient detail and assessment to support the claims made about effectiveness of mitigation. Also, more information should be provided about the management and ultimate fate of water captured by the collection system below the WRD sites, if found to be contaminated. The Project Proposal indicates that this water will be directed to the TSF, but this transfer appears to occur along unlined ditches which will likely result in significant loss of contaminated water to the subsurface and underlying groundwater. A mitigation to prevent this discharge is recommended. Also, does the TSF have the capacity to handle this water, will this water ultimately be discharged from the TSF and if so, how will it be treated before discharge?

It is recommended that more information be provided on the approach to encapsulation of the potentially acid generating (PAG) material in the non-acid generating (NAG) material to prevent generation of ARD from the WRD sites, to confirm the feasibility of this approach. It is also recommended that an expanded ARD assessment be undertaken at a later stage of the mining project and linked to each mining block, to ensure that the PAG and NAG material is handled appropriately and that sufficient NAG material is allocated at each phase of the project for PAG confinement.

Detailed review comments pertaining to the material reviewed are provided in Sections 3 to 5, below.

3.0 HYDROGEOLOGICAL ASSESSMENT

3.1 Review objectives

EBA, a Tetra Tech Company, was subcontracted by Ketza River Holdings (KRH) to assist KRH with the permitting and planning of the proposed Ketza River Mine. A Detailed Hydrogeological Assessment (DHA) was completed by EBA to provide the necessary hydrogeological baseline information required for preparing the YESAA project proposal submission. The DHA program assessed the site specific groundwater flow dynamics (including seasonal variations of the piezometric surface), the properties of the overburden and bedrock aquifer as well as the groundwater chemistry (including seasonal variations) to develop a baseline conceptual hydrogeological model for the site.

The review of the description of existing hydrogeological conditions (chapter 4.11 in the project proposal, Doc No 060-1 including Appendix H, Doc No 032-1 to 034-1), the hydrogeological environmental effects assessment and proposed mitigation measures (chapter 8.9 in the project proposal, Doc No 060-1) presented by KRH and EBA is guided by the YESAB information requirements for Executive Committee Project Proposal Submissions:

- Providing baseline information.
- Predicting potential adverse effects resulting from the proposed project.
- Proposing mitigation measures for identified potential adverse effects.

3.2 Baseline information

3.2.1 Monitoring network

The Detailed Hydrogeological Assessment (DHA) completed by EBA (Doc No 032-1 to 034-1) comprises the outcomes of a desktop study as well as two field work campaigns (2008 and 2010/2011).

During the 2008 campaign 19 diamond drill holes (DDHs) were drilled (5 to 160 metres below ground level), monitors were installed (including 5 nested wells), hydrogeological testing was completed (water level measurements, packer, slug and short term pumping tests) and groundwater samples were collected for analysis (major elements as well as total and dissolved metals).

During the 2010/2011 field campaign:

- 5 DDHs were drilled (60 to 200 metres below ground level within the proposed pit areas) and tested, and one nest of monitors installed.

- 14 Becker Hammer drill holes (BDHs) were drilled (5 to 25 metres below ground level, within the proposed TSF area) and 9 of these holes equipped as monitoring wells (2 nested wells).

Borehole logs including hydraulic properties (if determined) and installation details for all monitoring wells are provided in Doc No 033-1 and 034-1.

EBA based the design of the monitoring network on available information from existing water wells (including Camp Well, Lower Mill Well, Upper Mill Well, Core Shack Well, and 1510 Portal Well) and on the mine design as provided by KRH at the time of the assessment (i.e. located in the vicinity of existing and proposed mining infrastructure).

The design of the monitoring wells, especially the installation of the nested wells is considered adequate at this stage of the review, with the exception of a lack of monitor directly upgradient of the Canamax TSF. A monitoring location upstream of the Canamax TSF is recommended as part of the Project Application to establish current hydrochemistry baseline for comparison to downgradient water quality to assess impacts of this existing feature. This is considered important and relevant at this stage of the approvals process because an assessment of impacts from the current TSF can provide confirmatory information about site specific dilution and attenuation processes to enhance and validate the prediction of future impacts from the proposed mine facilities in the valley. Note that additional monitoring wells will be required for long-term monitoring of mining related groundwater impacts, but these other refinements to the monitoring network can likely be addressed during the licencing phase of the project.

3.2.2 Hydraulic characterization of geological units

The geological information provided in the Project Proposal (Doc No 060-1, appendix D) and in the Detailed Hydrogeological Assessment (Doc No 032-1 to 034-1) is generally deemed sufficient for the development of a conceptual hydrogeological model.

Additional representative geological cross-sections through the main axes of the Cache Creek (e.g. Tarn Lake through Tarn Dump, Peel Dump 3 through TSF to Water Retention Pond) and Misery Creek Valleys should be prepared at this stage of the approvals process. Groundwater flow is generally towards the valley bottoms and then laterally coincident with the valley bottoms and therefore, these are critical sections for demonstrating an understanding of flow along key subsurface pathways of potential contaminant migration. The cross sections should include information about the different lithologies and faults as well as groundwater to enhance the geological and subsequent hydrogeological understanding of the site.

