APPENDIX 8G

HYDRODYNAMIC MODELLING OF JAY AND MISERY PITS

Table of Contents

Figures

Abbreviations

Abbreviation	Definition
2-D	two-dimensional
AEMP	Aquatic Effects Monitoring Program
Diavik Mine	Diavik Diamond Mine
e.g.,	for example
Ekati Mine	Ekati Diamond Mine
GIS	geographical information system
i.e.,	that is
NWT	Northwest Territories
Project	Jay Project
TDS	total dissolved solids
W2	CE-QUAL-W2 Model

Units of Measure

Unit	Definition
%	percent
°C	degrees Celsius
km	kilometre
m	metre
m^2/s	square metres per second
m^3	cubic metre
g/m^3	grams per cubic metre
mg/L	milligrams per litre
$W/m^2/°C$	watts per square metre per degrees Celsius
masl	metres above sea level

8G1 INTRODUCTION

Dominion Diamond Ekati Corporation is proposing the construction and operation of the Jay Project (Project). The Project is an open-pit diamond mine located at Lac du Sauvage, Northwest Territories (NWT) that will extend the life of the Ekati Diamond Mine (Ekati Mine). The Project is located approximately 200 kilometres (km) south of the Arctic Circle and 300 km northeast of Yellowknife, NWT.

This appendix summarizes the implementation and results of the hydrodynamic modelling of the Jay and Misery pits. The objective of the hydrodynamic modelling was to predict stratification potential within the pits. The model assesses the pits under post-closure conditions of the Project (i.e., when the mined-out pits are entirely water-filled). The model setup, calibration, simulations, and predictions are described in the following sections.

8G2 METHODS

Hydrodynamics (i.e., water temperature and total dissolved solids [TDS] concentrations) in the Misery and Jay pits will be influenced by several input sources. During the initial phase of back-flooding, the pit lakes will be primarily influenced by groundwater inflows and the sources used to fill the pits. After both pits are back-flooded, these waterbodies will be influenced by surface runoff, and groundwater seepages, and losses to or from the pits.

Stratification potential in the Jay and Misery pits was analyzed using two methods:

- hydrodynamic modelling of the first 200 years after back-flooding, using CE-QUAL-W2 Model (W2) (Cole and Wells 2008); and,
- mass balance calculations over 15,000 years using a vertical mass-balance slice spreadsheet model.

8G2.1 Model Description

8G2.1.1 CE-QUAL-W2 Model

Hydrodynamic modelling was completed using W2, which is a two-dimensional (2-D), laterally averaged, hydrodynamic, and water quality model. The model is accessible within the public domain and is maintained and supported by the United States Army Corp. of Engineers Waterways Experiment Station.

The model simulates interactions of physical and chemical processes, including flow, thermal and substance mass loading regimes, meteorological forcing conditions (e.g., air temperature, wind, solar radiation, precipitation, evaporation), and lake-bottom interactions. The W2 model also includes a module to simulate ice-cover in the winter. The formation of a complete ice-cover prevents re-aeration, provides complete wind sheltering, and results in reduced thermal inputs via solar radiation. The model has established a well-recognized reputation as an effective and practical modelling tool for lake and reservoir hydrodynamics and water quality, and has been used extensively to simulate the potential performance of natural and constructed lakes, including mine pit lakes (Cole and Wells 2008; Castendyk and Eary 2009).

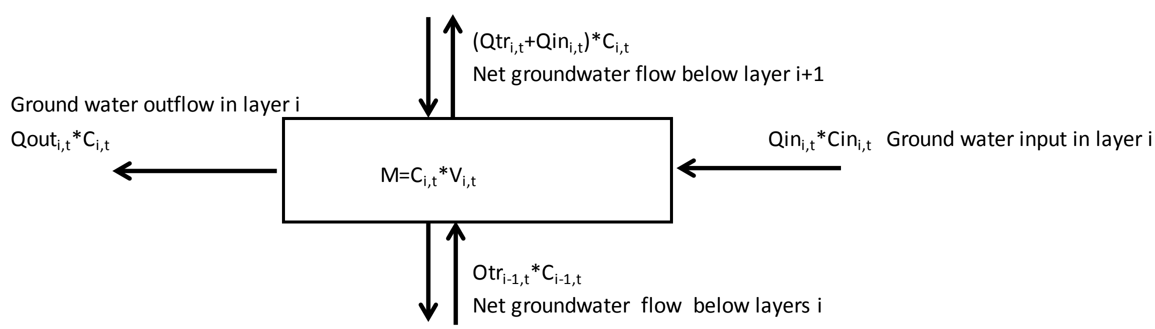
Hydrodynamic modelling is computer intensive, and consequently W2 was used to assess stratification potential at the Jay and Misery pits only for the first 200 years after back-flooding. Constituents modelled TDS and temperature; these required calibration, which is discussed in Section 8G2.3.

8G2.1.2 Vertical Slice Spreadsheet Model

To estimate stratification potential of the Jay and Misery pits beyond the first 200 years after back-flooding (up to 15,000 years), TDS profiles were calculated using a vertical slice spreadsheet model. The spreadsheet model provided efficient (i.e., quick) computation and was deemed adequate to represent long-term stratification potential at the pits. The vertical slice spreadsheet model incorporated exactly the same inflows and outflows used in W2 to simulate TDS profiles over 15,000 years.

The pits were divided in the slice model into layers that are each 25 metres (m) thick. Inflow volumes and concentrations were directed to the boundary of the affected layers. The initial conditions of the slice model and W2 were the same. A mass balance calculation was then performed within each layer at an annual time step. At each time step, excess water (i.e., the difference in volume between inflow and outflow at each layer) was directed upwards to the next segment. Total dissolved solids mass was transferred into each layer with the inflow and transferred out of the layer with the outflows. The schematic of the model calculation is presented in Figure 8G2.1-1. As a mass balance formulation, this model does not require calibration (i.e., no parameters for which values must be established).

Figure 8G2.1-1 Schematic Diagram of a Layer in the Vertical Slice Spreadsheet Model



Where:

i	=	Layer index
t	=	Time step index
Ci,t	=	Concentration in layer i at time step t (g/m^3)
Vi,t	=	Volume of layer i at time step t (m^3); the volume is constant over the entire simulation
Qini,t	=	Inflow to layer i at time step t (m^3)
Qouti,t	=	Outflow from layer i at time step t (m^3)
Cini,t	=	Concentration of inflow to layer i at time step t (g/m^3)
Qtri,t	=	Transfer (upward or downward) from layer i at time step t (m^3)

8G2.2 Model Inputs

To apply W2 to the pits, the model was first calibrated to measured data in Lac du Sauvage (Section 8G2.3). Model inputs were developed to apply W2 to Lac du Sauvage and the pits and the slice model to the pits. Model inputs therefore included:

- meteorological data (i.e., air temperature, precipitation, dew point, wind speed and direction, and solar radiation);
- geometric data (i.e., lake bathymetry and volume-area-elevation table of the lake and the pits);
- hydrologic data (input rates for each inflow source to Lac du Sauvage and the pits);
- hydrogeological data (input rates for groundwater inflows to and outflows from the pits);
- water quality characteristics (temperature and TDS concentrations) for each inflow source; and,
- boundary and initial conditions.

8G2.2.1 Lac du Sauvage (Model Calibration)

An hourly time series was constructed for each of meteorological inputs during the calibration time period, 2009 to 2013, based on measured data from an onsite meteorological station at the Diavik Diamond Mine (Diavik Mine). Where gaps existed in the site-specific data, data from an onsite meteorological station at the Ekati Mine were used.

A contour map of the lake was used to define bathymetry inputs for the W2 model and define model segmentation. Using Arc Geographic Information System (ArcGIS), the volume-area-elevation table was calculated for the lake based on the bathymetry.

Inflow rates to the lake were consistent with the Regional Water Balance Model (Appendix 8D). The main hydrologic inputs to Lac du Sauvage were tributary and non-point source inflows from the Lac du Sauvage basin, and direct precipitation on the lake. The main outflows from the lake were discharge from the outlet channel between Lac du Sauvage and Lac de Gras and evaporation.

Temperature and TDS data for baseline tributary inflows and non-point source inflows were represented by median data collected from Lac du Sauvage between 2004 to 2013 for the open-water season (Water and Sediment Quality Baseline Report; Annex XI).

8G2.2.2 Jay and Misery Pits (Model Simulations)

For future simulations, the hourly time series of meteorological inputs used to calibrate the model were repeated for 200 years into post-closure.

Contour maps of the pits were used to define bathymetry inputs for the W2 model and define model segmentation. Using ArcGIS, the volume-area-elevation table was calculated for each pit based on the bathymetry.

Inflow rates to the pits were consistent with the Regional Water Balance Model during the post-closure period (Appendix 8D). The main hydrologic inputs to the pits were natural runoff, waste rock runoff (for the Jay Pit only), and groundwater seepages. Groundwater inflows and losses to or from the pits were determined by the hydrogeological model (Appendix 8A) and were provided as inputs to the hydrodynamic model at several vertical points according to elevation, time-varying volumes, and TDS concentrations throughout the modelled time frame. In both pits, the net groundwater flux is negative, because losses to groundwater from the pits are more than groundwater inflows to the pits (Appendix 8A).

The inflows to the vertical mass-balance slice spreadsheet model were consistent with the W2 model. This model was run for 15,000 years after back-flooding; thus, groundwater inflow volumes and concentrations and outflow volumes were based on hydrogeological modelling for the first 1,000 years and were assumed to continue at constant volumes and concentrations thereafter. For other inflows (e.g., runoff), the last year of data (year 200) provided by the Regional Water Balance Model (Appendix 8D) was repeated from the year 200 to year 15,000.

