Klohn Crippen Berger

MetRes Pty Ltd

Millennium Coal Mine

Final Void Hydrology Study

Final Report

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Draft Report

Klohn Crippen Berger

5 December 2023

SLR Consulting
(on behalf of MetRes Pty Ltd)
Email delivery: hhowell@slrconsulting.com

Helena Howell
Associated Consultant – Environmental Assessment and Management

Dear Ms. Howell:

Millennium Coal Mine
Final Void Hydrology Study

KCB Australia Pty Ltd is pleased to provide MetRes Pty Ltd with this final void hydrology study for the Millennium Coal Mine.

We would like to thank MetRes Pty Ltd for the opportunity to provide this final void hydrology study. Should you have any questions, please do not hesitate to contact either of the undersigned.

Yours truly,

KCB AUSTRALIA PTY LTD.

Kirsty Bethune

Kirsty Bethune
Senior Water Resources Engineer

Jim Heaslop
Manager, Water Engineering

LH and KB:MS

EXECUTIVE SUMMARY

This report provides a hydrology study on the final voids proposed to be remaining as part rehabilitation and closure of Millenium Coal Mine (MCM). The assessment focused on the catchment hydrology and final void water balance modelling for three existing open cut voids, A and B Pit, M and D Pit and E Pit.

Investigations have focused on the hydrological characteristics of these three final voids, including long-term pit lake water levels, water quality and filling timeframes. Parallel hydrogeological studies have been undertaken by SLR, with the modelling outcomes considered within this assessment.

Key outcomes of the final void study include:

- All voids will maintain a permanent pit lake which will fluctuate around a steady state equilibrium level in response to periods of flood and drought.
- Water levels within the final voids are expected to reach equilibrium in approximately 140 years post closure for all three final voids.
- No voids are expected to reach levels that would result in overflow into downstream watercourse via a surface pathway.
- Fluctuations in the pit lake water quality (i.e., salinity) will continue to occur and be driven by climatic variability. All final voids showed an ongoing accumulation of salinity within the pit lake once water level equilibrium was reached. Salinity remains low enough to support beneficial reuse opportunities in agricultural land uses for a period of between 140 to 290 years post closure, but reuse will be dependent upon accessibility to the pit lakes.
- Sensitivity analysis undertaken produced water level ranges that fell within the range of results predicted by the base case envelope and were below the overflow levels.
- Recommendations have been made to:
  - increase the monitoring of existing in-pit water bodies with additional water quality parameters to enable long-term modelling of hydrogeochemical processes;
  - characterise spoil to confirm porosity and salt generation factors within each void;
  - establish a visual monitoring program of the voids at closure, focused on the emergence of new groundwater seepage faces, stability of spoil material and presence of chemical precipitation processes; and
  - further investigate the ability of the final voids to support opportunistic native flora and fauna species.

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CLARIFICATIONS REGARDING THIS REPORT

This report is an instrument of service of KCB Australia Pty Ltd (KCB) and has been prepared for the exclusive use of MetRes Pty Ltd (Client) for the specific application to the final void hydrology study for existing open cut voids at Millennium Coal Mine. It may not be relied upon by any other party without KCB's written consent.

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1 INTRODUCTION

1.1 Project scope

Millennium Coal Mine (MCM) is an open cut and underground metallurgical coal mine located in the Bowen Basin in central Queensland. It is approximately 160 km south-west of Mackay, 15 km south-west of the township Coppabella and 20 km south-east of Moranbah. MCM produces low ash coking and pulverized coal injection (PCI) coal for export to several Asian, European, and South American customers.

MCM is owned by joint venture partners M Resources and Stanmore Resources (MetRes). The site is currently operated by M Mining Pty Ltd (M Mining). The mine covers an area of approximately 3,258 hectares and is authorised under environmental authority (EA) EPML00819213 and mining leases (ML) ML 70313, ML 70344, ML 70401, ML 70457, ML 70483 and ML 70485.

MCM consists of two mining areas: the Mavis area (ML 70457, ML 70483, ML 70485); and the Millennium area (ML 70313, ML 70401, ML 70344). The site is currently approved to produce at a rate of 5.5 million tonnes per annum (Mtpa) of run of mine (ROM) coal. The ROM coal is washed in a coal handling and preparation plant (CHPP) on an adjoining infrastructure lease, ML 70312 (Millennium East). This CHPP is owned by BHP Mitsui Coal (BMC) Poitrel and is operated by the Red Mountain Infrastructure (RMI).

In accordance with the Department of Environment and Science (DES) guideline *Progressive Rehabilitation and Closure Plans* (PRCP) (DES 2023b) and the site's EA, the PRCP must, at a minimum, include a final void hydrology study, considering the effects of long-term water balance in the voids, connections to groundwater resources and water quality parameters in the long-term.

In response to this PRCP requirement, MetRes has engaged KCB Australia Pty Ltd (KCB) to undertake a final void hydrology study for the three voids expected to remain at MCM at closure:

- M and D Pit (in the Mavis mining area);
- E Pit (also in the Mavis mining area); and
- A and B Pit (in the Millennium mining area).

The location of these existing pits is presented in Figure 1.1 with further detail provided in Section 2.

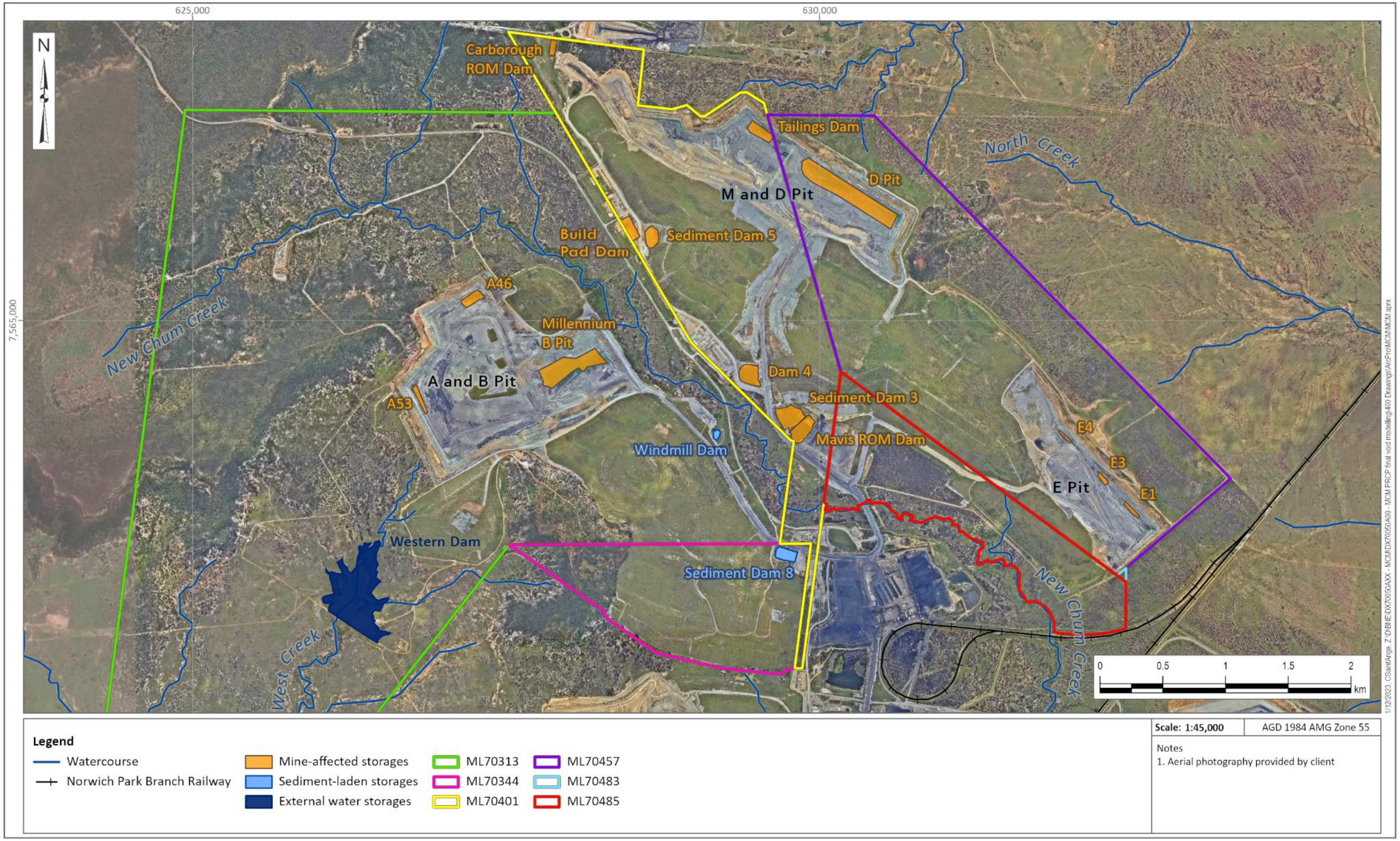

Figure 1.1 Existing MCM layout

The scope of the final void hydrology study includes:

- Review and definition of the physical characteristics of the final landform, including catchment area and stage storage characteristics for each final void.
- Establish appropriate hydrological inputs to be used for modelling, including rainfall and evaporation, and catchment yield.
- Incorporate hydrogeological inputs from SLR Consulting Australia Pty Ltd (SLR) to be used for modelling including spoil seepage and other groundwater interactions (i.e., flux rates) for each final void.
- Develop hydrogeochemical inputs for modelling water quality evolution and potential stratification within the final voids.
- Develop a GoldSim salt and water balance model for each final void (referred to herein as final void WBM).
- Undertake predictive long-term modelling, for each final void to estimate:
    - Time taken to reach equilibrium within each final void and the drivers that result in water level variation.
    - Salinity conditions within the final voids over time. This assumes a conservative mass transfer/mixing model using source concentrations and flow portions to provide an indication of the expected salinity.
    - Risk of discharges to surface waters either via overtopping of the final void crest or seepage to the groundwater system (i.e., via surface alluvial aquifers).
    - How outcomes of the items above may be affected by uncertainty associated with predictive model inputs and/or parameters (i.e. sensitivity analysis).
- Undertake a hydrogeochemical assessment[1], based on site specific and regional data, to understand how water quality within the voids may evolve over time. This included understanding the potential effects of secondary minerals present within the final void and how they might influence salinity and other metals.
- Develop a one-dimensional General Lake Model (GLM) to understand how temperature, salinity, and water density might vary with time.

Key personnel involved with the study to date include:

<u>M Mining on behalf of MetRes</u>

- Ashton Ingerson, Technical Services Manager

<u>SLR</u>

- Helena Howell, Associate Consultant – Environment Assessment and Management
- Ines Epari, Principal Hydrology and Hydrogeology

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[1] Long-term modelling of hydrogeochemical processes was not possible with the site data available at the time of the assessment.

KCB

- Kirsty Bethune, Senior Water Resources Engineer
- Jiajia Zheng, Geochemist
- Jim Heaslop, Manager - Water Engineering

1.2 Regulatory requirements

1.2.1 PRCP guideline

The requirements for void mine closure plans are detailed in the PRCP guideline (DES 2023b). The specific requirements and comment on how they relate to this study are presented in Table 1.1.

Table 1.1 PRCP void closure plan requirements

Requirement	Comment
▪ Options available for minimising final void area and volume (where a final void is proposed).	▪ Not addressed as part of this assessment. ▪ This assessment will build upon the outcomes of the previous work package to confirm rehabilitation objectives and it is assumed that the final void geometries provided to KCB by MetRes have taken this into consideration.
▪ Proposed final dimensions of the void (i.e., depth, length and width).	▪ Summary provided in this report, refer to Section 2.
▪ Pit wall geotechnical and geochemical stability, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events.	▪ Not addressed as part of this assessment.
▪ Proposed slope angles of high wall, low wall and end walls of each final void.	▪ Provided in final void characterisation figures, refer to Appendix II.
▪ Void hydrology, addressing the long-term water balance and water level in the voids, stratification connections to groundwater resources and potential for overflow.	▪ Void hydrology, connection to groundwater resources and potential overflow are addressed in this report. ▪ Stratification modelling and hydrogeochemical outcomes are provided in Section 7.
▪ Groundwater modelling to determine whether the void is acting as a sink or a source for groundwater.	▪ SLR has prepared groundwater modelling for the final voids at MCM. Information from the groundwater model has been integrated into the final void model.
▪ A water balance study including an assessment of void surface and groundwater interactions such as: ♦ Groundwater lowering/reduction in hydraulic head (flow new voids e.g. caves/karst system) ♦ Cones of depression and associated impacts ♦ The drainage and flooding behaviours of surface water in the vicinity of the void ♦ A conceptual model that incorporates all projected inflows, outflows, and recharge rates ♦ Water storage and long-term water balance ♦ Each of the major water fluxes into and out of the void	▪ Groundwater ♦ SLR has prepared a three-dimensional groundwater model which predicts flow into the underground mines and open cut pits which KCB integrated into the final void model. ▪ Surface water ♦ Surface water flooding is not assessed in this report. A flood study is being prepared (by Alluvium) to demonstrate no ingress of flood waters from New Chum Creek into the final voids up to and including a 1 in 1,000 annual exceedance probability (AEP) event. The final

Requirement	Comment
♦ The sources of surface water within the mine catchment that are likely to influence the water quality in the void.	voids being assessed (A and B Pit, M and D Pit, and E Pit) and not located within mapped watercourse floodplains. ▪ The conceptual model for the water balance is provided in Section 4 and considers all major surface and groundwater fluxes into and out of the void. ▪ Identification of specific catchment contamination sources is not addressed in this assessment, however, the final void WBM will account for salinity over time within the voids.
▪ Predicted water quality in the long-term including potential stratification.	▪ Water quality predictions are based on an approach using results from the final void WBM water level and salinity modelling and understanding of the other water quality parameters expected in the void water (based on pit water quality data) to identify potential secondary minerals that may influence salinity and metal mobility.

The closure of underground areas associated with MCM is not considered in this assessment because KCB understands that the access to the underground mine within the final voids will be appropriately sealed. In addition, as part of SLR's (SLR 2023b) work, the groundwater interactions associated with the closure of the underground mining areas are considered in the predicted volumes provided for the final void WBM.

KCB, in the development of this assessment, have considered three technical papers recently developed by the Office of the Queensland Mine Rehabilitation Commissioner (QMRC). The papers (Tomlin *et al* 2023a, 2023b and 2023c) provide advice on leading practices for mine void modelling used to support rehabilitation planning.

1.2.2 Environmental authority

Within Table F1, of EA EPML00819213 post-mining final land use for the MCM residual voids is nominated as waterbody.

1.3 Project data

A summary of the project data provided by MetRes, SLR and sourced from publicly available sources, is provided in Appendix I.

1.4 Report structure

The report is structured as follows:

- Section 2 provides details on the existing mining pit's and proposed final void configurations.
- Section 3 provides a summary of the sites location, climate, water resources and groundwater systems present.

- Section 4 provides a description of the conceptual model outlining how surface and groundwater interact with the final voids.
- Section 5 provides detail on the WBM development (i.e., physical characteristics for the site, hydrological, hydrogeological, salinity assumptions, and modelling of potential reuse options).
- Section 6 outlines the base case final void WBM outcomes.
- Section 7 includes an assessment of water quality considering existing monitoring data, discussion on hydrogeochemical outcomes and an assessment of potential stratification.
- Section 8 provides an assessment of water reuse opportunities.
- Section 9 outlines the uncertainty testing undertaken on key model inputs and assumptions. This section will also cover potential risks posed by the final voids based on the modelling predictions and sensitivities.
- Sections 10 includes recommendations for future work.
- Section 11 provides a summary of the assessment outcomes.

2 FINAL VOID DETAILS

2.1 Existing conditions

Open cut mining activities have recently ceased in the Millenium and Mavis Downs mining areas, with active underground mining in the Mavis Downs mining area only. Information on the existing inactive open cut areas, as they are described in the current water management plan (M Mining 2023), are provided in Table 2.1 with their locations shown in Figure 1.1.

Table 2.1 Summary of existing open cut areas

Mining area	Pit	Status	Full supply volume (ML)	Surface area (ha)	Full supply level and outlet type	Overflow location
Millennium	A Pit (A46)	No active open cut mining.	93	4.0	Spillway	A53
	A Pit (A53)	No active open cut mining.	2,002	3.0	Spillway	A46
	B Pit	No active open cut mining. Water storage located within B Pit	1,165	11	161 mAHD	A46
Mavis Downs	Mavis M Pit	No active open cut mining. Backfilling of pit occurring.	NA	NA	NA	NA
	Tailings Dam	Located within the floor of D Pit (north western end). Coal processing and the associated tailings dewatering process are conducted within disposal cells.	2,105	10.8	210 mAHD spoil crest level between Tailings Dam and D Pit	D Pit
	D Pit	No active open cut mining. Water storage located within D Pit (south-eastern end).	3,935	35	157 mAHD spillway	Tailings Dam
	E Pit	No active open cut mining, access to underground area. Small water storages present within E Pit (i.e., E1, E3 and E4 sumps)	NA	NA	NA	NA

2.2 Proposed rehabilitation approach

A final landform surface has been prepared by MetRes. This proposes to back fill A and B Pit, M and D Pit, and E Pit with available spoil material that will reduce the existing void capacity as far as practicable.

Physical characteristics of the final voids as part of the rehabilitation process is provided in Appendix II. Further detail on the final landform topography is provided in Section 5.3.1, with an assessment of slope angle and stability of the final landform completed by SLR. A summary of the information is provided in Table 2.2.

Table 2.2 Summary of final void physical characteristics

Final void	Maximum storage capacity (GL)*	Surface area (ha)	Base level of mining (mAHD)	Bottom of void (mAHD)	Crest level (mAHD)	Outlet type	Overflow catchment
A and B Pit	65.44	150.38	84.34	137.40	240.0	Void crest embankment overflow	Western Dam and West Creek
M and D Pit	58.69	141.10	131.52	144.66	259.5		North Creek
E Pit	28.03	75.85	130.80	144.35	238.0		New Chum Creek

Note: * based on a porosity of underlying spoil of 5%.

To support the data presented in Table 2.2:

- A and B Pit and M and D Pit will be used as mine-affected water storages leading up to closure. M and D Pit currently has a portion of the pit dedicated to a tailing dam which will also remain active up to closure. Management of these areas as water storages should be in accordance with the site water management plan and undergo ongoing reviews leading up to closure.
- Pit crest levels has been derived from the final landform topography. The lowest final void crest level is defined as the point at which water levels will result in surface water outflow occurring. This assessment has not included consideration of any potential lower control level where water levels should be managed based on geotechnical advice. This work will form a future recommendation.
- The final void base level has been derived from the deepest mined surface and is representative of the lowest invert for which spoil material has been emplaced.

Figure 2.1 presents the final landform surface, final void areas and the approximate void overflow locations.

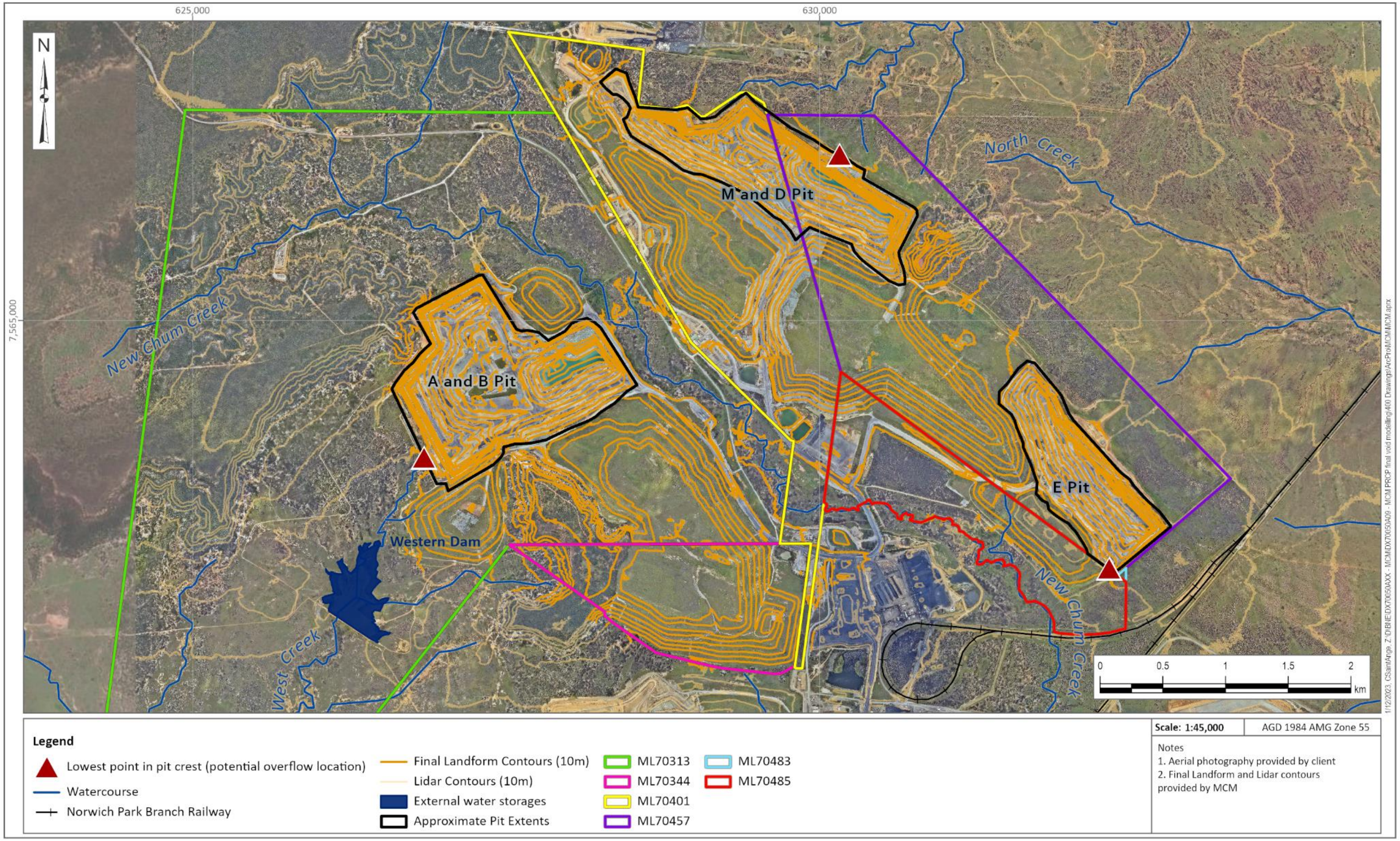


Figure 2.1 Final landform and final void areas

3 SITE SETTING

3.1 Location and existing topography

MCM is located approximately 22 km east of Moranbah and 16 km southwest of Coppabella in Central Queensland. The site is located within the Isaac Regional Shire Local Government Area (LGA).

The broad topography of the area is described as gentle undulating plains that drain via a broad floodplain with meandering channels (New Chum Creek) flowing to the south. Mesas occur as topographic features within the MLs, with these features providing the only areas of potentially steep gradient where their surrounds interface with the plains (Peabody 2009).

Figure 3.1 provides photographs of the existing open cut mining pits and the adjacent environment surrounding MCM.

East view of B Pit

North view of M and D Pit

North view of A Pit (West)

South view of E Pit

Figure 3.1 Aerial photographs of the existing open cut mining pits considered in the assessment

3.2 Climate data

3.2.1 Rainfall and evaporation

Climate data for MCM was obtained from the SILO Data Drill service (SILO 2023a) for the nearest location to MCM (-22.00 latitude/ 148.25 longitude). Table 3.1 and Figure 3.2 show the mean monthly and annual rainfall and lake evaporation for the site.

Table 3.1 Mean rainfall and evaporation for MCM

Month	Mean rainfall (mm)	Mean lake evaporation* (mm)
January	108	196
February	95	166
March	69	166
April	31	132
May	27	102
June	29	81
July	22	92
August	19	119
September	16	152
October	30	189
November	52	200
December	82	209
Mean annual	582	1805

Note: ‘* based on Mortin’s lake evaporation (SILO 2023a)

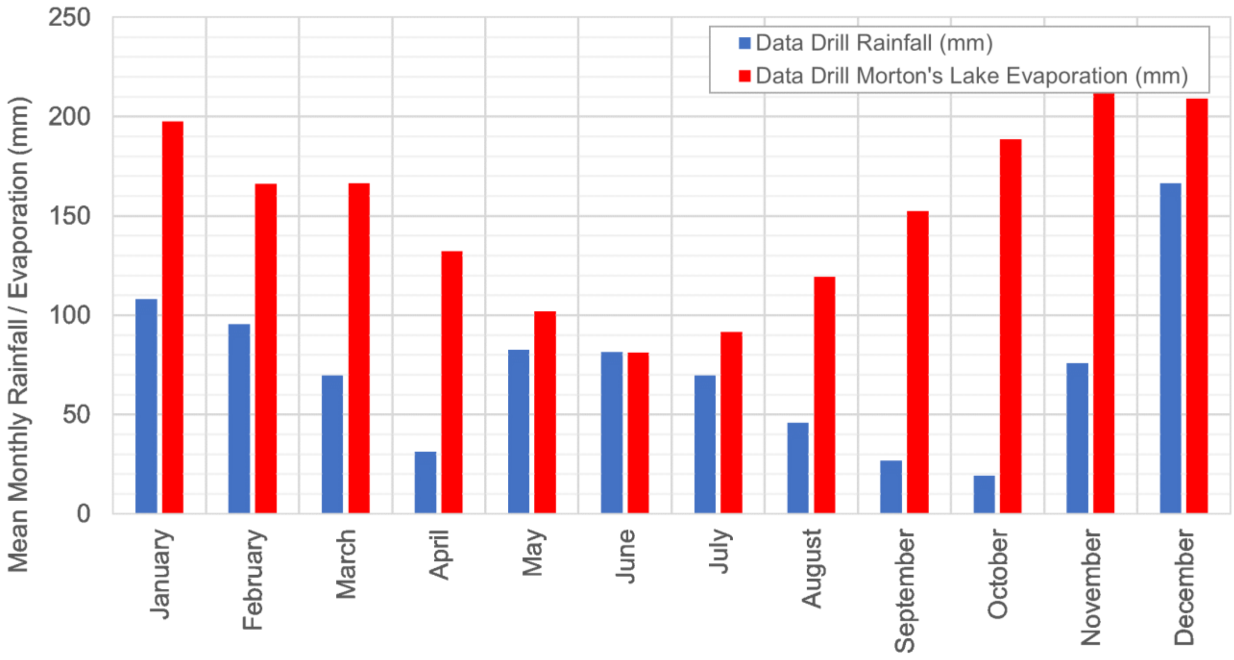


Figure 3.2 Monthly distribution of rainfall and evaporation for -22.00 latitude, 148.25 longitude (SILO 2023a)

From the monthly distribution presented in Figure 3.2, most of the annual rainfall for MCM occurs over the summer months with winter rainfall generally less than 25% of that occurring in summer.

Average lake evaporation exceeds average rainfall for all months of the year with an average annual rainfall deficit of 1,223 mm/year.

The climatic influences expected on the final voids include direct rainfall on the void opening, catchment runoff from areas external to the void, evaporation from the void water surface and evapotranspiration from their catchments. Application of rainfall and evaporation data in the modelling undertaken as part of this assessment is discussed further in Section 5.5.

3.2.2 Climate change

Variations in the rainfall and evaporation resulting from global climate change are important factors to be considered during the assessment of final void hydrology. To understand the potential changes to climate for the Issac River region, high level projections by CSIRO and BoM (CSIRO and BoM 2015) were reviewed for the east coast north and monsoonal north east subcluster. CSIRO predictions relating to rainfall and evaporation for the region are:

- annual rainfall changes are possible but unclear, affected by factors such as topography;
- increased intensity of extreme rainfall events is projected;
- time spent in drought is expected to increase; and
- potential evapotranspiration is projected to increase in all seasons as warming progresses.

The potential climate change effects for MCM have been considered as model sensitivities and are discussed further in Section 5.5.

3.3 Surface water resources

MCM is in the upper Isaac River catchment which is part of the Fitzroy River Basin. Consumptive users of water resources within the catchment are limited with one significant water retaining structure, the Burton Gorge Dam, located 45 km upstream of MCM.

The named watercourses relevant to MCM include:

- New Chum Creek.
- West Creek; and
- North Creek.

MCM is within the headwaters of New Chum Creek which is a tributary of the Isaac River and flows through the site to the south. New Chum Creek is characterised by a sandy bed channel incised within a wide floodplain. The main channel of the creek typically has a base width of approximately 3 m, a depth of 2 m, and moderate to steep bank slopes. The banks are stable and are well covered by trees and grass with a coarse sand bed material. Some waterholes persist in the channel for several weeks following rainfall, however, the stream flow is ephemeral, and there is little aquatic vegetation. New Chum Creek is crossed by several roads and a railway. Further downstream, the watercourse has been diverted around a neighbouring mining operation.

The south-western portion of MCM drains to West Creek which also joins to the Isaac River, upstream of its confluence with New Chum Creek. Within the West Creek catchment, the Western Dam is part of MCM infrastructure and serves as the primary water supply for operations with external water transferred to it via the local water utilities. Catchment to the dam is estimated at 5.6 km^2.

The north-eastern portion of MCM drains to the headwaters of North Creek. North Creek flows to the south where it also joins to the Isaac River downstream of its confluence with New Chum Creek. The portions of the North Creek catchment, historically disturbed by MCM, are limited to several small headwater gullies, on the north-eastern edge of MCM.

