Date: July 11, 2019

To: Affected Agencies, Organizations, and Interested Persons

Subject: Review of surface water and groundwater modeling for the Midas Gold Existing Conditions and Proposed Action

1. SCOPE OF REVIEW

While preparing the Groundwater and Surface Water technical reports for the Stibnite Gold Project, ERM reviewed and critically evaluated the following proponent-provided documents:

- Stibnite Gold Project Water Resources Summary Report (Brown and Caldwell 2017);
- Final Stibnite Gold Project Site-Wide Water Balance Proposed Action Report (Brown and Caldwell 2018a);
- Final Stibnite Gold Project Hydrologic Model Existing Conditions Report (Brown and Caldwell 2018b);
- Revised Final Stibnite Gold Project Hydrologic Model Proposed Action Report (Brown and Caldwell 2018c);
- Groundwater Hydrology Baseline Study (SPF 2017);
- Stibnite Gold Project Geochemical Modeling Work Plan (SRK 2017);
- Final Stibnite Gold Project Existing Conditions Site-Wide Water Chemistry (SWWC) Report (SRK 2018a); and,
- Final Stibnite Gold Project Proposed Action Site-Wide Water Chemistry (SWWC) Modeling Report (SRK 2018b).

The purpose of this review was to answer the following questions:

- Was the modeling approach consistent with standard industry practice?
- Do the hydrogeological and surface water conceptual models reasonably capture the known conditions of the area around the Stibnite Gold Project?

- Are the available hydrologic data sufficient for proper development and calibration of a model to be used to inform the EIS process?
- Was the correct type of information collected for use in the model?
- Was an industry-standard software code used for the model development?
- Were the model boundary conditions appropriate and justifiable?
- Was model parametrization, calibration, and sensitivity analysis completed according to standard industry practice for an EIS project?
- Were the hydraulic conductivity values and other hydrologic parameters (e.g., recharge) assigned in the model consistent with the known site properties or literature values? For example, were the recharge values assigned in the model consistent with the amount of precipitation and evapotranspiration that occur around the Stibnite Gold Project site (the site)? Were the hydraulic conductivity values consistent with site-specific data or literature values for different lithology types?
- Is the model sufficiently robust to assess/evaluate the potential environmental effects of the proposed project?

2. FINDINGS OF THE REVIEW

2.1 Groundwater Modeling

Models reviewed in this section for groundwater include the following reports:

- Stibnite Gold Project Water Resources Summary Report (Brown and Caldwell 2017);
- Final Stibnite Gold Project Site-Wide Water Balance (SWWB) Proposed Action Report (Brown and Caldwell 2018a);
- Final Stibnite Gold Project Hydrologic Model Existing Conditions Report (Brown and Caldwell 2018b); and,
- Revised Final Stibnite Gold Project Hydrologic Model Proposed Action Report (Brown and Caldwell 2018c).

2.1.1 Was the modeling approach consistent with standard industry practice?

While developing the groundwater flow model for the Stibnite Gold Project, Brown and Caldwell (2018a; 2018b; 2018c) followed industry standards for modeling that were developed by various authors and agencies in the USA and abroad. These include the British Columbia (Canada) Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities (Wels et al. 2012), and Australian groundwater modelling guidelines (Barnett et al. 2012). Both of those guidance documents include numerous references to relevant hydrogeology and groundwater modeling-related ASTM standards. The guidelines are followed by modelers around the world in preparing models for mining projects subject to EIS, Environmental Assessments, or Environmental and Social Impact Assessments.

2.1.2 Does the hydrogeological conceptual site model reasonably capture the known conditions?

- The conceptual site model (CSM) utilized recent data describing the hydrological system of the project area, including the Water Resources Summary Report (WRSR; Brown and Caldwell 2017). The presented CSM appears to be well supported by and consistent with the available data.

- In general, no extensive bedrock groundwater flow system has been found. Groundwater is locally contained in fractured bedrock along the valley bottoms and along faults, in isolated compartments, or in connection with overlying alluvial systems. The bedrock does not form a distinct regional lower aquifer.

- The CSM indicates that the groundwater system of interest is limited by horizontal boundaries that more or less coincide with surface water divides, including the watershed boundary that forms the study area. No relatively permeable bedrock structures were identified during extensive recent or historic drilling or in aquifer test analyses (i.e., packer testing the boreholes). The permeable unconsolidated surficial deposits are relatively thin outside of the mountain valley bottoms.

- Several bedrock fault zones have been identified within the study area described by the CSM. Those zones have a potential to influence groundwater flow. Faults typically contain breccias and fractures that have the potential to increase permeability. However, many of the breccias and fracture zones in the project area have been healed (i.e., sealed) by secondary mineralization and alteration (Brown and Caldwell 2017). In addition, discontinuities in breccias and fracture zones likely prevent the formation of conduits for deep groundwater flow over long distances. Sealed breccias and clay fault gouges also likely form barriers to horizontal groundwater flow (Brown and Caldwell 2017).

