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Your file - Votre référence
3AM-GRA1624

March 2, 2021

Our file - Notre référence
GCdocs#91293722

Richard Dwyer
Manager of Licensing
Nunavut Water Board
P.O. Box 119
Gjoa Haven, NU, X0B 1J0
sent via email: licensing@nwb-oen.ca

Re: Crown-Indigenous Relations and Northern Affairs Canada's comments on Sabina Gold & Silver Corp.'s hydrodynamic model submitted as part of their amendment application for water licence #2AM-BRP1831 for the Back River gold mine

Dear Mr. Dwyer,

Thank you for your February 12, 2021 invitation for review comments on the above referenced model. The Water Resources Division of Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) examined the model with Tetra Tech Canada Inc. For the Nunavut Water Board's consideration, their technical comments are attached as Annex A – Review of hydrodynamic modelling of Goose Lake.

In summary, the model is still preliminary because of uncertainties in the inputs. CIRNAC would request that the next version of this model addresses such issues as:

1. Ability to reproduce vertical physical structure of the lake temperature;
2. Whether cryo-concentrated water is outflowing, if so, when and how much;
3. Mixing zone near inflows rather than using the whole lake.

If there are any questions or concerns, please contact me at (867) 975-3876 or by e-mail at sarah.forte@canada.ca or Bridget Campbell at (867) 975-4282 and bridget.campbell@canada.ca.

Sincerely,

Sarah Forté

Sarah Forté
Water Management Specialist

ANNEX A – Review of hydrodynamic modelling of Goose Lake

Context:

Sabina provided a report "Hydrodynamic and Water Quality Modelling of Goose Lake" by Golder dated 12 February 2021. The report uses a three-dimensional hydrodynamic model to simulate the concentration of water quality constituents at the outlet of Goose Lake. General comments on the lake are provided here, followed by specific comments on the modelling report and results.

The volume of Goose Lake (11 Mm^3) is comparable to the inflows (11-15 Mm^3 depending on mine phase). As such, the residence time is ~1 year and no multi-year assimilation capacity is expected from Goose Lake. In the absence of in-lake processes, the outflow would be expected to be a smoothed average of the inflows with some degree of delay in time. However, the climate and large surface area allows ice formation to take up a significant proportion of the lake's water – on the order of half of the volume (Figure 2b). This creates a cryo-concentration effect where dissolved solids are excluded from ice and concentrate in the remaining water. Some outflow from Goose Lake occurs before ice-off, so the water quality leaving the lake could be worse than that entering the lake.

The way water in the lake mixes (or not) can also result in a change to water quality. Temperature stratification is observed in Goose Lake in both summer and winter. Stratification can isolate surface water from bottom water, reducing the amount of dilution available to an effluent or inflow. Density stratification due to dissolved solids can also occur – this is the key mechanism behind the long-term storage of saline water in pit lakes. Dimictic behaviour (stratification in summer and winter) is expected based on the lake depth and the limited observations provided. Therefore, the three-dimensional processes are important enough to model correctly, and the timing of inflows vs. cryo-concentration may be key to maintaining water quality at the outlet. Streamflow at the Goose Lake outlet is expected to begin in late May / early June (Hydrological Assessment of Effects from increased Goose Lake and Big Lake Withdrawals, Golder memo dated 13 March 2020, Table 4).

Technical Review Comments:

1. Model Validation – Hydrology and Chemistry

The hydraulic performance of the model is evaluated graphically, but predictions of monthly lake outflow must exist for a more quantitative comparison. The timing of lake outflows in the model should match those observed. Although complex, the amount of outflow that occurs while the lake is still ice-covered and contains cryo-concentrated water appears to be critical to downstream water quality.

The freshet-related super-elevation of lake levels appears to diminish by July (Figure 3), while the onset of summer stratification is not likely until July, so it is likely that inflows will occur during a period when the lake is well-mixed.

