March 2016

Ajax Mine Application for Environmental Assessment Certificate/
Environmental Impact Statement

Comments from Stk'emlupsemc te Secwépemc Nation

This document contains two supplementary memos from the Stk'emlupsemc te Secwépemc Nation (SSN) on KGHM Ajax Mining Inc.'s (Proponent's) Application for an Environmental Assessment Certificate / Environmental Impact Statement. These supplementary memos support comments from SSN in the SSN Comment Tracking Table, available at:

https://projects.eao.gov.bc.ca/p/ajax-mine/docs?folder=222

Proposed Ajax Mine Project – Application Review Working Group Comment Tracking Memo

363_SSN_Aquifer Compaction

Date: 02/03/2016

Name: Amanda Watson

Title: Tmicw Coordinator

Agency/Organization: St'kemlupsemc te Secwepemc Nation

Subject of comment: Aquifer Compressibility below TSF and MRSF report

Category of comment: Provincial EA Information Requirement

Section of the Application: Appendix 6.6-F

Overview of key issues in this memo:

- In Appendix 6.6-F, the proponent states that "the estimated bedrock aquifer compaction below the East MRSF is 0.02 and is negligible and is therefore not expected to change the hydraulic capacity of the aquifer".
- With compaction beneath some parts of TSF and MRSF calculated to be approximately 2 m, there is an increased risk of embankment failure during operation or closure.
- SSN requests that more soil and rock mechanic studies be completed.
- Vertical compressibility α is the main parameter used in estimating aquifer compressibility. The proponent has used literature values for α to conduct their compressibility analysis. Values for α should be determined by laboratory testing, using representative samples from the site.

Comment/Issue Description:

The TSF and each MRSF will increase the total stress and the effective stress on the natural materials below the storage facilities.

The footprint of the East MRSF, is located over mapped bedrock aquifer NO.0276- the Sugar Loaf Hill Aquifer.

The degree of compaction that may result will depend on the compressibility of the natural materials. Table 1 presents the range of values of compressibility for some geological materials from the literature (Freeze and Cherry, 1979)

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Table 1

Table 2.5 Range of Values of Compressibility	
Materials	Compressibility, a (m^2/N or Pa^{-1})
Clay	10^{-6} - 10^{-8}
Sand	10^{-7} - 10^{-9}
Gravel	10^{-8} - 10^{-10}
Jointed rock	10^{-8} - 10^{-10}
Sound rock	10^{-9} - 10^{-11}
Water (β)	4.4×10^{-10}

The foundation soils of the East MRSF are primarily glacial till (up to 30 m, often silty sand or sandy silt) underlain by the Iron Mask Batholith (Cherry Creek Unit and Hybrid Unit), which is mapped as part of bedrock aquifer 0276. Based on literature values presented in Table 1, the range of 10^{-8} to 10^{-10} Pa^{-1} would be appropriate for aquifer compressibility (α) for this bedrock unit.

The potential compaction of the bedrock aquifer below the East MRSF can be estimated from aquifer compressibility (α) as follows:

$\alpha = (-dH/H)/d\sigma e$; $dH = -\alpha H d\sigma e$ (Freeze and Cherry, 1979)

Where H = aquifer thickness, dH = change in aquifer thickness (or compaction), and dσe is equal to the change in effective stress, resulting from the load of the mine facility in question. For a maximum height of 100 m for the East MRSF, and a typical unit weight of 21 kN/m^3 for Structural Fill and 21.5 kN/m^3 for Anthropogenic Mine rock (Table 9, Mine site infrastructure Report, Knight Piésold Consulting, 2015), the resulting change in stress over the facility would be between 2,100 to 2,1500 kPa. The estimated bedrock aquifer compaction for the upper 100 m of bedrock would therefore be between:

$dH=-\alpha H d\sigma e = -10^{-10}\ Pa^{-1} \times 100\ m \times 2{,}100{,}000\ Pa = 0.02\ m$, and

$dH=-\alpha H d\sigma e = -10^{-8}\ Pa^{-1} \times 100\ m \times 2{,}150{,}000\ Pa = 2.15\ m$

As a result, the bedrock aquifer compaction below the East MRSF could reach 2.15 m. This is not negligible. In this case, the aquifer compaction will likely modify the hydraulic characteristics of the aquifer.

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364_SSN_Groundwater Flow Model

Date: 02/03/2016

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Subject of comment: Groundwater Flow Model

Category of comment: Provincial EA Information Requirement

Section of the Application: Appendix 6.6-D

Overview of key issues in this memo:

- GW Solutions has identified ten (10) issues/weaknesses regarding the completed groundwater model.
- SSN requests that the Modflow model be revised (see details below).