- Many wells and boreholes were subject to slug testing, packer testing and aquifer testing during 1996, 2011 and 2012. Alluvial wells / boreholes were subject to thirty one slug tests and two pump tests. Hydraulic conductivity values derived from those tests ranged from 0.3 to 139 feet/day (Brown and Caldwell 2017). Bedrock wells / boreholes were subject to twenty five slug tests and sixty eight packer tests. Hydraulic conductivity values derived from those tests ranged from 3×10^{-4} to 5.9 feet/day (Brown and Caldwell 2017). The higher values in the range were obtained from the tests completed in borehole segments opened to, or monitoring wells completed within, fractured crystalline bedrock, while lower values were obtained for unfractured bedrock.

- If groundwater migrates across the boundaries of the study area described by the CSM (across watershed boundaries), such migration is most likely insignificant.

- Among the tested formations, alluvium sediments, which are filling the bottoms of the mountain valleys, were found to be the most permeable - more permeable than the fractured sections of the tested bedrock boreholes. The results of hydraulic tests reported by the investigations (from 1994 to 2013) for the alluvial groundwater system are relatively consistent, and indicate hydraulic conductivity ranging from 1 to 100 feet/day, with an average of approximately 10 feet/day (SPF 2017). The alluvium aquifer pinches out a short distance down-gradient from Sugar Creek joining the EFSFSR, forcing groundwater to discharge to the EFSFSR.

- The overall collected data support the model-report-provided statement that a significant regional-scale groundwater flow across watershed boundaries (either structure- or lithology-enabled) is unlikely.

2.1.3 Are the available hydrologic data sufficient for proper development and calibration of a model to be used to inform the EIS process?

- The model was calibrated to average groundwater levels measured during fall (measurements collected over several consecutive years) in 50 monitoring wells; of these wells, 43 were completed in alluvium and 7 in bedrock. Although it is not stated in the modeling report, our understanding is that the calibration targets represent average groundwater levels calculated from a database of measurements collected during 2011.

- The monitoring wells used for calibration are completed within or near the bottom of mountain valleys, which is common for projects located in mountainous regions. In general, the wells are evenly distributed over the study area. Since the valley bottoms contain the most permeable formations, the wells cover the most important parts of the study area with regard to water balance and interaction of the project’s infrastructure with the environment.

- Although groundwater levels fluctuate seasonally at the site, using the fall data for calibration is considered adequate as the fluctuations are insignificant compared with the magnitude of relief of the mountain terrain; thus, changes in groundwater levels do not result in significant changes to hydraulic gradients and flow directions with season.

- Hydraulic property estimates used for modeling were based on an extensive database of slug tests, packer tests, and aquifer tests completed over the years, and average values were developed for each of the main identified hydrogeologic units: colluvium; overburden; and non-fractured- or moderately fractured- rock. Although the explanations provided in the model report with regard to how those values were developed from the database of measurements is somewhat deficient, the parameter values derived for each of the hydrogeologic units in the process of the model calibration appear to be consistent with measurements – see discussion below.

- Brown and Caldwell developed a detailed meteoric water balance using a long-term PRISM dataset for monthly values of precipitation. The balance was used to compute monthly values of snowmelt, rainfall and runoff and to calculate recharge to the groundwater system. The groundwater and surface water model was then iteratively run during calibration, and parameters of the meteoric water balance were among those adjusted.
- The amount of hydrogeological and hydrological data used to parametrize and calibrate the model (more than one hundred data points, including hydraulic-test-derived estimates of hydraulic conductivity, average groundwater head values calculated for all the monitoring wells used in the model calibration, stream flow measurements, etc.) is judged to be well within the standard practice for this type of project.

2.1.4 Was the correct type of information collected for use in the model?

- The model is based on the following types of information: groundwater levels; hydraulic conductivity / transmissivity measurements; stream baseflows; climatic data – site-collected and regional; boring logs and other geologic information; and topography. Those are typical types of information collected and used for setting up and calibrating groundwater flow models (Barnett et al. 2012; Wels et al. 2012).

2.1.5 Was an industry-standard software code used for numerical model development?

- Brown and Caldwell closely cooperated with John Shomaker & Associates, Inc. to implement the initial groundwater flow model into MODFLOW-NWT (Niswonger et al. 2011). MODFLOW is the U.S. Geological Survey (USGS) modular finite-difference flow model, which is a computer code that solves the groundwater flow equation. The program is used by hydrogeologists to simulate the flow of groundwater through aquifers. The source code is free public domain software, written primarily in Fortran, and can compile and run on Microsoft Windows or Unix-like operating systems. It has been successfully used since the 1980s on thousands of sites, and is considered to be the standard software for this application worldwide. Site specific modifications for MODFLOW are common, and are used to increase the accuracy of the model.
- MODFLOW-NWT was developed in 2005 by the USGS. It includes a Newton-Raphson solution formulation to improve simulation of unconfined groundwater flow, and incorporates minor code changes that preserve mass-balance accounting for dry cells. This is key for solving problems involving drying and rewetting of model cells, a primary consideration for simulation of seasonal flows in overburden material within the study area. This version of MODFLOW is appropriate for the application for which it is being used.