8G2.3 W2 Calibration

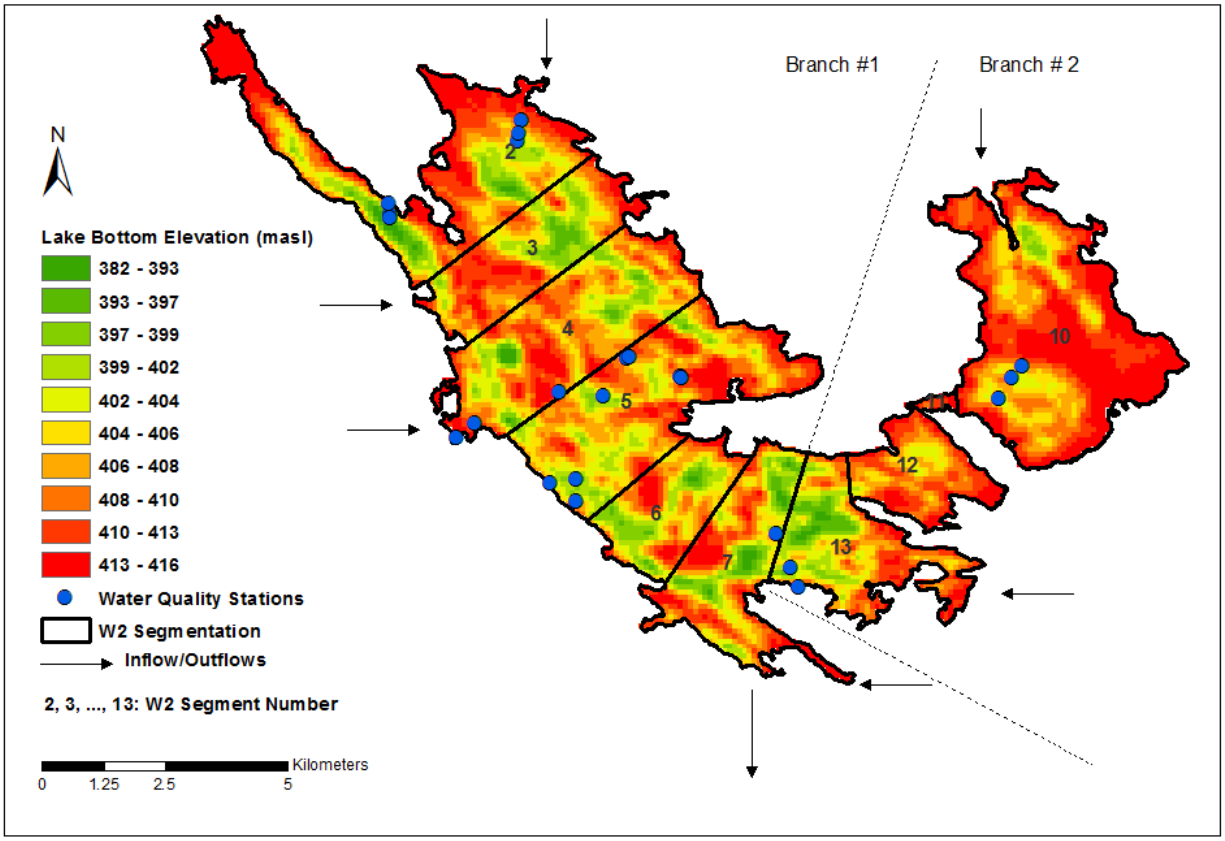
8G2.3.1 Model Setup

W2 includes several hydrodynamic parameters that may be used to calibrate the model to observed conditions. The Jay and Misery pits have not been constructed. Consequently, the W2 model cannot be calibrated to these waterbodies. However, to obtain estimates of hydrodynamic parameters, a W2 model was implemented and calibrated to observed temperature conditions at Lac du Sauvage. The spatial extent of the hydrodynamic model under the calibration scenario was Lac du Sauvage under pre-Project conditions.

For the calibration time period, a 2-D grid (Figures 8G2.3-1 and 8G2.3-2) was developed to represent the geometry of Lac du Sauvage in W2. Using the bathymetry data, the lake was represented in W2 as one waterbody, two branches, and 10 segments with individually defined lengths and orientations to approximate the Lac du Sauvage shape and water surface area (Figures 8G2.3-1 and 8G2.3-2). Each segment was composed of multiple layers that are defined with independent widths (based on the volume-area-elevation table), to define changes in the lake cross-sectional area with depth. The vertical layer depths were set to 1 m. The depth-storage characteristics of the model grid aligned with volume-area-elevation table. The final W2 model grid volume was within 1 percent (%) of the lake volume (Figure 8G2.3-3).

Initial TDS and temperature in the lake were set at measured data obtained from the Ekati Mine Aquatic Effects Monitoring Programs (AEMPs) in 2010, 2011, and 2012 (Rescan 2011, 2012; ERM Rescan 2013) and listed in the Water and Sediment Quality Baseline Report (Annex XI). Water quality monitoring stations used for data sourcing for calibration of the Lac du Sauvage model are shown in Figure 8G2.3-1.

Figure 8G2.3-1 Lac du Sauvage Segmentation (Plan View)



masl = metres above sea level

The W2 calibration was carried out to match the time series and vertical profiles of simulated and observed temperature for the Lac du Sauvage under pre-Project conditions. Hydrodynamic parameters were also adjusted to produce a reasonable match of ice-cover periods and annual evaporation rates in the range of observations presented in Hydrology Baseline Report (Annex X, Appendix B, Table B-5).

W2 was calibrated to measured data from 2009 to 2013. The calibrated hydrodynamic parameters were then applied to the post-closure case for the Jay and Misery pits.

Default model parameters were used for the thermal variables, with the following exception:

- To improve thermal profiles during the ice-covered seasons, sediment heat exchange coefficient was adjusted to 1 watt per square metre per degrees Celsius (W/m^2/°C).
- Based on the calibration, the sediment temperature was set at a constant value of 2 degrees Celsius (°C).
- The maximum vertical eddy viscosity was set to 0.001 square metres per second (m^2/s).
- Albedo of ice was adjusted to 0.9 and water-ice heat exchange coefficient was adjusted to 15 W/m^2/°C.

Figure 8G2.3-2 W2 Segmentation for Lac du Sauvage (Plan View and Profiles)

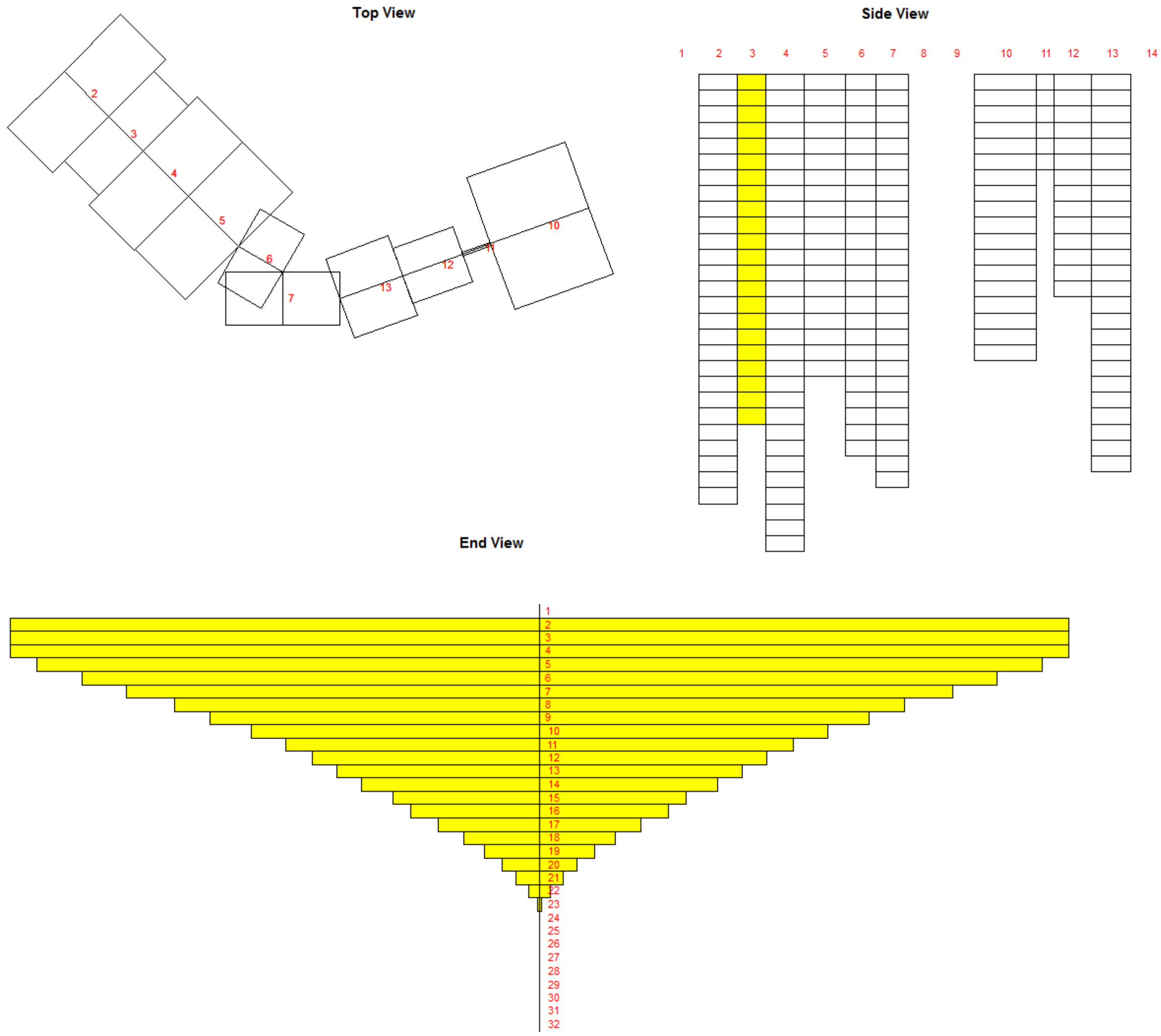
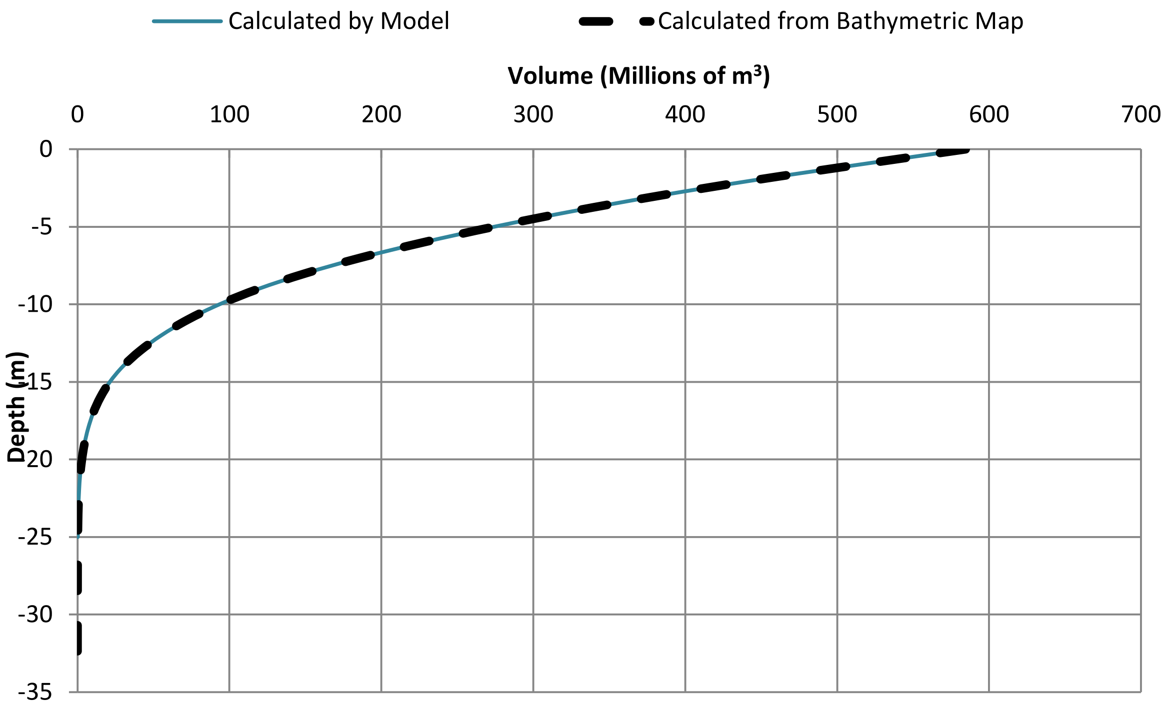


Figure 8G2.3-3 Hypsographic Curves for Lac du Sauvage Excluding Duchess Lake



m = metre; m^3 = cubic metre.

