TECHNICAL MEMORANDUM

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TO Jamie Quesnel and Michel Groleau
Agnico Eagle Mines Limited

CC David Brown

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WHALE TAIL PIT EXPANSION PROJECT
HYDRODYNAMIC MODELLING OF WHALE TAIL PIT LAKE

1.0 INTRODUCTION

Whale Tail and IVR are satellite gold deposits on the Amaruq exploration property located in central Nunavut. The site is located on Inuit Owned Land, approximately 150 km north of the hamlet of Baker Lake, and approximately 50 km northwest of the Meadowbank Mine, in the Kivalliq region. In early 2013, the property was acquired by Agnico Eagle subject to a mineral exploration agreement with Nunavut Tunngavik Incorporated.

Mine site and hydrodynamic modelling were carried out to supplement the mine site water quality predictive assessment and in support of the Approved Project Water Licence Term and Condition no.16 requesting this modelling be carried out on the Pit Lake as warranted.

The objectives of the hydrodynamic modelling study are to determine the time required to fill the Pit Lake, to assess whether the Pit Lake could stratify in time and to evaluate Pit Lake water quality during closure and post-closure. This modelling exercise uses input parameters developed through the site water balance and mass balance model. It provides a more detailed assessment of the distribution of mass (water quality) in the Pit Lake resulting from modelled hydrodynamic processes during filling and post-closure. The results of hydrodynamic modelling are used to refine the site wide water quality model to evaluate the effects of pit lake hydrodynamics on water quality in downstream lakes.

This technical memo provides the methods and results of hydrodynamic modelling performed on the Pit Lake during closure and post-closure periods.

2.0 BACKGROUND

2.1 Pit Lake Development

During the construction period, the North Basin of Whale Tail Lake targeted for mining will be cut off from the South Basin of the Lake by the construction of the Whale Tail dike. Water in the North Basin will be pumped out to provide access to the Whale Tail and IVR deposits. Two open pits will be excavated into the lake floor: Whale Tail and IVR pits. The IVR Pit will consist of two deeper basins separated by a shallower saddle or bedrock ridge. Upon flooding the Pit lake will include the three deep basins: the Whale Tail basin, the IVR East Basin and IVR West Basin. Both basins of the IVR Pit will be connected at an elevation of 130 masl above the rock ridge up to the final flood level of 153.5 masl for all basins of the Pit Lake. During the closure period of 2026 to 2050, the fully flooded Whale Tail Pit Lake will remain closed to the outside environment by dikes and the water level in the Pit Lake will be controlled by pumping to Mammoth Lake until water in the Pit Lake meets the quality criteria. The post-closure period will be initiated once the criteria are met (predicted to occur in 2051). At that time, the Whale Tail dike separating the Pit Lake and Whale Tail Lake (South Basin) will be decommissioned allowing water from the Pit Lake to be released into Mammoth Lake and downstream lakes. The Pit Lake will have a larger surface dimension and a different bathymetry compared to the original, pre-operations, Whale Tail Lake.

2.2 Modelling Objectives

A mine site water balance and water quality model was developed for the Expansion Project to assess the quality of future mine contact water. This model completed in the GoldSim platform (Golder 2018a) to define the water balance and the net mass balance of the Whale Tail and IVR pits assuming fully mixed conditions in the water column. More detailed hydrodynamic modelling (using as CE-QUAL-W2) was performed to determine the vertical and horizontal distribution of mass once it arrives in the lake system, and following the Approved Project Water Licence Term and Condition no.16. The specificity of a hydrodynamic models is to the density of fluids entering the water body, and predict the vertical stratification and vertical mixing of the water column as a function of site specific conditions, such as wind and air temperature, thereby providing the anticipated distribution of mass (water quality) within the water column.

The goals of the hydrodynamic model were:

- To predict the spatial distribution of mass within each pit, assuming all constituents are conservative (not removed by precipitation, adsorption, plant uptake or other processes that might decrease their concentration in the water column).
- To determine the time required to fill the Pit Lake to its steady-state overflow elevation of 153.5 masl.
- To evaluate the potential for complete mixing in the Whale Tail and IVR pits verses the potential for the development of permanent stratification (called meromixis).
- To predict and evaluate the water quality concentrations of constituents of principal interest to the system, namely: total dissolved solids (TDS), arsenic (As), nitrate (NO_3) and total phosphorous (P). The rationale for the focus on these parameters is as follows:
  - TDS has a strong influence on water density and therefore water mixing mechanics and salt is used in underground mining activities.
  - Arsenic is relatively enriched in rocks of the mineral deposit.
  - NO_3 and P are major nutrients which can influence the biological productivity or trophic level of the receiving environment. These four parameters along with other 33 parameters were evaluated in parallel in the site wide GoldSim model (Golder 2018a).

3.0 METHODS

3.1 Model Platform

The pit lake hydrodynamic model was developed in the CE-QUAL-W2 software package developed by the U.S. Army Corps of Engineers (Coles and Wells 2017). The CE-QUAL-W2 program is a two-dimensional (2-D, profile-view: horizontal distance vs depth), laterally-averaged, fluid mechanics and water quality model that has been widely used to evaluate the likelihood of complete mixing within lakes and reservoirs worldwide. The program provides 2-D flow fields from which the distribution of heat, momentum and mass can be simulated. The theoretical basis for CE-QUAL-W2 was the 2-D longitudinal-vertical transport model written by Buchak and Edinger (1984) which formed the hydrodynamic and transport basis of the first version (i.e., W1) of the water quality model (US Army of Engineer Waterways Experiment Station 1986).

3.2 Model Segmentation

Model segmentation is the discretization of a physical domain into individual grid cells that can be used by the model to iteratively calculate state variables (i.e., properties such as velocity and concentration) at all locations within the lake within each time step. A 2-D grid was developed to cover Whale Tail Pit, IVR Pit, and the Attenuation Pond (Figure 1). The horizontal grid spacing varied between 50 and 240 m. The vertical grid spacing varied between 0.5 m near the surface and 5 m near the pit bottom.

The model included four branches. Branch 1 represented IVR West Basin and included 4 horizontal segments and 53 vertical layers; Branch 2 represented IVR East Basin and included 4 horizontal segments and 51 vertical layers. Branch 3 represented the Attenuation Pond and included 4 horizontal segments and 17 vertical layers. Branch 4 represented Whale Tail Pit and included 9 horizontal segments and 96 vertical layers. The deepest layer occurred in Segments 22 and 23 and corresponded to a total depth of 273.5 m.

Within the model, the branches were connected as follows: (1) the connection between IVR West Basin (Branch 1) and IVR East Basin (Branch 2; Figure 1) was established via a lateral spillway connecting Segment 3 to Segment 8 above an elevation of 130 m (the elevation of the top of the ridge separating these basins); (2) Segment 17 in the Attenuation Pond (Branch 3) was connected to Segment 22 in the Whale Tail Pit (Branch 4; Figure 1) above an elevation of 146.3 m; (3) Segment 10 in IVR East Pit (Branch 2) was connected to Segment 20 in the Whale Tail Pit (Branch 4; Figure 1) above an elevation of 149.3 m.

These connections allowed volume and mass exchange between the connected branches above the specified overflow elevations. Water and mass were removed from Segment 26 in the Pit Lake at an elevation of 153.5 m, which represented the overflow to Mammoth Lake. Figure 2 shows the profile along cross-section A-A[1], selected to cross through the deeper point of IVR West and East Basins and Whale Tail Pit. Figure 3 shows the vertical discretization as visualized in CE-QUAL-W2.

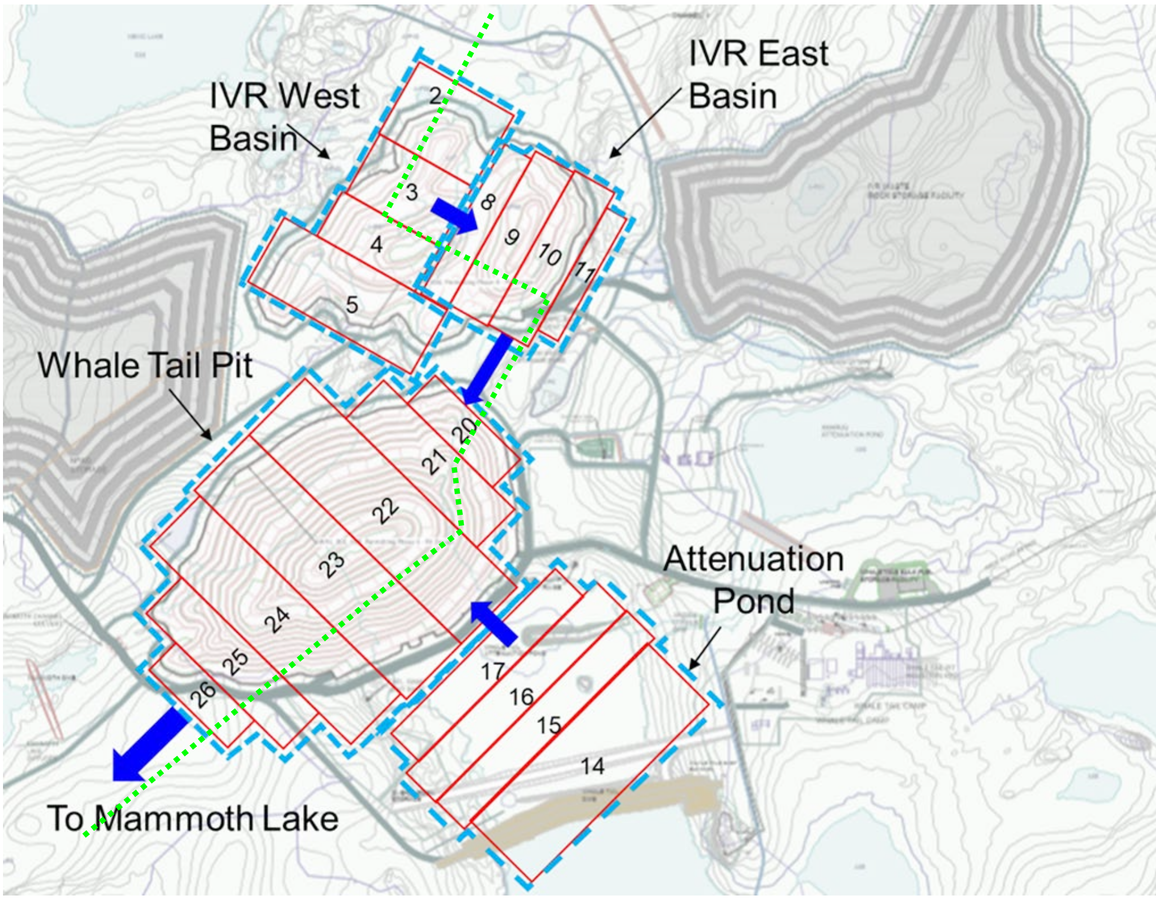

Figure 1: Plan view of segments (centerline of segment shown) used to represent the IVR West Basin (Branch 1), IVR East Basin (Branch 2), the Attenuation Pond (Branch 3) and the Whale Tail Pit (Branch 4) in CE-QUAL-W2. Profile for section A-A[1] (green dashed line) included in Figure 2.