2.1.6 Were the model boundary conditions appropriate and justifiable?

- For the existing conditions model, water is described as entering the model domain (the subsurface groundwater bearing formations) primarily through surface recharge, with minor recharge from stream losses. Water discharges from the model domain as recharge to surface streams. This appears to mimic conditions observed in the field, where streams are found to gain or lose flow over their length.

- Anthropogenic boundary conditions including open pit dewatering were added to the model to simulate the proposed mining and associated mine project activities. Open pit dewatering was simulated using drain elements with the drain configuration changing with time to reflect the planned evolution of the pits. Using drains is a standard method of representing dewatering of pits, even though in practice, dewatering wells will be used to lower groundwater levels below the pit walls/slopes and bottom.

- Streams were simulated using a stream package. This package was used to track a water balance for each reach of the simulated streams for each month of the model simulated time. This package allows a more realistic representation of the streams and their interaction with the groundwater system than other types of boundaries (like the often used prescribed head).

- Recharge values to the groundwater system were developed using detailed meteoric water balance and the model calibration to groundwater levels and measured stream discharge. A detailed meteoric water balance developed for each month of the model simulations represents a more involved and accurate methodology compared to what is typically done for groundwater models (like using a bulk value for different recharge zones without analyzing elements of a water balance, such as evapotranspiration, runoff, snowmelt, or sublimation).

- Lateral model boundaries were set as no flow boundaries coinciding with surface water drainage boundaries. This is an often applied approach based on (1) known general patterns of groundwater flow from high terrain to valley bottoms, and (2) a typical lack of detailed information to differentiate between surface water and groundwater divides (drainage boundaries) on a smaller scale. This approach is additionally justified by the overall data, which indicate no significant groundwater flow through bedrock occurs across drainage boundaries (see the discussion above).

2.1.7 Was parametrization, calibration, and sensitivity analysis completed according to standard industry practice for an EIS project?

- Parametrization of the model was completed using standard industry practice and formulas. In order to model groundwater in any area, and/or to evaluate the impact of changes to the groundwater regime, it is essential to know the aquifer parameters. These are chiefly Transmissivity (T) and Storativity (S). These are derived from using pump test data, and analytical data, using standardized formulas, and by model calibration.

- In order for a groundwater model to be used in any type of predictive role, it must be demonstrated that the model can successfully simulate aquifer behavior observed prior to applying a stress (like developing a mine). Calibration is a process wherein certain parameters of the model, such as recharge and hydraulic conductivity, are altered in a systematic fashion, and the model is repeatedly run, until the computed solution matches field-observed values within an acceptable level of accuracy (+/- 10%). Ideally the model can be used to accurately predict past water levels and flow over multiple years, using the input factors from that particular year. For example, precipitation records are entered into the model, and the model accurately predicts groundwater elevations and streamflow. While a large amount of data is collected to support the model development, the available data often only represent a small fraction of the total aquifer mass, and the data collected may be averaged over several years or measurements. Calibration allows small adjustment to be added to the input data to make the model predicted heads and flows come into more accurate alignment with measured values. It accounts for small variations in subsurface flow that cannot be measured.

- The calibration of this model was conducted by adjusting the values of model parameters, including water balance parameters, aquifer physical parameters, streambed conductance, and recharge, until the model generated values of groundwater heads and stream discharges reasonably matched the measured values). This is a standard process applied for model calibration.

- In addition to calibrating the model to average hydraulic heads (average of fall measurements) and stream flow conditions (average of monthly flow conditions), the model was calibrated using heads measured in monitoring wells during a 30-day long Gestrin Airstrip well aquifer test. Moreover, the “existing conditions model” simulates annual drying and rewetting of overburden, with saturated flow in the upland overburden generally occurring in March or April through September or October. This additional level of detail in the model calibration is more than is typically done in these situations for similar modeling projects. Quite often the model is calibrated only to average hydraulic heads.

- This added effort in the calibration appears to have significantly increased the model predictive power. The “Scaled RMS error” used by Brown and Caldwell to measure the level of model calibration to groundwater levels is 1.5%. This is a low value, indicating a good calibration – typically 5% is considered a sufficient level of calibration. Calibration of the model to measured stream flows is also very good, showing a close match between the measured and simulated monthly stream flows for multiple simulated years. This level of agreement for two categories of measurements (groundwater levels and stream flows) is better than average and indicates a model that is representative of the actual subsurface conditions.

2.1.8 Were the hydraulic conductivity values and other hydrologic parameters (e.g., recharge) assigned in the model consistent with the known site properties or literature values?

- Review of the contents of the Stibnite Gold Project Water Resources Summary Report (also developed by Brown and Caldwell - Brown and Caldwell 2017, Section 8.4 – Aquifer Testing) indicate that the model-calibrated hydraulic conductivity values are within the range of measured values (from slug tests, packer tests, and aquifer tests). This water resources report not only summarizes what was measured within the study area, but also provides a discussion of how the measurements compare with the values provided in literature for similar geologic formations (Section 8.4.4 of that Brown and Caldwell 2017 report).

