KCGM Fimiston Operations

Closure Water Balance and Pit Lake Geochemistry: Technical Summary

1 August 2022

J-AU0175-001-R-Rev1

MINE WASTE MANAGEMENT
GREENROAD GROUP

GROUNDWATER RESOURCE MANAGEMENT

NORTHERN STAR RESOURCES LIMITED

KCGM Fimiston Operations

Closure Water Balance and Pit Lake Geochemistry: Technical Summary

Document Number: J-AU0175-001-R-Rev1

Document Date: 1 August 2022

Prepared for:

Northern Star Resources Limited

Level 1, 388 Hay Street, Subiaco, Western Australia 6008

Prepared by:

Mine Waste Management Pty Ltd

Suite 2, 435 Vincent Street W, West Leederville, WA 6007 AUSTRALIA

+61 8 9381 2938

www.minewaste.com.au

in collaboration with:

Groundwater Resources Limited Pty Ltd (GRM)

PO Box 442, Bayswater, WA 6933

+61 8 9433 2222

www.g-r-m.com.au

REVISION	DATE	AUTHOR	RECORD OF REVIEW
Rev A	30-6-2022	TR	PW
Rev 0	29-7-2022	TR	PW
Rev1	1-8-2022	TR	PW

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

BLANK PAGE

1 INTRODUCTION

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM), a wholly-owned subsidiary of Northern Star Resources, has operations situated adjacent to the city of Kalgoorlie-Boulder in the Eastern Goldfields Region of Western Australia. KCGM's Fimiston Operations comprise the Fimiston Pit (commonly referred to as the 'Super Pit'), Mt Charlotte Underground Mine, the Fimiston and Gidji Processing Plants, and associated Tailings Storage Facilities (TSFs) and waste rock dumps (WRDs) as shown in Figure 1. Process water is supplied from borefields intercepting the Roe palaeochannel system while potable water is supplied via the Goldfields Water Supply Scheme.

KCGM is currently preparing for submission of approvals for an extension of the Fimiston Pit. For these submissions, KCGM required an updated pit lake model and closure water balance model, which incorporates the proposed pit shell at closure and post-closure management of water from the WRDs and TSFs.

Mine Waste Management (MWM), in collaboration with Groundwater Resource Management Pty Ltd (GRM), were engaged to update the closure water balance and hydrogeochemical model for the pit lake that will develop in the Fimiston Pit at mine closure, building on a study completed in 2021 (MBS, 2021). This update reflects the proposed expansion of the open pit, plans for an in-pit WRD, a revised closure schedule, and incorporation of additional TSF cells that will provide seepage inputs to the pit lake post-closure. Hydrological aspects of this work (i.e. revised closure water balance, assessment of overtopping risk, elevation-area-volume stage curve for the pit) were completed by GRM. Hydrogeochemical modelling and report preparation were completed by MWM.

This report presents a technical summary covering the key aspects of the approaches and outcomes of the work undertaken by MWM and GRM during 2021 and 2022.

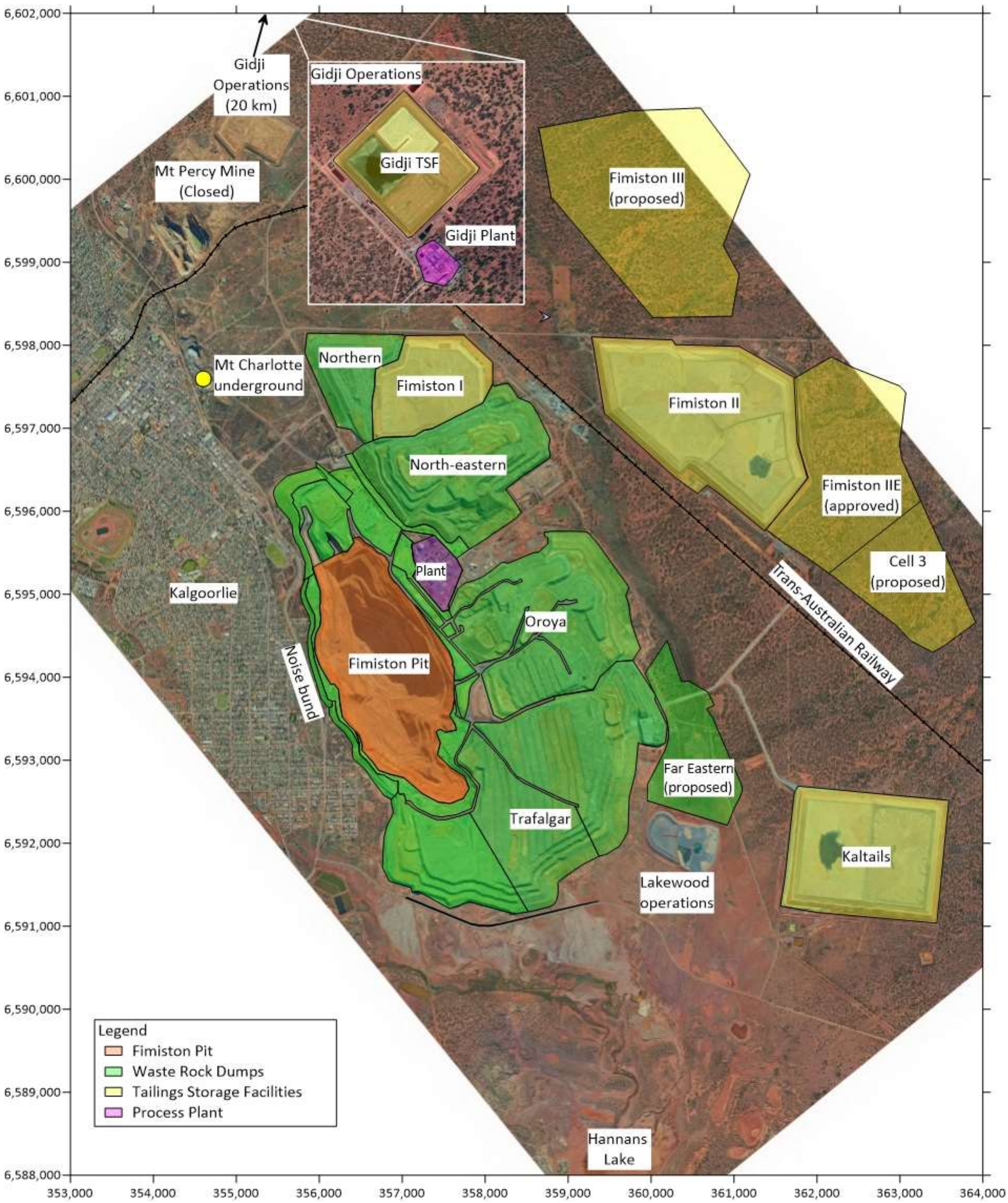

Figure 1: Current and proposed mining activities.

Source: Provided by GRM as part of this scope of work.

2 ENVIRONMENTAL SETTING

The environmental setting of the KCGM operations is described in detail in MBS (2021) and provided in summary form herein.

The Kalgoorlie region has a semi-arid climate with hot summers and mild winters. Annual rainfall varies between 108 and 530 mm with an average of 266 mm. Rainfall occurs during all months of the year. The region is experiencing a distinctive long-term change in rainfall patterns characterised by reduced winter rainfall and a greater number of extreme rainfall events in summer. Climate studies by the CSIRO (2015) indicate that the decreasing winter rainfall trend will be continuing due to climate change with higher probabilities of extreme summer rainfall events.

The KCGM mine is located on an elevated topographic area, which forms a topographic divide between two major palaeodrainage systems that occupy the lower part of the subdued landscape features typical of the Kalgoorlie area. KCGM is situated in the salt lake hydrological region and comprises numerous drainage systems flowing to terminal salt lake systems, clay pans, and other natural surface depressions. KCGM is situated in the Hannan catchment which is associated with the Roe palaeovalley system. The Hannan catchment drains an area of about 230 km^2 and runoff flows to the Hannan Lake, situated south of the operations.

There are three major active groundwater systems in the KCGM area namely:

- Palaeochannel systems: A localised but extensive network of alluvial sands at around 60 m depth. This system is well defined and is the primary source of process water for KCGM and for other mining operations.
- Ferricrete and alluvial sedimentary system: Sand, gravel and fractured ferricrete within clay deposits. These deposits are present in the lower elevation areas at the centre of the surface water catchments.
- Fractured bedrock system where groundwater flow occurs in fractured and weathered zones within the basement rocks at depth. The Fimiston Pit is entirely situated within the fractured bedrock zone.

In general, groundwater at KCGM is naturally saline with TDS (total dissolved solids) concentrations ranging between 75,000 and 170,000 mg/L with higher TDS concentrations observed in monitoring bores near to the TSFs. Groundwater pH is circum-neutral to slightly alkaline in fractured bedrock groundwater systems. Groundwater pH in the ferricrete, paleochannel and alluvial groundwater system is naturally low with an observed range typically between 2.8 to 4.

3 HYDROLOGICAL MODEL DEVELOPMENT

A probabilistic, dynamic systems modelling approach was followed to simulate the closure and post-closure mine water conditions. The GoldSim™ software was used to represent the closure water flow conditions. GoldSim is a graphical, object orientated program for performing dynamic, deterministic or stochastic simulations. The software is frequently used for water balance studies and is well suited for operational and closure water balance studies.

3.1 Inputs from Existing Models

A historical operational model, representing the operational period at KCGM for 1996 to 2019, was developed previously (MBS, 2021). The historical operational model was calibrated to measured dewatering rates and water levels in the underlying historical mine workings. A comparison of calibrated modelled water levels versus measured water levels for the Fimiston Pit is shown in Figure 2. As part of the calibration, model input parameters were derived including groundwater inflow rates and pit wall rainfall runoff coefficients. These model parameters were used in the closure water balance to predict the pit filling rate after closure.

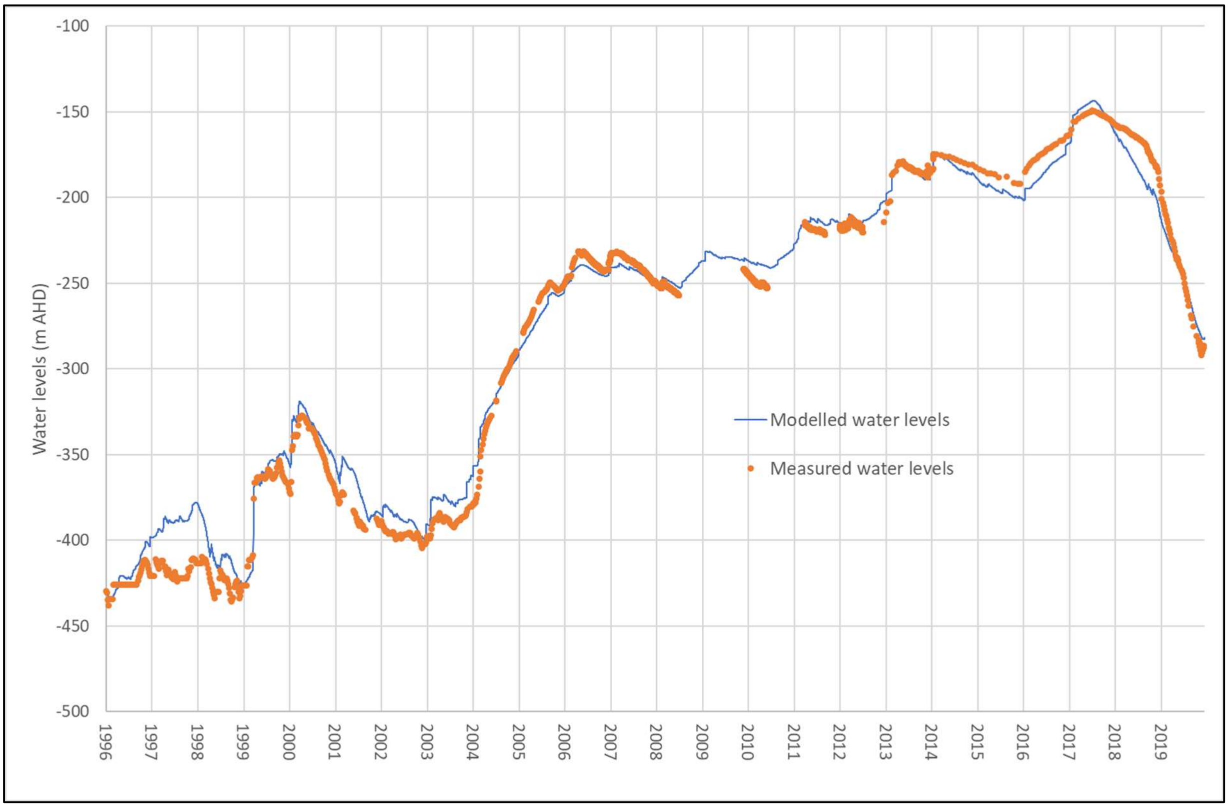

Figure 2: Measured and modelled water levels for Fimiston Pit.

Source: MBS (2021).

Previous work described in MBS (2021) also included developing stochastic rainfall and evaporation datasets for base case conditions and those reflecting changes in the Goldfields climate due to climate change. These datasets were relied upon to predict inflows to the pit related to rainfall (e.g. runoff from pit walls, rainfall to the lake surface) and evaporation from the lake surface.

Climate change projections were also used to develop an alternative closure water balance to assess the sensitivity of the base case model predictions to increased long-term rainfall and evaporation rates, based on the "Australian Climates Futures" decision support tool (CSIRO, 2015).

3.2 Closure Water Balance Model

A revised predictive closure model was developed for this study, which simulates the development of the Fimiston Pit lake over a period of 566 years after closure. The following sections describe the methods, input data and assumption used in developing this model.

During operations, several TSFs and waste dumps will reach their capacity and will be closed and rehabilitated. Both the Mt Charlotte underground workings and Fimiston Pit will be closed, and water levels will be allowed to recover. The sequence of closure at KCGM is as follows:

- 2023: Fimiston II TSF will almost reach its capacity and deposition of tailings will occur occasionally. After closure of the processing plant, the TSF will be closed and rehabilitated over several years, allowing for the settlement of the tailings and drying of the TSF surface to be accessible for the placement of the cover. Seepage from the TSF will require active management for several years post-closure. Thereafter, the TSF is not expected to have significant water release to the environment other than occasional small amounts of runoff from the embankments.
- 2026: Fimiston I and Kaltails TSFs will almost reach capacity and deposition of tailings will occur occasionally. As with the other TSFs, Fimiston I and Kaltails will be closed when processing stops and rehabilitated over several years. Seepage will require active management for several years after which no significant water release to the environment is expected other than occasional small amounts of runoff from the embankments.
- 2027: Waste rock will be managed using both in-pit and ex-pit dumping, allowing for the rehabilitation of some of the completed dump surfaces and slopes.
- 2034: All mining and processing at KCGM will cease. Both the Fimiston and Gidji plants will be decommissioned and rehabilitated. Tailings deposition on Fimiston IIE and Fimiston III are planned to cease and the TSFs will be rehabilitated over several years. As with all the TSFs, seepage will require active management for several years post-closure. Since the process plant will be decommissioned and seepage recovery water will no longer be used as supply water for this, KCGM is planning to pump recovered decant and seepage-affected groundwater from the TSF borefields to the Fimiston Pit for several years, until the seepage impacts on the groundwater have been reduced.

The conceptual model for the post-closure flow balance is shown in Figure 3. At this stage, the borefields and process plants will have been decommissioned and rehabilitated. Landforms will be rehabilitated, including TSFs and WRDs. Pit and underground workings dewatering will have ceased.

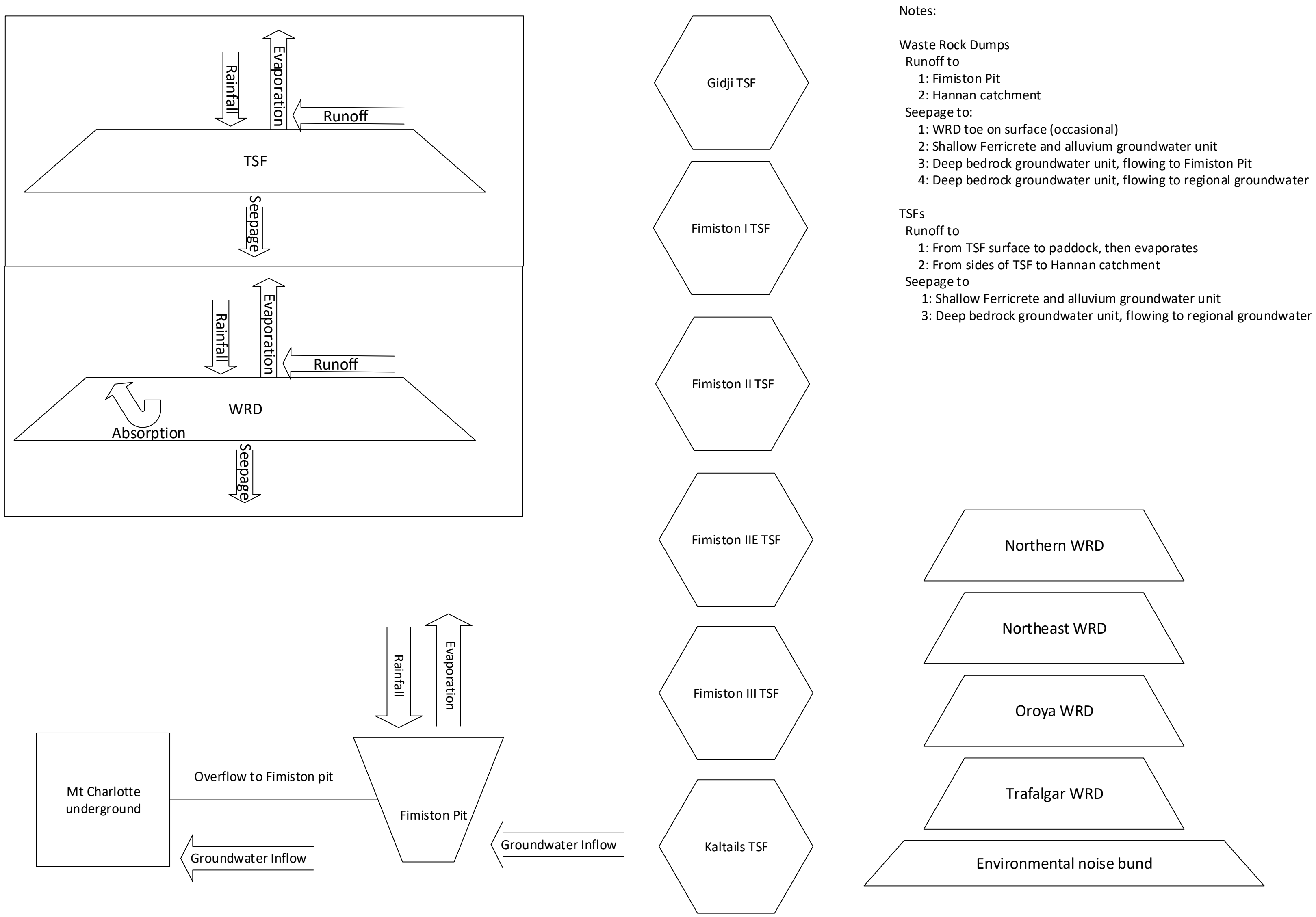

Figure 3: Conceptual flow diagram at closure.

Source: Provided by GRM as part of this scope of work.