Based on assessment work completed by SLR (SLR 2023a), surface water systems in the area, based on their ephemeral nature, do not have a groundwater baseflow component with all watercourses defined as water-losing systems.

3.4 Groundwater systems

Groundwater systems and their interactions at MCM have been assessed and modelled by SLR (SLR 2023b). SLR generally summarise the existing groundwater as comprising of three main hydrostratigraphic units. These include:

- Quaternary alluvial sand of the Isaac River Alluvium, located along Isaac River and New Chum Creek. These are predominantly recharged by rainfall and stream flow infiltration during high streamflow events. Typically, they are higher-yielding aquifers but are limited in their size;
- Quaternary/Tertiary alluvial and colluvial sediments, an unconfined perched aquifer that is predominantly recharged by rainfall; and
- Permian aged Rangal Coal Measures and Fort Cooper Coal Measures which are semi-confined to confined aquifers. Most groundwater flow within these aquifers occur through higher permeability coal seam layers. The aquifers are predominantly recharged through rainfall where the deposit outcrops at surface, or by vertical leakage from overlying alluvium. The siltstones and sandstones that make up the majority of the interburden are considered to act as confining layers, due to their low permeabilities compared to the coal seams.

Due to the presence of several underground mines surrounding MCM, cumulative influence on the existing groundwater system is likely to be a factor in any assessment. SLR, in their regional modelling of the existing conditions, have considered the surrounding open cut mining operations to quantify the function of the regional groundwater system. Groundwater inflow to the open cut areas (during operations) has been relatively minor based on observations made by MCM.

For further information on the assumptions of the regional groundwater system as part of the groundwater model, reference should be made to the SLR report.

4 CONCEPTUAL MODEL

The conceptual model for the final void water balance is presented in Figure 4.1 and includes several surface and groundwater inflows and outflows. Within each final void, over time, it is expected that a pit lake area will develop and remain. The conceptual model has built on the previous preliminary assessment work by KCB on the M and D Pit (KCB 2023).

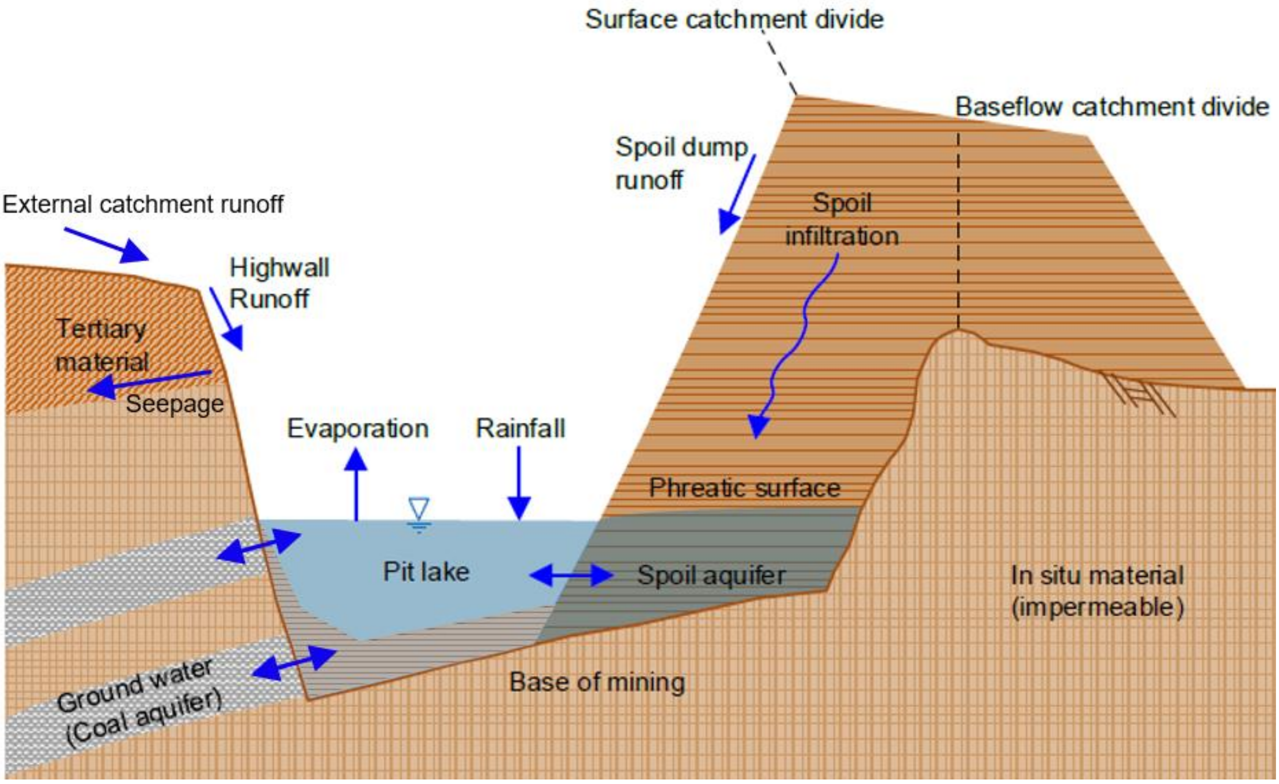


Figure 4.1 Conceptual final void water balance

Based on Figure 4.1 the key water inputs and outputs include:

- Inputs:
  - rainfall on the pit lake water surface;
  - rainfall infiltration through the spoil;
  - runoff from pit faces (i.e., highwall, low wall and spoil dumps) and rehabilitated or natural upstream catchment areas; and
  - groundwater interception.
- Outputs:
  - evaporation from the pit lake surface;
  - evapotranspiration from the contributing catchment;
  - seepage outflow through the tertiary or weathered material dependent upon the pit lake water levels; and

- surface water outflow if the pit lake water level exceeds the containment of the final void (i.e., void crest level).

The proposed final landform will use available spoil to backfill the residual voids as much as practicable. This will modify the existing shape of the pit floor where water has currently formed. This is specifically relevant for A and B Pit. Within M and D Pit and E Pit, minimal water volumes are stored as these potential changes in shape are unlikely to be a factor.

The backfill spoil within the voids is likely to be porous. The available water storage volume within the spoil has been considered within the overall water storage volume of the void using a spoil porosity factor. SLR (SLR 2023b) have considered a 5% porosity factor for spoil material as part of the groundwater model and this has been adopted within the WBM.

Following completion of the final landform, water is expected to accumulate within each void with the water level rising to a point where the void will reach a steady state. At this time, the combined inputs, or the direct rainfall, catchment runoff and groundwater interception, will be balanced by the evaporative losses from the wetted surface area of pit lake. Once the groundwater and pit water levels have equilibrated, variation above and below this water level will occur seasonally in the short term and long-term during prolonged periods of wet and dry climatic conditions (i.e., periods of floods and droughts).

Consideration of the groundwater fluxes in the model is required given the void’s interaction with coal seam aquifers and historical mine backfilling works. Through modelling by SLR (2023b) groundwater fluxes over time for each void were determined based on an initial water balance hydrology input. The results between the groundwater and water balance models converged on a common result through an iterative process. The groundwater flux data considered interactions via spoil catchments and fractured rock and coal seam groundwater systems.

The final landform will result in backfill spoil material covering the outcrop of coal seams within each void however the groundwater interactions are still likely to be present and may occur as inputs or outputs depending on the regional groundwater table at the time (and more pronounced along the dip of the seam). The rate of flow through spoil aquifers is dependent on an assumed porosity and hydraulic conductivity which varies across the site, but form part of the considerations made in the simulations completed by SLR. The consideration of seepage loss from each void has also been assumed based on modelling undertaken by SLR and includes water lost to adjacent country rock and spoils.

With respect to understanding the water quality dynamics within the conceptual model, it is expected that the characteristics of surface water compared to groundwater sources are likely to be significantly different. The greater volume of contribution from either source will likely drive the resultant water quality present within the void. Dissolved salts enter the final void via groundwater, spoil infiltration, and catchment runoff. In the absence of seepage or surface outflows to the environment, there is generally no removal of salts from the system with salts expected to accumulate over time, and the pit acting as a sink, within each pit lake formed.

This assessment has not considered how the voids may interact with existing ecological systems, other than surface water and groundwater.

5 FINAL VOID WBM DEVELOPMENT

5.1 Model aims and objectives

The aims and objectives of the final void WBM are to:

- provide a hydrological data set for use in the groundwater modelling of the MCM final voids;
- predict the water level at equilibrium for each final void considering surface and groundwater inputs and outputs;
- determine whether any of the final voids are likely to overtop and release water to the receiving environment;
- determine the likely water quality of each pit lake using salinity as an indicator and understand whether the final voids could provide a water source for beneficial use; and
- undertake sensitivity testing on key model components to understand the potential variance in results and consider these outcomes from a risk perspective.

5.2 GoldSim model

MetRes maintain an operational WBM of the water management system at MCM, built in the GoldSim software platform (Jacobs 2019). This operational WBM has been used as a basis for the development of a water balance / water quality model (i.e., final void WBM) also developed in the GoldSim software package (Version 14.0).

The final void WBM simulates the generation, movement and loss of water and salt on a daily time step within each final void over a 1,000-year period and comprises two components:

- a component to simulate the water inflows and outflows as described in Section 4 (i.e., runoff, direct rainfall, groundwater and spoil inflows / outflows and evaporation); and
- a component to allow prediction of the pit lake salinity.

Both components are interlinked as the inflows and outflows and associated salinity loads contribute to the final void water quality. These components are used to estimate the volume of water and associated salinity of the water, that report to each final void, from other identified or known sources.

The key final void WBM inputs and parameters summarised in the following sub-sections of this report include:

- Physical characteristics: based on provided project data (refer to Appendix I).
- Hydrological parameters: based on publicly sourced climate data (refer to Appendix I) and the Australian Water Balance Model (AWBM) catchment yield parameters adopted for the operational WBM.
- Hydrogeological parameters: based on provided project data and timeseries data provided by SLR (SLR 2023b).

- Potential water usage: based on publicly available government recommendations for cattle usage estimates.

5.3 Physical characteristics

5.3.1 Current and final landform description

The current landform topography for MCM is presented in the site locality plan in Figure 1.1. The current landform is based on LiDAR surface topography information provided by MCM in 2023. M Mining is progressively diverting more clean water around the MCM operations to reduce the load on the existing in-pit water management system.

The final landform design is specific to the existing open cut pit voids of A and B Pit, M and D Pit, and E Pit. Much of the external area to these final voids has already been shaped and rehabilitated. As described in Section 2.2, the existing voids will be backfilled with the remaining available spoil material as far as practicable.

The final landform associated with the final voids includes a number of reduced batter slopes, generally resulting in the reduction of existing batters of 1 vertical (V) to 2 horizontal (H) (50%) down to batters resembling 1V to 4H (25%).

Backfill spoil will generally raise the pit floor in each void, however, this amount does vary depending on the pit shape and surrounding batters.

Through the development of the final landform, there is not expected to be any significant diversion of catchments from the current landform assumptions. At the time of writing (late 2023) , consideration for the future diversion of external catchments contributing to M and D Pit from the north is in a planning phase and these changes have been considered as part of sensitivity testing on the model outcomes. As previously indicated, MCM have been planning and installing additional clean water diversions around the site, which have been considered as part of the catchment delineation assumptions.

5.3.2 Level-surface area-volume relationship

Level – surface area – volume relationships for the free water (i.e., water not contained in rock, soil, spoil, etc) and relationships including spoil within the final voids are presented in Appendix II. The level – surface area – volume relationships are derived from computer analysis of the final landform and deepest mined surface topography.

5.3.3 Catchment areas

Surface runoff catchment areas reporting to each final void is shown in Figure 5.1. The amount of external catchment contributing to each final void is minimal with M and D Pit having the largest external catchment contribution. A and B Pit and E Pit catchments are limited to the surface area of the void.

The delineation of catchments has been based on the final landform topography with the areas shown in Figure 5.1 and Appendix II.

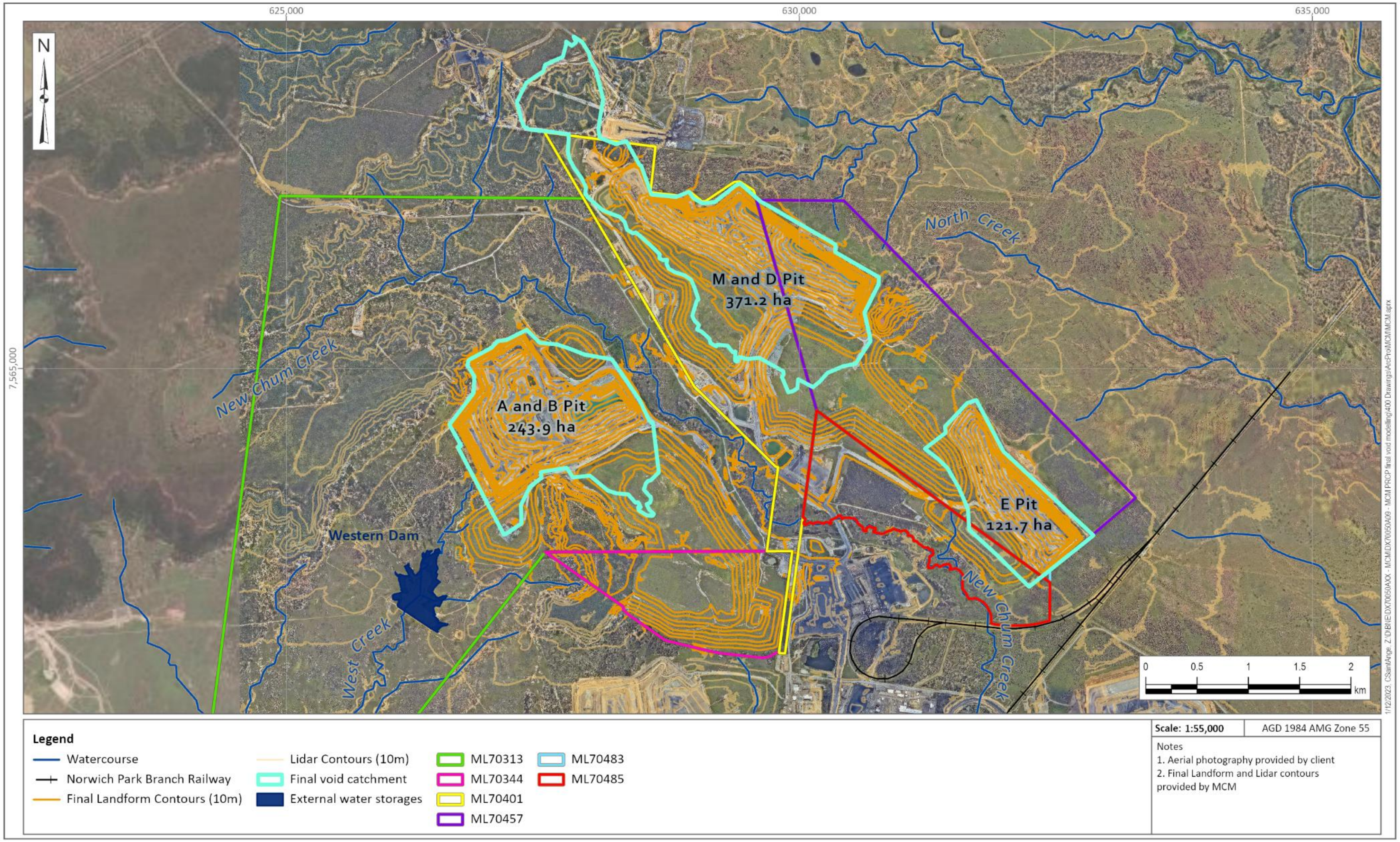


Figure 5.1 Final void catchment areas

5.4 Catchment land use

A review of the aerial imagery and existing operational WBM provided by MetRes has determined that applicable catchment land use categories for consideration in the model include natural, rehabilitated areas and mining pit/hardstand.

With consideration to the progressive rehabilitation of the disturbed catchment areas, the land use classification adopted for the final void catchments have been based on the following assumptions:

- Rehabilitated land and mining pit low walls are expected to revert, over time, to natural or pre-mining conditions because of topsoil consolidation and weathering. This transitional process is relevant as part of hydrological assumptions in the model. The majority of external catchment surrounding the final voids comprises rehabilitated spoil dumped over the low wall, with the date of its initial rehabilitation unknown, hence it was lumped in with the rehabilitation of the final void backfill spoil.
- Rehabilitated low wall areas will be progressively offset by the wetted surface area in each void (i.e., they will get covered by water as the pit fills).
- Pit highwalls and end walls are expected to continue to produce higher runoff than the rehabilitated areas due to the relative difference in slope and cover and are assumed to remain as mining pit/hardstand land use category. Long-term changes to this land use type are unlikely.

A breakdown of catchment land use categories of the final voids is provided in Table 5.1 and presented in Figure 5.2.

Table 5.1 Catchment land use type at commencement of closure

Final void	Natural	Mining pit/hardstand	Rehabilitated spoil
A and B Pit	0	53.9	190.0
M and D Pit	63.5	39.6	268.1
E Pit	0	28.6	93.1

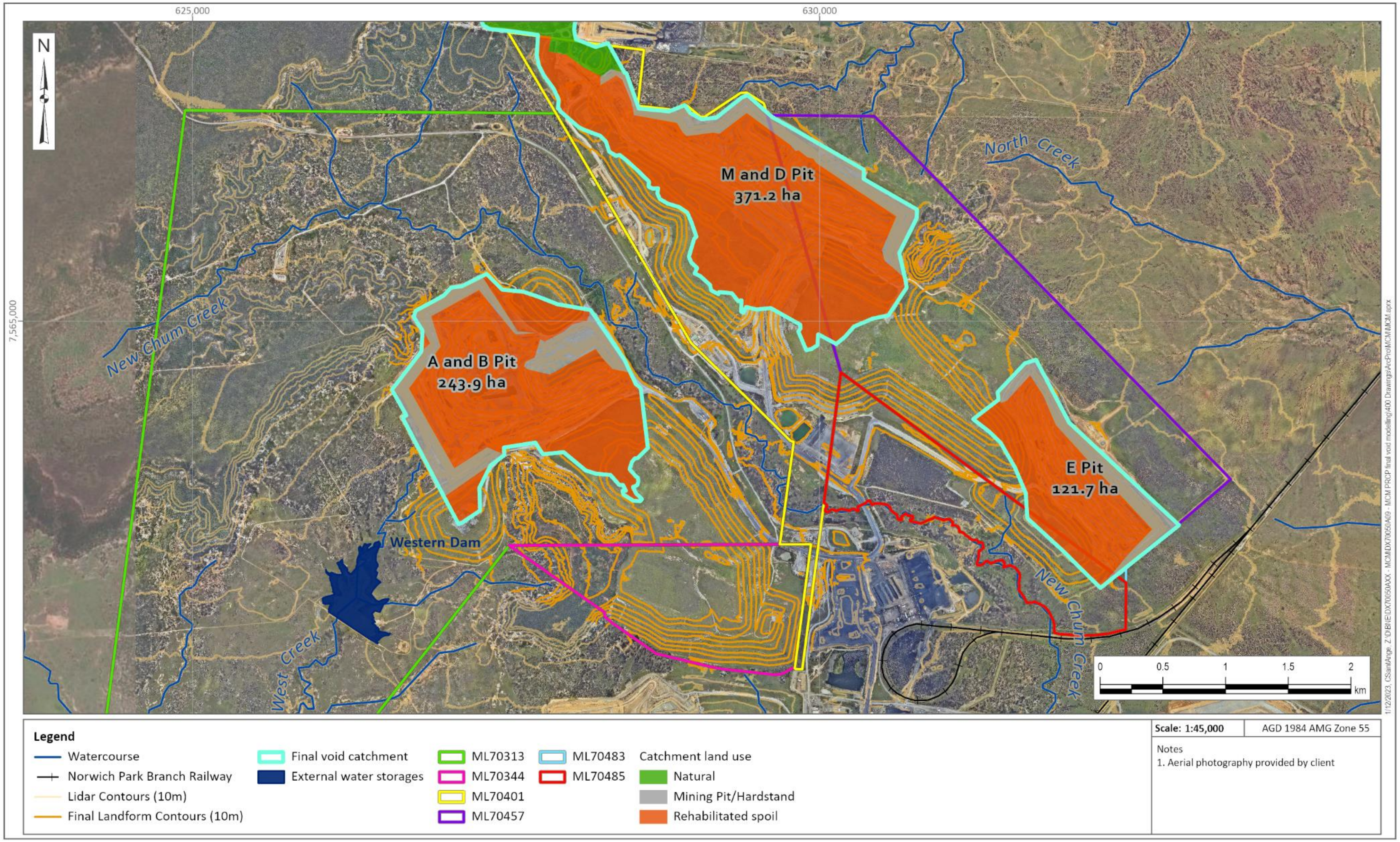


Figure 5.2 Catchment land use at commencement of rehabilitation

5.5 Hydrological inputs

As detailed in the conceptual model (refer to Figure 4.1), the climatic influences on each final void include direct rainfall on the pit lake surface, catchment runoff, evaporation from the pit lake water surface and evapotranspiration from the contributing catchments. The final void WBM used long-term historical climate data, spanning over 134 years, to model rainfall, evaporation, and evapotranspiration within the catchments. These past climatic conditions are assumed to be indicative of persistent local trends which are likely to be observed in the future. The possible effects of climate change have been considered as sensitivities on the model outcomes and are discussed in Section 9.1.5.

As discussed in Section 3.2, long-term daily rainfall and evaporation datasets (from 1 January 1889 to 14 February 2023) were obtained through SILO (2023a).

A review of the monthly Data Drill and MCM site rainfall, through the use of a double mass curve (refer to Figure 5.3) indicated that the SILO data set is generally consistent with the site data being recorded and hence deemed suitable to model the final void conditions.

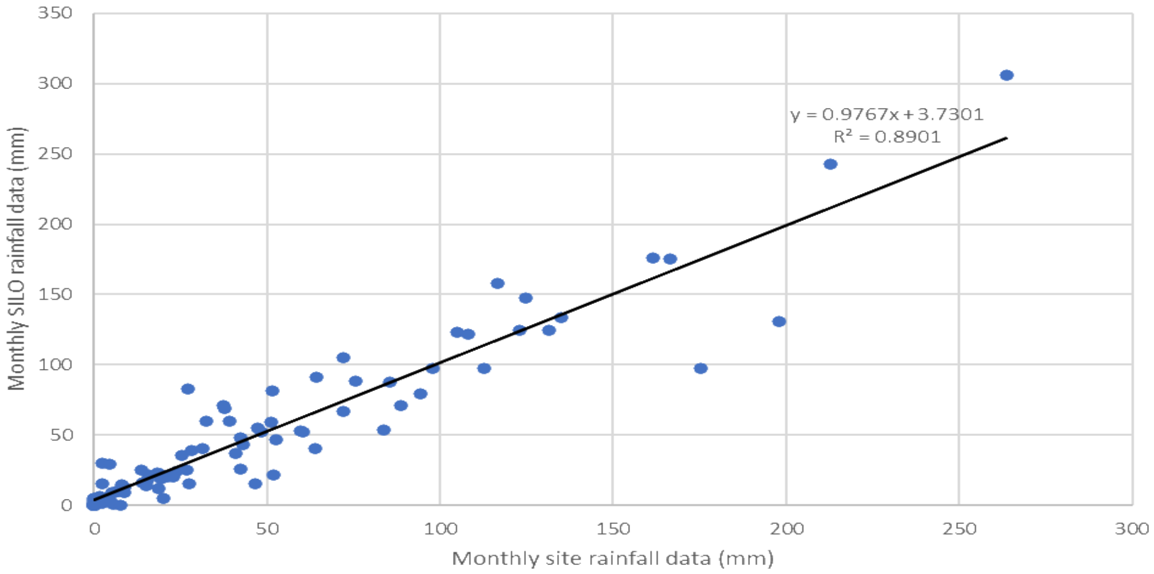


Figure 5.3 Double mass curve comparison of monthly MCM site and SILO rainfall data

Through sequential repetition of the 134-year Data Drill climate datasets, long-term 1,000-year datasets were established for the final voids at MCM. The Data Drill rainfall and evaporation datasets used for the final voids WBM have been summarised in following sections of the report.

5.5.1 Rainfall

Historical annual rainfall totals over the recorded period and a percentile distribution are presented in Figure 5.4.

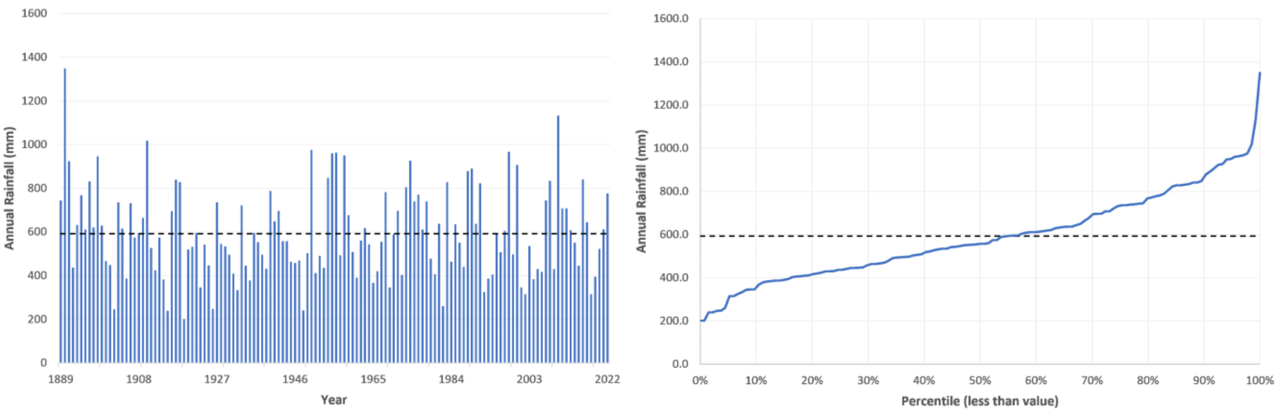


Figure 5.4 Data Drill annual rainfall totals – time series data and percentiles

Key annual rainfall statistics for the period 1889 to 2022 are summarised in Table 5.2.

Table 5.2 Annual rainfall statistics

Statistics	Annual rainfall (mm)
Minimum	201.1
Maximum	1,348.6
Average	592.4
80% Range	±260.9

A rainfall residual mass curve for the rainfall dataset is presented in Figure 5.5. The curve has been derived from the cumulative sum of the difference between each year’s annual rainfall from the mean annual rainfall.

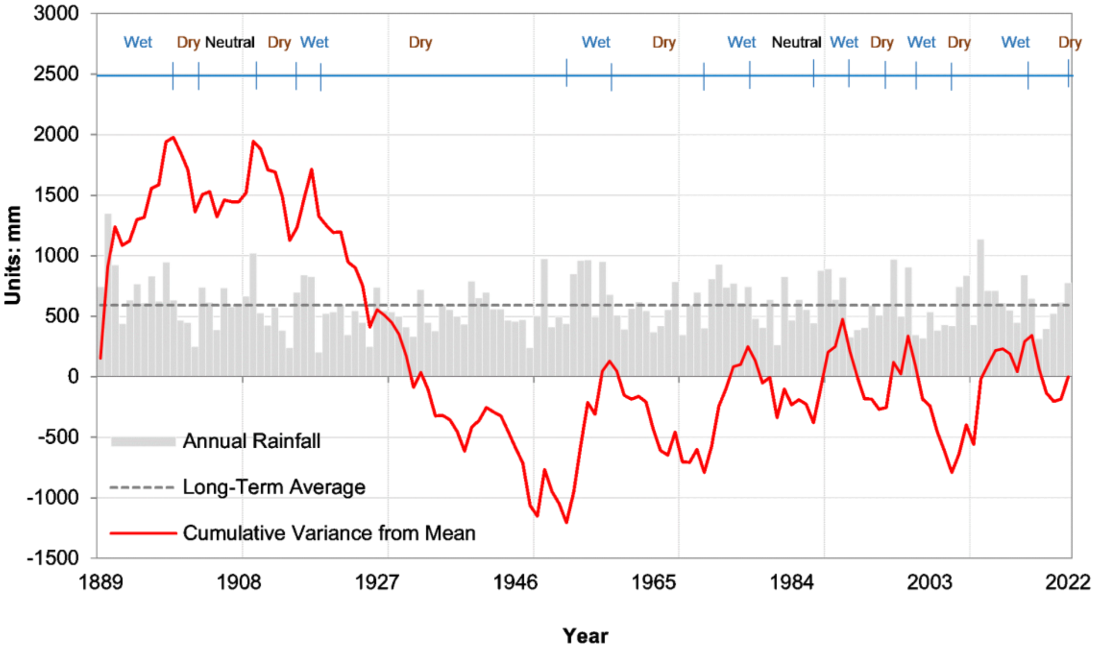


Figure 5.5 Rainfall residual mass curve and seasonality analysis

Figure 5.5 shows that the historical rainfall sequence, from 1889 to 2023, features several downward trends indicating periods of drought and persistent upward trends, typical of above average rainfall.

5.5.2 Evaporation and adjustment factor

Evaporative losses have been calculated within the final void WBM based on the following evaporation data sourced from the Data Drill (SILO 2023):

- Morton lake (M_{lake}) evaporation – used as the primary data input for the final void WBM to estimate evaporation from the pit lake surface areas.
- Morton wet (M_{wet}) evaporation – used to estimate evapotranspiration losses from catchment areas.