- A robust model calibration process provides additional assurance that the model-used values of hydraulic conductivity are approaching the real values for the shallow, unconsolidated formations, which are the most permeable formations within the study area. This is especially important in view of the fact that the results of slug tests often characterize the hydraulic properties of the sediment (or fractured / weathered shallow bedrock) only in an immediate area around the tested borehole / well. Such tests are often ineffective in capturing hydraulic properties of a larger volume of the geologic formation – the groundwater flow within which may occur predominantly through preferential pathways.

- There is a possibility that the results of packer tests conducted on several boreholes by HydroGeo Inc. (6 packer tests) and SRK (62 tests) are not capturing hydraulic properties of fault zones present within the study area. However, proper accounting of fault zone hydrogeologic parameters is difficult and often not practical. As a result, models resort to running sensitivity analysis, assuming a range of conductivities / transmissivities and noting the corresponding change in prediction results. Brown and Caldwell's existing conditions modeling report (Brown and Caldwell 2018b) provides a statement that, "The potential for flow in geologic structures will be assessed through sensitivity analysis during simulation of site operations." However, ERM reviewers could not find any reference to, or description of, such analysis in either of the Brown and Caldwell modeling reports (Brown and Caldwell 2018b, 2018c).

- An alternative to sensitivity analysis would be to run the so called 'Calibration-Constrained Monte-Carlo', also called 'Null Space Monte Carlo' or similar analysis (Doherty 2003). However, such an approach is not practical outside the realm of research, and some proposed practical and simplified solutions to a calibration constrained model predictive error analysis (Rzepecki 2011) are neither well known nor used.

- Brown and Caldwell provides a note in the existing conditions part of the model report stating that, "The potential for flow in geologic structures will be assessed through sensitivity analysis during simulation of site operations." However, the proposed action part of the model report does not provide any such sensitivity analysis, but the report does provide analysis of the potential effects of climate variation on hydrologic system changes and its responses to project activities during the mine operational period.

- Since the completed packer test results do not indicate that the fault zones are characterized by higher hydraulic conductivity than the rock mass outside of such zones, Brown and Caldwell chose not to represent the fault zones in the model. There is no evidence of highly transmissive faults within the study area, and this supports such an approach. The high degree of agreement between simulated and observed water levels and stream flows also indicates that incorporating fault zones into the model is not necessary to achieve an accurate model calibration.

2.1.9 Is the model sufficiently robust to assess/evaluate the potential environmental effects of the proposed project?

- The presented model is based on a sound conceptual site model, and constructed with the proper use of ample, site-specific, and regional data. The model is sufficiently restrained via multiple lines of calibration to provide a tool that can be used to make reasonable predictions. However, it is important to note here that any predictions generated by a model of a natural system will always contain uncertainties.

- As with any model, the calibrated parameters could likely be adjusted in different ways to achieve a valid calibration, and such adjustments would result in somewhat different model predictions. However, the predictive differences between the various model versions would likely be modest, while the overall water balance would likely be similar.

2.2 Surface Water Modeling

Models reviewed in this section for surface water include the:

- Final Stibnite Gold Project Site-Wide Water Balance (SWWB) Proposed Action Report (Brown and Caldwell 2018a);

- Final Stibnite Gold Project Hydrologic Model Existing Conditions Report (Brown and Caldwell 2018b);

- Revised Final Stibnite Gold Project Hydrologic Model Proposed Action Report (Brown and Caldwell 2018c);

- Stibnite Gold Project Geochemical Modeling Work Plan (SRK 2017);

- Final Stibnite Gold Project Existing Conditions Site-Wide Water Chemistry (SWWC) Report (SRK 2018a); and,

- Final Stibnite Gold Project Proposed Action Site-Wide Water Chemistry (SWWC) Modeling Report (SRK 2018b).

Midas Gold Idaho, Inc. (MGII or Midas Gold) expects to provide water management and/or treatment to avoid exceeding applicable surface water quality criteria or permit limits. Additional modeling is ongoing to evaluate these options and these modeling results will be presented under a separate cover.

2.2.1 Was the modeling approach consistent with standard industry practice?

It is standard industry practice to develop predictive models to evaluate potential water quality and quantity effects associated with proposed development projects; predictive surface water modelling represents a tool to inform mitigation and management strategies as well as to generate predictions to support analysis of the Proposed Action and Alternatives in the National Environmental Policy Act (NEPA) process. There are no national or international guidance documents specific to geochemical source term development, estimation and application of scaling factors, or development of predictive water balance, hydrologic and water quality modelling. Instead, development of predictions for quality of mine contact waters, mine effluent flows, and associated water quality in the receiving environment is governed by designated professional experts and practitioners.

2.2.1.1 Water Quality

Mass-balance modelling in conjunction with geochemistry modelling tools (PHREEQC) have been developed to determine surface water impacts from individual proposed mine facilities and subsequently incorporated into a Site-Wide Water Chemistry (SWWC) model to assess surface water quality at key points of the identified receiving environment (e.g., East Fork of the South Fork of the Salmon River, [EFSFSR]). This is consistent with industry-standard practices, although, in recent years fully integrated deterministic water balance and water quality models have become more common (e.g., GoldSim^{TM}). These tools are more adept at modelling complex systems, less error prone than Excel-based tools, and have substantially improved ease-of-use regarding sensitivity analyses or assessment of effects for changing climates, for example. The predictive water quality modeling has proceeded in accordance with the methodology outlined in the Stibnite Gold Project Geochemical Modeling Work Plan (SRK 2017) that has been reviewed by the U.S. Department of Agriculture, Forest Service (USFS), Idaho Department of Lands (IDL), Idaho Department of Environmental Quality (IDEQ), the Environmental Protection Agency (EPA), and AECOM.