3.2.1 Tailings Storage Facilities

TSFs will be rehabilitated to be internal draining, i.e. rainfall runoff from the rehabilitated TSF surfaces will be collecting in the centre of each TSF paddocks, from where it will evaporate. Evaporation rates exceed rainfall by a significant margin, hence TSF surfaces are expected to be dry for most of the time with some water accumulation following large rainfall events. Side slopes of the TSFs will be rehabilitated with runoff reporting to the Eastern Floodway and ultimately Hannans Lake (Figure 4).

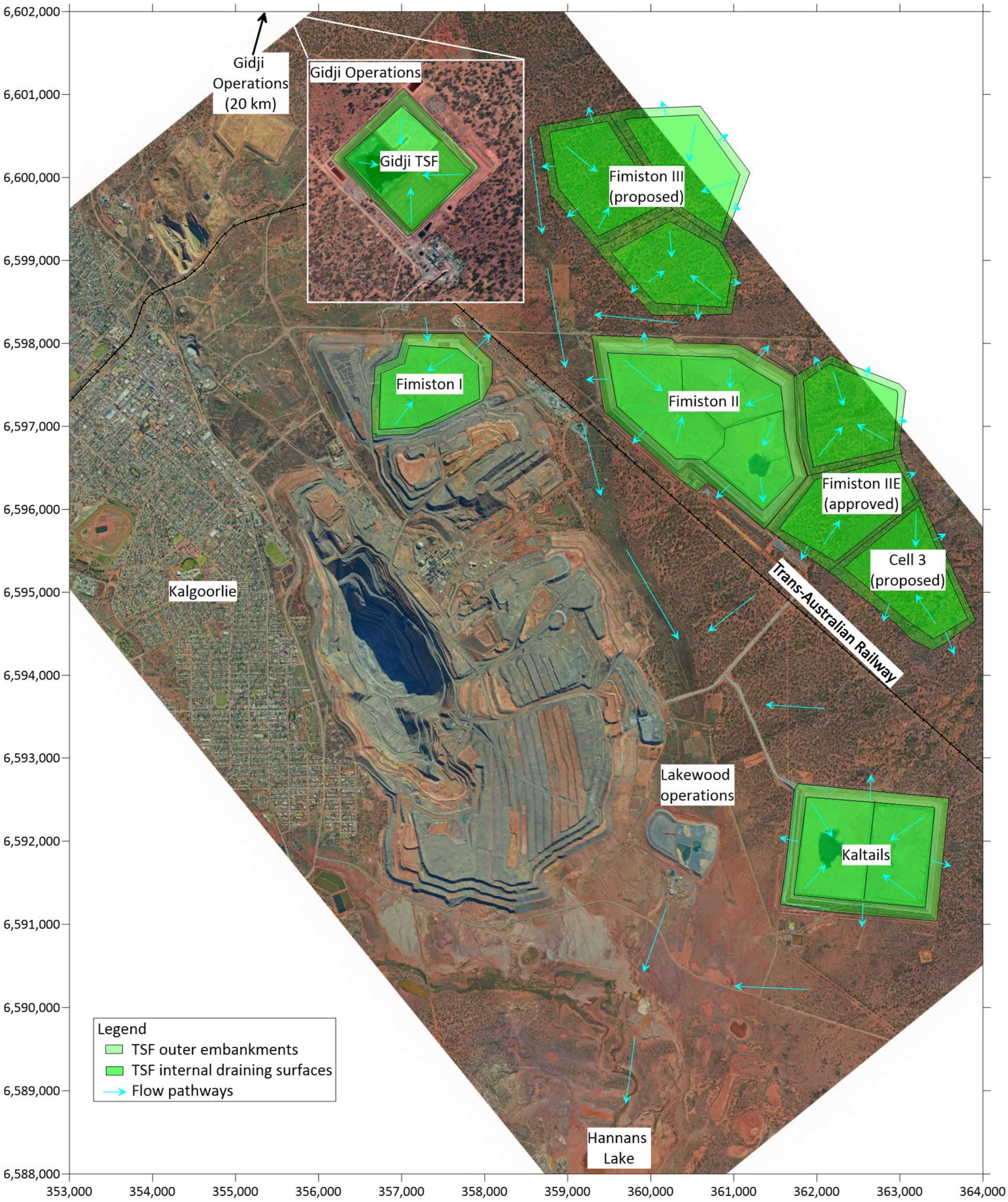

Figure 4: Surface water flow pathways from rehabilitated TSFs.

Source: Provided by GRM as part of this scope of work.

Seepage from the TSFs during the drain-down period is expected to require active management to avoid groundwater level rises around the TSFs over a period of between 10 and 15 years (conservative approach). Cover modelling indicates that minimal seepage will occur from the rehabilitated TSF surfaces after the drain-down period (Big Dog Hydrogeology, 2022).

During the active management period, seepage interception pumping will continue. Seepage is currently intercepted in accordance with the Seepage and Groundwater Management Plan (SGMP) (KCGM, 2020a). This management plan will be revised for the management of seepage during the drain-down period. Tailings deposition will mostly cease on Fimiston I and Fimiston II TSFs during the operational period, though the TSFs might be used occasionally up to closure of the process plants. After closure of the process plants, all TSFs will also be closed and intercepted seepage will be pumped to the Fimiston Pit.

An estimated 75 L/s of recovered seepage and underdrainage will be pumped to Fimiston Pit over 2 years, decreasing to 10 L/s over the following 8 years (Table 1). If the drain-down period is longer than expected (15 years), then 115 L/s of recovered seepage and underdrainage will be pumped to Fimiston Pit for 3 years, falling to between 105 and 12 L/s for the following 12 years (Big Dog Hydrogeology, 2022).

Table 1: Base case tailings seepage and underdrainage inflow rates after closure (L/s)

YEARS POST CLOSURE	CALENDAR YEAR	RECOVERED SEEPAGE				UNDERDRAINAGE		TOTAL
		FIM. I	KALTAILS	FIM. IIE	FIM. III	FIM. IIE	FIM. III	
0	2034	10	15	10	15	10	15	75
1	2035	10	15	10	15	10	15	75
2	2036	10	15	10	15	10	15	75
3	2037	0	0	1	4	1	4	10
4	2038	0	0	1	4	1	4	10
5	2039	0	0	1	4	1	4	10
6	2040	0	0	1	4	1	4	10
7	2041	0	0	1	4	1	4	10
8	2042	0	0	1	4	1	4	10
9	2043	0	0	1	4	1	4	10
10	2044	0	0	1	4	1	4	10

3.2.2 Waste Rock Dumps

The WRDs are progressively rehabilitated during operations. Both in-pit and ex-pit waste rock placement will occur from 2027. Waste rock dumps will be rehabilitated over several years during operations and rehabilitation could be completed by the time processing stops in 2034. The rehabilitation comprises the placement of a topsoil cover on the surfaces and sides of the waste dumps.

A numerical model was developed to determine the infiltration, evapotranspiration, and rainfall runoff from the rehabilitated WRD surface (KCGM, 2020b) as illustrated in Figure 5. Cover modelling indicates that most of rainfall on the rehabilitated WRDs will infiltrate the waste rock (80%). However, significant losses are predicted to occur as rainfall percolates through the waste rock due to absorption and vaporisation. Runoff rates from the rehabilitated WRDs are estimated to be small, ranging between 2% of rainfall on the waste dump surface to 5% of rainfall on the side-slopes.

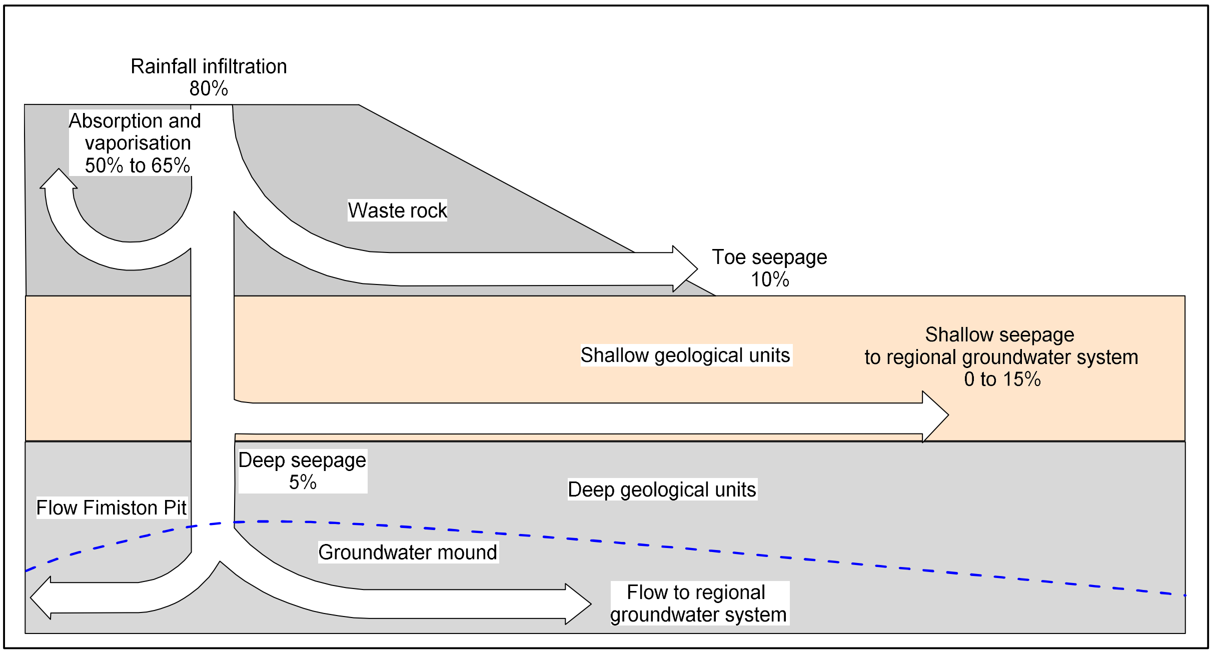

Figure 5: Conceptual flow model for the waste rock dump body and base.

Source: Provided by GRM as part of this scope of work.

Runoff from the WRD surfaces will be conveyed to the Fimiston Pit via drains aligned to existing haul roads, while runoff from the WRD side slopes will flow onto the Eastern Floodway and Gribble Creek sub-catchments, respectively (Figure 6 shows the delineated WRD catchments). The eastern side slopes report to the Eastern Floodway. The western side of the Northern and Trafalgar WRDs and a small western portion of the noise bund report to Gribble Creek (separate landforms are identified in Figure 1).

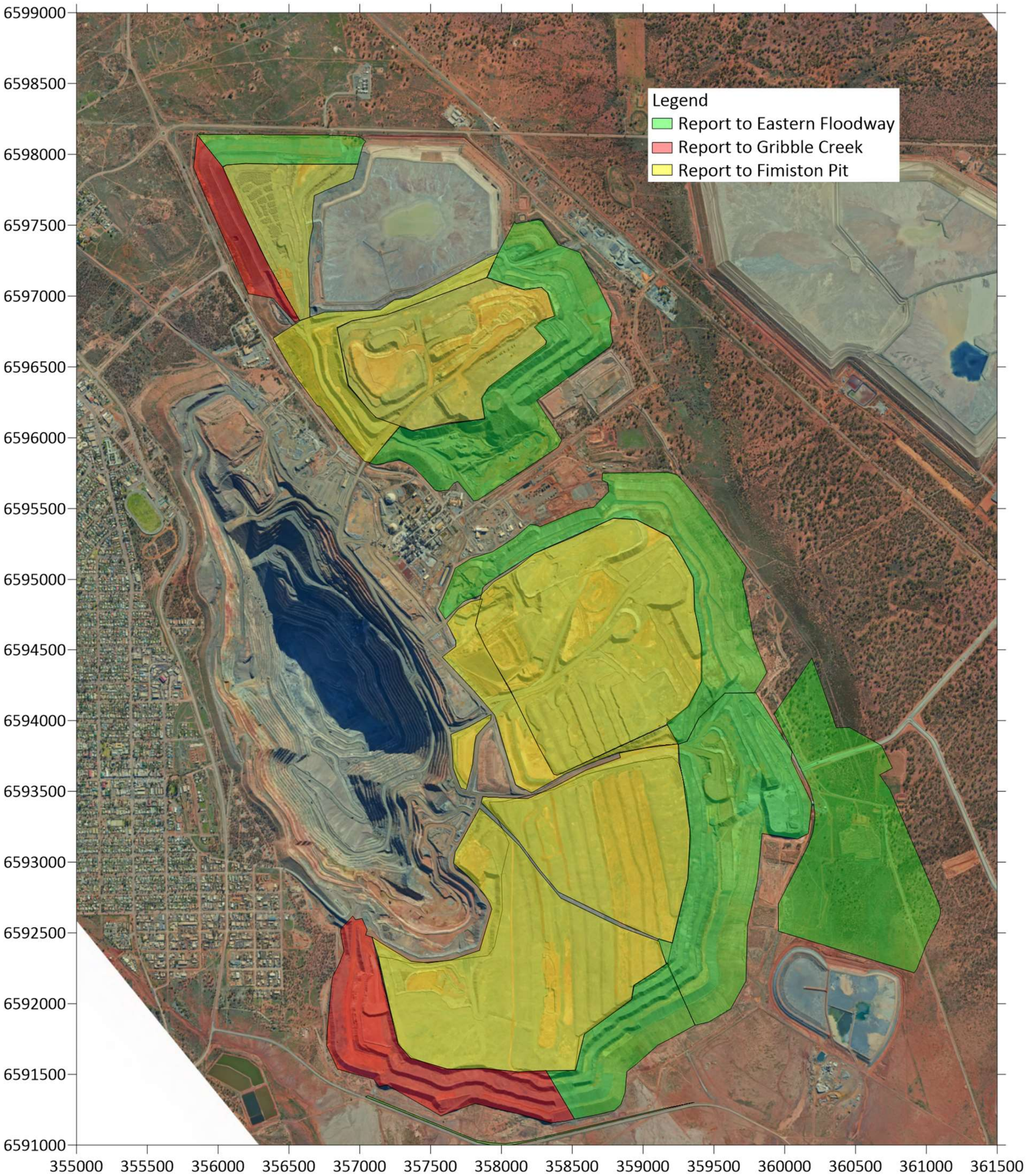

Figure 6: Waste dump surface water catchments at closure.

Source: Provided by GRM as part of this scope of work.

It is possible that some seepage could occur along the toe of the WRD following large rainfall events, discharging down-gradient at the southeastern side of the WRD. During large rainfall events, macropores in the WRD form preferential pathways with rainfall infiltration rapidly percolating through the waste rock material. During such events, rainfall may discharge along the toe of the dump to the ground surface.

Once percolating water reaches the base of the WRD, water that does not seep from WRD toes would generally infiltrate the ground and flow into the underlying ferricrete and alluvium groundwater system, where present, or enter the fractured bedrock aquifer where it can flow either towards the pit or to the regional groundwater system associated with the Hannan groundwater catchment as illustrated in Figure

7 and Figure 8. Estimated seepage flows at WRD toes and to the alluvium and fractured bedrock aquifers were based on GRM professional judgement and experience with the Fimiston Operations and are subject to refinement as part of detailed mine closure planning (pers com. Jan Vermaak, GRM, email dated 18 July 2022).

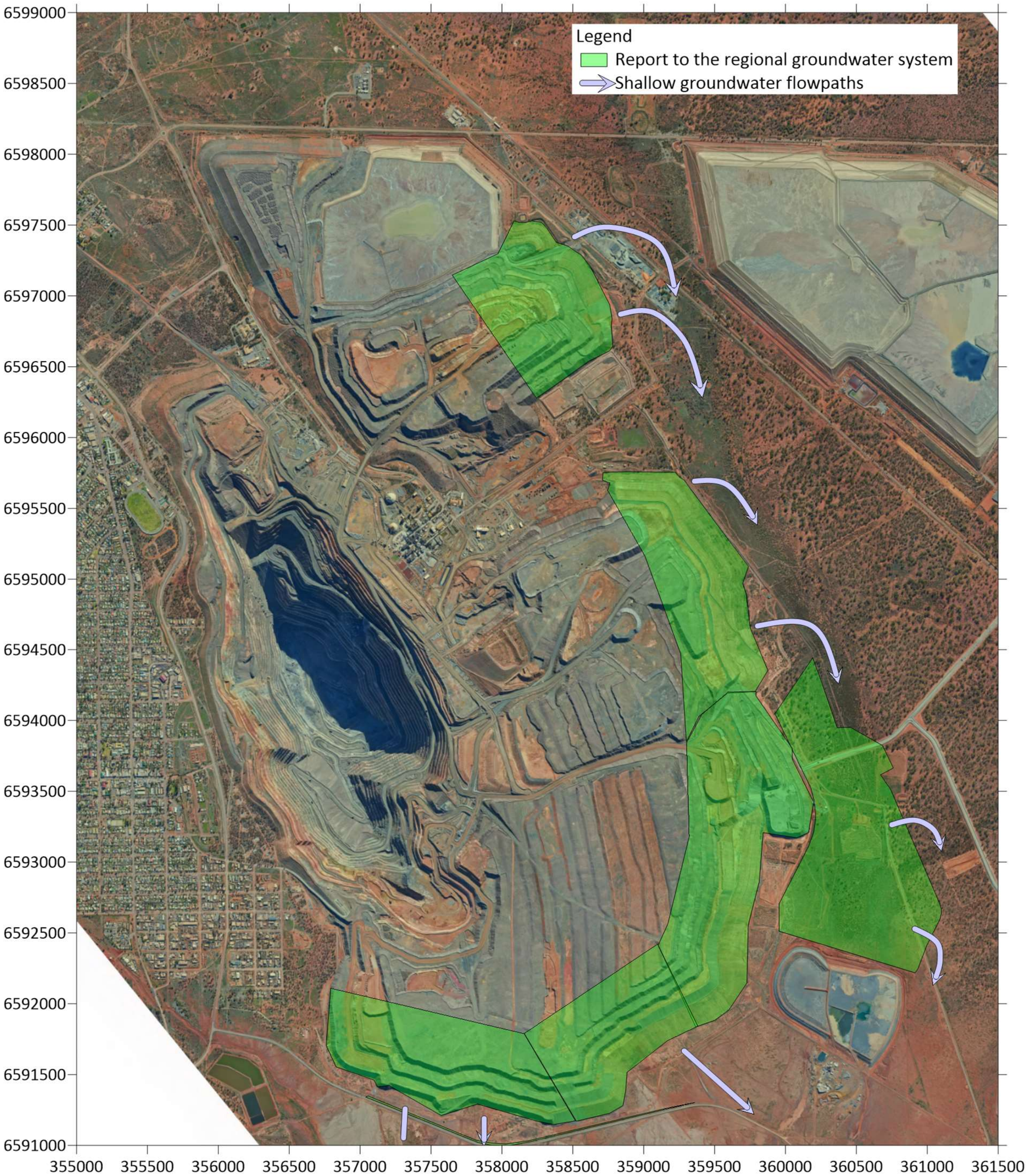

Figure 7: Catchments contributing to seepage to the ferricrete and alluvium groundwater system.

Source: Provided by GRM as part of this scope of work.

