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BHP Mitsubishi Alliance (BMA)

Void Closure Plan

Saraji Mine

January 2024

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Void Closure Plan
Saraji Mine

BHP Mitsubishi Alliance (BMA)

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Rev	Date	Details
Rev A	9 December 2022	Void Closure Plan for Saraji Mine (draft)
Rev 0	23 December 2022	Void Closure Plan for Saraji Mine (final)
Rev B	22 November 2023	Void Closure Plan for Saraji Mine (draft-Information Request Notice response)
Rev 1	21 December 2023	Void Closure Plan for Saraji Mine (final Information Request Notice response)
Rev 2	8 January 2024	Void Closure Plan for Saraji Mine (final Information Request Notice response)

	Name	Date	Signature
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Reviewed/Approved by:	Raina Hattingh	8 January 2024	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Acronyms, abbreviations, and terms

Acronym / abbreviation / term	Description
AEP	Annual Exceedance Probability
AHD	Australian Heigh Datum
AWBM	Australian Water Balance Model
BMA	BHP Mitsubishi Alliance
CHPP	Coal Handling and Processing Plant
CQCA	Central Queensland Coal Associate
DES	Department of Environment and Science
EA	Environmental Authority
EP Act	Environmental Protection Act 1994
FoS	Factor of Safety
GDE	Groundwater Dependent Ecosystems
LOD	Land Outcome Document
LOR	Limit of Reporting
MCM	Moranbah Coal Measures
MIA	Mine Infrastructure Area
Ml	Megalitres
ML	Mining Lease
ML/yr	Megalitres per year
NUMA	Non-use Management Area
PMF	Probable Maximum Flood
PMLU	Post-mining Land Use
PRC plan	Progressive Rehabilitation and Closure Plan
QC	Quality Control
RCP	Representative Concentration Pathway
SRM	Saraji River Mine
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
WBM	Water Balance Model

1 Introduction

Saraji Mine (SRM) is an open-cut coal mine which forms part of BHP Mitsubishi Alliance's (BMA's) central region mine complex. SRM is located 30 kilometres (km) north of Dysart in the Bowen Basin, Central Queensland. The site is operated on various Mining Leases (MLs): ML1782, ML1775 (part), ML1784, ML2360, ML2410, ML70142, ML70294, ML70298, ML70328, and ML700021.

Operations at SRM are authorised under Environmental Authority (EA) (EPML00862313), which is jointly held by Central Queensland Coal Associate (CQCA) Joint Venture, namely BHP Coal Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investments Pty Ltd, Umal Consolidated Pty Ltd, QCT Resources Pty Limited, QCT Mining Pty Ltd, and BHP Queensland Coal Investments Pty Ltd. Holders of an EA are required to submit a progressive rehabilitation and closure plan (PRC plan) that meets requirements under the *Environmental Protection Act 1994*. A Transition Notice was issued by the Department of Environment and Science (DES) to BHP for SRM, requiring a PRC plan be submitted to the administering authority by 1 April 2023. This was submitted.

Following submission of the PRC plan on this date, BMA received an Information Request Notice from the DES. A formal response to the Information Request Notice is due to be submitted to the DES by BMA by 22 January 2024. This void closure plan has been updated in response to the Information Request Notice received by BMA.

This void closure plan presents outcomes of technical studies completed to support closure planning and achievement of safe, stable and non-polluting residual voids at SRM – specifically the residual voids associated with Jacaranda/Bauhinia Pit, Coolibah/Dogwood Pit, Ebony/Grevillea Pit, and Hakea Pit. This void closure plan is an appendix to the SRM PRC plan and is required by the DES *Progressive rehabilitation and closure plan (PRC plans) Guideline (version 3.0)*, hereafter referred to as the 'PRC Plan Guideline', dated 4 April 2023.

The technical studies, including the hydrogeology and rehabilitation flood modelling, have been undertaken through an iterative approach with the development of the closure landform design and also respond to the Information Request Notice. These iterations have resulted in a closure landform design that includes refinements comprising residual void partial backfill, increased off-set distances, removal of culverts and other infrastructure from watercourses/floodplains, and changes to flood protection landforms to provide increased protection from flood water. This void closure plan documents how these refinements contribute to minimising environmental harm, as it relates to the SRM final residual voids.

1.1 Scope and objectives

SRM currently has eight mining pits in various operational stages – Hakea, Grevillea, Ebony, Dogwood, Coolibah, Bauhinia, Acacia, and Jacaranda pits. Post-closure, these pits are pre-approved as non-use management areas (NUMAs) and will be combined in a final landform design as four final residual voids – Jacaranda/Bauhinia, Coolibah/Dogwood, Ebony/Grevillea, and Hakea (herein referred to as the SRM residual voids).

The objective of this void closure plan is to document the rehabilitation and management approach, capturing how BMA will aim to achieve safe, stable, and non-polluting residual voids at closure. This void closure plan will also help to:

- Minimise risk of the residual voids and surrounding areas within the NUMA extents
- Minimise active management of the residual voids post-closure
- Avoid unmitigated access to the NUMA by humans and livestock.

The following sections present information as required by sections 3.4 and 3.6.3 of the *PRC Plan Guideline*, specifically:

- Section 3 – Proposed residual voids
- Section 4 – Groundwater
- Section 5 – Flooding assessment
- Section 6 – Void water balance
- Section 7 – Geotechnical stability
- Section 8 – Geochemical stability
- Section 9 – Residual void management.

1.2 Applicable legislation and guidelines

The following applicable legislation and guidelines have informed the development of this void closure plan:

- *Environmental Protection Act 1994* (QLD)
- EA (EPML00862313) dated 29 June 2023
- *PRC Plan Guideline* (version 3.0) dated 4 April 2023.

2 Site overview

SRM is a hard coking coal resource, located 30 km north of Dysart in the Bowen Basin and approximately 167 km south-west of Mackay, Queensland.

SRM is a conventional open-cut strip mine using draglines and truck/shovel equipment to produce metallurgical coal. Most coal mining activities occur on ML1775 and ML1782, with a small portion having occurred on ML2360 and ML2410. Currently there are eight mining pits in various operational stages: Hakea, Grevillea, Ebony, Dogwood, Coolibah, Bauhinia, Acacia, and Jacaranda pits.

Mining involves land clearing, the removal and stockpiling of topsoil material, drilling and blasting of overburden/interburden as required, stripping of overburden/interburden material using a combination of draglines and truck and shovel fleets. As mining progresses, most of the overburden/interburden material is placed in the void of the previous strips. Coal is hauled from the pits to the coal handling and preparation plant (CHPP) run-of-mine (ROM) area, or to designated stockpiles. A conveyor transfers product coal from the CHPP to the train load-out area. Fine rejects from the CHPP are disposed in tailings storage facilities (TSFs) and coarse rejects are disposed in the mining spoil or old ramp voids. Product coal is transported by rail to the Hay Point Coal Terminal for export.

Operations at SRM started in 1974. Each void has a different closure year based on the current projected mine plan. These closure years are 2080 for Ebony/Grevillea Pit, 2082 for Coolibah/Dogwood Pit, 2096 for Hakea Pit, and 2098 for Jacaranda/Bauhinia Pit.

An overview of the existing environment within and surrounding SRM is provided in the PRC plan, and therefore not repeated in this void closure plan.

3 Proposed residual voids

Residual voids are identified and authorised under Schedule E (Condition E10 and E11) of the EA (which is SRM's Land Outcome Document (LOD)). Therefore, the four proposed SRM residual voids are being transitioned as pre-approved NUMAs in the SRM PRC plan.

The pits will be partially backfilled with spoil to reduce the pit extents as well as to assist with flood protection so that the proposed residual voids are not subject to inundation from floodwaters (refer to Section 5). Indicative final dimensions of the residual voids are presented in Table 3.1. A three-dimensional (3D) void design plan for all the SRM residual voids, including the void lakes, is presented in Figure 3.1.

Table 3.1 Indicative residual void dimensions

Residual void	Indicative maximum width (m)	Indicative maximum length (m)	Indicative maximum depth (m)
Jacaranda/Bauhinia	900	4,400	240
Coolibah/Dogwood	840	5,400	230
Ebony/Grevillea	1,160	6,700	300
Hakea	680	3,570	160

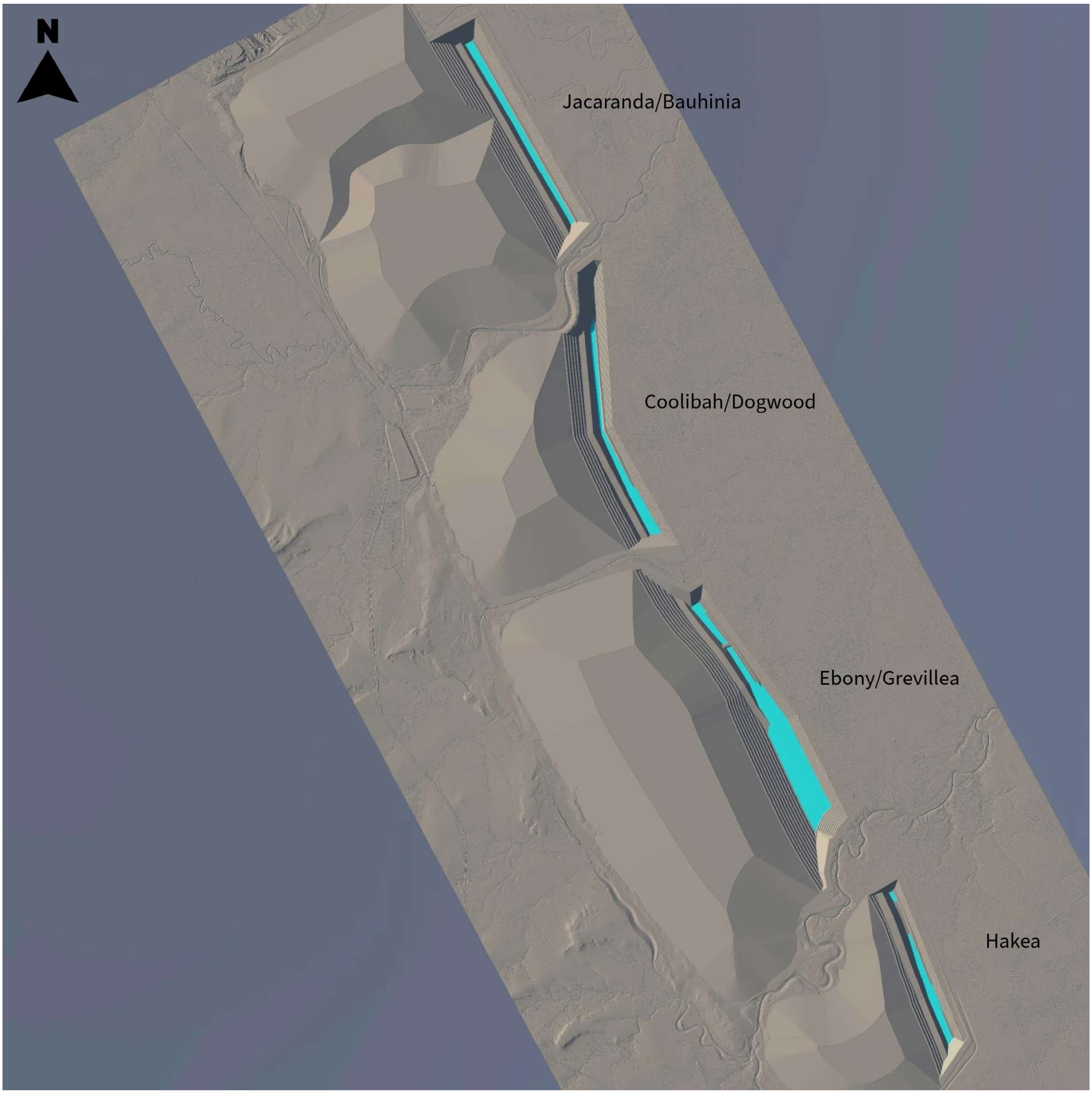


Figure 3.1 3D void design plan: overview of SRM residual voids and void lakes

4 Groundwater

The hydrogeological assessment completed, included conceptual and numerical modelling to determine groundwater interactions with, and the potential for contaminant transport from SRM residual voids (SLR, 2023a). The complete hydrogeological assessment including details of the model set-up, calibration, and discussion of the results is provided as an attachment to the PRC plan, and therefore not repeated in this void closure plan. This section presents a summary of the hydrogeological assessment of the SRM residual voids, as it relates to the rehabilitation and management approach to achieve safe, stable, and non-polluting residual voids at closure.

A post-mining conceptual site model (CSM) was developed which depicts groundwater interactions with the residual voids. A visual representation is presented in Figure 4.1. The CSM's key findings, relevant to post-mining groundwater impacts, are as follows:

- Formation of residual void lakes in all four voids was predicted, with lake water levels stabilising below both pre-mining groundwater elevations and shallow post-mining Permian strata including the base of surficial weathering and shallow hydrostratigraphic units (i.e., alluvium, basalt and regolith).
- Inward hydraulic flow gradients towards the residual voids will be maintained within the Moranbah Coal Measures (MCM) upon stabilisation of groundwater and residual void lake levels. This is driven by evaporative losses from the void lakes, with no outflows of water to the surrounding hydrostratigraphic units predicted to occur.
- Infiltration of rainfall through in-pit spoil dumps and groundwater flows from beneath the mine industrial area (MIA) will continue to be captured in the residual voids.
- There will be little to no additional impact on surficial aquifers, including the alluvial aquifers, beyond what has already been predicted at the time when mining is anticipated to end.
- There will be little to no impact on environmental or anthropogenic receptors.