8G2.3.2 Results

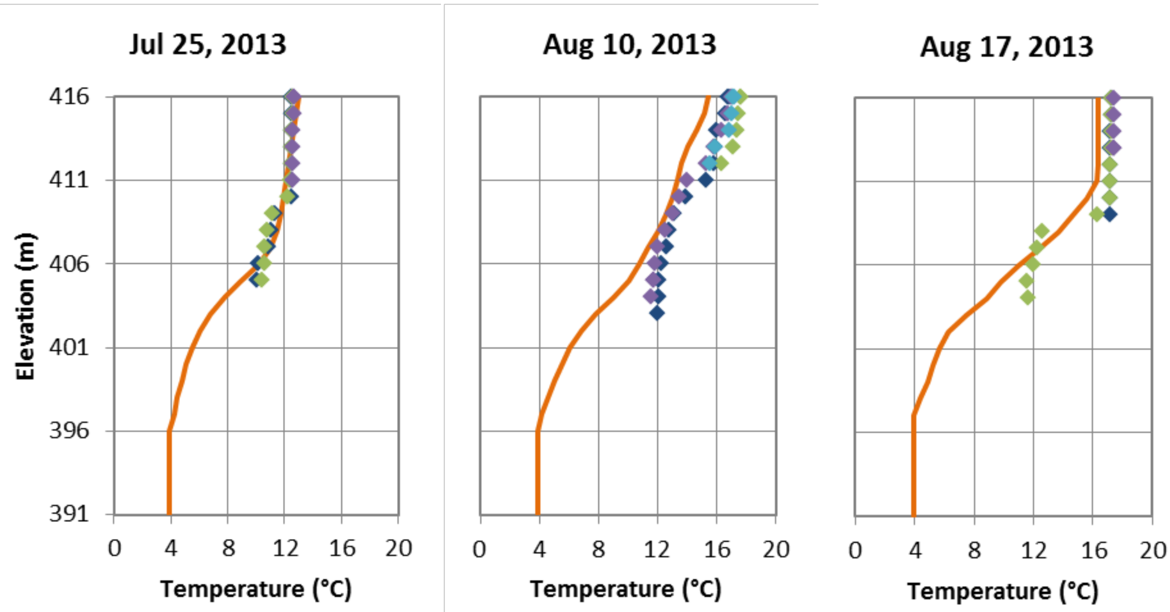
The first step in the calibration process was to achieve a water balance within the model. This was achieved by using input tributary flows consistent with those presented in the Regional Water Balance Model (Appendix 8D).

The model parameters in the ice module were adjusted to match simulated and observed timing for ice formation/melting on the lake. The calibrated model predicts that ice starts forming on the lake around mid-October and melts by mid- to late June. These results match the observations noted in the 2011 Ekati Mine AEMP (Rescan 2012).

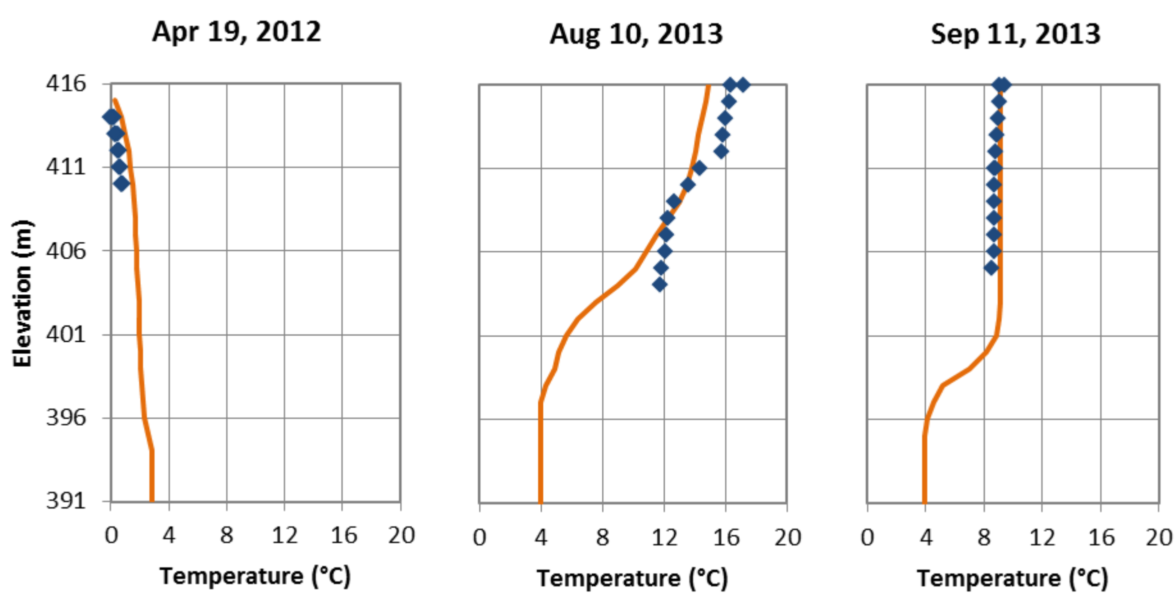
Examples of calibrated water temperature vertical profiles, and time series are presented in Figures 8G2.3-4 and 8G2.3-5, respectively, for each segment where measured data were available. The calibration results show that the model matched well the trend of measured temperature time series and profiles at different locations in the lake during the summer months (when measured data were available).

Figure 8G2.3-4 Lac du Sauvage Vertical Temperature Profile Calibration Plots

Segment #2



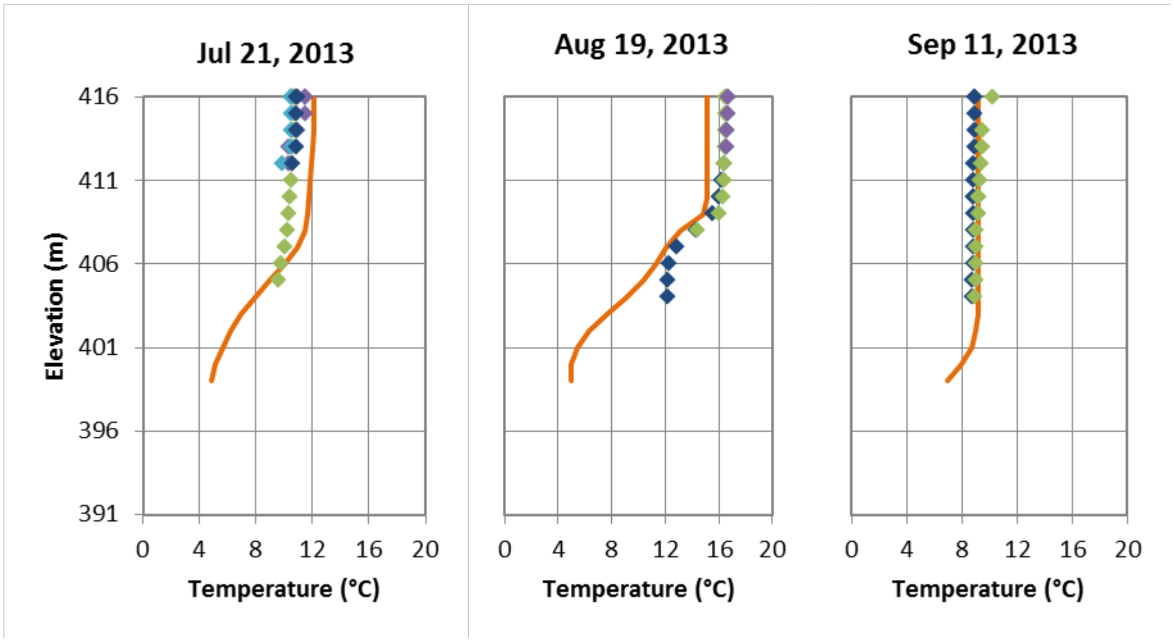
Segment # 4



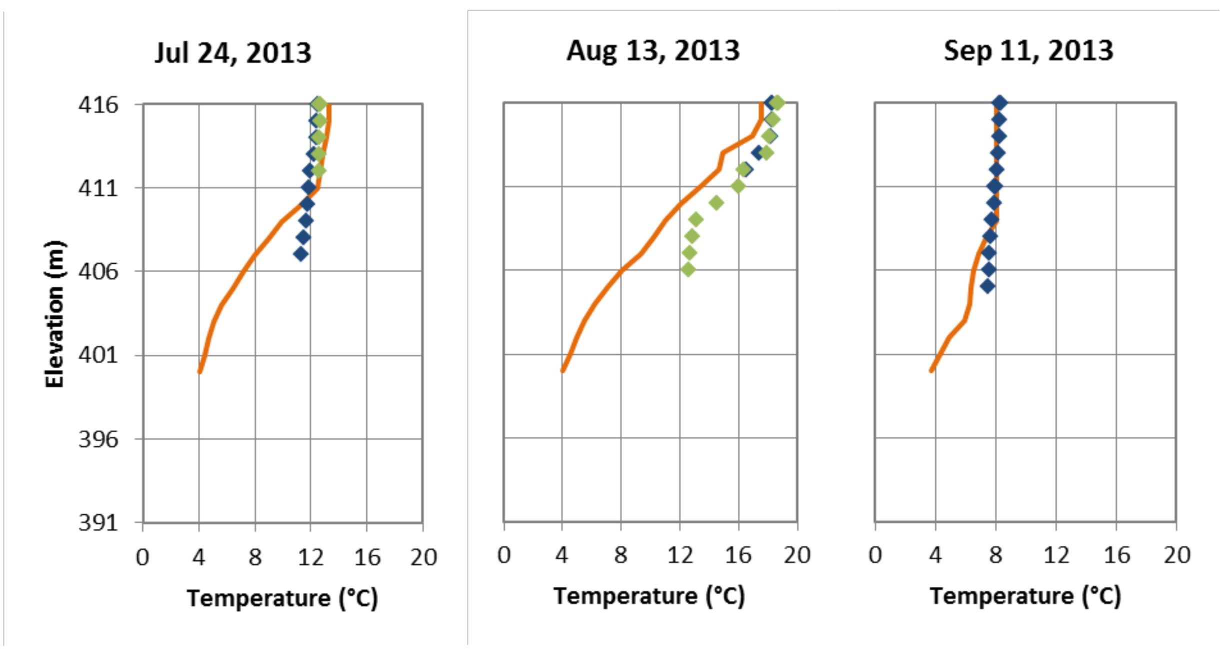
Solid line represents model results; dots represent measured temperature at different monitoring locations; m = metres, °C = degrees Celsius.