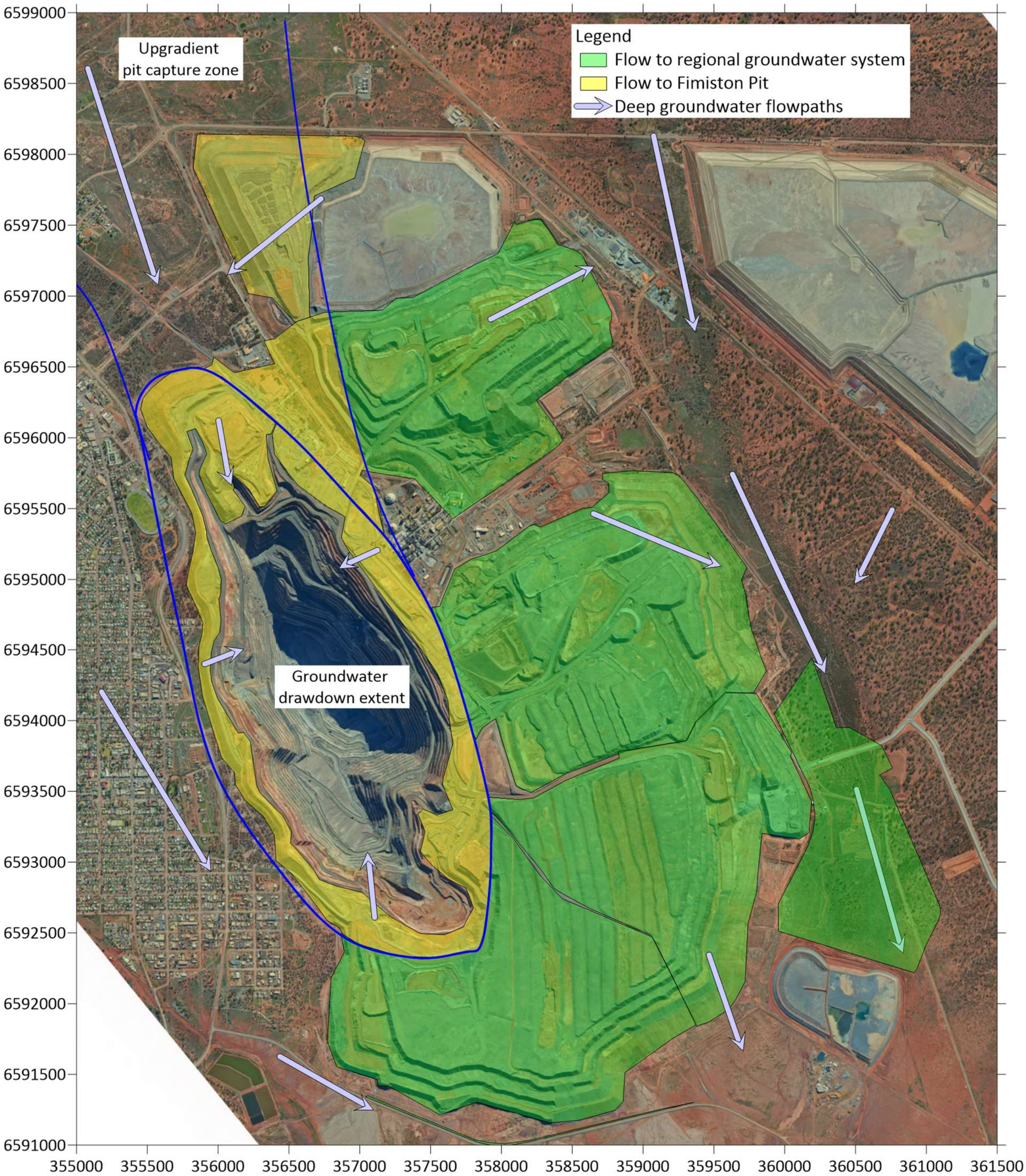

Figure 8: Catchments contributing to seepage to the fractured bedrock groundwater system.

Source: Provided by GRM as part of this scope of work.

3.2.3 Mt Charlotte Underground Working

Peter Clifton and Associates (2014) carried out a hydrogeological assessment of the Mt Charlotte underground workings after closure.

The Mt Charlotte Underground mine used to be accessed via the Sam Pearce Decline, which is located at the northern end of the Fimiston Open Pit. The decline tracks to the northwest and joins the main underground workings of Mt Charlotte on the 9 Level (9L), which is at an elevation of -106 mAHD.

Numerical modelling indicated that the voids in the underground mine workings will slowly fill with groundwater after closure. Initially, groundwater inflow rates are expected to remain constant, but as groundwater levels rise, groundwater inflow rates are expected to decrease because of the lower hydraulic gradient.

Eventually, groundwater levels are expected to reach the Sam Pearce Decline and then overflow into Fimiston Pit. The numerical model indicated that groundwater levels will reach the decline 99 years after closure and the rate of overflow would be 33 kL/d (0.4 L/s). Mt Charlotte is planned to be closed by 2034, which means overflow to Fimiston Pit is predicted to potentially occur by 2133.

3.2.4 Fimiston Pit

The Fimiston Pit will gradually fill with water, mainly from groundwater inflow, rainfall and pit wall runoff in the long-term. However, during the initial stages of closure the pit will also receive relatively substantial volumes of water pumped from the TSF seepage interception bores as well as underdrainage systems installed in Fim IIE and Fim III cells.

As the pit fills with water, the pit lake area will increase, thereby exposing a larger water body surface to evaporation losses. When total inflow rates are the same as the water losses through evaporation, the pit lake will reach equilibrium conditions, pit lake water levels will stabilise, and only seasonal fluctuations are expected thereafter. The pit lake modelling was developed based on the final pit shell design (Pit Design for s38 plus Inpit Dumps Single Surface.dxf) provided by KCGM (pers. com. Stephen Kable, Senior Strategic Planning Engineer, Northern Star Resources, email dated 1 April 2022).

GRM used this pit shell to develop the elevation-area-volume stage curve for the pit. The stage curve was used to determine the pit water levels and pit lake areas as the pit fills with water. The maximum capacity of the pit void (i.e., the capacity to the lowest pit crest elevation at 351 m AHD) is 975 GL and the total area of the pit void is about 479 ha. The final pit void has a strike length of about 3,780 m and a width of about 1,610 m. The pit floor has an elevation of -390 m AHD. The crest elevation ranges from 351 m AHD at the southwestern corner of the pit to 390 m AHD along the northern corner of the pit (average about 360 m AHD). The depth of the pit from the average pit crest elevation is 750 m. Figure 9 shows a 3D rendering of the final pit shell without in-pit backfill.

The oxide interface occurs at elevations ranging between 280 m AHD along the southern and southwestern parts of the pit to 330 m AHD along the remaining sections of the pit. The oxide interface is at a higher elevation than the inferred pre-mining groundwater levels and much higher than the predicted equilibrium pit lake water levels described in more detail later. As such, the oxide layer does not affect the pit water balance significantly, nor is the presence of the pit lake expected to affect the stability of the upper pit slopes.

KCGM is planning to partially backfill the pit void with an in-pit WRD commencing in 2027 over a period of six years. The in-pit waste rock will significantly reduce the capacity of the pit void and this was taken in consideration during the development of the model. The in-pit WRD will occupy around 68 GL of volume within the portion of the void to be occupied by the lake (to -122 m AHD at equilibrium level), which is 58% of the total void volume to this depth. Figure 10 shows a 3D rendering of the final pit shell with in-pit backfill.

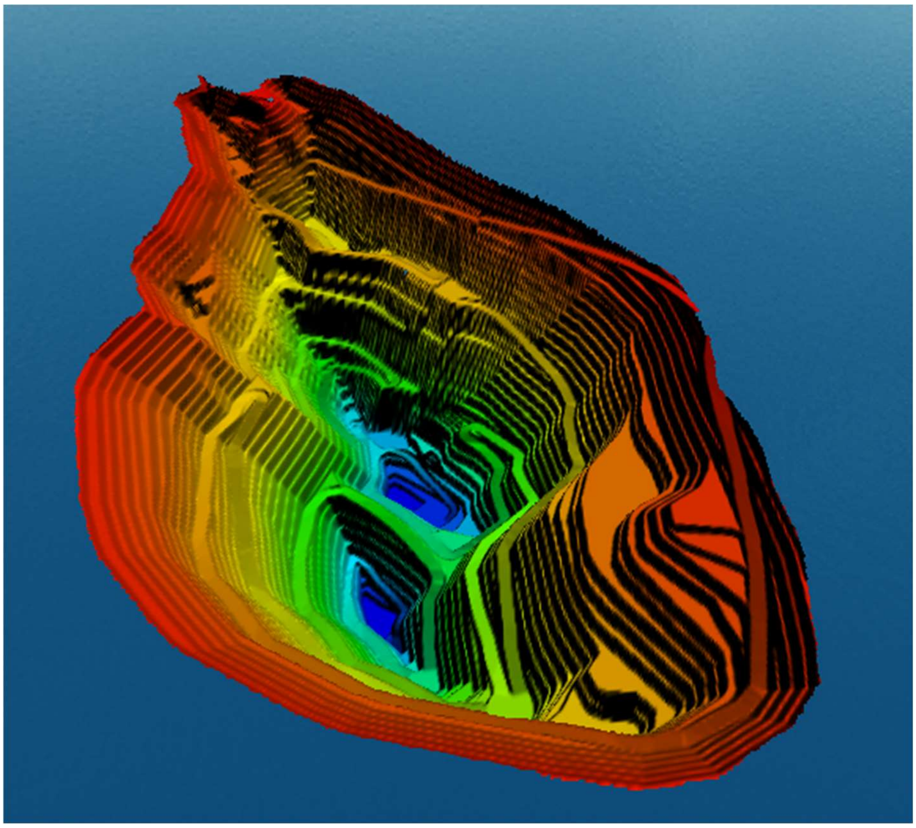

Figure 9: 3D rendering of the Fimiston Pit final pit void without in-pit backfill.

Source: Provided by GRM as part of this scope of work.

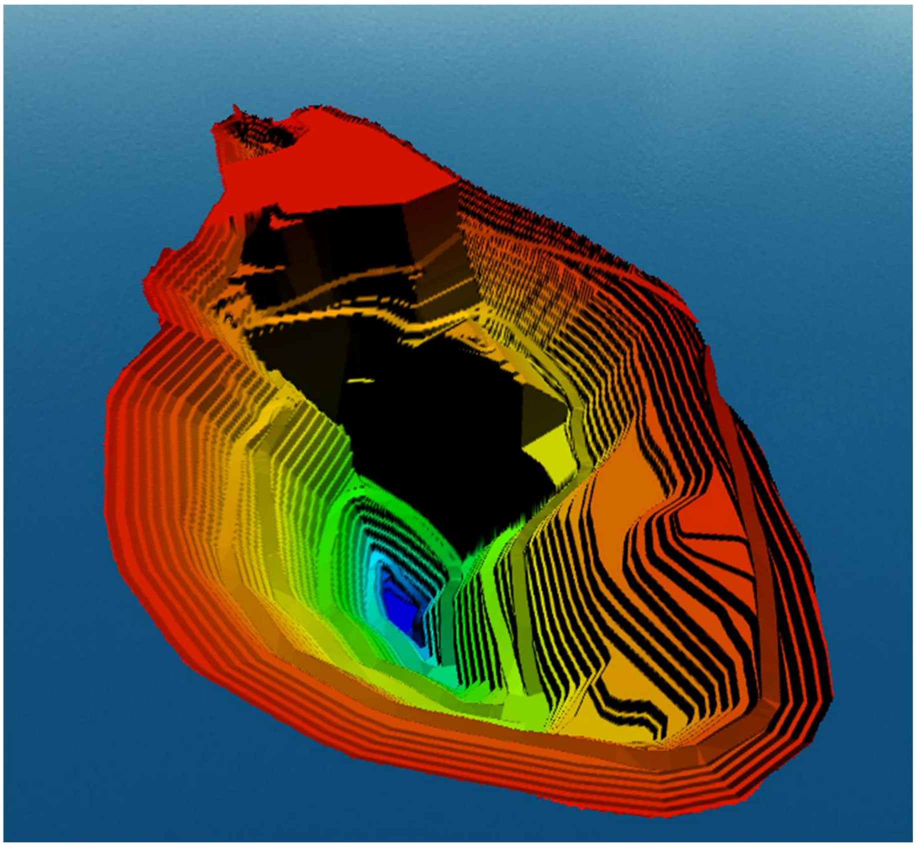

Figure 10: 3D rendering of the Fimiston Pit final pit void showing in-pit backfill .

Source: Provided by GRM as part of this scope of work.

The modelled inflows and outflows to the pit lake during the closure period are summarised in Table 2. Groundwater pumping and elevation data suggest that groundwater inflow rates reached near equilibrium conditions and groundwater inflow rates are unaffected by the pit lake levels up to an elevation of about -100 m AHD. The equilibrium conditions exist because bedrock below -100 m AHD is almost impermeable and groundwater inflow mainly occurs from the more permeable units above -100 m AHD, which flow into historical mine workings below the pit floor level.

The predicted Fimiston Pit lake areas after closure are presented in Figure 11. The results show the pit lake areas over a period of 566 years after closure and were developed by applying the stochastic rainfall and evaporation rates and running the GoldSim flow model for 1,000 realisations. Results are expressed in terms of probability of non-exceedance.

The model shows that the Fimiston pit lake is predicted to reach equilibrium approximately 400 years after closure. There is some variation of pit lake areas ranging between 38 ha and 66 ha at equilibrium with a median equilibrium value of 48 ha. The variation is mainly due to the uncertainties of the rate of evaporation, given effects such as wind shielding, shading, the effect of the lake area, salinity and increased solar radiation due to the higher pit wall albedo.

The predicted pit lake elevations are shown in Figure 12. Equilibrium (nominally 400 years post closure) pit lake level ranges between -159 m AHD to -69 m AHD with a median value of -122 m AHD. Equilibrium pit lake levels are about 473 to 493 m below the pit crest and 453 m deeper than the pre-mining groundwater level. The deep equilibrium pit lake levels are indicative of the high evapotranspiration potential in the region and the relatively low groundwater inflow rates. The maximum water depth at equilibrium is about 290 m. Figure 14 presents a 3D rendering of the pit lake with a water level at -122 m AHD. The model predicts that the lake will reach around 30% of the equilibrium depth after the first year post-closure and around three quarters (73%) of the equilibrium depth of the lake is attained during the first 50 years post-closure, after which the pit lake level rises steadily before reaching equilibrium levels. Seasonal water fluctuations are about 0.5 m though larger fluctuations will occur following large rainfall events.

Figure 13 shows the range in predicted pit lake volumes. Equilibrium pit lake volumes range between 51 GL to 110 GL with the median value of 72 GL. The large range of predicted pit lake volumes is mainly a function of the stage curve whereby a relatively small change in pit lake areas could cause a substantial change in pit lake volume. The predicted pit lake volumes are substantially smaller than the Fimiston Pit capacity of 975 GL. Whilst most of the equilibrium lake depth is attained 50 years post-closure, 55% of the equilibrium lake volume is attained at this time due to the quasi-inverse conical morphology of the void.

Table 2: Estimated inflows and outflows from the Fimiston Pit lake.

INFLOW/OUTFLOW	APPROACH	NOTES
Groundwater inflow	Based on estimated groundwater inflows as determined through calibration.	Assumed to be constant until it reached -100 m AHD, then gradually decreases.
Direct rainfall	Stochastic rainfall applied to the pit lake surface.	Pit lake surface area was modelled dynamically, i.e., lake surface increases as pit fills up with water.
Pit wall runoff	Based on estimated pit wall runoff coefficients as determined through calibration.	Includes pit wall runoff coefficients for both normal and high rainfall events.
Backfill runoff	Surface area of backfill estimated from the backfill schedule. Runoff assumed to be similar to runoff from WRDs	
Backfill seepage	Seepage assumed to be similar to toe seepage rates from WRDs	It has been assumed that a cover system will not be installed on the in-pit WRD.
TSF seepage interception and underdrainage	Post closure pumping rates from the seepage interception system estimated based mainly on monitoring data.	TSF seepage interception will be required for a relatively short period (10 to 15 years) and will have a small effect on pit water levels.
Mt Charlotte Underground Mine	Based on an earlier study.	Small inflows predicted.
Runoff from the WRDs	Based on Hydrus modelling of the rehabilitated WRD surfaces.	
Toe seepage from the WRDs	Based on the pre-mining surface contours and assumption of seepage rates.	Only a small section of WRDs produces toe seepage flowing to the pit.
Seepage from the WRDs flowing to the fractured bedrock groundwater system	Estimates based on observed groundwater levels responses from groundwater monitoring data.	Seepage rates are small.
Evaporation	Based on the stochastic evaporation applied over the pit lake surface.	Included a pan factor (0.63 with standard deviation of 0.05) to account for lower evaporation rates over a lake surface.

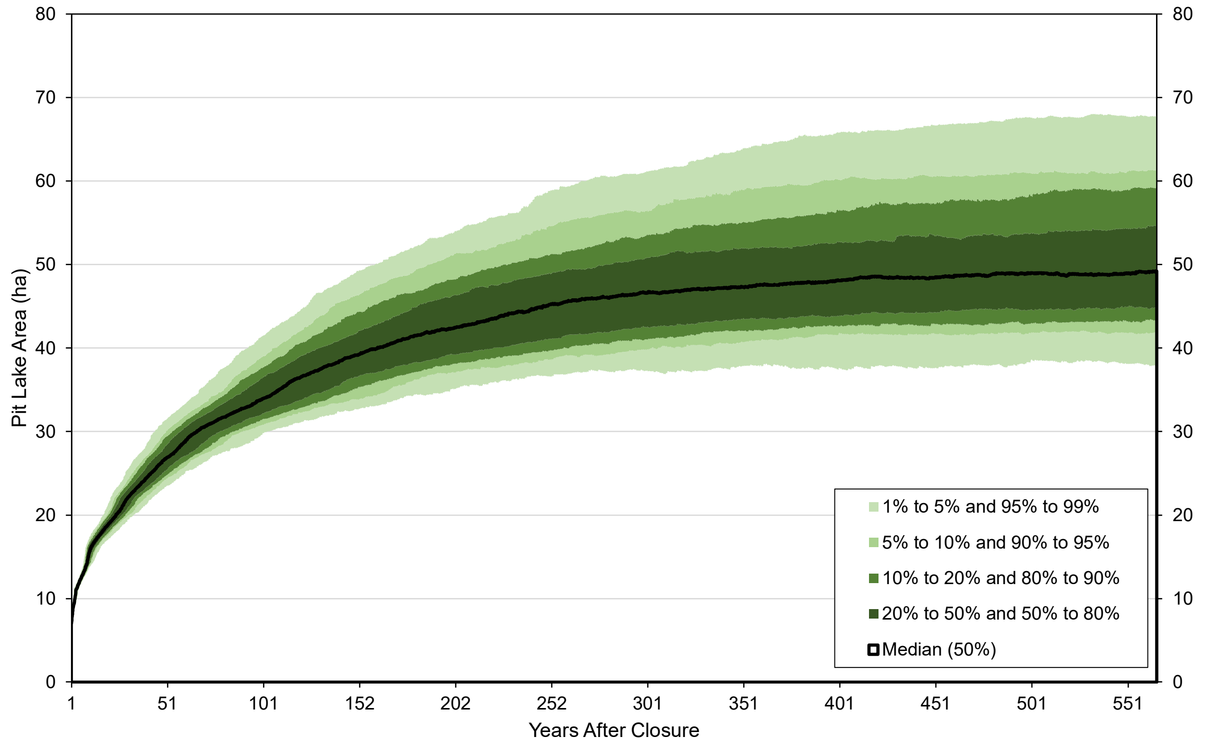

Figure 11: Predicted Fimiston Pit lake surface area (base case conditions).