Hydraulic testing of the installed monitoring wells (Table 4.11-2 in Doc No 060-1 and chapter 4.4 in Doc No 032-1) yielded generally plausible values for the tested lithologies, despite the often poor fit of observed data with the chosen analytical solutions for the slug and pumping tests (Doc 034-1). Variances between the conductivity values derived with different test methods (packer, slug and pumping tests) are not discussed, but, based on the information review, are within acceptable margins.

The relationship between hydraulic conductivity values and the tested lithologies, aquifers (overburden or bedrock) and mining areas are not consistently reported in the different Project Application documents (for example, see Table 4.11-2 in Doc 60-1 and tables in chapter 4.4, Doc 032-1 which do not identify the lithology associated with each test result).

It is recommended they be added to the documents, at this stage of the project review, to enable an evaluation of potential spatial variability.

3.2.3 Groundwater elevation and flow directions

EBA presents in the DHA (Doc No 034-1, chapter 4.2) a discussion of observed water level measurements and their seasonal variability for boreholes with multiple observations. From the limited number of boreholes with multiple data, a pronounced seasonality of water levels in the deeper bedrock aquifer is evident. Seasonal variations of up to 25 metres were observed and are indicative of a seasonally recharged, low porosity aquifer. Water levels observed in nested boreholes indicate a poor hydraulic connection between the overburden and bedrock aquifer.

Only the February 2011 dataset was used to interpolate groundwater contours and to derive flow directions in the bedrock aquifer. No interpolation method is provided. The derived contours are generally a subdued copy of the regional topography and groundwater flow is generally towards the lower lying valleys and rivers. A cross-plot of ground surface and water table elevations would provide additional support for the assumed model. It is recommend that either the interpolation method be described or a rationale for not providing the interpolation method be added in the Project Application at this stage of the review,

Based on the strong seasonality of observed water levels, a separate “summer” groundwater contour map should be developed, as it might change the gradients used in the predictive models for the environmental impact assessment.

3.2.4 Hydrogeochemical site characterization

As part of the 2008 and 2010/2011 fieldwork program, EBA sampled numerous boreholes using acceptable methods and quality control measures. Most samples show acceptable ion balance errors (<5%) or exceed it only slightly (5 – 7 %). An exception is sample HYD-08-27 (from well HYD-08-11A), which should be treated with precaution due to an unacceptable ion balance error of above 17% (Table 3, Doc No 032-1).

The site specific groundwater chemistry shows a substantial variability with regard to pH values (3.6 to 8.2), dissolved oxygen (1.11 to 13.3 mg/L), total dissolved solids (87 to 3280 mg/L) and subsequent elemental concentrations. The water facies range from a Ca-Mg-HCO_3 type in non-mineralised areas (e.g. Lab-Hoodoo Dump) to a Ca-Mg-HCO_3-SO_4 type in the mineralised Manto Zone to Ca-Mg- SO_4 type in the mineralised Shamrock Zone, clearly reflecting the underlying lithology and the ore body.

It is interesting to note that numerous samples influenced by the ore body show clearly elevated arsenic concentrations (originating from the weathering of arsenopyrite), but only moderately elevated sulphate concentrations. Exceptions from this trend are samples from wells HYD-08-06A, HYD-08-11A (also lowest pH value and highest iron concentration) and HYD-10-01A, which show highly elevated sulphate and arsenic concentrations. The sample from well HYD-10-01A, located between the Tarn Lake and Tarn B pit, shows the overall highest sulphate concentration (2,150 mg/L) along with highly elevated concentrations of dissolved arsenic (1.05 mg/L). This apparent anomaly in the data set (i.e. the origin of this water quality upstream of the Tarn B pit) should be discussed in the Project Application as it reflects current baseline conditions.

While the geogenic water quality is discussed by the authors, they do not address and document potential impacts of historical mining activities (i.e. pits, waste rock dumps and the Canmax TSF) on the regional water quality, which might shed light on some of the outliers mentioned above. An assessment of the effects of historical mining activities is also important and relevant to the Project Proposal because they provide site specific case histories about the potential for impacts and provide information on contaminant dilution and attenuation mechanisms that can be used to enhance and validate the predictions of future mining impacts.

A comparison of the dissolved metal concentrations to water quality guidelines and standards by the authors show numerous exceedances of applicable limits, including the Yukon Contaminated Site Regulation standards (for arsenic, cobalt, cadmium, copper and sulphate).

It is for this reason, that the geogenic water quality (influenced by the in-situ ore body) should be differentiated from the anthropogenic water quality (influenced by past mining and potentially current exploration activities) to enable monitoring of potential future mining related water quality impacts against the site-specific baseline.

3.2.5 Conceptual hydrogeological model

The authors summarize the available site-specific hydrogeological information in a straight forward and sound conceptual model, comprising of an unconfined overburden and a deeper bedrock aquifer.