Comment/Issue Description:

Issue 1:
Evapotranspiration was not simulated within streams or in the adjacent grid cells representing the surrounding hyporheic zone (i.e., the area of interaction between groundwater and surface water adjacent to the stream bed).

Discussion - 1:
MODFLOW models are generally not able to accurately simulate surface water exchange between stream reaches and the atmosphere due to model discretization limitations. Consequently, total stream flows are overestimated.

In the Modflow model completed by KGHM, water that would normally be lost to evaporation from streams and the hyporheic zone was instead included in the recharge boundary conditions and the stream cell boundary condition water balances, respectively.

Issue 2:
There is no discussion about the calculation and estimation of the groundwater recharge or flux in the LSA or RSA.

Discussion - 2:

In both the water balance and baseline reports, there is no discussion about the estimation, calculation, or measurement of the parameters defining the groundwater recharge, discharge, or flux. How was the model calibrated using the groundwater balance data? Why did the modeller use the "Zone Budget" package when there is no estimated nor calculated data to compare to during model calibration/simulation? The proponent should provide the input data.

Issue 3:
Groundwater divides are interpreted to exist along the south and south-west boundaries of the domain and were set as no flow boundaries.

Discussion - 3:
Based on the conceptual hydrogeological model and the elevation of groundwater, the south boundary of the Model Domain should be assumed as a General Head Boundary (GHB) and not as a no flow boundary.

Issue 4:
Hydraulic conductivity values within the modeled zones were specified based on hydrogeologic testing and modified within measured and expected ranges during model calibration. Model calibrated hydraulic conductivity and storage parameters (i.e., specific storage and specific yield) are summarized by material type in Tables 01 and 02 for surficial deposits and bedrock, respectively. We consider that the assumed range for calibration of the Hydraulic Conductivity was not adequate for each layer.

Discussion - 4:
Based on Table 2 below, the model always chose the minimum hydraulic conductivity in every range during calibration. For example, the hydraulic conductivity of the Sugar Loaf aquifer is the same as other non fractured bedrock. This is likely not representative of the hydrogeological characteristics of this aquifer.

Table 1: Summary of bedrock hydraulic parameters in the Calibrated Numerical Groundwater Flow Model

Main Rock Type	Age (Epoch)	Stratigraphic Unit		Rock Type	K (m/s)	Ss (m^{-1})	Sy (-)	Porosity (-)
		Group	Formation					
Sedimentary and Volcanic	Miocene	-	-	Basaltic volcanic rocks	3.5E-09	1.0E-03	2.0E-02	0.25
	Eocene	Kamloops Group	-	Undivided volcanic rocks	1.0E-09	1.0E-06	5.0E-03	0.05
			Tranquille Formation	Mudstone, siltstone, shale fine clastic sedimentary rocks	1.0E-09	1.0E-06	5.0E-03	0.05
	Upper Triassic	Nicola Group	Eastern Volcanic Facies	Basaltic volcanic rocks	3.2E-09	1.0E-06	5.0E-03	0.05
			-	Mudstone, siltstone, shale fine clastic sedimentary rocks	1.0E-09	1.0E-06	5.0E-03	0.05
			-	Lower amphibolite/kyanite grade metamorphic rocks	3.5E-09	1.0E-06	5.0E-03	0.05
	Devonian to Permian	Harper Ranch Group	-	Mudstone, siltstone, shale fine clastic sedimentary rocks	1.0E-09	1.0E-06	5.0E-03	0.05
Intrusive	Eocene	-	Battle Bluff Plutonic Complex	Diabase, basaltic intrusive rocks	3.5E-09	1.0E-06	5.0E-03	0.05
			-	Feldspar porphyritic intrusive rocks	3.5E-09	1.0E-06	5.0E-03	0.05
	Late Triassic to Early Jurassic	Iron Mask Batholith	Cherry Creek Unit	Dioritic intrusive rocks	1.9E-08	1.0E-06	5.0E-03	0.05
			Sugarloaf Unit	Dioritic intrusive rocks	1.0E-09	1.0E-06	5.0E-03	0.05
			Pothook Unit	Dioritic intrusive rocks	5.9E-09	1.0E-06	5.0E-03	0.05
			Hybrid Unit	Dioritic intrusive rocks	1.5E-09	1.0E-06	5.0E-03	0.05
		-	-	Granodioritic intrusive rocks	3.5E-09	1.0E-06	5.0E-03	0.05
			-	Ultramafic rocks	3.5E-09	1.0E-06	5.0E-03	0.05
3D Geologic Model	NA			Mafic volcanics - Nicola Group	1.0E-09	8.2E-06	5.0E-03	0.05
				Picrite unit	1.0E-09	2.0E-07	5.0E-03	0.05
				Sugarloaf Diorite	2.6E-08	1.0E-07	5.0E-03	0.05
				Sugarloaf Volcanic Hybrid	1.8E-08	6.3E-07	5.0E-03	0.05
				Iron mask hybrid	1.0E-09	9.1E-06	5.0E-03	0.05
				Pyroxene Plagioclase Porphyry	1.2E-09	1.0E-06	5.0E-03	0.05
Undifferentiated Bedrock				Outcrop	4.6E-08	1.0E-03	5.0E-02	0.25
				Shallow	5.8E-08	1.0E-04	5.0E-02	0.25
				Deep	4.6E-10	1.0E-06	5.0E-03	0.05
Fault Zone[2]				Fault	3.2E-08	1.0E-06	5.0E-03	0.05