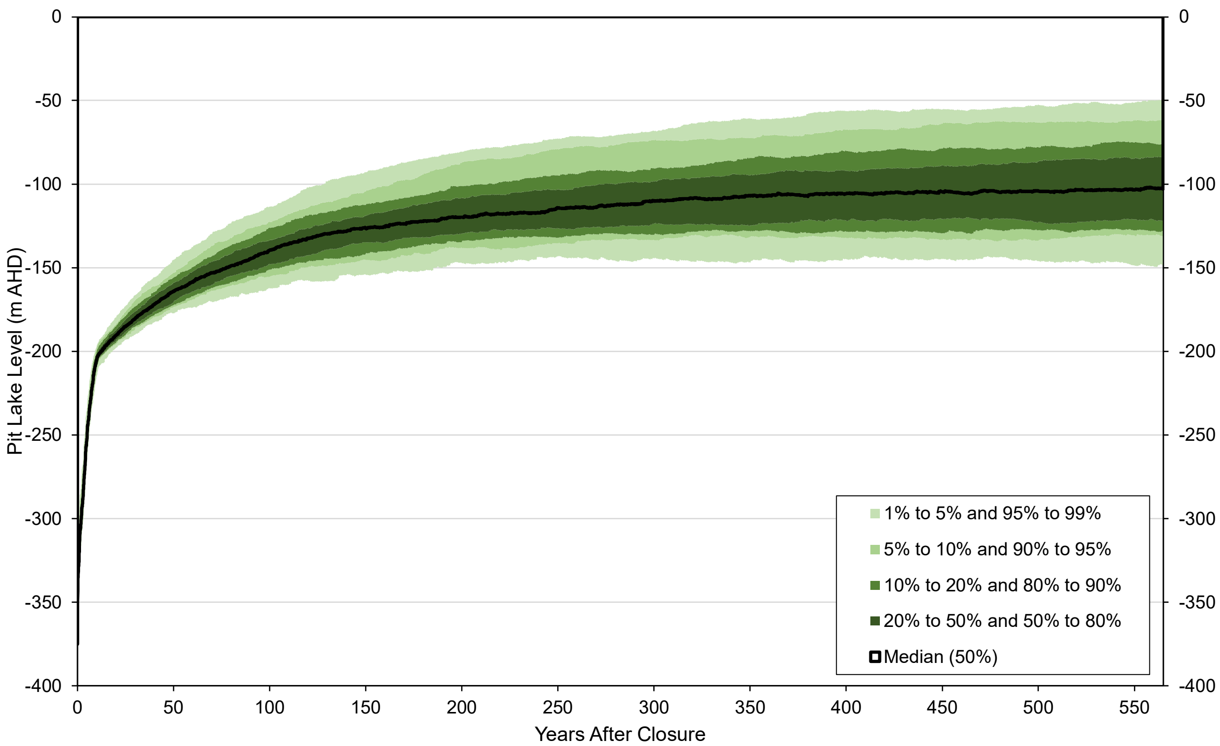

Figure 12: Predicted Fimiston Pit lake elevation (base case conditions).

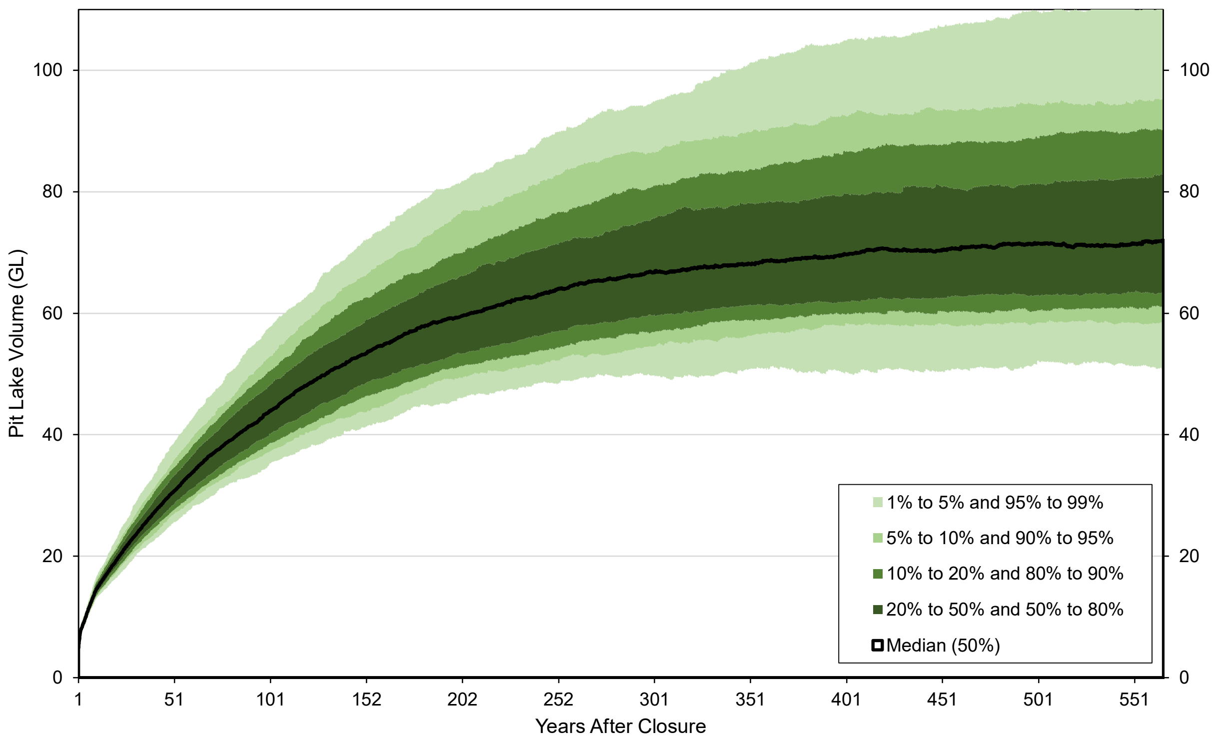

Figure 13: Predicted Fimiston Pit lake volume (base case conditions).

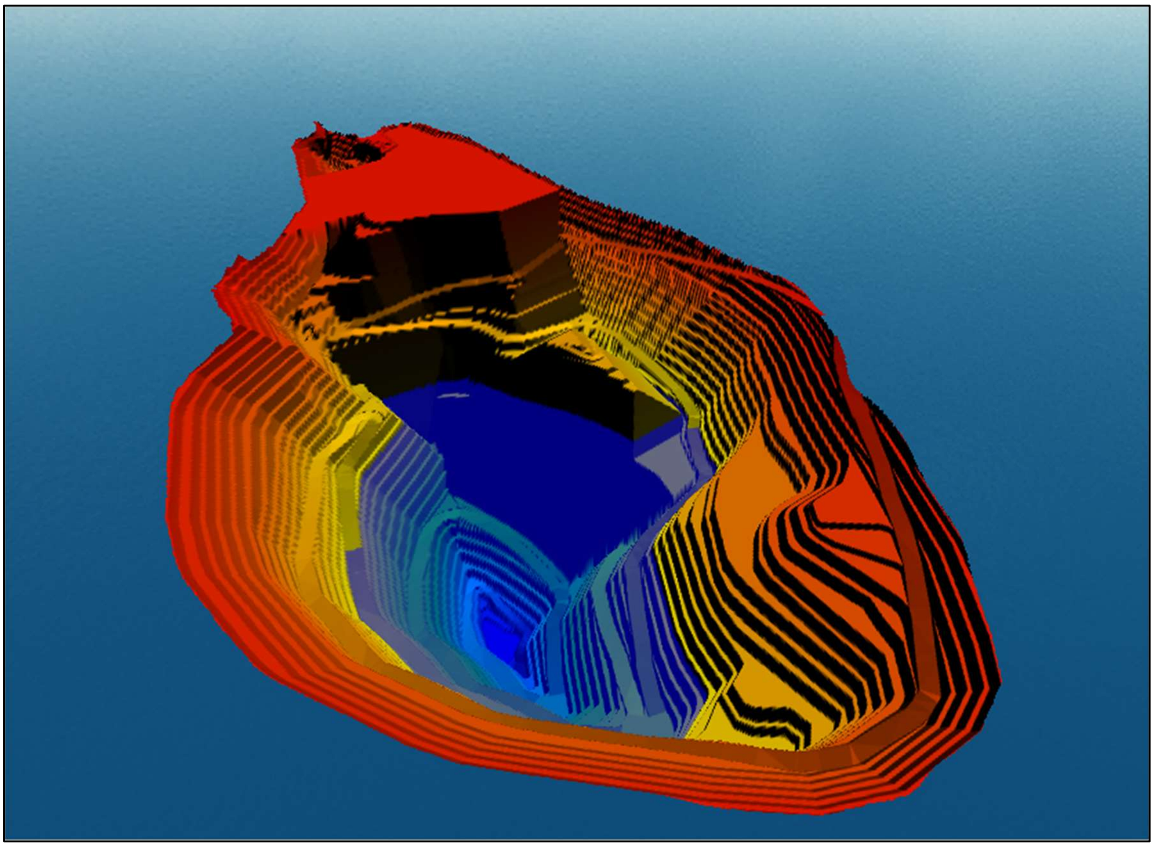

Figure 14: 3D rendering of the pit lake surface at -122 m AHD.

Source: Provided by GRM as part of this scope of work.

Figure 15 shows the contribution of inflows to the pit lake (base case conditions). Initially, intercepted TSF seepage and underdrainage inputs (tailings water) will be the largest inflow to the pit, representing up to 62% of water entering the pit lake in the first ten years after closure (nominally 2044). The next most substantial inflows at this time are groundwater (23%) and pit wall runoff (7%). With time, groundwater inflow and pit wall runoff will become the larger contributors to the pit lake. At 100 years after closure, groundwater inflow and pit wall runoff will comprise 51% and 14% of the pit lake inputs to date, respectively. Because tailings water inputs cease ten years after closure under base case conditions, their relative contribution to the total inflow volume during the first 100 years post-closure will be reduced to 14%. After 400 years post-closure groundwater represents over half (53%) of the total inflow volume to the lake, followed by pit wall runoff (14%), direct rainfall (13%) and runoff/seepage from the in-pit WRD (12%). All other inflows, including tailings water, represent less than 3% of the cumulative inflows up to that point in time.

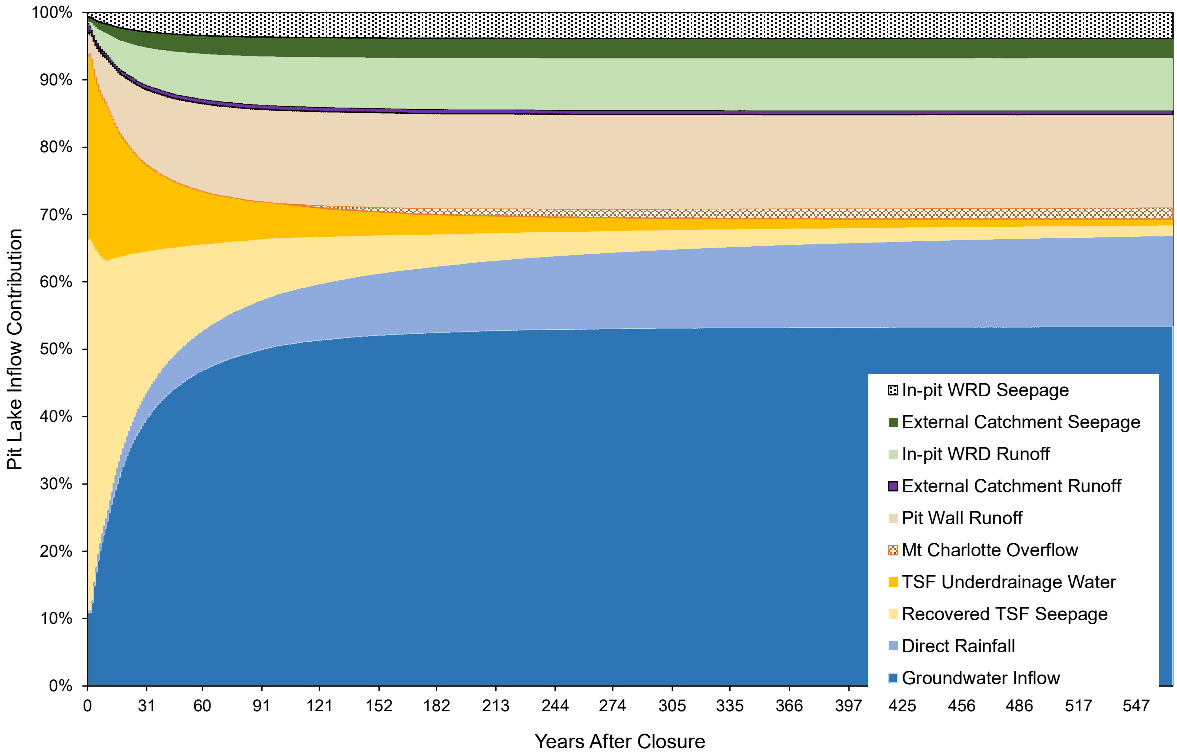

Figure 15: Predicted Fimiston Pit lake inflow contribution (base case conditions).

GRM carried out a sensitivity and uncertainty analysis to assess which model parameters could affect the future outcome of the model predictions as related to the pit lake water balance. An initial, qualitative assessment was undertaken to identify the key parameters which could affect the model outcome and required further assessment. Based on the initial assessment, two additional water balance model runs were undertaken, namely:

- A climate change scenario, whereby both long-term rainfall and evaporation rates increase in accordance with the latest climate projection models (Section 3.1); and
- A scenario whereby seepage and underdrainage interception water is pumped to the Fimiston Pit over a longer time period as discussed in Section 3.2.1. This scenario is considered to represent worst-case tailings water inflow estimates, based on observed draindown trends at the Kaltails TSF and the Fimiston I TSF during the operating period.

Results for the climate change scenario indicated that the range of predicted water levels at 400 years post-closure (between -145 m AHD and -60 m AHD) was slightly higher than those for the base case scenario (between -160 m AHD and -76 m), with a median level (-110 m AHD) around 12 m higher than the base case prediction. Compared to base case conditions at 400 years post-closure, cumulative proportional inflows from groundwater, rainfall and pit wall runoff were slightly higher (~ 2 percentage points) and evaporation rates from the pit lake surface are also higher. Predicted pit lake levels were similar because the increased average rainfall, which causes higher equilibrium water levels, would be being offset by the increased evaporation rates.

The results from the extended TSF inputs model scenario indicated that extending the duration of tailings water inputs from 10 years to 15 years post-closure will have a negligible influence on pit lake level and volume at 400 years post-closure (equilibrium) compared with the base case scenario. However, the predicted make-up of the pit lake water would be affected, especially during the early period of pit filling. The cumulative proportion of total inflow volume from recovered TSF seepage and underdrainage water at 100 years post-closure (30%) is higher than the equivalent for the base case scenario (14%). The difference is still notable at 400 years post-closure, whereby tailings water comprises 9.4% of total inflows for the extended TSF inputs scenario, compared with 3.6% for the base case scenario.

4 FIMISTON PIT LAKE HYDROGEOCHEMICAL MODEL

An integrated solute accounting, mixing, stratification and geochemical speciation model was developed for the Fimiston Pit lake, based on water balance and flow modelling described previously, as well as materials characterisation data and water quality monitoring data. Models were developed for baseline scenario, climate change scenario, and extended TSF inputs (seepage and underdrainage recovery) scenario.

4.1 Derivation of Hydrochemical Source Terms

Hydrochemical source terms were developed to represent the chemical characteristics of each pit lake inflow (e.g., groundwater inflow, TSF seepage) using a combination of water quality monitoring data and results from materials characterisation studies as summarised in Table 3. The chemical compositions of the resulting source terms are presented in Table 4 through to Table 6.

Table 3: Summary of source terms, data sources and considerations.

INPUT	DATA SOURCES AND CONSIDERATIONS
Groundwater	Water quality monitoring data from several bores intersecting voids beneath the Fimiston Pit, collected between 2005 and 2020. Using this monitoring data is likely conservative as water from the voids may already be affected by mining activities.
Rainwater	Data from rainfall composition monitoring network established by the CSIRO (Crosbie *et al*., 2012), using data from the Meekatharra monitoring site.
Pit wall runoff (dolerite and basalt lithologies)	Data from geochemical characterisation studies (e.g., static leachate testing data) of the main lithologies to be present on the pit walls at closure as reported in MBS (2020).
Pit wall runoff (Black Flag shale)	Synthesised leachate and acid base accounting (ABA) data from field-based kinetic weathering trials (MBS, 2017; 2020) and geochemical characterisation studies (MBS, 2017; GCA, 2010). Consideration given to the variable potential for exposed shale to generate acid and metalliferous drainage (AMD) and neutral metalliferous drainage (NMD), estimates of sulfide oxidation rates from kinetic trials and potential weathering (sloughing) rate of pit wall shale (pers. com. Charlotte Woolley, Geotechnical Superintendent, Northern Star Resources, email dated 17 August 2021). Source term is conservative given apparent evapoconcentration of leachates from kinetic weathering trials (i.e. dilution can reasonably be expected to reduce concentrations in pit wall runoff under high rainfall event conditions).
Reactive pit wall carbonate	Data from geochemical characterisation studies as summarised in MBS (2020) and GCA (2010). Assumptions around pit wall weathering depth were used to estimate carbonate potentially available to neutralise pit water acidity.

INPUT	DATA SOURCES AND CONSIDERATIONS
Reactive carbonate from in-pit WRD	Data from geochemical characterisation studies as summarised in MBS (2017; 2020) and GCA (2010). Assumptions around reactive ANC availability based on estimated median waste rock particle diameter and reaction depth, and a nominal volume (2 m^3 per m^2 exposed to lake water) of in-pit waste providing neutralising capacity to the pit water.
TSF seepage recovery water	Water quality monitoring data from process plant (mill) inputs from bore fields collecting seepage-affected groundwater at Kaltails, Fimiston I and II TSFs collected between February 2013 and April 2020.
TSF underdrainage recovery water	Water quality analysis (metals, metalloids etc.) for decant from Fimiston II TSF (MBS, 2016) and cyanide monitoring data for decant from Fimiston II TSF (September 2021 – March 2022) provided by KCGM (pers. com. Genevieve Tait, Environmental Advisor, email dated 16 March 2022).
Mt Charlotte underground floodwater	Water quality monitoring data from samples reflecting dewatering the underground workings and various groundwater inflow seepage locations, between January 2014 and February 2016.
Waste rock runoff and seepage	Water quality data for samples collected from ramps leading into the pit (May 2020) and reflecting inputs of WRD toe seepage at several locations between July 2009 and February 2020. Adjustments to salinity and major ion composition were made to account for inputs of saline water used for dust suppression (where not reflective of closure conditions).

Table 4: Source term composition for groundwater, rainfall, Mt Charlotte floodwater and waste rock runoff and seepage.

PARAMETER (mg/L)	GROUNDWATER	RAINFALL	MT CHARLOTTE FLOODWATER	WASTE ROCK RUNOFF AND SEEPAGE
TDS	64,344	11.6	36,960	10,883
pH	7.4	-	6.9	6.9
Density (kg/L)	1.03	1.00	1.03	1.00
Alkalinity as HCO_3	342	2.4	183	39
Ag	0.01	-	0.0005	0.1
Al	0.05	0.03	0.02	0.05
As	0.02	-	0.001	0.02
B	5.5	-	5	3.5
Ba	0.08	-	0.07	0.2
Ca	1500	0.95	1,500	70
Cd	-	-	0.0005	0.008
Cl	35,000	2.4	19,834	6,300
Cyanide (total)	-	-	-	-
Co	0.1	-	0.05	0.28
Cr	0.005	-	0.0025	0.03
Cu	0.2	-	0.01	0.26
F	0.2	0.03	0.2	0.2
Fe	7	-	0.02	-
K	200	0.2	160	32
Mg	2,600	0.4	1,500	470
Mn	4	0.04	0.3	5.8
Mo	0.02	-	0.007	0.2
Na	19,000	1.9	10,000	3,300
Ni	0.015	-	0.03	0.05
Pb	0.005	-	0.001	0.005
Sb	0.005	-	0.002	0.005
Se	-	-	0.002	-
SO_4	6,000	1.6	3,700	550
Sr	20	-	-	-
U	-	-	-	-
Zn	0.1	0.09	0.05	0.1

Values presented in mg/L unless otherwise stated. Dashes indicate that no value has been defined (i.e., not indicated as present based on laboratory analysis).