A comparison of evaporation and evapotranspiration annual statistics for the period 1889 to 2022, from the Data Drill is provided in Table 5.3.

Table 5.3 Annual evaporation and evapotranspiration summary

Statistic	Annual M_{lake} (mm)	Annual M_{wet} (mm)
Minimum	1,525.7	1,484.1
Maximum	1,970.8	1,862.6
Average	1,797.1	1,719.2
80% Range	±90.7	±79.0

Wind shielding and shading conditions on each final void may result in reduced evaporation from the pit lake surface. To account for this reduction in evaporative losses, an evaporation adjustment factor has been incorporated in the final void WBM.

A pit evaporation factor of 0.7 is commonly used for mining pits and is consistent with experience with similar water balance studies for open cut coal mines in the Bowen Basin (Tomlin *et al*, 2023a). However, as the water level within each final void rises, the evaporation factor is expected to increase due to the reduced shading and wind shielding with the opposite also expected (i.e., decreased evaporation adjustment factor as the water level decreases).

Mining pits vary in shape and size which in some cases may potentially reduce the impact of wind shielding and shading. To account for the uncertainty inherent with this parameter, the final void WBM has included sensitivity cases comparing pit evaporation factors of 0.7 and 0.9 on model results (refer to Section 9.1.1).

5.5.3 Catchment yield

The final void WBM used the AWBM to model catchment yield. Use of this model in the assessment is consistent with the operational WBM for MCM and is widely accepted and commonly used for mine WBMs in Australia.

As outlined in Section 5.4, natural, mining pit/hardstand and rehabilitated spoil land use classifications have been modelled as the most appropriate long-term representation of the final void catchment conditions. Adopted AWBM parameter sets for each land use type are presented in Table 5.4 which are consistent with the values used in the operational WBM for MCM. The long-term catchment yield for each AWBM parameter set has also been presented in Table 5.4.

Table 5.4 AWBM catchment yield parameters

Parameter set	Partial area			Soil moisture capacity (mm)			Ks	Baseflow*		S_{avg}	Long-term yield (%)
	A_1	A_2	A_3	S_1	S_2	S_3		K_b	BFI		
Natural	0.1	0.2	0.7	2	13	100	0	0	0	72.6	19.0%
Mining pit/hardstand	0.1	0.9	0	13	38	0	0	0	0	35.5	22.5%
Rehabilitated spoil	0.1	0.9	0	12	221	0	0	0	0	200.1	6.2%

Note: * Baseflow has been made to be zero in this assessment due to the potential double counting through the hydrogeology modelling being undertaken by SLR (refer to Section 5.5.5).

Based on the long-term yield percentage presented in Table 5.4, as rehabilitation areas transition to a natural state, catchment runoff should also increase. Residual areas of mining pit/hardstand areas (i.e., highwalls and end walls) are expected to generate the highest rates of runoff.

5.5.4 Initial conditions

The final void WBM is configured to simulate water accumulations from the expected water level within the final void at the onset of closure. Based on information provided by MetRes, the initial water level has been set to be at the lowest position of the void and corresponding salinity values have been set to zero at the commencement of closure at MCM, with a nominal starting date assessed as 1 January 2027.

The soil moisture capacity, within the AWBM model, also considered an assumed initial condition of zero storage (i.e., dry catchment) at the commencement of closure.

5.6 Hydrogeological inputs and assumptions

Information on hydrogeology of the final voids has been assessed and modelled by SLR (SLR 2023b) who maintain the regional numerical groundwater model for MCM.

Key hydrogeological assumptions and inputs used in the final void WBM included:

- Groundwater inflows: groundwater inflow rates are predicted to be generally small. This is consistent with observations made by MCM in their coal mining activities. Positive time series data for groundwater inflows from SLR were used as direct inputs to the final void WBM.
- Spoil inflows: considers the inflows to the void contributing from spoil. This is different from the considerations of the spoil material’s ability to serve as part of the storage capacity of the void (which is assumed at a 5% porosity) and considers the difference of the deepest mined and final landform surface. Sensitivity testing of this value is provided and discussed in Section 9.1. Further information on the level-volume relationship is provided in Appendix II. Positive time series data for spoil inflows from SLR were used as direct inputs to the final void WBM.
- Seepage outflows: negative time series data from SLR were used in the final void WBM to model outflow from each void from both spoil and geology present.
- Hydraulic connectivity: based on final landform topography and predicted water levels within some of the final voids, the presence of multiple pit water bodies is likely in M and

D Pit and A and B Pit. A key assumption in the final void WBM is that in these cases, the water level will equalise between these pit water bodies with an assumed connection through effectively a saturated spoil aquifer. The modelling within the final void WBM assumes that there is no restriction on the saturated spoil aquifer to balance flows from a total void perspective. One exception to this assumption is how M and D Pit and E Pit are modelled. Due to the nature of past mining in the area, a connection pathway exists between the two pits. As shown in the deepest mined surface, an internal crest wall (at approximately 199 mAHD) is located between the two pits with E Pit generally located downstream of M and D Pit. The final void WBM has considered a potential subsurface flow pathway between these two pits which estimates flow transfer volumes using a simple Darcy equation driven by water level in the two pits, along with a hydraulic conductivity and porosity value determined by SLR. This flow path is assumed to respond within the time step of the final void WBM which is a conservative assumption. The estimated volume of flow is not expected to be significant in the broader system context, however, if connection does occur, it has been considered.

Hydrogeology information from SLR's regional numerical groundwater model was provided to KCB for incorporation into the final void WBM as individual time series. To align the two predictive models, iterations between the groundwater model and final void WBM were undertaken to converge on consistent results. The measure of a converged result is detailed in the assessment by SLR (SLR 2023b).

Time series for groundwater and spoil inflows and total seepage outflows for each final void, provided by SLR and used as input into the final void WBM, are shown in Figure 5.6 to Figure 5.8.

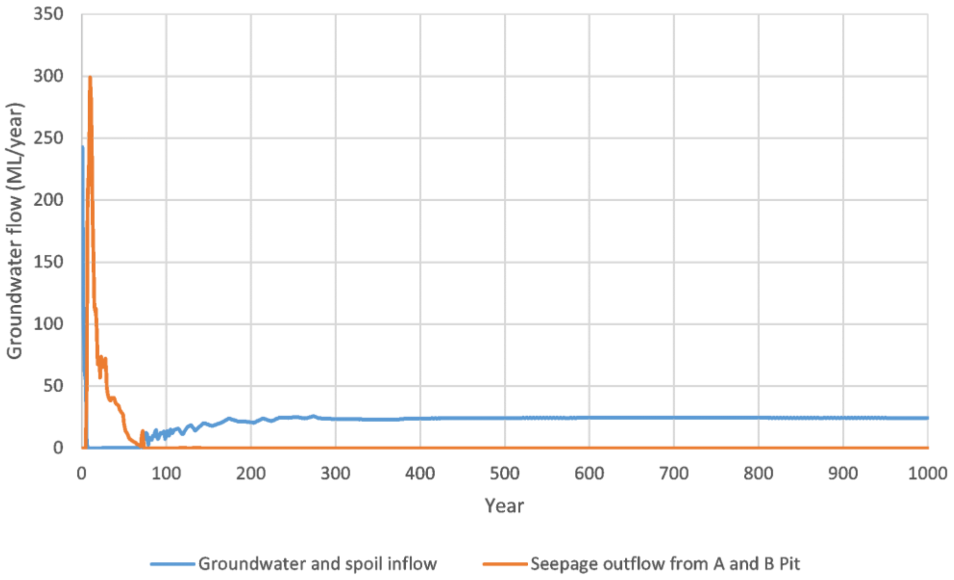


Figure 5.6 A and B Pit groundwater and spoil interactions

Figure 5.7 **M and D Pit groundwater and spoil interactions**

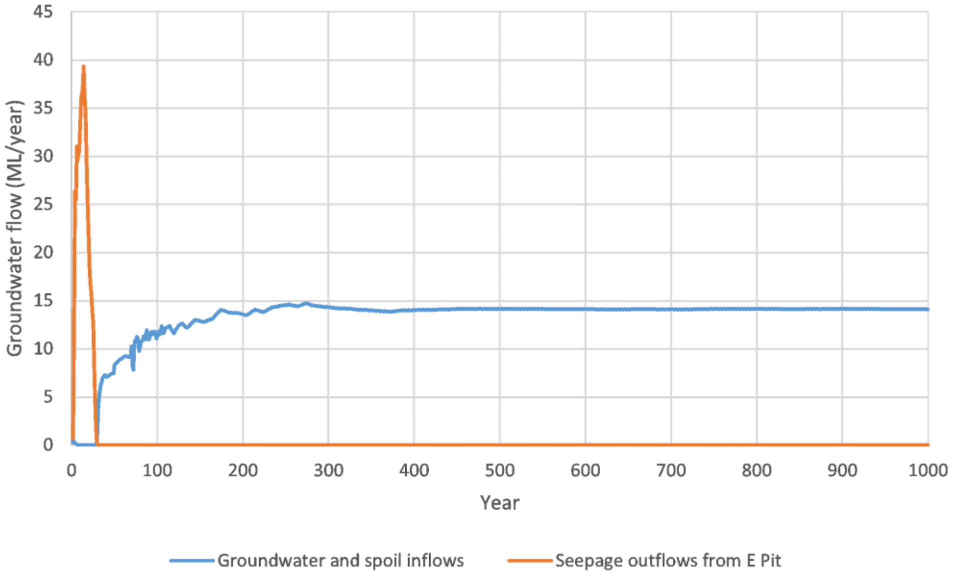


Figure 5.8 **E Pit groundwater and spoil interactions**

Further detail on the time series data used in the final void WBM is provided in Appendix I.

5.7 Salinity generation

The final void WBM tracked the net accumulation of salt mass within each final void. Salt has been modelled as a mass and reported in terms of total dissolved solids (TDS) in units of milligrams per litre or electrical conductivity (EC) in units of micro-siemens per centimetre (µS/cm), calculated assuming a conversion factor or 0.67, (i.e., EC x 0.67 = TDS).

As indicated, as part of the model conceptualisation (refer to Section 4), salts enter the final void via groundwater inflows and catchment runoff. Salt inflows have been calculated by assuming a salinity concentration for each source. The adopted salinity concentrations for each source are summarised in Table 5.5 and are consistent with previous assessments undertaken at MCM and the operational model (M Mining, 2023).

Table 5.5 Salinity concentrations considered in the WBM

Salinity source	Concentration	
	EC (µS/cm)	TDS (mg/L)
AWBM mining pit/hardstand catchment land use	5,000	3,350
AWBM natural catchment land use	350	235
AWBM rehabilitation spoil catchment land use	5,000	3,350
Groundwater inflows	5,000	3,350
Spoil inflows	5,000	3,350

5.8 Potential water usage

Implementation of any beneficial usage activity is expected to both remove water from each final void and lead to the removal of salt and assist in reducing the long-term salt load. As detailed in the MCM water management plan (M Mining 2023), the current main beneficial reuse of local surface water resources is opportunistic stock watering. Depending on the quality, water within each final void may be used to provide water for stock (consistent with Table F1 of the EA (DES 2023b)).

Assumptions for the beneficial reuse of water from the final voids in meeting livestock water demands considered in the final void WBM scenarios are:

- Average cattle usage of 50 L/head/day consistent with government recommendations for cattle water requirements (45 to 60 L/head/day water requirements for cattle (Future Beef 2022);
- Stock rating of 1 head/5 ha of area based on Queensland Government advice (Future Beef 2021);
- Maximum of 2,828 ha of cattle grazing area is available which equates to ~566 head of cattle that could potentially use final void as a water source (assuming only area within existing MLs, appropriate access and topography for stock to access water from the voids).
- Total estimated volume of 10.3 ML/year (or 28.3 kL/day) of water potentially used by stock collectively from the final voids, proportioned based on the area of service available from each void.
- Water used by stock is dependent on the drinking water quality requirements, with a maximum TDS tolerance of 5,000 mg/L (equivalent EC of 7,463 mS/cm) adopted with beef cattle expected to be the main livestock to use the final void as a water sources (based on livestock TDS tolerances as presented in Table 5.6).
- Cattle are able to safely access the water surface within the final voids.

Table 5.6 Tolerances of livestock to TDS (salinity) in drinking water (ANZECC 2000)

Impact	TDS (mg/L)			
	Beef Cattle	Dairy Cattle	Sheep	Horses
No adverse effects on animals expected	0 - 4,000	0 – 2,500	0 - 5,000	0 - 4,000
Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production	4,000 – 5,000	2,500 – 4,000	5,000 – 10,000	2,500 – 4,000
Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually	5,000 – 10,000	4,000-7,000	10,000 – 13,000	4,000 – 7,000

Besides stock watering, other beneficial usage activities that could be implemented for water stored within the final voids could include irrigation for agricultural activities and industrial process water demands (including neighbouring mining operations).

Consideration of the potential water usage of water from the final voids has been assessed in Section 8.

6 BASE CASE WBM PREDICTIONS

6.1 Overview

As detailed in Section 5.1, the aim of the study was to develop a final void WBM that quantifies the hydrologic function of final voids at MCM and predict the water level at equilibrium for each final void.

The assessment has been undertaken using a daily time step WBM to estimate the time taken to reach equilibrium and the water level once equilibrium conditions have been reached.

The base case model was based on:

- physical parameters as presented in Section 5.3 (i.e., level – surface water – volume relationships, reporting catchment areas and associated land use characterisation);
- hydrology parameters as presented in Section 5.5 (i.e., rainfall, evaporation, and catchment yield); and
- hydrogeology inputs and assumptions presented in Section 5.6 (i.e., groundwater interactions).

The results of the base case model are provided below in Section 6.2.

The base case has been used also to test uncertainty of several key final void WBM parameters and to quantify the impact of uncertainty on the predicted water level fluctuations, with sensitivity cases presented in Section 9.1.

6.2 Results

6.2.1 A and B Pit

Predicted long-term water level fluctuations within A and B Pit for the base case are presented in Figure 6.1.

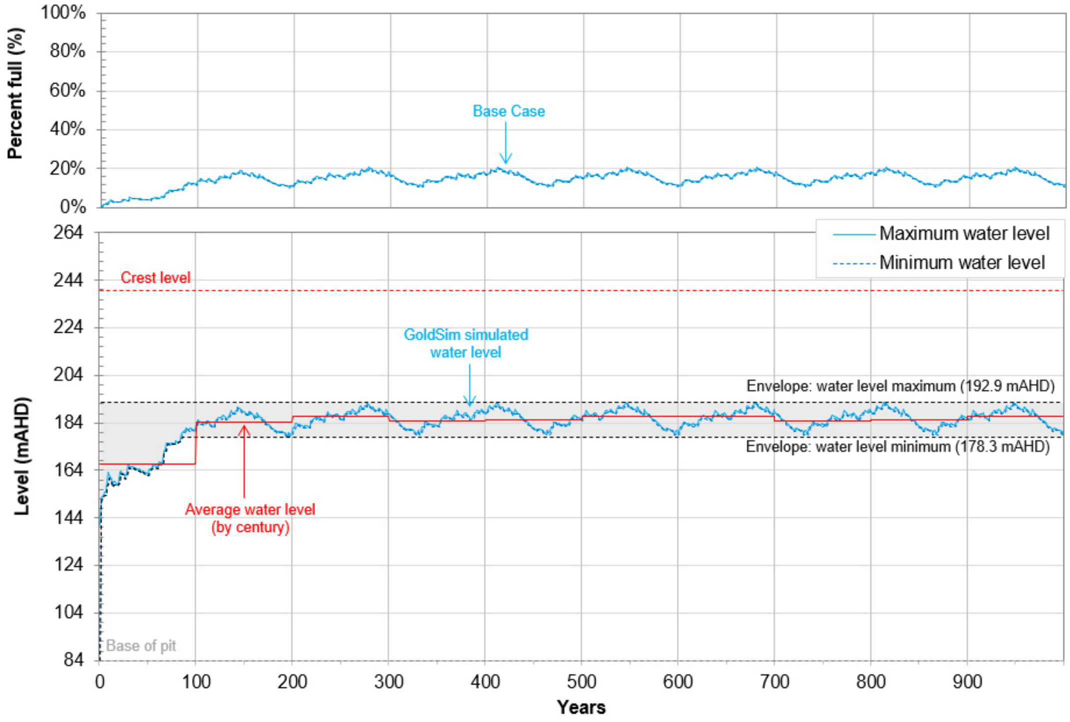


Figure 6.1 A and B Pit water levels – base case

Model results for A and B Pit indicate:

- A and B Pit is expected to be able to continuously maintain multiple bodies of water (i.e., not completely dry out under drought periods) and not result in overflows from the void under wet periods. The bodies of water formed within the void will be separated by the emplaced spoil with assumed subsurface connectivity between water bodies occurring through these areas.
- Percentage storage compared with water level freeboard is reflective of a significant area of spoil that is available for storage. A and B Pit includes the backfilled C Pit as part of the level-surface area-volume relationship.
- Simulated water level within the final void is expected to increase from 2027 for a period of approximately 140 years until equilibrium is predicted to be reached.
- Once equilibrium conditions are reached:
  - Water level fluctuations will vary seasonally within an envelope defined by maximum and minimum water levels estimated at 192.9 mAHD and 178.3 mAHD, respectively.
  - Water level fluctuations are expected to be below the crest level with no release of water via overtopping predicted.
  - Around 47 m of freeboard storage is predicted between the maximum water level envelope and crest level of the void.

6.2.2 M and D Pit

Predicted long-term water level fluctuations within M and D Pit for the base case are presented in Figure 6.2.

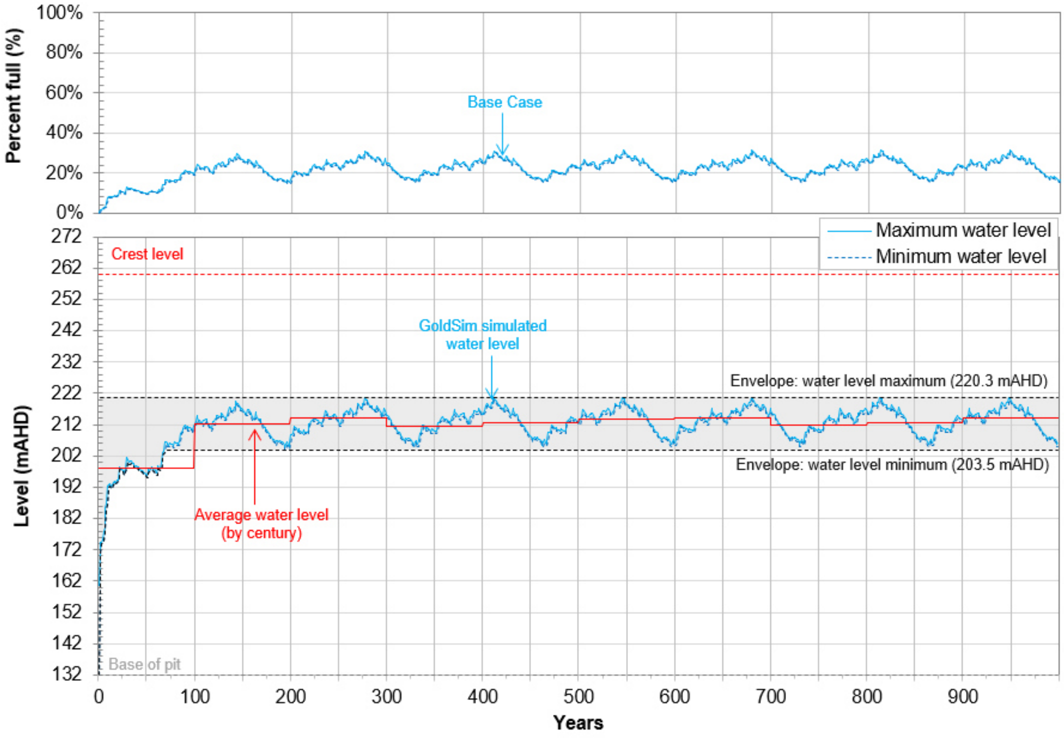


Figure 6.2 M and D Pit water levels – base case

Model results for M and D Pit indicate:

- M and D Pit is expected to be able to continuously maintain multiple bodies of water, once equilibrium is reached, and not result in overflows from the void under wet periods.
- Simulated water level within the final void is expected to increase from 2027 for a period of approximately 140 years, like A and B Pit, until equilibrium is predicted to be reached.
- Once equilibrium conditions are reached:
  - Water level fluctuations will vary seasonally within an envelope defined by maximum and minimum water levels estimated at 220.3 mAHD and 203.5 mAHD, respectively.
  - Water level fluctuations are expected to be below the crest level with no release of water via overtopping predicted.
  - Around 39 m of freeboard storage is predicted between the maximum water level envelope and crest level of the void.

6.2.3 E Pit

Predicted long-term water level fluctuations for E Pit for the base case are presented in Figure 6.3.

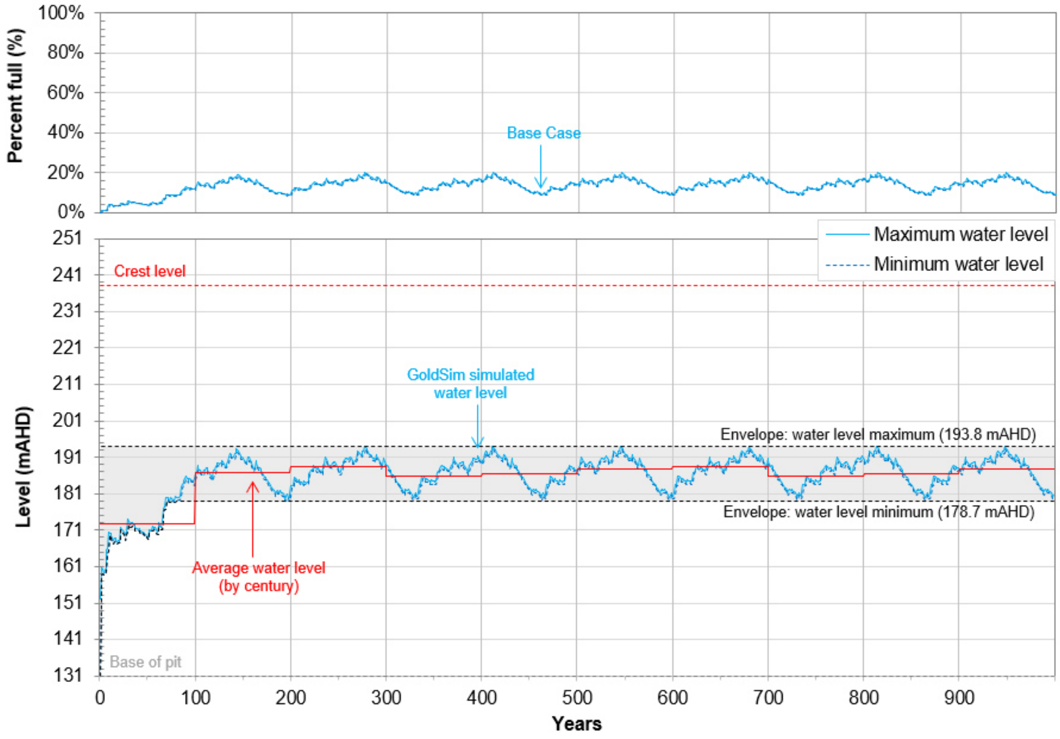


Figure 6.3 E Pit water levels – base case

Model results for E Pit indicate:

- E Pit is expected to be able to continuously maintain a single body of water and not result in overflows from the void under wet periods.
- Simulated water level within the final void is expected to increase from 2027 for a period of approximately 140 years, like the other final voids until equilibrium is predicted to be reached.
- Once equilibrium conditions are reached then:
    - Water level fluctuations will vary seasonally within an envelope defined by maximum and minimum water levels estimated at 193.8 mAHD and 178.5 mAHD, respectively.
    - Expected water level fluctuations are expected to be below the pits' crest level and as such the release of water via overtopping is not predicted.
    - Around 44 m of freeboard storage is predicted between the maximum water level envelope and crest level of the void.

6.3 Summary

Base case results indicate that the three final voids are expected to form constant pit lakes (in some cases, consisting of multiple waterbodies within the void) with no overflows, via the void crest, to the receiving environment expected. The pit lakes formed within each final void were predicted to typically consume 20 to 30 % of the available storage volume within each void, based on the level-surface area-volume relationship assumptions of the final void model.

Further to these base case results:

- assessment of expected water quality within the final voids is discussed in Section 7;
- assessment of water reuse opportunities for the final voids is discussed in Section 8; and
- consideration of uncertainty in the final void WBM and assessment of risk is discussed in Section 0.

7 WATER QUALITY ASSESSMENT

7.1 Monitoring data

7.1.1 Available data

Water quality monitoring at MCM occurs within surface water dams, groundwater bores, water stored within pits and at several locations within the surface water environment as part of the receiving environment monitoring program (REMP).

For this study, available water quality monitoring data from MCM has been used to:

- understand typical water quality of runoff from the existing catchment, through monitoring of existing surface water dams on site;
- characterise groundwater water quality specifically, coal seam aquifers and other stratigraphy likely to interact with the void; and
- understand the water quality of existing in-pit waterbodies.

To inform the hydrogeochemical considerations and stratification modelling, the baseline data outlined in Table 7.1 to Table 7.3 was considered, with associated sampling locations shown in Figure 7.1.

Table 7.1 Surface water quality monitoring

Location	Purpose	Period	Number of samples	Monitoring analytes
Sediment Dam 8	Sediment laden water	March 2018 to May 2023	5	Physicochemical parameters: pH, EC, Total Suspended Solids (TSS), and TDS Metals (dissolved and total): aluminium (Al), arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn) Major ions: sulfate (SO_4), silicon (Si), and fluoride (F) Other: free and total residual chlorine
Windmill	Sediment laden water	August 2021 to May 2023	8	
Dam 4	Mine affected water	March 2018 to May 2023	16	
Sediment Dam 5	Mine affected water	March 2018 to May 2023	14	
Build Pad Dam	Mine affected water	November 2021 to May 2023	7	

Table 7.2 Groundwater quality monitoring locations

Location	Water table height (mAHD) and geological unit	Period	Number of samples	Monitoring analytes
MB2	86.8-81.7 Permian Rangal unit	March 2018 to May 2023	5	Physicochemical parameters: water depth
MB8B	65.9-63.3 Fort Cooper unit	March 2018 to May 2023	21	

Location	Water table height (mAHD) and geological unit	Period	Number of samples	Monitoring analytes
MB9A	26.9-23.3 Fort Cooper / New Chum Creek Alluvium	March 2018 to May 2023	21	Physicochemical parameters: water depth, pH, EC, TSS, and TDS Major ions: magnesium (Mg), sodium (Na), potassium (K), calcium (Ca), chloride (Cl), SO_4, total alkalinity, and bicarbonate alkalinity Metals (dissolved and total): Al, As, antimony (Sb), molybdenum (Mo), selenium (Se), silver (Ag), iron (Fe), and mercury (Hg) Petroleum hydrocarbons: C6-C10 and C10-C40 fraction
MB9B	36.8-30.7 Fort Cooper unit	March 2018 to May 2023	21	
MB10A	19.9-10.7 Fort Cooper / New Chum Creek Alluvium	June 2018 to May 2023	18	
MB10B	20.0-17.2 Fort Cooper unit	June 2018 to May 2023	19	

Table 7.3 In-pit water quality monitoring locations

Location	Sample depth	Period	Number of samples	Monitoring analytes
B Pit	Near surface grab sample	October 2020 to February 2023	9	Physicochemical parameters: pH, EC, TSS, TDS Metals (dissolved and total): Al, As, Cd, Cr, Co, Cu, Pb, Ni, and Zn Major ions: SO_4, Si, and F Other: free and total residual chlorine
D Pit		October 2020 to February 2023	8	
E Pit (E1, E3 and E4)		October 2020 to February 2023	8	

There are limitations in the data available for current in-pit water quality sampling with the dataset representative of grab samples taken from the water surface only and these may not be representative of water quality at depth in the pits. The data set also does not consist of a consistent suite of analytes when compared to groundwater monitoring.

Water quality sampling at depth and an increase in the analytes tested will be required to assist in future validation of modelling results and will be a future recommendation from this study (discussed further in Section 10).

7.1.2 Data analysis

Surface water quality monitoring across MCM includes runoff from both sediment and coal contact catchment areas. Monitoring sites detailed in this study have considered predominately sediment-laden water storages for the purposes of salinization of the potential water quality from rehabilitated catchments.