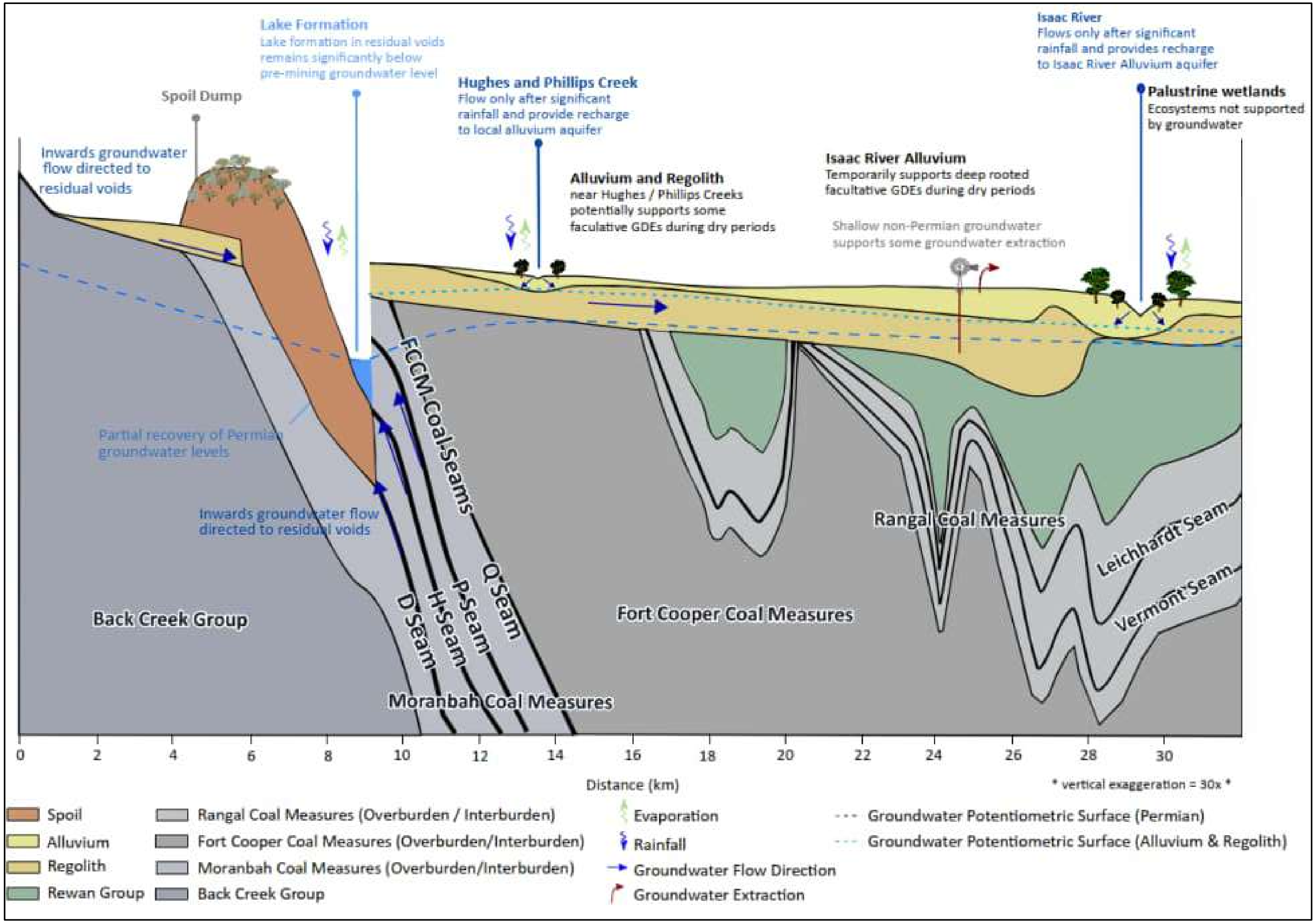


Figure 4.1 SRM post-mining conceptual site model (SLR, 2023a)

Calibrated numerical modelling was undertaken (SLR, 2023a) to evaluate the potential impacts of the final closure state landforms for the SRM residual voids on the groundwater regime. The objectives of the predictive modelling were to:

- Simulate the water level and rate of recovery of the residual void lakes, and the water level and rate of recovery from mining-related groundwater drawdown in the groundwater system surrounding the voids.
- Assess groundwater inflow to the final voids.
- Identify areas of potential environmental or anthropogenic risk, such as impacts to private water supply bores or groundwater dependent ecosystems (GDEs), where groundwater impact mitigation/control measures may be necessary post-closure.

The final closure state landforms were replicated in the model, including the four SRM residual voids and the spoil dumped within mined out pits. The model timeframe was developed to commence at the end of mining and cover a period of 2,249 years over 54 model stress periods. The predicted end of mining groundwater level was used as the starting heads (SLR, 2023a).

Three climate scenarios (wetter-R1, mid-R4, and drier-R6) from the water balance model (WBM) (refer to Section 6) were adopted to generate three sets of groundwater model predictions to account for climate sensitivity. Groundwater level predictions and the associated discussion herein focus primarily on the mid-climate scenario (R4) with the drier (R6) and wetter (R1) scenarios reported as sensitivities. The predicted equilibrium (long-term steady state) of the water table elevation adjacent to the final voids is shown in Figure 4.2 for the mid-climate scenario.

The groundwater levels in the water table proximal to the residual voids is predicted to remain below pre-mining groundwater levels in the long-term, driven by ongoing groundwater discharge to the residual void lakes and governed by the lake elevations themselves (Figure 4.2). Long-term inwards groundwater flow gradients are maintained post-mining.

Hydraulic gradients to the residual voids are steepest at the northern end of the Jacaranda/Bauhinia residual void, the southern end of the Ebony/Grevillea residual void and to the west of residual voids within the spoil areas. Shallower hydraulic gradients are modelled to the east of the residual voids (SLR, 2023a).

Water table suppression east of SRM is predicted to extend 2 km from the eastern lease boundary for the Coolibah/Dogwood, Ebony/Grevillea and Hakea residual voids. Water table suppression proximal to the Jacaranda/Bauhinia residual void has been modelled to extend approx. 0.5 km from the void crest.

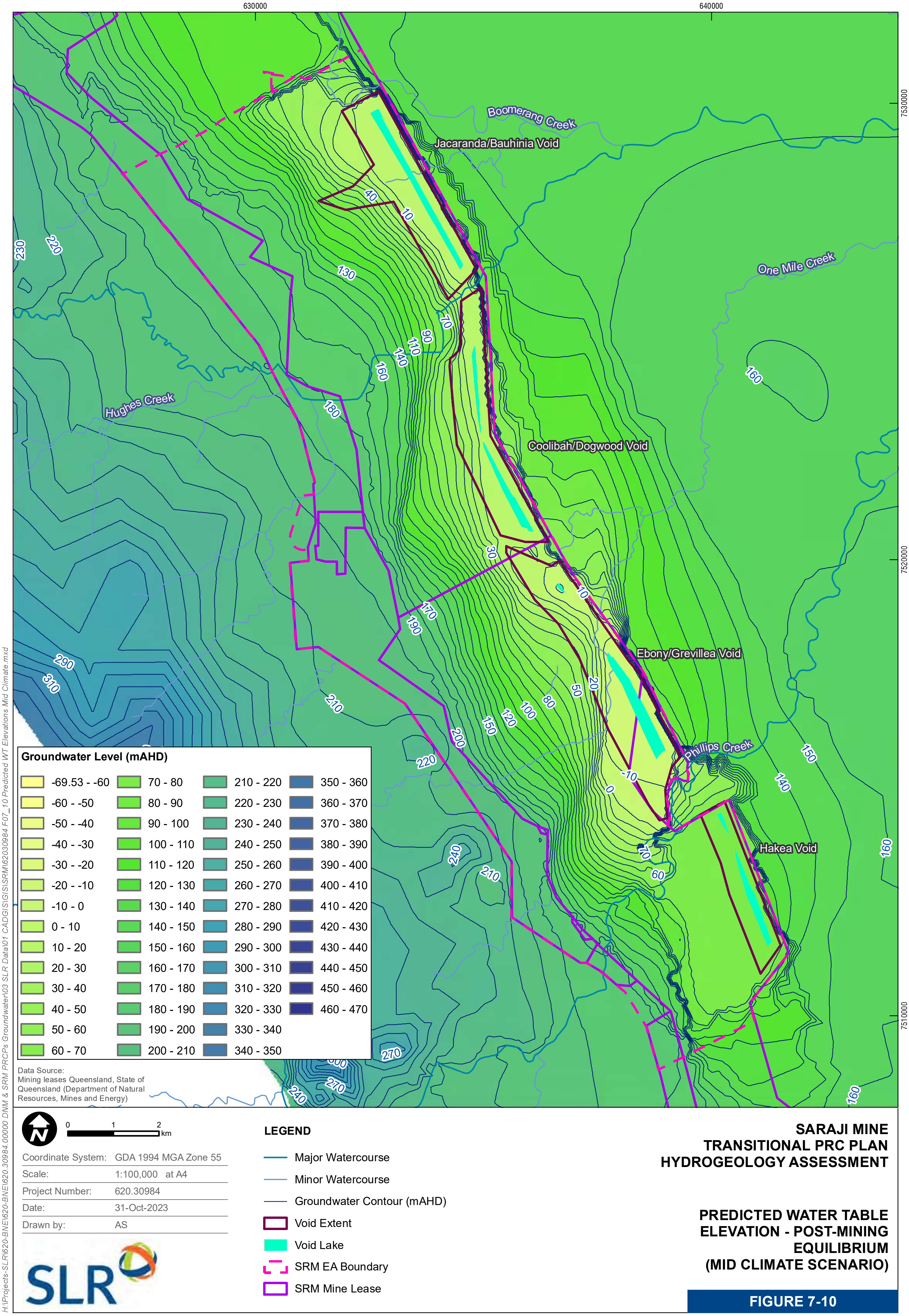


Figure 4.2 Predicted water table elevation at SRM – post-mining equilibrium (mid-climate scenario) (SLR, 2023a)

There are periods of variability in inflows and outflows of groundwater predicted by the groundwater model for the SRM residual voids in the first 50-years post-mining. Predicted groundwater inflows for the mid-climate scenario for SRM residual voids are shown on Figure 4.3 to Figure 4.6.

During this initial 50-year period, groundwater levels are recovering from mine dewatering activities and remain below the residual void lake levels, as predicted by the WBM (see Section 6). Over this time, modelled groundwater fluxes to the voids are largely controlled by the difference between the modelled residual void lake levels and predicted groundwater levels in the spoil. The void lake levels rise and fall periodically according to the climatic simulation applied to the WBM, as well as how the daily timestep water balance results are translated to the comparatively simplified stress periods set up in the groundwater model. As such, fluxes in groundwater inflows and outflows to the residual voids are predicted to occur over the following approximate time periods:

- Jacaranda/Bauhinia residual void: up to 16 years post-mining.
- Coolibah/Dogwood residual void: up to 33 years post-mining.
- Ebony/Grevillea residual void: up to 55 years post-mining.
- Hakea residual void: up to 95 years post-mining.

Model results indicate that over these initial periods, outflows derived from rainfall captured in the residual voids periodically flow to the in-pit spoil (typically the low-walls) surrounding the residual void lake. This occurs as the groundwater levels in the surrounding in-pit spoil landform (and natural geological formations) slowly recover from mining activities. However, as the groundwater levels in the surrounding in-pit spoil landform and natural geology recover to elevations above the void lakes and lake levels stabilise, the direction of flow out of the void lakes to the in-pit spoil is reversed and long-term groundwater inflow to the lakes is established. After these initial periods for the SRM residual voids, inflow only conditions prevail with most groundwater inflows to the residual voids occurring via in-pit spoil areas (SLR, 2023a).

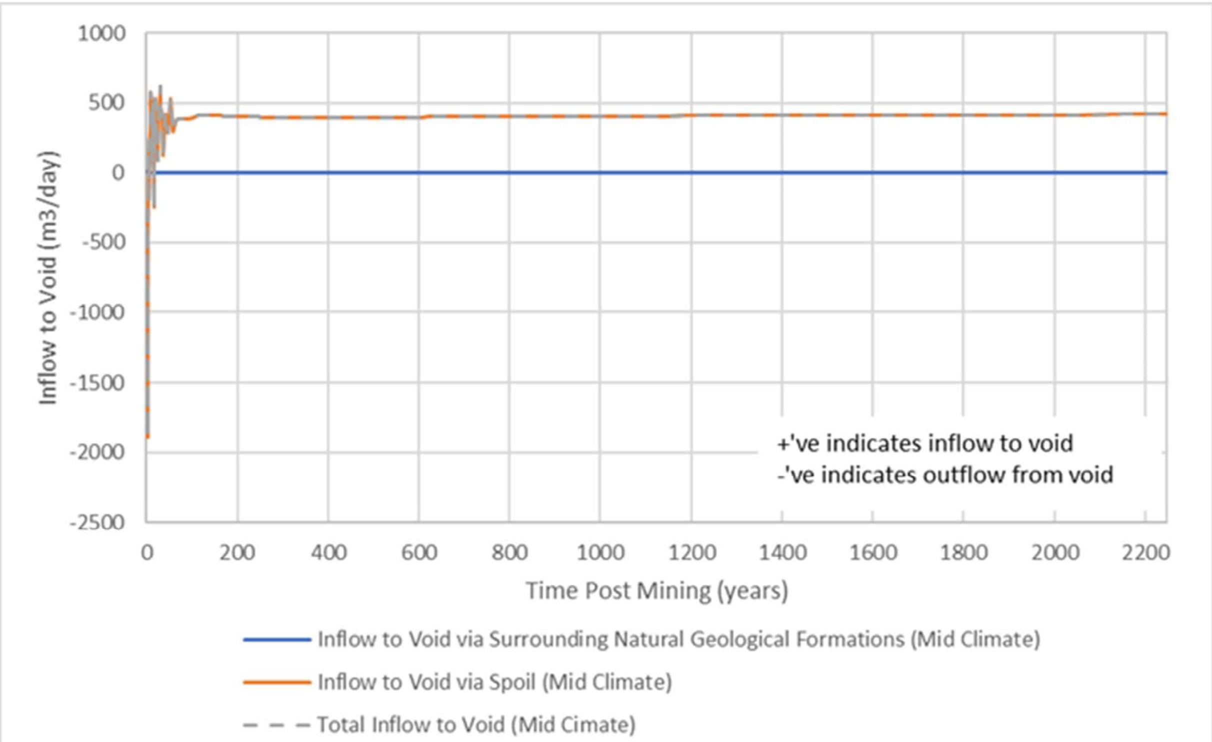


Figure 4.3 Predicted void groundwater inflows – Jacaranda/Bauhinia residual void (SLR, 2023a)

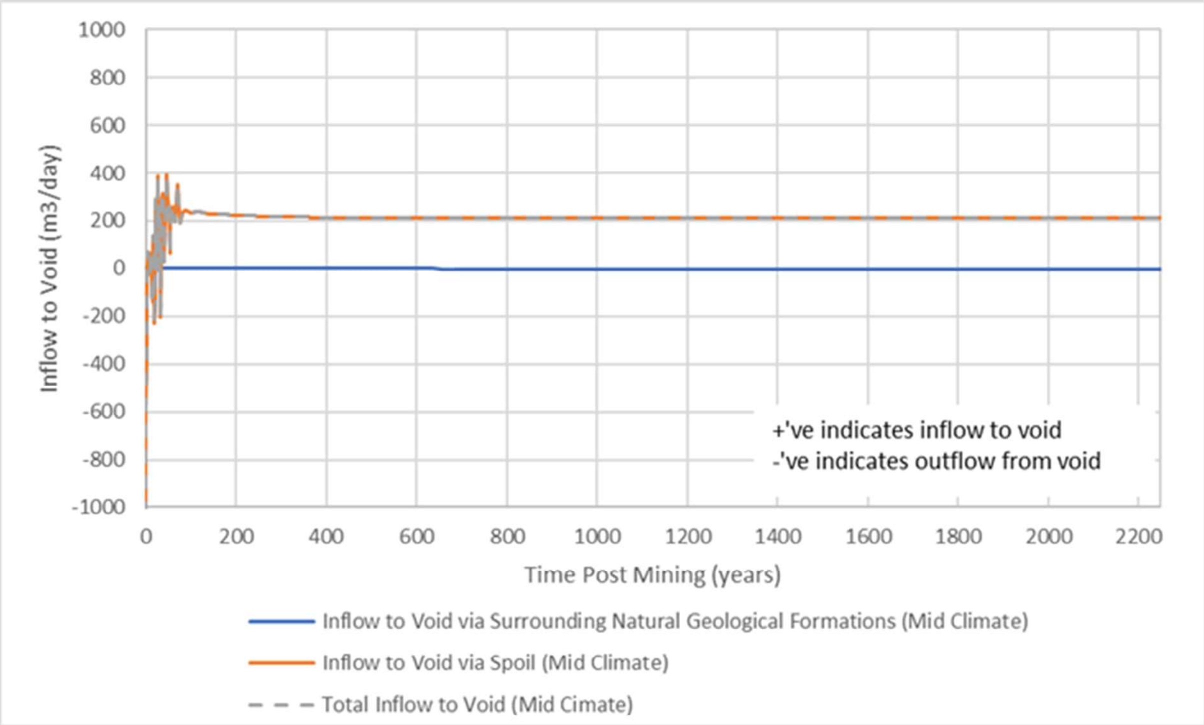


Figure 4.4 Predicted void groundwater inflows – Coolibah/Dogwood residual void (SLR, 2023a)