Table 5: Source term composition for runoff from key lithologies exposed on the final pit walls.

PARAMETER (mg/L)	DOLERITE	BASALT	OXIDE ZONE BLACK FLAG SHALE	OXDISED UNWEATHERED/TRANSITION ZONE BLACK FLAG SHALE
TDS	104	137	95	44,055
pH	8.7	8.8	8.8	2.6
Density (kg/L)	1.00	1.00	1.00	1.00
Alkalinity as HCO_3	26	46	6.6	-512*
Acidity as $CaCO_3$	-	-	-	3,500*
Ag	0.025	-	0.26	0.007
Al	1.1	1.0	0.7	542
As	0.002	0.02	0.03	0.13
B	-	-	-	3.8
Ba	0.002	0.001	0.003	0.026
Ca	13	13	9.8	518
Cd	-	-	-	2.3
Cl	45	46	41	10,929
Co	-	-	-	21
Cr	-	-	-	1.1
Cu	-	-	-	170
F	0.09	0.07	0.12	-
Fe	-	-	-	141
K	4	5	14	68
Li	0.008	0.007	0.004	-
Mg	6	4	5	5,206
Mn	0.004	0.01	0.001	99
Mo	-	-	0.006	0.004
Na	7	20	5	5,054
Ni	-	-	-	24
Pb	-	-	-	0.26
Sb	0.004	0.015	0.12	0.002
Se	-	-	-	0.45
SO_4	2	2	13	21,694
Sr	0.04	0.03	0.08	-
U	-	-	-	0.028
V	-	-	-	0.82
Zn	-	-	-	80

**Negative alkalinity predictions by PHREEQC are not analogous to acidity. Acidity was estimated from aluminium (assuming Al^{3+}), iron (assuming Fe^{2+}), manganese concentrations and pH. Note that acidity estimates are presented for reference purposes and were not explicitly used in the PHREEQ model.*

Table 6: Source term composition for recovered groundwater seepage and underdrainage water.

PARAMETER (mg/L)	RECOVERED TSF SEEPAGE		TSF UNDERDRAINAGE: FIMISTON I/II/III
	KALTAILS	FIMISTON II/II/III	
TDS	81,622	111,580	142,284
pH	2.8	2.9	7.9
Density (kg/L)	1.1	1.1	1.07
Alkalinity as HCO_3	-133*	-82*	183
Acidity as $CaCO_3$	1,300*	1,460*	-
Ag	0.01	0.01	0.24
Al	215	249	2.3
As	0.005	0.005	0.006
B	8.8	8	10
Ba	0.03	0.04	0.49
Ca	1,100	2,500	2,827
Cd	-	-	-
Cl	46,241	65,733	78,153
Cyanide (total)	1.1	0.7	30
Co	2.9	1.5	2.8
Cr	0.1	0.04	0.06
Cu	0.13	0.02	32
F	0.3	0.3	0.26
Fe	4.4	0.7	1.8
K	130	300	568
Hg	-	-	0.046
Mg	3,429	2,690	4,130
Mn	8.8	5.5	0.69
Mo	-	-	0.17
Na	24,491	35,860	47,762
Ni	0.5	0.25	1.3
Pb	0.1	0.2	0.03
Sb	0.005	0.005	0.13
Se	0.05	0.05	0.3
SO_4	6,123	4,283	8,579
Sr	24	38	-
U	0.01	0.05	0.001
Zn	0.05	0.07	0.06

**Negative alkalinity predictions by PHREEQC are not analogous to acidity. Acidity was estimated from aluminium (assuming Al^{3+}), iron (assuming Fe^{2+}), manganese concentrations and pH. Note that acidity estimates are presented for reference purposes and were not explicitly used in the PHREEQ model.*

4.2 Potential for Stratification

Limnological modelling was undertaken as part of the previous study for the Fimiston Pit lake (MBS, 2021), using the one-dimensional General Lake Model (GLM Version 3) to predict whether a stratified lake is likely to form. Given the close similarity between the closure conditions for the previous and current studies, the findings were used to inform the solute accounting and mixing components of the model. The outcomes of the limnological modelling are summarised herein.

The GLM computes vertical profiles of temperature, salinity and density by accounting for the effect of inflows/outflows, mixing and meteorological factors. Meteorological parameters were derived from rainfall data for Kalgoorlie-Boulder Airport (1989 – 2020, BoM 2020) and others (solar radiation, cloud cover, air temperature, humidity and windspeed) were derived using data from the SILO database (Queensland Department of Environment and Science). The 1-D approach adopted by GLM resolves a vertical series of layers that capture the variation in water column properties, which is suitable for a wide range of lakes (including pit lakes) and climatic conditions (Hipsey et al. 2019).

For up to 50 years post-closure, the lake was predicted to be stratified whereby a layer of less saline water (less than 20 m deep) was predicted to form above a deeper, more saline and denser body of water (Figure 16). The salinity of the surface layer was predicted to be in the order of 10,000 – 30,000 mg/L TDS (total dissolved solids) compared with the underlying water with salinity in the order of 60,000 – 100,000 mg/L TDS. After this initial period, the salinity stratification was predicted to break down, resulting in a fully mixed lake for the remainder of the projection period (up to 566 years post-closure).

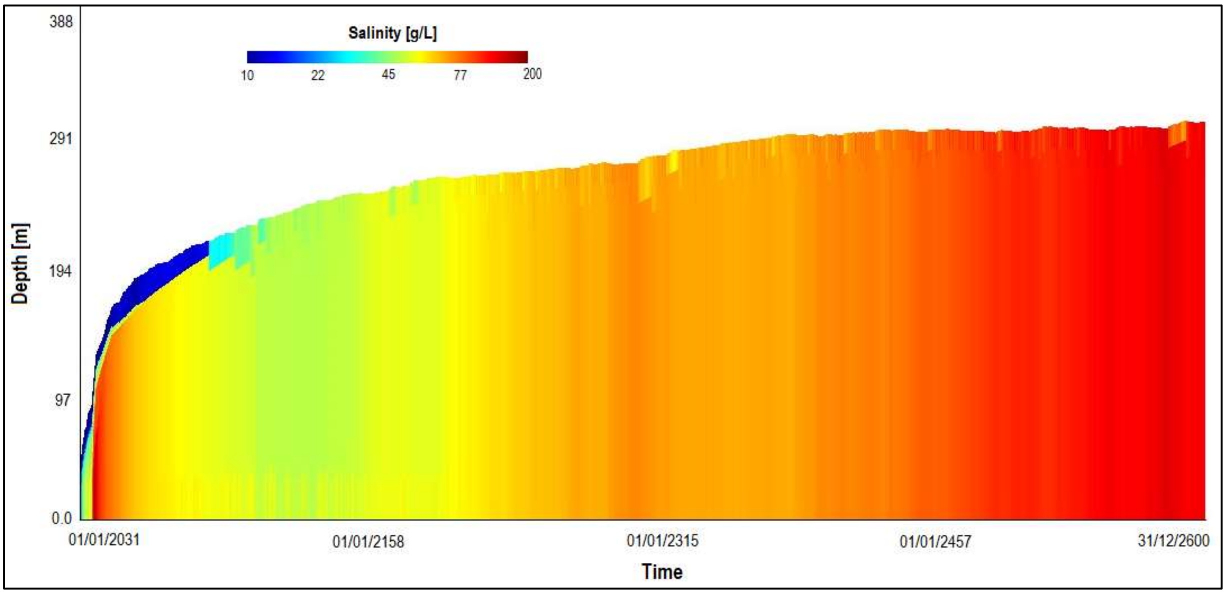

Figure 16: Modelled vertical distribution of salinity.

Source: MBS (2021)

The prediction of a temporary ‘lens’ of lower salinity water during the early development of the pit lake is attributable to several factors:

- Inputs of pit wall runoff, which was characterised as having low salinity (most of the pit walls were assigned a salinity equivalent to <140 mg/L TDS excepting minor proportions of more concentrated runoff from Black Flag shale), are expected to comprise a substantial proportion of the inflow during early stage lake filling due to the large, exposed pit wall catchment relative to the volume of the lake;

- Inputs of highly saline TSF seepage recovered from multiple TSFs (up to 112,000 mg/L TDS) was predicted during this phase of the lake development;
- Contrasting salinity and temperature (hence density) of these two inputs was considered to drive the predicted formation of the surface lens; and
- The density disparity driving the formation of the lens was expected to diminish once inputs of recovered TSF seepage cease and inflows of saline groundwater (64,000 mg/L TDS) make a larger proportion of the lake volume relative to pit wall runoff and rainfall.

Predicted surface (top 20 m of the lake) and sub-surface (>20 m) water temperatures (Figure 17) indicated a stable subsurface temperature of approximately 16 °C. The temperature at the lake surface was predicted to fluctuate with annual seasonal cycles, ranging between 13 °C to 28 °C. The lack of temperature disparity between surface and subsurface water on the annual timescale is consistent with the lack of salinity stratification on the timescale of the model.

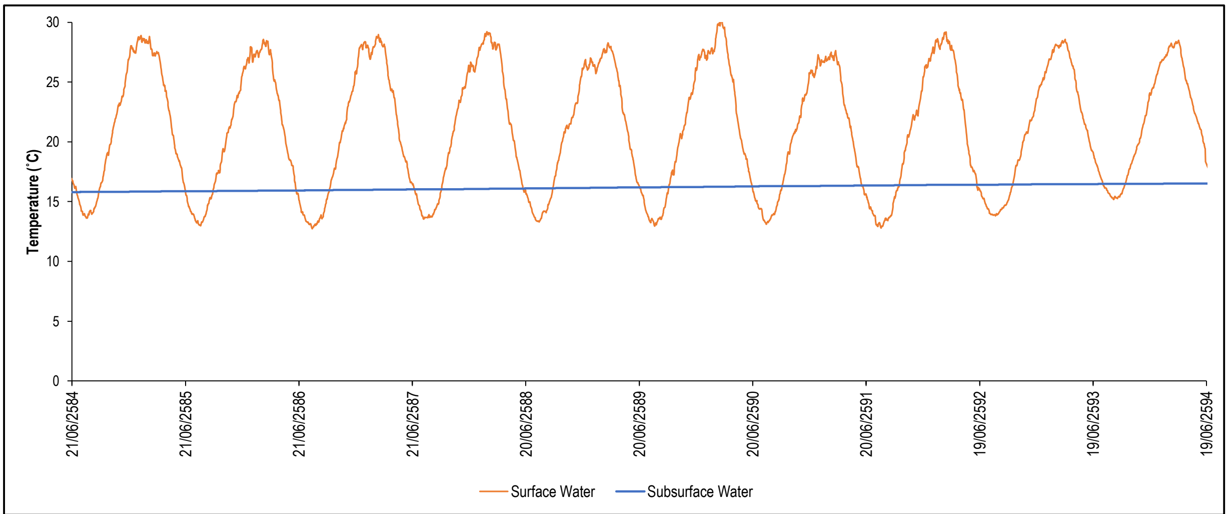

Figure 17: Surface and subsurface temperature variations.

Source: MBS (2021)

4.3 Solute Accounting, Mixing and Geochemical Speciation

Solute accounting (i.e., attribution of hydrochemical source terms to pit lake inflows), mixing and geochemical speciation were integrated into a single PHREEQC geochemical speciation model (USGS 2021), including sequential mixing and geochemical reactivity of lake water in ten intervals spanning the time from mine closure and when an equilibrium pit lake level is expected to be attained (up to 566 years post-closure). The model intervals are shown alongside predicted pit lake depth in Figure 18.

For the water in each mixing interval (base case model), the model incorporated:

- Mixing of each source term in proportions equivalent to the inflows calculated for the closure water balance model;
- Concentration of the resulting mixed lake water by removal of pure water, representing evapoconcentration as calculated from the closure water balance;

- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for mechanisms including:
  - Equilibration with atmospheric gases (O_2 and CO_2);
  - Precipitation of secondary minerals, principally hydrated oxides, predicted to be oversaturated in the mixed lake water; and
  - Adsorption of dissolved metals and metalloids to hydrous ferric oxide (HFO) as represented by precipitated iron (hydr)oxide minerals.

The solution composition and mineral phase assemblages from each mixing interval were incorporated into the subsequent mixing interval. In this way, the model was a reactive mixing model simulating geochemical reactivity and evapoconcentration as a sequential, dynamic process.

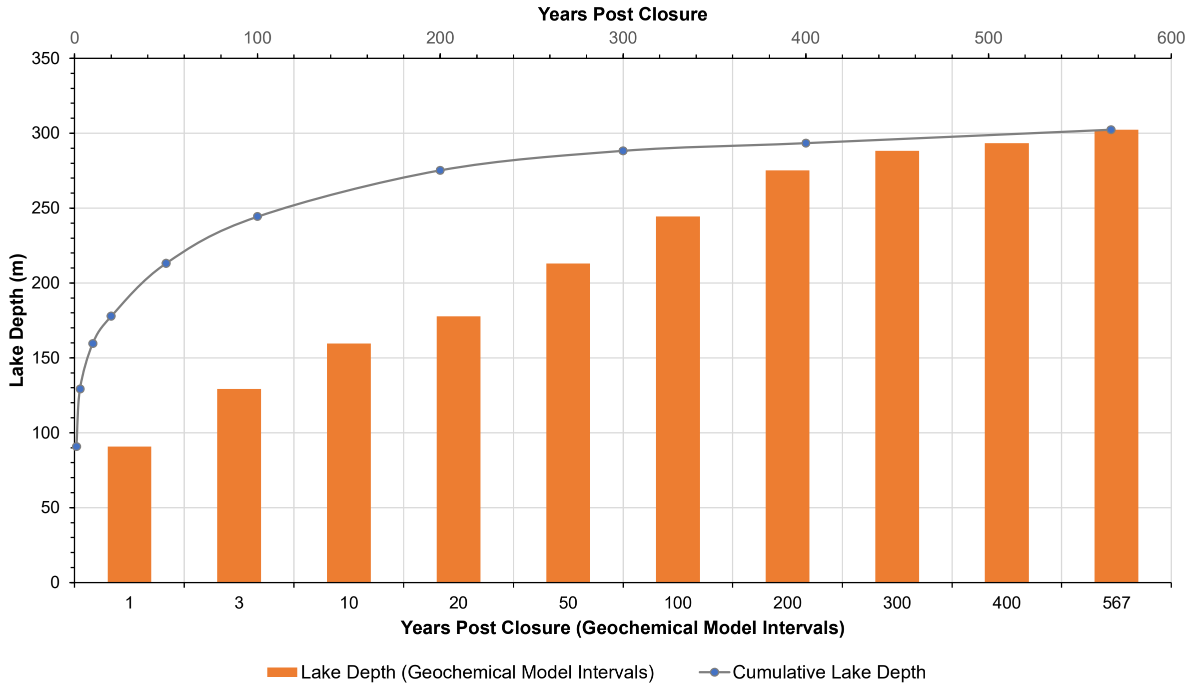

Figure 18: Cumulative lake depth and model intervals vs. year post-closure.

Based on the limnological model findings (Section 4.2), two bodies of water were defined in the base case hydrogeochemical model (upper and lower strata) for the initial five projection intervals, which covered the period up to 50 years post-closure:

- The upper stratum received most of the inflow from less saline, less dense inputs (direct rainfall, runoff from pit catchment) and was subject to evaporation. All rainfall was assigned to the upper stratum as well as 90% of the pit wall runoff and ex-pit catchment runoff to maximise consistency between hydrogeochemical and limnological model predictions;
- The lower stratum received all inflows from more saline, denser water sources (TSF seepage and underdrainage water and groundwater) but was not subjected to evaporation loss; and
- At the point where the stratification was predicted to diminish (nominally 75 years post-closure), the two bodies of water were completely mixed. The mixing model from this point onwards reflected a fully mixed lake.

Given that an unstratified model provides a satisfactory long-term representation of the lake geochemistry, unstratified models were developed for the two sensitivity scenarios (climate change, extended TSF inputs – refer to Section 3.2.4). The results were compared with an unstratified base case model to identify sensitivity of the model outcomes with respect to these three scenarios.

4.4 Limitations and Assumptions

The following assumptions and limitations apply to the solute balance and geochemical speciation modelling and the adopted conceptual pit lake model:

- All reports and data provided to MWM and GRM were accepted as accurate and representative.
- The outputs of water balance models developed by GRM and provided to MWM were accepted as accurate and fit for purpose.
- Modelling did not explicitly account for the rates (i.e. kinetics) of gas exchange, mineral dissolution and mineral precipitation, which are processes occurring simultaneously. Rates of these processes will affect the accuracy of pH predictions over time and consequently pit lake solute composition. Results from more extensive kinetic trials would be required to define solute release rates.
- Thermodynamic speciation codes such as PHREEQC rely on solution equilibria data generated by laboratory studies of solutes for low to moderate ionic strength solutions, corresponding with fresh to slightly saline conditions. Modelling highly saline solutions represents an extrapolation of solution equilibria data, which may affect the accuracy of predictions for various metals and metalloids.
- The geochemical model does not simulate biochemical processes; therefore, concentrations of biologically important species (nitrate, phosphate, and silicon) were not adjusted for biochemical processes.
- The geochemical model does not simulate oxidative degradation of cyanide (i.e. cyanide is treated as a conservative ion); therefore, predicted concentrations are overestimated. Cyanide (e.g. from tailings water inflows) will break down when exposed to circum-neutral water, oxidants and ultraviolet light. Given these limitations, predicted cyanide concentrations should be interpreted as maximum potential concentrations rather than likely concentrations.
- The GLM 3.0 limnological model is one-dimensional and assumes no horizontal variability in lake water temperature, density or salinity. As such, only variations in the vertical dimension of the lake (depth) are predicted. The model is considered fit for purpose, given the long timescale for the model predictions and level and quality of available input data.
- Parameters used to estimate quantities of reactive pit wall and in-pit WRD carbonate, which provide acid neutralisation for the pit lake, were nominal and based on reference information and estimates. Whilst intentionally conservative values were adopted, the actual reactive carbonate quantity was not determined by geochemical measurements.

4.5 Long Term Pit Lake Quality Predictions

4.5.1 Salinity and pH

Predicted pit lake pH, salinity and major ion concentrations for base case conditions (stratified) are presented in Table 7. Equivalent results for the sensitivity analysis scenarios are provided in Appendix A.

The trend for predicted pit lake pH was consistent for the three model scenarios (Figure 19). During the first three years post-closure a substantial proportion of the inflow volumes will be acidic TSF seepage recovered from groundwater and moderately acidic runoff from Black Flag shale exposed on the lower levels of the pit walls. Throughout this early stage the lake is predicted to be moderately acidic (pH 4.0 – 4.1) which reflects the rapid inflow of acidic water, limited availability of acid buffering capacity attributed to the pit walls and limited time for acid buffering reactions with the pit wall to occur (note that the in-pit WRD, which also provides buffering capacity, will not directly interact with the lake during this time).