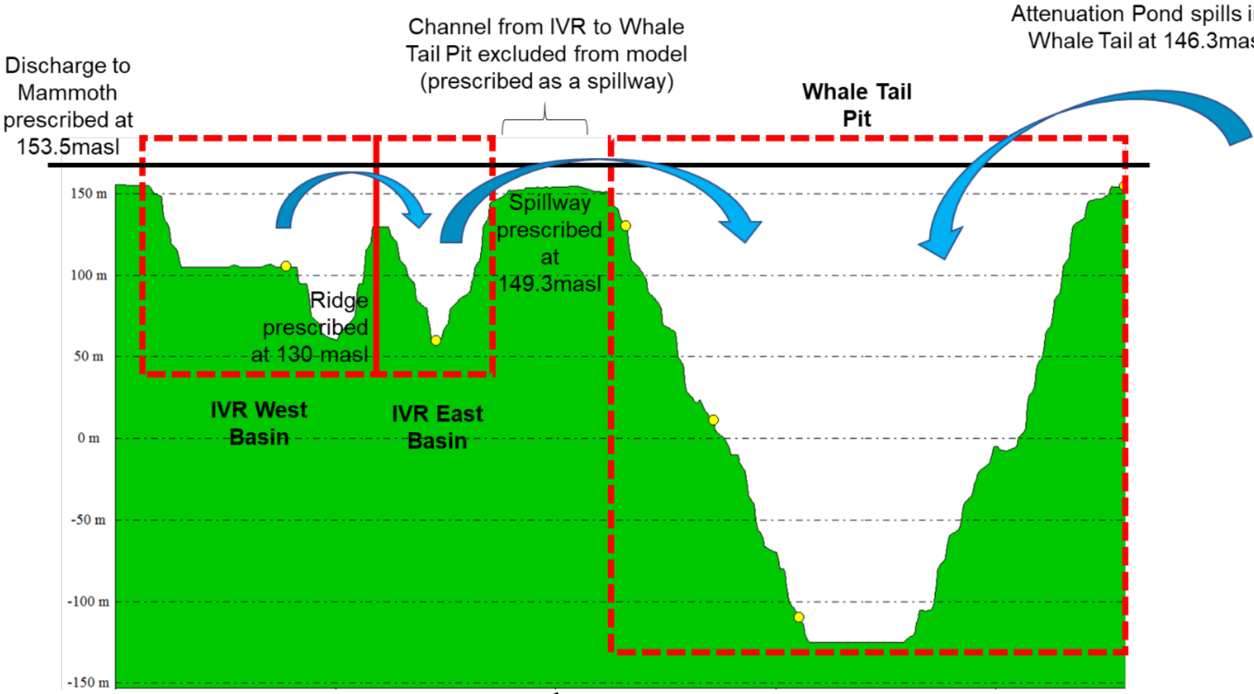

Figure 2: Profile view of along cross-section A-A[1] (refer to Figure 1). Attenuation Pond excluded from the cross-section profile.

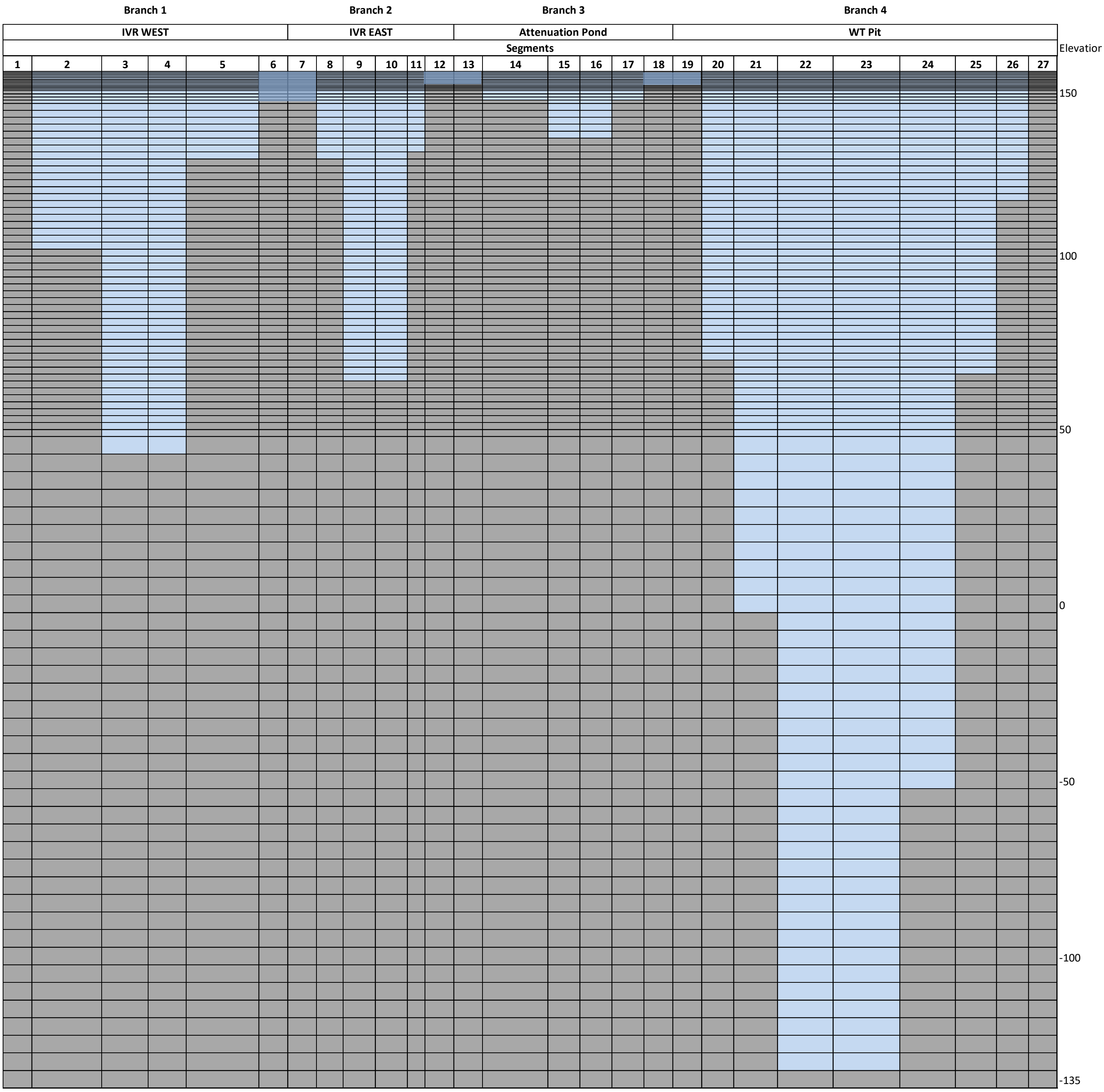

Figure 3: Profile view of vertical layers in the IVR West Basin, IVR East Basin, Attenuation Pond, and Whale Tail (WT) Pit modelled in CE-QUAL-W2. The upper most cells are directly connected across the model once the pit fills (the cell lines 6, 7, 12, 13, 18,19 do not represent actual space between the basin, they are a graphical representation artefact from the model).

3.3 Assumptions

Key assumptions used for this model are outlined below:

- Assumptions regarding inflows:
  - The volume of overland runoff was allocated to the most upstream segment of each branch and added monthly. Runoff chemistry was determined by the water and mass balance model conducted in GoldSim and presented in Golder (2018a).
  - The monthly volume of groundwater inflow and associated chemistry for the closure and post-closure periods were specified based on predictions generated by the hydrogeological model (Golder 2018c).
  - Groundwater inflow during closure and post-closure only occurs to and from the Attenuation Pond and to Whale Tail Pit but not IVR Pit, as the East and West Basins of the IVR Pit will be within permafrost (Golder 2018c) beyond the extends of the modelling period. The IVR Pit will only connect with the deep groundwater aquifer once all permafrost melts. The time required for permafrost to melt is in the order of hundreds of years (Golder 2018c), long after water quality criteria are predicted to be achieved. Because the hydrodynamic model only spans a few decades, groundwater discharge from the IVR Pit area of the Pit lake is not considered here.
  - Pumped flows were allocated to the closest segment to the proposed location. With the exception of overflows between water bodies (i.e., between IVR West Basin and the IVR East Basin, between IVR East Basin and Whale Tail Pit, and between the Whale Tail Attenuation Pond and Whale Tail Pit), all remaining surface inflows were added to the upstream segment of each branch.
  - All surface water inflows to the IVR Pit were allocated to the IVR West Basin, with the exception of pit wall runoff and land runoff. This assumption is based on anticipated water management at the mine plan. Pit wall runoff and land runoff were divided between the East and West basins based on the ratio of the surface area of exposed pit walls between the basins. This assumption was in agreement with the water balance and site water quality model (Golder 2018a)
  - All inflows are applied to the top 3 surface layers, with the exception of groundwater. CE-QUAL-W2 places the groundwater inflows in a vertical location in the water column based on the density of the groundwater (calculated from TDS concentration and temperature) and the density profile of the water column. The groundwater inflows are allocated to a depth of neutral buoyancy within the water column.
- Assumptions regarding outflows:
  - The lake becomes a groundwater source during post-closure only. Groundwater is one of three outflows from the Pit Lake, together with evaporation (calculated by CE-QUAL-W2) and overflow to Mammoth Lake.
  - Outflow to the groundwater is prescribed in the Attenuation Pond and Whale Tail Pit as a withdrawal of water and mass based on predictions generated by the hydrogeological model for post-closure conditions (Golder 2018c).
  - Groundwater was removed uniformly across the saturated depth of Segments 16 and 23, which corresponds to the area of predicted outflow to groundwater (Golder 2018c).