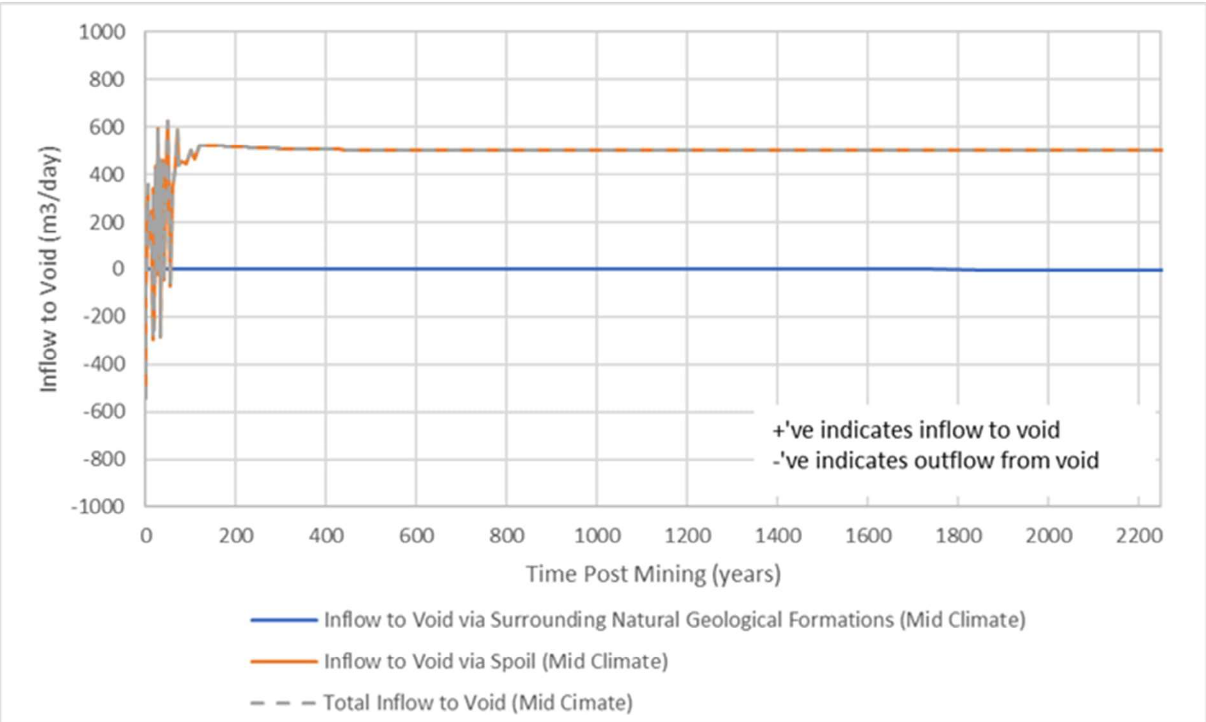


Figure 4.5 Predicted void groundwater inflows – Ebony/Grevillea residual void (SLR, 2023a)

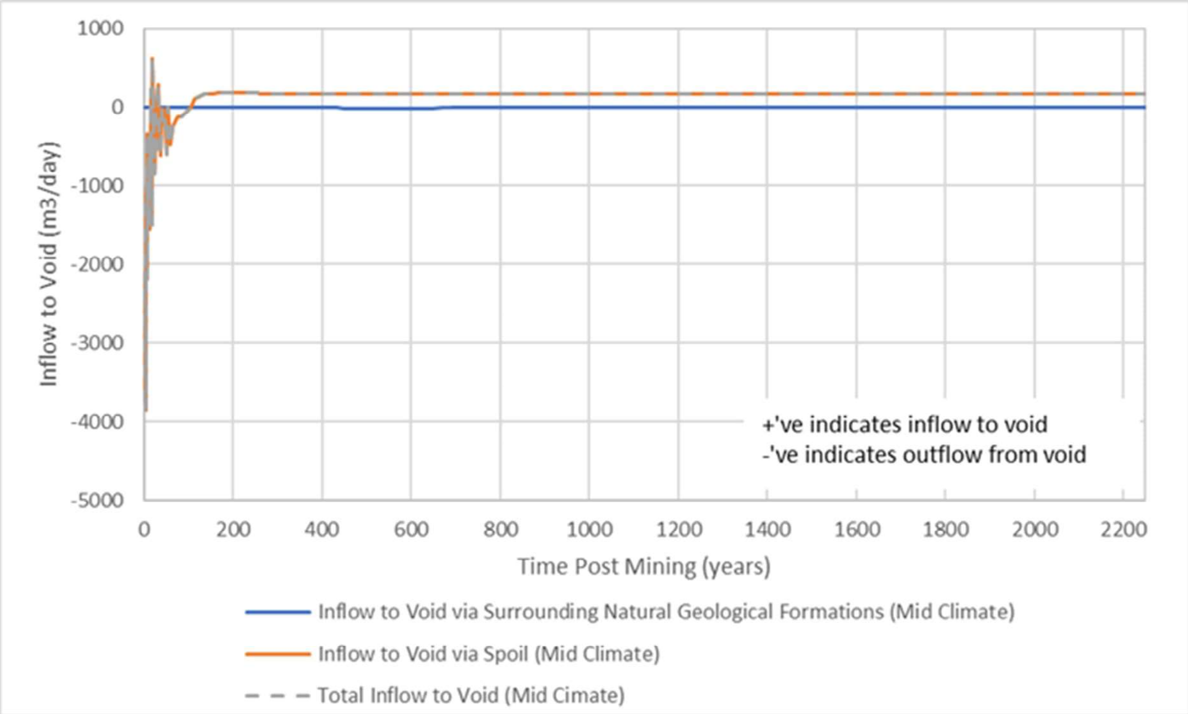


Figure 4.6 Predicted void groundwater inflows – Hakea residual void (SLR, 2023a)

Groundwater levels in the MCM are predicted to remain below pre-mining conditions in the long-term; however, post-mining drawdown is not expected to be greater than that predicted during the operational mining period. Predictive hydrographs for the MCM seams in areas adjacent to the residual voids show the change in groundwater levels over time (Figure 4.7 to Figure 4.11).

The hydrographs indicate the initial fluxes of groundwater inflows and outflows from the residual voids predicted to occur in the initial post-mining period have minimal effect on the groundwater levels in the adjacent MCM seams.

Predicted residual void lake levels remain below the predicted groundwater levels for the duration of the modelled period for Jacaranda/Bauhinia, Coolibah/Dogwood, and Ebony/Grevillea residual voids. This indicates a very low potential for outwards movement of void water to the MCM seams outside these residual voids.

It is anticipated that two individual lake areas will develop in the Hakea residual void due to differing void floor elevations. Therefore, two sets of predictive hydrographs were generated representing the north (Figure 4.10) and south (Figure 4.11) of the void. The predicted residual void lake levels remain below the predicted groundwater levels for the duration of the modelled period for the Q seam in the MCM, indicating very low potential for outwards movement of void water to this seam outside the residual void. The hydraulic gradient towards the Hakea residual void is reduced towards the northern end of the void compared to the southern end. As a result, the Hakea residual void lake levels at the northern end hydrograph location are predicted to recover to within approximately 0.5 m of the predicted recovered groundwater elevations for the MCM seams P, H, and D. Net inward hydraulic gradients are predicted to prevail in the long-term as supported by the potentiometric surfaces, and net flux over the post-mining period remains inwards for each void (SLR, 2023a).

Environmental receptors associated with the seams have not been identified, net flux over the post-mining simulation remains inwards for each void, i.e. any outwards flux in the first few years post-mining is recaptured by the voids in the long term post-mining. Furthermore, the deeper D Seam is not mined at Hakea Pit and therefore there is no mechanism for direct hydraulic connection of the Hakea residual void lake and the D seam, limiting the potential for water exchange (SLR, 2023a).

Water quality within the MCM is generally saline within the coal seams. Electrical conductivity of the groundwater within the H and D seams and the pH of the D seam of the MCM are above the Isaac River sub-basin water quality objectives for both shallow (<30 m) and deep (>30 m) groundwater (SLR, 2023a). Additionally, by the end of the simulation of the residual void water quality (see Section 8), the electrical conductivity for Hakea residual void lake does not exceed the EA upper trigger value and the pH returns to within the EA trigger value range. As such, any potential outflows to the MCM seams are considered to pose minimal risk to the environment if they were to occur.

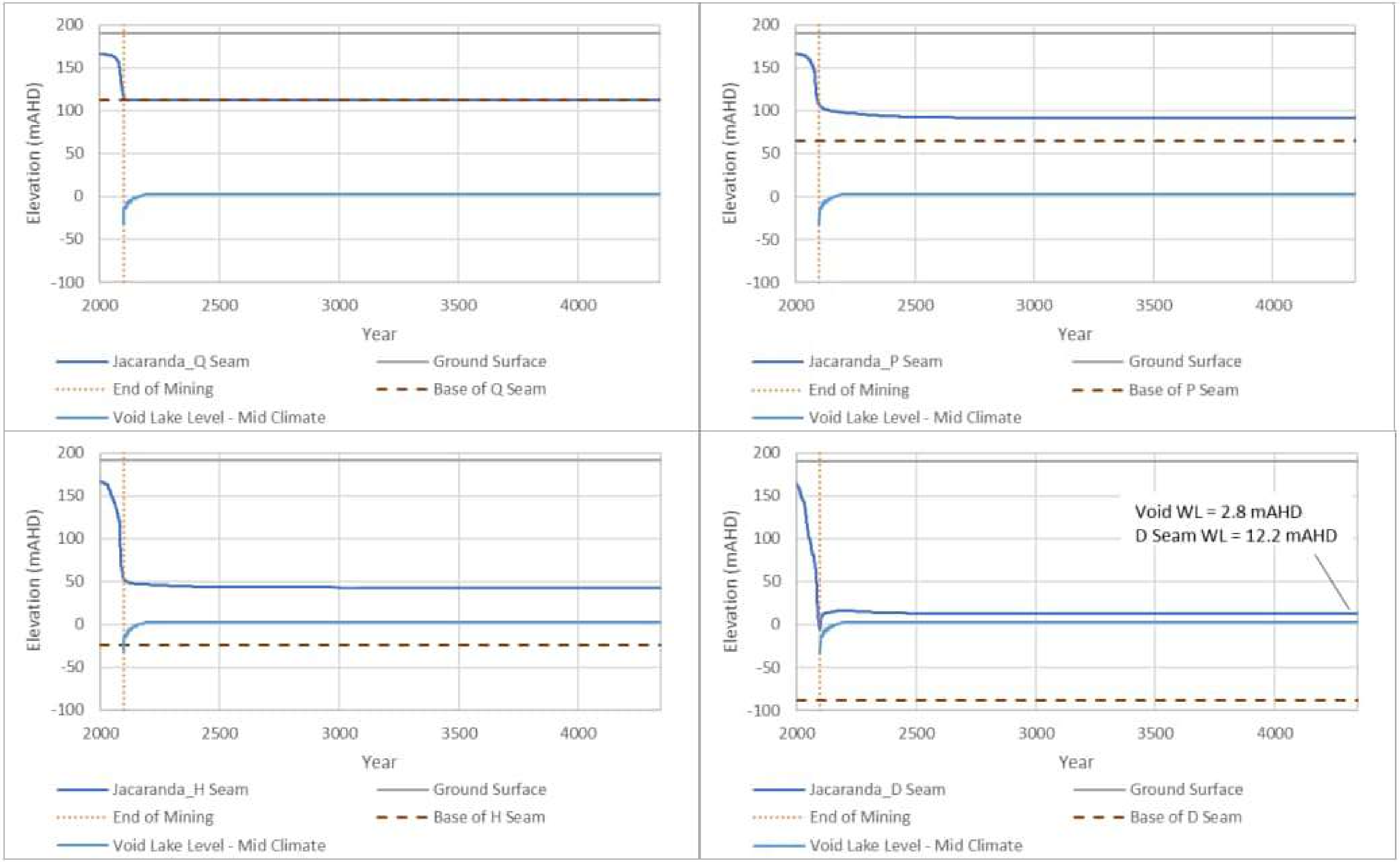


Figure 4.7 Predictive hydrographs for MCM seams adjacent to Jacaranda/Bauhinia residual void (SLR, 2023a)