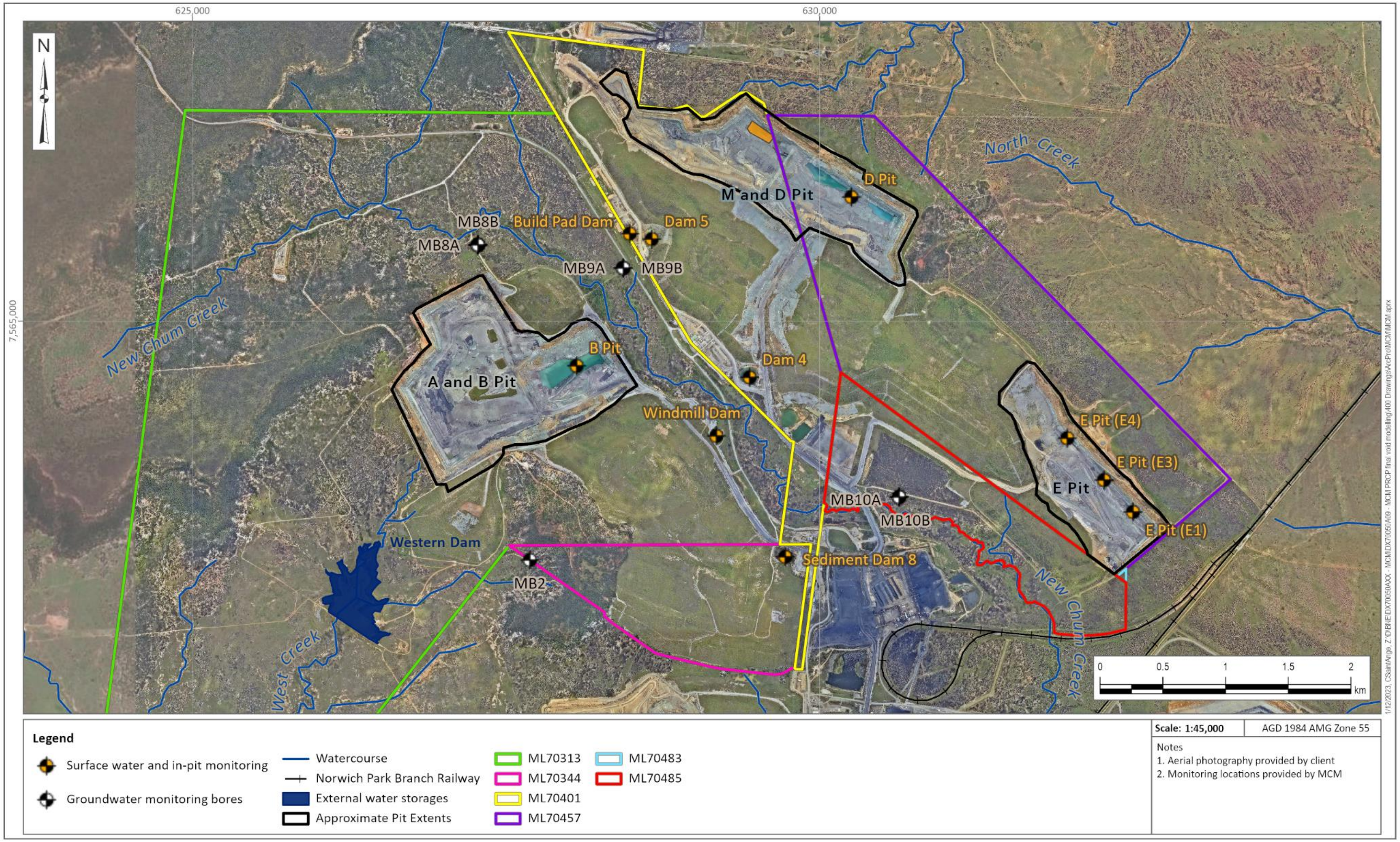


Figure 7.1 Water quality monitoring locations

Available surface water quality data at MCM indicates:

- pH levels range from ~8 to ~10, with catchment runoff likely to be the most alkaline of water sources contributing to final voids in the future.
- EC levels vary across the surface water monitoring sites tested; however, monitoring indicates ECs less than 6,000 µS/cm with an average for many monitoring locations below 1,000 µS/cm.
- Concentrations of Al, As, Cu, Ni and Zn occur in surface runoff above detection limits, but these do vary across catchments being monitored. Several dissolved metals were typically below detection limits and included Cd, Cr, Co, and Pb.
- SO4 concentrations were found to vary over the period of data available, with many monitoring locations averaging between 20 mg/L and 230 mg/L.

Groundwater quality data collected at MCM indicates:

- Monitoring bores are located within two distinct groundwater environments: a shallow and deep system. The shallow groundwater system is characterised by distinctly lower concentrations of SO_4, K and Mg.
- pH levels range from 7.0 to 8.5, with pH levels more neutral than the slightly alkaline in-pit waterbodies.
- EC levels varied significantly across groundwater monitoring bores. Near surface groundwater is less saline, with EC typically ranging from 5,000 to 10,000 µS/cm and groundwater systems associated with the coal seam typically had an average EC of 23,000 µS/cm.

Available in-pit water quality data collected at MCM indicates:

- EC levels range between 4,000 to 5,000 µS/cm.
- pH levels range between 7 to 9, with conditions slightly alkaline.
- SO_4 levels range from 600 to 800 mg/L, with the highest concentrations located within E Pit.
- Average metal concentrations vary across each pit, however, E Pit tends to generally have a higher metal concentrations compared with Pit B and Pit D, with concentrations typically in a dissolved form. Many of the sample results indicated metal concentrations less than the limit of detection.
- The ability to compare the in-pit data set with the groundwater water quality is limited by the analytes currently being tested. A lack of testing of major ions and suite of metals makes consideration of future geochemical dynamics difficult. Similar limitations were noted in the surface water quality monitoring program.

7.2 Salinity modelling integrated within the final void WBM

The final void WBM included a TDS mass balance which when compared to stored volume allows estimation of EC. As detailed within Section 5.7, TDS concentrations are considered as part of water inflows (i.e., catchment runoff, direct rainfall and groundwater and spoil inflows) and removed by any outflows, except for evaporation (i.e., overflow and seepage).

7.2.1 Results

7.2.1.1 A and B Pit

Predicted long-term TDS fluctuations for A and B Pit base case are presented in Figure 7.2. The results have been compared against typical reuse tolerances for stock.

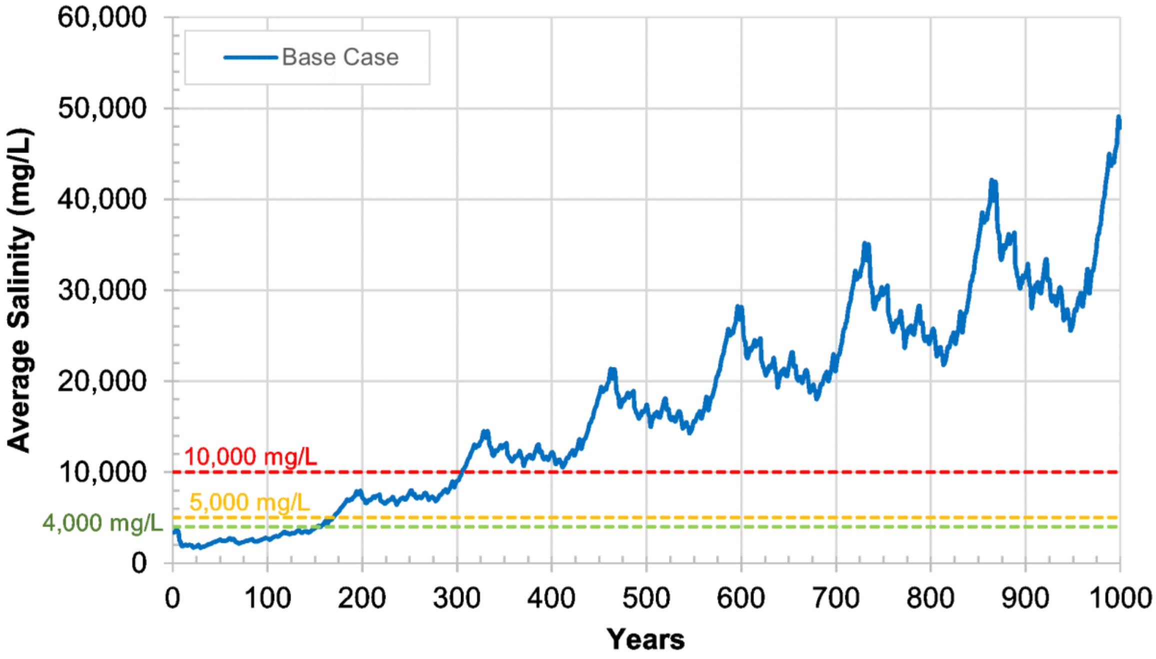


Figure 7.2 A and B Pit salinity – base case (expressed as TDS mg/L)

Modelled results for A and B pit indicate that simulated TDS concentrations are expected to increase over time, with some fluctuations dependent on seasonal changes and expected wet periods and droughts.

7.2.1.2 M and D Pit

Predicted long-term TDS fluctuations for M and D Pit for the base case are presented in Figure 7.3.

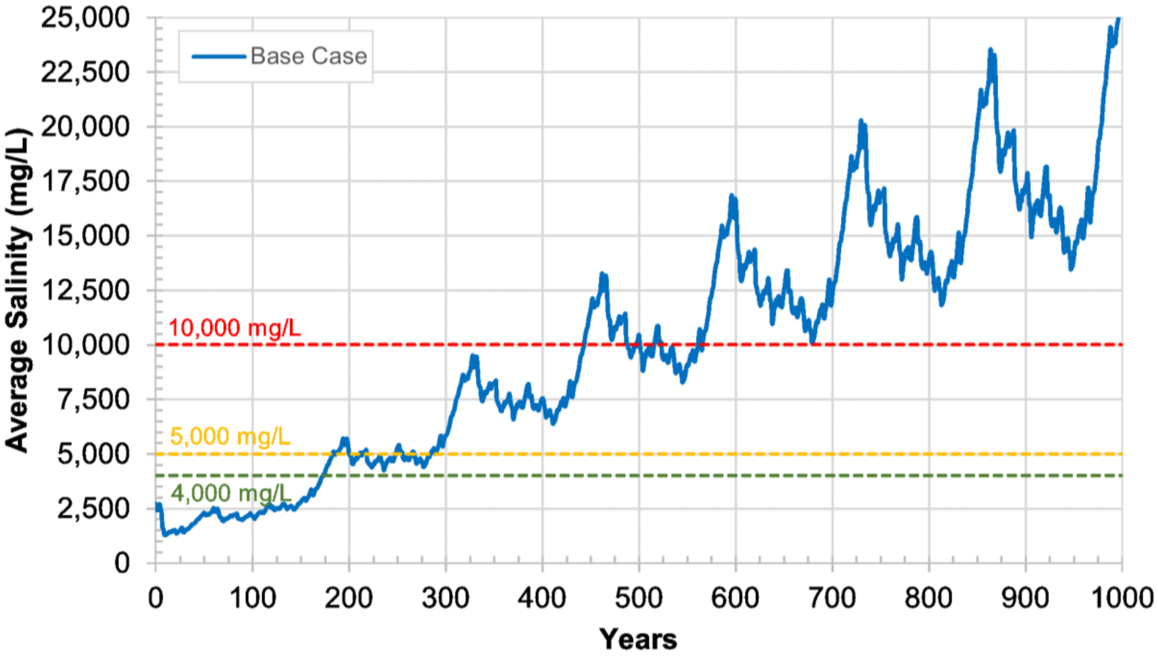


Figure 7.3 M and D Pit salinity – base case

Due to the large external catchment contributing to M and D Pit, modelled salinity levels within the void increase more gradually with the 10,000 mg/L threshold being maintained over a longer time frame compared to A and B Pit. The long-term deterioration of water quality however is also predicted at M and D Pit due to the evaporation effects which dominate the salt balance. Similar to A and B Pit, some fluctuations are predicted, due to seasonal changes and expected wet periods and droughts over the 1,000 years, however, these are more significant within the M and D Pit due to the larger amount of catchment contributing to the final void.

7.2.1.3 E Pit

Predicted long-term TDS fluctuations for E Pit for the base case are presented in Figure 7.4.

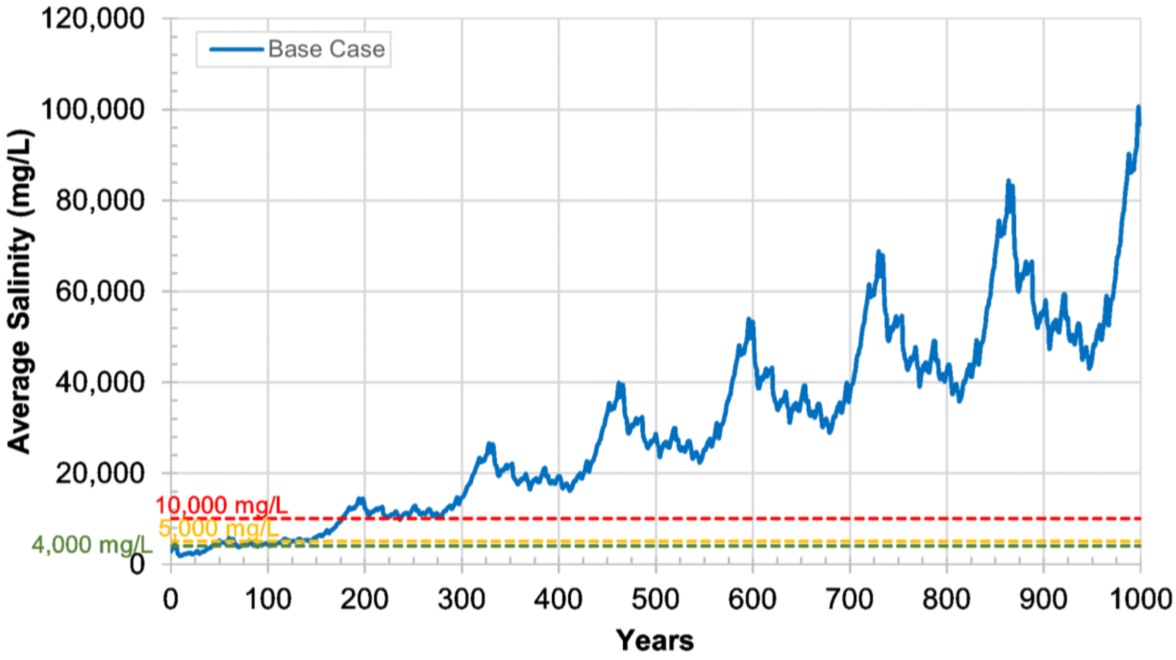


Figure 7.4 E Pit salinity – base case

Modelled salinity levels predicted within E Pit are expected to be the largest of the three final voids at MCM. This result is likely because of the relatively small available storage volume of E Pit and its small contributing catchment. The highly saline groundwater contribution to E Pit is similar to that predicted at M and D Pit and unlikely to be a specific factor to overall salinity.

7.2.2 Summary

Base case average salinity within each void at various years are presented in Table 7.4.

Table 7.4 Predicted average salinity in the final voids (rounded to the nearest 10 mg/L)

Model year	A and B Pit (mg/L)	M and D Pit (mg/L)	E Pit (mg/L)
100	2,650	2,140	4,290
150	3,810	2,780	5,940
500	17,410	10,460	28,640
1000	47,800	25,840	96,650

Whilst salinity levels within each void are initially representative of the existing pit water and the relative contribution of each inflow, the concentrating effect of evaporation increases salinity to values typical of seawater (or higher) by the end of the simulation period. The highest EC over the model period is predicted to occur in E Pit which also has the fastest rate of salinisation.

Overall, a deterioration of long-term water quality in each of the final voids is expected because of the dominance of evaporation. This will result in the void salinity progressively increasing with limited opportunities for dilution effects from local runoff and rainfall.

7.3 Hydrogeochemical assessment

Water quality within final void pit lakes typically evolve over time. The controls on this water quality evolution are dependent upon the dominant sources of water contributing. In many cases this is groundwater once equilibrium is achieved (MRIWA and CRC Care, 2022).

Hydrogeochemical models assist in understanding the potential chemical evolution of residual void waters from changes in pH and redox conditions that may occur due to groundwater discharges, rainfall, surface water runoff, minerals present within the pit walls or materials emplaced within the pit. Due to limited major ion monitoring results available in site monitoring modelling of the pit water chemistry evolution is not possible. However, a number of conclusions can be determined based on the findings discussed in other public studies from the region and surrounding mine sites, as shown below:

- Major ion composition of pit lake water at open cut coal mine sites at Bowen Basin indicate a sodium-chlorine dominated feature.
- pH values for monitored surface pit lake water indicate a general neutral to mildly alkaline range, which is important as it limits the solubility of most of the metals of concern.

7.4 Stratification assessment

In addition to the final void WBM, a GLM model was developed for MCM to investigate the water stratification over the long-term evolution of the water quality within each final void.

GLM is a one-dimensional vertical stratification hydrodynamic model that computes vertical profiles of temperature, salinity, and density by accounting for the effect of inflows and outflows, meteorology, surface heat exchange and mixing processes (refer to Figure 7.5). The model is ideally suited to long-term investigations ranging from seasons to decades, and for coupling to biogeochemical models that then facilitate exploration of the role that stratification and vertical mixing play on the dynamics of the final void ecosystem.

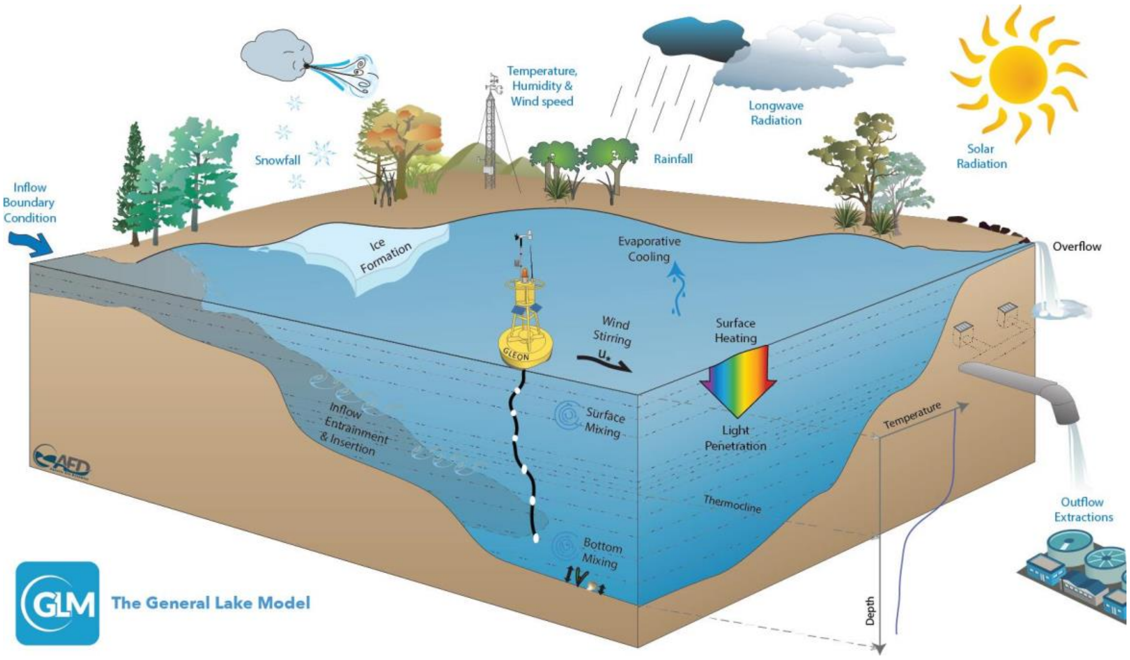


Figure 7.5 GLM simulation domain
(blue text = input information and black text = simulated processes)

The GLM model solves the one-dimensional (1D) hydrodynamic equations using water, thermal and mass balances. The inputs/outputs into the GLM are required on a sub-daily (meteorological data) and daily (inflows and outflows) basis.

Key model details, inputs and outputs are presented in Table 7.5.

Table 7.5 GLM Model Inputs and Parameters

Items	Description	Source
Software	▪ GLM v3.3.0a9	(Hipsey et al 2019)
Model time frame	▪ January 1960 to June 2022 ▪ Based on available climate data for the site	
Model time step	▪ Hourly	
Metered data	▪ Final void level, inflows and outflows (if available)	
Geometry	▪ Final void stage storage curve as used in the integrated water balance / water quality model.	Refer refer to Figure 5.1 and Appendix II
Climate data	Hourly values for: ▪ short wave radiation; cloud cover; relative humidity; air temperature; wind speed extracted from European Centre for medium-ranged weather forecasts (ECMWF) model database; and ▪ rainfall from SILO data Drill service for the nearest location to MCM (i.e., -22.00, 148.25)	(ECMWF 2022) (SILO 2023a)
Pit initial condition	▪ Initial void water depth is consistent with GoldSim model setting on 01/01/2028 for each pit to be consistent with climate input and catch the system dynamic at the early stage of pit lake evolution	
Catchment water quality	▪ Temperature of 24 °C ▪ Based on water quality estimation of the GoldSim model	

Items	Description	Source
Inflow and outflow rates	Consistent with the integrated water balance / water quality model and include: ▪ catchment runoff; ▪ rainfall; ▪ groundwater inflows and outflows, ▪ overflows; and ▪ evaporation.	Refer to Section 5.
Boundary conditions	▪ Based on surface water and groundwater models developed as part of this final void hydrology study	
Calibration strategy	▪ No salinity and temperature profiles of the existing A and B, M and D and E Pits were available for calibration. ▪ As such, comparisons to GoldSim simulated results of final void water depth and volume have been undertaken.	
Model outputs	Simulated final void water: ▪ depth; ▪ volume; ▪ temperature; and ▪ salt concentrations.	
Exclusions and limitations	▪ The model has excluded active triggers related to level, salinity and oxygen. ▪ Boundary conditions have been explicitly specified.	

As detailed in Table 7.5, the GLM model has been used to simulate physical variables critical to the development and evolution of stratification in a void. Typical model outputs, such as water temperature and salinity as a function of water depth over time across each pit lakes, are presented in further detail in Appendix III, with key model outputs summarised as follows:

- GLM model simulated water depth and volumes within the final voids are relatively lower than outcomes from the final void WBM. This is mainly caused by the differences in evaporation assumptions between GLM and GoldSim systems.
- Void water depth is expected to increase within the first ten years.
- The final void system is expected to show an overall increasing trend in salinity.
- The final void system is likely to become strongly stratified in temperature and mild in salinity between the surface and bottom layers.
- There are significant cycles of simulated temperature between summer and winter for the pit lake upper layers, between 15 °C and 31 °C most of the time.
- Almost no seasonal changes in temperature were identified for layers deeper than 20 m.
- Simulated results show limited seasonal variations in salinity but mild stratification in salinity levels between the surface and bottom layers.

8 POTENTIAL WATER USAGE ASSESSMENT

8.1 Overview

The potential for beneficial reuse of water captured within each of the final voids for stock watering has been assessed using the final void WBM to understand the potential supply reliability and benefit to reducing salt load. This is based on the assumption that suitable access will be provided to allow the cattle to access the final void water surface safely.

As discussed in Section 5.8, the main beneficial reuse of local surface water resources for MCM is opportunistic stock watering. Considering the stock water usage assumptions (Section 5.8) along with base case water level fluctuations (Section 6.2) and salinity predictions (Section 7.2.1), an assessment of how much void water could be reused for stock watering was completed

Figure 8.1 shows the assessed stock area available for each final void based on MCM ML boundaries and areas of appropriate topography for stock. The total area available was estimated at approximately 28 km^2.

8.2 Results

Based on the total reuse demand of 10.3 ML/year of water up to a TDS limit of 5,000 mg/L, each void was assumed to supply a portion of this demand based on available area of stocking.

Model results indicated:

- A and B Pit supplied a maximum of 1.5 ML/year between 2027 and 2197 (170 years);
- M and D Pit supplied a maximum of 6.0 ML/year between 2027 and 2318 (291 years); and
- E Pit supplied a maximum of 2.8 ML/year between 2027 and 2172 (145 years).

Based on modelled results, the TDS limit of 5,000 mg/L was found to be a major limiting factor in the reliability of supply for stock watering.

The potential change of water level within each final void, based on model results, was predicted to be minor, with total reuse volumes from each void predicted to be between 255 and 1,660 ML. Reuse opportunities are best suited to a period of 150 years post closure. During this period stock access to the free water surface may be constrained due to the stored volume being present within spoil material. The safety of stock and access routes to the free water surface within each void will required further consideration.

Table 8.1 presents a summary of stock reuse compared to the base case (no stock reuse) in terms of water level and salinity difference. Negligible change in water level and salinity within each void is expected.

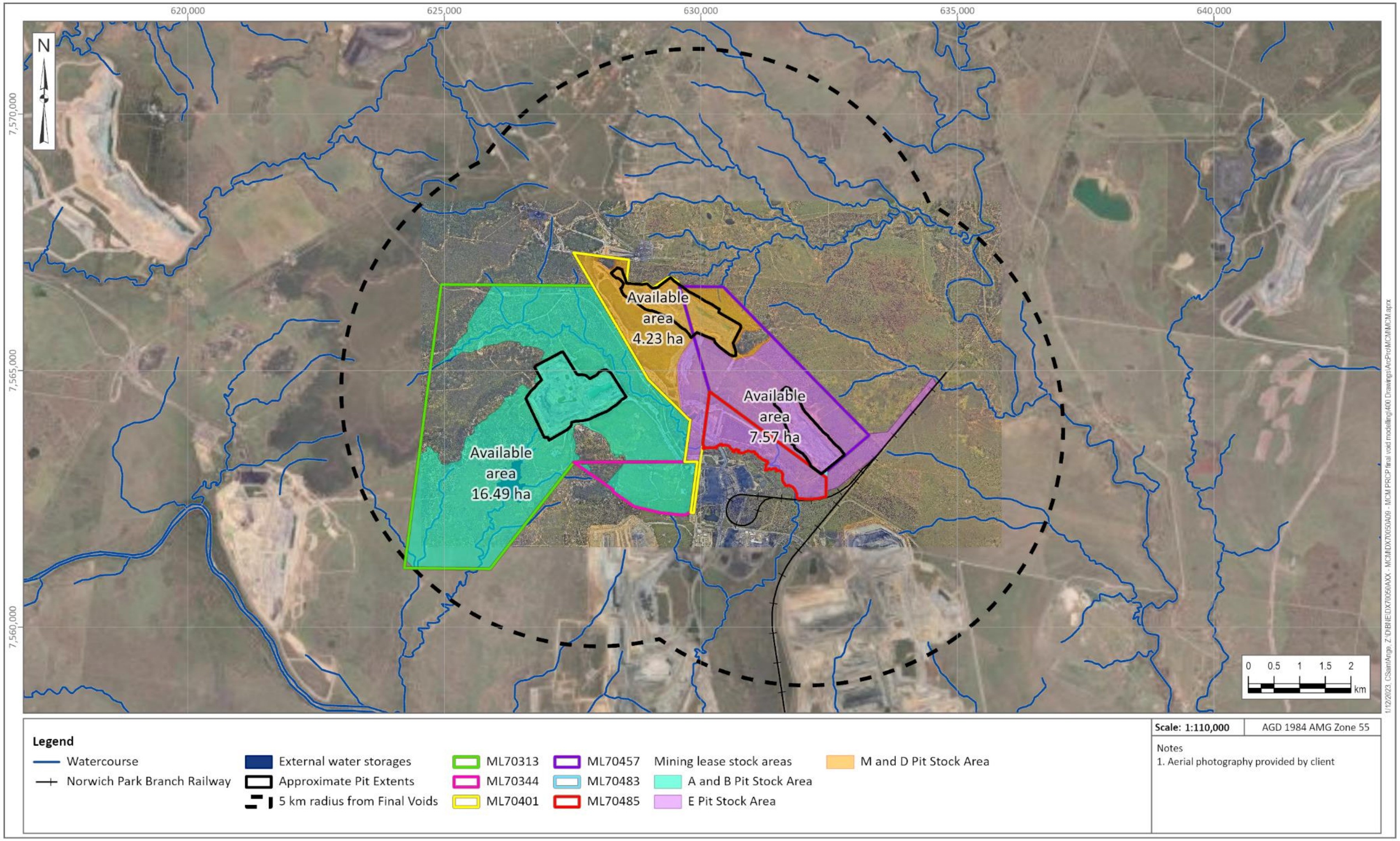


Figure 8.1 Assessed stock areas associated with each final void

Table 8.1 Predicted change in water level and salinity on final voids

Final void	Change in maximum water level (m)	Change in salinity* (mg/L)
A and B Pit	-0.2	-100
M and D Pit	-0.6	-470
E Pit	-0.7	-1,150

Note: Salinity has been rounded to the nearest 10 mg/L

Sensitivity testing on the cattle usage assumptions has been undertaken and is discussed in Section 0.

8.3 Other reuse options needing assessment

Besides stock watering reuse opportunities, other reuse options may exist and could be considered as part of further works and/or as part of an assessment of options. Additional reuse options include irrigation for agricultural activities and supply of water to third parties to meet industrial process water demands. Key to alternative options being considered is the additional monitoring of water ionic composition.

Irrigation of crops has a comparable threshold for salinity as for stock. ANZECC 2000 indicates a typical upper root zone salinity threshold of 8,174 mg/L. Without further works being undertaken to confirm the areas of potential cropping (including suitability of the soils for irrigation) and a demand being calculated, it is not clear if irrigation for agricultural activities could allow the reuse for any more water from voids than what is estimated for stock.

Several operational coal mines surround the MCM site. The supply of water to meet industrial process water demands at these sites could provide additional beneficial reuse volumes than what has otherwise been predicted under a stock watering scenario. Additional works and agreements would be required to quantify the demand that could be supplied to these operations. On review of public mapping information (GSQ 2019) there are six active coal mines within a 35 km radius and 17 coal mines within a 100 km radius of MCM. Supply of water to a third party would require confirmation of an acceptable water chemistry and salinity envelope as water quality requirements for industry vary within and between industries. Generally, it is expected that acceptable salinity thresholds for water supply in coal processing systems could range from 670 mg/L to 3,350 mg/L. Department of Environment and Heritage (DEHP) (DEHP 2011) currently has no water quality objective in place for industrial water reuse activities.