2.2.1.2 Water Quantity

The SWWB model was developed using the GoldSim^{TM} software that is widely used in the mining industry and is considered an industry standard tool. The predictive water quantity models were comprised of a long-term meteoric water balance and a numerical groundwater flow model (MODFLOW-NWT). As described for groundwater, while developing the models, Brown and Caldwell followed industry standards for modeling that were developed by various authors and agencies in the USA and abroad, including British Columbia (Canada) Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities (Wels et al. 2012), and Australian groundwater modelling guidelines (Barnett et al. 2012). Both of those guidelines include numerous references to relevant hydrogeology and groundwater modeling related

ASTM standards. The guidelines are followed by modelers around the world preparing models for mining projects subject to EIS, Environmental Assessments, or Environmental and Social Impact Assessments.

2.2.2 Does the conceptual site model reasonably capture the known water quality and water quantity conditions?

2.2.2.1 Water Quality

In order to evaluate the overall effectiveness of the modeling method and identify potential data gaps, SRK (2018a) used the SWWC model to predict existing surface water quality at a series of prediction nodes in Meadow Creek and the EFSFSR. Model calibration results outlined in SRK (2018a) show that the majority of constituents can be predicted with a high level of confidence. For example, seventy-five percent of mass balance concentrations were found to be comparable to actual conditions (within the ±20% acceptable RPD bracket). This indicates that the major chemistry controls were accounted for in the calculations, supporting the use of the conceptual site model as a tool to evaluate the change in constituent load as a result of the proposed mining and reclamation activities. Therefore, the conceptual water quality model developed by SRK (2018a, 2018b) reasonably captures the known water quality conditions.

2.2.2.2 Water Quantity

The conceptual SWWB model reasonably captures the known water quantity conditions. It considers five primary water balance components that include water supplies and demands of the Project (i.e., ore processing, the tailings storage facility [TSF], contact water, dewatering for pit development, and potable water supply). It was developed considering the recent data sources describing the hydrological system of the project area, including the Plan of Restorations and Operations (Midas Gold 2016) and the Water Resources Summary Report (WRSR; Brown and Caldwell 2017). The presented CSM is deemed reasonable and well documented by the available data.

The hydrologic model combined a meteoric water balance with a numerical groundwater and surface water flow model developed using MODFLOW-NWT. Input data for the meteoric water balance component was derived using long-term regional climate parameters by the Parameter-Elevation Regressions on Independent Slopes Model (PRISM; www.prism.oregonstate.edu). The data set generated for the model was 122 years and from that, 14-year periods were selected to represent average, above average, and below average conditions. As described in the groundwater model review, the groundwater component of the hydrologic model correctly presents the system as limited by horizontal boundaries that more or less coincide with surface water divides, including the watershed boundary that forms the study area. Surface water flows simulated by the model were compared to measured flows at USGS gage locations as monthly averages, and the model reasonably reproduced the approximate timing and magnitude of the annual hydrographs. The model components described here represent the known conditions well.

2.2.3 Are the available water quality and water quantity data sufficient for proper development and calibration of a model to be used to inform the EIS process?

2.2.3.1 Water Quality

Data considered in the SWWC model included site-wide water chemistry data, groundwater quality from September 2012 to March 2016, and surface water quality from April 2012 to March 2017. In the geochemical characterization program, phase 1 humidity cell test (HCT) results through week 144 and the phase 2 HCT results through week 48 were used to calculate source term geochemistry. Overall, ERM deems the available water quality and geochemical data to be sufficient to support the SWWC model and impact assessment. However, the following observations have been noted:

- SRK (2017) stated that additional humidity cell testing was being carried out as part of the Phase 2 Geochemical Characterization Program. In the instance that one of these cells develops acidic conditions, the chemistry from that cell would be used to represent potentially acid generating (PAG) development rock chemistry. Assuming no acidic conditions have developed in these additional humidity cell experiments, data from the humidity cell with the highest sulfur content and sulfate release rate can be used to represent PAG in the SWWC model. However, if acidic conditions have meanwhile developed, it is recommended that the implications on this model component loading source be evaluated.

- As stated in the PA SWWC model report (SRK 2018b), any contact water runoff from the Development Rock Storage Facilities (DRSFs) will be captured and used in mining activities. Water quality treatment measures would only be required if the amount of water exceeds what can be accommodated by the milling process. The assumption that this water is not expected to enter the surface water can be considered valid. Regardless, a sensitivity model run is recommended to simulate the potential impact of the release of DRSF runoff on surface water quality.