Figure 8G2.3-4 Lac du Sauvage Vertical Temperature Profile Calibration Plots (continued)

Segment #5

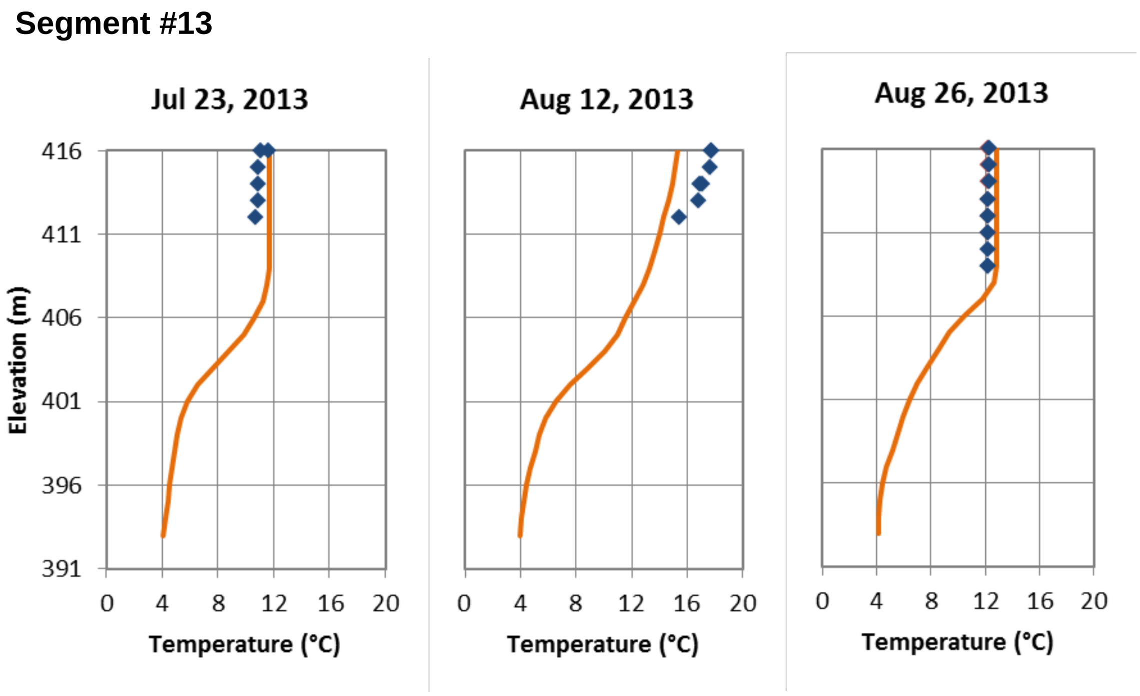


Segment # 10



Solid line represents model results; dots represent measured temperature at different monitoring locations; m = metres, °C = degrees Celsius.

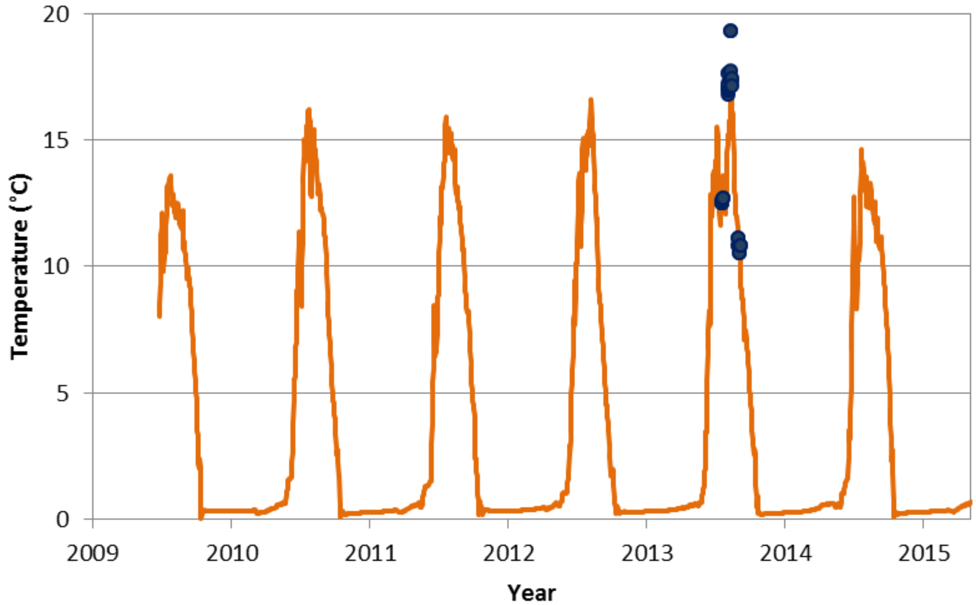
Figure 8G2.3-4 Lac du Sauvage Vertical Temperature Profile Calibration Plots (continued)



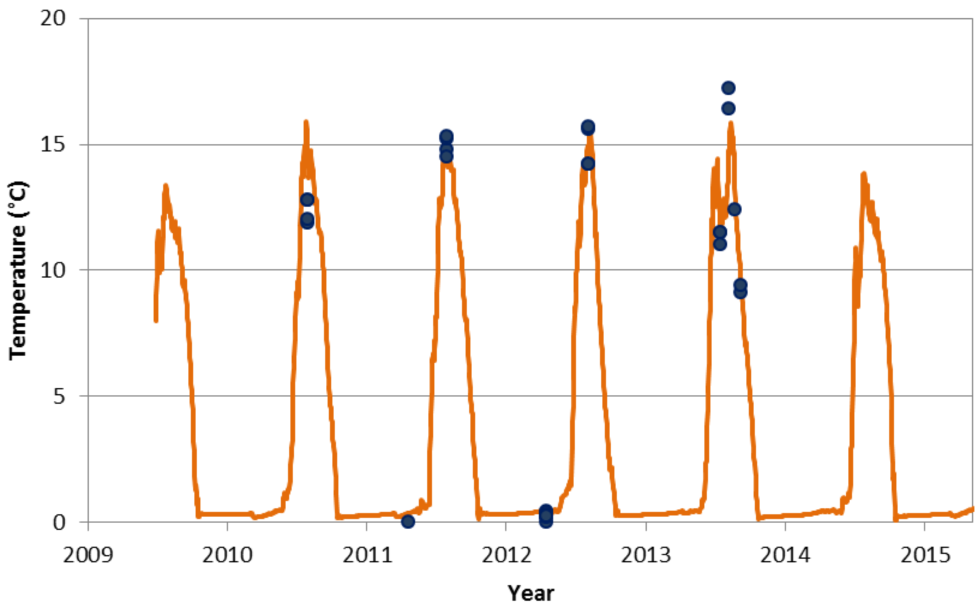
Solid line represents model results; dots represent measured temperature at different monitoring locations; m = metres, °C = degrees Celsius.

Figure 8G2.3-5 Lac du Sauvage Surface Water Temperature Time Series Calibration Plots

Segment #2



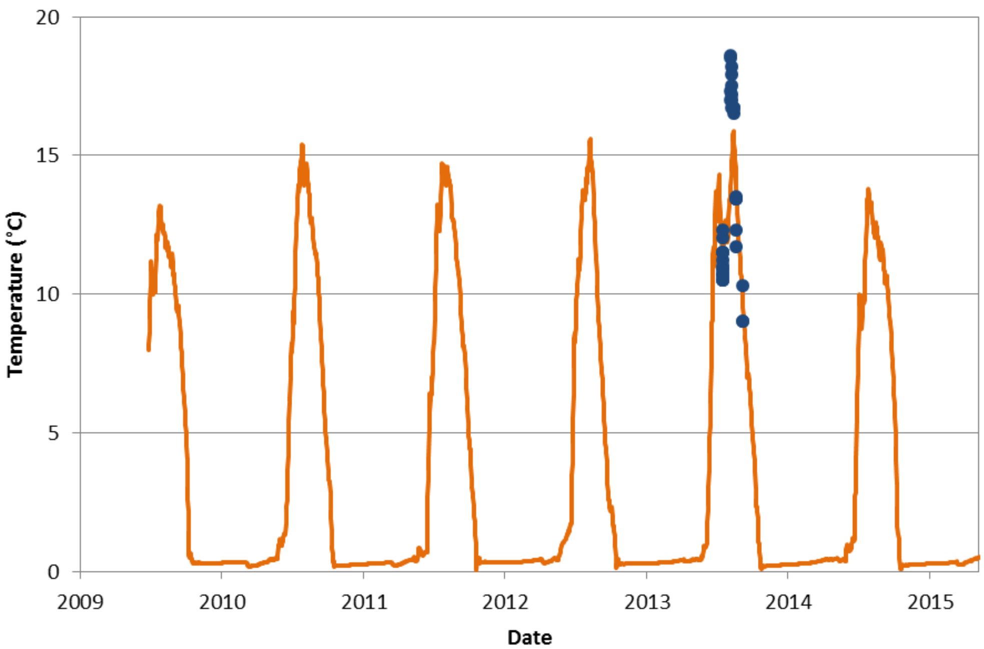
Segment #4



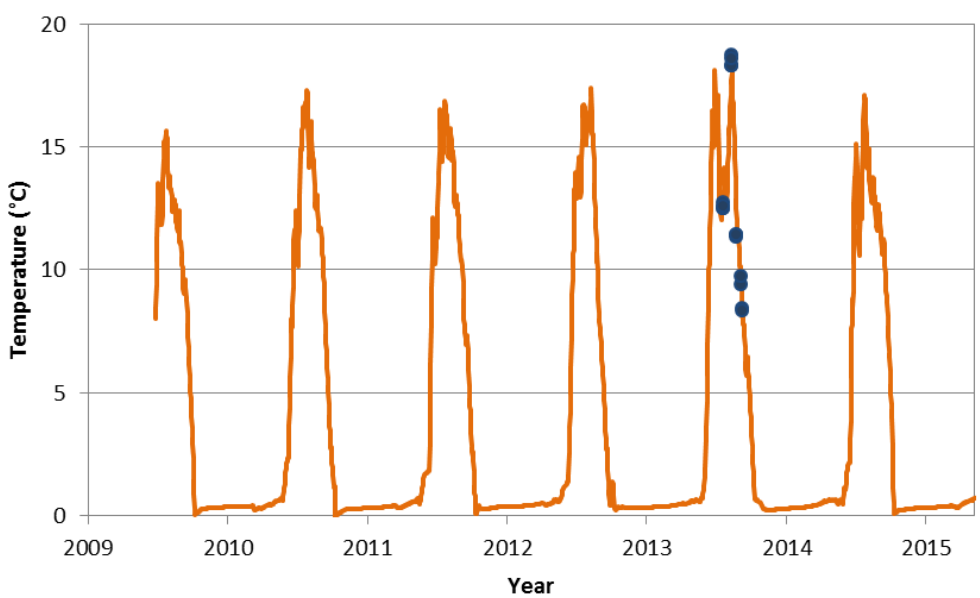
Solid line represents model results; dots represent measured temperature at different monitoring locations; °C = degrees Celsius.