Groundwater recharge occurs predominantly at higher elevations and discharges towards lower lying river courses. Recharge as well as surface - groundwater interaction is only discussed qualitatively. The regional groundwater flow is visualised on a contour map as well as in two hydrogeological cross-sections, which lack any geological information. The hydrogeological cross-sections should include available geological and structural information.

The authors present the groundwater chemistry as a function of the underlying lithology and do not address, as discussed earlier potential anthropogenic impacts.

While chapter 4.11.2.6 of the Project Proposal (Doc No 060-1) suggest that groundwater flow and permeability in the bedrock aquifer is structurally controlled, it also suggest that flow directions mimic surface topography and that flow is not controlled by a few discontinuities based on the small range of determined hydraulic conductivities. These contradictions should be rectified in the document.

The final description of local hydrogeological conditions in the different mining areas uses Darcy's law to estimate mean groundwater flow velocities for the different areas. Such approach assumes that the fractured bedrock can be represented by an equivalent porous media on the scale of investigation. The validity of this assumption is questionable for areas intersected by major faults, which are likely to enhance flow velocities locally.

The authors used porosity values from the literature between 5 and 15%, which appear to not be conservative enough in view of the lithologies and should be replaced with site specific or more conservative values (1 to 5%).

3.3 Prediction of impacts

The hydrogeological baseline information presented in Doc No 060-1 and Doc No 032-1 to 034-1 was subsequently used for the environmental effects characterisation and assessment (chapter 8.9 in Doc No 060-1).

The authors structured the effects characterisation broadly into quantitative (mine inflows) and qualitative (contaminant transport) impacts, and is reviewed as such.

3.3.1 Quantitative impacts

Inflows into the open pits and underground mines are estimated using simplified analytical solutions by Marinelli & Niccoli (2000) and by Goodman et al. (1965), respectively.

Open pit inflows

The authors correctly stress the assumptions of the solution by Marinelli & Niccoli (2000) and that the solution is likely to overestimate pit inflows. All calculations appear correct and the estimated pit inflows appear relatively conservative for an environmental impact assessment, however, some further scientific substantiation is recommended at this stage to explain the basis for halving the volumes.

Underground mine inflows

For the open pit inflow estimations, the authors correctly question the validity of assumptions for the used analytical solution of steady-state groundwater flow into a tunnel by Goodman et al. (1965).

However, the input parameters for the solution (Table 8.9-2 in Doc No 060-1), based on assumptions for the yet not designed underground mine workings, are questionable, especially if considering the preceding open pit inflow estimations. While an open pit dewatering depth (equal to saturated thickness above pit bottom) of 42 m was assumed for the Lab-Hoodoo open pit (Table 8.9-1, Doc No 060-1), the estimation of the Lab-Hoodoo underground mine inflows assumes a depth below groundwater of 15 m for the drift centre. In other words, while parts of the pit Lab-Hoodoo pit bottom are assumed to be 42 metres below the groundwater table, the supposedly deeper underground mine workings are only an assumed 15 metres below the groundwater table. Furthermore, the hydraulic conductivity values used for the Lab-Hoodoo open cast and underground mine inflow estimations differ by a factor of almost two (9E-07 versus 5E-07 m/s) without any further explanation (e.g. reduction of rock permeability with depth). Using the initial hydraulic conductivity of 9E-07 m/s, would consequently result in an almost two-fold increase of groundwater inflows due to the direct proportionality. We note that at location GT-10-02, which is identified in Section 4.4 of Appendix H to be in close proximity to the existing mine workings, the hydraulic conductivity of the rock is reported as being "extremely high".

The above mentioned figures do not add up and a significant increase in mine inflows is expected if a more reasonable depth below the groundwater table and a higher hydraulic conductivity is assumed for the Lab-Hoodoo drift. Estimations for the Peel underground mine workings do not show a similar overlap of dewatering depth or differences in hydraulic conductivity.

The statement in the text that Table 8.9-2 (Doc No 060-1) represents the inflow rates per metre of underground development should be corrected, as the calculated values assume drift lengths of 1000 metres.

An approximate design of the underground mine voids is required to arrive at a more reliable estimation of mine inflow rates and the impact assessment re-visited taking the design into consideration.

Combined mine inflows

The presentation of the combined (open cast and underground) mine inflows over the life of mine in Table 8.9-3 (Doc No 060-1) show a peak inflow of 3,300 m^3/day in year 3 of the life of mine, before they decline to 250 m^3/day at the end of life of mine. The presented breakdown of mine inflows assumes essentially an instantaneous equilibration of groundwater and pit lake levels in the mine voids once active dewatering stops (and starts). It is recommended that a gradual decline as well as rebound of the water tables be assumed during operation as well as post closure for each mine void. If such behaviour would be taken into account, the maximum cumulative impact of mine dewatering will occur at later times and might be larger.

In view of the uncertainties associated with the applied analytical solutions for the estimation of mine inflow rates, the authors estimated the total dewatering volumes over the life of mine with a separate water (sic. infiltration) balance model. As for the analytical solution, steady state conditions (no change in storage) was assumed.