- The assumptions of the PA SWWC model report are consistent with what is stated in the PRO and SWWB model report, and the models assume that none of the contact water will be discharged to the environment without treatment. The need for treatment is currently being evaluated and the findings will be provided under a separate cover. If need for treatment is deemed required during the life of the Project and/or discharges of contact water will occur, these processes should be incorporated into the predictive models.

2.2.3.2 Water Quantity

The hydrologic model consisted of a long-term meteoric water balance and a numerical groundwater flow model. The meteoric water balance to compute snowmelt and rainfall, runoff, and recharge to the groundwater system used a long-term PRISM dataset. Monthly values of the main parameters of water balance were developed and then used to calibrate the model to groundwater levels and stream flow. The groundwater model was calibrated to average groundwater levels measured during fall (measurements collected over several consecutive years) in 50 monitoring wells; of these wells, 43 were completed in alluvium and 7 in bedrock. Although it is not stated in the modeling report, our understanding is that the calibration targets represent average groundwater levels calculated from a database of measurements collected during 2011. It is our understanding that the model was calibrated to steady state groundwater conditions. Although groundwater levels fluctuate with season, the model report points out that the +/- 10 foot fluctuations are negligible compared to the terrain relief in the study area. Further details on the groundwater data used in the model are included in the groundwater model review section. The amount of meteorological, hydrogeological, and hydrological data used to parametrize and calibrate the model is well within the standard practice for this type of project.

2.2.4 Was the correct type of information collected for use in the model?

2.2.4.1 Water Quality

Overall, the information used in the SWWC model can be deemed appropriate and is consistent with standard industry practices for designing and calibrating a deterministic water quality model to support an impact assessment. Model inputs consist of the following types of information: (1) humidity cell testing results; (2) mineralogy and static tests; (3) site-wide chemistry data; (4) groundwater quality; (5) surface water quality; (6) pit wall seepage/contact water quality; (7) TSF tailings consolidation water quality; and (8) TSF/DRSF seepage water quality. In addition, model output from the Stream/Pit Lake Network Temperature (SPLNT) Model as well as the Hydrologic Model was used in the SWWC model.

Source terms for development rock facilities were developed using the results of site-specific laboratory leach tests (i.e., HCT) that are scaled to field conditions. Scaling factors have been standardly applied to account for the differences in reaction rates, temperature, and liquid-to-solid ratios between the laboratory tests and field conditions. Development of site-specific scaling factors is outlined in SRK (2017).

An assumption not deemed conservative is the DRSF surface runoff during post-closure, which is assumed to only interact with the growth media cover. Rainwater quality was used as a surrogate source term for runoff in contact with the growth media cover (SRK 2018b). This assumption is anticipated to under predict the associated runoff load during post-closure. This assumes a 100% reclamation and cover-efficiency (which is not standard practice) and excludes the possibility of surface runoff encountering the underlying development rock or any impact of percolating water. Thus, the effects during post-closure may be underestimated or underrepresented in this regard.

2.2.4.2 Water Quantity

The information used in the model for streamflow predictions is considered correct and is typical for setting up and calibrating a hydrologic model. The model is based on the following types of information: (1) meteoric water balance (precipitation, snow accumulation, and snowmelt) with model inputs from both on-site data and long-term regional data analyzed using the Parameter-Elevation Regressions on Independent Slopes Model (PRISM); and (2) groundwater flow with model inputs of on-site groundwater levels, hydraulic conductivity / transmissivity, stream baseflows, boring logs, topography, and other geologic information. The meteorological dataset used to develop the model was 122 years and three 14-year periods were selected to represent the average, above average, and below average conditions, and are considered to represent the site conditions reasonably. The groundwater data were collected over many years and locations that are considered to represent the site. In terms of surface water quantity predictions, the model was calibrated using data from five USGS streamflow gauges within the analysis area that had data available for the period from 2011 to 2016, providing adequate data for the calibration process.

2.2.5 Was an industry-standard software code used for model development?

2.2.5.1 Water Quality

The SWWC model is based on the principle of water and chemical mass balance and was developed using a combination of mass-balance calculations in Excel and thermodynamic calculations carried out using the United States Geological Survey (USGS) software PHREEQC (Parkhurst and Appelo 1999). Assuming all calculations underwent extensive quality control / quality assurance, this approach can be deemed appropriate. Note that in recent years, fully integrated deterministic water balance and water quality models have become more standard in the industry (e.g., GoldSim™). These tools are more adept at modelling complex systems, less error prone than Excel-based tools, and have substantially improved ease-of-use regarding sensitivity analyses or assessment of effects for changing climates, for example.

2.2.5.2 Water Quantity

Water quantity modeling was conducted using several models: (1) the SWWB model was developed to account for water production, usage and reuse, consumption, handling, and storage throughout the mine construction, operation, and early closure periods for the Project; and (2) the Hydrologic model was developed to assess potential changes to groundwater and surface flow conditions due to mining activities.

The SWWB model was developed using the GoldSim software that is widely used in the mining industry. The hydrologic model consisted of a long-term meteoric water balance that tracks precipitation, snow accumulation, and snowmelt and a numerical groundwater flow model developed using MODFLOW-NWT. Streamflow was simulated using the MODFLOW Surface Flow Routing package. Both GoldSim (SWWB model) and MODFLOW-NWT (hydrologic model) are considered industry standards for water balances and predictive modeling.