9 UNCERTAINTY AND RISK

9.1 Sensitivity analysis

Sensitivity analysis has been undertaken to better understand the uncertainty of several final void WBM parameters and inputs and to quantify the impact on expected water level and salinity fluctuations results when compared to the base case (discussed in Section 6).

Table 9.1 outlines the sensitivity cases considered.

Table 9.1 Sensitivity cases

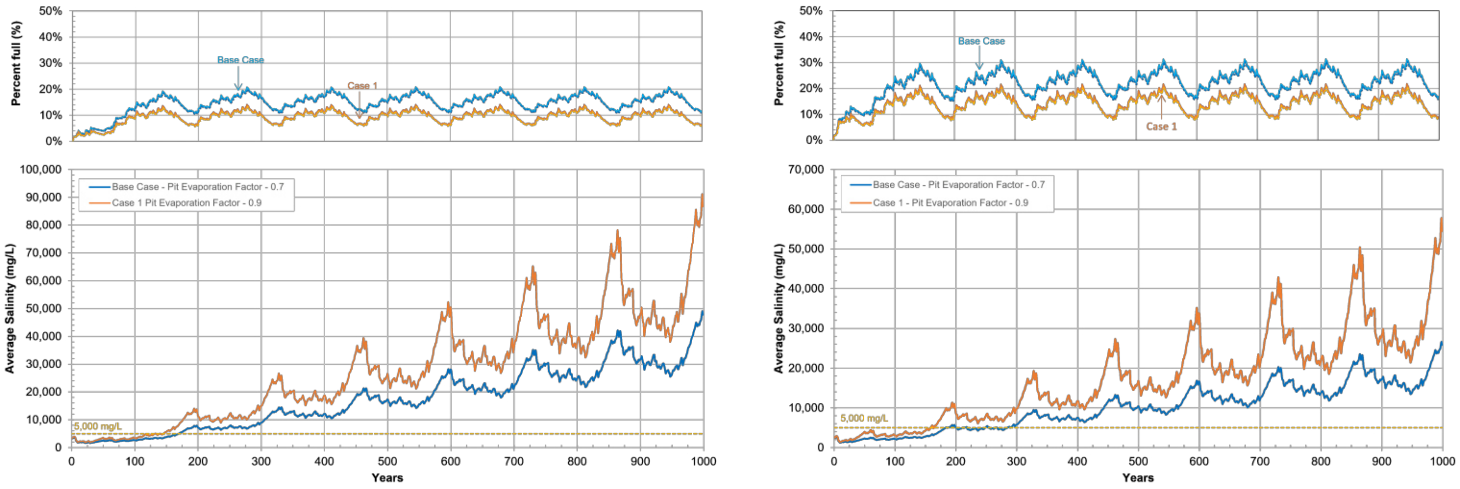
Case	Parameter / input	Base case	Variability tested
1	Pit evaporation factor	0.7	0.9 (increased evaporation)
2a, 2b	Spoil porosity	5%*	Case 2a: 0% (free water only) Case 2b: 15%
3a, 3b	Uncertainty in groundwater inflows	Data as provided by SLR (SLR 2023)	Case 3a: -5% Case 3b: +5%
4	Catchment area to M and D Pit	Inclusion of external catchment from Fitzroy ML, northwest of M and D Pit	Diversion of catchment areas from Fitzroy ML around M and D Pit
5a, 5b, 5c	Climate change	Historical rainfall data from SILO	Detailed climate projection predictions for Queensland: Case 5a: 2030 Case 5b: 2050 Case 5c: 2070
6	Maximum stock numbers and use	Areas of grazing based on ML boundaries and gentle sloping pasture = 566 head of stock	Combined area within a 5 km radius of final voids not considering constraints or other land uses = 2,620 head of stock
7	Salinity generation factors for groundwater and spoil	Assumptions as per Table 5.5	Increased groundwater and spoil conductivity to 10,000 µS/cm

Note: *SLR use a 5% porosity for existing rehabilitated spoil and for consistency between models, the final void WBM has adopted this value for the base case.

The following sections provide a summary of how the water level and salinity fluctuations responded to each sensitivity case.

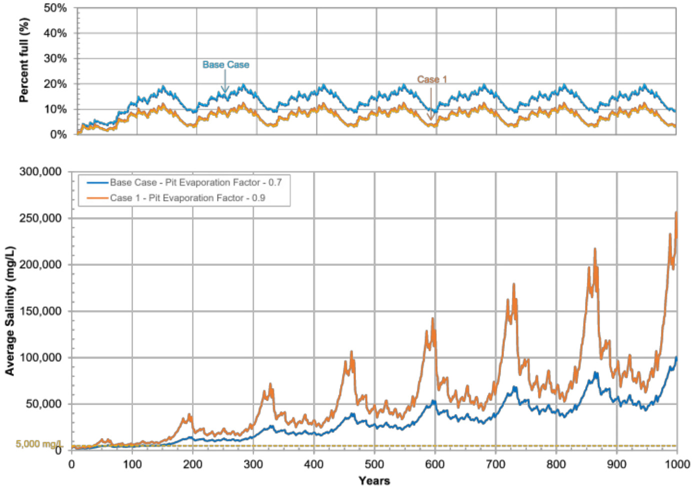
9.1.1 Case 1 - pit evaporation factors

Case 1 considered the potential change in volume and salinity because of an increase in pit evaporation factor from 0.7 to 0.9 with long-term percentage full and salinity results presented in Figure 9.1.



A and B Pit

M and D Pit



E Pit

Figure 9.1 Percentage full and salinity – case 1

Case 1 model results indicated:

- With an increased evaporation factor, decreased equilibrium water level and increased salinity arise. The decrease in equilibrium water level was predicted to vary between 11.4 m and 13.2 m across the final voids assessed. An increase in salinity, at the time equilibrium was reached, was predicted to vary between 1,030 mg/L to 2,725 mg/L across the final voids assessed.
- An increase in evaporation factor exacerbated the existing evapoconcentration effects on salinity within the final voids. With higher evaporation, an increase in salinity is predicted and the likelihood of stored water being suitable for reuse opportunities reduces. The time that E Pit is likely to be able to supply water to beneficial reuse activities is shortened to less than 50 years following closure because of the increased evaporation.
- As predicted storage in the base case is expected to be typically low (i.e., < 50% full), an evaporation factor of 0.7 is deemed to be appropriate, as the shading and wind effects of the inner pit are likely to be a realistic representation of conditions within the final voids.

9.1.2 Case 2 – spoil porosity

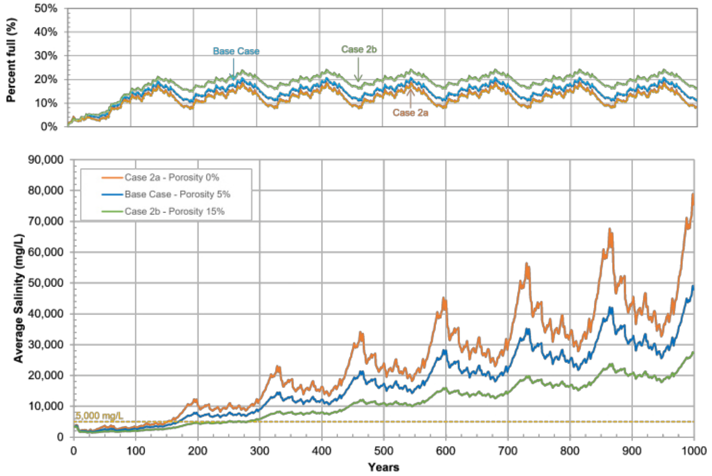
Case 2 considered the potential change in volume and salinity because of a change in porosity of backfilled spoil material and associated water storage within the spoil.

Long-term percentage full and salinity results are presented in Figure 9.2 for a reduction of spoil porosity to 0%, (case 2a) and an increase to 15% (case 2b).

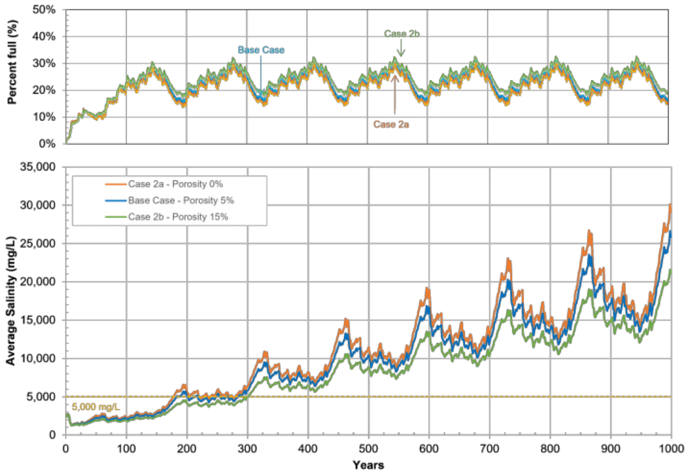
Case 2 model results indicated:

- With an increased spoil porosity, an increased water storage volume arises, leading to predicted decreased salinity. This result is likely due to a reduced free water surface volume and an increased subsurface water capacity, reducing the evaporative effects on stored water, however the model is able to consider the potential salinity changes of water as it moves in and out of spoil. With effectively no porosity, the evaporative losses from the free water surface are increased, leading to a reduction in stored water and an increase in salinity over time.
- A and B Pit has the greatest change in predicted water level and salinity due to changing spoil porosity. This is because of the large spoil volume within the pit and surrounding (specifically the previously mined C Pit area). The variation in equilibrium water level between case 2a and case 2b, compared with the base case was -0.9 m to +1.4 m.
- Less change in predicted water level and salinity is evident in M and D Pit and E Pit since the spoils play a smaller role in the void balance.
- Equilibrium salinity predictions from case 2a (0% porosity) increased to 743 mg/L, whereas for case 2b (15% porosity), salinity levels were predicted to decrease by -819 mg/L.
- Spoil porosity can vary throughout a mine site. A 5% spoil porosity was adopted for the base case based on SLR advice and for consistency with SLR's groundwater model.

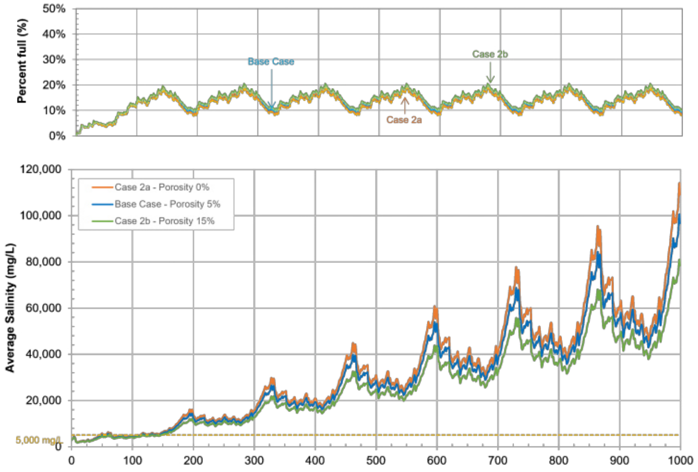
Overall, A and B Pit was found to have the greatest potential for uncertainty in storage volumes and salinity based on the spoil porosity used.



A and B Pit



M and D Pit



E Pit

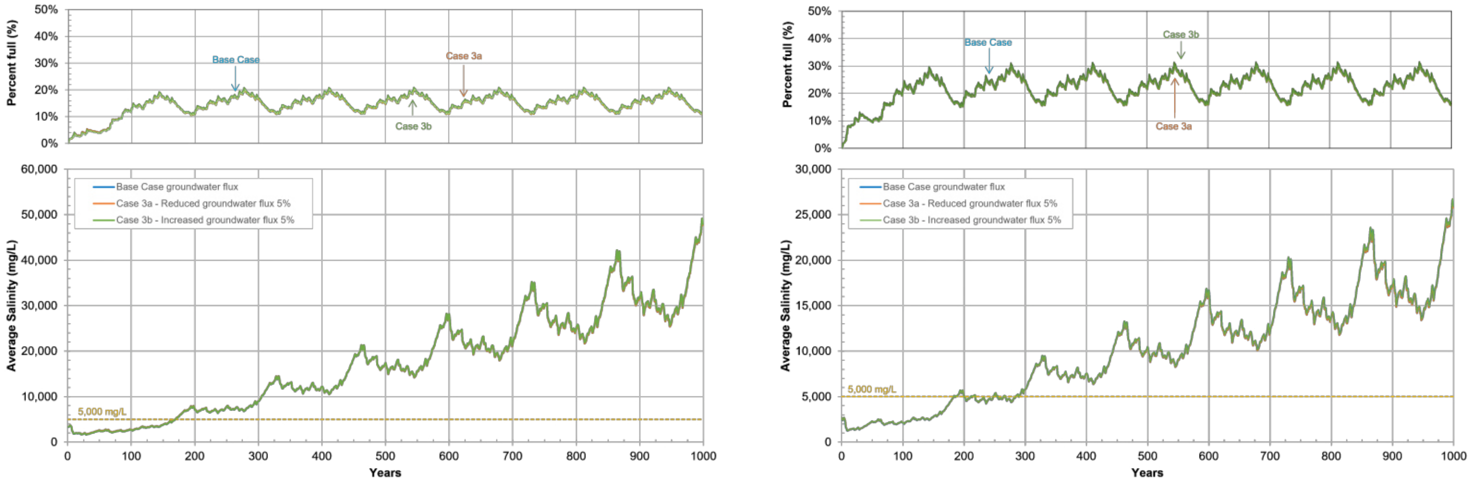
Figure 9.2 Percentage full and salinity – case 2

9.1.3 Case 3 - groundwater inflows

Groundwater flux data for the final void WBM were provided by SLR (SLR 2023b) with uncertainty considered in these results as part of their assessment. Case 3 considered the potential change in volume and salinity because of a change in groundwater inflows. Long-term percentage full and salinity results are presented in Figure 9.3 for a 5% increase (case 3a) and 5% decrease (case 3b) in groundwater inflows.

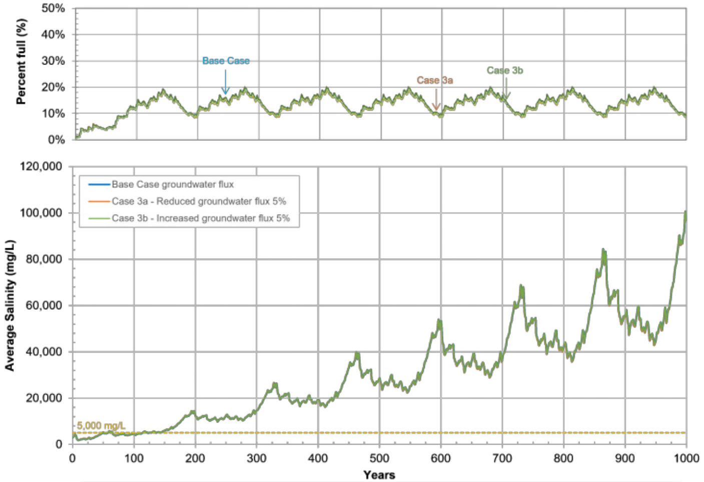
Case 3 model results indicated:

- Groundwater data, as discussed in Section 5.6, included large fluxes early within the modelled period (before equilibrium). Any change in groundwater is likely to be evident in this early period. Once equilibrium is reached, groundwater inflows are stable and there is minimal seepage occurring.
- Minimal change in percentage full within the three final voids. Within A and B Pit, groundwater variation resulted in the maximum change to water levels (+/-0.5 m) within the first 100 years. A similar response was evident in the predictions of E Pit, however, the change was less at +/- 0.2 m.
- Minimal change in salinity (due to minimal change in volume), with the greatest change to salinity in E Pit with +/- 260 mg/L.
- M and D Pit and E Pit had very minor changes in predicted storage percentage and salinity. This is likely because of the very low contribution that groundwater has on the water balance in these final voids. Water level and salinity changes were predicted to be negligible for M and D Pit.
- For further information on the assumptions and uncertainty in groundwater data reference should be made to SLR (SLR 2023b). Groundwater data uncertainty was found not to significantly change the results.



A and B Pit

M and D Pit



E Pit

Figure 9.3 Percentage full and salinity – case 3

9.1.4 Case 4 - catchment areas

Catchment areas to A and B Pit and E Pit, determined from the final void landform, are expected to be limited to the surface area of each void opening. This was not the case for M and D Pit which has an external catchment area in the north (including 53.9 ha from neighbouring Fitzroy Australia Resources Pty Ltd ML) contributing to the void. Case 4 considered the potential change in volume and salinity because of a reduction in reporting catchment (i.e., diversion of the external catchment around M and D Pit).

Long-term percentage full and salinity results are presented in Figure 9.4 for a reduction in area (case 4). The proposed concept for the diversion of this catchment is shown in Figure 9.5.

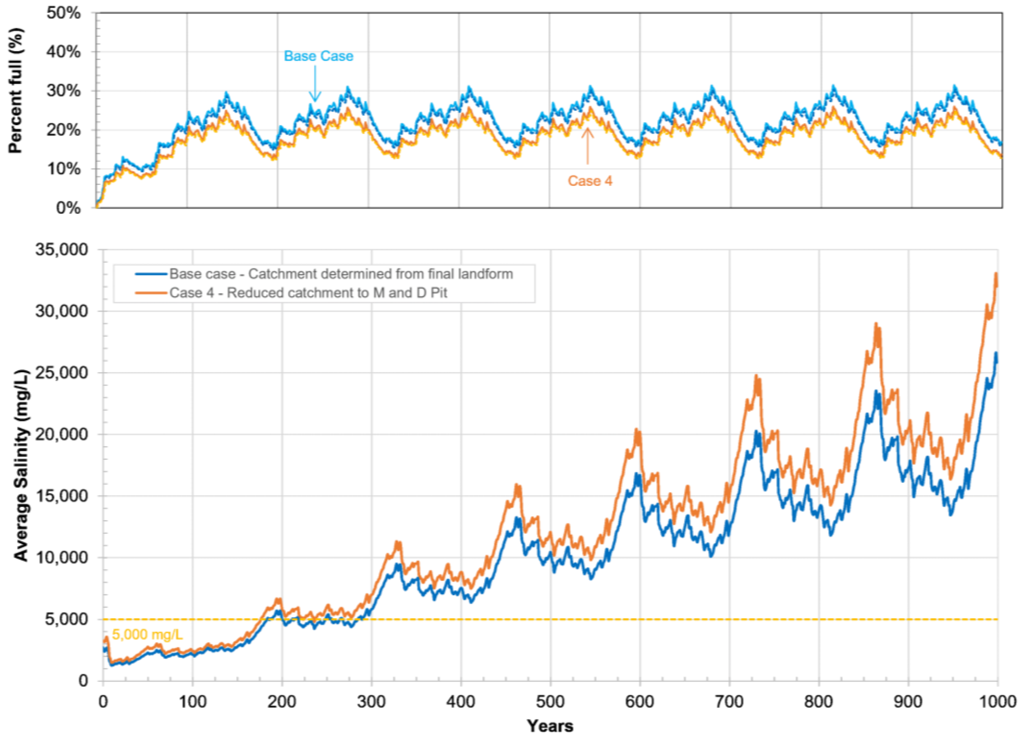


Figure 9.4 Percentage full and salinity – case 4

Case 4 model results indicated:

- Reduced storage volume in M and D Pit because of a reduction in annual runoff volumes. This corresponded to an increased salinity level within the final void over time.
- The benefit of implementing this diversion is predicted to be a reduction of 4 m to 4.7 m on the equilibrium water levels. However, with this reduced water level, salinity was predicted to increase by +340 mg/L when equilibrium was reached, concentrating over time.

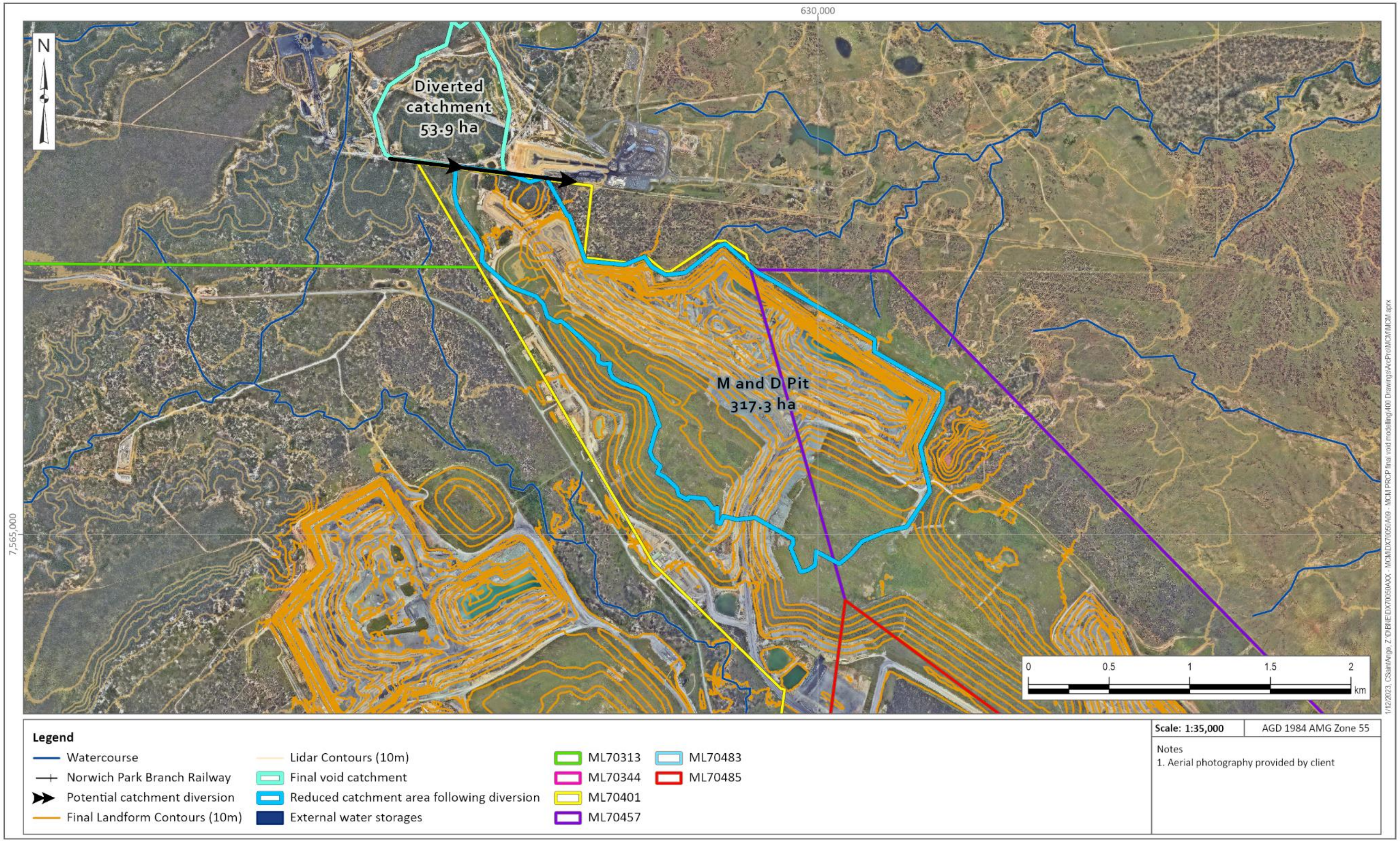


Figure 9.5 Catchment area changes to M and D Pit

9.1.5 Case 5 - climate change

To quantify the expected changes in rainfall and evaporation, future climate projection data was downloaded from the biophysical modelling database from SILO for consistent climate scenarios (CCS) based on MCM (-22.00 latitude, 148.25 longitude) (SILO 2023). To assess climate change sensitivities, the following assumptions have been made in the future climate projection data used:

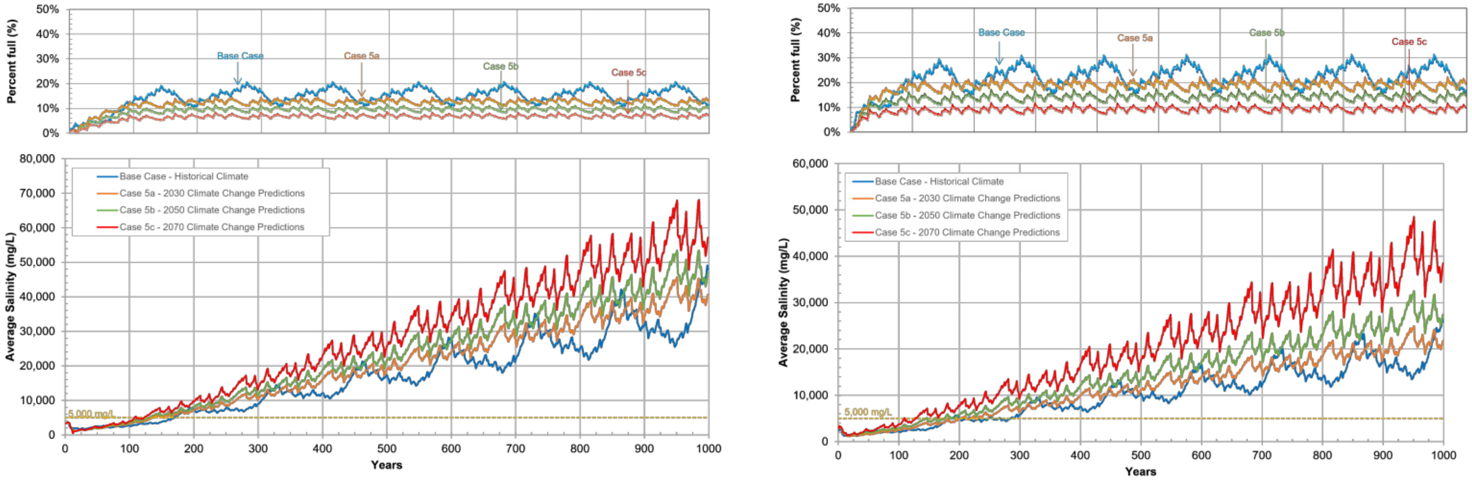
- Based on projections made for three pivotal years of 2030, 2050 and 2070.
- Key climate projection parameters consider:
- Representative concentration pathway (RCP) of 8.5 which is the highest baseline emissions scenario;
- High climate warming sensitivity; and
- SILO enables the selection of one of the four mean climate response patterns, defined as models HI, HP, WI, and WP. HP composite data was used which includes approximately 12 global climate models and is based on a high global warming factor and a faster warming Western Pacific Ocean compared with the Eastern Indian Ocean.

A summary of the annual rainfall and pan evaporation changes for the pivotal years is presented in Table 9.2 for the 10th, 50th and 90th percentile probabilities (i.e., P10, P50 and P90, respectively).

Table 9.2 Projected annual rainfall and pan evaporation change based on global climate models

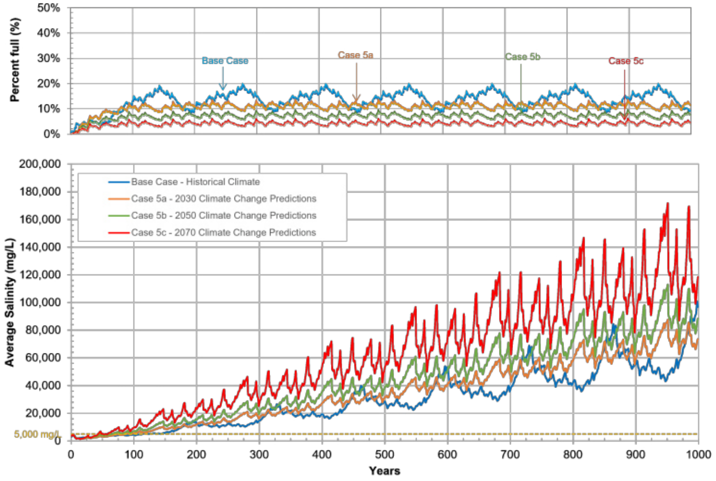
Value	Percentile	Present SILO data	RCP8.5 – HP Composite 2030	2050	2070
Rainfall					
Absolute value (mm)	P10	354.44	333.28	302.40	263.88
	P50	560.1	522.40	472.00	427.00
	P90	863.48	808.22	736.20	665.14
Change compared with SILO (%)	P10		-6%	-15%	-26%
	P50		-7%	-16%	-24%
	P90		-6%	-15%	-23%
Pan evaporation					
Absolute value (mm)	P10	1778.42	1852.74	1941.56	2055.74
	P50	2005.5	2089.60	2190.4	2317
	P90	2213.78	2309.72	2421.84	2562.92
Change compared with SILO (%)	P10		+4%	+9%	+16%
	P50		+4%	+9%	+16%
	P90		+4%	+9%	+16%

Case 5 considered the potential change in volume and salinity because of climate change. Long-term percentage full and salinity results are presented in Figure 9.6 for the pivotal years of 2030 (case 5a), 2050 (case 5b) and 2070 (case 5c).