- TDS, arsenic, nitrate, and total phosphorous were modelled as 100% conservative constituents (i.e., reactions such as biological uptake or surface adsorption that would reduce dissolved concentrations were not modelled), to produce a mass-conservative water quality prediction. In reality, these reactions may happen to some degree, resulting into an improved water quality compared to predicted values.
- Frozen, ice-covered conditions were assumed to persist from October to May each year.
- Temperatures and precipitation rates were based on historic observations and do not consider potential future climate change.
- The water quality of inputs was conservatively assumed to be constant over time, as defined in the site wide water quality model (Golder 2018a). Inflows were characterized using representative water quality (i.e., water temperature and TDS, arsenic, nitrate, and phosphorous concentrations) from both modelled (i.e., as used in the Site Wide Water Quality Model in GoldSim) and measured data. In reality, concentrations are likely to decrease over time, resulting into an improved water quality.
- The total daily arsenic mass contributed to the Pit Lake from both watershed runoff and pit wall flushing (e.g., first submergence of wall rock) was calculated in GoldSim and was added to the pit lake as part of watershed runoff. Watershed runoff corresponds to flows from all areas reporting to each basin, including the previous and/or existing facilities, including WRSF, former ore stockpiles, etc.
- Existing stage-storage and area-storage curves used in the model included rehabilitated (sloped and covered) IVR Pit high walls that minimize mass contribution to IVR area of the Pit Lake and pushbacks to the north and south walls of Whale Tail Pit. The model assumes these geometric relationships do not change over closure and post-closure.
- The governing equations in CE-QUAL-W2 are laterally averaged. Lateral averaging assumes that lateral variations (y-direction) in velocities, temperatures, and constituents are negligible. This limitation is not expected to materially affect pit lake simulations, which are primarily concerned with vertical (z-direction) water stratification.
- Although CE-QUAL-W2 can model formation of ice cover, it does not consider the removal of dissolved constituents from liquid upon conversion of liquid water to ice. In reality, ice is composed of only fresh water whereas the constituents dissolved in water are extruded during ice formation and sink downward in the water column relatively enriching the unfrozen water below in these dissolved constituents. For lakes at high latitude, dissolved constituent exclusion is known to have an important influence on vertical mixing. Golder estimates that the low dissolved constituent load expected in Whale Tail Lake limits the significance of this process because the TDS is low and the lake volume is relatively large.
- Arrival of spring freshet in June, and pumped flows from the South Basin of Whale Tail Lake into the IVR West Basin.

3.4 Model Inputs

The model was run for a period of 25,064 days, representing the period of January 1, 2026 (start of closure) to December 31, 2090 (65 years) into post-closure.

Inputs to the model include lake bathymetry, meteorological, hydrologic, hydrogeologic, and water quality data, as described in the following sections. The temperature, volume, and concentration of each input were specified in the model on daily time steps.

3.4.1 Meteorological Inputs

Meteorological input data required for this hydrodynamic model include: air temperature, dew point temperature, wind speed and direction, and solar radiation. An hourly time-series was constructed for each of these inputs during the modelling time period (i.e., 2026 to 2090) based on observed data from the nearest Environment Canada Meteorological Station, Baker Lake A (Station ID 2300500), located approximately 125 km southeast form the Whale Tail Lake. Observations from 1998 to 2017 were repeated for the modelling time period, except for solar radiation, where the record from 1998 to 2012 was repeated.

Where data gaps existed, these were either filled by interpolation (for time gaps < 24 hours) or filled using the previous day or next day's values (for time gaps > 24 hours). The record air temperature was adjusted to compensate for the distance and elevation differences between the Baker Lake A station and the site. The dew point temperature was calculated using the air temperature, relative humidity and air pressure. Solar radiation was calculated from the horizontal irradiance.

Precipitation inputs were provided as monthly values representative of an average year (Golder 2018d).

As will be demonstrated, one of the most important inputs is spring freshet resulting from the melting of accumulated snow. The model tracked the total precipitation added to the pit watershed between October and May, assumed all precipitation to be snow, and incrementally added this water as runoff during the month of June. The timing of spring freshet was fixed at a constant date in the model, and the precipitation reported between 1998 and 2017 was assumed to be accurate for the entire closure and post closure periods. In other words, the model did not account for potential climate change nor annual climate variations.

3.4.2 Hydrologic Inputs

The hydrologic inputs for the model originated from the water balance modelling conducted in GoldSim (Golder 2018d) and represent average flow volumes from each infrastructure component using mean annual climate data. Inflows include:

- direct precipitation over Whale Tail Pit, IVR Pit, and Attenuation Pond;
- surface runoff from the site watershed to each water body;
- surface runoff from the pit walls to each water body;
- pumped flows to the IVR West Basin during refilling from: i) the Whale Tail Waste Rock Storage Facility (WRSF); ii) the Whale Tail WRSF Water Collection System; iii) the North East Channel; and iv) Whale Tail (South Basin);
- flows to Whale Tail Pit: pumped flow from the IVR WRSF (pumped until fully flooded, then gravity flow), ii) flow from the North Channel, and iii) runoff from the GSP area;
- flows associated with the footprint of the ore stockpile (pad is present but ore stockpile is consumed during operations), construction materials area, industrial sector, IVR Attenuation Pond area, main camp sector and pumped flow from the sewage treatment plant (STP) reporting to the Whale Tail Attenuation Pond;
- natural flow from Whale Tail (South Basin) to the Pit Lake (via the Whale Tail Attenuation Pond) after Whale Tail dike is decommissioned at post-closure;
- seepage flows from the Whale Tail Attenuation Pond; and
- groundwater inflows reporting from shallow depths.

Outflows included:

- groundwater outflow from the bottom of the Whale Tail Pit;
- evaporation; and
- outflow to Mammoth Lake over the Mammoth sill (calculated by CE-QUAL-W2).

Inflows were placed within the upstream segments of their respective basins, (i.e., Whale Tail Pit, IVR West or East Basin, and the Whale Tail Attenuation Pond). All inflows were added to the surficial layer of their respective waterbodies with the exception of groundwater. Groundwater inflows were vertically placed based on the density profile of the water column, and the depth of neutral buoyancy for the influent groundwater.

Groundwater losses from the Pit Lake were removed from deep segments based on groundwater modelling results (Golder 2018c).

Each input was assigned a temperature. Surface runoff and pit wall runoff inflows were set equal to the average daily air temperature in the meteorological data file. Negative air temperatures were converted to 0°C. Pumped flows from storage basins were assigned a constant temperature of 8.1°C based on the average water temperature observed in Mammoth Lake. Groundwater inflows were assigned a constant temperature of 2ºC based on the average value found in a groundwater investigation at the project site.

Finally, each input was assigned a concentration for TDS, arsenic, nitrate and total phosphorous. With the exception of post-closure groundwater inflows, concentrations for each input were calculated in the GoldSim water and mass balance model for the mine site (Golder 2018a). Post-closure groundwater TDS concentrations were obtained from the groundwater model (Golder 2018c).

3.4.3 Model Coefficients

Default coefficient values were generally used for hydrodynamic and energy terms. The following coefficients were based on a calibrated CE-QUAL-W2 model created by Golder for a pit lake at Dominion Diamond mine in the Northwest Territories (2014); an Arctic pit lake:

- sediment temperature was set to 2ºC;
- the maximum eddy viscosity was set to 0.001 m^2/s; and
- the coefficients in the ice module were modified to reflect a northern environment (Dominion Diamond 2014).

4.0 RESULTS

4.1 Time of filling

Based on the storage capacity and water balance alone, it is predicted that the water level in the West and East basins of the IVR Pit would rapidly rise during the 2026-2027 period (Figure 4) as it is actively being flooded with South Basin water. In 2027, the water level exceeds the overflow elevation (149.3 masl), and water spills into Whale Tail Pit. The second source of flooding water is the stored snowmelt within each water body catchment released in June during freshet. Inflows occurring during the ice-free season cause a step increase in predicted water levels in the middle of each year.

Water in Whale Tail Pit rises to the spillway elevation of the Whale Tail Attenuation Pond during freshet of 2039. During the freshet of 2040 the Whale Tail Pit and Attenuation Pond coalesce with IVR Pit and the entire system (referred to as the Pit Lake) rises as single waterbody upon the water level reaching an elevation of 149.3 masl. The water level in the system continues to rise to 153.5 masl which is reached during the freshet of 2041, at which point, controlled flow from Whale Tail (South Basin) and into Mammoth Lake begins to keep Whale Tail Lake at an average elevation of 153.5 masl.

The closure period ends and the post-closure period begins when the pit lake water quality meets receiving water quality criteria and the water retention dikes have been decommissioned. The objectives are predicted to be met approximately 10 years after the pit lake is fully flooded after which water retention dikes are decommissioned and water is allowed to circulate naturally from Whale Tail South Basin into the Pit Lake and out to Mammoth Lake.

The accuracy of the predicted model results is higher at early stages of the simulation and lower in time as model variations (such as climate, inflows, outflows, water quality data) compound in time.