2.2.6 Were the model boundary conditions appropriate and justifiable?

2.2.6.1 Water Quality

Overall, the model boundary conditions used in the SWWC model are appropriate and justifiable. Results of the facility geochemical models considering the Hangar Flats, Fiddle, and West End DRSFs; the Hangar Flats, West End and Midnight Area pit lakes;

and the Yellow Pine backfilled pit were incorporated into the SWWC model. Future conditions incorporate water quality predictions from the DRSFs, pit lakes, TSF, and Yellow Pine backfilled pit. However, the following boundary conditions were identified that may need further development as they cannot be deemed industry-standard:

- Water quality predictions during pre-mining years (i.e., construction phase) were not included in the PA SWWC model report (SRK 2018b). However, the cumulative effects of the events that will take place in the pre-mining years (mine years -3 through -1) are accounted for in the Year 1 PA SWWC model predictions.
- Seasonal adjustment factors (SAF) were developed for each prediction node by examining baseline surface water data as well as stream flow measured at USGS gages. The SAFs are a series of 12 coefficients (one for each month) that when multiplied by a predicted annual average concentration produce monthly estimates. Although this differs generally from common practice, it is not inappropriate. However, many of the water quality predictions for site infrastructure (e.g., pit lakes, RIBs, etc.) are provided as annual averages instead of monthly or seasonal averages. In particular, pit lakes were recognized to experience seasonal stratification in the SPLNT model and subsequently in the PA SWWC model (SRK 2018b). In addition, only annual average concentrations for the predicted water quality entering the Rapid Infiltration Basins (RIBs) is provided. This means any monthly or seasonal variation in groundwater concentrations for water reporting to the RIBs may not be captured in the model.

2.2.6.2 Water Quantity

The model boundary conditions are considered appropriate and justifiable in regards to surface water quantity. Water is described as entering the model domain primarily through surface recharge, with minor in-flows from stream losses. Water discharges from the model domain as flow to surface streams.

- Anthropogenic boundary conditions including open pit dewatering were added to the model to simulate the proposed mining and associated mine project activities. Open pit dewatering was simulated using drain elements with the drain configuration changing with time to reflect the planned evolution of the pits. Using drains is a standard modeling method of representing dewatering of pits, even though in practice, dewatering wells will be used to lower groundwater levels below the pit walls/slopes and bottom.
- Streams were simulated using a stream package. This package was used to track a water balance for each reach of the simulated streams for each month of the model simulated time. This package allows a more realistic representation of the streams and their interaction with the groundwater system than other types of boundaries (like the often used prescribed head).
- Recharge values to the groundwater system were developed using the detailed meteoric water balance and the model calibration to groundwater levels and measured stream discharge. A detailed meteoric water balance developed for

each month of the model simulations represents a more involved and accurate methodology compared to what is typically done for groundwater models (like using a bulk value for different recharge zones without analyzing elements of a water balance, such as evapotranspiration, runoff, snowmelt, or sublimation).

- Lateral model boundaries were set as no flow boundaries coinciding with surface water drainage boundaries. This is an often applied approach based on (1) known general patterns of groundwater flow from high terrain to valley bottoms, (2) a typical lack of detailed information to differentiate between surface water and groundwater divides (drainage boundaries) on a smaller scale. This approach is additionally justified by the overall data which indicate no significant groundwater flow through bedrock occurs across drainage boundaries (see the discussion above).

2.2.7 Was parametrization, calibration and sensitivity analysis completed according to standard industry practice for an EIS project?

2.2.7.1 Water Quality

Sensitivity analyses have not been made available. However, SRK (2017) states that sensitivity analyses will be performed on the DRSF, pit lake, and Yellow Pine backfill models to address uncertainties in the model inputs. Sensitivity analyses are required to support an impact assessment and the EIS. Planned sensitivity runs will include: (1) scaling assumptions relating to the proportion of flow paths, fine particles, and temperature in the DRSFs and Yellow Pine pit backfill; (2) scaling assumptions relating to the pit wall fracture thickness and density; (3) NPR cut-off value for defining PAG and non-PAG material; (4) assumptions regarding specific yield within the bedrock and alluvial aquifers; and (5) TSF cover thickness. The results of the sensitivity and uncertainty analysis will be available prior to the draft EIS.

Regarding model calibration, the SWWC model was developed to predict existing surface water quality at a series of prediction nodes in Meadow Creek and the EFSFSR. Seventy-five percent of mass balance concentrations were found to be comparable to actual conditions (within the ±20% acceptable RPD bracket), indicating that the major chemistry controls were accounted for in the calculations. These results indicate that the majority of constituents can be predicted with a high level of confidence, which supports the use of a predictive SWWC model to evaluate the change in constituent load as a result of the proposed mining and reclamation activities.