After ten years post-closure, circumneutral conditions (pH 6.7 – 7.2) are predicted under all model scenarios (comparisons between scenarios refer to unstratified conditions). This reflects additional acid buffering capacity available from the pit walls and the in-pit WRD (dolomite and basalt), which will be largely submerged, as well as alkalinity associated with more substantial proportions of inflows such as groundwater. Whilst buffering capacity provided by pit walls and in-pit waste rock have a significant influence on lake pH during the first 100 years post-closure, the effect of dilution and alkalinity associated with long-term groundwater inflows means that the lake is predicted to become circumneutral within 100 years even if those lithologies provide no buffering capacity (Figure 20). Apart from levels of acidity, the key influence of acid buffering on water quality in the lake during the first 100 years post-closure is the constraint that increased pH places on concentrations of metals with highly pH-dependent solubility (aluminium, copper, and manganese).

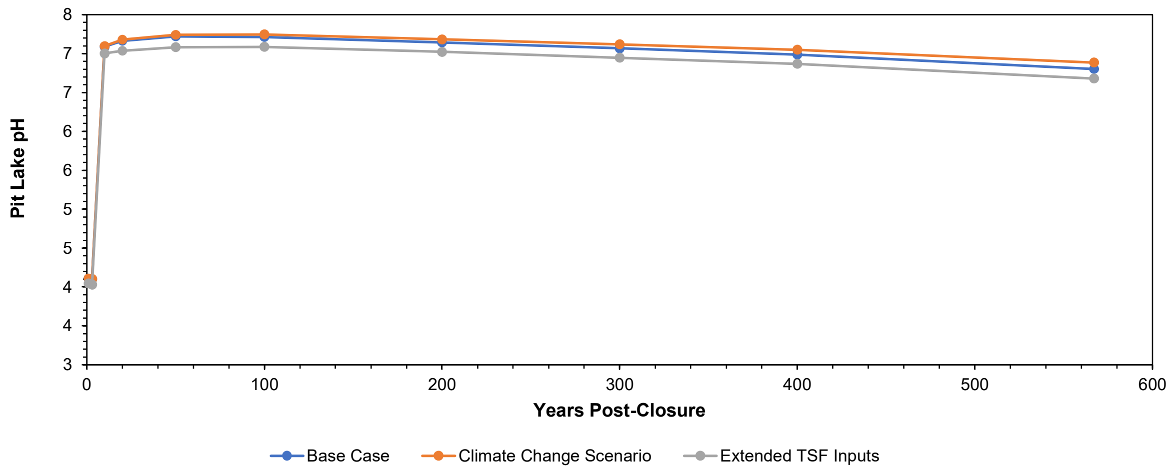

Figure 19: Comparison of lake pH for base case and sensitivity scenarios – unstratified conditions.

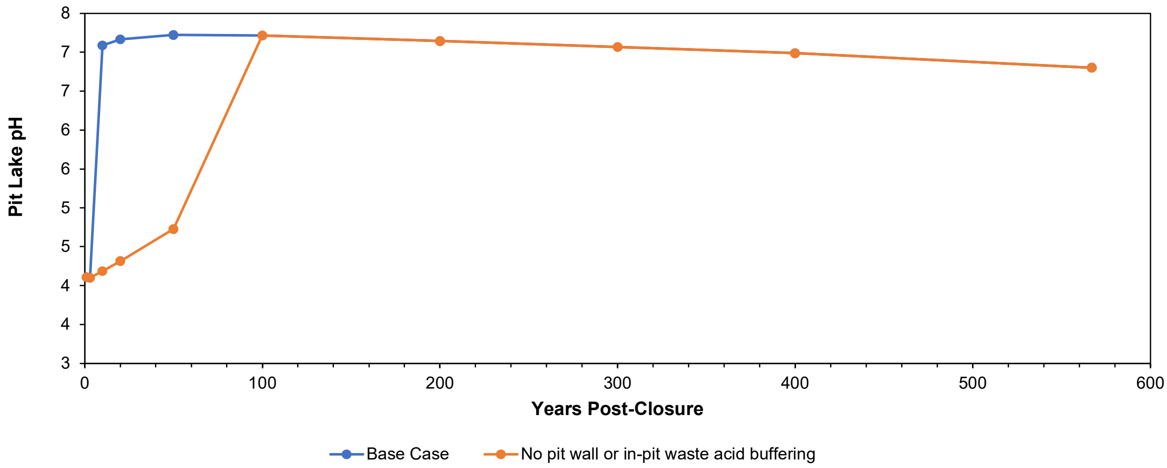

Figure 20: Effect of acid buffering capacity from pit walls and in-pit waste work on lake pH evolution.

Pit lake salinity (expressed as TDS) is predicted to follow the same overall trend for the three model scenarios (Figure 21). Due to the initial inputs of saline TSF seepage and underdrainage water stored in the lake after closure, the lake will have high salinity from the early stages of filling. In the first 10 years post-closure, salinity is expected to be in the order of 100,000 mg/L TDS (hypersaline) regardless of model scenario. In each scenario salinity is predicted to decrease from 10 to 20 years post-closure as inflows of less saline water begin to comprise a larger proportion of the lake volume. From 200 years post-closure onwards, salinity is predicted to start increasing due to evapoconcentration effects and continual inflow of saline groundwater. The final (566 years post-closure) salinity is expected to be in the order of 130,000 – 170,000 mg/L TDS depending on the model scenario. The climate change scenario yields the lowest overall salinity, which can be attributed to slightly larger inputs of less-saline inflows (i.e., rainwater), whilst the extended TSF inputs scenario yields the highest salinity owing to more substantial volumes of highly saline seepage/underdrainage water.

The dominant ions in the lake are predicted to be sodium, chloride and sulfate, reflecting the composition of the major inflows (e.g., groundwater and pit wall runoff). Calcium and magnesium concentrations are expected to be lower since they are likely to be constrained by precipitation of dolomite ($CaMg(CO_3)_2$).

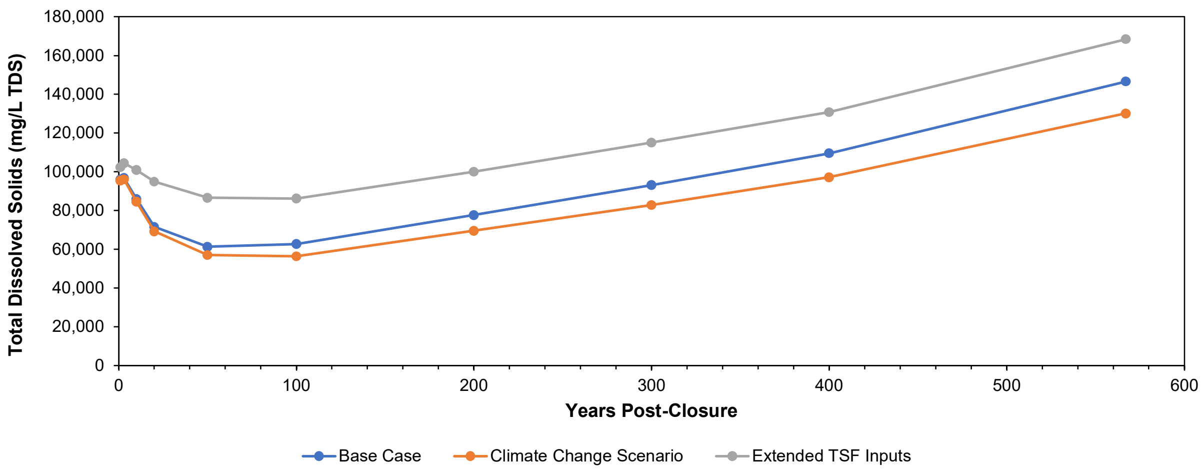

Figure 21: Comparison of lake salinity (TDS) for base case and sensitivity scenarios.

The predicted effects of stratification on salinity during the first 50 years of the pit lake development, as shown for the base case model in Figure 22, include:

- Water in the upper stratum is predicted to be saline, in the order of 8,000 – 17,000 mg/L TDS for the first 50 years post-closure, reflecting the accumulation of water from relatively less saline inflows (i.e. pit wall runoff, rainwater) above a denser lower stratum. Increases in salinity reflect evapoconcentration from this stratum as well as the salinity of the inflows;
- Water in the lower stratum is predicted to be hypersaline (order of 100,000 mg/L TDS) within the first 3 years post closure, due to the accumulation of highly saline and dense TSF seepage/underdrainage inputs in this deeper portion of the lake. Salinity is predicted to decrease to around 75,000 mg/L between 10 and 50 years post-closure, as inflows of less saline water (i.e., groundwater) start to comprise a larger proportion of the volume in this stratum; and
- The strata are predicted to converge (nominally 70 years post-closure), from which time relatively linear increases in salinity are expected due to continual inflows of saline groundwater and evapoconcentration.

Stratification effects related to pH are not expected to be significant, with the upper stratum pH being up to 0.4 units higher than the lower stratum for the first 50 years post-closure.

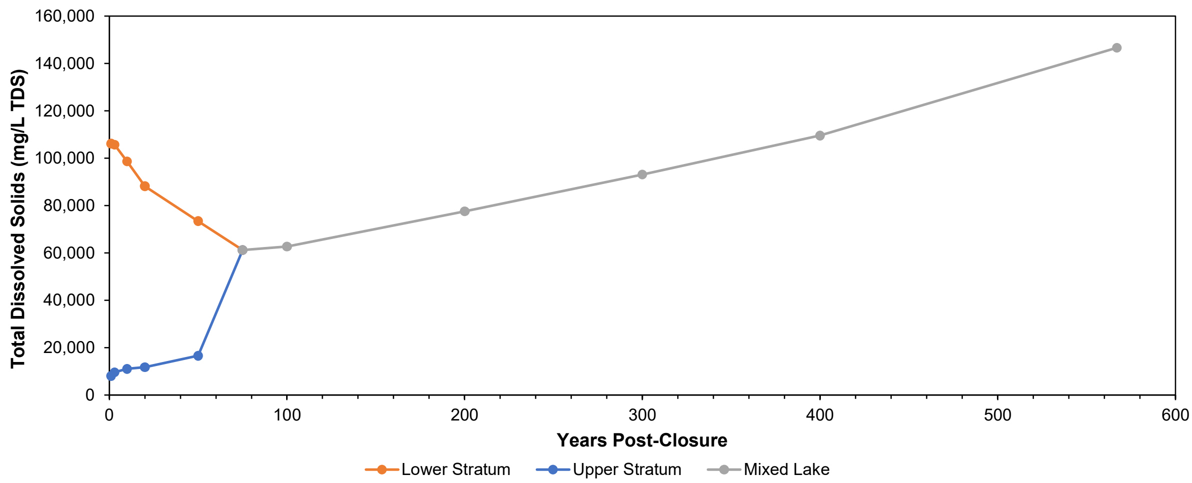

Figure 22: Predicted lake salinity under stratified and unstratified base case conditions.

4.5.2 Metals, Metalloids and Trace Ions

Predicted concentrations of metals and metalloids for the stratified base case model, over the projected timeframe of 566 years post-closure, are presented in Table 8.

To identify potential water quality hazards, concentrations were compared to livestock drinking water Default Guideline Values (DGVs, ANZECC 2000/ANZG 2018) and Non-Potable Groundwater Use (NPUG) guideline values (DER, 2014). Note these guideline values were used for comparison/screening purposes only and are conservative since pit lake water (and local groundwater) has no identified beneficial uses other than mining due to high salinity.

Comparison against screening values indicated that concentrations of arsenic, barium, cobalt, chromium, fluoride, iron, lead, lithium, manganese, strontium, uranium, vanadium and zinc are predicted to remain relatively low during the 566 year projection period, indicating these elements are of limited environmental significance within the lake post-closure.

Despite being overestimated (i.e., breakdown through photooxidation was not accounted for in the model), predicted cyanide concentrations are low at the lake surface (<0.1 mg/L total cyanide). The model predicts more elevated cyanide concentrations in the lower stratum (up to 50 years post-closure) and then continual decreases for the remainder of the projection period because cyanide is only significant in TSF underdrainage water to be stored in the lake during the first decade post-closure (Table 6). In the long-term dilution from other inflows exceeds the effect of evapoconcentration, although more realistically the cyanide would not be environmentally stable over such a long period and levels would be expected to diminish much more rapidly than predicted by the model. Cyanide complexation also increases metal/metalloid solubility, indicating that modelling cyanide conservatively also results in some overestimation of dissolved metal/metalloid concentrations in the lake.

Elevated concentrations of aluminium (9-117 mg/L) and copper (4-10 mg/L) were predicted to exist within the lake during the first 3 years post-closure, which can be attributed to high concentrations of these elements present within TSF seepage/underdrainage inflows and the acidic conditions (pH 4) expected to prevail for this short period (Figure 23 and Figure 24). After 10 years post-closure, predicted concentrations of these elements diminish to essentially negligible levels as they are sparingly soluble under circumneutral conditions expected from this time and precipitate with secondary minerals (i.e. gibbsite) or chemisorb to surfaces of minerals such as iron oxyhydroxides.

Trends for dissolved metals and metalloids that are expected to become more concentrated in the upper stratum of the lake versus the lower stratum (those exceeding screening values), which includes cadmium, molybdenum and nickel, are shown in Figure 25 to Figure 27. The accumulation of these elements in the upper stratum can be attributed to their presence in pit wall runoff (particularly runoff from unweathered Black Flag shale), which is apportioned to the upper stratum in the stratified model. Whilst cadmium and nickel concentrations are expected to remain relatively stable under unstratified conditions, due to a balance between dilution (by inflows containing less of these elements) and evaporation, molybdenum concentrations are predicted to continually increase with evaporation since molybdenum is present in multiple inflows contributing to the lake over the long-term.

Similar long-term trends are also observed for metals and metalloids predicted to accumulate predominantly in the lower stratum in the stratified model (antimony, boron, mercury, and selenium) as shown in Figure 28 to Figure 31. The model predicts that these elements will be present in relatively high concentrations in the lower stratum during the first few years of the lake filling due to inputs of acidic and metal/metalloid enriched TSF seepage and underdrainage water. In each case, concentrations are expected to decrease until at least 50 years post-closure as other inflows with lower metal/metalloid content effectively dilute that tailings water. As noted above, the model predicts antimony and boron concentrations will continue to increase over time due to evapoconcentration whilst concentrations of mercury and selenium are projected to decrease because these are only significant in early tailings water inflows and the effect of subsequent dilution by other inflows exceeds that of evapoconcentration over time.

Concentrations of major ions, trace ions, metals and metalloids are presented for the base case, climate change scenario and extended TSF inputs scenario in Appendix A.

The extended TSF inputs scenario model predicts that extending the duration during which tailings water (recovered seepage and underdrainage) is stored in the mine void from 10 years to 15 years after closure would increase concentrations of some metals and metalloids in the lake over the long-term. Levels of cobalt, fluoride, lithium, molybdenum, antimony and vanadium are predicted to increase by factors of 2 to 3 versus the base case scenario. Chromium concentrations are predicted to increase by factors of 3 to 5 compared with the base case scenario, whilst projected iron concentrations increase markedly (by a factor of 50 to 500 – up to 0.5 mg/L). These differences are clearly attributed to the presence of these elements at elevated concentrations in the tailings water versus other inflows.

Results for the climate change sensitivity scenario model indicate that metal and metalloid concentrations would be generally similar to those expected under base case conditions. The only notable deviations from the base case predictions are for cobalt (~30% reduction), iron (~30% reduction) and molybdenum (~25% reduction).

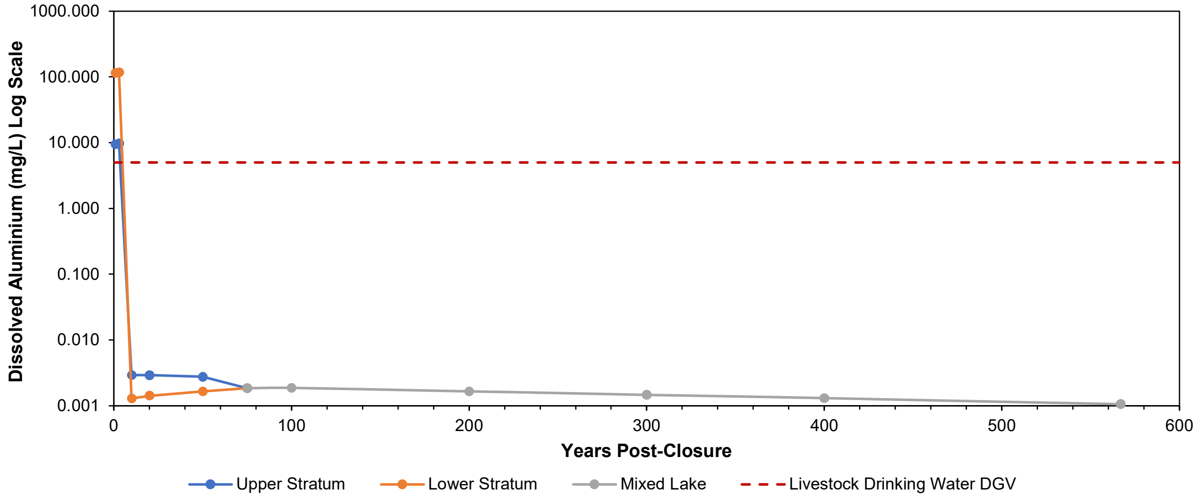

Figure 23: Predicted dissolved aluminium concentrations (base case model)

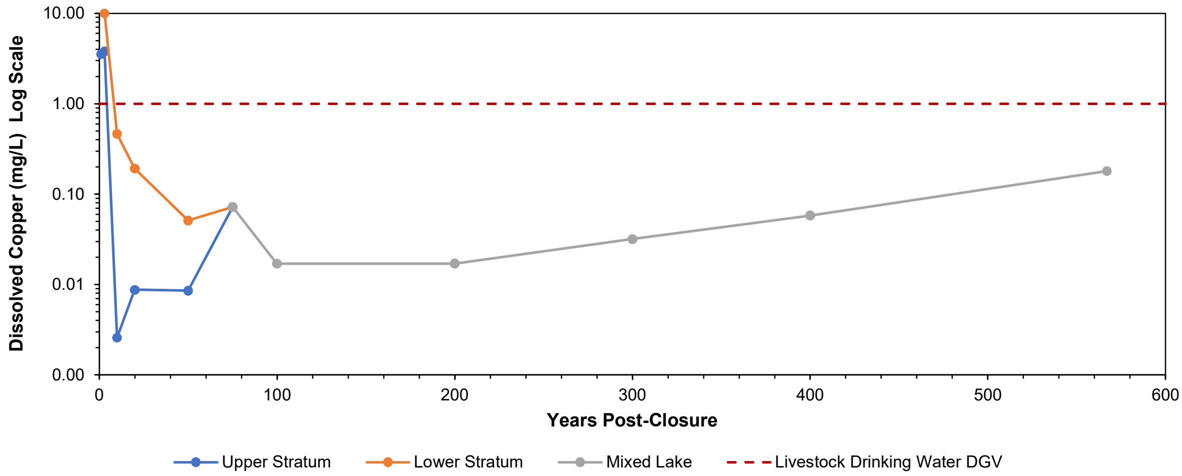

Figure 24: Predicted dissolved copper concentrations (base case model).