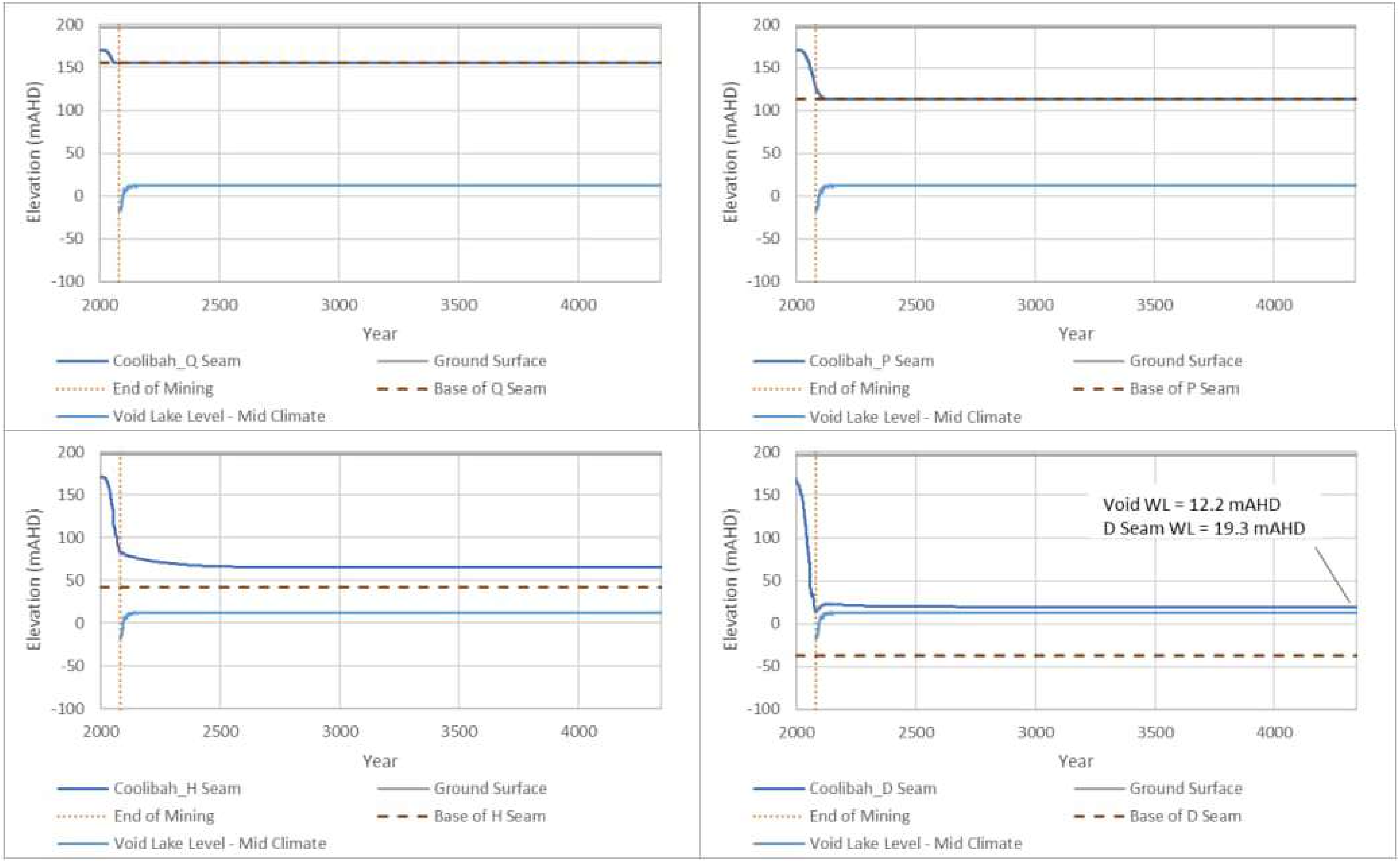


Figure 4.8 Predictive hydrographs for MCM seams adjacent Coolibah/Dogwood residual void (SLR, 2023a)

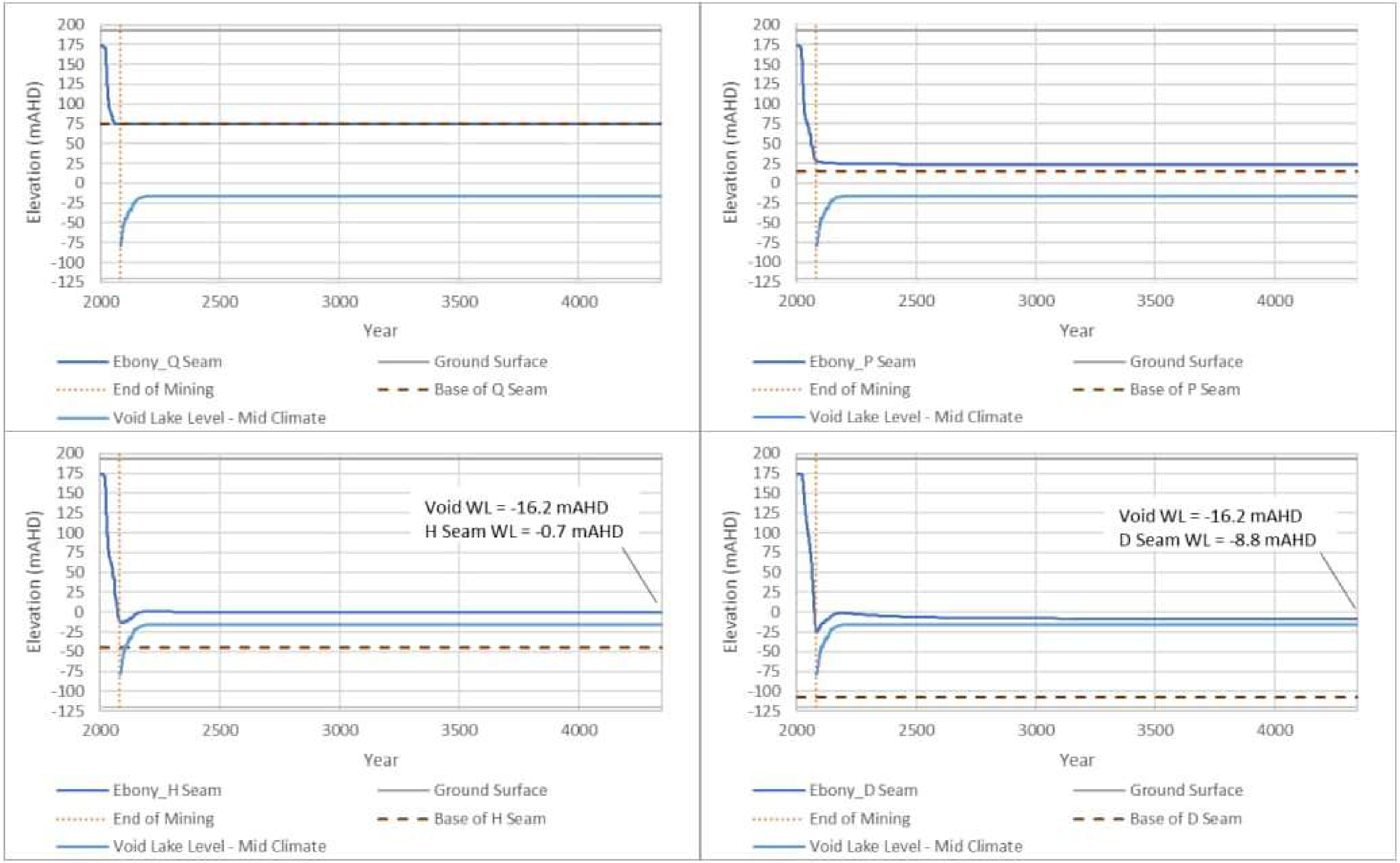


Figure 4.9 Predictive hydrographs for MCM seams adjacent Ebony/Grevillea residual void (SLR, 2023a)

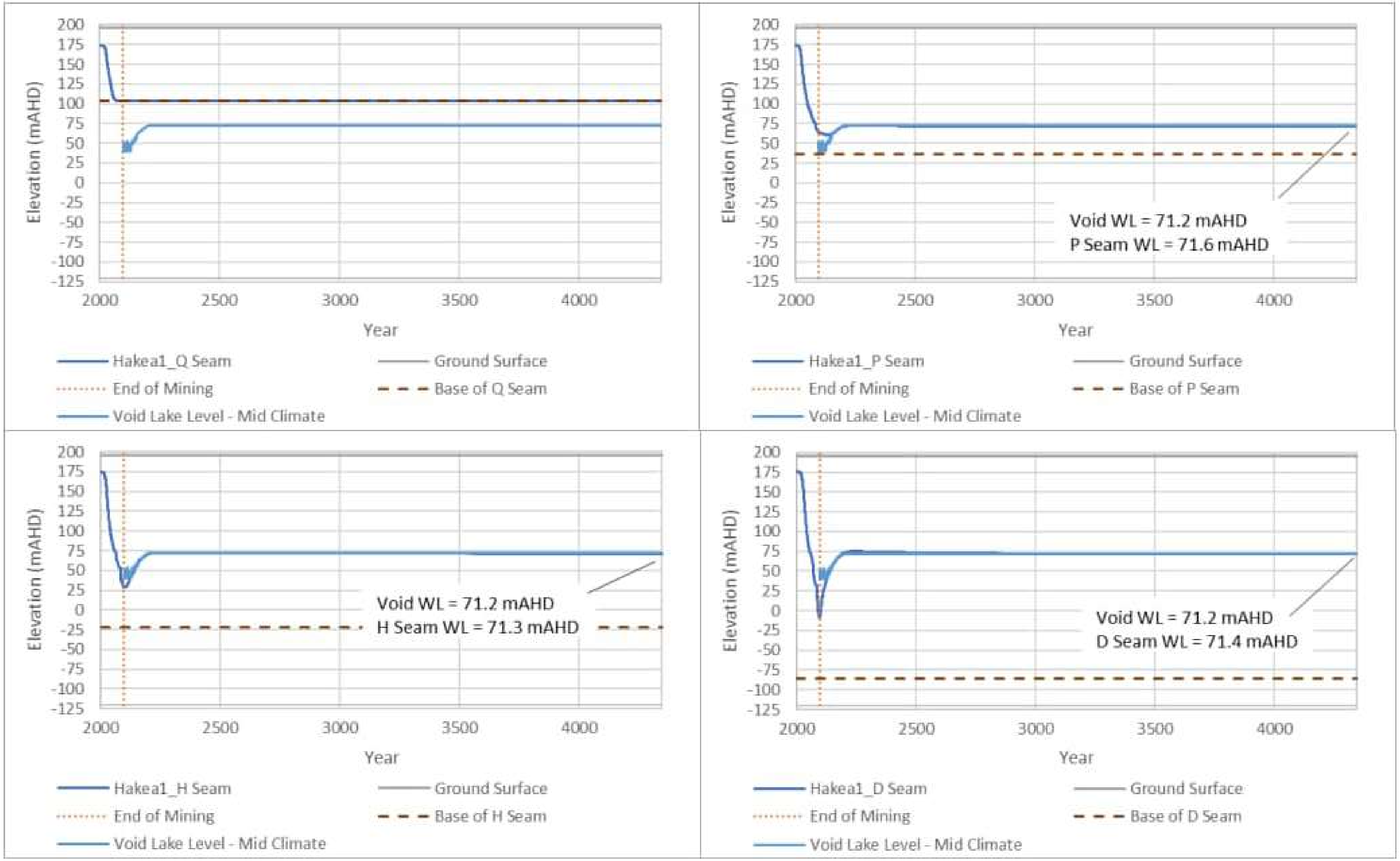


Figure 4.10 Predictive hydrographs for MCM seams adjacent Hakea residual void (north) (SLR, 2023a)

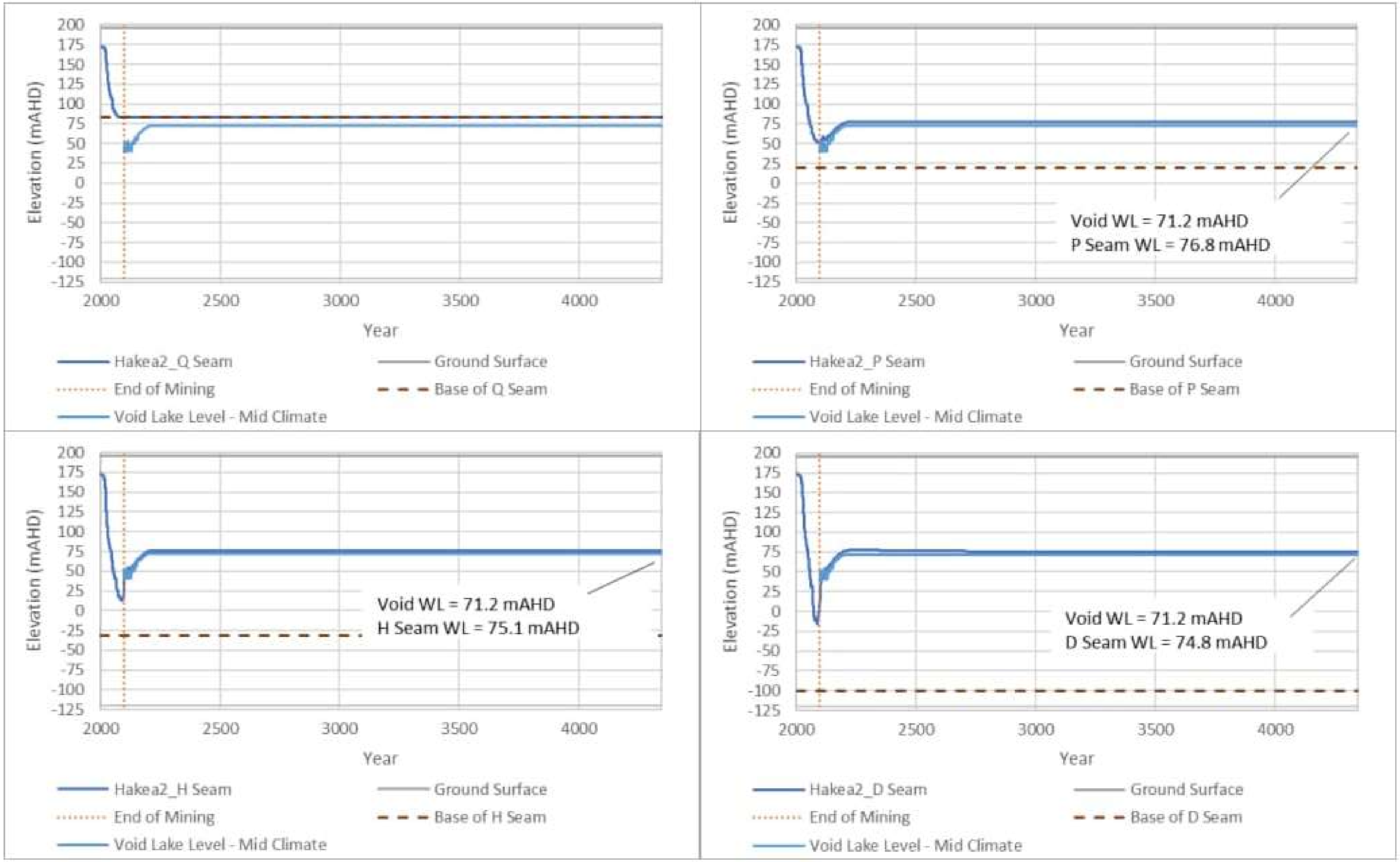


Figure 4.11 Predictive hydrographs for MCM seams adjacent Hakea residual void (south) (SLR, 2023a)

Using the numerical groundwater model and the 'mod-PATH3DU' code, an analysis of the water movement within the final closure state landform was completed to simulate and assess the movement and fate of water particles through the groundwater system post-mining (SLR, 2023a).

The particle movement simulation for particles placed within the residual voids (Figure 4.12) indicated that groundwater at SRM will remain within the final closure state landform (i.e., rehabilitated in-pit spoil and residual voids) in the long-term (SLR, 2023a). This included the modelled initial fluxes of water from the residual voids to the in-pit spoil of the final closure state landform. The simulation also predicted that all voids would remain groundwater sinks and the particles would not flow from the residual voids off-site to the receiving environment. The particles placed outside of the residual voids at the potential contaminant sources (MIA, TSF, CHPP) are all captured within the final closure state landform.

Although initial fluxes of rainfall derived water captured in the residual voids to the in-pit spoil is predicted to occur, no environmental harm is expected to result beyond that of the voids themselves from these minor fluctuations. This is due to the initial outflows to the in-pit spoil areas returning to the residual voids once groundwater levels and lake levels stabilise and net inward hydraulic gradients are predicted to prevail in the long-term. This is supported by the groundwater modelling, particle tracking, and the absence of third-party bores and GDEs within the spoil areas of the residual voids and the MCM seams that may interact with the void lake. The water quality model (see Section 8) also indicates that the water quality within the voids is unlikely to establish acidic conditions and the total dissolved solids have not yet evapoconcentrated beyond the lower EA groundwater trigger values during the period of potential outflows. Total dissolved solids concentrations are not predicted to exceed the upper EA groundwater trigger value for the void water quality modelled period.