It must be noted that the authors present in this section for the first time infiltration values, which were incorrectly (interflow neglected) equated to and used as groundwater recharge in the earlier calculations. The presentation of quantitative infiltration values should be moved to the conceptual model section and referred to in the analytical solutions.

The authors use a fraction (25%) of the total annual infiltration over a catchment area of 7.8 km^2 as a conservative estimate of required dewatering volumes. The determined dewatering volumes of 10 600 m^3/month or around 350 m^3/day are an order of magnitude lower than the values based on the analytical solutions. It must be noted that the earlier presented maximum mine inflow value of 3 300 m^3/day for year 3 would equate to around 235% of the total annual infiltration over a 7.8 km^2 catchment area, highlighting the shortcomings of the applied steady-state analytical solutions with regard to their assumptions and the likely conservative nature of estimated pit inflows.

It is recommended that the different dewatering figures and units reported be reconciled.

Following the mine inflow estimates, the authors discuss the post-closure rebounding of the water table qualitatively as well as potential dewatering and discharge options. The nominal design flows of 10,000 m^3/month (or 333 m^3/day) towards the TSF are lower than any of the mine void inflow rates presented above and needs to be reassessed for the final TSF design (not reviewed here) or a provision for additional water treatment capacity should be made in the Project Application.

Groundwater abstraction

The authors do not assess the impacts of the proposed groundwater abstraction, though it might be covered by an existing licence.

Summary of inflow assessments

While numerous assumptions of the applied analytical models are not met by the site specific aquifer conditions, the estimated inflow rates appear conservative and therefore suitable for an environmental impact assessment (e.g. worst case scenario due to steady state flow assumptions).

Inconsistencies in the presented figures for cumulative inflows need to be rectified at this stage of the Project Application review. The estimates of inflow range from about 10,000 m^3 to 100,000 m^3 depending on which approach is used, but the design and impact assessment seems to be based on the 10,000 m^3 value without substantiation and without a sensitivity analysis to assess the impact of larger dewatering volumes should they be realized.

3.3.2 Contaminant transport

Groundwater flow through mine voids

Based on the geochemical test work the authors identified groundwater flow through open pits and underground mine voids correctly as potential sources of pollution and estimate the through flow rates by applying Darcy's law for groundwater flow in porous media.

However, no post-closure estimation of contaminant transport from the flooded pits or mine voids was provided in the Project Proposal. An estimation of through flow rates does not replace a contaminant transport prediction model with appropriate source terms and the assessment of water quality impacts from the mine voids is therefore considered to be a significant data gap. Also, as noted previously an assessment of effects from the existing mined space could be included to enhance this assessment of future impacts.

Darcy's law used in the Project Proposal for flow through porous media is not considered to be applicable for flow through open (mine) voids, which tends to channel groundwater through flow as a result of their reduced flow resistance (the authors assumed conductivities of the surrounding rock mass for the voids); the flow assessment is therefore not considered to be conservative. In addition, the gradients used do not represent, for all mining areas, the maximum gradients reported in chapter 5.2 of the detailed hydrogeological assessment (Doc No 032-1).

Leakage from the Tailings Storage Facility

The authors correctly identify seepage from the TSF as a potential source of pollution for receiving surface and groundwater bodies. However, no quantitative estimation of seepage rates and associated contaminant transport rates from the TSF was done for the operational or post-closure phase.

Instead a qualitative discussion of leachate minimisation by natural (overburden) and constructed (geosynthetic clay liner) barriers and leachate collection systems is provided. However, the assumption that a liner will completely “block” any leachate from the TSF is not supported by empirical data and the authors should use literature values of seepage rates for the chosen liner design. Once the seepage rate and the source term concentrations (from the geochemical test work) are established, they should be used in a site-specific transport model to assess potential environmental impacts for the operational and post-closure phase.

Chemical spills and releases

The authors correctly refer the potential impacts of spillages and releases to the spill contingency plan; no separate assessment is required here.

Waste Rock Dumps

The WRD sites are correctly identified as potential sources of pollution, but no quantitative assessment of contaminant transport impacts from the WRD's was done for the operational or post-closure phase. The authors present instead mitigation measures aimed to minimise potential impacts on the groundwater quality (encapsulation of PAG material, engineered waste rock pad and drainage collection including potential water treatment system) and rationalize that because of this there will be little, if any impacts and therefore, further assessment is not warranted. Based on the information provided, leakage from the WRD's would appear to be a probability and therefore, it is recommended that a more detailed quantitative assessment of impacts be completed at this stage of the project to determine if these impacts are acceptable or can be mitigated.