Figure 8G2.3-5 Lac du Sauvage Surface Water Temperature Time Series Calibration Plots (continued)

Segment #5

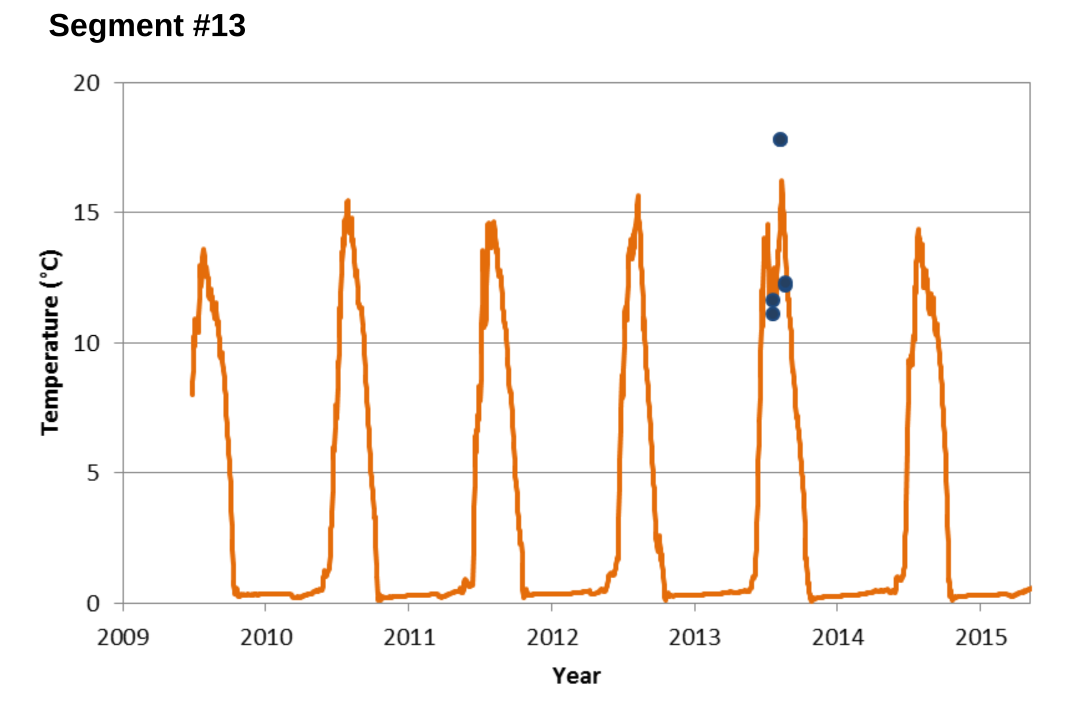


Segment #10



Solid line represents model results; dots represent measured temperature at different monitoring locations; °C = degrees Celsius.

Figure 8G2.3-5 Lac du Sauvage Surface Water Temperature Time Series Calibration Plots (continued)



Solid line represents model results; dots represent measured temperature at different monitoring locations; °C = degrees Celsius.

The calibrated hydrodynamic parameters were applied to the closure case for Jay and Misery pits, since they are located in the same region. The same influence from the climate, particularly wind, is expected on the lake and pits.

8G2.4 Model Simulations

W2 and the vertical mass-balance slice spreadsheet model were applied to the Misery and Jay pits in the post-closure period. Total dissolved solids (TDS) concentrations were predicted with these two models, as this water quality constituent is deemed to be the main variable (instead of water temperature) impacting stratification potential in both pits. The modelling results (200 years with W2, and 15,000 years with the slice model) are presented in the subsections below.

Initiation of the Project closure phase corresponds to the cessation of mining of the Jay Pit on January 1, 2030. From that date, water will be pumped from the Misery Pit to the Jay Pit, decreasing the water surface elevation at the Misery Pit. Subsequently, water from Lac du Sauvage will be pumped to the Misery Pit to provide a 60 m freshwater cap to that pit. The closure period for the Misery Pit will last approximately one year and nine months.

Following the transfer of water from the Misery Pit to the Jay Pit, water from Lac du Sauvage will be pumped to the Jay Pit to a water surface elevation of 416 metres above sea level (masl). This pumping will include back-flooding the diked area of the Jay Pit. The closure period for the Jay Pit will last approximately three years and ten months.

Initial TDS concentrations in the Misery and Jay pits were set at concentrations consistent with the beginning of post-closure as determined by the Site Discharge Water Quality Model (Appendix 8E, Section 8E2.2), accounting for water transfers throughout the back-flooding period. Consequently, the Misery Pit will contain a lower layer (i.e., the monimolimnion) with higher TDS and density, overlain by a 60 m upper layer (i.e., the mixolimnion) of low TDS, less dense freshwater. Post-closure back-flooded conditions at the Jay Pit will be similar to those at the Misery Pit, but with 160 m of freshwater cap.

It is recognized that these upper and lower layers will not form a sharp boundary between density differences (i.e., the stratification of TDS within the water column or pycnocline), and that some mixing at the interface may occur due to turbulence caused by surface flows and other factors. This was reflected in the hydrodynamic simulations, which indicated that transport and mixing in the first simulation years would be rapid across the boundary between the upper and lower layers. A relatively thin transition zone between these two layers was predicted to form in the first year, and would thereafter slowly expand in thickness and approach a relative stable stratification. Therefore, the assumption of a sharp boundary of initial concentration was considered reasonable, since all mass transferred by the initial mixing was accounted for within the first year.

As a support to the Site Discharge Water Quality Model (Appendix 8E), the transfer of TDS from the monimolimnion to the mixolimnion in each pit was predicted by simulating a tracer in W2. The initial tracer concentration was set to 1 milligram per litre (mg/L) in the monimolimnion of both pits and 0 mg/L in the mixolimnion. Based on the simulated vertical profiles of tracer concentrations and the elevation of the pycnocline at each time step, equivalent replacement volumes in the monimolimnion were calculated based on the tracer concentration and water volume of each layer. The calculated replacement volume was then transferred to the Site Discharge Water Quality Model, and the volume used as a time series of water movement from the bottom of both pits into the upper layer of the pits. An associated mass of constituents from both pits was also transferred upwards in the Site Discharge Water Quality Model.

8G2.4.1 W2 Setup

The W2 model was setup for both the Misery and Jay pits after closure and simulations were completed for 200 years in the post-closure period (starting from year 2032 for the Misery Pit and 2034 for the Jay Pit). In the beginning of the post-closure period both pits have high TDS water in the lower layer and low TDS freshwater in the upper layer (Site Discharge Water Quality Model, Appendix 8E, Section 8E3).

Two-dimensional grids were developed in W2 to represent the geometry of the Misery Pit (Figure 8G2.4-1) and the Jay Pit (Figure 8G2.4-2). The method for developing the grid was similar to that used for Lac du Sauvage (Section 8G2.3.1). Using bathymetry data, the Misery Pit was represented in W2 as one waterbody, one branch and three segments, while the Jay Pit was defined as one waterbody, one branch and five segments. The vertical layer depths were set to 1 m in the top half portion of the Misery Pit and 5 m in the bottom half of that pit, and 1 m layers were used through the entire water column of the Jay Pit. The depth-storage characteristics of the modelling grids aligned with the proposed volume-area-elevation curves for the pits (Figures 8G2.4-3 and 8G2.4-4).