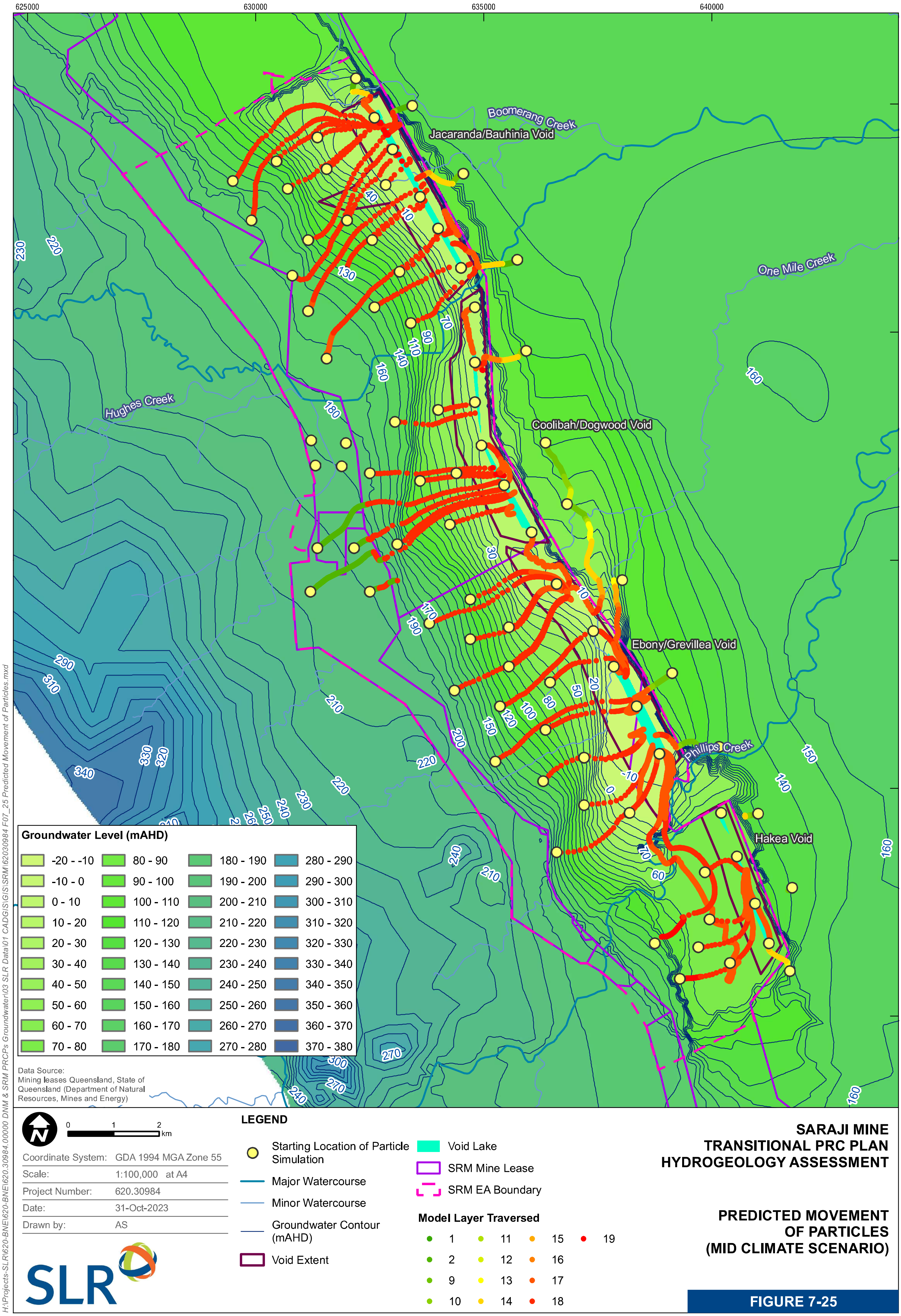


Figure 4.12 Predicted movement of particles from particle tracking – mid climate scenario (SLR, 2023a)

Predictive hydrographs, derived from the groundwater model, at the potential GDE sites identified in and adjacent to the SRM area (Figure 4.13) indicate that most water table drawdown in the vicinity of the potential GDEs is predicted to occur prior to the end of mining (i.e., associated with approved SRM mining operations), with comparatively little additional drawdown occurring over the post-mining period. Given the initial predicted depth to the water table exceeds 10 m, a depth that indicates the total plant groundwater use would be negligible, these GDEs are likely to be low potential. The hydrographs (Figure 4.14) suggest that the relatively small additional drawdown impacts that occur post-mining are residual impacts from approved previous active mining activities (i.e., a time lag from active mining), rather than new impacts caused by the final closure state landform design.

Predictive hydrographs at the potential GDE site associated with the One Mile Creek Dam, located in the west of the SRM area and adjacent to the mine infrastructure area (MIA), shows no drawdown either during mining or post-closure (Figure 4.14). Note there was no difference in the hydrographs for the drier or wetter climate scenarios.

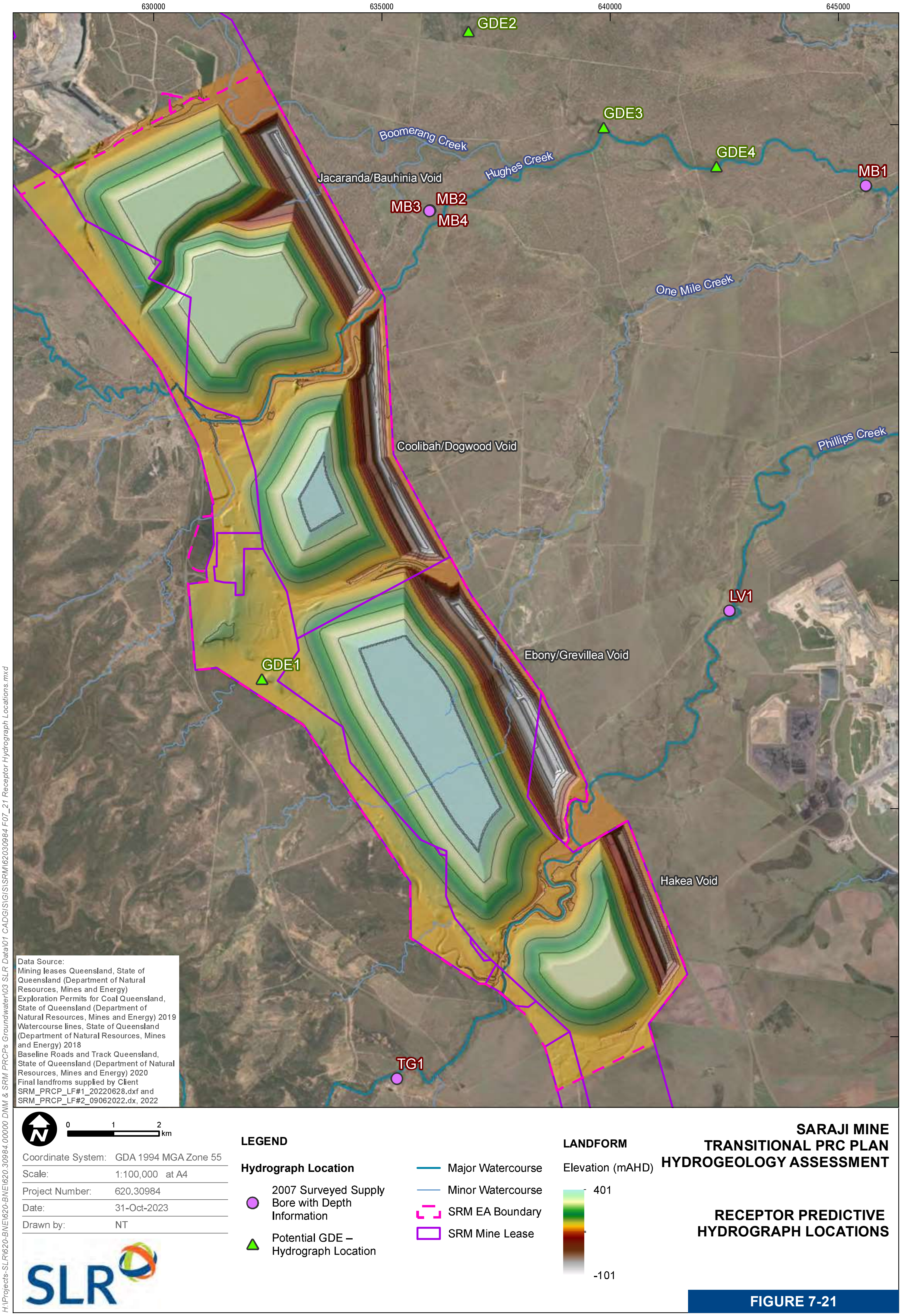


Figure 4.13 Predictive hydrograph locations of potential SRM receptors (SLR, 2023a)

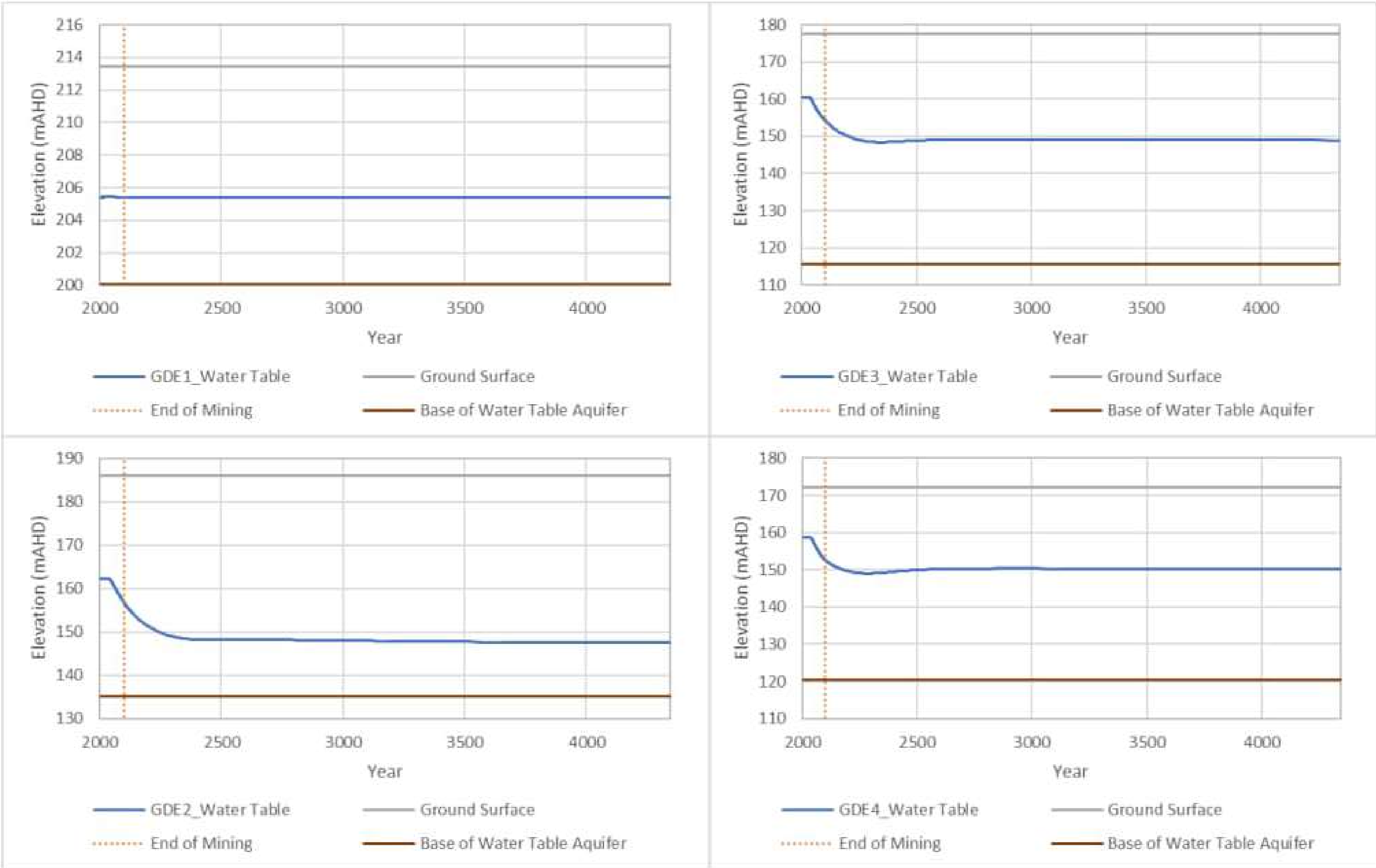


Figure 4.14 Predictive hydrographs for potential GDE sites (SLR, 2023a)

Predictive hydrographs were derived from the groundwater model for the six identified third-party water supply bores with sufficient information to attribute a source aquifer (Figure 4.13). These hydrographs show negligible post-mining groundwater drawdown at the bore located south-west of SRM in the regolith overlying the Back Creek Group. Only a relatively small drawdown (approximately 1 m) is predicted post-mining for the third-party water supply bore located in the Fort Cooper Coal Measures along Hughes Creek 9 km east of SRM.

Other third-party water supply bores located east of SRM in the Fort Cooper Coal Measures show the groundwater drawdown trends that commenced during SRM mining continue post-mining on the same trend. This drawdown trend reaches a maximum post-mining drawdown between about 130 and 500-years post-mining before commencing recovery, with no change in the trends observed between the mining and post-mining periods. These drawdowns are considered to be mostly related to mining activities as well as regional-scale influences represented in the model such as other third-party mining activities given these bores access groundwater from the Fort Cooper Coal Measures, a geological unit not present across the vast majority of the SRM area. Note that there was no difference in the hydrographs for the drier or wetter climate scenarios.

5 Flooding assessment

Residual void flooding assessments were completed to determine surface water interactions, and the drainage and flooding behaviour of surface water in the vicinity of Jacaranda/Bauhinia, Coolibah/Dogwood, Ebony/Grevillea, and Hakea residual voids. This section presents the assessment findings, as relevant to void closure at SRM.

5.1 Voids in floodplains

The locations of the pre-approved NUMAs that are the four SRM residual voids are not identified in the LOD (EA EPML00862313) and therefore, in accordance with the DES *PRC Plan Guideline* transitional provisions, an assessment of voids in flood plains was undertaken (SLR, 2022). As a conservative approach, the final void extents used for the voids in flood-plain assessment were the preliminary extents of the final voids – prior to any final landform design considerations and/or final void partial backfill that provides for flood protection.

The flood plain assessment of the *pre-mining landform* identified that the Bauhinia Pit would be located within the flood plains of Boomerang Creek and Hughes Creek. The remaining pits are located outside the flood plain in the 0.1% annual exceedance probability (AEP) event, except for fringe encroachments at the extents of the Coolibah Pit and Grevillea Pit. These pits encroach into the modelled flood plains for Boomerang Creek/Hughes Creek and Phillips Creek. For the final closure state landforms, the extents of the residual voids modelled in the voids in floodplain assessment have been reduced and refined following the relevant studies to reduce the environmental impact through partial backfill, placement of landforms and increasing residual void set-backs.