For example, the material from which the pad underlying the WRD sites will be constructed is described as low permeability waste rock. This material may be of lower permeability than the regular waste rock material, but from the perspective of preventing leakage of leachate it is not clear how material derived from crushed rock can provide sufficiently low permeability. As a result, vertical leakage through the WRD's and into the groundwater is still likely to occur and subsequent impacts need to be quantified. The quantification should be separated for the operational and post-closure phase, as contouring and covering of the WRD sites will change infiltration characteristics. The statement that rapid percolation or short residence times in the WRD sites are likely to limit metal leaching may not be accurate based on experience from other WRD's and especially for WRD sites with prolonged snow cover. It is recommended this statement be omitted if it cannot be supported with additional rationale

It is recommended that for the engineered pad's being constructed under the WRD sites, sufficient information be provided at this stage to evaluate the potential for leakage through the WRD liners. Detailed design information is not required, but basic information such as the conceptual facility design and parameters critical to impact assessment such proposed hydraulic conductivity and thickness of the liner should be provided at this stage of the approvals process.

A further concern is the potential conveying and discharging of drainage water from the WRD sites towards the TSF, if contaminated, as this water appears to be conveyed along ditches which are likely unlined. As a result, leakage of contaminated water into the subsurface is likely to occur along these ditches. It is recommended that a mitigation strategy be developed to prevent this from happening. Also, the additional water being directed to the TSF from the WRD sites (if impacted) might exceed the capacity of the TSF (TSF design not reviewed).

ROM stockpiles

ROM stockpiles are potential sources of groundwater pollution, but typically excluded from groundwater assessments due to engineering designs preventing infiltration of water. However, the Project Proposal does not provide details about the engineered controls that will be installed. They only state that the ROM pad will be engineered to prevent infiltration. It is recommended that details about the ROM be provided (e.g. materials from which the pad will be constructed, thickness of pad and the target hydraulic conductivity of the pad).

Summary of contaminant transport models

No quantitative assessment of water quality impacts from mine residue deposits (TSF, WRD sites) and leakage from mine voids is provided.

Such assessment, using applicable models (preferably numerical models) and appropriate source terms (from the geochemical test work) should be included in the report.

3.4 Proposed mitigation measures and monitoring

3.4.1 Mitigation measures

The authors provide in Table 8.9-5 (Doc No 060-1) an overview of proposed mitigation measures including an evaluation of their anticipated success. The following review evaluates each item separately.

- **Dewatering of mine workings** – quality impacts: Highly unlikely that a complete mitigation success can be achieved for the underground mine workings. The capacity of the TSF to cope with potential groundwater discharges needs to be reviewed during this phase of the project review.

- **Dewatering of mine workings** – quantity impacts: Changes in baseflow during operational phase and potential long term impacts on Tarn Lake not quantitatively assessed.

- **Mine workings**: Quality and quantity impacts not quantitatively assessed and likely to be long term. Potential post closure remediation unlikely scenario and probably no financial provision made. Anticipated success should be changed to none.

- **TSF**: Quality impacts not quantitatively assessed. Even a full liner does not completely prevent seepage into groundwater. Anticipated success should be changed to partial.

- **Waste Rock Dump Sites**: Quality impacts not quantitatively assessed. The WRD sites will potentially leach metals and the proposed liner under the WRD's is being constructed of waste rock which will still allow leakage of leachate into the subsurface. The potential diversion of water to the TSF if discharge criteria are exceeded cannot be maintained post closure. Passive treatment systems should be considered. No conceptual design for the NAG/PAG WRD sites is provided. Anticipated success should be changed to partial.

- **ROM Stockpile**: Success of mitigation depends on design (not reviewed).

Overall, it is recommended that additional more quantitative assessment be completed at this stage of the approvals process to demonstrate/confirm that the proposed mitigation strategies will be effective and to determine the significance of the residual effects after application of mitigation.

3.5 Residual Effects

The authors present a quantification and assessment of residual effects for the dewatering and seepage through mine voids impacts and conclude that there are no residual impacts from mine residue deposits (TSF, WRD sites).

It is recommended that the chapter on residual effects be updated to assess long-term impacts associated with mine residue deposits.

3.5.1 Dewatering effects on groundwater quantities

The authors assess the impacts of dewatering of the Tarn pits on Tarn Lake and generally on the Cache Creek in chapter 8.9.6 (Doc No 060-1) - dealing with residual effects - rather than in the earlier effects characterization chapter 8.9.4.

The assessment of groundwater flow from the Tarn Lake towards the Tarn Pits is again based on Darcy's law, with an assumed lake geometry including a depth of only 10 meters and a hydraulic conductivity of 2E-08 m/s. It must be noted that the hydraulic conductivity is considerably lower than the values used for the earlier Tarn Pit inflow estimations (7E-08 m/s, Table 8.9-1) and reconciliation is necessary.

Using these simplified assumptions the authors report a flow rate of 185 m^3/day, while based on the values provided, the result should be 0.194 m^3/day. However, the authors apparently used the latter correct value to arrive at a total dewatering volume of around 50 m^3 for a 9 month abstraction period.