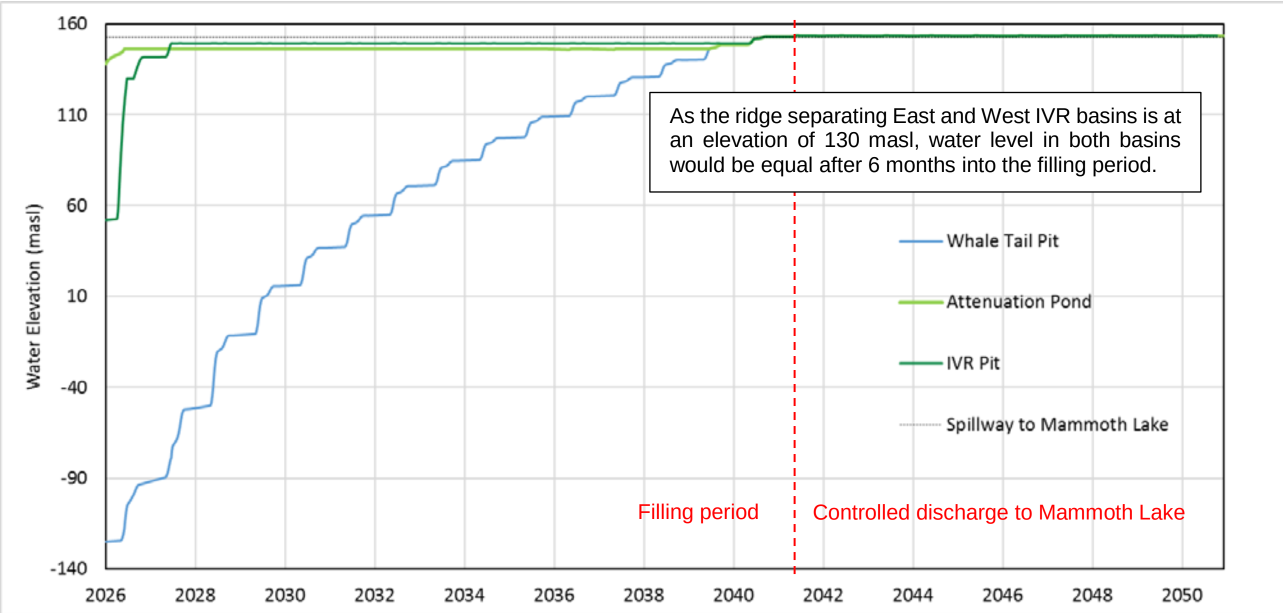

Figure 4: Predicted water elevations in the Whale Tail Pit, IVR Pit (West) and the Attenuation Pond during closure. IVR East was excluded as the water level would be same than in IVR West after June 2026.

4.2 Lake Circulation

Predicted profiles of temperature, TDS and arsenic concentrations were used to evaluate seasonal circulation in the IVR (West and East) and Whale Tail pits following full filling of the system. Although not shown, the same chemical patterns were found for nitrate and total phosphorous profiles. Lake circulation exhibited the same behaviour in each of the water bodies, therefore, only vertical profiles for a segment located in the Whale Tail Pit Area of the Pit Lake are shown in Figure 5.

During October to June, the Pit Lake is predicted to exhibit winter stratification, where concentrations and temperature show a stepwise increase with depth. The lowest concentrations are predicted to occur immediately below lake ice. The bulk of the lake shows a homogeneous concentration with depth. The depth of the thermocline is approximately 15 m from surface during winter (Figure 5).

Temperature and concentration profiles are predicted to homogenize between June and July as a product of complete mixing. Mixing is driven by three factors:

1) the loss of lake ice early June, which allows wind energy to be imparted on the water surface
2) the increase in surface water temperature to 4 °C, the maximum density of fresh water
3) water at all depths below the surface having a lower density than water at the surface

With these conditions in place, wind events in the spring are predicted to drive complete mixing of pit lake water.

Stratification is predicted to return for a brief period during the summer months (July to October, not shown). This summer stratification is caused by the warming of surface water relative to deep water by solar radiation. Model results show that summer thermocline ranges between 5 and 15 m in depth. This condition causes the density of surface water to become lower than the density of deeper water resulting in thermal stratification. During this period, the surface layer would not mix with deeper water, and inputs to one layer would not affect the chemistry of the other layer. In October, less daylight and cooler air temperatures leads to the cooling of surface temperatures and a second complete mixing event; the fall turnover. Thereafter, the lake is predicted to return to winter stratification.

In summary, the Pit Lake (and each water body, individually) is predicted to exihibit weak seasonal thermal stratification each summer and winter, and to undergo complete mixing each spring and fall. This behavoir is characteristic of a dimictic lake (e.g., a lake which experiences bi-yearly mixing), and is consistent to the seasonal behaviour observed in Mammoth Lake.

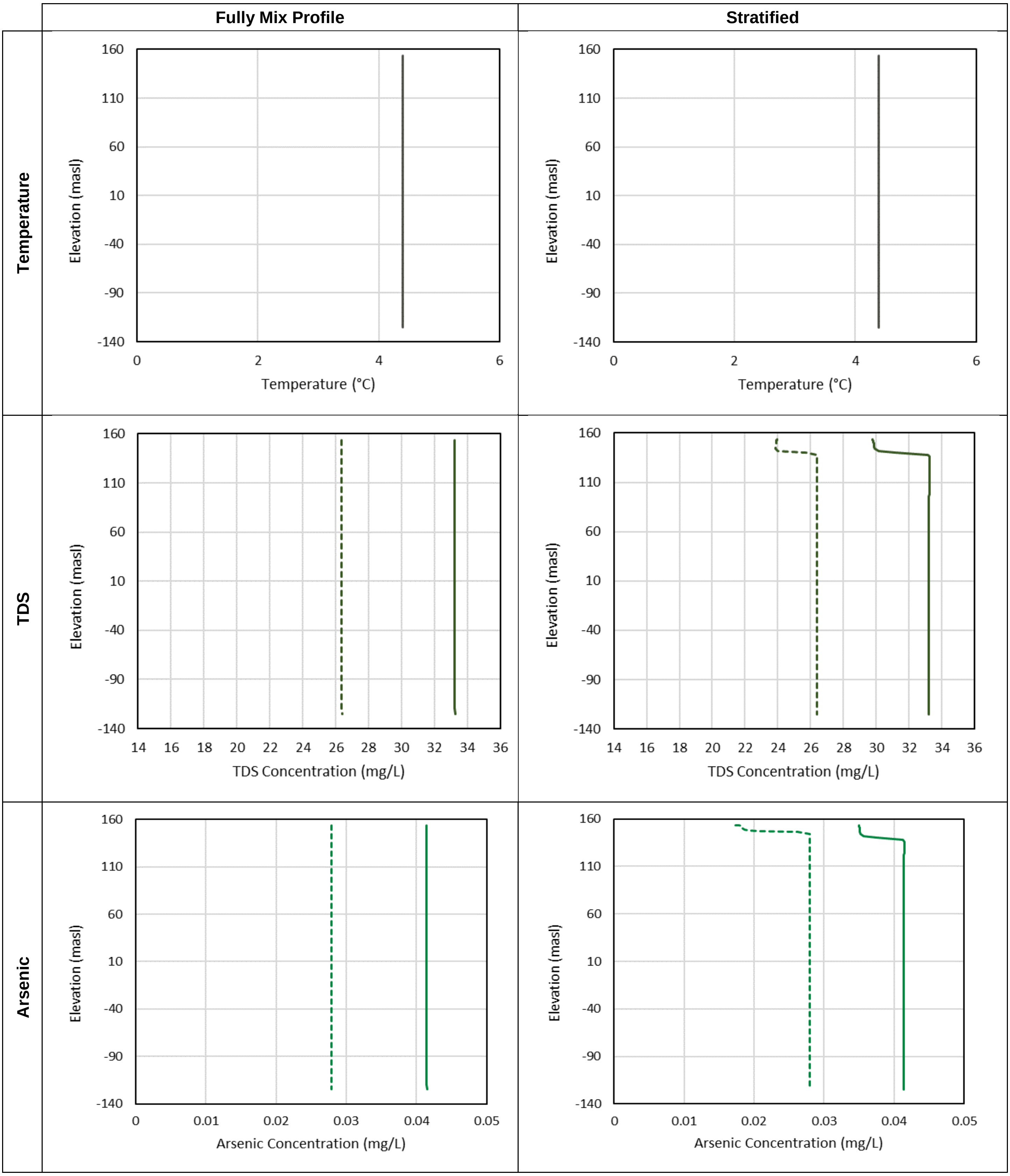

Figure 5: Profiles of temperature in 2042 and TDS and arsenic concentrations predicted for the Pit Lake (segment selected at Whale Tail Pit) in 2042 (solid line) and 2051 (dashed line). Stratified conditions corresponding to the end of winter (May). Fully-mixed conditions are shown corresponding to the end of fall turnover (October).

4.3 Water Quality

To illustrate changes in pit lake water quality over time, time series plots of TDS, arsenic, nitrate, and total phosphate concentrations were generated for three points in the water column representing the surface, middle, and bottom for each water body.

4.3.1 Whale Tail Pit

For Whale Tail Pit Lake, results are presented for 150 masl, 100 masl and -120 masl corresponding to depths of 3.5-m, 53.5-m, and 273.5-m when the Pit Lake is full. The time series of predicted concentrations are presented in Figure 6 and Figure 7. Concentrations increase rapidly at the beginning of the closure period due to the initial flush of mass from the site compared to the relatively small volume of the pit lake. Concentrations decrease annually, in a step-wise manor, owing to:

- the large addition of freshwater from the IVR East Basin spilling into Whale Tail Pit during the closure period and subsequent inflow from Whale Tail (South Basin) once the Pit Lake is fully flooded;
- the low concentrations of constituents assumed in spring freshet water (i.e., dilution); and
- complete annual mixing of waters within the Whale Tail Pit basin.

In the model, spring freshet arrives just before spring turnover, which causes a brief dip in shallow water concentrations (150 masl) relative to deep water concentrations (-120 masl). Complete mixing results in a step reduction in all concentrations, and homogenizes concentrations predicted at each depth over time.

Nitrate concentrations are predicted to be below site water quality criteria during the entire simulation while there are no receiving TDS water quality criteria. For arsenic and phosphorous, concentrations are predicted to be slightly above site-specific water quality objectives of arsenic and the upper limit of the oligotrophic-mesotrophic range for phosphorous once the Pit Lake is fully flooded (2041) but well below the effluent criteria. Phosphorous is likely to be overpredicted as it is expected to be up taken by biological activity but as previously stated, all concentrations are assumed to behave conservatively (i.e., reactions such as biological uptake or surface adsorption that would reduce dissolved concentrations were not modelled). In reality, these reactions may happen to some degree, resulting into an improved water quality.

Outflow from the Whale Tail Basin of the Pit Lake will be control-discharged into Mammoth Lake until Pit Lake water quality objectives are met. This is predicted to occur, based on the CE-QUAL-W2 model, approximately 10 years after the Pit Lake is fully flooded given the predicted concentrations in 2041. Results fitted onto the GoldSim model suggest that arsenic and phosphorous concentrations meet receiving water quality criteria by the end of 2050. These dates represent the range of potential outcomes.

Discharge of Pit Lake water to groundwater is only expected to occur during the post-closure period, after discharge to Mammoth Lake begins. As shown in Figures 6 and 7, Pit Lake water quality will be largely improved by the time groundwater discharge begins, such that addition of Pit Lake water to the surrounding aquifer is expected to have minimal impact on groundwater quality.