5.2 Closure state landform flooding

For the final closure state landform, rehabilitation flood modelling was undertaken on a range of design storm events for a range of AEPs including 0.1%, Probable Maximum Flood (PMF), and smaller events in accordance with the DES *PRC plan Guideline* to predict the flood event inundation extent and depths for post-mining conditions (WMS Engineering, 2022).

Hydrologic modelling estimated runoff hydrographs that informed the hydraulic modelling. The programs RORB and XP-Rafts were utilised for the hydrologic modelling, and the catchments of Hughes Creek, One Mile Creek, Phillips Creek, Boomerang Creek, and the southern drain were included. Five hydraulic models were developed, covering the five watercourses, to determine flood behaviour around the final closure state landforms associated with the residual voids.

Effects of climate change through the increase in rainfall intensity were considered in the hydrological analysis, with the upper climate change Representative Concentration Pathway (RCP) 8.5 at or above the 90th percentile scenario (RCP 8.5 P90) modelled as the upper rainfall for a 28% rainfall intensity increase. RCPs are projections of greenhouse gas and aerosol concentrations (pathways) and, together with land use change, are consistent with a set of broad climate outcomes adopted by the Intergovernmental Panel on Climate Change and used by the climate modelling community.

For the final closure state landform, the pits will be partially backfilled with spoil to reduce the extent of the final voids. Spoil dumping will be conducted so that the final residual voids of the NUMAs are not impacted by inundation from floodwaters up to and including the 0.1% AEP under the climate change RCP 8.5 P90 scenario. The results of the hydraulic model showed the proposed SRM residual voids are not subject to inundation from floodwaters for the modelled flood events (WMS Engineering, 2022). Figure 5.1 to Figure 5.5 show modelled peak flow depths for Phillips Creek, Hughes Creek, One Mile Creek, Boomerang Creek, and Southern Drain for the 0.1% AEP under the climate change RCP 8.5 P90 scenario.

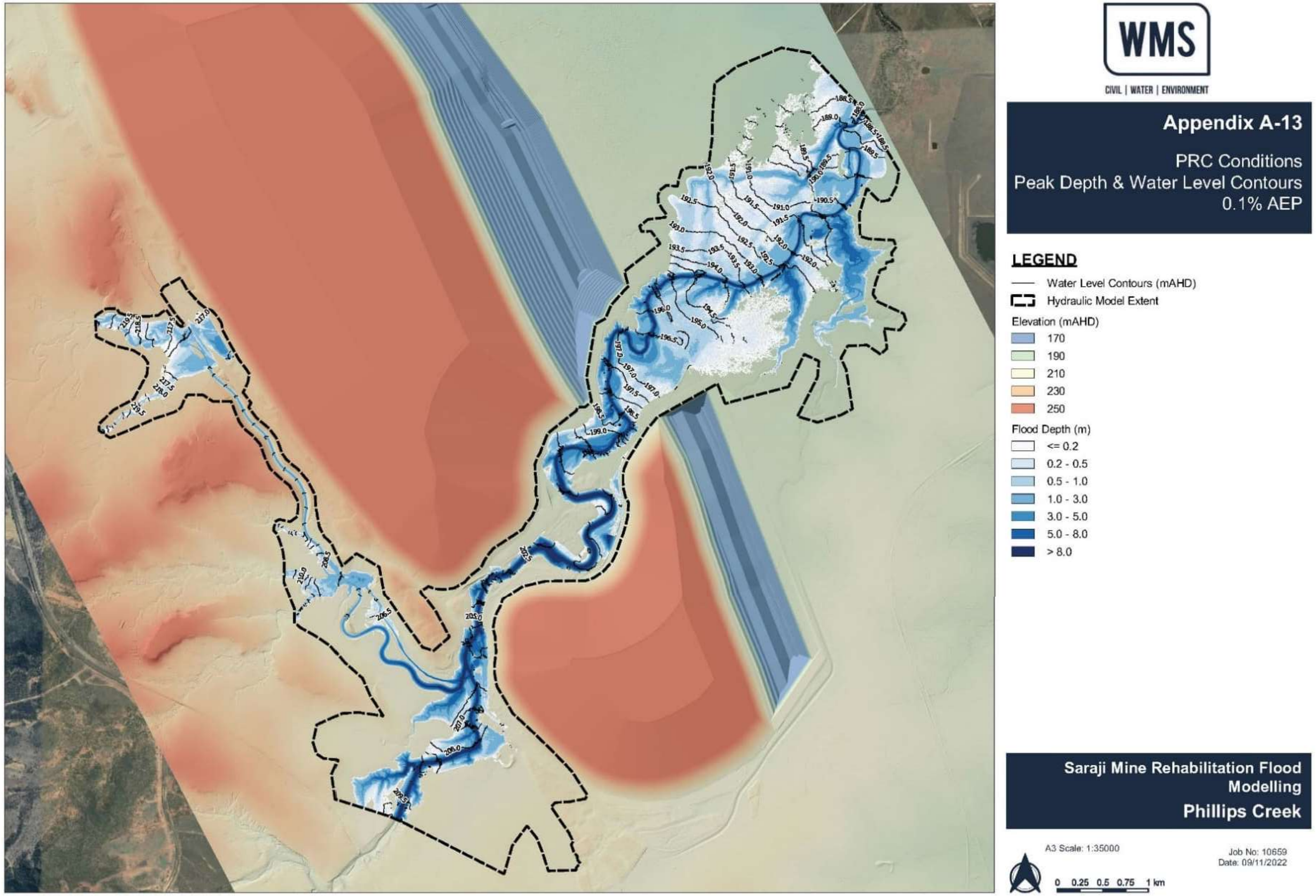


Figure 5.1 Modelled peak flood depths for Phillips Creek (0.1% AEP climate change RCP 8.5 P90 scenario) (WMS Engineering, 2022)

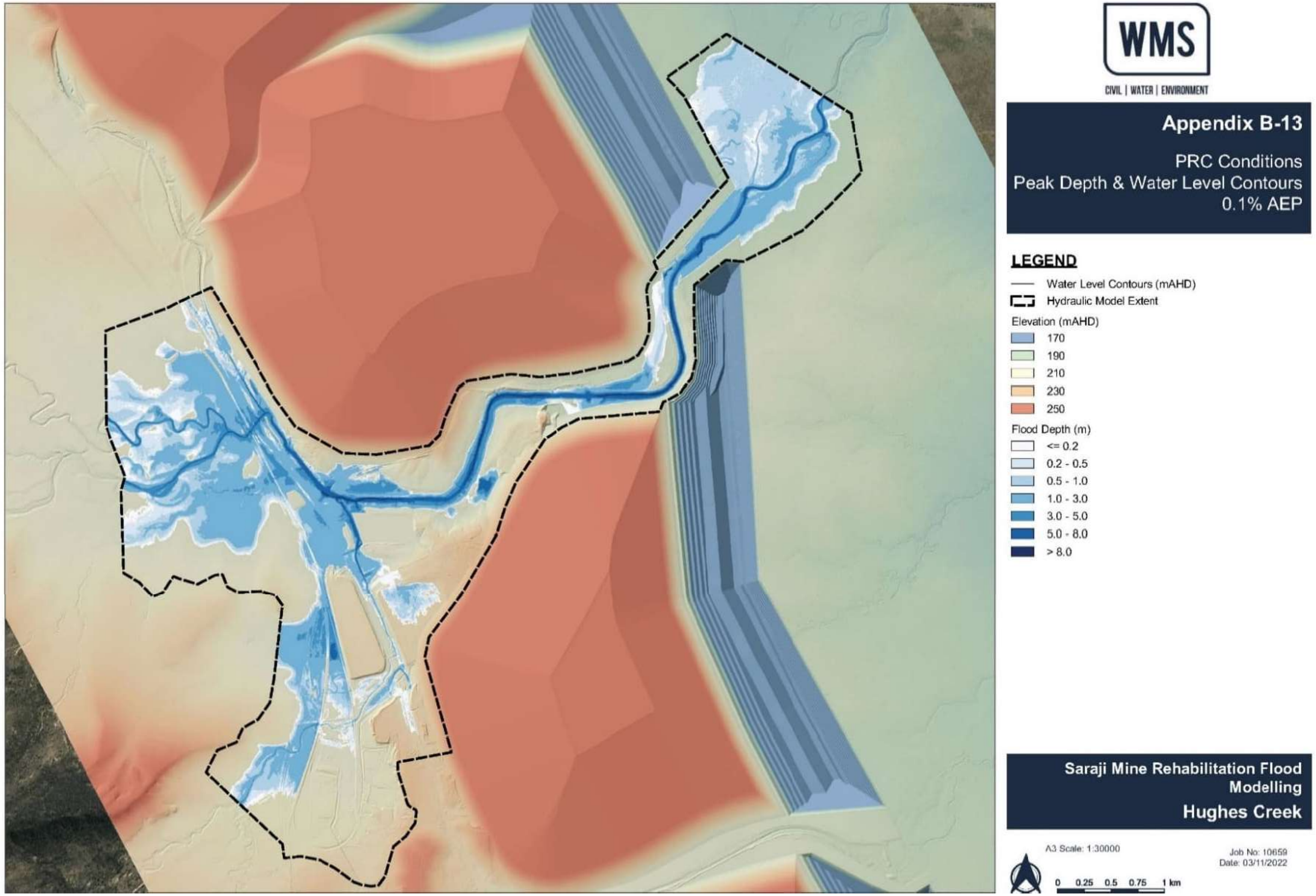


Figure 5.2 Modelled peak flood depths for Hughes Creek (0.1% AEP climate change RCP 8.5 P90 scenario) (WMS Engineering, 2022)

Figure 5.3 Modelled peak flood depths for One Mile Creek (0.1% AEP climate change RCP 8.5 P90 scenario) (WMS Engineering, 2022)

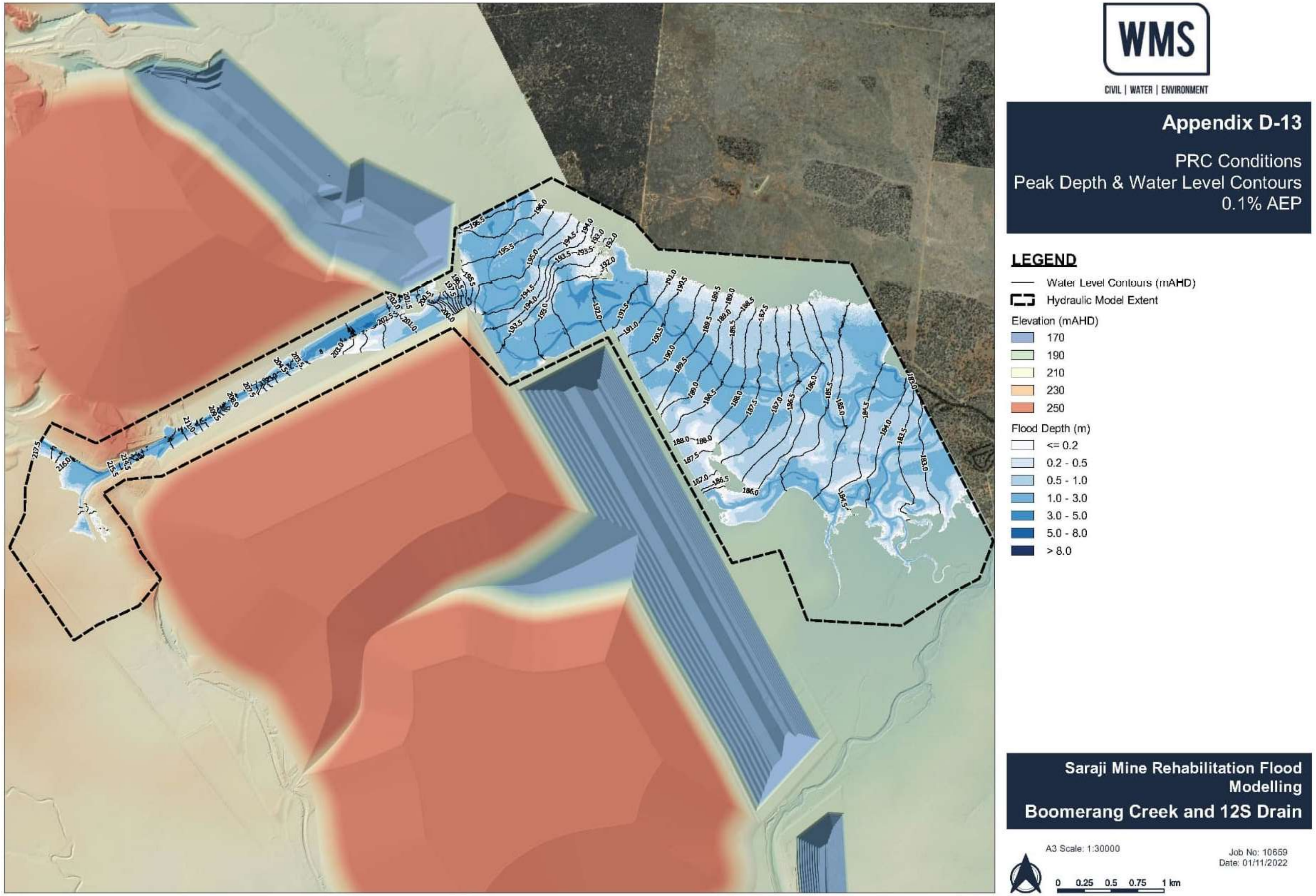


Figure 5.4 Modelled peak flood depths for Boomerang Creek (0.1% AEP climate change RCP 8.5 P90 scenario) (WMS Engineering, 2022)