Figure 8G2.4-1 W2 Misery Pit Segmentation

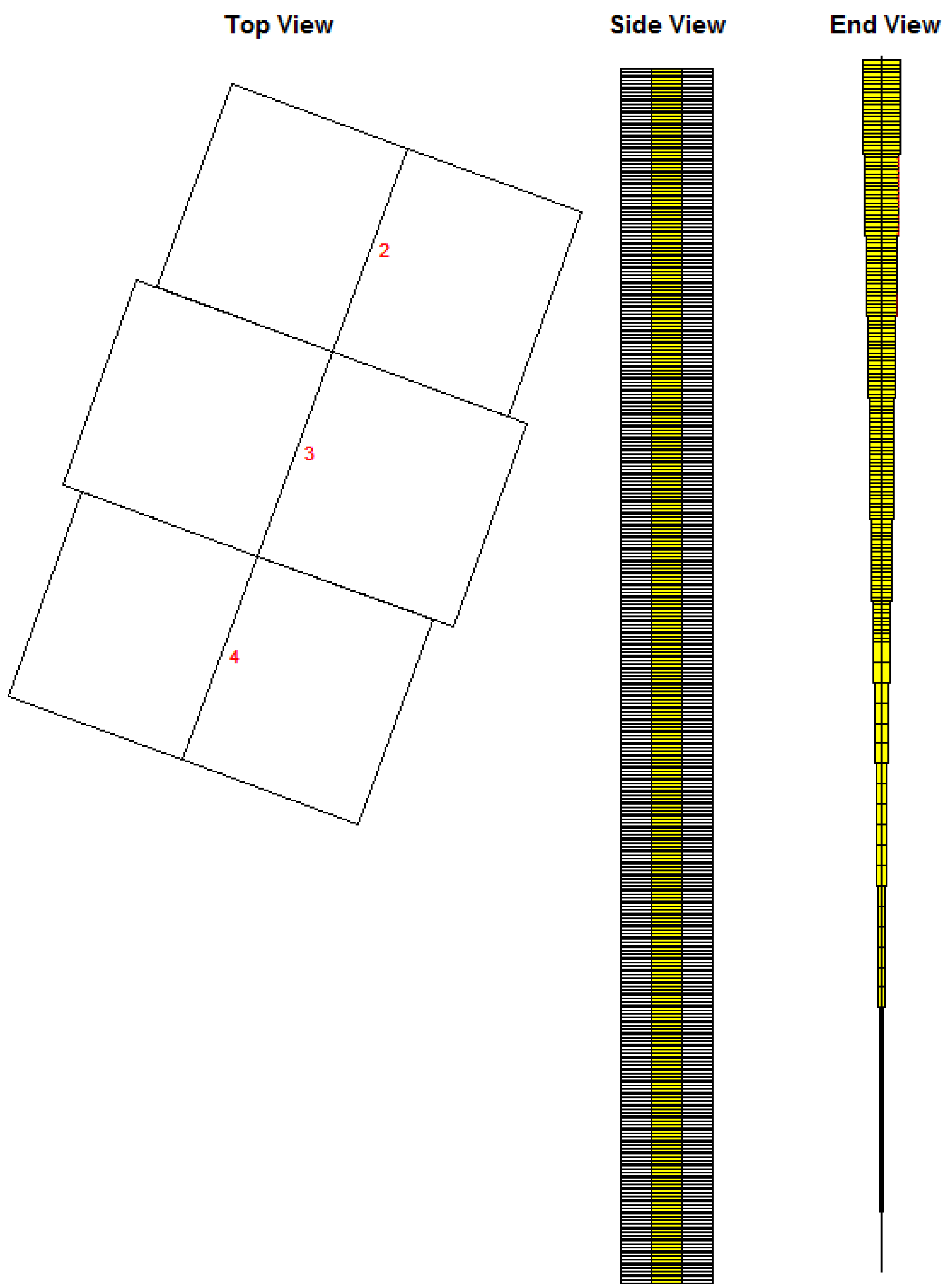


Figure 8G2.4-2 W2 Jay Pit Segmentation

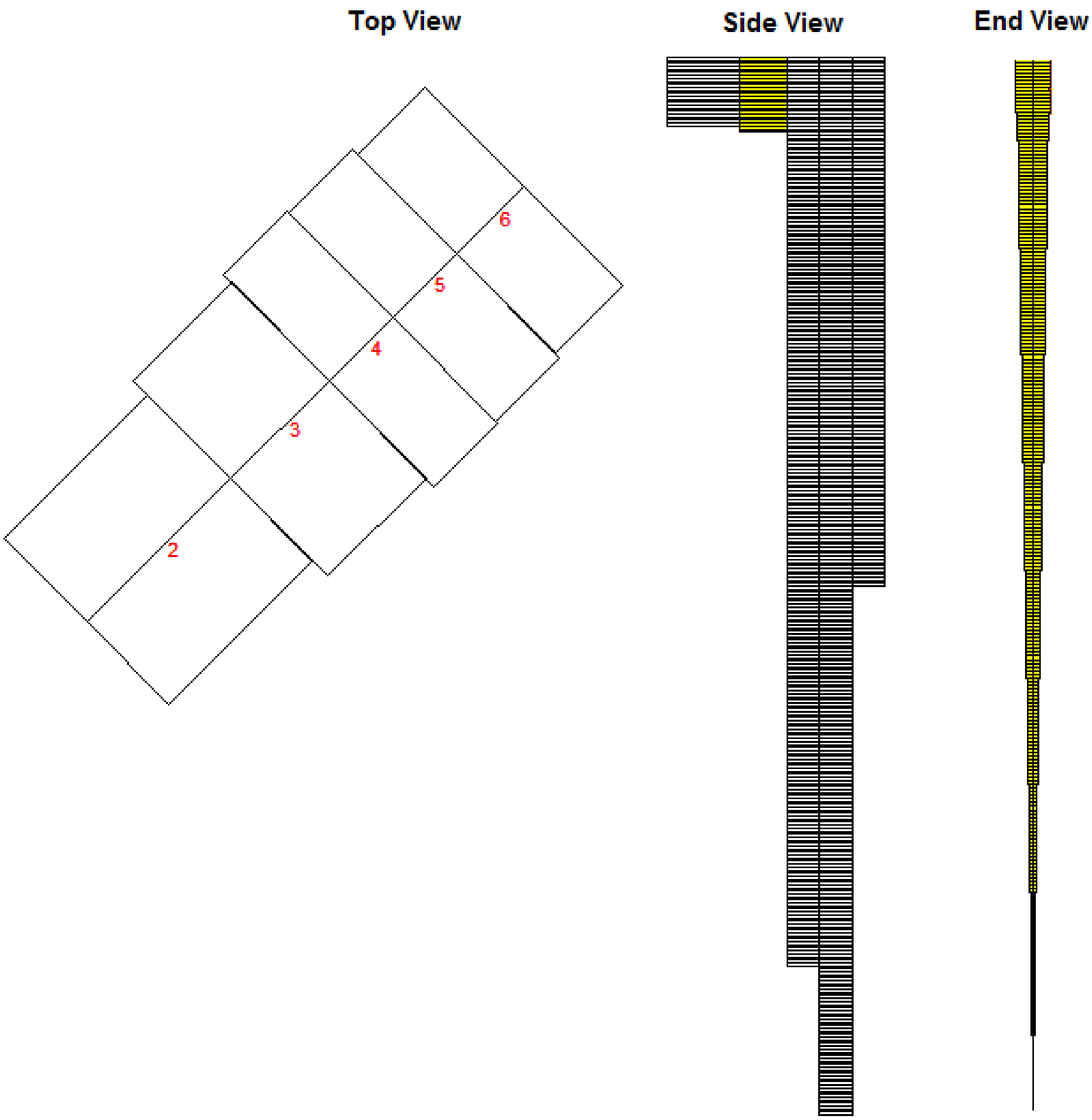
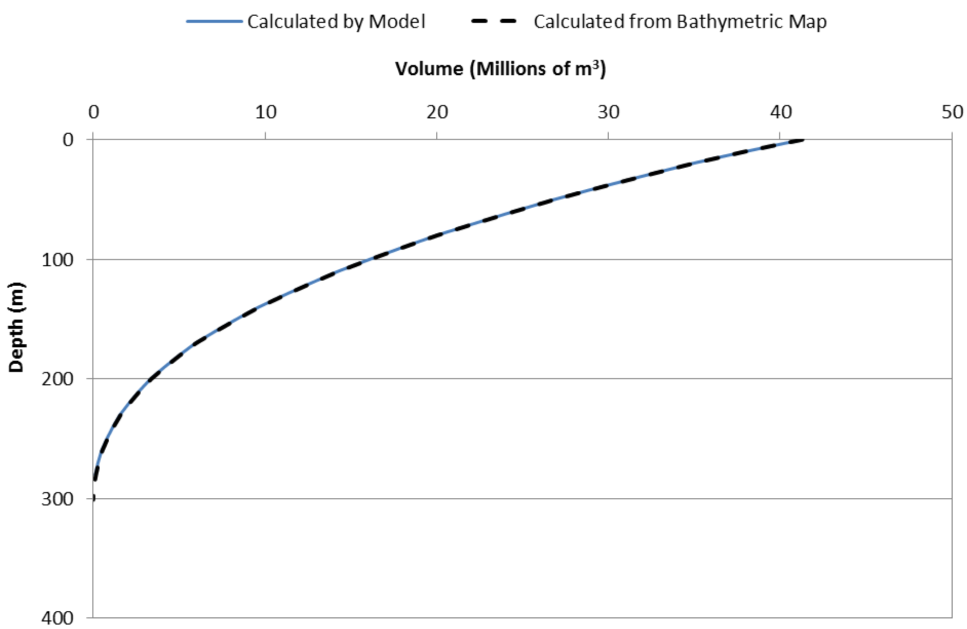
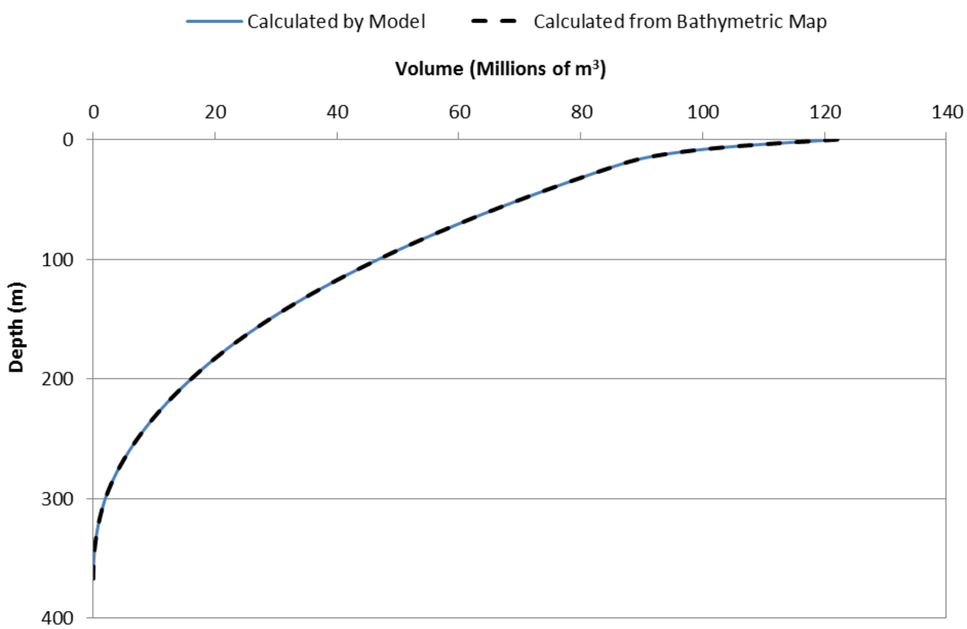


Figure 8G2.4-3 Hypsographic Curves for Misery Pit



m = metre; m^3 = cubic metre.

Figure 8G2.4-4 Hypsographic Curves for Jay Pit



m = metre; m^3 = cubic metre.

8G2.4.2 W2 Results

As explained in the previous sections, to determine the stability of stratification in the pits and the resulting transfer of water and constituents from the pits to the surface, the model was run for 200 years after closure. Long-term upward flux of water and constituents were determined by initializing the model with two distinct layers, each comprised of either 100% higher density or lower density water. This section describes results of the W2 model for both the Misery and Jay pits.