Beyond the inconsistency in conductivity data, the simplified assessment assumes incorrectly that groundwater discharge from the Tarn Lake towards the lower lying pits occurs only through its cross-section area, instead (theoretically) through the entire water covered wall and bottom area (almost 100 times larger area and subsequent flows). Such assumption can only be made for through-flow estimations on a regional scale (see above), but not for estimations of dewatering rates on a local scale. Furthermore, the maximum dewatering period of 9 months assumes an unrealistic, instantaneous rebound of the water table once pit dewatering stops. Similar errors are encountered in the calculations for the Penguin pit.

The assessment of pit dewatering effects on the Tarn Lake during the life of mine is therefore not considered to be defendable and most probably not conservative. It is recommended the assessment be redone using an appropriate model at this stage of the Project Application review.

The presented assessment of operational and post-closure impacts of mine dewatering on the creeks (i.e. surface water baseflow) entails only qualitative statements that operational impacts are short lived and that pre-mining conditions will be established shortly after mine closure.

An estimation of the groundwater contribution to baseflow for the creeks within the mine area should be done to quantify potential impacts of mine dewatering. This is of even greater importance as the rebound of the water table might take a few decades.

3.5.2 Post-closure seepage through open pits and underground mine voids

The authors use the ratio between the earlier derived, questionable flow rates through the mine voids and minimum discharge values in the Cache Creek as a measure to assess potential long term impacts on the water quality.

As stated earlier, an estimation of flow rates does not replace a contaminant transport model with appropriate source terms and the assessment is therefore considered insufficient or absent at this stage of the adequacy review. Development of a site specific groundwater flow and contaminant transport model and the use of this model to assess mine impacts is recommended.

3.6 Conclusion and recommendation

The review of the hydrogeological component (groundwater) Ketza River Holdings Ltd. Project Proposal by SLR Consulting identified the following data-gaps/issues. Data-gaps/issues which should be addressed at this stage of the Adequacy Review include:

- Geological/hydrogeological cross-sections along the key flow paths along the base of the valleys should be developed for the mining area.
- The hydrogeochemical site characterisation should differentiate between the natural, geogenic water quality and the water quality impacted by earlier mining activities.
- Impacts of mine residue deposits (TSF's, WRD sites) and mine voids on the groundwater quality were only discussed qualitatively, whereas a quantitative assessment should have been done.

It is recommended that the available data are incorporated into a site-specific numerical groundwater flow and transport model to assess the single and cumulative environmental impacts arising from a multitude of mine voids and mine residue deposits. The used model code should be capable of simulating unsaturated flow and transport from the WRD sites and TSF towards the saturated zone.

The post-closure assessment should address potential decanting from underground mine voids and establish final pit lake water levels (if any) using water balance approaches.

4.0 GEOCHEMICAL CHARACTERISATION PROGRAM (ARD REPORT)

A geochemical characterisation program was undertaken by EBA for KRH in August 2011 on a number of waste rocks samples and tailing and ore material taken from the Ketza River Mine Site. The results of the geochemical characterization program are presented in an Acid Rock Drainage (ARD) Report (Doc. No. 060-1, Appendix K) and are summarized in Chapter 6.4 (Project Description – Geological setting) and Chapter 8.7 (Environmental Effects Assessment – Surface water quality) of the Project Proposal (Doc. No. 060-1).

The following review focuses on the summaries mentioned above while acknowledging the details provided in Appendix K.

4.1 Waste rock

- The number of representative samples is based on the Mine Environmental Neutral Drainage (MEND) guidelines (Price, 2009) and is considered appropriate, particularly in view of the increased sample numbers of potentially acid generating (PAG) material.

- No sample handling procedures were outlined in the report; therefore no comments can be made.

- The location of the waste rock samples in relation to the pit layout and development (spatial coverage over time) are not given in the report; therefore no comments can be made.

- In view of the large sample number, only summary tables of the samples collected for the geochemical characterisation program (Table 6.4.1) and Acid Rock Drainage (ARD) classification per material type (Table 6.4-2) are provided. While minimum and maximum Neutralising Potential Ratio (NPR) values are provided, the tables lack the minimum descriptive statistics recommended in the MEND guideline (Price, 2009), i.e. percentiles and measures of central tendency (mean, median etc).

- The classification of material types (NAG, PAG or uncertain) based on the NPR values (as recommended in the MEND guideline) is generally acceptable, however the reviewer is concerned by the *'non-acid generating'* classification of the unaltered argillites from the Manto Zone (Manto-ARG-Unaltered) and the oxidised argillites from the Shamrock Zone (QB-ARG-Oxide) as presented in Table 6.4-2 (Doc. No. 060-1) despite a large number of samples from these material being classified as "uncertain" or "PAG" (especially for QB-ARG-Oxide). General reclassification of these materials could result in substantially increased PAG waste volumes and a sub-division of these materials based on the detailed geology (if recorded) or alteration type is recommended.

- A discrepancy has been identified between the classification of the oxidised argillites from the Shamrock Zone (QB-ARG-Oxide) in Appendix K ("uncertain") and the classification for the same lithology in the main document (Table 6.4-2 in Doc No 060-1) ("NAG"). This discrepancy requires explanation / correction. It is recommended, as a precautionary measure, to classify samples as "uncertain" or precautionary "PAG" if the material type is not further sub-divided.