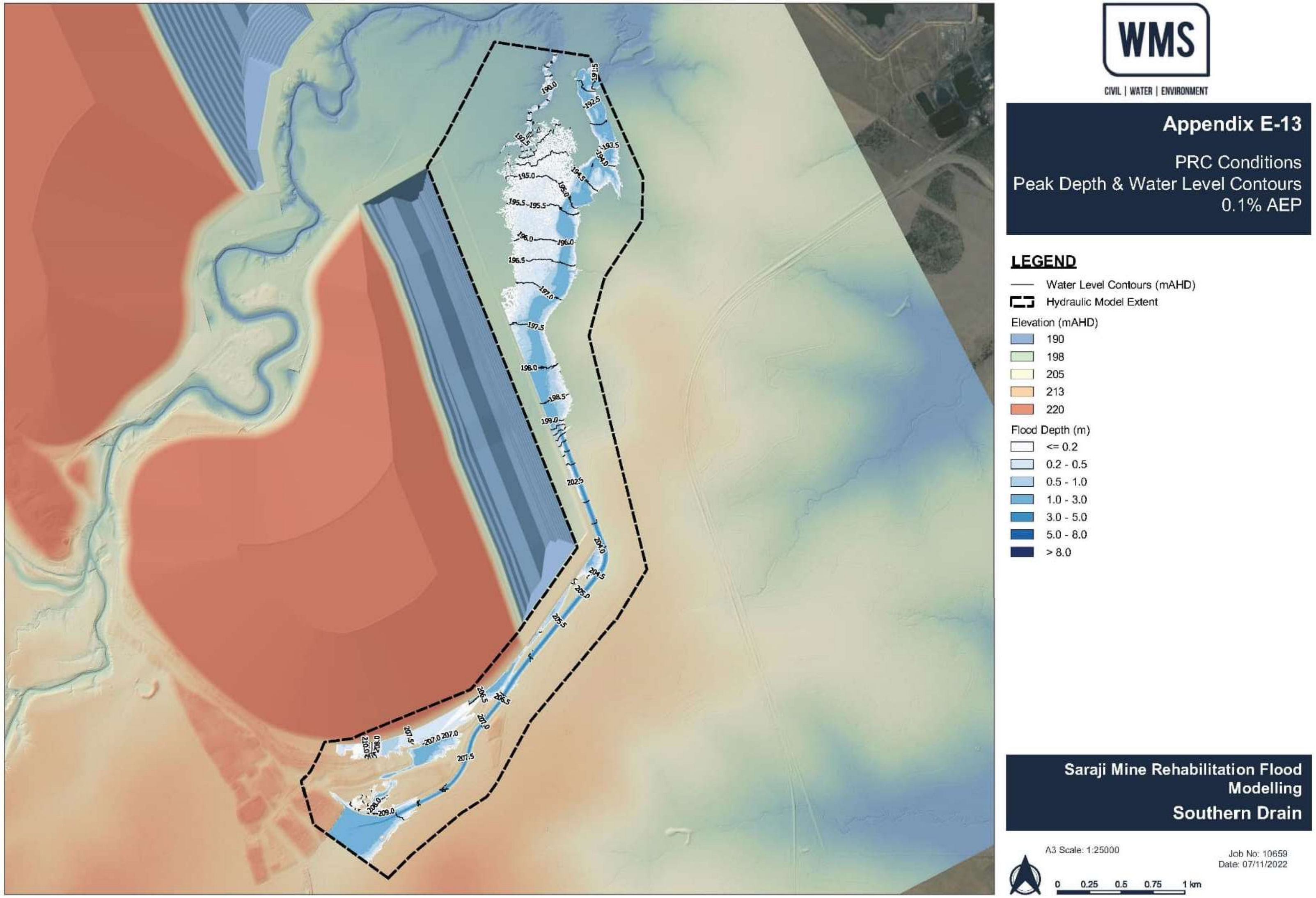


Figure 5.5 Modelled peak flood depths for Southern Drain (0.1% AEP climate change RCP 8.5 P90 scenario) (WMS Engineering, 2022)

There are several locations across SRM where floodwaters make contact with the landforms; however, as these locations are at the edge of the floodplain, the velocities and stream power are generally low.

A flood risk profile was developed based on the hydrologic and hydraulic model results, using the framework provided in BHP's Risk Management Guideline. The flood risk profile outcome was that the risk in terms of Maximum Foreseeable Loss was rated below four and therefore no control measures are required to be identified (WMS Engineering, 2022).

6 Void water balance

A void water balance assessment was completed to determine the behaviour of the SRM residual voids in their closure state. The assessment also sought to understand the inherent hydrological closure risks and to inform separate assessments relating to geotechnical and geochemical stability of the voids over time (findings from these separate assessments are presented in Section 7 and Section 8 respectively). Findings from the void water balance assessment, where relevant to void closure at SRM, are presented below.

6.1 Water balance model

A WBM was developed using the software program GoldSim to estimate the changes in the volume of water in the final closure state landforms over time in response to water inflows and outflows. The WBM adds the possible inflows and calculates the possible outflows for every step of the duration over the modelled period. The WBM for the SRM residual voids incorporated direct rainfall, surface water runoff, groundwater interactions, and evaporation.

A model period of 120 years – from the year 2080 to 2199, with a daily time-step was selected. The Hakea void simulation period was extended by 50 years (2080 to 2259 – 180 years) to allow the void to reach a state of equilibrium. No operational processes (i.e., pumping or transfers to/from the assessed structures) were considered active for the period modelled.

6.1.1 Catchment areas

The conceptual final closure state landform for the SRM residual voids was used to generate contour lines and calculate the drainage network of the area. The catchment subdivision of each void was estimated by analysing a slope map, generated using the software, QGIS. This slope map recognises zones with 'flat' slopes and zones with downward slopes. This information was then used to delimitate the void catchment areas into three areas: natural, void, and rehabilitated. The 'natural' area was assigned as the area that will remain undisturbed, while comparing the proposed residual voids' landform and the current topography of the area. The 'void' area (represented as 'pit' in Figure 6.1) was assigned as the area of the residual void itself at the spill level. Finally, the 'rehabilitated' area represents the remaining catchment area of each residual void. The delimitation of each of the areas is presented in Figure 6.1 and Table 6.1.

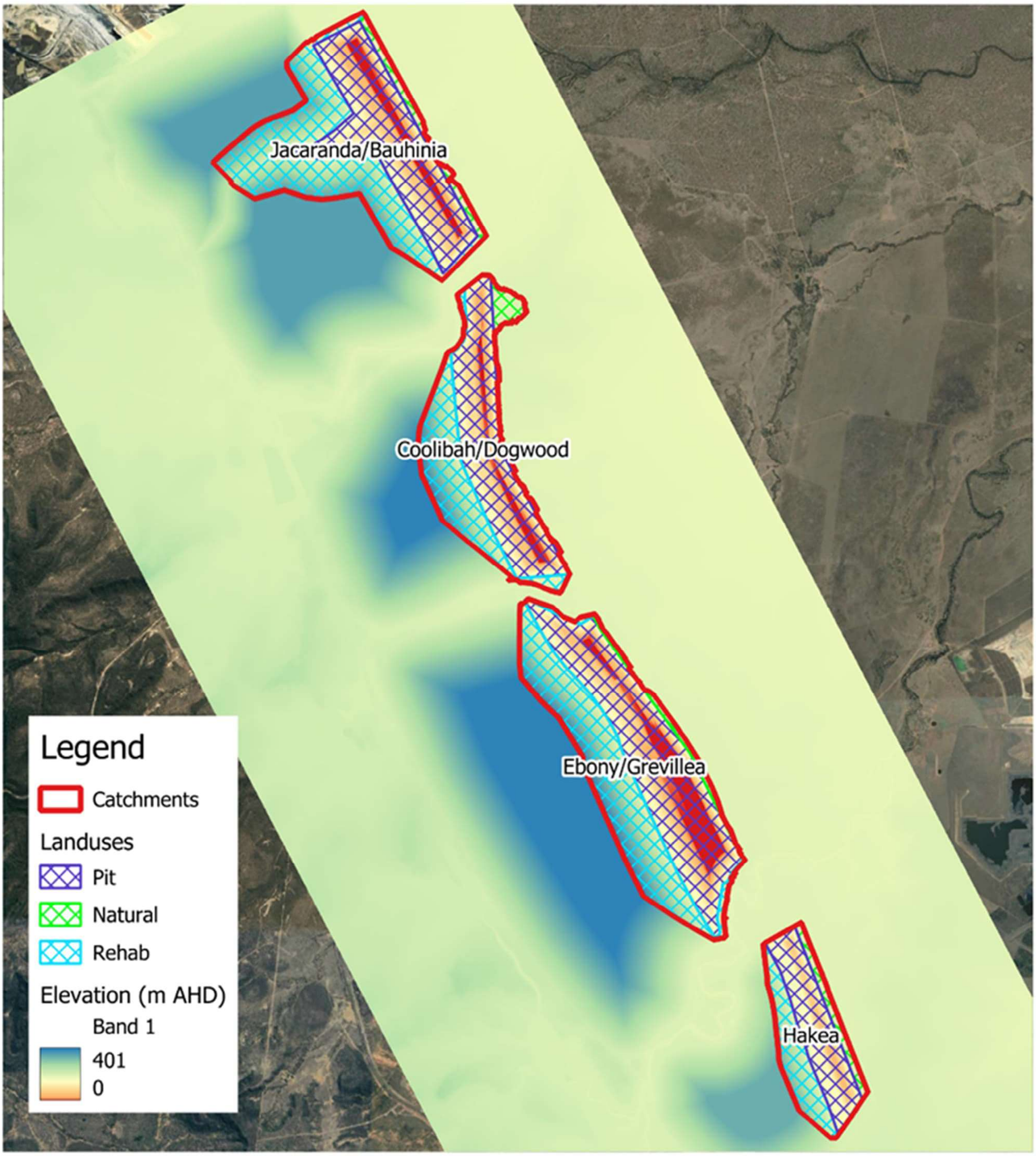


Figure 6.1 Catchment delimitation applied to the WBM for the SRM residual voids

Table 6.1 Catchment areas for the SRM residual voids

Surface catchment	Jacaranda/Bauhinia (ha)	Coolibah/Dogwood (ha)	Ebony/Grevillea (ha)	Hakea (ha)
Natural	48	42	26	43
Rehabilitated	473	228	412	129
Void	416	374	542	189
Total	**937**	**644**	**980**	**361**

The final closure state landform was analysed to determine the spill elevation of each of the voids and is presented in Table 6.2.

Table 6.2 Spill elevation for the SRM residual voids

Void	Jacaranda/ Bauhinia	Coolibah/Dogwood	Ebony/Grevillea	Hakea
Spill elevation (m AHD)	183	192	192	195

Stage-storage relationships were derived from the closure state landform to obtain the relationship between lake elevation and volume/surface of the lake, as shown in Figure 6.2 to Figure 6.5. These relationships were used in the WBM to estimate the lake surface area and elevation based on the lake volume for each modelled time-step.

The residual voids were initially assumed to begin at a zero level, implying that they were considered empty at the cessation of mining and hence the start of the simulations.