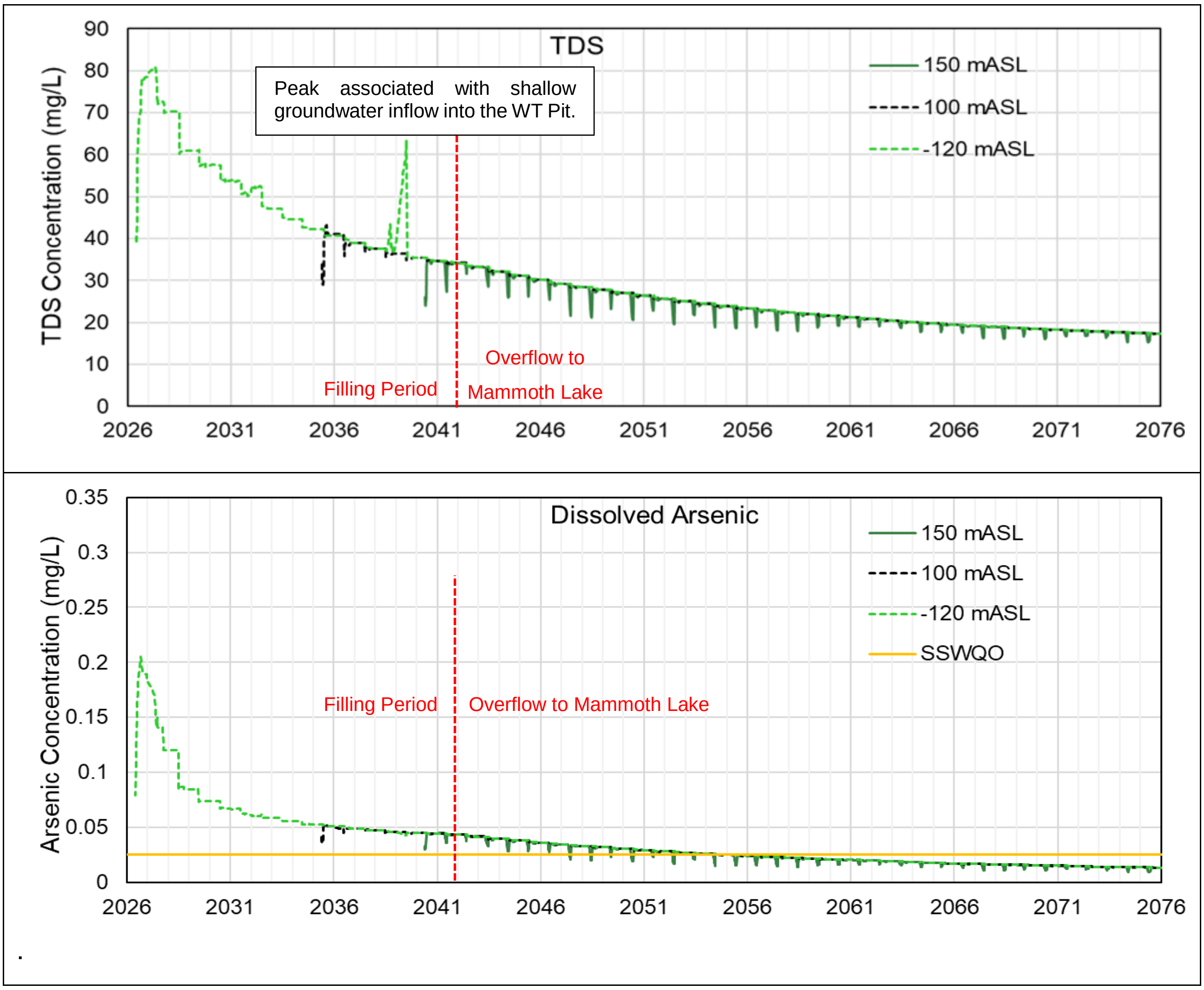

Figure 6: Time-series of TDS and arsenic concentrations at 150 masl, 100 masl and -120 masl in the Whale Tail Pit. Site-specific water quality objectives value is 0.025 mg/L

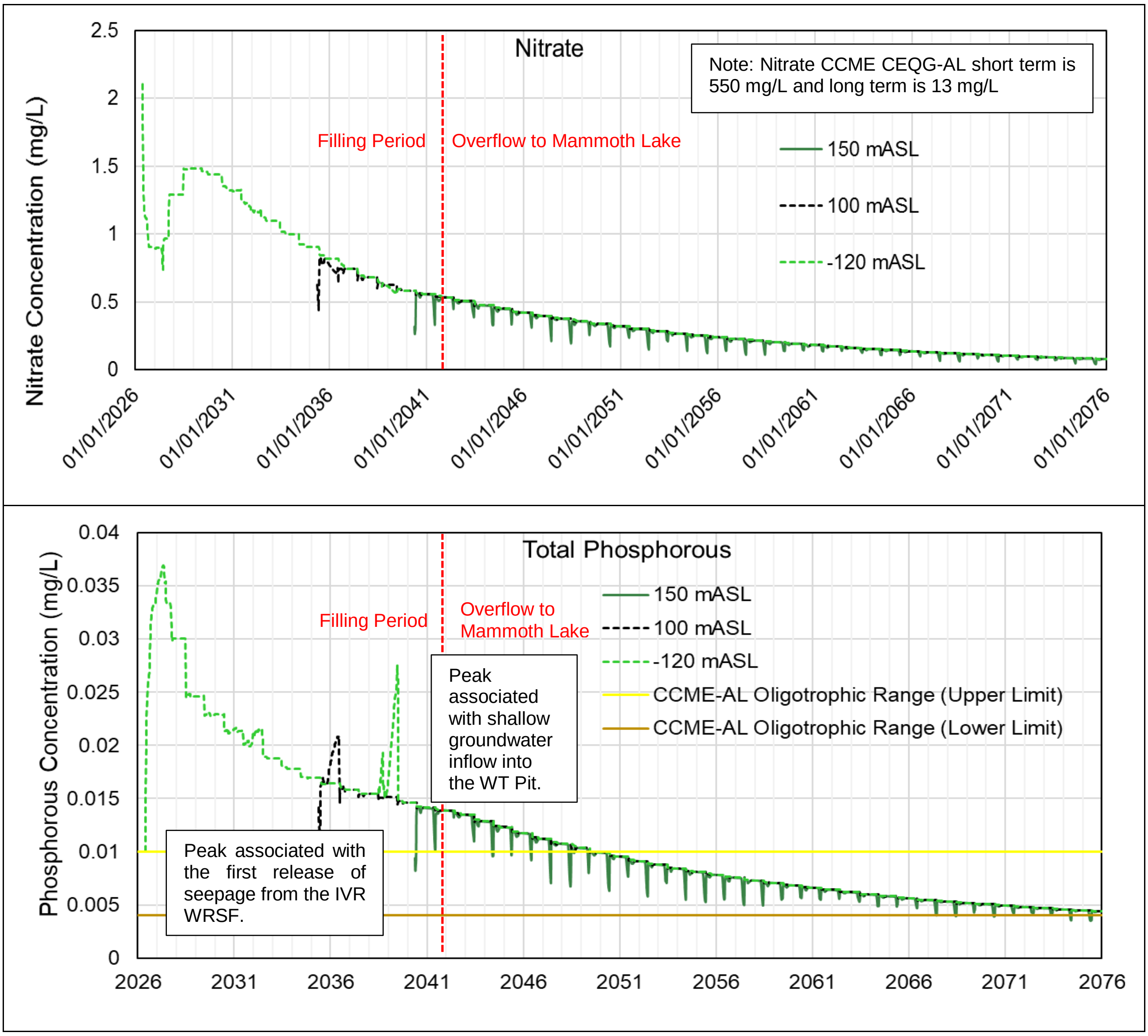

Figure 7: Time-series of nitrate and total phosphorous concentrations at 150 masl, 100 masl and -120 masl in Whale Tail Pit. The CEQG objectives for Phosphorous correspond with the lower (0.004 mg/L) and upper (0.01 mg/L) range of this constituent for oligotrophic water bodies.

4.3.2 IVR West Basin

For IVR West Basin, results are presented for 150 masl, 100 masl and 50 masl corresponding to depths of 3.5-m, 53.5-m, and 103.5-m when the Pit Lake is full. The time series of predicted concentrations are presented in Figure 8 and Figure 9. Concentrations increase rapidly at the beginning of the closure period (2026) until the IVR is full and spills into Whale Tail Pit (2027) via the spillway specified in the Eastern most portion of IVR Pit. This location will maximize circulation between the inflow point in located in the IVR West Basin, to discharge point in IVR East Basin.

Once spill into Whale Tail Pit begins, concentrations in IVR West Basin decrease annually, in a step-wise manor, owing to:

- the large addition of freshwater (pumped water from Whale Tail [South Basin]) to the northern portion of the IVR West Basin and associated mass exchange on the surficial layers of IVR Pit;
- the low concentrations of constituents assumed in spring freshet water; and
- complete annual mixing of lake water.

For all constituents, the concentrations in the IVR area of the Pit Lake are predicted to be below site water quality criteria at the start of the overflow into Mammoth Lake (2041) and for the remaining duration of the simulation period. Concentrations for all constituents are predicted to exhibit a temporary increase in 2036 when the WRSF is predicted to reach field capacity (Golder 2018a) but this is predicted to have a short-lived effect.