Notes:

1. Compiled from Massesy et al. (2005).
2. Edith Lake Fault Zone included in sensitivity analysis as 50 m wide zone.
3. Porosity estimates are based on professional judgment.

Issue 5:

The proponent states: "The amplitude of the simulated responses was somewhat lower than the observed responses in transient Model. The cause of the differences is uncertain, however, the observed variations may be larger than simulated due to processes not represented in the model".

Discussion - 5:

In a model that will be used for prediction scenario, the uncertainties should be reduced to a minimum. So, the proponent should determine the cause of the differences between observed variation and simulated

variations. For example, seasonal pumping and surface water diversions related to agricultural land uses, fluctuations in surface water elevations in the ungauged Mine Site ponds, or pumping and drilling activities in the Mine Site, and vadose zone (i.e. unsaturated) flow may explain some of these uncertainties. In addition, we understand pumping from domestic water wells was not simulated in the Model.

Issue 6:
In the transient simulation of the pumping test, there is no discussion about the modification of the specific yields, specific storage and hydraulic conductivity of the layers near Jacko Lake. In addition, there is no sensitive analysis completed.

Discussion - 6:
It appears that the modeller did not take into account the results of the pumping test in the adjustment of the parameters for the two layers for which the pumping test provided specific information. Also, sensitive analyses are standard practice in modelling.

Issue 7:
Based on the modeling results, the simulated changes to groundwater elevations during operation do not extend to the Aberdeen area.

Discussion - 7:
Streams and creeks outside of the Peterson Creek watershed and close to Aberdeen area were simulated using the MODFLOW drain package (DRN). The drain package is similar to the river package except that only outflow of groundwater from the model is simulated. Where the simulated hydraulic head in a grid block falls below the specified water elevation, no water is removed at the boundary cell. It is more accurate to use River Package instead of Drain Package for whole streams in RSA to evaluate the effect of changing groundwater elevation during operation.

Issue 8:
In the predictive models, the proponent has not created a scenario that takes into account climate change. Only present recharge conditions are used to model construction, operation, closure and post closure.

Issue 9:
In the predictive models it appears that the change in hydraulic conductivity due to a) compaction beneath the Tailings Storage Facility (TSF) and the Mine Rock Storage Facilities (MRSFs) and b) blasting and isostatic rebound have not been taken into account.

Issue 10:
A critical assumption of the model is that dewatering of the pit will rely on a passive method of dewatering. What will happen if observed conditions are different from assumed, and that for slope stability reason dewatering wells need to be drilled? How will that change the outputs of the model?

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Information Request:

SSN requests that the Modflow model be revised. The recharge zones and the recharge rates should be modified to consider the indirect evaporation from shallow groundwater and direct evaporation from streams. Details must be provided about the steps, data, and assumptions used when applying the Zone Budget package. KGHM needs to provide the input data, information about its source, and explain the processes followed during the creation and calibration of the model. The south boundary of the Model Domain should be assumed as a General Head Boundary (GHB) and not as a no flow boundary.

SSN requests that the model be refined enough and that the difference between simulated and observed results be adequately explained.

SSN requests that the model integrate hydrogeological parameters (i.e., hydraulic conductivity) obtained from representative field testing and long-term pumping tests. In particular, SSN requests that the proponent explains how they have integrated the information gained through the completion of pumping test BGC10-PW01 in the model and why the model calibration process resulted in the selection of K of 10^{-9} m/s, very different (28 times smaller) from what the pumping test provided (2.8×10^{-8} m/s).

SSN requests that the proponent use the River Package, instead of the Drain package for all the streams and creeks in the RSA. Proper sensitive analyses should be conducted.

SSN requests that the modeled scenarios take into account the impact of climate change.

SSN requests that compaction under the TSF, blasting, and isostatic rebound be also taken into account in predictive modelling.

Finally, SSN requests that KGHM thoroughly addresses the alternative of having to use dewatering wells at the periphery of the pit, should higher groundwater flow than expected prevent using a passive dewatering method.