8G2.4.2.1 Misery Pit

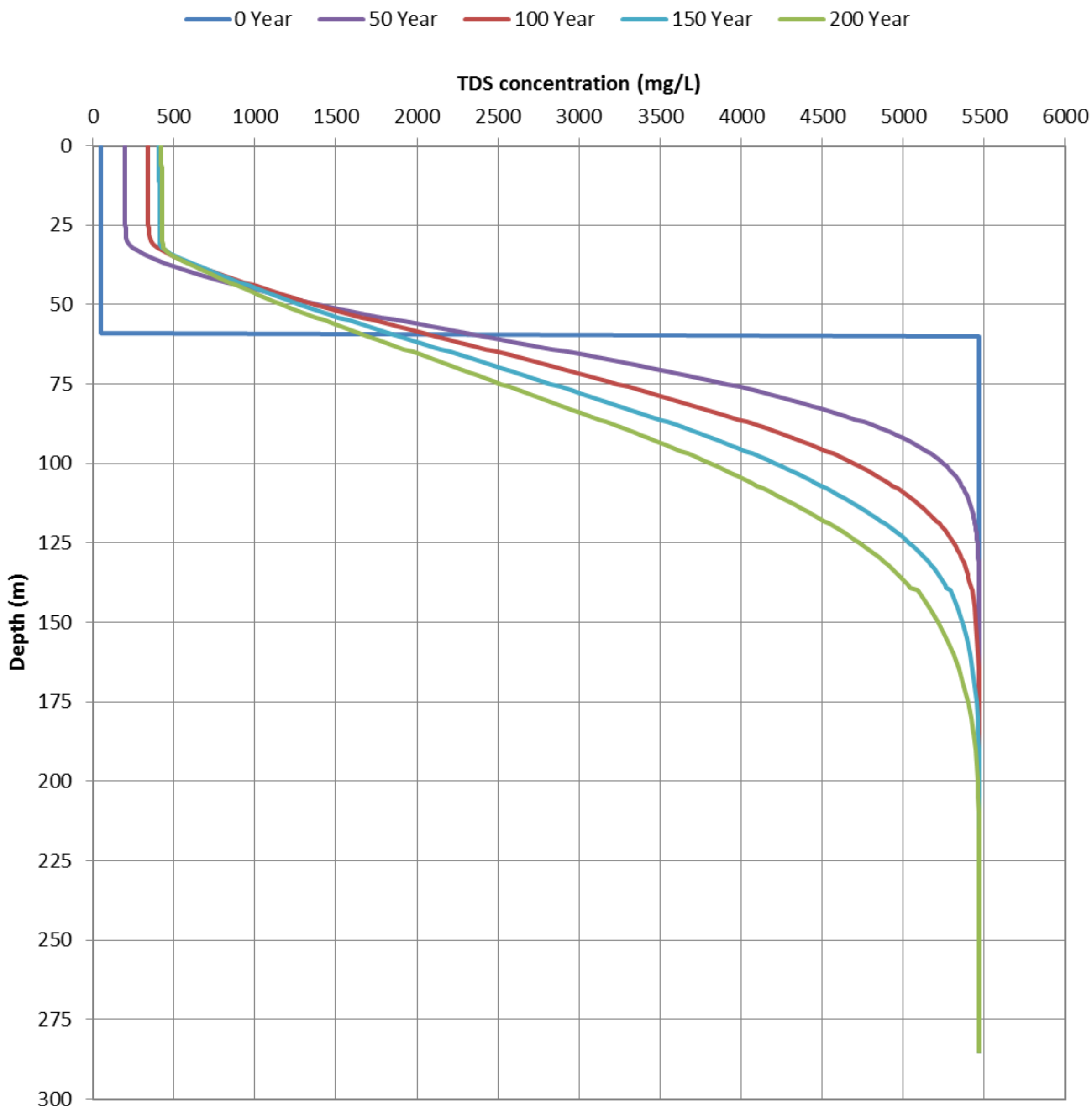
Vertical profiles of TDS concentrations for the Misery Pit are presented in Figure 8G2.4-5. The results from W2 indicate that the top of the pycnocline will move upwards in the first 50 years, and then remain relatively unchanged afterward. It is predicted that the TDS concentration of the freshwater cap will increase over time until it reaches steady state conditions around 200 years into post-closure (435 mg/L). The TDS concentration in the freshwater cap is in part dependent on the amount of natural runoff to the pit over time, which is a source of low TDS.

W2 predicted that the thickness of the transition between the monimolimnion and mixolimnion will increase with time. The elevation of the transition between high- and low-TDS waters is not predicted to change appreciably, but the gradient will become less pronounced, reflecting an upward transfer of mass from the pit bottom to the freshwater cap. This upward movement is predicted to occur rapidly after back-flooding, and gradually thereafter.

The pit is predicted to stay stratified during the entire 200 year simulation period (Figure 8G2.4-5). The stratification is characterized by a deep transition layer that provides relative stability to lake hydrodynamics, since wind-driven forces are applied at the pit surface and the energy required to perturb the system (i.e., the pit lake) increases with depth

Total dissolved solids (TDS) concentrations at depth are not predicted to increase over the 200 year time period, since hydrogeological modelling predicted groundwater losses (i.e., outflows) at depths higher than 100 m and no inflows (Appendix 8C, Section 8C4).

Figure 8G2.4-5 Predicted TDS profiles over 200-year Period after Closure of Misery Pit



m = metres; mg/L = milligrams per litre.

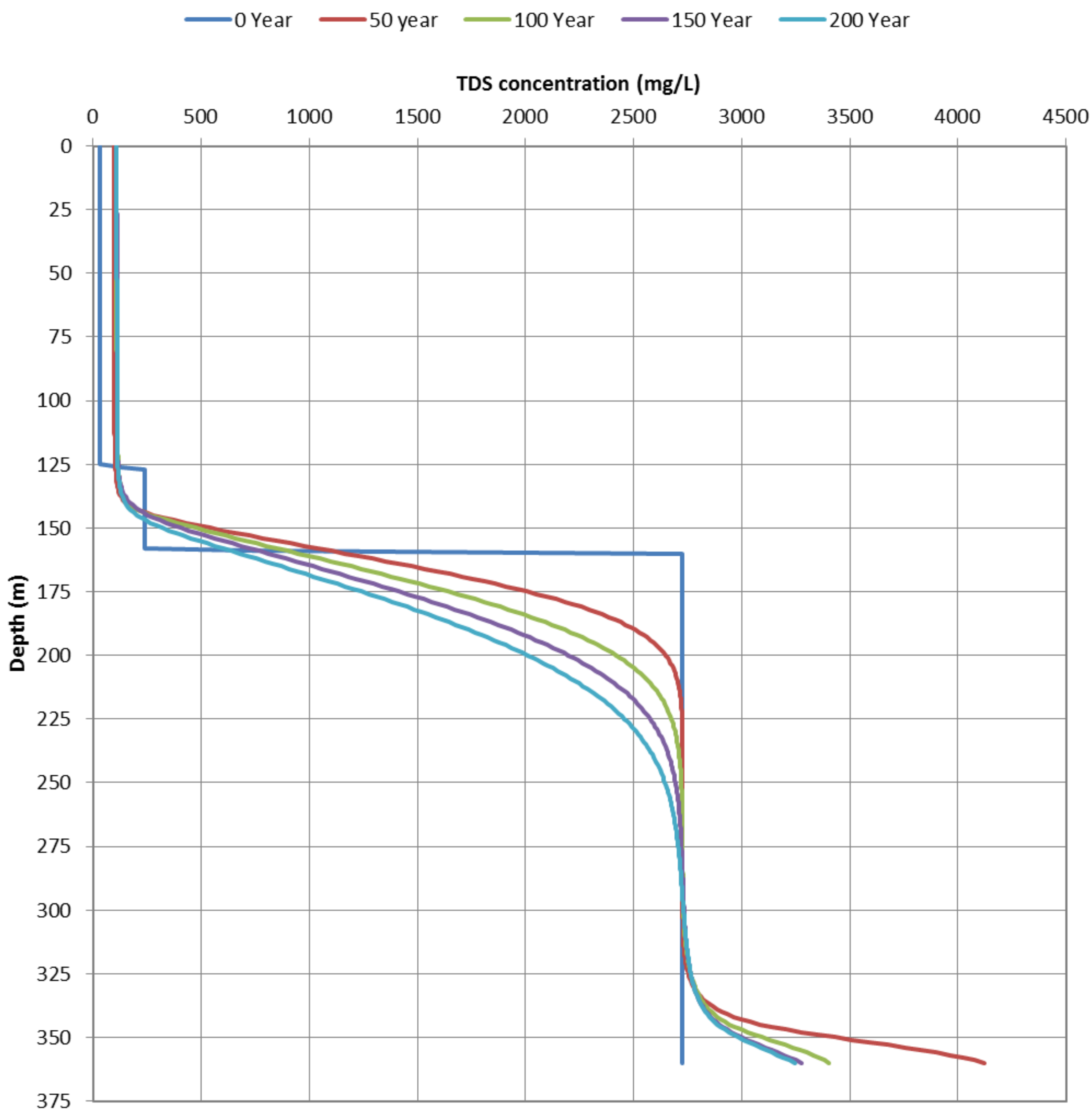
8G2.4.2.2 Jay Pit

Vertical profiles of TDS concentrations for the Jay Pit are presented in Figure 8G2.4-6. The hydrodynamic results indicate that the elevation of the pycnocline will remain relatively unchanged at the initial elevation. However, similar to the Misery Pit, the thickness of the transition between the monimolimnion and mixolimnion will increase with time. The elevation of the transition between high- and low-TDS waters will not change appreciably, but the gradient will become less pronounced, reflecting an upward transfer of mass from the pit bottom to the freshwater cap. This upward movement is predicted to occur rapidly in the first year after back-flooding, and gradually thereafter.

The decreasing speed of upward transfer of water and mass has two implications for water quality in Lac du Sauvage. First, it indicates that influences of Jay Pit water on the lake water quality will diminish with time, since the relative amounts of upward flux water from the Jay Pit to the lake will decrease over time. Second, it indicates that the transition between the monimolimnion and mixolimnion becomes deeper. Similar to the case presented for the Misery Pit, a deeper transition layer provides stability to lake hydrodynamics, since wind-driven forces are applied at the pit surface and the energy required to perturb the system increases with depth.

Inflows of very high TDS groundwater predicted by the groundwater modelling (Appendix 8B, Section 8B3) are predicted to increase TDS concentrations at depth (greater than 300 m) in the first 50 years. However, TDS concentrations will decrease over time at the bottom of the pit after 50 years since outflows from the pit to groundwater are higher than the groundwater inflows to the pit.

Figure 8G2.4-6 Predicted TDS profiles over 200-year Period after Closure of Jay Pit



m = metres; mg/L = milligrams per litre.

8G2.4.3 Vertical Mass-Balance Slice Model Results

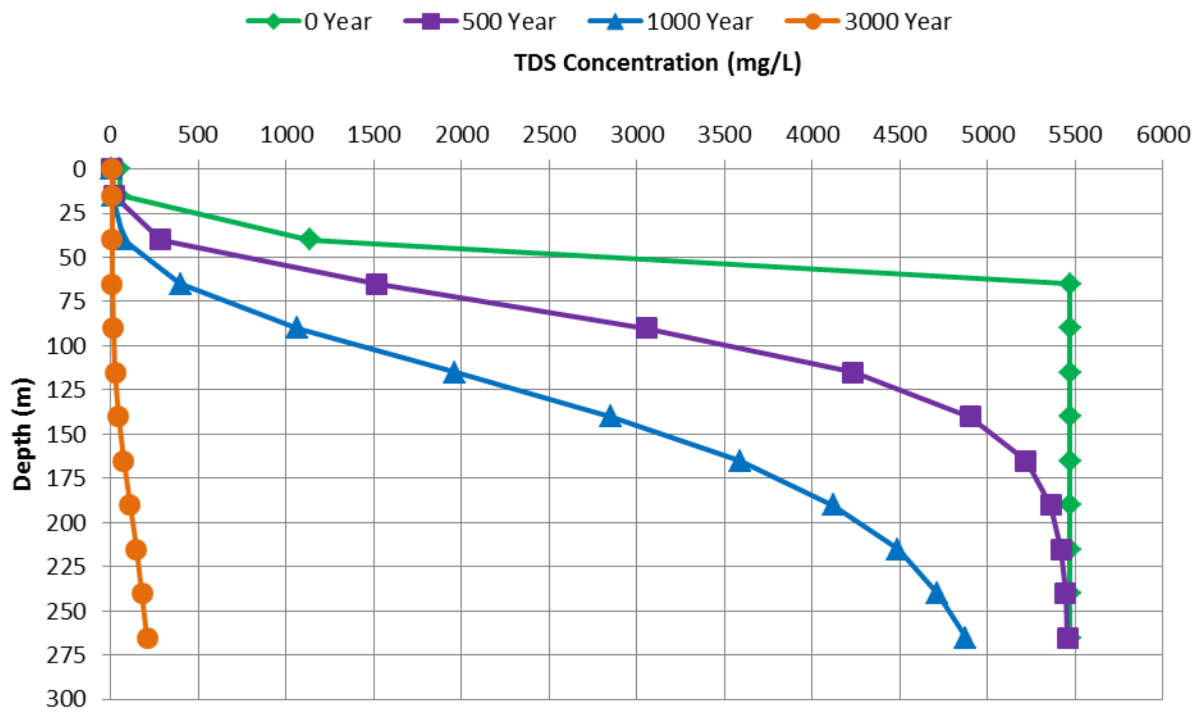
8G2.4.3.1 Misery Pit

The vertical mass-balance slice spreadsheet model was run for the Misery Pit for 15,000 years into the post-closure period. Results indicated that TDS concentrations in the monimolimnion would decrease over the next 3,000 years (Figure 8G2.4-7).