A and B Pit

M and D Pit



E Pit

Figure 9.6 Percentage full and salinity – case 5

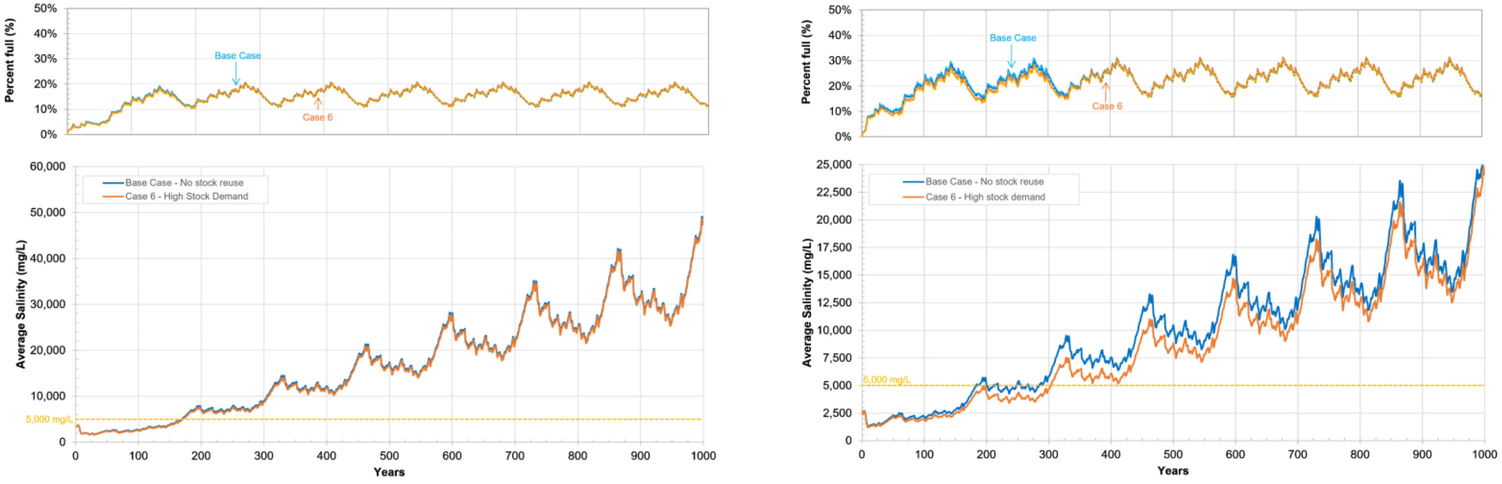
Case 5 model results indicated:

- Modified climate data sets were limited to an equivalent period of 1960 to 2022, many of the historical climate trends (shown in Figure 5.5 and discussed in Section 5.5.1) have not been considered. As such, once equilibrium is reached, differences in the time series pattern existed, with multi-year trends less evident in the climate change cases when compared to the base case.
- Reductions in predicted water levels (and percentage filled) and increased evaporation lead to increased salinity over time for the three climate change pivotal year projections (i.e., cases 5a, 5b and 5c).
- Seasonal variability in the base case storage volume and salinity predictions were shown to fall within range predicted for the 2030 and 2050 pivotal years (i.e., cases 5a and 5b).
- Greatest change in water level was predicted in M and D Pit, with reductions of up to 21 m, with the lowest being A and B Pit, with reductions of up to 18 m in case 5c.
- Greatest change in equilibrium salinity levels was predicted in E Pit, increasing to between 4,737 mg/L to 15,721 mg/L.
- Climate change predictions did not result in an increase in water levels, either through short term peaks or long-term. Generally, water levels are predicted to decrease through reduced rainfall and increased evaporation. When considering the predicted salinity , the voids are likely to become more constrained as potential future water supplies in regards to the potential beneficial reuse of water.

9.1.6 Case 6 – stock numbers and reuse consumption

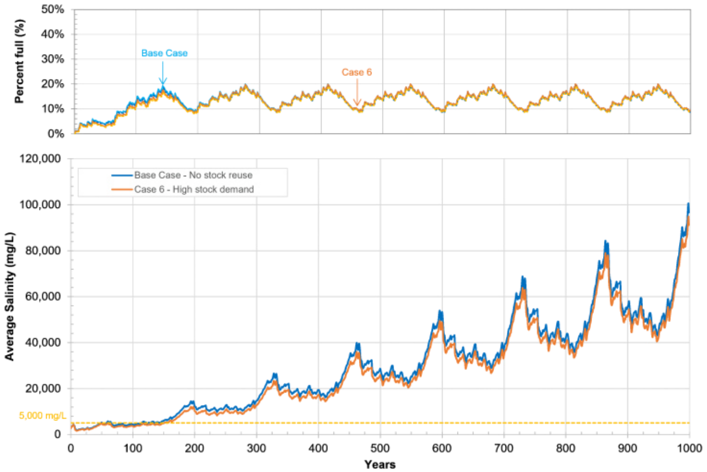
The main factor in stock water beneficial reuse demand is the expected number of stock to use a water source. Case 6 considered the potential change in volume and salinity because of an increased stock number from 566 to 2,620 head of cattle. The increased number of stock has been based on a 131 km^2 area of supply equivalent to a 5 km radius (based on Meat and Livestock Australia generally accepted distances for cattle to travel to water (MLA 2023)), from all voids associated with this study, unrestrained by constraints such as topography or existing land use.

Long-term percentage full and salinity results are presented in Figure 9.7 for the increased cattle usage (case 6).



A and B Pit

M and D Pit



E Pit

Figure 9.7 Percentage full and salinity – case 6

Case 6 model results indicated:

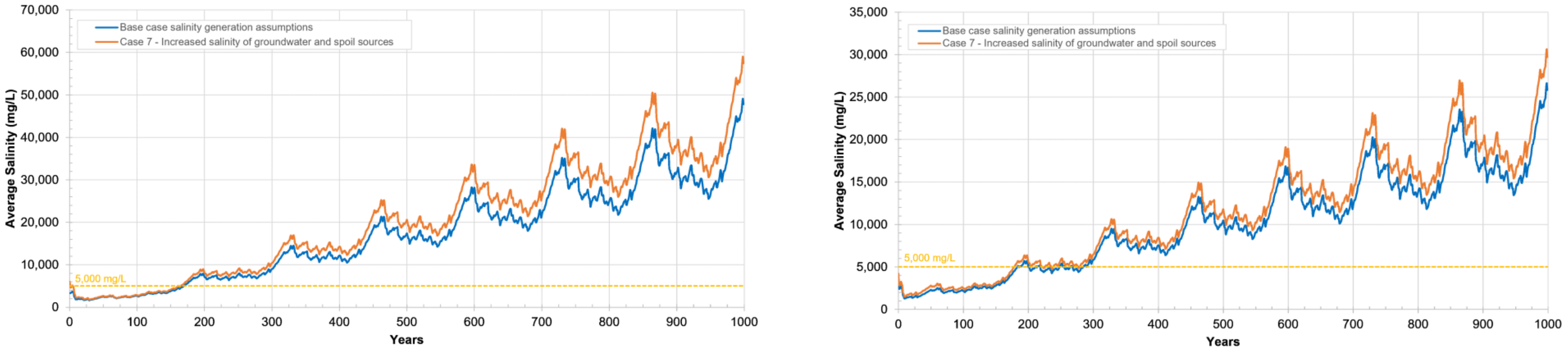
- Supply of water for stock increased to 7.1 ML/year, 27.7 ML/year, and 12.3 ML/year for A and B Pit, M and D Pit, and E Pit, respectively. The duration of supply ranged from 157 to 304 years with M and D Pit able to supply water for cattle for the longest.
- When the final voids were able to supply water for reuse, a decrease in storage water level was predicted at 1 m to 3 m. When the water was unsuitable (too saline) for stock water, the storage levels within each void returned to equilibrium levels.
- Salinity levels were notably reduced in M and D Pit and E Pit with the removal of salt from these voids possible through cattle consumption. However, the storage salinity concentration is still predicted to increase over time as cattle consumption. The reuse activities reduced salinity within M and D Pit and E Pit by 293 mg/L and 886 mg/L respectively, at equilibrium.
- It is beneficial (i.e., reduced salinity) to increasing stock numbers beyond the boundaries of the MCM MLs and topographic constraints. However, this benefit is expected to be short term (i.e., < 300 years from closure) and is dependent on appropriate water access routes within the void, given the typically low storage volumes expected.

9.1.7 Case 7 – increased salinity of spoil and groundwater fluxes

On the review of groundwater data for MCM, some bores located within the coal seam reported elevated EC levels above that considered in the final void WBM. Case 7 considered the potential change in salinity because of an increased TDS for groundwater and spoil inflows (i.e., groundwater and spoil TDS of 6700 mg/L (10,000 µS/cm)). Long-term salinity results are presented in Figure 9.8 for increased salinity generation rates (case 7).

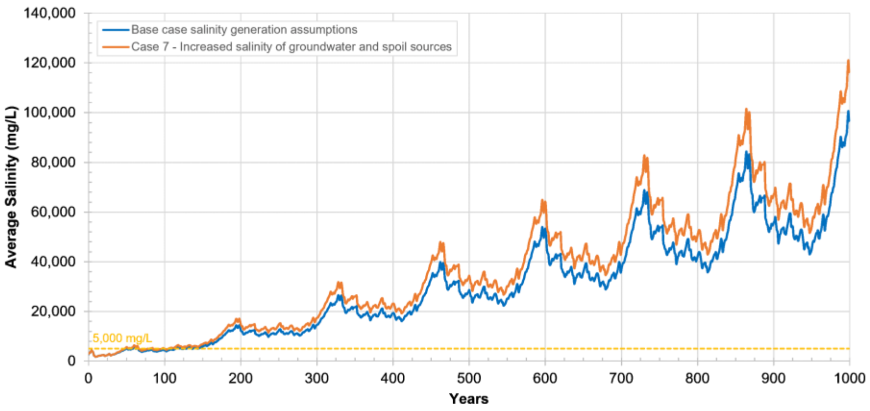
Case 7 model results indicated:

- Similar relationships to the base case, however, with increased salinity from groundwater and spoil sources resulting in higher salinity in the final voids.
- A and B Pit and E Pit had minimal sensitivity within the first 150 years because of an increased source concentration due to water being lost to groundater from the void over this period, removing the effect of the increased salinity. However, M and D Pit, which had a relatively small volume of seepage loss in the period before equilibration (~ 150 year period), indicated a noted increased in salinity due to the increased source concentrations.
- Potential reuse options for E Pit area would be reduced by increased salinity generation from groundwater and spoil.
- Equilibrium salinity results were predicted to increase by +274 mg/L in A and B Pit up to +753 mg/L in E Pit. After 500 years, differences from the base case increase further to +3,202 mg/L and +5,608 mg/L for A and B Pit and E Pit, respectively.



A and B Pit

M and D Pit

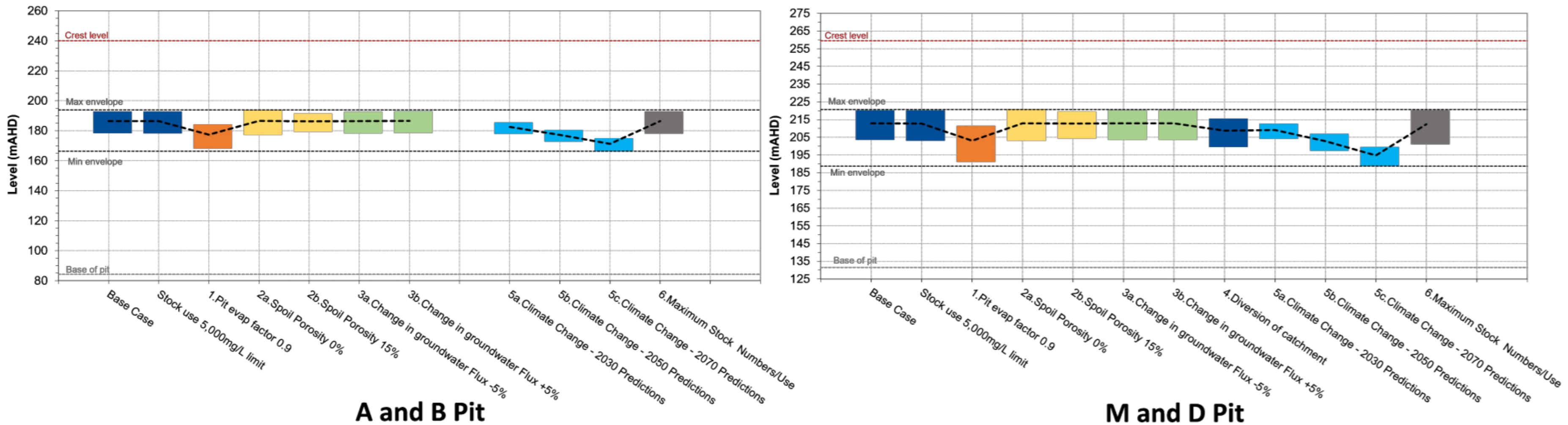


E Pit

Figure 9.8 Salinity – case 7

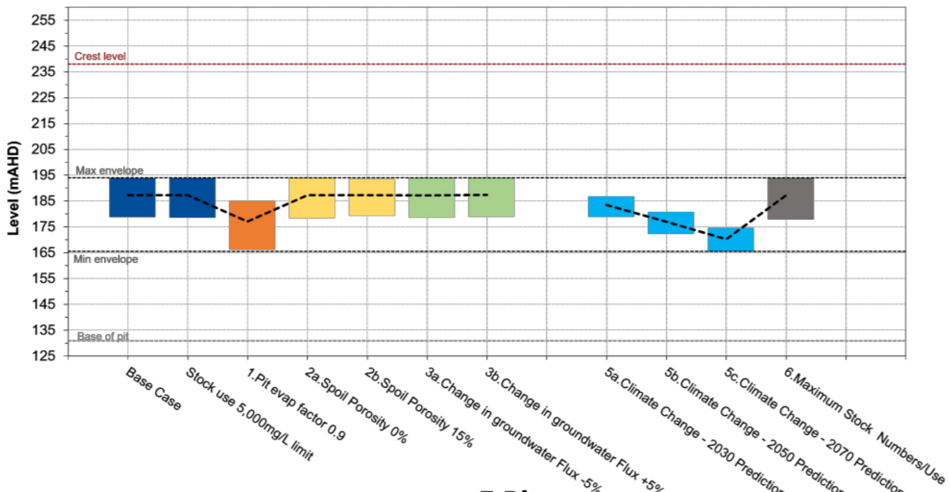
9.1.8 Summary

A comparison of base and sensitivity cases is provided in Figure 9.9 for each final void. For each case, simulated water level fluctuations (including maximum, average, and minimum envelopes) are presented in Figure 9.9 as a single data range once equilibrium has been reached. This provides a graphical presentation of the uncertainty range associated with each key parameter. Water levels are compared with the crest and base inverts of the void. Figure 9.10 provides the salinity results for the base and sensitivity cases.



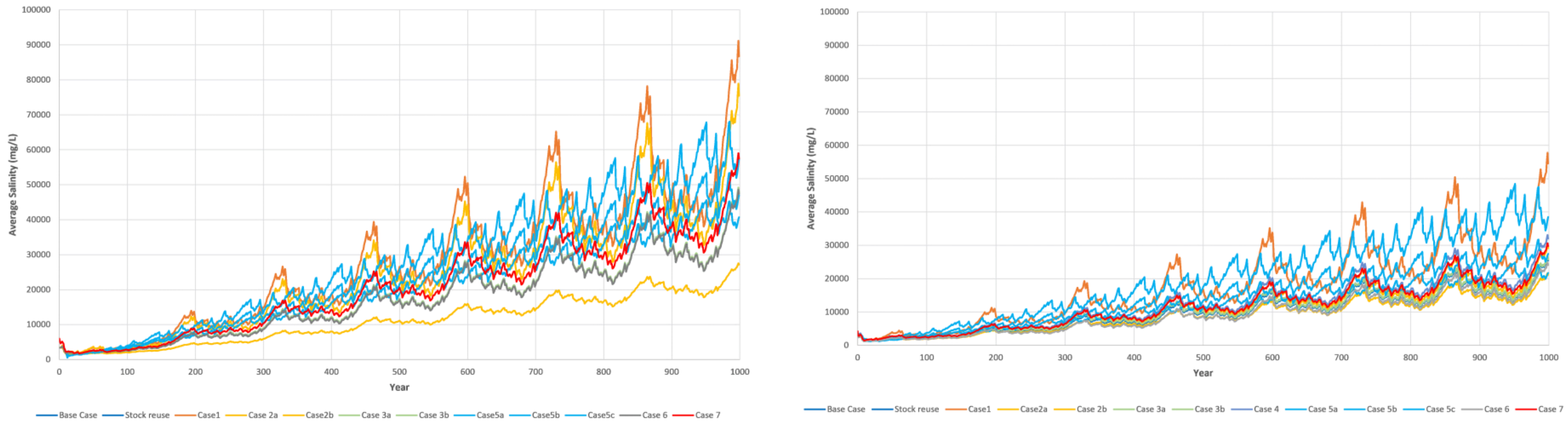
A and B Pit

M and D Pit



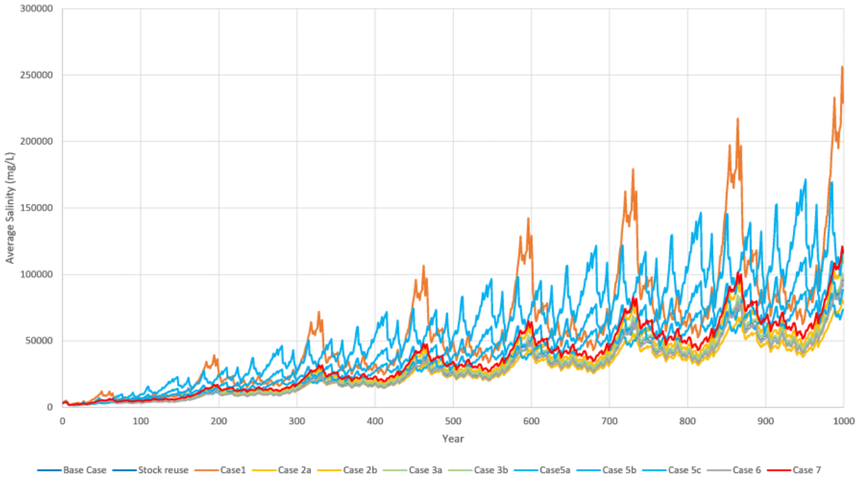
E Pit

Figure 9.9 Water level range - all cases



A and B Pit

M and D Pit



E Pit

Figure 9.10 Salinity - all cases

9.2 Risk assessment

A risk assessment of potential environmental impacts caused by the final voids expected to remain at MCM, based on the outcomes of final void modelling undertaken in this study is summarised in the sections below. It has considered the outcomes from the testing of sensitivities on input data and model assumptions.

9.2.1 Storage capacity and release of water from final voids

For the base and sensitivity cases modelled, maximum water level envelopes are all predicted to remain well below the crest level for the three final voids, with overflow of water to the receiving environment unlikely.

The following outcomes were also determined from final void modelling:

- A and B Pit was the most sensitive to variation in the assumed porosity with the greatest volume of spoil backfill based on the deepest mined surface.
- Connectivity of final voids with underground mining areas has not been considered in the final void WBM. If this occured, the predicted base case water level is likely to be less because of the increased storage capacity available through access to underground mining areas. Underground mining areas are currently only within E Pit.
- Climate change predictions are unlikely to result in increases to the predicted water level of the base case. Changes in climate at MCM are likely to result in increased evaporation and reduced rainfall totals annually.
- Variability in the groundwater data considered within the model is unlikely to result in changes to the equilibrium water levels predicted in the base case scenario.

9.2.2 Adverse water quality impacts from the final void

The final void WBM included the consideration of how salinity levels change within the final void over time. In all voids, salinity levels will increase over time with evapoconcentration effects significant. Through testing of a range of model sensitivities, the rate of increase does vary dependent upon the conditions considered with the following key outcomes:

- E Pit is likely to have the greatest salinity and is least likely to be suitable for beneficial reuse activities.
- M and D Pit has the lowest salinity predicted over time, due to more external catchment contributing to provide dilution.
- Variability in salinity predictions was greatest in A and B Pit and E Pit. Variability in these two voids occurred due to assumptions around the spoil storage capacity and pit evaporation factors.
- Through supporting GLM modelling, it has been identified that strong stratification in temperature and mild stratification in salinity levels in summer between the surface and bottom layers across all modelled pits in this study.

Beyond salinity, to reduce the uncertainty on the geochemical evolution of water quality within the final voids, further understanding of the ionic composition of the water within the final voids is required. Based on historical water quality monitoring data, it is understood that current in-pit waterbodies are generally neutral to alkaline with an EC level typical of the groundwater environment however this is limited by the length of data available and the water depth of sample taken. Additional in-pit water quality monitoring is recommended and discussed further in Section 10.

10 MONITORING AND VALIDATION

10.1 In-pit water quality monitoring

To address the remaining uncertainties in site water quality data, it is recommended that additional monitoring be undertaken within the in-pit waterbodies to confirm the ionic composition prior to closure. This data will be used to undertake future geochemical modelling to understand the evolution of water quality. The existing groundwater and surface water monitoring program is recommended to continue. Surface water quality monitoring should align monitoring parameters with the existing groundwater program sufficient to determine ionic composition of runoff water quality.

The water quality monitoring program for in-pit water quality is summarised in Table 10.1 and is proposed to be undertaken over a two-year period prior to closure.

Table 10.1 Recommended in-pit water quality monitoring program

Sample location	AGD 1984 AMG Zone 55		Parameters
	Eastings (m)	Northings (m)	
Millennium B Pit	628022	7564615	Physicochemical parameters: pH, EC, TSS, TDS, depth below surface, dissolved oxygen, oxidation-reduction potential (ORP), and temperature Metals (dissolved and total): Al, As, Cd, Cr, Co, Cu, Pb, Ni, Zn, Sb, Mo, Se, Ag, Fe, and Hg Major ions: Mg, Na, K, Ca, Cl, SO_4, total alkalinity, bicarbonate alkalinity, Si, and F Nutrients: nitrate, phosphate, ammonia Other: free and total residual chlorine
D Pit	630238	7565992	
Tailings Dam	629526	7566490	
E4 sump	631956	7564061	
E3 sump	632254	7563729	
E1 sump	632493	7563469	

To further address uncertainties associated with in-pit spoil material, it is recommended that characterisation of the material be undertaken to confirm appropriate porosity and salt generation factors. This process of spoil characterisation should occur in each void.

10.2 Site inspections and visual monitoring

Upon completion of open cut mining operations in each final void at MCM, it is recommended that a visual monitoring program be implemented as part of ongoing site inspections. This monitoring program should consider:

- Formation of subsurface flow paths between M and D Pit and E Pit. Monitoring should identify if areas on the northwestern embankment in E Pit show evidence of seepage as water levels in M and D Pit increase (when being used as a mine affected water storage).

- Inspect the water edge of each final void (where safe to do so) and evaluate the stability of spoil material subject to water level oscillation, and whether there is evidence of any chemical precipitation processes occurring because of the water quality of the water stored within the void.

10.3 Ecology

From a regional context, MCM is in a zone in Australia that experiences extended periods of wet and dry, that may last in one cycle for years to decades. As detailed in Section 3.3, the region is characterized by having ephemeral watercourses (i.e., only experience flows for short periods following rainfall) and limited naturally occurring permanent water bodies. In response to these conditions, the ecology of the region has developed the ability to establish opportunistic populations that are salt-tolerant and thrive under a cycle of boom-and-bust conditions. As such, the pit lakes may represent a novel habitat in an area characterised by ephemeral creek systems and floodplains.

To understand whether the final voids are likely to support opportunistic native flora and fauna species (that are able to relatively quickly respond to changes in salinity) and the diversity of the aquatic community, a high-level ecology study is recommended. This may also assist in providing structural features which can be built into the voids to enhance the aquatic habitat by providing a more suitable and diverse physico-chemical and physical habitat.

11 CONCLUSIONS

The MCM final void hydrology study has been undertaken in accordance with the scope of work outlined in the KCB proposal PR23DX203-16 (dated 29 May 2023). This report documents aspects of the study relating to final void hydrology including:

- Review of topographic data to define physical characteristics of the proposed final landform design including topography, drainage, catchment areas and level – surface area – volume characteristics associated with the final voids.
- Definition of hydrological characteristics of the MCM site (i.e., rainfall, evaporation and catchment yield etc.) based on review of available reports and data.
- Inclusion of hydrogeological inputs of the MCM site (i.e., groundwater interactions and associated inflow rates and spoil aquifer storages) from work undertaken by SLR (2023b).
- Development of a final void WBM.
- Predictive modelling to estimate hydrological characteristics of final voids.
- An assessment of hydrogeological and stratification potential within the final voids.

Key outcomes of the final void study include:

- Three final voids within A and B Pit, M and D Pit and E Pit are proposed to remain as part of the final landform and are expected to maintain permanent pit lakes.
- Water levels within the final voids are expected to reach equilibrium in approximately 140 years post closure. Until this time, the voids are predicted to lose water to the groundwater system.
- Once equilibrium has been reached, the pit lakes within the final voids are expected to fluctuate around a steady state equilibrium level. No voids are expected to reach levels that would result in overflow into downstream watercourse via a surface pathway (i.e., no water levels above the original natural ground level and spoil crest level).
- Fluctuations in the pit lake water quality (i.e., EC/TDS levels) will continue to occur and be driven by climatic variability as cycles of above and below average rainfall result in rapid water quality fluctuations when compared with long-term trends of gradual accumulation of salinity.
- The final voids may prove beneficial to future land uses associated with agriculture however due to water quality within the voids, the timeframe for these activities is limited to between less than 300 years. Other reuse opportunities may also exist; however, further works would be required to understand the effectiveness of these at reducing water levels and salinity.
- Sensitivity analysis has been undertaken to determine how final void hydrological characteristics vary in response to changes in model parameters. Changes to parameters in isolation generally produced water level ranges that fell within the range of results predicted by the base case envelope and were below the overflow levels.
- Recommendations have been made to:

- increase the monitoring of existing in-pit water bodies with additional water quality parameters to enable long-term modelling of hydrogeochemical processes;\
- characterise spoil material to understand porosity and salt generation factors;
- establish a visual monitoring program of the voids at closure, focused on the emergence of new groundwater seepage faces, stability of spoil material and presence of chemical precipitation processes; and
- undertake a site-specific high-level ecology study.

12 CLOSING

This report is an instrument of service of KCB and has been prepared for the exclusive use of MetRes for the specific application to the final void hydrology study at MCM. The report's contents may not be relied upon by any other party without the express written permission of KCB. In this report, KCB has endeavoured to comply with generally accepted professional practice common to the local area. KCB makes no warranty, express or implied.

Please contact the either of the undersigned if you have any queries or require further assistance.

Yours truly,

KCB AUSTRALIA PTY LTD.

Kirsty Bethune

Kirsty Bethune
Senior Water Resources Engineer

Jim Heaslop
Manager, Water Engineering

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APPENDIX I

Project data

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MCM aerial photography from June 2023.
Projection in file AGD 84 AMG Zone 55.
Aerial photography used for locality plan and to show current pit extent.
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Daily rainfall and evaporation data sourced from the online SILO Data Drill database (Data Drill) for latitude -22.00 and longitude 148.25 (DES 2023a)
Data was downloaded from 1 January 1889 to 14 February 2023.
Long-term statistics for the rainfall data are:

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<tr><td>St. Dev</td><td>18</td><td>16</td><td>13</td><td>9</td><td>6</td><td>5</td><td>5</td><td>6</td><td>7</td><td>9</td><td>12</td><td>14</td><td>142</td></tr>
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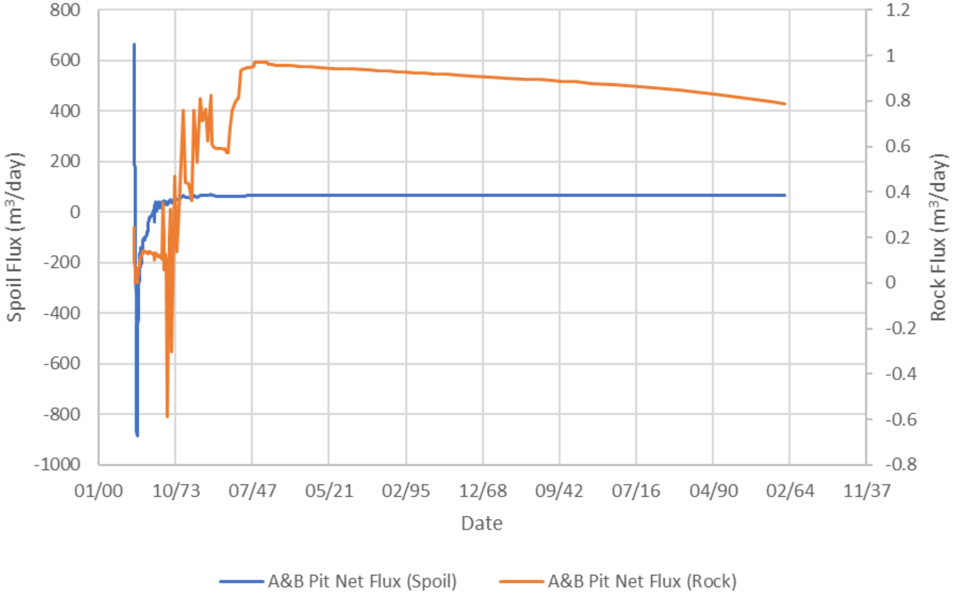
Groundwater data	*Millennium_PRCP_Inflows_Iteration4_to_KCB*	▪ Four rounds of surface water and groundwater model iterations undertaken between KCB and SLR with convergence of water levels for both models assumed after the fourth iteration. ▪ Spoil and groundwater inflow rates provided by SLR for each iteration, with fourth round rates used in the final void modelling. ▪ Groundwater inflows/outflows for fourth round iteration presented below (as provided by SLR) presented below. 