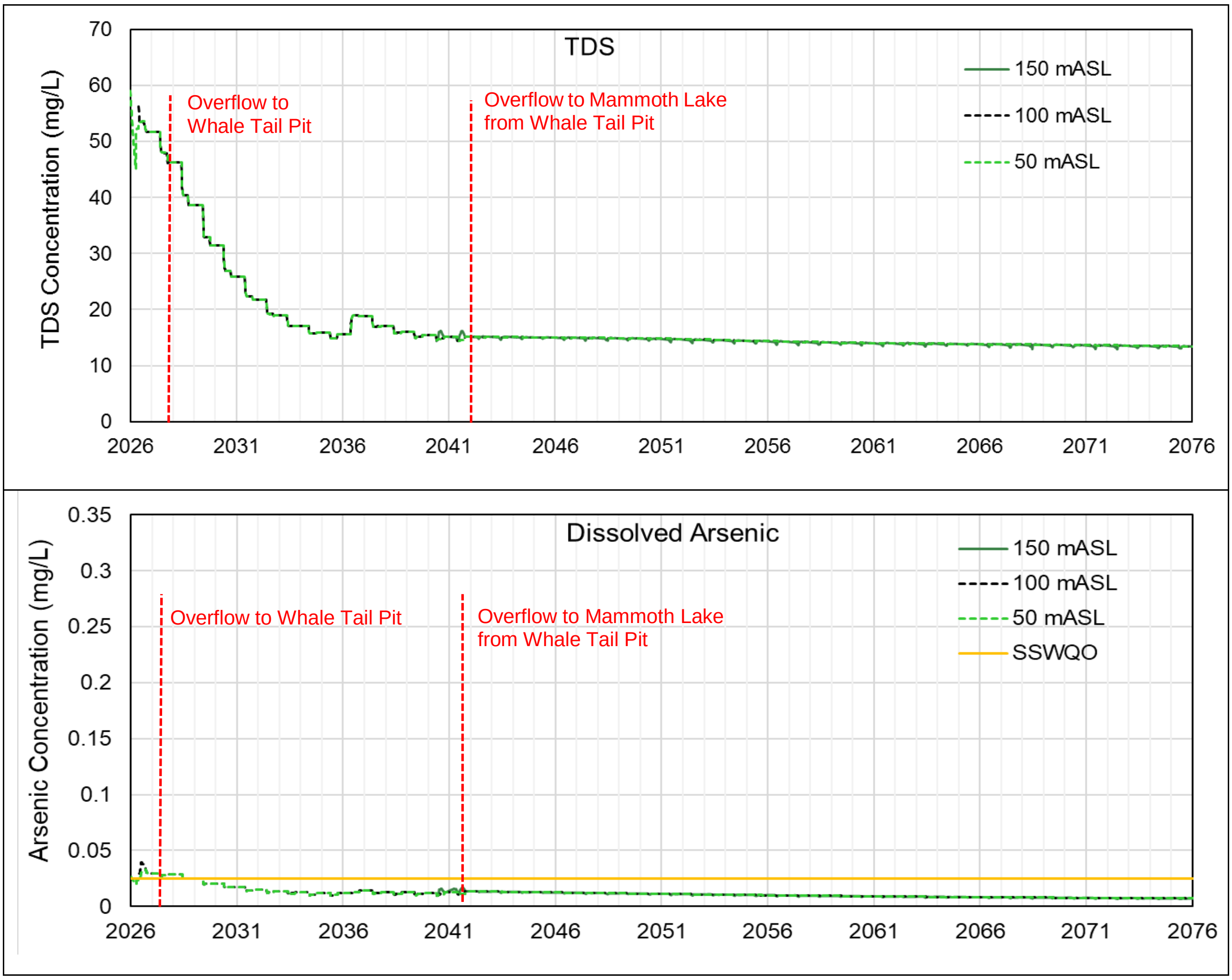

Figure 8: Time-series of TDS and dissolved arsenic concentrations at 150 masl, 100 masl and 50 masl in IVR West Basin.

Figure 9: Time-series of nitrate and total phosphorous concentrations at 150 masl, 100 masl and 50 masl in IVR West Basin.

4.3.3 IVR East Basin

Results for IVR East Basin are presented in Figure 10 and Figure 11. Conclusions derived from the observation of these figures are very similar to those presented for IVR West Basin shown in Figure 8 and Figure 9. The differences lie in the initial concentrations during the first few months of 2026 (beginning of closure), where concentrations in the IVR East Basin are higher than concentrations in the IVR West Basin. During the first months of filling, the only inflows to IVR East Basin are pit wall runoff and land runoff. As soon as IVR West Basin reaches the elevation of the ridge between the two basins (i.e., 130 masl), water spills into IVR East Basin and concentrations drop, reaching values and trends similar to those presented for the IVR West Basin. Therefore, for all constituents, the concentrations are predicted to remain below site water quality criteria at the start of the overflow into Mammoth Lake (2041) and for the remaining duration of the simulation period.

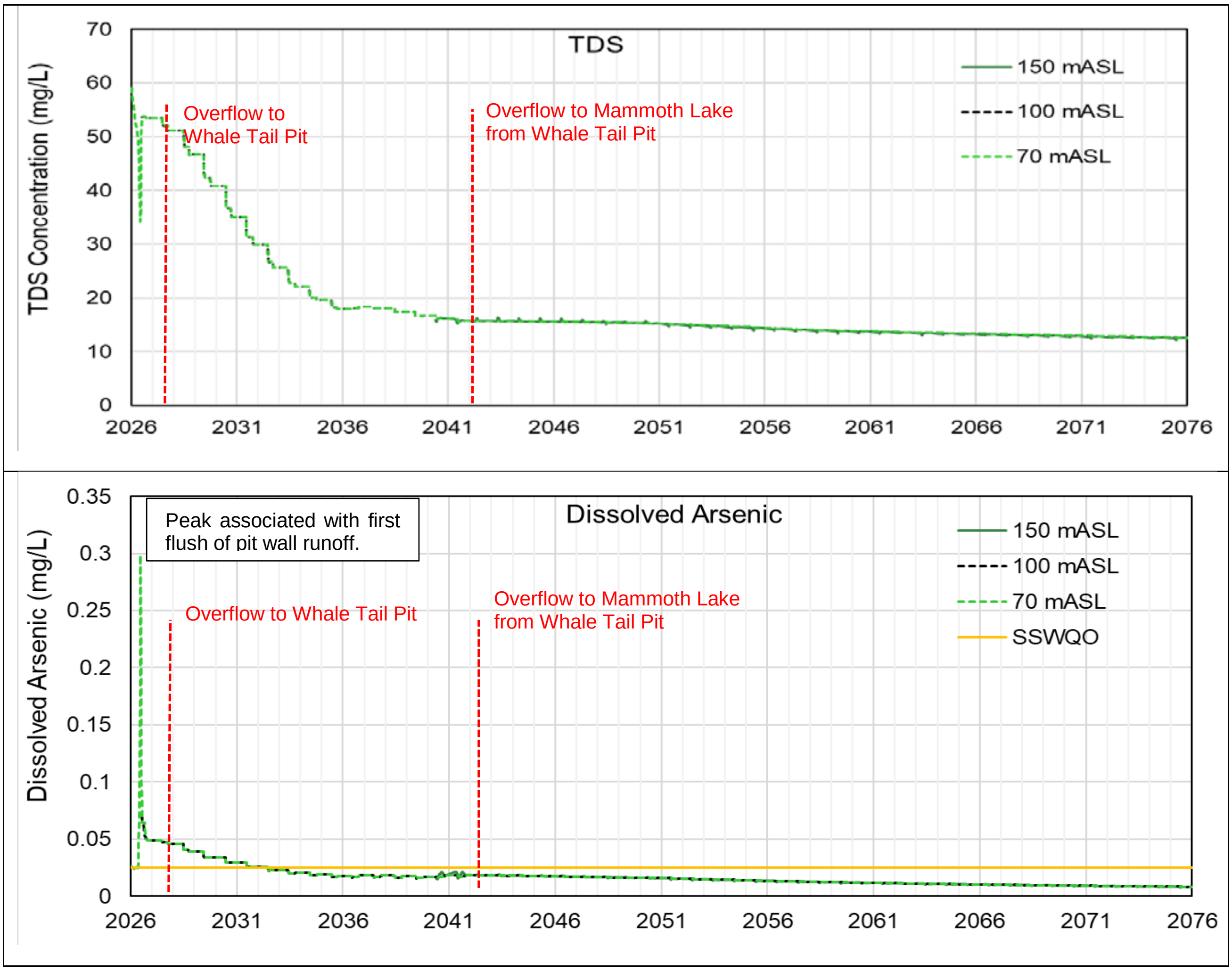

Figure 10: Time-series of TDS and dissolved arsenic concentrations at 150 masl, 100 masl and 50 masl in IVR East Basin.

Figure 11: Time-series of nitrate and total phosphorous concentrations at 150 masl, 100 masl and 50 masl in IVR East Basin.

5.0 MODEL QUALITY ASSURANCE

Field observations are required for model validation. Because the Pit Lake does not yet exist, Pit Lake model calibration and validation with site data are not possible at this time. However, the model was set up based on calibrated models formerly developed by Golder for pit lakes in Northern Regions that have undergone regulatory review. The model presented herein was modified based on Golder's considerable experience modelling existing pit lakes in the Arctic.

The follow additional aspects were investigated to demonstrate internal consistency between the Pit Lake module of the Site Wide Water Quality model in GoldSim and the CE-QUAL-W2 model, and to provide model quality assurance:

- Water Levels: The model was initialized to allow lake filling during the closure period. The predicted water levels generated by CE-QUAL-W2 for each branch were compared to predicted water levels generated by the GoldSim model. The CE-QUAL-W2 model predicted filling of the Pit Lake to the overflow elevation at 153.5 masl by early June 2041, while the GoldSim model predicted the filling to be completed at by September 2041. The slight difference between the two filling times (3 months) is within the accuracy of both models.

- Evaporation losses: Predicted evaporation losses from the system were also compared between by the GoldSim and CE-QUAL-W2 models (Figure 12). Cumulative losses are in good agreement for the total period of simulation.

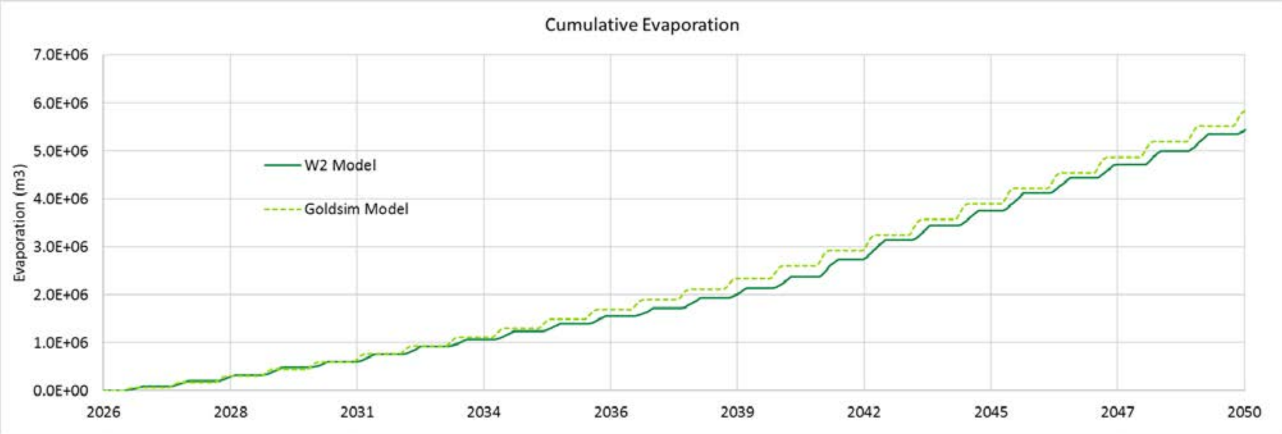

Figure 12: Cumulative evaporation predicted by CE-QUAL-W2 and the GoldSim water balance model during the closure period (2026 to 2050) for the combined Pit Lake.