Total dissolved solids (TDS) observations are used as validation data for the model's handling of scalar transport and mixing, including the cryo-concentration process. TDS is suitable for such a validation and is representative of other conservative water quality constituents. In Section 3.2, the model shows approximately double the observed range in TDS at site GLWB, but the range is well-matched at GLCB. According to the discussion, the inputs and validation data have slightly different methods of TDS calculation and therefore the "absolute values would not be expected to match." Ignoring absolute value and just considering the range, if one site matches well but another does not, then the model is not in fact consistently validated.

No vertical variability in TDS appears in the GLTL data, indicating that at these two locations and dates TDS was well-mixed. The sparsity of calibration data and the isolated nature of the GLTL location means that this comparison does not tell us whether there is vertical variability in TDS elsewhere in the lake or at other times of year. However, the TDS range over the course of a year at GLTL near the outlet is generally similar to observed, indicating that the degree of cryo-concentration is appropriate at this location, and mismatches at GLWB may be related to the shallow depth or proximity to inflows.

2. Model Validation – Vertical Lake Dynamics

Models must be validated before use. Ideally such a model would be compared to a time series of temperature at surface and bottom. It is understood that suitable data are sparse in Goose Lake, and two usable vertical temperature measurements are presented. Alternatively, better data from a lake similar in size and climate could be used to show that the chosen model parameters are suitable.

The ability of the model to simulate the vertical behaviour of temperature, and then dissolved constituents of potential concern, is not demonstrated. The comparisons in Figure 4 do indicate that heat fluxes are reasonably predicted, but the degree of stratification in the data is not reproduced by the model. Predicted bottom temperatures are not shown for the two deeper sites (GLCB, GLSE), so it is not clear whether the lack of stratification is lake-wide or only in the small basin near the outlet (GLTL). The profiles selected in Figure 5 reinforce that the model does not fit the data well.

This result is not surprising considering the vertical viscosity values in Table 7. Viscosity is an important model tuning parameter for vertical and horizontal variability of currents, temperature and dissolved parameters. The value for 'Vertical Eddy Viscosity' is extremely high; although it may be that this is a maximum, not an imposed value and the k-ε routine is selecting the actual value used in the model. All other viscosity and dispersion parameters appear to be on the high end of the recommended range. The model should also have been able to reproduce reverse stratification in the winter (i.e. zero degree water at the surface, near 4 °C at the bottom). Also, neither the vertical gridding scheme or the vertical resolution of the model are specified in Section 2.4.1. Thus it is not clear whether the model implementation is fully three-dimensional.

Stratification in Goose Lake may be relevant to water quality at the outlet, and three-dimensional patterns in lakes with local meltwater, freshet inflows, and multiple basins can be complex (Cortes and Macintyre 2020). The sill (shallow area) between the outlet area (PNO3 and observation location GLTL) and the rest of the lake is ~1.5 m deep (Figure 1), so during stratified conditions only surface waters may be expected to comprise the outflow. The inflow area is similarly shallow, setting up the potential for high-concentration inflows to "short-circuit" mixing with deeper parts of the lake and transit towards the outflow with limited mixing. This could occur in summer (warmer water at the surface) or winter if inflows were artificially high.

The vertical behaviour of the water excluded from ice (containing cryo-concentrated constituents) is also not simulated by the model – does it mix to the bottom or does the reverse stratification keep it near the surface? The density stratification from a 300 mg/L TDS difference (the TDS range in Figure 8) are comparable to the natural temperature gradients in the lake. Salinity stratification can also inhibit mixing; the reduction of spring turnover in a similar-depth lake is discussed in Pieters and Lawrence (2009). More work would be required to comment on whether the density gradient due to salinity reinforces or counteracts the density gradient due to temperature.