The following observations pertain to model parametrization:

- The pit lake models predict chemistry under well-mixed, annual average conditions. The SPLNT modeling demonstrates that the lakes will stratify seasonally, and will turn over each spring and fall. Given that the pit lakes stratify seasonally, it would be industry-standard for the proponent to provide monthly or seasonal predictions rather than predictions of annual average concentrations (SRK 2018b) to reflect any of the associated water quality changes.

- An NPR cut-off <1 is typically applied to define PAG material and an NPR cut-off >2 is typically applied to define non-PAG material (INAP 2014; MEND 2009). The proposed site-specific NPR cut-off of 1.5 represents the mid-point between these two values and is confirmed by the kinetic test program on site-specific materials. Based on the current group of humidity cells, the proposed NPR cut-off of 1.5 seems appropriate given that acidic conditions have not been generated to date. However, discussion should be made regarding the sample selection process for humidity cell test work; specifically is it thought that more appropriate samples could have been selected to demonstrate acid generation? Or are these samples considered representative? This will have implications on modelling results and also the need for additional sensitivity analyses to support the impact assessment, for example.

- Three waste grade development rock samples were reported with paste pH < 6. Non-acid generating (NAG) test results indicate that multiple development rock samples could go acidic given that NAG values > 10 kg H_2SO_4/t and pH values < 4 were confirmed. There is a risk that PA SWWC model predictions (SRK 2018b) do not adequately capture the PAG contributions to surface water quality. Sensitivity analysis on this topic was not included in the PA SWWC model report (SRK 2018b) but has been promised by the proponent.

- Predictions for ammonia concentrations were not included in the PA SWWC model report (SRK 2018b), despite the proposed use of ammonium nitrate fuel oil (ANFO) for blasting during development. Therefore, this may limit the usefulness of the SWWC model to inform any effects assessment on fisheries and aquatic life. It is recommended ammonia to be included as a modeled parameter to support the EIS.

- First-flush chemistry for contact water coming off the DRSFs was not considered relevant to surface water quality predictions (SRK 2018b). This is deemed a non-conservative assumption, and consideration of this process is highly recommended for either inclusion in the base case or a relevant sensitivity analysis run.

- The solubility controls affecting trace element adsorption relied on values that are widely used in published literature and are also the recommended/default values for use in PHREEQC (Parkhurst and Appelo 1999). This approach can be considered industry-standard, although it is generally thought to be non-conservative, highly variable and very sensitive to user-based inputs and assumptions. As such, sensitivity analysis is highly recommended in this regard. Further, the documentation provided in the model report regarding the approach and application of PHREEQC is insufficient to support data and document requirements for an EIS. Further details should be included in an appendix to the main model report, or similar.

2.2.7.2 Water Quantity

Parameterization, calibration, and sensitivity analysis were completed to industry standards. Parametrization of the model was accomplished using a combination of field measurements (e.g., hydraulic properties, hydraulic heads, and stream baseflows) and model calibration, keeping the model parameters (arrived at during calibration) within the range of measured values. Simulated surface flows were compared to measured flows at five USGS gauge locations within the analysis area and the flows are considered well calibrated.

2.2.8 Is the model sufficiently robust to assess/evaluate the potential environmental effects of the proposed project?

2.2.8.1 Water Quality

Without appropriate water management and/or treatment, several constituents are predicted to be elevated above applicable water quality guidelines during several project phases including post-closure. This emphasizes the need for a robust predictive SWWC model. Several modeling approaches have been identified that are generally considered as non-conservative and not consistent with industry practice. The most fundamental ones include:

- Reclamation and closure of DRSF and related facilities is considered 100% efficient and surface runoff during post-closure is assumed to only interact with the growth media cover.
- Sensitivity analyses have not been made available, but they are planned. Sensitivity analyses are required to support an impact assessment and EIS application.
- Annual average concentrations as opposed to monthly or seasonal predictions were provided in SRK (2018b). It is standard practice that seasonal predictions are accessed for the surface water quality effects assessment and for related value components (e.g., aquatics, fisheries, wildlife, etc.).
- Predictions for ammonia concentrations were not included in the SWWC model report (SRK 2018b).

2.2.8.2 Water Quantity

The hydrologic model presented is considered sufficiently robust to assess/evaluate the potential environmental effects of the proposed project on stream flows within the analysis area. It is our judgment that the model presented is based on a sound conceptual model, and constructed with the proper use of ample, site-specific, and regional data. The model is sufficiently constrained via multiple lines of calibration to provide a tool that can be used to make reasonable predictions. However, it is important to note that any predictions generated by a model of a natural system will always contain uncertainties. The details of the presented model could be justifiably altered in different ways, and such adjustments could result in a somewhat different prediction outcome. However, the predictive differences between the various model versions would likely be modest, while the overall water balance would likely be similar.

Specifically related to modeled stream flow, the model predictions are limited to the surface water analysis area boundary and it does not predict effects to streamflow at downstream locations outside the analysis area. Although modelling results are limited to the analysis area, the extent of analysis is acceptable because the extent of the predicted impacts to flows is expected to be mainly localized around the pits where dewatering indirectly affects downgradient surface flow though groundwater drawdown. It has been assumed that farther downstream (outside analysis area), baseflow reduction would be lower due to additional natural flows.

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