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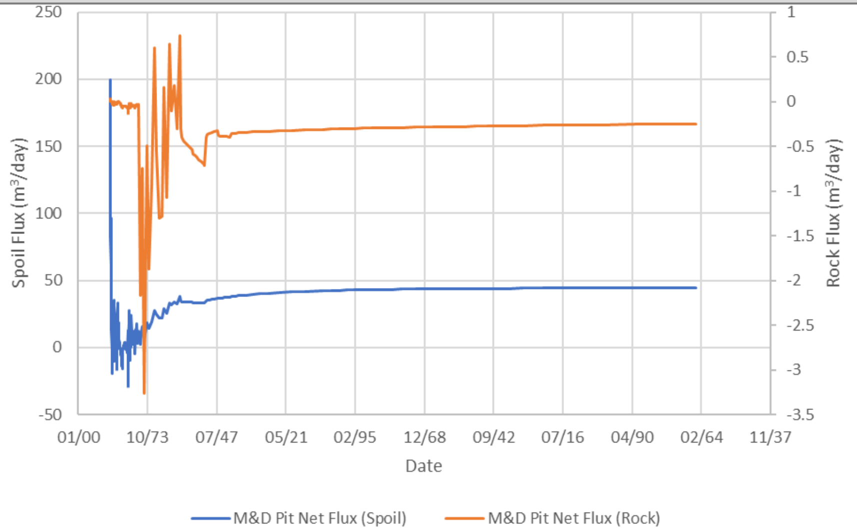

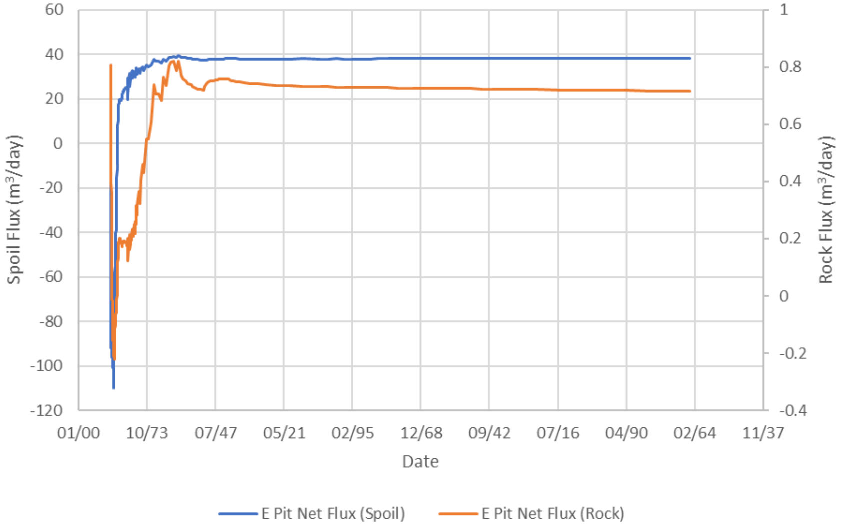

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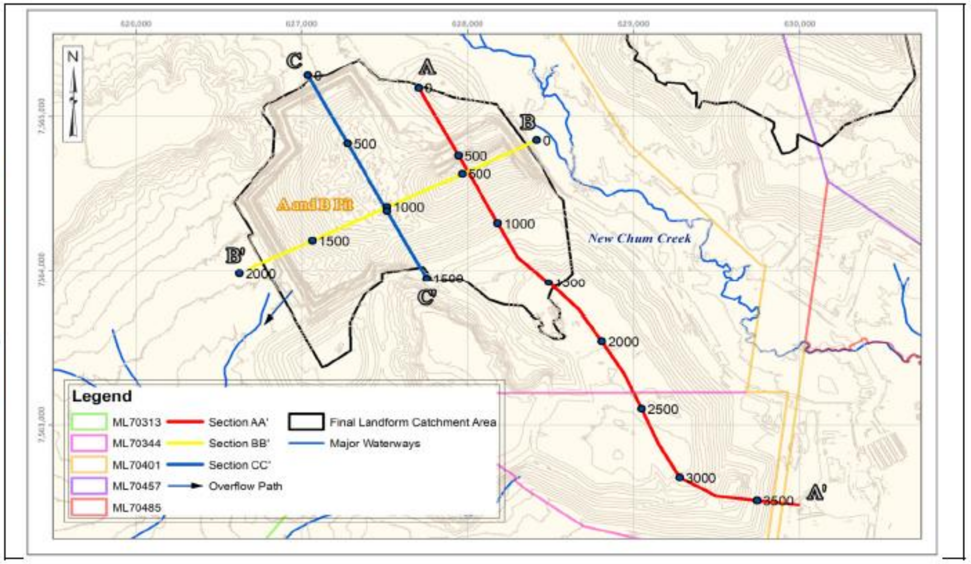
Type	Item (reference / filename)	Description
Water quality data	*20230613 CURRENT Millennium SWGW WQ Data.xlsx*	▪ Surface water and groundwater quality data provided by MetRes. ▪ Data provided from October 2020 to May 2023.
Operational water management	*230714 UPDATED_CURRENT_REP MIL Site water inventory and rainfall tracking spreadsheet_V8 SURVEY.xlsm*	▪ MCM water inventory tracking spreadsheet.
Reference data	*231009R MCM M and D Pit Rehabilitation.pdf*	▪ MCM surface water assessment for the M and D Pit final landforms report
	230929Dr WMP 2023 Update.pdf	▪ MCM Water Management Plan 2023 (M Mining 2023).
	EPML00819213_20230612.pdf	▪ EA EPML00819213 for MCM issued by DES on 12 July 2023.
	Millennium PRCP Pit Release Dates.pptx	▪ Project information provided by M Mining October 2023.
	620.V31396.00000_R01_v2.0-20230929_Optimized.pdf	▪ Groundwater Assessment M and D Pit Rehabilitation Options (SLR 2023).
Topographic data	Current pit surfaces *A&B Pits current pit surface 230421 with approved mining.txt* *E Pit current pit surface 230628.txt* *M&D Pits current pit surface 230528.txt* Deepest mine surface *A&B Pits Prime model.txt* *M&D Prime model.txt* *MDE Pits Prime model.txt*	▪ Current and deepest mine surfaces provided by MetRes.
	Millennium_PRCP_FinalLandform_1m_AGD84Z55_202310091.tif	▪ Final landform provided by SLR, dated 9 October 2023.

APPENDIX II

Final void data sheets

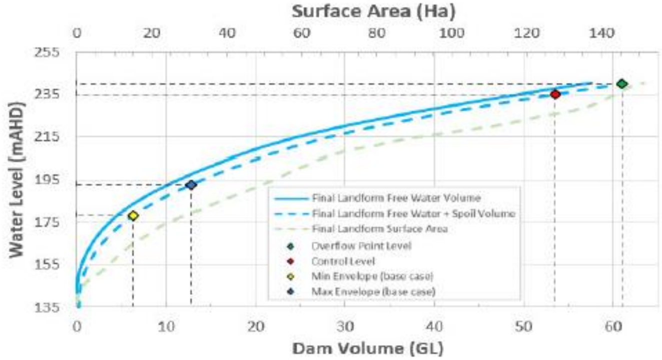
Locality and Catchment Plan



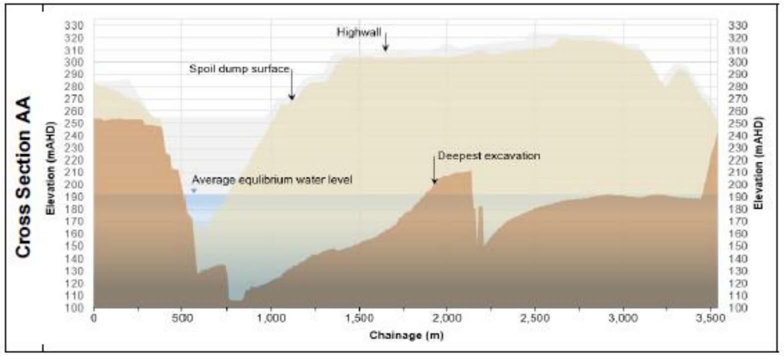
Notes

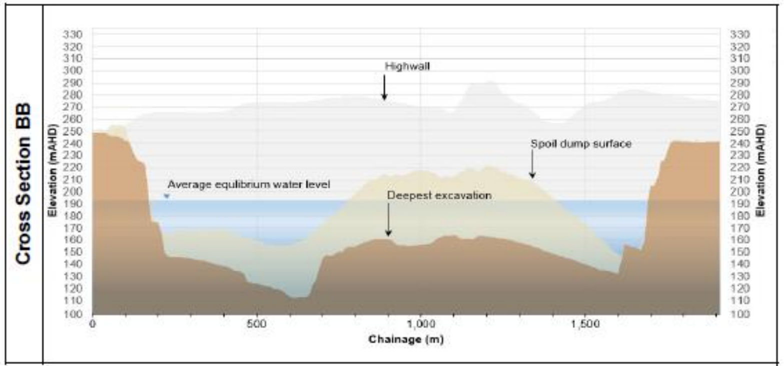
Locality and Catchment Plan, Cross Sections and Stage Storage Curve

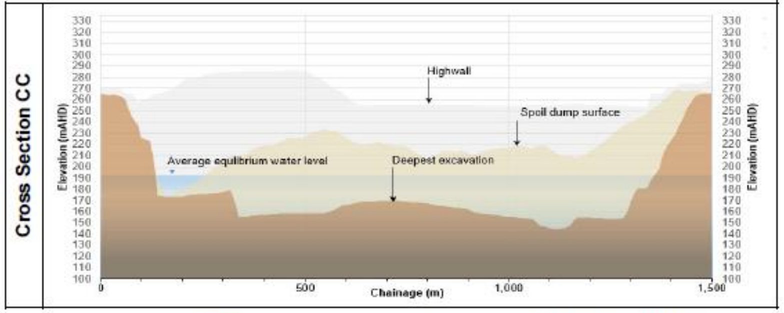
The lowest base level for the deepest mine extent was measured at a nominal elevation of 84.34 mRL at the base of B Pit.
The lowest base level for the final landform extent was measured at a nominal elevation of 137.4 mRL in the western corner of A and B Pit.
The initial water level within A and B Pit was assumed empty at the start of the simulation.
The lowest elevation at which surface water would overflow from the A and B Pit final void is set nominally at 237.5mRL, with flows directed south-westerly towards Western Dam.
Highwall areas are shown in grey tones are not located on the plan sections, but would be visible looking perpendicular to the section line.
The control level specified within the Stage Storage Curve has been set at nominal 5 m below overflow level to account for wave/wind action, geotechnical and topographic uncertainty.
The minimum and maximum envelopes specified within the Stage Storage Curve represent the results for the 'base case' scenario water levels.



Catchment area (ha)	243.6
Base of mining pit (mRL)	137.4
Control level (mRL)	232.5
Overflow level (mRL)	237.5
Starting water level (mRL)	Empty







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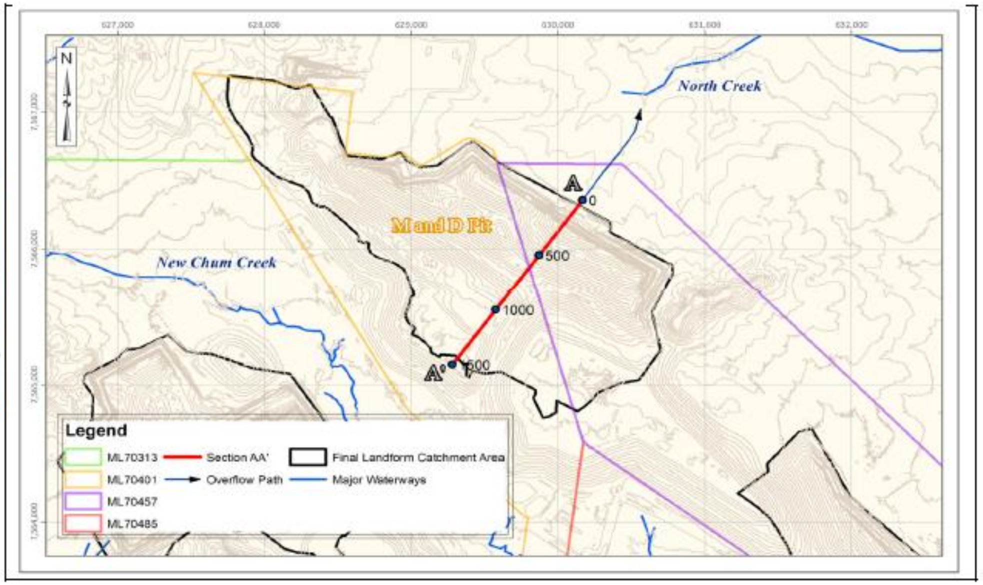
CLIENT
MetRes
Klohn Crippen Berger

PROJECT
MILLENNIUM COAL MINE
PRCP FINAL VOID HYDROLOGY STUDY

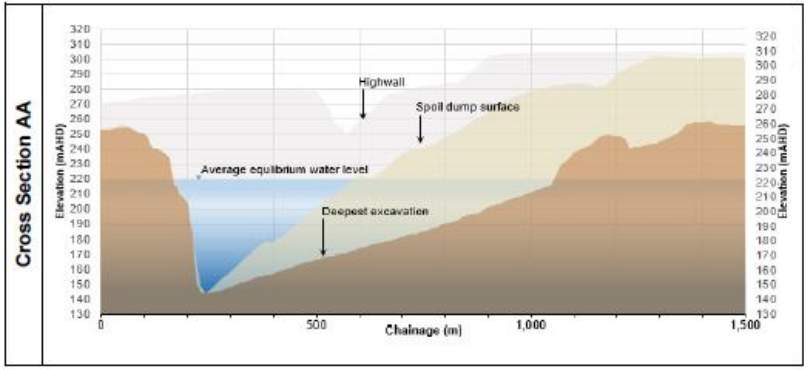
TITLE
FINAL VOID DATA SHEET
A AND B PIT (BASE CASE)

PROJECT No.
DX70050A09

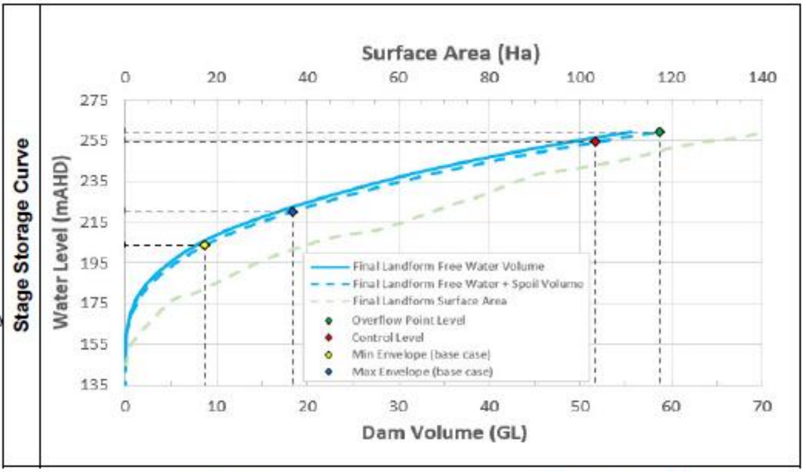
Locality and Catchment Plan



Cross Section AA



Stage Storage Curve



Notes

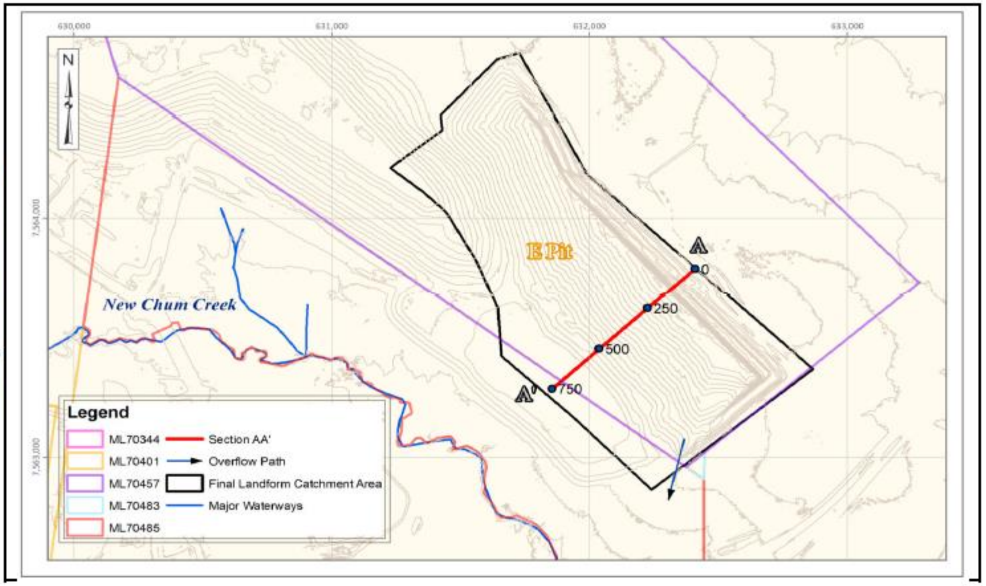
Locality and Catchment Plan, Cross Section AA and Stage Storage Curve

The lowest base level for the deepest mine extent was measured at a nominal elevation of 131.5 mRL in M and D Pit.
The lowest base level for the final landform extent was measured at a nominal elevation of 144.7 mRL in M and D Pit.
The initial water level within M and D Pit was assumed empty at the start of the simulation.
The lowest elevation at which surface water would overflow from the A and B Pit final void is set nominally at 259.5mRL, with flows directed north-easterly towards North Creek.
Highwall areas are shown in grey tones are not located on the plan sections, but would be visible looking perpendicular to the section line.
The control level specified within the Stage Storage Curve has been set at nominal 5 m below overflow level to account for wave/wind action, geotechnical and topographic uncertainty
The minimum and maximum envelopes specified within the Stage Storage Curve represent the results for the 'base case' scenario water levels.

Catchment area (ha)	371.0
Base of mining pit (mRL)	144.7
Control level (mRL)	254.5
Overflow level (mRL)	259.5
Starting water level (mRL)	Empty

CLIENT	MetRes
	Klohn Crippen Berger
PROJECT	MILLENNIUM COAL MINE PRCP FINAL VOID HYDROLOGY STUDY
TITLE	FINAL VOID DATA SHEET M AND D PIT (BASE CASE)
PROJECT No.	DX70050A09

Locality and Catchment Plan



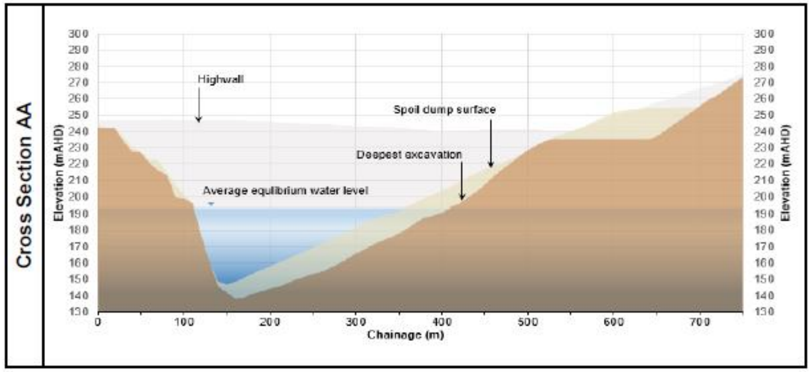
Notes

Locality and Catchment Plan, Cross Section AA and Stage Storage Curve

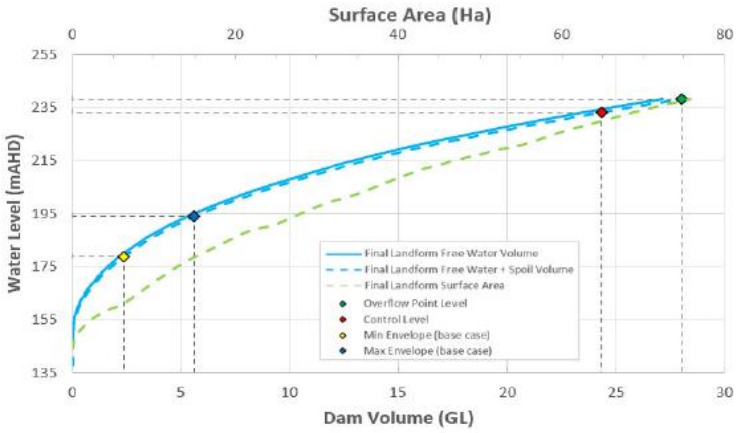
The lowest base level for the deepest mine extent was measured at a nominal elevation of 130.84 mRL.
The lowest base level for the final landform extent was measured at a nominal elevation of 144.35 mRL.
The initial water level within E Pit was assumed empty at the start of the simulation.
The lowest elevation at which surface water would overflow from the E Pit final void is set nominally at 238mRL, with flows directed south-westerly towards New Chum Creek.
Highwall areas are shown in grey tones are not located on the plan sections, but would be visible looking perpendicular to the section line.
The control level specified within the Stage Storage Curve has been set at nominal 5 m below overflow level to account for wave/wind action, geotechnical and topographic uncertainty
The minimum and maximum envelopes specified within the Stage Storage Curve represent the results for the 'base case' scenario water levels.

Catchment area (ha)	121.2
Base of mining pit (mRL)	144.4
Control level (mRL)	233
Overflow level (mRL)	238
Starting water level (mRL)	Empty

Cross Section AA



Stage Storage Curve



CLIENT
MetRes
Klohn Crippen Berger

PROJECT
MILLENNIUM COAL MINE
PRCP FINAL VOID HYDROLOGY STUDY

TITLE
FINAL VOID DATA SHEET
E PIT (BASE CASE)

PROJECT No.
DX70050A09

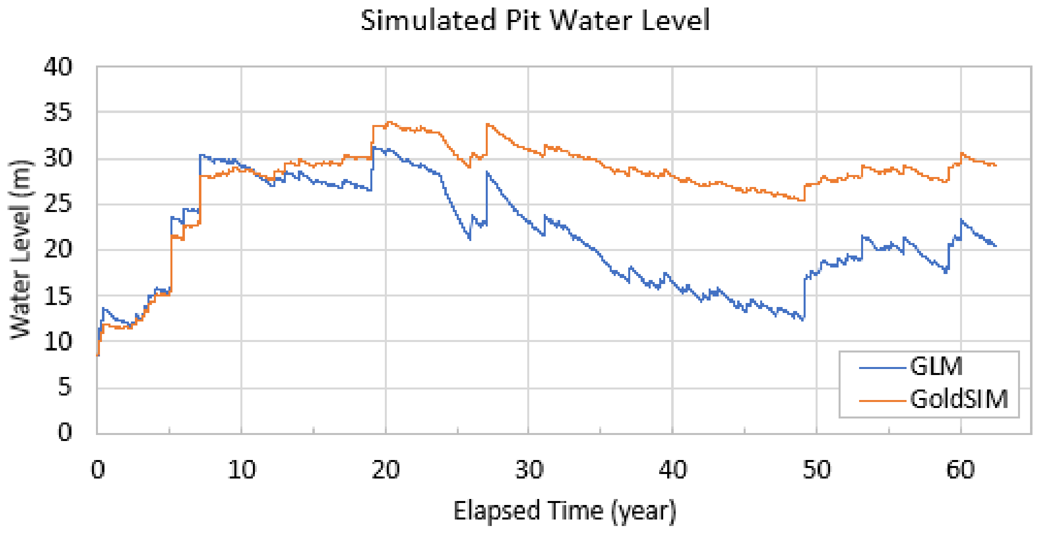
APPENDIX III

GLM modelling results – base case

A and B Pit

GLM simulation results are demonstrated in Figure III.1, Figure III.2, and Figure III.3 with key outcomes:

- Final void salinity is expected to decrease from the initial level of 3.5 psu to around 0.5 psu from year 5.
- Final void system is likely to predict strong stratification effects in temperature and mild effects in salinity.
- Significant cycles of simulated temperature between the summer and winter seasons for the pit lake upper layers.
- Simulated temperature of void water fluctuates between 15 °C and 31 °C for the surface layer (Figure III.3).
- Simulated results show mild stratification in salinity levels between the surface and bottom layers (Figure III.3).
- Approximately 5 m difference between the GoldSim and GLM results in pit water elevation. This is likely to be caused by the differences in local evaporation assumptions between the two modelling approaches. The storage response to the various inputs and outputs of the system remains similar between the models.



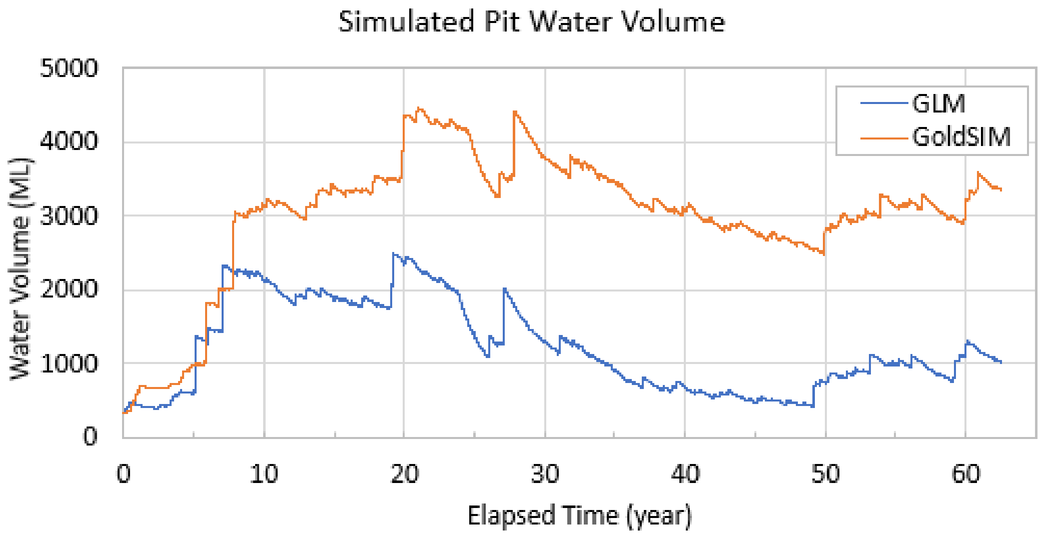


Figure III.1 Time series of modelled final void water depth and volume - base case

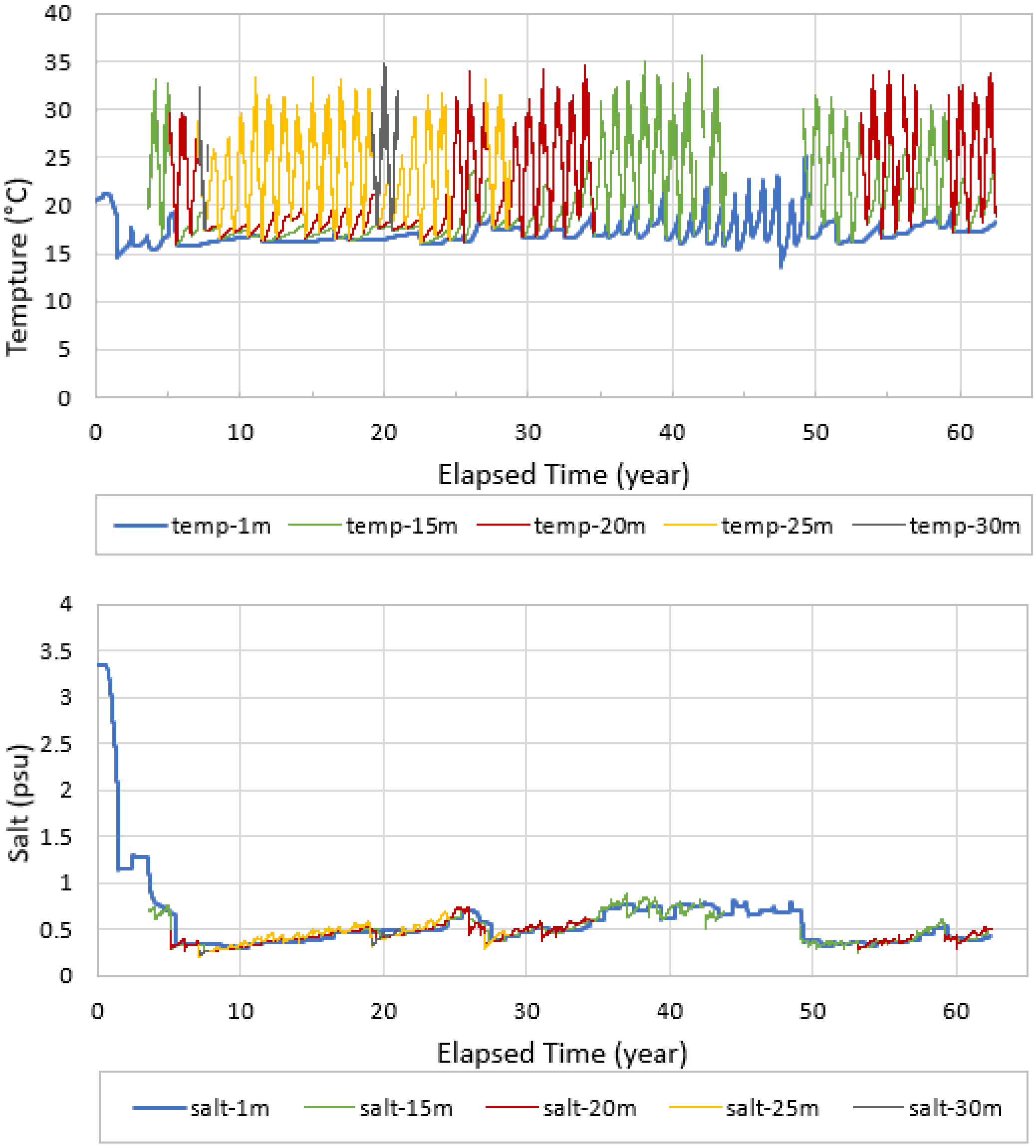


Figure III.2 Time series of modelled final void temperature and salinity - base case