3. Inflow and Outflow Chemistry

The report is focussed on the concentration of parameters at the lake outlet and does not report the concentration at the various mixing zones around each inflow. The report suggests the lake outflows have a higher concentration than lake inflows. Using copper as an example – the highest incoming copper concentration is 0.0059 mg/L from PN04 during closure, and this inflow constitutes ~21% of the total flow. Other inflows during closure have lower (0.0013 – 0.0018 mg/L) copper concentrations. According to the model, the maximum monthly average copper concentration for the closure period is 0.0064 mg/L, higher than the inflowing concentration as well as the guideline (Table 8). This increase is presumably due to the effect of cryo-concentration as tracers are otherwise modelled as conservative. Figure 8 shows a maximum cryo-concentration factor of 2-3 depending on the year and mine phase.

The prediction of higher outflow concentrations than the inflow concentrations is counter-intuitive but could, in theory, be correct. However, there is not enough information on the model's hydrology to understand how much cryo-concentrated water is leaving the lake**.** Furthermore, fresh meltwater should help dilute cryo-concentrated water as it reaches the outflow point, but vertical lake dynamics are relevant to this process. Goose Lake outflow does not occur in all months – the surface of the lake and most streams are frozen up for the winter. If the goal of the modelling exercise is prediction of in-lake concentration then Table 8 is suitable. However, the wording of Table 8 "at Outlet of Goose Lake" does not clarify whether the reported values are the concentration of actual outflowing water, or just of the lake near the outflow. The numbers reported are maximum and average values, and if the maximum value is from a month with zero outflow then it is not representative of risk to the downstream environment. Similarly, it appears that the table entries under "monthly average constituent concentrations for mine period" are averaged across all months, so include both months where outflow occurs and does not occur. The results section of the report misses the opportunity to present which months have outflow exceedances and which exceedances are limited to Goose Lake itself, with potential implications for the prediction of downstream effects and the degree of water treatment required.

4. Potential Risks

Some of the points raised in this review identify potential underpredictions of the concentrations at the lake outlet.

Goose Lake appears to be dimictic, stratifying in summer and winter and mixing in spring and autumn. The timing of high-concentration inflows relative to ice-off and subsequent mixing and re-stratification could potentially result in high-concentration outflows. Similarly, the behaviour of a layer of cryo-concentrated water in the lake was simulated, but not in three dimensions due to the excessive mixing in the model. It is clear from the modelling that the potential for cryo-concentration in Goose Lake is critical to outflowing water quality.

In summer, a stratified lake could allow inflows to transit towards the lake outlet with less mixing than modelled.

5. Potential Over-Conservatism

Some of the points raised in this review identify reasons why the reported modelled results might be unrealistically high.

The presentation of model results may over-estimate potential parameter concentrations in outflowing water. If the goal is reducing downstream effects of guideline exceedances, then reporting in-lake concentrations when there is minimal or no outflow would misrepresent the risk. Validation of the model's hydrologic cycle to observed outflows would allow presentation of water quality constituents in months with active outflow. Table 8 presents maximum monthly average concentrations without clarifying the volume of outflow occurring. Presentation of a zoomed-in version of Figure 8, alongside the outflow volume, would allow better understanding of the sequence of events and potential downstream risk.

Recommendations:

- The performance of the model in simulating vertical temperature variability (stratification) must be improved for acceptable validation. No model results that depend on the vertical distribution of dissolved material can be relied upon without a reasonable match to observed temperature stratification.
- The timing of modelled Goose Lake outflows should be presented against observed data, and the goals of the modelling study clarified. In-lake and outflowing concentrations should be reported separately if the environmental or regulatory concerns are separate.
- The report should discuss the fate of water with cryo-concentrated dissolved solids. Is there any mechanism for this water to leave Goose Lake with elevated concentration, or does it in fact mix and dilute with meltwater before outflow? Similarly, is there any mechanism during summer stratification for inflows to transit quickly to the lake outlet with reduced mixing?
- The performance, capabilities and opportunities for improving the results of the model should be further discussed during the upcoming Technical Meetings.