- Water quality parameters: Predicted water quality concentrations from the Pit Lake were compared between by the results of the fully mixed water model GoldSim and this CE-QUAL-W2 hydrodynamic model (Figure 13 and 14). The GoldSim model predictions extend to 2051 (Figure 13 and14). Concentrations are generally in good agreement. The GoldSim model predicts that receiving water quality criteria for phosphorous will be met in 2049 and for arsenic at the end of 2050, allowing post-closure to start at that time, whereas the CE-QUAL-W2 hydrodynamic model predicts that most criteria will be met by 2049 and arsenic by 2055, 4 years later. This is considered to be a minor discrepancy for events happening over 30 years from present day. The accuracy of the predicted model results is higher at early stages of the simulation and lower in time as model variations (such as climate, inflows, outflows, water quality data) compound in time.

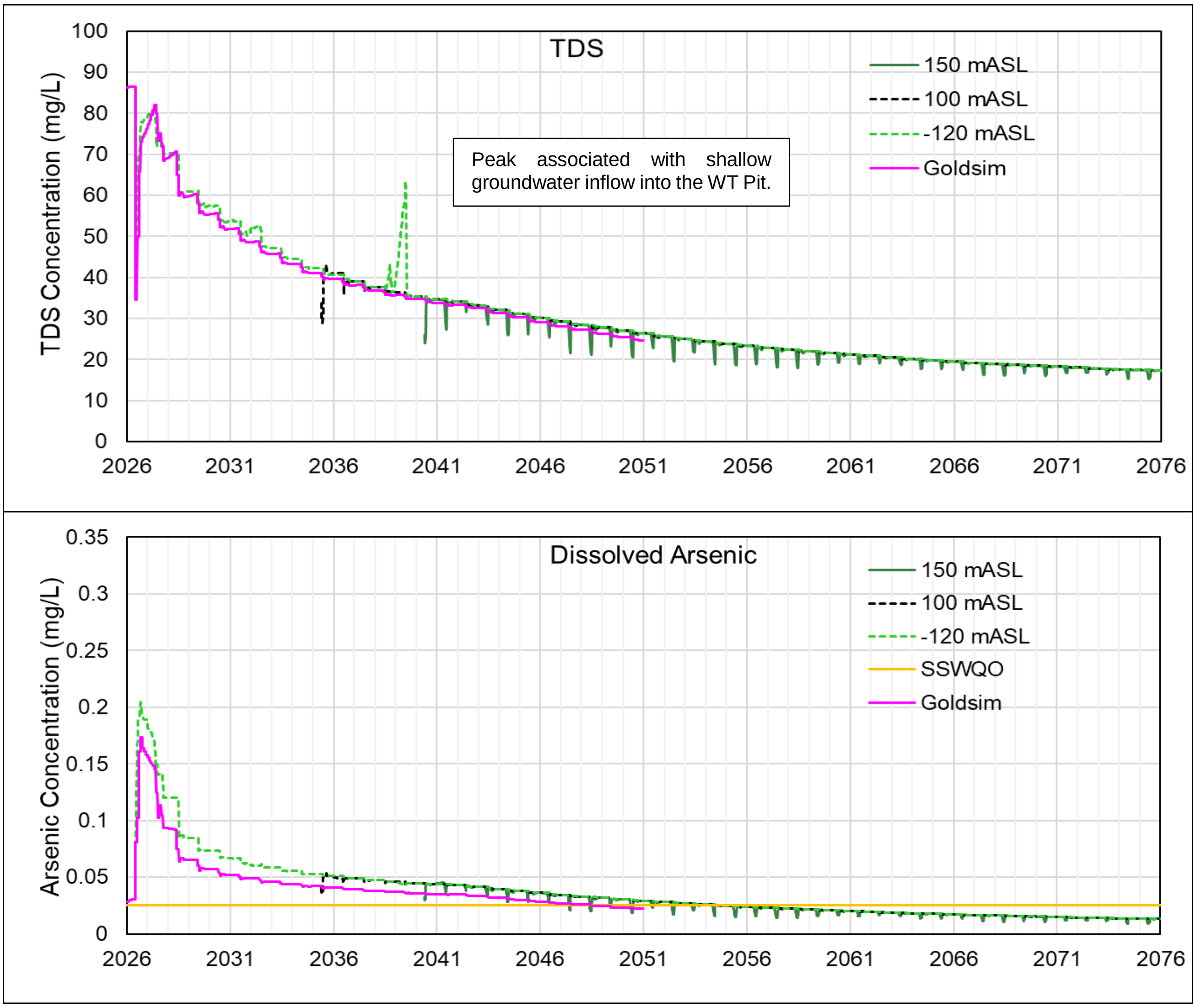

Figure 13 Comparative plot of predicted TDS and arsenic in Whale Tail Pit Lake using GoldSim model (Pit waters are assumed fully mixed) and CE-QUAL-W2 hydrodynamic model at three depths: 150 masl, 100 masl and -120 masl.

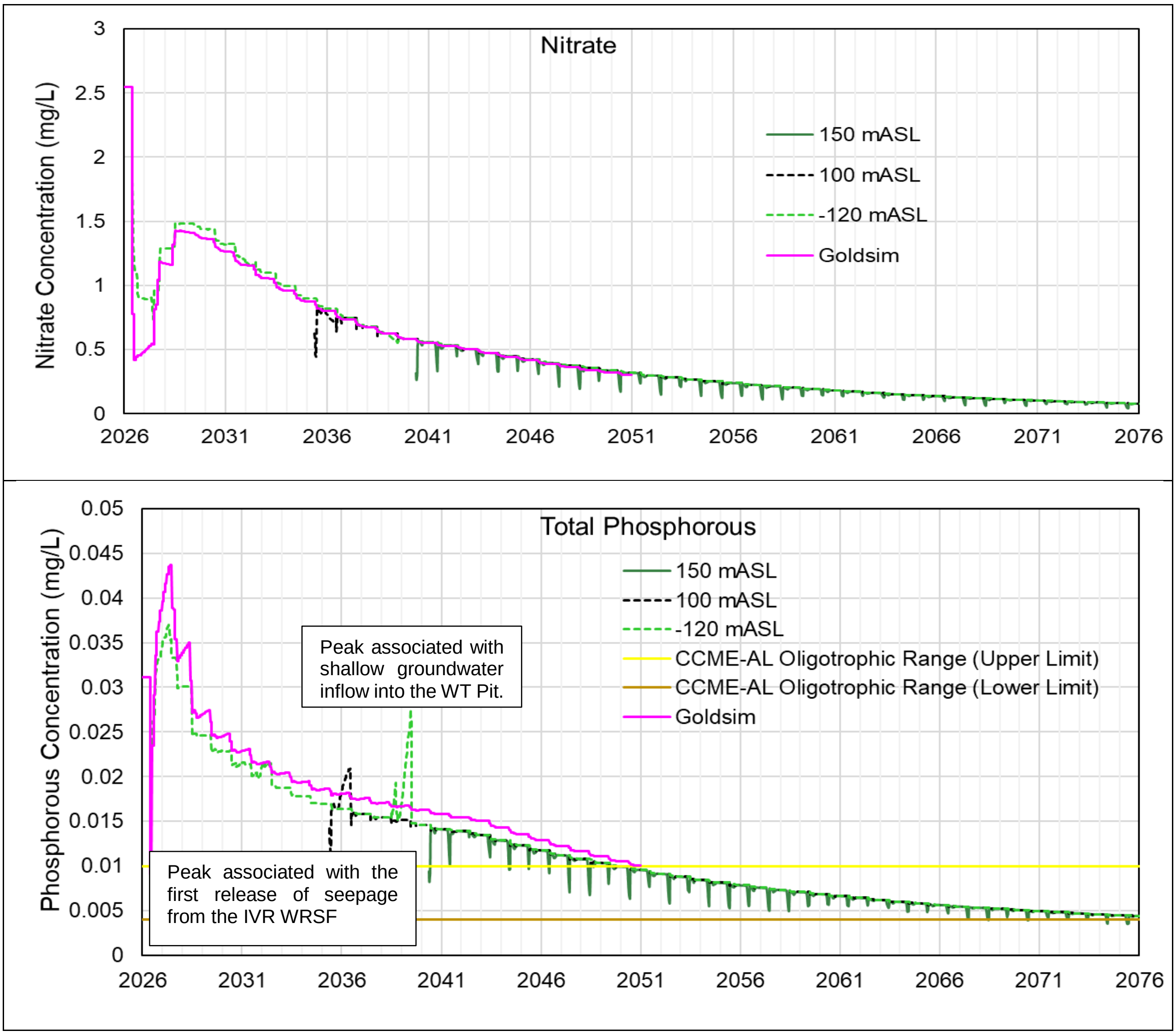

Figure 14 Comparative plot of predicted nitrate and total phosphorous in Whale Tail Pit Lake using GoldSim model (Pit waters are assumed fully mixed) and CE-QUAL-W2 hydrodynamic model at depth of 150 masl, 100 masl and -120 masl.

- Predicted Lake Temperatures: The summer temperature profiles predicted for the upper 15 m of Whale Tail Pit Lake at the outlet to Mammoth Lake were compared with temperature profiles observed in Mammoth Lake between July and September in 2016 and 2017. The measured data was plotted against statistical data generated from the 65-year prediction at the same depths and during the same months (Figure 15). In general, Mammoth lake data is 2 to 8 degrees warmer than Whale Tail Pit Lake in July and August and cooler in September, with the greatest differences occurring in July. This is expected, as the Whale Tail Lake (270 m) is much deeper than Mammoth Lake (15 m), has a much larger volume, and takes much more energy to warm (in early summer) and to release heat (in early fall); a phenomenon called thermal inertia. The closest match occurs for the predicted September data. Overall, observed temperatures in Mammoth Lake plot within the 5th and 95th percentile of predicted shallow temperatures for the Pit Lake, suggesting that the CE-QUAL-W2 model generates reasonable shallow temperatures for a lake in this region.