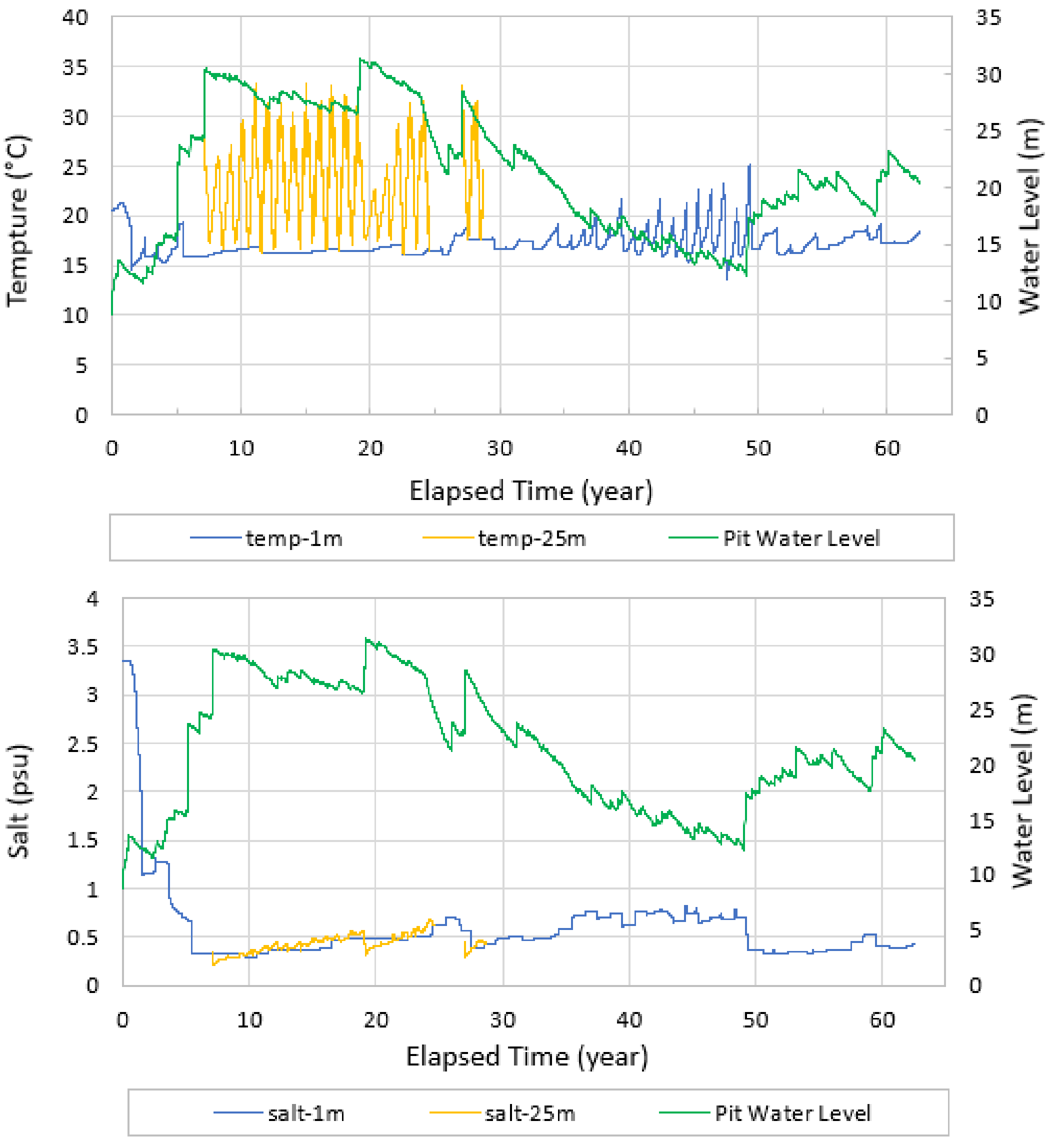


Figure III.3 **GLM simulated final void temperature and salinity against pit water level - base case**

M and D Pit

GLM simulation results are demonstrated in Figure III.4, Figure III.5, and Figure III.6, with key outcomes:

- Final void salinity is expected to decrease from the initial level of 3.5 psu to around 0.5 psu from year 5, followed by a slow recovery to around 1.5 psu.
- Final void system is likely to predict strong stratification effects in temperature and mild effects in salinity.
- Significant cycles of simulated temperature between the summer and winter seasons for the pit lake upper layers.
- Simulated temperature of void water fluctuates between 15 °C and 31 °C for the surface layer (Figure III.5) most of the time.

- Simulated results show mild stratification in salinity levels between the surface and bottom layers (Figure III.5) in summer.
- Approximately 5 m difference between the GoldSim and GLM results in pit water elevation. This is likely to be caused by the differences in local evaporation assumptions between the two modelling approaches. The storage response to the various inputs and outputs of the system remains similar between the models.

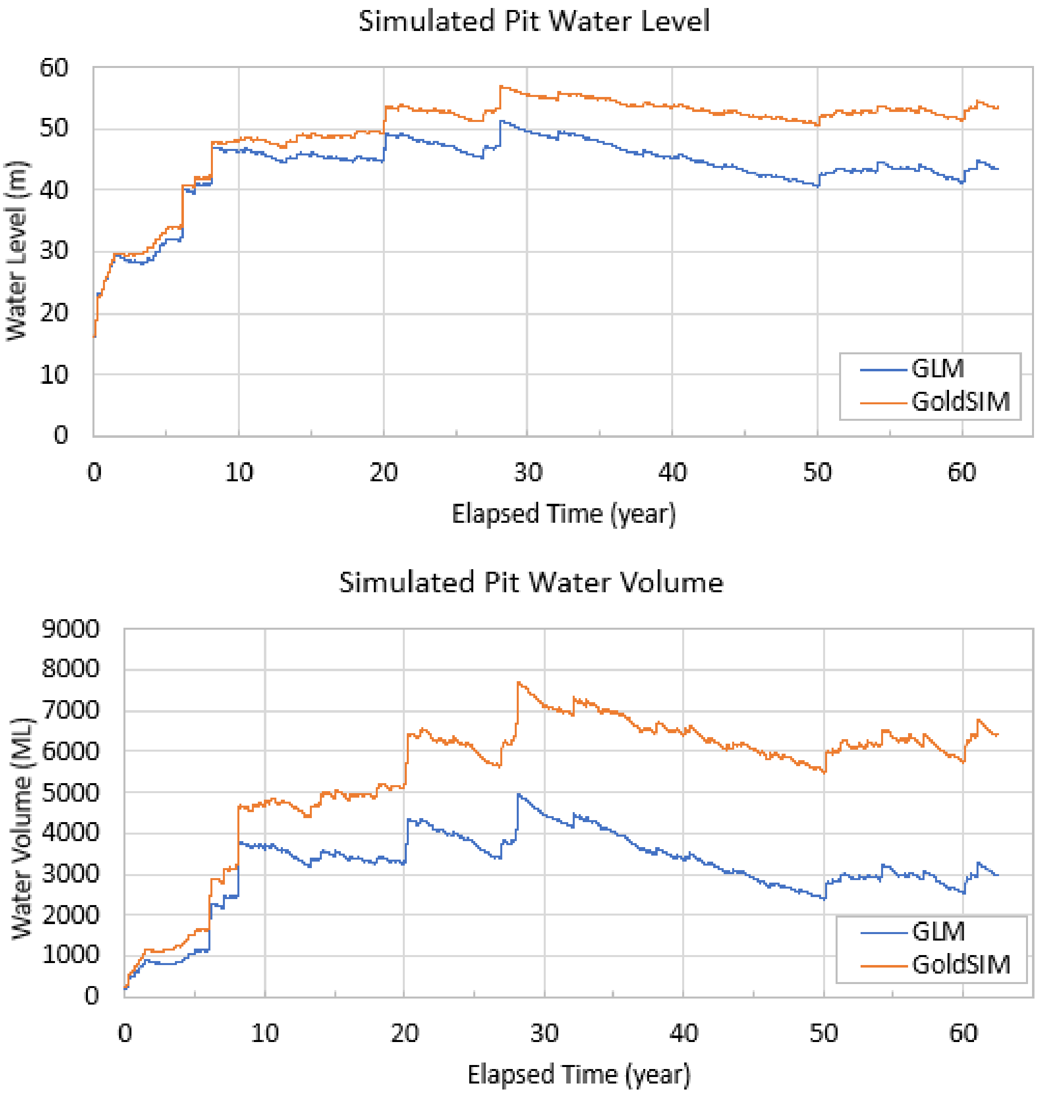


Figure III.4 Time series of modelled final void water depth and volume - base case

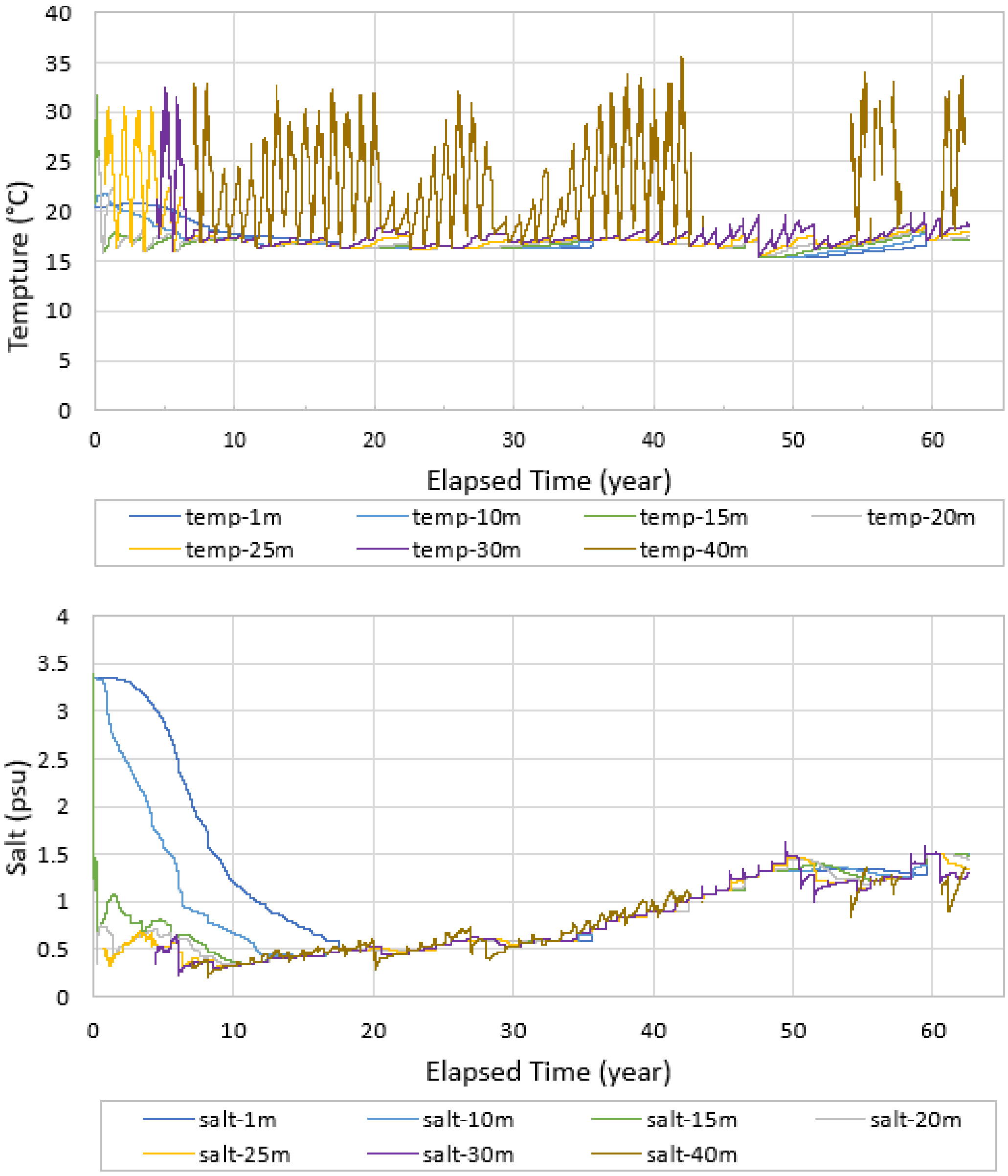


Figure III.5 Time series of modelled final void temperature and salinity - base case

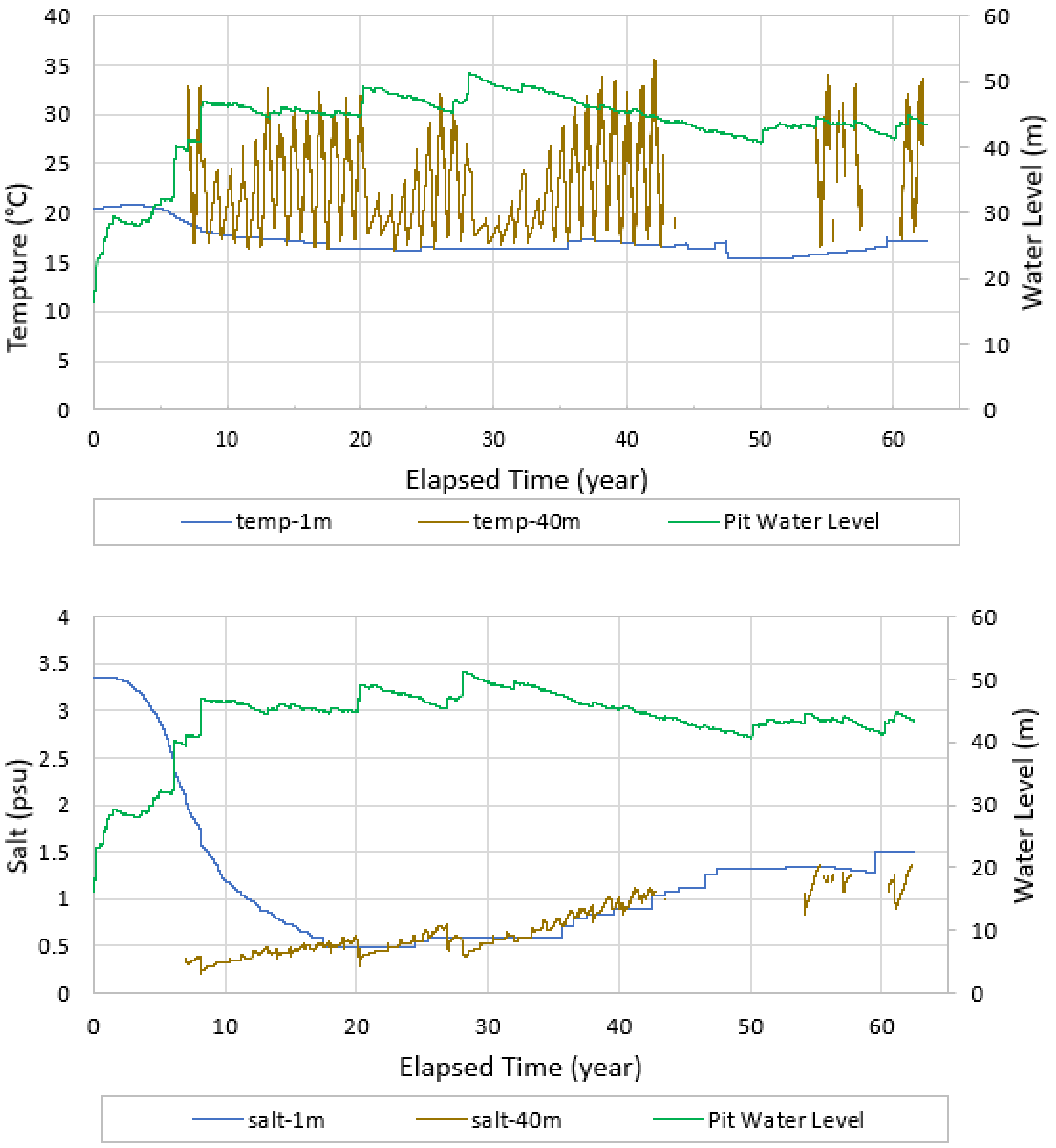


Figure III.6 **GLM simulated final void temperature and salinity against pit water level – base case**

E Pit

GLM simulation results are demonstrated in Figure III.7, Figure III.8, and Figure III.9 with key outcomes:

- Final void salinity is expected to decrease from the initial level of 3.5 psu to around 0.5 psu from year 5, followed by slow recovery to around 1.5 psu after year 50.
- Final void system is likely to predict strong stratification effects in temperature and mild effects in salinity.
- Like the other pits, there are significant cycles of simulated temperature between the summer and winter seasons for the pit lake upper layers.

- Simulated temperature of void water fluctuates between 15 °C and 31 °C for the surface layer (Figure III.8) most of the time.
- Simulated results show mild stratification in salinity levels between the surface and bottom layers (Figure III.8) in summer.
- Approximately 5 m difference between the GoldSim and GLM results in pit water elevation. This is likely to be caused by the differences in local evaporation assumptions between the two modelling approaches. The storage response to the various inputs and outputs of the system remains similar between the models.

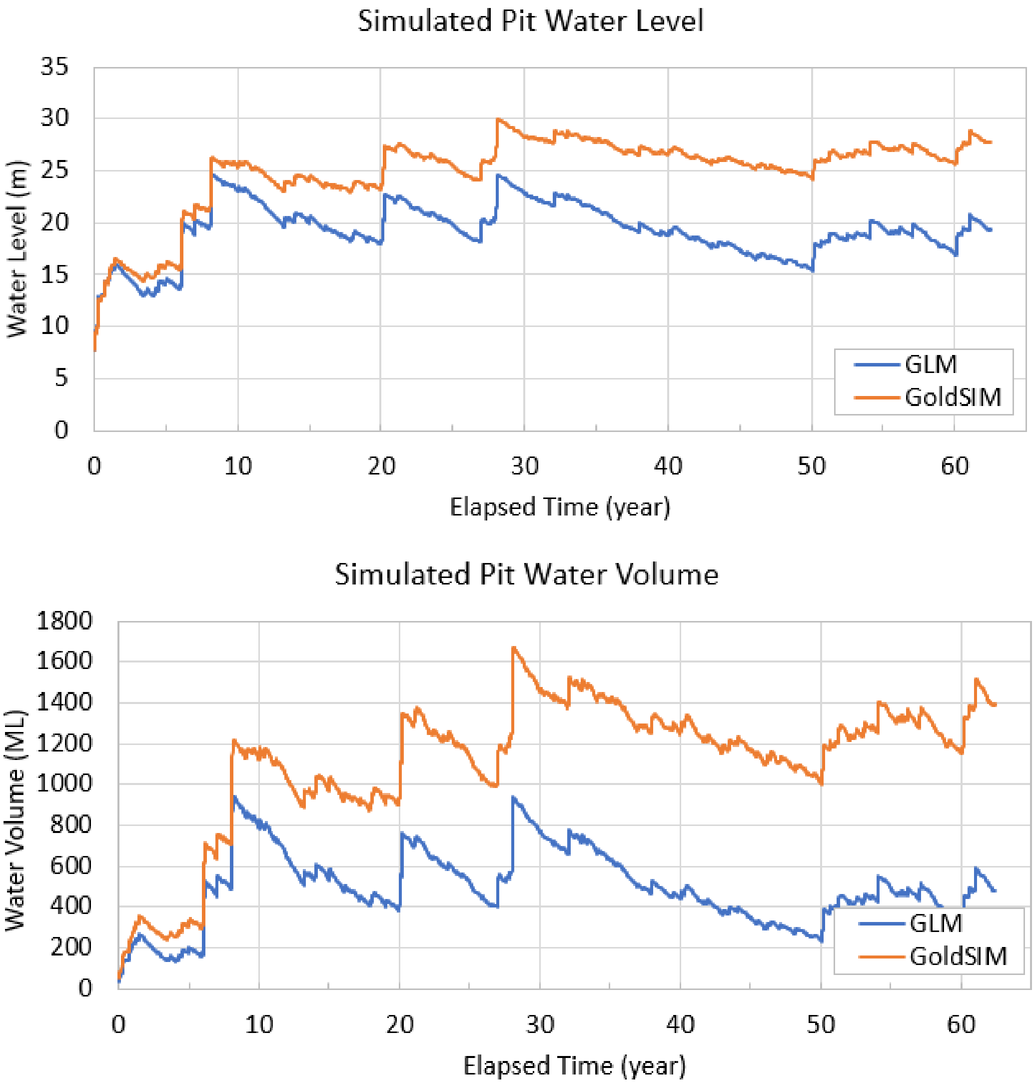


Figure III.7 Time series of modelled final void water depth and volume – base case

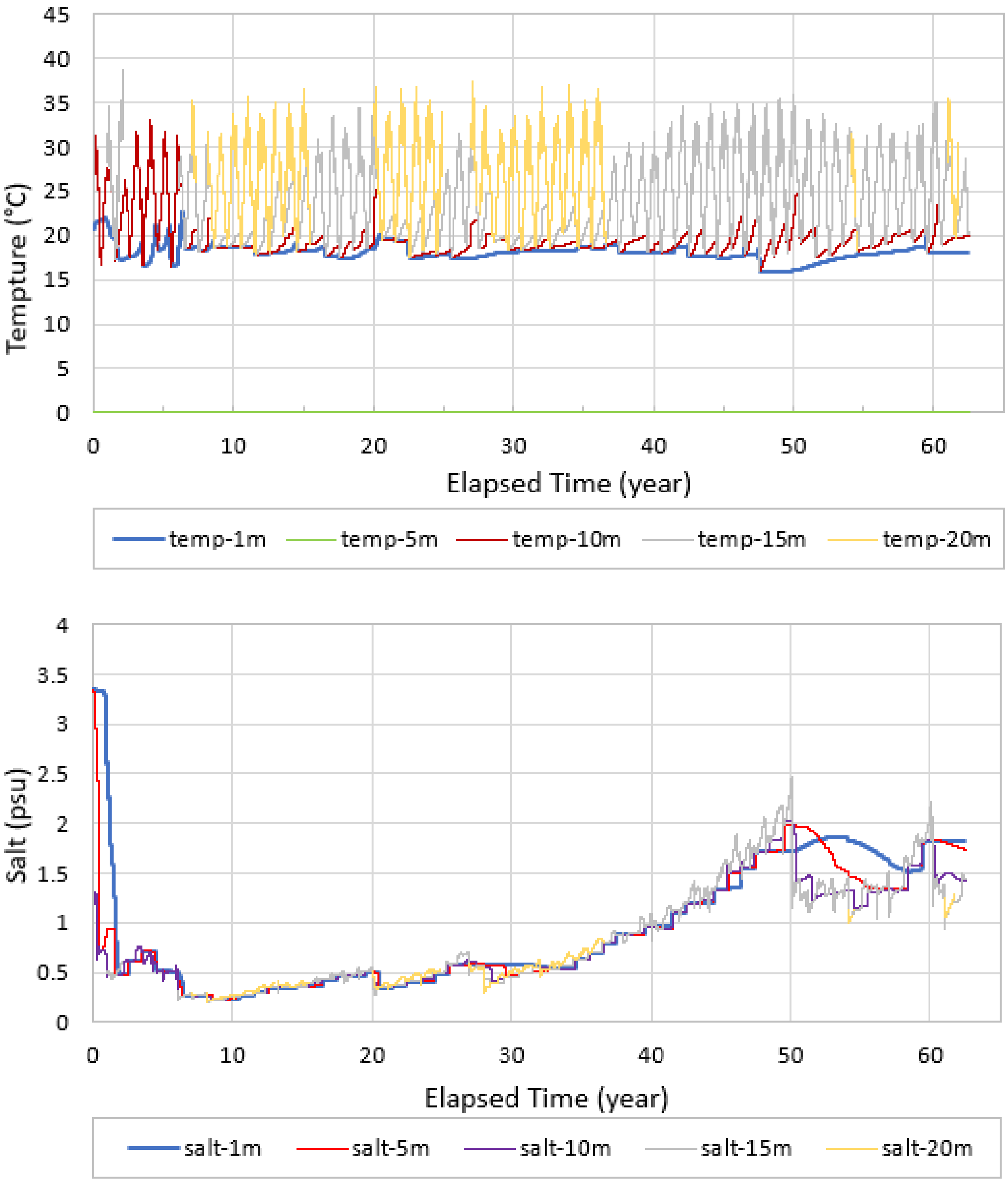


Figure III.8 Time series of modelled final void temperature and salinity – base case

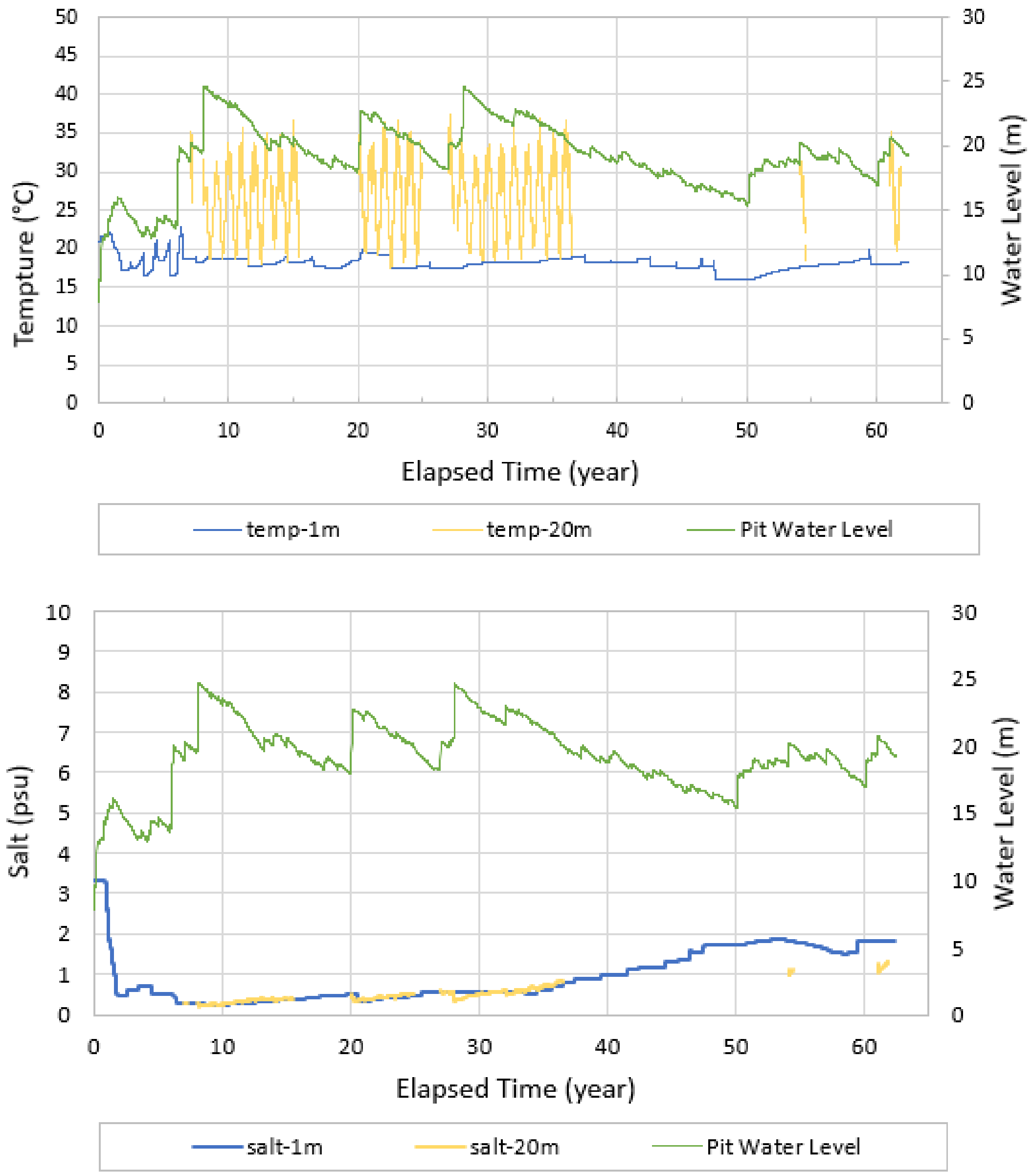


Figure III.9 GLM simulated final void temperature and salinity against pit water level – base case