- It is considered that the potential for metal leaching from the different waste rock units was correctly identified using the shake flask testing as summarised in Table 6.4-3 (Doc No 060-1). Appendix K correctly states exceedances of the CCME (Canadian Environmental Quality guidelines) guideline limits for aluminium, arsenic and iron (some at three to four times more than the appropriate CCME limit), however these are not consistently presented through all the documents which are of concern to the review and should be reviewed.

- The negative values presented in Table 6.4-3 (Doc. No. 060-1) *"Average Concentrations and Standard Deviation of leachable Metals per Waste Rock Type"* need to be corrected.

- While average values along with standard deviations are given within the various tables, they lack percentiles (10%, 90%) of leachable metals as recommended in the MEND guideline (Price, 2009). The use of the 'median' instead of 'arithmetic averages' is recommended as they are less influenced by erroneous values (outliers).

- Humidity cell tests were performed on all waste rock units with the exception of the argillite sulphides and trans-sulphides from the Shamrock Zone (based on small estimated waste rock volumes). It is recommended that kinetic tests (humidity cell tests) be undertaken on these samples at a later date.

- The humidity cell results confirm the strong potential for metal leaching, especially of arsenic with increasing concentrations observed in the test results over time.

4.2 Tailings and ore material

- The assessment was based on a single tailing sample and a single ore sample only, therefore no quality control or outlier assessment was possible.

- The NAG/PAG classification of the single samples is acceptable.

- The metal leach tests results for composite ore sample were not presented in Table 6.4-7 (Doc No 060-1) and therefore not reviewed.

- As with the waste rock samples, the potential for metal leaching from the the oxide and sulphate tailings samples was correctly identified using the shake flask testing. Concentrations of arsenic (As) exceed the CCME limits by orders of magnitude. While the arsenic exceedances are recognised and discussed, exceedances of the CCME limits for chromium, copper and silver, iron are recorded but are not discussed. A discussion of these exceedances is required.

- The humidity cell test results undertaken on the tailing samples are not presented in the main document or Appendix K (Doc. No. 060-1) therefore a thorough review of the results is not possible.

- The authors recognise the potential for acid production and leaching of metals (copper and iron) for the ore and sulphide tailing. However it is not understood by the reviewer why arsenic is not identified at higher concentrations and does not exceed applicable CCME limits through the Shake flask testing when concentrations are elevated in the leach test results. In addition, it is not understood by the reviewer why arsenic has only been identified in leachate from the oxide ore tailings material and not from the sulphide ore tailing material. It is recommended that the results be reviewed and potentially further test work be carried out to clarify this discrepancy.

- No analysis of the tailings liquor is provided. It is noted that the tailings liquor provides the source term during active tailings deposition and the results would be of importance.

4.3 Mitigation Measures

The proposed confinement of PAG with NAG waste rock as well as recommendations for the WRD design are generic at this stage of the project and will require further detail and refinement as the project develops.

The suggested treatment of discharge from the WRD sites is unlikely to be sustainable post-closure and alternative treatment methods should be considered.

4.4 Recommendations

Based on the review it is recommended that the following data-gaps/issues be addressed at this stage of the adequacy review:

- Laboratory or field column tests with predicted NAG/PAG mixing ratios should be included in the ARD assessment to confirm the rate of acid generation and consumption to ensure the overall alkaline drainage quality.

- The metal leach test results for the composite ore sample should be provided as part of to the Project Application.

- Humidity cell test results for the tailings and ore material should be provided as part of to the Project Application.

- Tailings liquor should be analysed and assessed separately from the tailings solids. It is recommended this be done at this time to establish source term (concentrations) for the TSF.

5.0 SURFACE WATER INFORMATION

Surface water quality in the mine site and regional area was assessed between 1988 and 1996 and between 2005 and 2011. The surface water quality results are discussed in Section 4.9 of the Project Application (Doc. No. 060-1) and the impact of the project on water quality is discussed qualitatively in Section 8.7 of the Project Application.

5.1 Baseline Surface Water Quality

Background surface water stations - The selection of surface water stations representative of natural background conditions should be further clarified. The Project Application indicates that surface water quality locations have been selected to represent areas upstream of known areas of historical development, however the background stations include at least two locations potentially impacted by historical mining activities, KR11, downstream of mining activity not related to Ketza River Property and KR23 at an historical adit not related to Ketza River Property.

CCME exceedances - A definition was provided for each of the categories (e.g. always, rarely) used to describe surface water quality exceedances above CCME ALG (page 151, Doc. No. 060-1). 0-30% of the analytical results exceeding a parameter specific CCME ALG is considered to be a rare occurrence in the Project Application. It is recommended that a rationale be provided as to why an interval up to 30% exceedance is considered as “rare” occurrence. Typically, “rare or infrequent occurrence” is considered as <10%.