Although the W2 simulation indicated very little change in TDS in the monimolimnion in the first 200 years, the vertical slice model indicated that TDS concentrations would gradually decrease in the first 1,000 years, because groundwater outflow rates (losses) are higher than groundwater inflow rates (i.e., zero below depth of 100 m). After 3,000 years, the model indicated that the concentrations in the monimolimnion would approach natural surface water concentrations. It may be concluded that the Misery Pit will become fully mixed over time with water that is consistent with natural surface water TDS concentrations (Figure 8G2.4-7).

This simplified model did not account for upward or downward diffusion due to a concentration gradient. This model also extrapolated groundwater inflows beyond the timeframe modelled by hydrogeological modelling.

Figure 8G2.4-7 Modelled Water Column Distribution of Total Dissolved Solids Concentration in the Misery Pit Projected Over Time



m = metres; mg/L = milligrams per litre.

8G2.4.3.2 Jay Pit

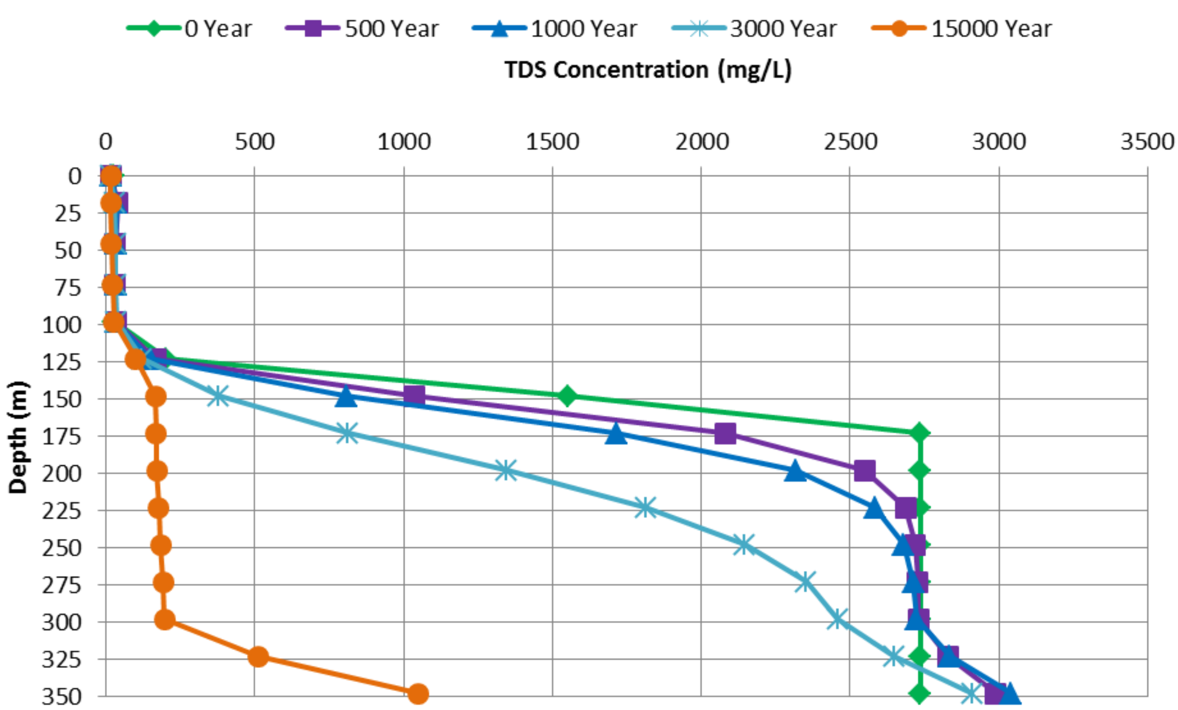
The vertical mass-balance slice spreadsheet model results for the Jay Pit indicated that TDS concentrations in the monimolimnion would decrease over the next 15,000 years (Figure 8G2.4-8). The pit is predicted to remain stratified over the first few thousand years. However, the strength of the stratification is predicted to weaken in the long term and monimolimnion concentrations will approach natural surface water concentrations. This weakening of the stratification over time is the result of natural surface runoff to the pit and higher groundwater outflow rates than groundwater inflow rates.

Similar to the results of the W2 simulation, TDS concentrations in the monimolimnion are predicted to increase initially due to early high-TDS groundwater inflows, and then decrease over time.

While the general trend of decreased TDS concentrations and downward expansion of the pycnocline is deemed realistic, this model may over-predict the extent to which these phenomena may occur. The model did not account for upward or downward diffusion due to a concentration gradient, and it extrapolated groundwater inflows beyond the timeframe modelled by hydrogeological modelling.

Nevertheless, it may be concluded from this modelling that stratification in the Jay Pit will weaken over time (15,000 years), and that miximolimnion water column TDS concentrations will approach natural surface water concentrations; however, stratification is still predicted to remain and continue to isolate the deeper high TDS in the pit (Figure 8G2.4-8).

Figure 8G2.4-8 Modelled Water Column Distribution of Total Dissolved Solids Concentration in the Jay Pit Projected Over Time



m = metres; mg/L = milligrams per litre.

8G3 DATA GAPS, MODEL ASSUMPTIONS AND UNCERTAINTY

Water quality modelling requires many assumptions due to the uncertainty related to determining the physical and geochemical characteristics of a complex system. Predictions are based on several inputs (i.e., surface flows, groundwater flows and seepage, background water quality, and geochemical characterization), all of which have inherent variability and uncertainty. Given all of the inherent uncertainties, the results of the model should be viewed as a tool to aid in the design of monitoring programs, mine planning, developing mitigation strategies, and outlining potential risks rather than to predict absolute concentrations.

Important sources of model uncertainty are presented below:

- It is assumed that the water chemistry profiles used as inputs to the models are representative of their respective sources. This is an inherent assumption in all modelling that data obtained as part of the baseline programs adequately represent the input sources, and will continue to do so in the future.
- The hydrodynamic model was built using large area lateral grid cells. Thus, some lateral resolution is lost, meaning predictions by the model may not match observed conditions well at all locations, and in all seasons (Section 8G2.3).
- Vertical layer depths of 1 and 5 m were used in the hydrodynamic model of the Misery Pit. Some vertical resolution is lost using a 5 m layer depth, meaning stratification elevation in the model may not be exactly representative of real conditions. A lower grid depth would have made the model run time prohibitively long. It is not the purpose of the model to match observed conditions exactly, or make precise predictions about future conditions.
- For temperature calibration, field data from only a few open water seasons were available. Therefore, the models could not be calibrated to general seasonal trends in field data because insufficient field data were available. While the trend in model predictions is reasonable considering general lake processes, the exact timing and trend in Lac du Sauvage may be different.
- The Lac du Sauvage hydrodynamic model was capable of reproducing temperature reasonably well during the calibration time period. Predictions in Lac du Sauvage only apply to the discharge water quality noted in this appendix. Changes to discharge water quantity and quality may result in possible changes to the predictions in the lake beyond the range presented in this appendix.

Following are the key modelling assumptions:

- The governing equations in W2 are laterally and layer averaged. Lateral averaging assumes that lateral variations in velocities, temperatures, and constituents are negligible.
- Although W2 can model formation of ice cover, it does not include salt exclusion.

Care was taken to incorporate known processes as understood during model development. However, in natural systems and complex constructed systems, observed conditions, particularly on a daily basis, will almost certainly vary with respect to estimated conditions.

The data and approaches used to estimate future water quality are currently believed to provide a reasonable approximation of the system as currently understood, within the context of the assumptions used in the model.

Due to the factors listed above, even the best of models cannot be expected to match operational monitoring data. It is the goal of modelling to conservatively predict concentrations, so concentrations of monitored constituents are anticipated to be less than predicted concentrations. Once the Project is operational, monitoring of water quality and periodic re-assessment of effects predictions based on measured data will be required.

8G4 CONCLUSIONS

A hydrodynamic model of the Jay and Misery pits was developed using W2, which predicts stratification will develop within the pits throughout post-closure of the Jay Project.

The model was calibrated to Lac du Sauvage using existing field data. Overall, the stratification pattern and temporal calibration were deemed satisfactory. A lack of under-ice field data at most sampling locations throughout the lake added uncertainty in the calibration of the model to seasonal trends; however, the model predictions matched the magnitude of field measurements well. The developed W2 model was considered a reasonable representation of the system, and was then applied to both pits.

A W2 model was built for each of the pits and run for 200 years into post-closure. Results indicated that the pits will stay stratified during the entire 200 year simulation period.

Long-term TDS profiles of the Misery and Jay pits were calculated using a vertical slice spreadsheet model to estimate the long-term stability of the pits. Results indicated that TDS concentrations in the monimolimnion would decrease and approach natural surface water concentrations throughout the water column over the long term for both pits, but that in the deeper Jay Pit, stratification would still be predicted to remain and continue to isolate the deeper high TDS water.

DOMINION DIAMOND

8G5 REFERENCES

Castendyk DN, Eary LE. 2009. Mine Pit Lakes: Characteristics, Predictive Modeling, and Sustainability. Society for Mining, Metallurgy and Exploration Inc. Littleton, Colorado. 304 pp.

Cole TM, Wells SA. 2008. CE-QUAL-W2: A Two-dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.6 User Manual. August 2008.

ERM Rescan (ERM Rescan Environmental Services Ltd.). 2013. Ekati Diamond Mine 2012 Aquatic Effects Monitoring Program Annual Report. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.

Rescan (Rescan Environmental Services Ltd.). 2011. Ekati Diamond Mine: 2010 Aquatic Effects Monitoring Program Annual Report. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.

Rescan. 2012. Ekati Diamond Mine 2011 Aquatic Effects Monitoring Program Annual Report. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.