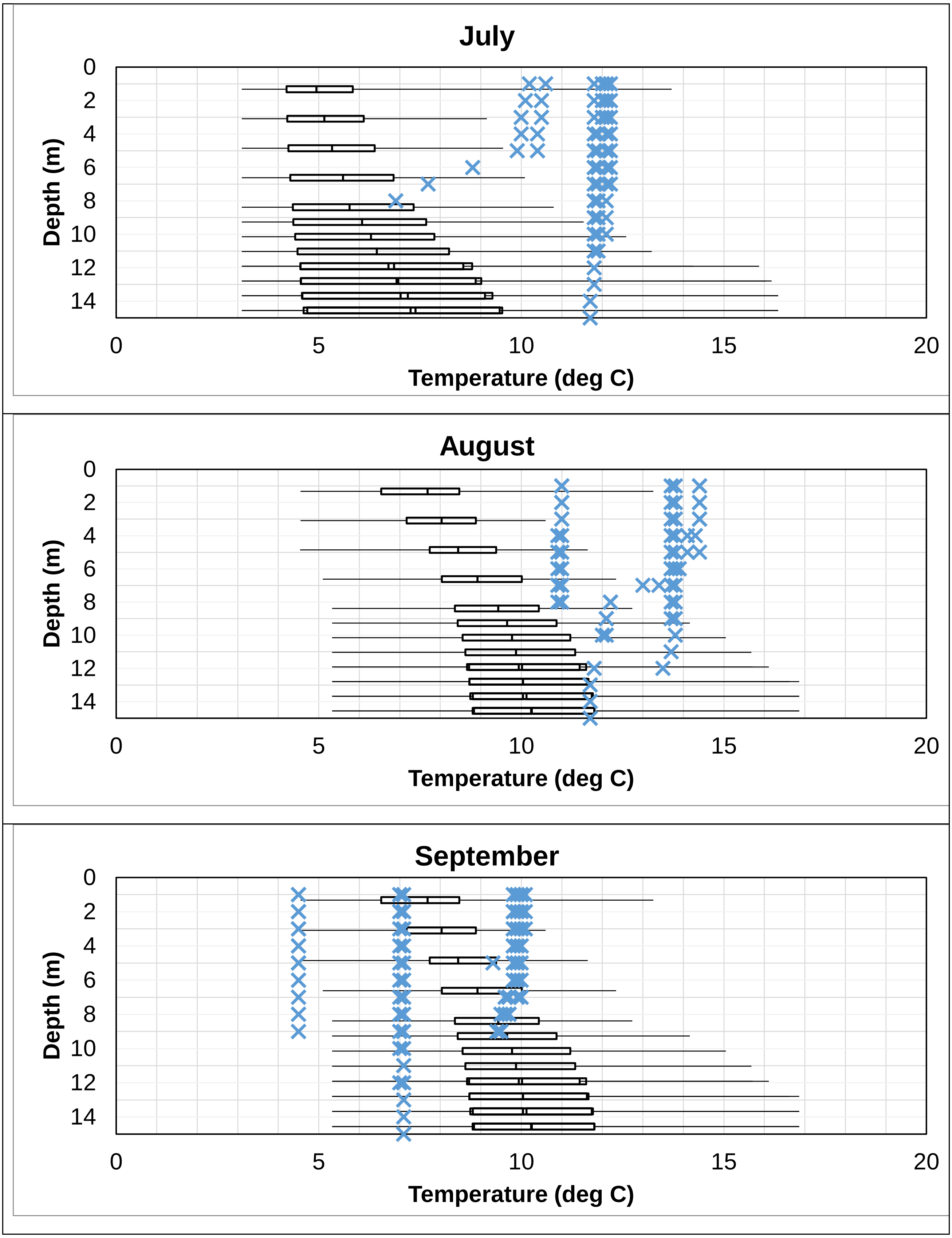

Figure 15: Comparison of the modelled temperatures predicted for the Whale Tail Pit sub-basin for the months of July, August and September (box and whisker plot showing the mean, median, 5th, 25th, 75th and 95th percentiles), against observed temperatures in Mammoth Lake in 2016 and 2017 (blue x symbols)

6.0 SUMMARY

Hydrodynamic modelling was performed to predict the following:

i) Time to flood the combined Pit Lake to an elevation of 153.5 masl, above which water discharges to Mammoth Lake;

ii) Future water circulation patterns within the Pit Lake, specifically the potential for development of stratification; and

iii) Water quality trend of the Pit Lake during the closure and post-closure periods for key constituents of interest to geochemistry (Golder 2018b), namely, total dissolved solids (TDS), arsenic (As), nitrate (NO_3), and total phosphorous (P). All parameters were modelled as conservative ions, not attenuated by biological or chemical processes (ex: biological uptake of phosphorous, precipitation of arsenic). In reality, the concentration of these parameters could be lower than predicted.

These results were used to calibrate the Pit Lake module of the Site Wide Water Quality model (in GoldSim; Golder 2018a) from which is derived the water quality predictions for the Pit Lake and downstream Lakes for additional constituents to those investigated in this study.

This technical memorandum presents the methods and results of hydrodynamic modelling of the combined (IVR and Whale Tail) Pit Lake performed in the CE-QUAL-W2 code. The CE-QUAL-W2 model allows to predict the vertical distribution of mass within each pit while the GoldSim model allows to identify the mass present in each pit. Because well-mixed conditions were predicted by CE-QUAL-W2, water quality predictions using the CE-QUAL-W2 model were compared against water quality predictions separately performed in the dynamic simulation model GoldSim (Golder 2018a). This comparison was performed for internal consistency and to validate or modify the GoldSim model to carry forward for the downstream model (Golder 2018a).

The model ran for a period of 65 years (2026 to 2090) to span the mine closure period (active flooding: 2026 to 2050) and almost five decades into post-closure (2051 to 2090) which is an adequate period to achieve stability following mine closure and identify long-term trends.

The hydrodynamic model results indicate the following:

- All water bodies fully mix, including the initial water bodies that develop in Whale Tail Pit, IVR East Basin, IVR West Basin, and the Whale Tail Attenuation Pond, as well as the combined Pit Lake. Each water body is predicted to completely mix twice per year during the spring and fall, and to exhibit weak thermal stratification during summer and winter months. As a result, any waters added by groundwater or surface water sources becomes fully mixed during turnover events and does not form an isolated bottom layer. A fully mixed pit lake is thus carried forward in the Mine Site Water Quality Model completed in GoldSim (Golder 2018a).
- The combined Pit Lake will be fully flooded to an elevation of 153.5 masl by Q3 2041, at which point, controlled inflow from Whale Tail South Basin and controlled discharge into Mammoth Lake will occur to maintain this water elevation in the Pit Lake.
- Based on fitting of the CE-QUAL-W2 hydrodynamic results to the GoldSim model results (Golder 2018a), water quality is predicted to meet receiving water quality criteria for most constituents by the time the Pit Lake is fully flooded. Arsenic and phosphorous are predicted to meet their respective water quality objectives approximately 10 years following full flooding given the predicted Pit Lake concentrations in 2041, and by the end of 2050 according to the GoldSim model, providing a range of potential outcomes.

- From 2041 to December 2050, Pit Lake water is control-discharged into Mammoth Lake. After water quality objectives are met, the water retention dikes are decommissioned and the connection with Whale Tail (South Basin) and Mammoth Lake are re-established.
- Pumped water from Whale Tail (South Basin) into the IVR West Basin, and annual spring freshet are the driving forces behind both the rate of water level rise and progressive improvements to lake water quality over time. The model predictions are sensitive to assumptions in the system. Specifically, the assumptions which have a lager effect on the model predictions are those related to water management during the filling period, assumed water qualities and water quantity of spring freshet reporting to each basin.
- Predicted water quality is sensitive to the hydraulic connectivity between individual basins within the combined Pit Lake. Specifically, the connection between IVR East Basin and Whale Tail Pit, and the initial pump flows from Whale Tail (South Basin) into IVR West Basin, are important to creating a flow through system that meets receiving water quality criteria and site-specific water quality objectives within the IVR East Basin. Short-circuiting of flow between IVR West Basin and Whale Tail Pit could limit the flushing of the IVR East Basin and lead to the accumulation of chemical mass including arsenic.

7.0 CLOSING

The reader is referred to the Study Limitations (see below), which forms an integral part of this memorandum.

We trust that the content of this technical memorandum meets your expectations. Please do not hesitate to contact the undersigned should you have any questions or comments.

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REFERENCES

Buchak E.M., and Edinger J.E. 1984. Generalized, Longitudinal-Vertical Hydrodynamics and Transport: Development, Programming and Applications. Prepared for US Army Corps of Engineers Waterways, Experiment Station. Vicksburg, MS, USA.

CCME (Canadian Council of Ministers of Environment). 2014. Canadian Environmental Quality Guidelines (CEQG) for the Protection of Aquatic Life, accessed October 2018: http://st-ts.ccme.ca/en/index.html

Cole, T.M., and Wells, S.A. 2017. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 4.1 User Manual. October 2017.

Dominion Diamond. 2014. Developer's Assessment Report Jay Project: Appendix 8G Hydrodynamic Modelling of Jay and Misery Pits. October 2014.

Golder. 2018a. Mine Site and Downstream Receiving Water Quality Predictions. Whale Tail Pit – Expansion Project. Ref No.1789310-R-Rev0. November 2018.

Golder. 2018b. Evaluation of the Geochemical Properties of Waste Rock, Ore, Tailing, Overburden and Sediment from the Whale Tail Pit, Agnico Eagle Mines, Meadowbank Division. Document No. 182. October 2018.

Golder. 2018c. Hydrogeological Assessment and Modelling, Whale Tail Pit – Expansion Project. Ref No.1789310-213-RPT-Rev0. November 2018.

Golder. 2018d. Mean Annual Water Balance, Whale Tail Pit – Expansion Project. Ref No. 1789310-204-RPT-Rev0. November 2018.NIRB (Nunavut Impact Review Board). 2018. NIRB Project Certificate No.: 008. March 15, 2018.

US Army Engineer Waterways Experiment Station. 986. CE-QUAL-W2: A Numerical Two-Dimensional, Laterally Averaged Model of Hydrodynamics and Water Quality; User's Manual. Defence Technical Information Center. Washington, DC, USA.

STUDY LIMITATIONS

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