CCME exceedances - Tables 4.9-3 to 4.9-6 in Section 4.9 of the Project Application show percentages exceeding CCME guidelines for measured parameters at stations upstream, within and downstream of the proposed project area. It is recommended that the CCME ALG guidelines used to derive these percentages be provided in a table, the hardness, pH and/or temperature values used to derive variable-dependent CCME guidelines should be explicitly identified in this table.

Statistics used to describe parameter concentrations – Section 4.9 of the Project Application provides the mean and standard deviation (SD) to describe surface water quality. It is recommended that additional statistics be provided as the mean and SD alone do not adequately provide the information necessary to compare concentrations among locations, especially when the data may be (positively) skewed. The summary statistics should also provide the median, minimum, maximum and percentiles. The median, for example, would provide an indication of typical concentration for the area and the percentiles would provide information on their occurrences. It is noted that the median are provided in Appendix G, however these values are not discussed in Section 4.9.

Figures used to represent parameter concentrations – Parameter concentrations were represented graphically by their mean and SD (Figure 4.9-3 to 4.9-12). It is recommended that boxplots be used instead as the current figures do not provide information on the presence of outliers. The SD currently shown on the figure may represent the spread of most data or be strongly influenced by higher values, the current figures do not show if skewness or outliers are present.

Statistics used to describe significant difference between locations - The statistics used [(overlap of standard deviation, (SD)] indicated that the parameter concentrations were not significantly different between areas. The appropriateness of this statistical method to accurately detect significant difference should be further discussed in the Project Application. The SD quantifies variability; however, it does not account for the sample size, and both variability and sample size should be taken into account to assess statistical significance. The overlap of SD errors bars may not provide adequate information on whether the difference is statistically significant. It is recommended that non parametric approach such as the Mann-Whitney test or Kruskal-Wallis test (test difference between median) be used to identify significant differences in parameter concentrations among stations.

Water Quality data provided in Appendix G – Raw data, including sample dates and applicable guidelines, should be included in Appendix and provided electronically, if possible, to the reviewers. The tables should indicate if the results are for total or dissolved metals.

Seasonal and temporal trends – The Project application indicated that no chronological or seasonal trends were noted in the data (with the exception of seasonal trends for arsenic and cadmium, page 163). It is recommended that the supporting information (e.g. graphical representation of trends) be provided in Appendix G.

Statistics used to describe significant difference during Canamax Tailings Storage Facility discharge and non-discharge periods – Mean and SD were used to compare arsenic concentration during TSF discharge and non-discharge periods (page 163); the comments made regarding the adequacy of the statistics used to compare parameter concentrations among stations also applies here. I.e., it is recommended that additional statistics be provided as the mean and SD alone do not adequately provide the information necessary to compare concentrations among locations, especially when the data may be (positively) skewed. Boxplots and Mann-Whitney or Kruskal-Wallis tests should be considered.

TSS-metals correlations – The statistical summary for TSS indicates that concentrations ranged from less than the reported detection limit to 270 mg/L. It is recommended that the Project Application discuss potential correlation between TSS and particulate associated trace metals. The discussion should also indicate if the observed elevated TSS levels are related to heavy rain or freshet periods. The correlations (assuming their existence) could be used to identify TSS levels which would results in metal exceedances of the CCME ALG (specifically for the background stations).

5.2 Prediction of Impacts

The potential impacts of the proposed project on surface water quality have been assessed qualitatively based on the interaction between project activities and surface water quality, and are presented in Tables 8.7-1, 8.7-2 and 8.7-3.

The assessment of potential impacts on surface water is not considered to be adequate at this time and should include the following information (for the various phases of the project):

- Prediction of the quality and quantity of contaminants from future point and non-point discharges;
- Prediction of downstream water quality;
- Discussion of contaminant predicted to exceed CCME guidelines in the receiving water bodies;
- Proposed site-specific water quality objectives for the receiving water bodies (if applicable);
- Discussion of mitigation measures (e.g., treatment and effluent limits);
- Monitoring programs for surface water quality (including monitoring location, parameters, sampling frequency, reporting frequency, reporting limits; and,
- Adaptive management plan for surface water (including additional/alternative mitigation measures should contaminant concentrations be higher than predicted).

A mass balance model should be used to predict surface water parameter concentrations in downstream receiving water bodies. The mass balance should include effluents and contact and non-contact areas and should be run for conditions critical to aquatic life such as minimum low flow and maximum flow.

Model selection should be described and justified as well as any assumption made when selecting model inputs and should include a sensitivity analysis.

A surface water quality monitoring program should be developed to confirm the findings of the impact assessment.

6.0 REFERENCES

Marinelli, F. and Niccoli, W.L. (2000). Simple analytical equations for estimating ground water inflow to a mine pit. *Groundwater* 38(2): 311-314.

Goodman, R.E., Moye, D.G., Van Schalkwyk, A. and Janvandel, I. (1965). Groundwater inflows during tunel driving. *Engineering Geology* Vol. 2: 39 – 56.

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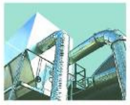
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