



MEMORANDUM

To: Yukon Environmental and Socio-economic Assessment Board
Date: March 26, 2020
Attention: Andrew Reid, Senior Assessment Officer
cc: Mohsen Nicksiar, Ph.D. P.Eng.
From: Jeremy Zandbergen, P.Eng. Project: 644413
Alistair James, P.Eng.
Subject: Proposed Kudz-Ze-Kayah Underground Mining – Geotechnical Risk Discussion

1 Introduction and Scope

SNC-Lavalin Inc. (SNC-Lavalin) was retained by the Yukon Environmental and Socio-economic Assessment Board (YESAB) to provide technical support services, specifically the geotechnical engineering aspects for assessing the project proposal by BMC Minerals for its Kudz-Ze-Kayah (KZK) mine project, southeast of Ross River, YT.

SNC-Lavalin provided reports for the project in May 2017 and March and September 2019, along with iterative reviews of supplemental information during the adequacy review stage. Our documents addressed geotechnical and geo-environmental issues including potential risks in the design of an underground excavation.

On February 12th, 2020, YESAB requested further analysis and clarification on potential issues related to underground excavation including:

- Identification of site-specific geotechnical risks for underground mining at the KZK mine (including hydrogeological conditions);
- Whether those site specific risks are, relatively, unusual or challenging;
- Whether the measures identified by the proponent have considered those risks that are relatively unusual or challenging;
- Potential mitigations for those risks; and
- Performing our analysis at a level reflective of the detail in BMC Minerals' project proposal, being key points, acknowledging the limitations of the available data.

The following sections answer the questions from YESAB with the available information. In preparation of this memorandum, the document provided in SNC-Lavalin's final report (May 2017) along with BMC responses to the comments (July 2017) were used, along with general review of the original project application documents.

2 Geotechnical Risks for Underground Mining

Underground mining plans have been designed on a preliminary basis using a relatively limited amount of subsurface information at this time. Preliminary opening widths and heights and lengths have been proposed for stopes. The Proponent is planning to support the rock underground using techniques such as rock bolting and shotcrete. As well, paste backfill (cemented tailings returned underground from surface) is proposed to be placed in mined out openings and stopes to fill voids and stabilize the ground. Ventilation, safety refuge, haulage and other aspects of underground mining operation have been planned, and the Proponent acknowledges the specifications and requirements of the Occupational Health and Safety Regulation.

The Ross River community and Kudz-Ze-Kayah site are situated in the Tintina Trench which is a 1,000 km long valley tracing the Tintina Fault from central Alaska through Dawson City and Watson Lake southeast to northern British Columbia. From there it ties into the Rocky Mountain Trench which is also a long, fault-related valley extending deep southeastward deep into the United States. Geological literature and texts indicate these faults have been inactive for approximately 65 million years. Considering the geological setting of the site, the presence of joints, fractures and faults can be considered as the key geotechnical risks, and past borehole drilling for the KZK project encountered these features. Numerous underground and open pit mines have been operated along the Tintina Trench (i.e. Keno Hill) and Rocky Mountain trench (i.e. Sullivan Mine).

The presence of the faults and joints and fractures can cause potential wedge failure or excessive caving during underground excavation. Moreover, groundwater flow in the rock mass mainly occurs as flow within open joints and fractures. In some instances, such flow can pose a risk for operations, if a fault or densely spaced fracture zone is encountered during the excavation. Flooding underground may pose a risk to personnel and equipment working underground. Other rock stability hazards may also pose a risk to safety if not mitigated in design and operation.

Although such risks are present for the proposed underground component of the KZK mine, these are common risks in underground mining. A thorough geotechnical investigation is always necessary in the lead-up to mining commencement to provide enough information to plan for mitigation measures such as proper support systems, stope widths and heights and spacing, etc.

The existing geotechnical risk is challenging to quantify at this stage of development; the pervasiveness and condition of discontinuities (joints, fractures, faults) in the bedrock are not well defined given the limited subsurface drilling investigation and data available to the Proponent or SNC-Lavalin. The available design reports provided by the Proponent have not provided sufficient information to thoroughly categorise the groundwater conditions and the presence of high-permeable zones (such as faults or shear zones). As described above these features could allow water to flood tunnels and underground openings rapidly if such zones are encountered during the mining. The existing reports are considered to be Pre-Feasibility Study level documents and are adequate for that purpose.