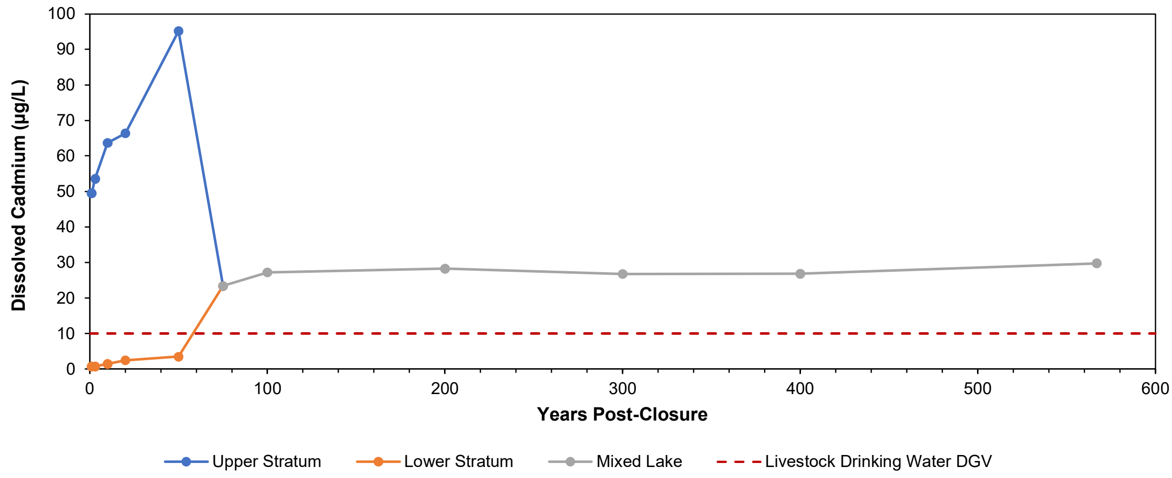

Figure 25: Predicted dissolved cadmium concentrations (base case model).

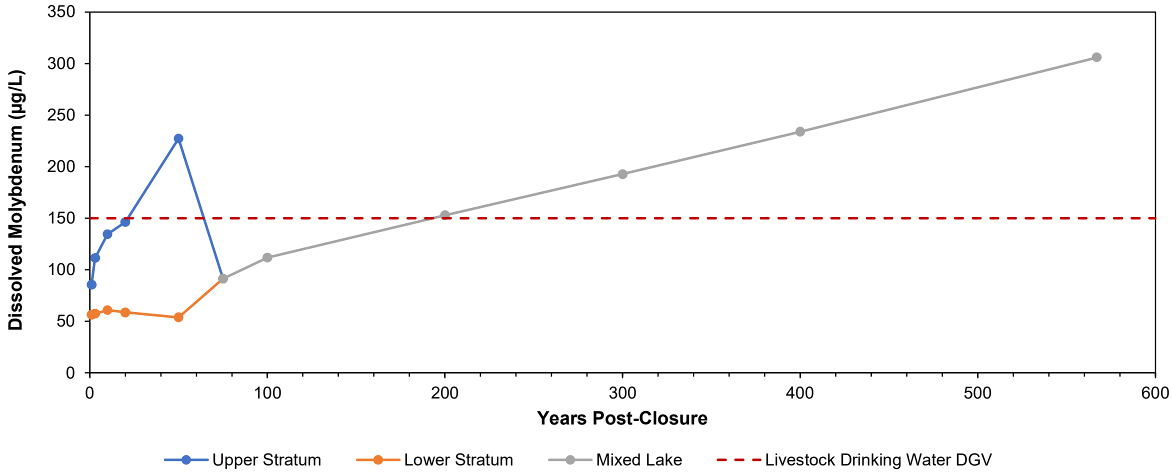

Figure 26: Predicted dissolved molybdenum concentrations (base case model).

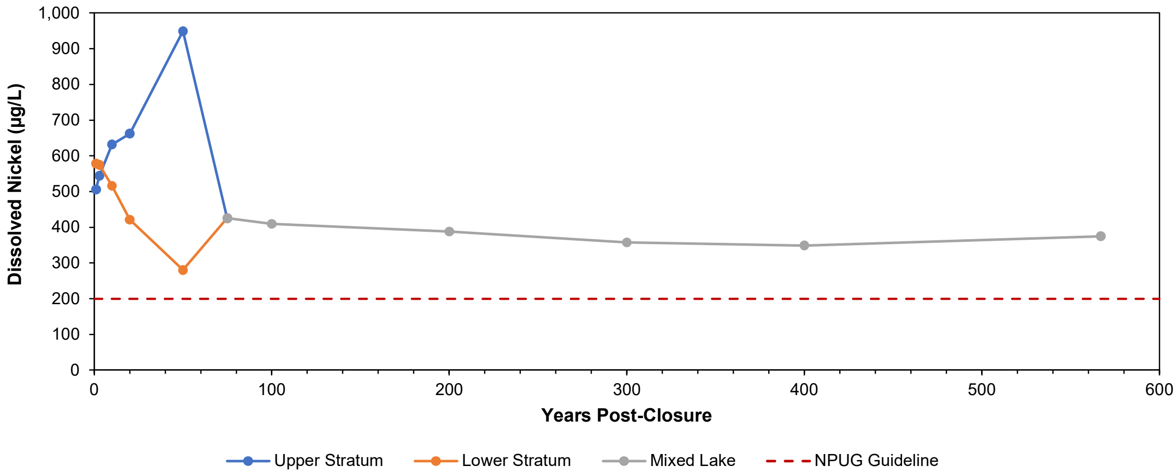

Figure 27: Predicted dissolved nickel concentrations (base case model).

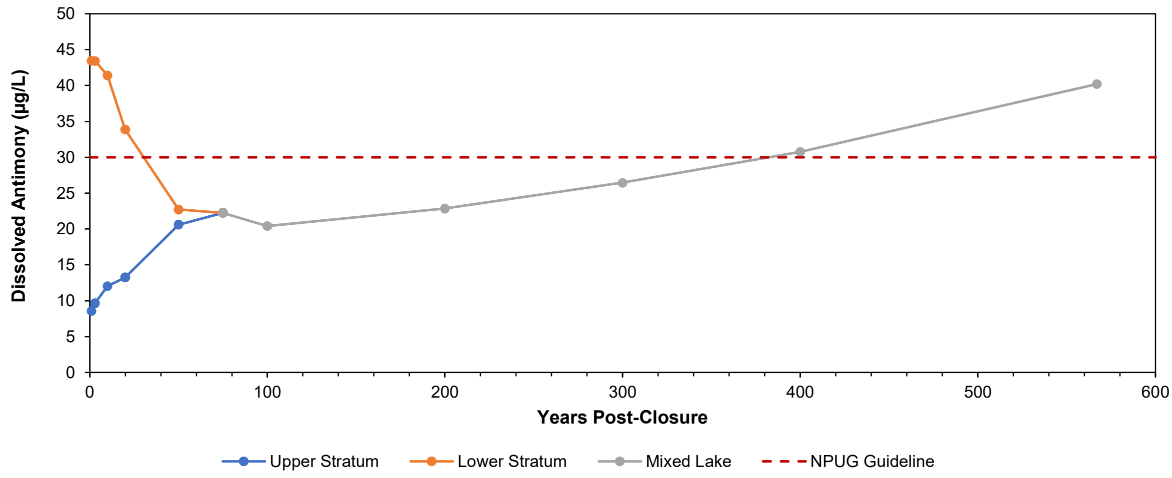

Figure 28: Predicted dissolved antimony concentrations (base cade model).

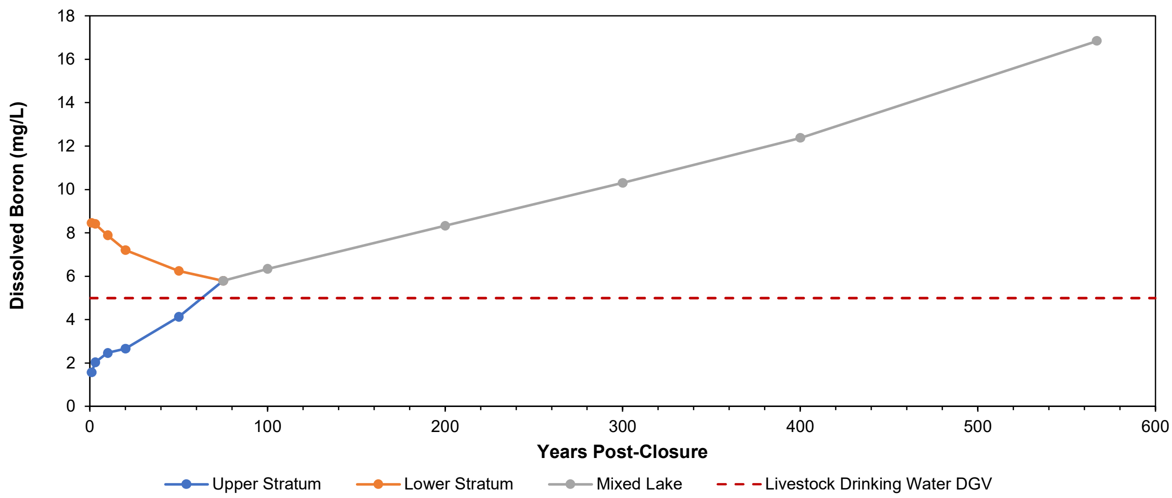

Figure 29: Predicted dissolved boron concentrations (base case model).

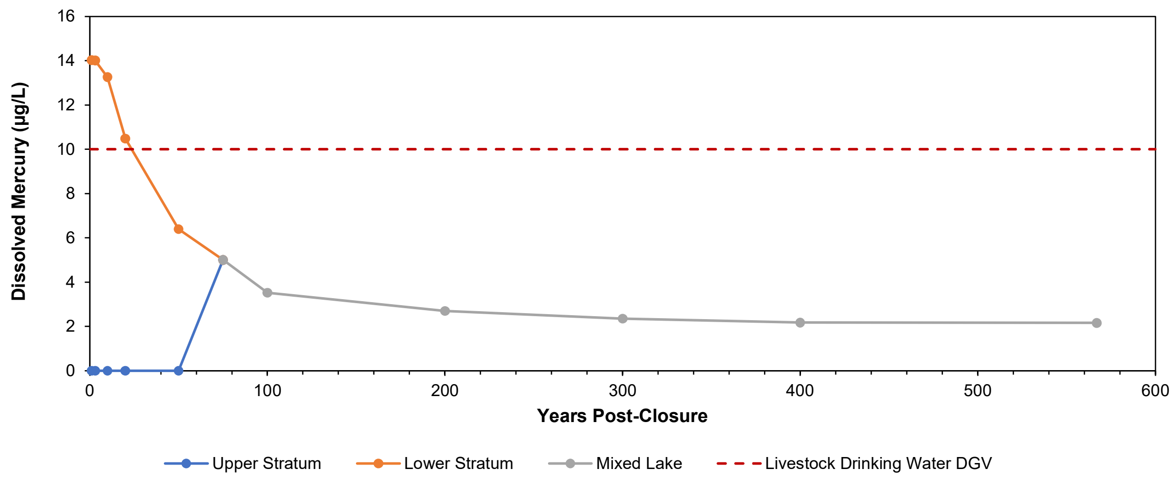

Figure 30: Predicted dissolved mercury concentrations (base case model).

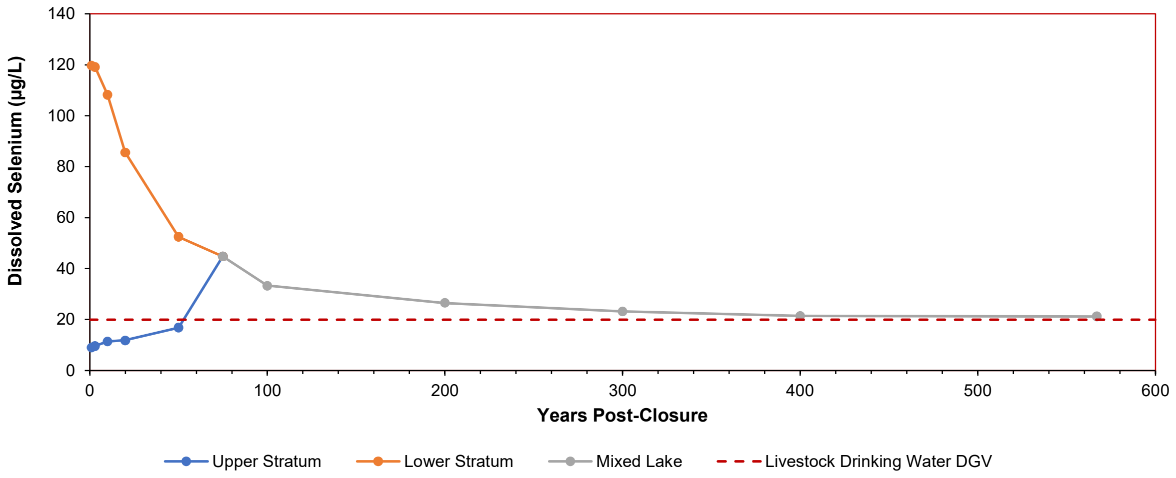

Figure 31: Predicted dissolved selenium concentrations (base case model).

Table 7: Key parameters and major ions for base case model.

STRATUM	YEARS POST CLOSURE	pH	ALKALINITY (mg/L AS HCO_3^-)	CYANIDE (mg/L)	Cl (mg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/l)	Sulfate (mg/L)	TDS (mg/L)
Upper	1	4.6	-	<0.1	2,944	794	18	309	1,521	2,461	8,063
	3	4.6	-	<0.1	3,777	825	23	378	1,956	2,609	9,583
	10	7.4	50	<0.1	4,583	850	28	470	2,372	2,737	11,096
	20	7.5	50	<0.1	4,957	859	30	502	2,567	2,798	11,769
	50	7.4	49	<0.1	7,659	895	46	757	3,969	3,240	16,624
Lower	1	4.1	-	10	61,823	1,389	336	3,210	35,161	4,011	106,107
	3	4.1	-	10	61,536	1,386	335	3,195	35,009	4,019	105,659
	10	7.0	56	9	57,352	1,341	323	3,104	32,676	3,776	98,667
	20	7.1	54	7	50,914	1,266	287	2,868	28,855	3,894	88,175
	50	7.1	50	4	41,870	1,161	237	2,549	23,464	4,090	73,451
Mixed	75	7.2	50	3	34,443	1,132	196	2,159	19,234	3,978	61,218
	100	7.2	50	2	35,224	1,075	201	2,347	19,467	4,307	62,699
	200	7.1	52	2	44,047	1,023	252	3,064	24,121	4,988	77,583
	300	7.1	56	2	53,268	992	306	3,765	29,050	5,608	93,084
	400	7.0	64	1	63,057	970	363	4,497	34,308	6,252	109,550
	566	6.8	93	1	85,052	941	490	6,117	46,175	7,685	146,601
Livestock drinking water DGV (ANZECC, 2000)				NG	NG	1,0000	NG	NG	NG	1,000	4,000 (Cattle)
NPUG (DER, 2014)				0.8	250	NG	0.8	NG	NG	1,000	NG

NG No guideline applicable.

Table 8: Metal and metalloid concentrations for base case model.

STRATUM	YEARS POST CLOSURE	Al (mg/L)	As (µg/L)	B (mg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (mg/L)	F (mg/L)	Fe (µg/L)	Hg (µg/L)	Li (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sr (mg/L)	U (µg/L)	V (µg/L)	Zn (mg/L)
Upper	1	9	18	2	7	50	<0.1	35	4	0.1	1	<0.1	5	12	86	506	7	9	9	0.02	1	17	2
	3	10	21	2	8	54	<0.1	40	4	0.2	1	<0.1	6	14	111	544	8	10	10	0.03	1	18	2
	10	<0.01	0.4	2	8	64	<0.1	43	<0.01	0.2	<0.1	<0.1	7	<0.1	135	632	1	12	11	0.03	1	1	2
	20	<0.01	1	3	8	66	<0.1	47	0.01	0.2	<0.1	<0.1	8	<0.1	146	662	1	13	12	0.04	1	2	2
	50	<0.01	2	4	8	95	<0.1	71	0.01	0.4	<0.1	<0.1	12	<0.1	227	949	2	21	17	0.1	1	3	3
Lower	1	115	7	8	12	1	753	52	10	0.3	<0.1	14	0.1	4,420	57	578	106	43	120	21	22	0.2	0.1
	3	117	7	8	12	1	725	51	10	0.3	<0.1	14	0.1	4,396	57	574	105	43	119	21	22	0.2	0.1
	10	<0.01	9	8	12	1	193	43	0.5	0.3	<0.1	13	0.1	<0.1	61	516	87	41	108	19	18	0.4	0.1
	20	<0.01	11	7	11	2	<0.1	36	0.2	0.2	295	10	0.2	<0.1	59	421	70	34	86	18	14	1	0.1
	50	<0.01	9	6	11	3	<0.1	26	0.1	0.2	17	6	0.4	<0.1	54	280	44	23	53	17	9	1	0.2
Mixed	75	<0.01	8	6	10	23	<0.1	36	0.1	0.3	1	5	3	<0.1	91	425	35	22	45	13	7	1	1
	100	<0.01	8	6	10	27	<0.1	37	0.02	0.3	0.1	4	4	<0.1	112	409	26	20	33	15	5	2	1
	200	<0.01	11	8	9	28	<0.1	41	0.02	0.4	<0.1	3	5	<0.1	153	388	23	23	27	19	4	1	1
	300	<0.01	14	10	9	27	<0.1	45	0.03	0.5	<0.1	2	7	<0.1	193	358	23	26	23	18	3	1	1
	400	<0.01	19	12	8	27	<0.1	50	0.1	0.6	<0.1	2	9	<0.1	234	349	25	31	21	18	3	0.4	1
	566	<0.01	35	17	7	30	<0.1	64	0.2	0.8	<0.1	2	12	0.1	306	375	29	40	21	16	3	0.3	1
Livestock drinking water DGV (ANZECC, 2000)		5	500	5	NG	10	1,000	1,000	1	2	NG	2	2,500*	NG	150	1,000	100	NG	20	NG	200	NG	20
NPUG (DER, 2014)		0.2	100	40	20,000	20	NG	500	20	15	300	10	NG	5,000	500	200	100	30	100	NG	170	NG	3

NG No guideline applicable.

** ANZECC (2000) STV/LTV irrigation water*

5 SUMMARY AND KEY FINDINGS

Integrated water balance and hydrogeochemical models developed for the Fimiston Pit lake (MBS, 2021) were revised and augmented to reflect the proposed extension of the Fimiston Pit, changes to in-pit waste rock backfill design and associated changes to mine closure schedules (i.e. bringing cessation of pit dewatering and processing forward from 2035-2038 to 2034) and water management strategies.

The revised closure water balance was based on the probabilistic, dynamic systems modelling approach used in previous studies for the Fimiston Pit (MBS, 2021), and was completed using GoldSim™. The updated closure water balance was developed from existing historical and operational water balances with consideration of predictions for borefield production, processing demand and tailings water management reflecting a revised mine and closure plan (Big Dog Hydrogeology, 2022).

A revised hydrogeochemical model for the Fimiston Pit lake was based on updated water balance predictions (i.e. inflow rates to the pit), revised assessment of lithologies to remain exposed after mine closure and additional consideration of reactive lithologies on the pit walls (Black Flag shale) and in-pit waste rock.

An assessment of post-closure water management requirements (Big Dog Hydrogeology, 2022) indicates that active management of seepage from the TSFs is required over a period between 10 and 15 years (15 years if extended recovery is necessary) to avoid impacts related to rising groundwater levels from mounding, during the tailings drain-down period. Seepage interception and underdrainage water will be pumped to the Fimiston Pit using the existing seepage interception water infrastructure. After the drain-down period, no further outflows to the environment are predicted from the TSFs.

The revised closure water balance predictions indicate that the equilibrium pit lake water elevations will be between -159 m AHD and -69 m AHD (median level of -122 m AHD), which will be reached about 400 years after closure. Pit lake water levels will be substantially lower than the estimated pre-mining water levels. As such, the pit lake will be a groundwater sink with no outflows to the surrounding environment and no risk of overtopping. Equilibrium water levels are predicted to be between 473 m and 493 m below the pit crest. The oxide weathering interface is much higher than the predicted equilibrium pit lake water levels and therefore does not significantly affect the pit water balance, nor is the presence of the pit lake expected to significantly affect the stability of the upper pit slopes.

The hydrogeochemical modelling predicted that in the long-term (up to circum-600 years post closure), the Fimiston Pit lake will:

- Be unstratified, hypersaline (>100,000 mg/L TDS) and circum-neutral (pH 6.7 – 6.9). Stratification is predicted for the initial 50 years post-closure only.
- Contain marginally elevated dissolved concentrations of some potentially environmentally significant metals and metalloids (antimony, boron, cadmium, molybdenum, nickel and selenium), noting that the water has no known beneficial use, is considered too saline for significant consumption by fauna and will be physically inaccessible; and
- Continue to accumulate solutes over time due to evapoconcentration (i.e., in perpetuity), noting that halite (NaCl) precipitation will eventually limit salinity to <300,000 mg/L TDS.

The lake is predicted to be moderately acidic (pH 4.0 – 4.1) during the first three years post-closure, owing to the storage of substantial volumes of acidic TSF seepage recovered from groundwater in the void and moderately acidic runoff from Black Flag shale exposed on the lower levels of the pit walls. After ten years post-closure, circumneutral conditions (pH 6.7 – 7.2) are predicted under all model scenarios, reflecting additional acid buffering capacity available from the pit walls and the in-pit WRD (dolomite and basalt), which will be largely submerged, as well as alkalinity associated with more substantial proportions of inflows such as groundwater.

Sensitivity analysis, examining the potential impacts of climate change, indicated that:

- Median equilibrium pit lake level under the climate change scenario was about 15 m higher than the base case scenario prediction. Predicted pit lake levels were similar because the increased average rainfall, which causes higher equilibrium water levels, would be offset by the increased evaporation rates under the climate change model conditions; and
- Predictions for pit lake pH, salinity and concentrations of metals, metalloids and trace ions were very consistent with those for the base case scenario.

Another alternative model scenario reflecting an extended period of TSF seepage/underdrainage discharge (15 years vs. 10 years) into the pit, indicated that:

- Extended tailings water inputs would not significantly affect long-term pit lake level, volume and area versus the base case model;
- Extending tailings water inputs would increase concentrations of some metals/metalloids and ions in the lake, typically by factors of between 2 and 5. These elements, which are present in the tailings water at much higher levels than in other inflows to the lake, include: cobalt, chromium, fluoride, iron, lithium, molybdenum, antimony, and vanadium. Increased concentrations of this magnitude are not considered to significantly alter the overall environmental risk profile of the pit lake.

The hypersalinity of the pit lake is unlikely to pose a threat to the surrounding environment since the lake is expected to remain a terminal groundwater sink, the pit void exists in association with hypersaline groundwater, and the pit lake surface will be far below ambient ground level. These factors also limit the environmental significance of elevated concentrations of some metals and metalloids.

Access to the pit lake for terrestrial fauna is likely to be extremely limited due to the steep gradients from ground level and substantial freeboard, as access via ramps and roads will be limited at closure. Whilst flying fauna (e.g., birds and bats) may be able to access the lake surface, the water is unlikely to remain palatable for more than 50 years due to increasing salinity. Furthermore, consumption of the brackish to saline water is unlikely to be substantial where more attractive freshwater sources are available to avifauna.

6 REFERENCES

ANZECC. 2000. National Water Quality Management Strategy, Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Australia and New Zealand Governments (ANZG). 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Canberra, ACT: ANZG. www.waterquality.gov.au/anz-guidelines (accessed 30 November 2018).

Big Dog Hydrogeology. 2022. KCGM SGMP Pumping Rates in Closure Rev D. Unpublished technical memorandum prepared by Big Dog Hydrogeology Pty Ltd for Kalgoorlie Consolidated Gold Mines Pty Ltd.

BoM. 2020. Climate Data for Kalgoorlie-Boulder Airport. Australian Government Bureau of Meteorology (BoM). Available: www.bom.gov.au (accessed 30 June 2020).

Climate Change in Australia. 2020. Australian Climate Futures Tool retrieved from https://www.climatechangeinaustralia.gov.au/en/

Crosbie et al. 2012. New insights to the chemical and isotopic composition of rainfall across Australia. CSIRO Water for a Health Country Flagship. https://publications.csiro.au/rpr/pub?list=SEA&pid=csiro:EP125581 (accessed 2 December 2019).

CSIRO and Bureau of Meteorology. 2015. Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia

Department of Environmental Regulation (DER). 2014. Assessment and Management of Contaminated Sites: Contaminated Sites Guidelines. Perth, WA: DER (DWER).

GCA 2010. Geochemical Characterisation of Mine Waste Samples (Golden Pike Project) – Implications for Mine Waste Management. Report prepared for KCGM October 2010 by Graeme Campbell and Associates Pty Ltd.

Hipsey, M.R., Bruce, L.C., Boon, C., Busch, B., Carey, C.C., Hamilton, D.P., Hanson, P.C., Read, J.S., de Sousa, E., Weber, M. and Winslow, L.A. 2019. A General Lake Model (GLM 3.0) for linking with high-frequency sensor data from the Global Lake Ecological Network (GLEON). Geoscientific Model Development 12: 473-523.

KCGM. 2020a. Fimiston Seepage and Groundwater Management Plan – June 2020. Kalgoorlie Consolidated Gold Mines Mine (KCGM)

KCGM. 2020b. WRD and ramps 07052020.xlsx. Spreadsheet containing data from the 20165 Hydrus modelling by Landloch (no report).

MBS. 2016. Geochemical Tailings Characterisation – Mine Closure Planning. Unpublished technical memorandum prepared by MBS Environmental Pty Ltd for Kalgoorlie Consolidated Gold Mines Pty Ltd.

MBS. 2017. Fresh Rock Waste Geochemical Characterisation for Fimiston Open Pit. Unpublished draft technical report prepared by MBS Environmental Pty Ltd for Kalgoorlie Consolidated Gold Mines Pty Ltd.

MBS. 2020. Fimiston Open Pit Geochemistry Review and Fimiston South Geochemical Characterisation. Unpublished technical report prepared by MBS Environmental Pty Ltd for Kalgoorlie Consolidated Gold Mines Pty Ltd.

MBS. 2021. Kalgoorlie Consolidated Gold Mines Site-Wide Water Balance and Pit Lake Geochemistry – February 2021. Unpublished technical report prepared by MBS Environmental Pty Ltd (MBS) and Groundwater Resources Management Pty Ltd (GRM) for Kalgoorlie Consolidated Gold Mines Pty Ltd.

NHMRC and NRMMC. 2011. Australian Drinking Water Guidelines 6. Version 3.5 – Updated August 2018. National Water Quality Management Strategy. National Health and Medical Research Council and National Resource Management Ministerial Council, Commonwealth of Australia: Australian Government.

Peter Clifton and Associates. 2014. Assessment of Post-Closure Mine Flooding: Mt Charlotte Underground Gold Mine. Unpublished technical report prepared by Peter Clifton & Associates Consulting Hydrogeologists for Kalgoorlie Consolidated Gold Mines Pty Ltd.

USGS. 2021. PHREEQC Interactive Geochemical Modelling Software. Version 3.7.0.15749. Reston, Virginia USA: United States Geological Survey

7 LIMITATIONS

Attention is drawn to the document "Limitations", which is included in Appendix C of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A PREDICTED WATER QUALITY RESULTS - SENSITIVITY ANALYSIS SCENARIOS

Table A1: Key parameters and major ions for base case and sensitivity analysis scenario models (unstratified).

MODEL SCENARIO	YEARS POST CLOSURE	pH	ALKALINITY (mg/L as HCO_3^-)	Cl (mg/L)	CYANIDE (mg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)	SULFATE (mg/L)	TDS (mg/L)
Base Case	1	4.1	-	55,675	9	1,359	303	2,909	31,650	3,920	95,973
	3	4.1	-	56,143	9	1,359	306	2,933	31,922	3,944	96,767
	10	7.1	53	49,592	8	1,305	279	2,717	28,220	3,711	85,910
	20	7.2	51	40,860	6	1,226	231	2,351	23,105	3,774	71,627
	50	7.2	50	34,449	3	1,134	196	2,160	19,234	3,979	61,227
	100	7.2	50	35,229	2	1,076	201	2,348	19,468	4,307	62,707
	200	7.1	52	44,054	2	1,023	252	3,065	24,121	4,988	77,592
	300	7.1	57	53,272	2	993	306	3,766	29,052	5,608	93,091
	400	7.0	64	63,060	2	970	363	4,498	34,310	6,252	109,558
	566	6.8	94	85,059	2	941	490	6,119	46,178	7,685	146,613
Climate Change Scenario	1	4.1	-	55,363	9	1,357	301	2,894	31,471	3,915	95,457
	3	4.1	-	55,736	9	1,357	304	2,912	31,689	3,937	96,095
	10	7.1	53	48,720	8	1,301	274	2,671	27,719	3,700	84,472
	20	7.2	50	39,385	5	1,222	223	2,271	22,263	3,748	69,191
	50	7.2	49	31,907	3	1,130	181	2,011	17,803	3,906	57,014
	100	7.2	50	31,410	2	1,076	179	2,108	17,339	4,158	56,345
	200	7.2	51	39,225	2	1,029	225	2,743	21,455	4,758	69,520
	300	7.1	54	47,124	1	1,001	271	3,344	25,671	5,284	82,786
	400	7.0	59	55,651	1	979	321	3,982	30,243	5,837	97,110
	566	6.9	79	75,256	1	947	434	5,426	40,812	7,094	130,093
Extended TSF Inputs	1	4.0	-	59,784	9	1,470	323	2,969	33,917	3,750	102,394
	3	4.0	-	61,039	9	1,479	330	3,023	34,632	3,779	104,474
	10	7.0	56	59,043	8	1,437	314	3,096	33,361	3,511	100,860
	20	7.0	54	55,314	7	1,389	298	2,949	31,239	3,580	94,862
	50	7.1	53	50,109	6	1,283	273	2,833	28,119	3,830	86,537
	100	7.1	53	49,719	5	1,197	273	2,988	27,703	4,194	86,165
	200	7.0	58	57,895	4	1,115	323	3,704	31,977	4,921	100,034
	300	6.9	65	66,811	3	1,069	376	4,414	36,717	5,583	115,078
	400	6.9	76	76,149	3	1,037	430	5,133	41,711	6,241	130,824
	566	6.7	120	98,464	3	1,006	560	6,779	53,753	7,683	168,416

Table A2: Predicted metal and metalloid concentrations for base case and sensitivity analysis scenario models (unstratified)

MODEL SCENARIO	YEARS POST CLOSURE	Ag (µg/L)	Al (mg/L)	As (µg/L)	B (mg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (mg/L)	F (mg/L)	Fe (µg/L)	Hg (µg/L)	Li (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sr (mg/L)	U (µg/L)	V (µg/L)	Zn (mg/L)
Base Case	1	80	102	8	8	12	6	574	50	9	0.3	<0.1	13	1	4,427	60	571	96	40	108	19	20	2	0.3
	3	82	105	8	8	12	6	564	50	9	0.3	<0.1	13	1	4,486	62	571	96	40	109	19	20	2	0.2
	10	82	0.001	12	7	12	11	<0.1	44	0.3	0.3	17	11	1	<0.1	72	535	76	37	94	17	16	3	0.4
	20	74	0.002	15	6	11	16	<0.1	39	0.1	0.2	47	8	2	<0.1	78	476	57	29	69	14	11	5	1
	50	71	0.002	21	6	11	23	<0.1	37	0.1	0.3	1	5	3	<0.1	92	428	38	22	45	13	7	7	1
	100	78	0.002	27	6	10	27	<0.1	38	0.1	0.3	0.1	4	4	<0.1	113	411	30	20	33	15	5	9	1
	200	100	0.002	39	8	9	28	<0.1	42	0.1	0.4	<0.1	3	5	<0.1	154	390	27	23	27	19	4	8	1
	300	123	0.001	50	10	9	27	<0.1	47	0.1	0.5	<0.1	2	7	<0.1	196	359	27	26	23	18	3	7	1
	400	149	0.001	61	12	8	27	<0.1	53	0.1	0.6	<0.1	2	9	<0.1	240	350	28	31	21	18	3	7	1
	566	201	0.001	84	17	7	30	<0.1	67	0.2	0.8	<0.1	2	12	0.1	328	376	33	40	21	16	3	7	1
Climate Change Scenario	1	80	101	8	8	12	6	565	50	9	0.3	<0.1	12	1	4,425	60	570	95	40	108	19	20	2	0.3
	3	82	104	8	8	12	6	554	50	9	0.3	<0.1	13	1	4,487	63	570	95	40	108	19	20	2	0.3
	10	81	0.001	12	7	12	11	<0.1	43	0.3	0.3	44	11	1	<0.1	72	533	75	37	92	16	15	4	0.4
	20	74	0.002	15	6	11	17	<0.1	39	0.1	0.2	33	8	2	<0.1	79	473	55	29	67	14	11	6	1
	50	70	0.002	21	5	11	25	<0.1	36	0.1	0.2	0.4	5	3	<0.1	93	429	36	21	42	12	7	8	1
	100	78	0.002	27	6	10	29	<0.1	38	0.1	0.3	<0.1	3	4	<0.1	115	412	27	19	30	13	5	9	1
	200	103	0.002	39	8	9	30	<0.1	43	0.1	0.4	<0.1	2	6	<0.1	161	395	25	22	24	17	4	9	1
	300	128	0.002	49	10	9	29	<0.1	48	0.1	0.5	<0.1	2	8	<0.1	205	361	25	26	21	19	3	8	1
	400	155	0.001	60	11	8	29	<0.1	54	0.1	0.6	<0.1	2	9	<0.1	252	352	26	30	19	18	3	7	1
	566	212	0.001	83	16	8	32	<0.1	69	0.2	0.8	<0.1	2	13	0.1	347	378	30	40	19	17	3	7	1
Extended TSF Inputs	1	78	122	7	8	13	4	792	48	9	0.3	<0.1	12	0.4	4,379	55	556	113	39	110	22	25	1	0.2
	3	80	130	7	8	13	4	840	49	9	0.3	<0.1	13	0.4	4,447	57	562	116	40	113	22	26	1	0.2
	10	75	0.001	9	8	13	5	603	50	0.3	0.3	<0.1	11	1	<0.1	58	547	111	37	104	22	24	2	0.2
	20	77	0.001	11	8	13	9	233	48	0.3	0.3	<0.1	10	1	<0.1	67	538	99	35	95	21	21	3	0.4
	50	79	0.001	17	8	12	17	<0.1	47	0.1	0.3	80	8	2	<0.1	85	519	80	30	76	20	17	5	1
	100	87	0.001	25	8	11	23	<0.1	48	0.1	0.3	21	7	3	<0.1	109	510	67	29	62	20	14	7	1
	200	111	0.001	38	10	10	26	<0.1	53	0.1	0.4	11	6	5	<0.1	156	500	61	31	54	21	12	8	1
	300	136	0.001	49	12	9	26	<0.1	58	0.1	0.6	10	5	7	<0.1	200	470	58	34	48	19	10	7	1
	400	161	0.001	61	14	9	26	<0.1	63	0.2	0.7	10	5	8	0.1	246	459	57	38	45	18	10	7	1
	566	214	0.001	84	19	8	29	<0.1	78	0.5	0.9	21	5	11	0.5	335	487	62	48	45	17	10	7	1

APPENDIX B DEFINITIONS

NAME	DESCRIPTION
AHD	Altitude relative to Australian Height Datum
Circum-neutral	Approximating to acid-base neutrality (typically pH 6.5 to 7.5).
Deterministic Simulation	A simulation where input parameters are represented using single values (i.e. they are determined or assumed to be known with certainty).
EC	Electrical conductivity, an indicator of salinity.
Elapsed-time Simulation	A simulation that tracks time using the time since the start of the model run.
Element	A GoldSim component that forms the basic model building blocks.
Entrainment (water)	Water that occurs within the pores of a granular matrix such as tailings.
HDPE	High density polyethylene. A plastic commonly used to manufacture water-proof sheeting.
Hydraulic Conductivity (K) [Permeability]	The volume of water that will flow in a unit time under a unit hydraulic gradient through a unit area. Analogous to the permeability with respect to fresh water (units commonly m/d or m/s).
Hypersaline	Significantly saltier than typical seawater (37 g/L).
Limnological	The study of limnology includes aspects of the biological, chemical, physical, and geological characteristics and functions of inland waters.
mbgl	Metres below ground level
Mean	The expected value of a distribution or first moment of the distribution.
Median	The 50th percentile of a distribution.
Monte Carlo Simulation	A method of propagating uncertainties in model inputs into uncertainties in model results, by using random or pseudo-random sampling of distributions over a number of realisations.
Percentile	An amount on a scale from 1 to 100 that indicates the percent of a distribution that is equal to or below a certain value.
PHREEQC	A chemical thermodynamic equilibrium speciation model developed by the United Stated Geological Survey.
Probabilistic (Stochastic) Simulation	A simulation in which the uncertainty in input parameters is explicitly represented by defining them as probability distributions.
Probability Distribution	A mathematical representation of the relative likelihood of a variable having certain specific values.

NAME	DESCRIPTION
Realisation	A single model run within a Monte Carlo simulation. It represents one possible path a system might follow through time.
Seepage	Water that has percolated through a waste landform (e.g. waste rock dump or tailings storage facility).
SILO (database)	A database of Australian climate data from 1989 to present.
Source term	Describes the characteristic chemical composition (e.g. of a pit lake inflow source).
Stochastic	An element that can be used to quantitatively represent the uncertainty in a model input.
Supernatant	Liquid remaining after setting of tailings solids.
TDS	Total Dissolved Solids (contained within a water sample), expressed in mg/L.
Time-Step	A discrete interval of time used in dynamic simulations.

APPENDIX C LIMITATIONS

This Document has been provided by Mine Waste Management Pty Ltd (MWM) subject to the following limitations:

This Document has been prepared for the particular purpose outlined in MWM's proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

The scope and the period of MWM's services are as described in MWM's proposal, and are subject to restrictions and limitations. MWM did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in this Document. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by MWM in regards to it.

Conditions may exist which were undetectable given the limited nature of the enquiry MWM was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required.

In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. MWM's opinions are based upon information that existed at the time of the production of this Document. It is understood that the services provided allowed MWM to form no more than an opinion of the actual conditions of the site at the time the site was reviewed and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

Any assessments made in this Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Document.

Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by MWM for incomplete or inaccurate data supplied by others.

MWM may have retained subconsultants affiliated with MWM to provide services for the benefit of MWM. To the maximum extent allowed by law, the Client acknowledges and agrees it will not have any direct legal recourse to, and waives any claim, demand, or cause of action against, MWM's affiliated companies, and their employees, officers and directors.

This Document is provided for sole use by the Client and is confidential to it and its professional advisers. No responsibility whatsoever for the contents of this Document will be accepted to any person other than the Client. Any use which a third party makes of this Document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. MWM accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this Document.

MINE WASTE MANAGEMENT

GREENROAD GROUP