The proponent responses of July 2017 acknowledged the presence of such risks; the proponent has planned a dedicated geotechnical investigation is to be performed in later phases of the project. BMC responded in their July 2017 document that:

“in the next stage of assessment, a dedicated geotechnical drilling program will be planned to obtain representative geotechnical information, and this will identify significant weak discontinuities, unfavorable discontinuity orientations, and faults and shear zones if present. This information will be used to inform the designs and documentation required for approval of a Quartz Mining Licence by the Department of Energy, Mines and Resources, including the preparation of a Mine Development and Operations Plan. The mapping

of rock quality and geotechnical structures underground will continue over the life of the mine and will be used to inform ongoing and regular reviews of the adequacy of ground support design which will then be modified by qualified site personnel as required.”

3 Potential Mitigation Measures

This section provides general advice and procedures for mitigation measures for underground mining planning and operation and aligns with standard engineering practices. These measures and recommendations are not unusual, nor consist of any requirement over and above what would normally be expected and undertaken. Rather, this section explains the normally expected design and operational mitigation work, and describes how this work mitigates geotechnical risk.

Two main categories of mitigation of risk can be undertaken including:

- i. Conducting the proposed detailed geotechnical drilling program and engineering; and
- ii. Site-specific underground support and dewatering to be implemented as underground mining occurs by personnel directly engaged in the observation of the rock mass conditions and adapting the engineering solution to the conditions encountered.

A suitably detailed field investigation can provide useful information for design, understanding the following characteristics of the rock mass:

- (a) The joint system, fracture networks or fault zones.

Once the nature of the discontinuities within the rock mass is evaluated from oriented cores, thorough numerical analysis needs to be performed to evaluate the size, scale, frequency and location of the potential wedges. Then, a suitable support system such as rock bolts, wire mesh, etc. can be proposed to mitigate such failures by the proponent.

- (b) Stress-induced failure due to high in-situ horizontal stress.

Performing horizontal in-situ stress measurements during the field investigation can indicate if spalling may be anticipated. Spalling is generally a greater risk in deeper underground excavation and may be a low risk factor for this project. After field measurement, thorough numerical modelling should be performed to evaluate stress re-distribution around the excavated openings. Such modelling will also show if failure is anticipated and the designer can mitigate that by recommending measures such as altering the geometry of the excavation.

- (c) High groundwater flow zones.

If during field investigation a fracture or fault zone is discovered, a dewatering or grouting plan may be necessary. Generally, an in-situ permeability test will be performed in the boreholes encountering these features allowing the evaluation of the hydraulic conductivity of such zones. The information will then be used to model the anticipated groundwater inflow to the excavation. Then a temporary or permanent dewatering and/or grouting mitigation will be planned to mitigate such risks.

During operations, the underground mining plan will be utilized by applying recommended mitigation / stabilization techniques based on the condition of exposed rock mass. The underground mining plan would provide guidance as to what type of mitigation or support is to be implemented for certain levels of rock mass quality. Inspections and modifications should be made by the qualified underground mining engineer, adapting the mining plan to actual and changing rock mass conditions and ore recovery plans.

4 Conclusion

The geotechnical risks identified in this memorandum are common for underground mining and such mines have previously been successful from a geotechnical standpoint in the same geological setting and the general Yukon region. Planning to mitigate these risks can be undertaken in accordance with the current standard engineering practice of underground mining, should adequate field investigation program be performed in advance. The response provided by BMC Minerals in July 2017 stated its intention to complete a detailed field investigation program, as the available information reviewed by SNC-Lavalin in April 2017 was found to be inadequate to foresee the risks or to provide a site-specific mitigation plan at this time. Our understanding is BMC Minerals is aware of such data gaps and would submit the results of its detailed field investigation program and underground mining plan in a later stage of the Quartz Mining Licence permitting process. SNC-Lavalin considers that the timeline proposed by BMC Minerals for conducting a detailed subsurface investigation and underground mine engineering is reasonable and can mitigate potential risks at that time.

5 References

BMC Minerals project application documents package, April 2017

BMC Minerals (No.1) Lts., Response to YESAB Executive Committee Adequacy Review of KZK, July 2017

SNC-Lavalin Inc., Response to YESAB Executive Committee Adequacy Review Of KZK, May 2017