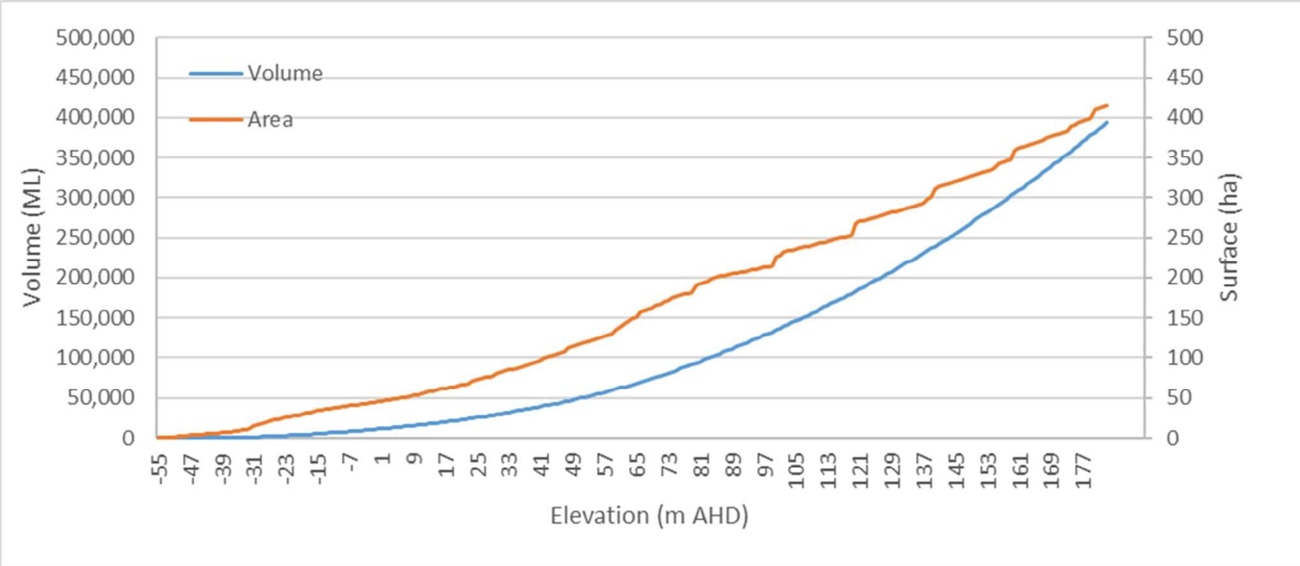


Figure 6.2 Jacaranda/Bauhinia residual void stage-storage relationship

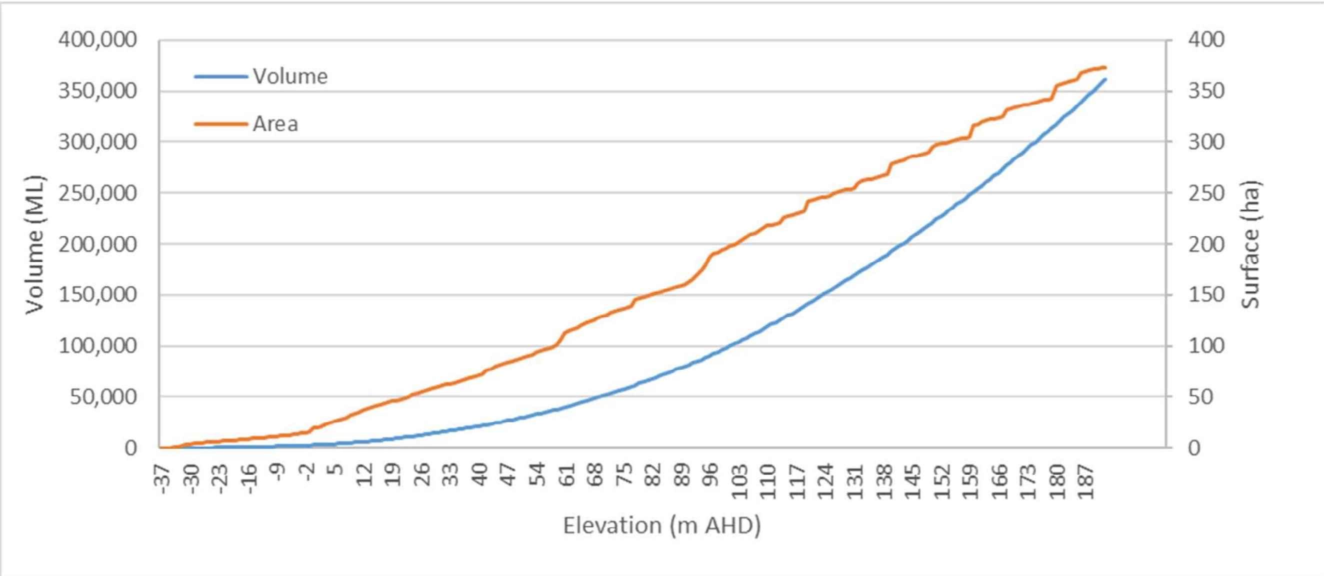


Figure 6.3 Coolibah/Dogwood residual void stage-storage relationship

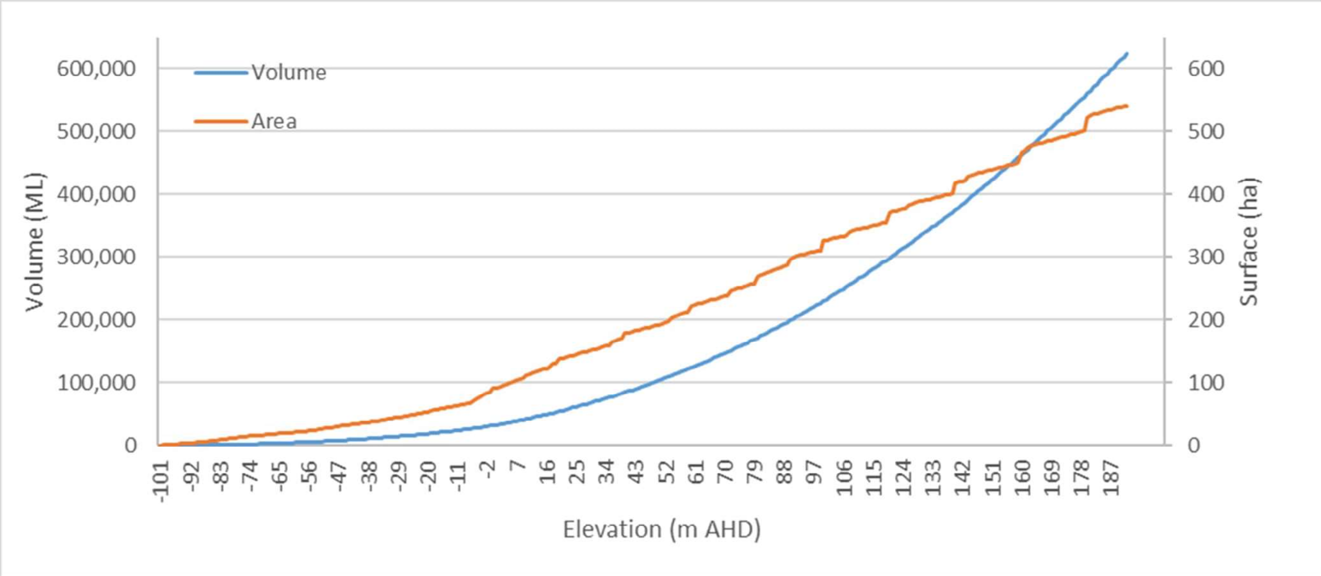


Figure 6.4 Ebony/Grevillea residual void stage-storage relationship

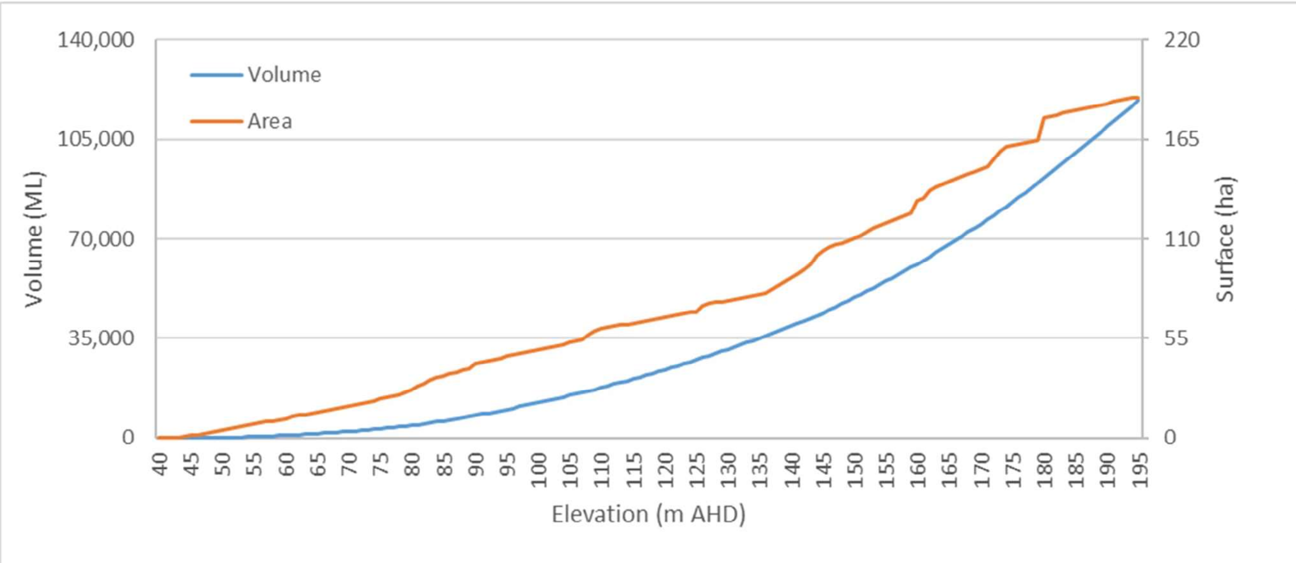


Figure 6.5 Hakea residual void stage-storage relationship

6.1.2 Rainfall, evaporation, and surface runoff

The amount of surface water runoff resulting from rainfall was calculated using the Australian Water Balance Model (AWBM), a catchment WBM that relates daily rainfall and evapotranspiration to runoff and calculates losses from rainfall for flood hydrograph modelling.

The projected evaporation and rainfall data (BMA, 2022) was applied to the AWBM to determine the surface runoff that should be input into the WBM. The AWBM contained five storages:

— Three surface storages to simulate partial areas of runoff

— One base flow storage

— One surface runoff routing storage.

The three surface storages have different capacities (small, medium, and large) for each catchment area, as shown in Figure 6.6 and presented in Table 6.3. Each capacity is added together with fractional areas for weights, which are summarised in Table 6.4.

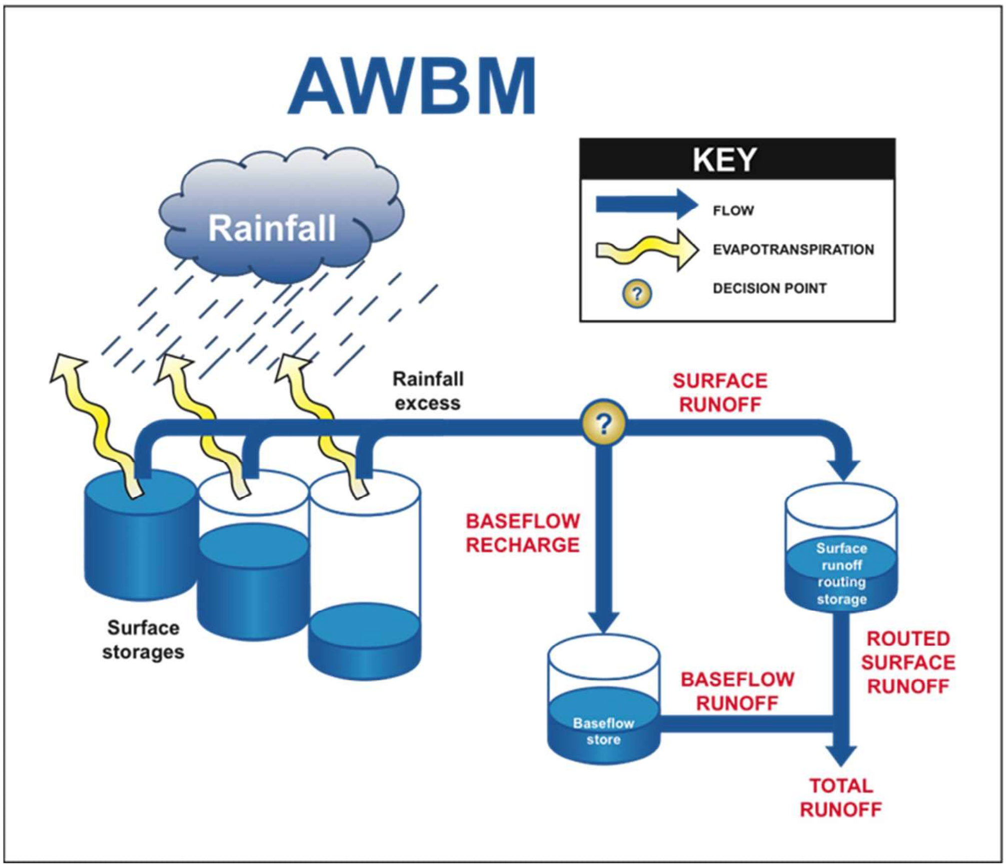


Figure 6.6 Structure of AWBM rainfall-runoff model including small, medium, and large surface storages

Table 6.3 Surface storage capacities (BMA, 2022) applied to the water balance model for SRM

Land use	Small (mm)	Medium (mm)	Large (mm)
Natural	7	120	142
Void	5	20	35
Rehabilitated	10	100	140

Table 6.4 Surface storage proportions (BMA, 2022) applied to the water balance model for SRM

Land use	Small	Medium	Large
Natural	0.134	0.433	0.433
Void	0.134	0.433	0.433
Rehabilitated	0.134	0.433	0.433

Table 6.5 presents the remaining AWBM parameters (baseflow index, channel coefficient, and baseflow coefficient). Surface water runoff considers flows as daily averages and do not include effects of high intensity and short duration events.

Table 6.5 Baseflow and channel parameters (BMA, 2022)

Area	Baseflow index	Channel coefficient (1/day)	Baseflow coefficient (1/day)
Natural	0.35	0.1	0.7
Void	0.1	0.1	0.7
Rehabilitated	0.35	0.1	0.7

6.1.3 Climate change considerations

To reasonably represent future climate conditions in the WBM assessment, climate change data was used from the projections of different climate models (Access 1-0Q and MPI-ESM-LRQ). The climate model Access 1-0Q was evaluated under two RCP's (4.5 and 8.5) while MPI-ESM-LRQ was evaluated under RCP 8.5.

Simulations were completed for three climate realisations. These realisations were selected to represent a reasonable range of probable climate scenarios based on the climate models used, being the maximum (R6), middle (R4) and the minimum (R1) ranges. This provides a reasonable potential range of climate impacts for each void. A summary of the combined pathways and models considered in each realisation (R#) of the WBM is presented in Table 6.6.

Table 6.6 Climate change scenarios considered in each realisation of the SRM WBM

Realisation	Climate model	RCP
R1	ACCESS1-0Q	4.5
R4	ACCESS1-0Q	8.5
R6	MPI-ESM-LRQ	8.5

To cover the WBM simulation period of 120 years, the climate projections were applied from 2080 until 31 December 2199. For Hakea void, the WBM simulation was extended and covers a period of 180 years, from 2080 to 31 December 2259. As the climate projections data only cover the interval from 2020 to 2099, the period between January 2080 to December 2099 was repeated to act as the projected rainfall conditions beyond 2099. This methodology is summarised in Table 6.7.

Table 6.7 Rainfall data used for each simulated period in the SRM WBM

Simulated period	Data used	
	From	To
01-01-2080 to 31-12-2099	01-01-2080	31-12-2099
01-01-2100 to 31-12-2119	01-01-2080	31-12-2099
01-01-2120 to 31-12-2139	01-01-2080	31-12-2099
01-01-2140 to 31-12-2159	01-01-2080	31-12-2099
01-01-2160 to 31-12-2179	01-01-2080	31-12-2099
01-01-2180 to 31-12-2199	01-01-2080	31-12-2099

The annual mean rainfall data from 2080 to 2099 was calculated and is presented in Figure 6.7.

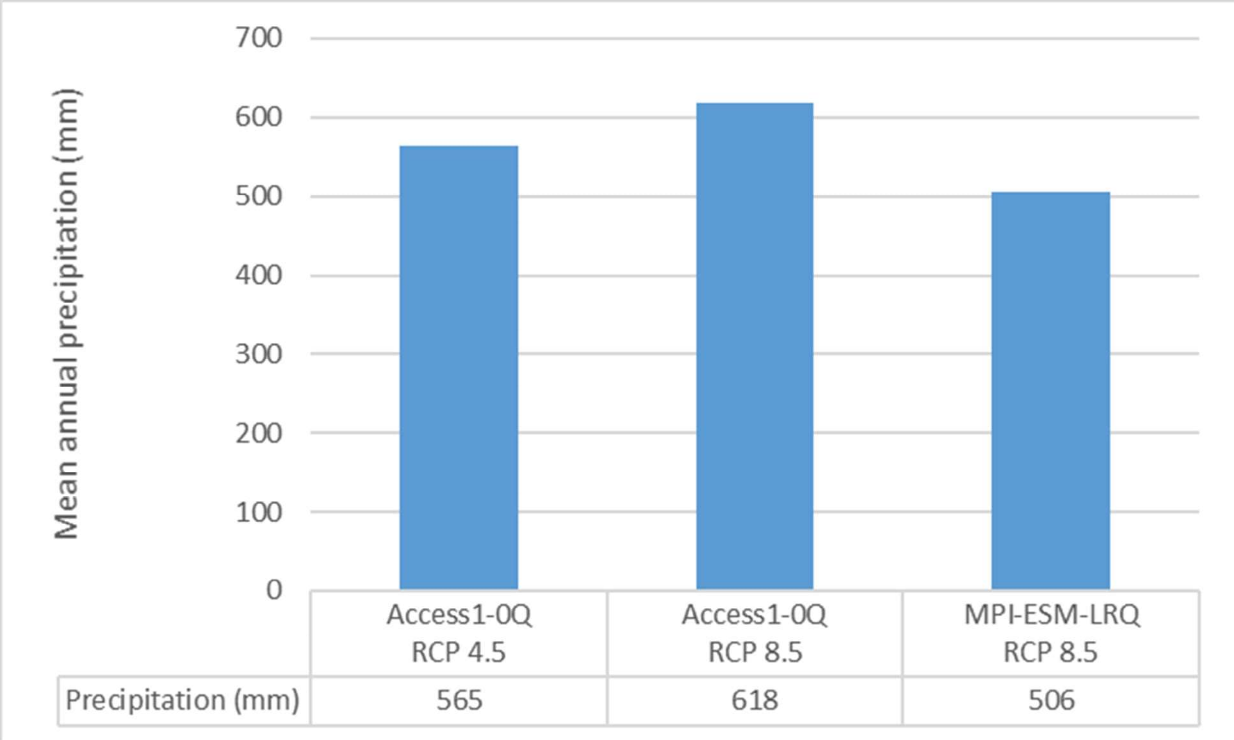


Figure 6.7 Annual mean rainfall for the period from 2080 to 2099 for (left to right) R1, R4, and R6 applied to the SRM residual voids WBM

The future increase in evaporation was estimated considering:

— Projected period between 2080 and 2099

— Reference period between 1986 to 2005.

The result is a value showing the annual increase in evaporation for each climate change scenario. This factor was applied to the monthly values for evaporation. These factors are presented in Table 6.8.

Table 6.8 Percentage increase of evaporation considered for each realisation from 2080 to 2099

Aspect	R1	R4	R6
Mean evaporation 1986-2005 (mm/yr)	1,594	1,597	1,616
Mean evaporation 2080-2099 (mm/yr)	1,818	2,044	2,087
Increase in average evaporation (%)	14	28.0	29.2

6.1.4 Groundwater inflows

Groundwater inflows to each of the residual voids post-closure were simulated using the numerical groundwater model, and time-series data (SLR, 2023a). The modelled groundwater inflow rates used as inputs to the WBM are presented in Figure 6.8 to Figure 6.11.

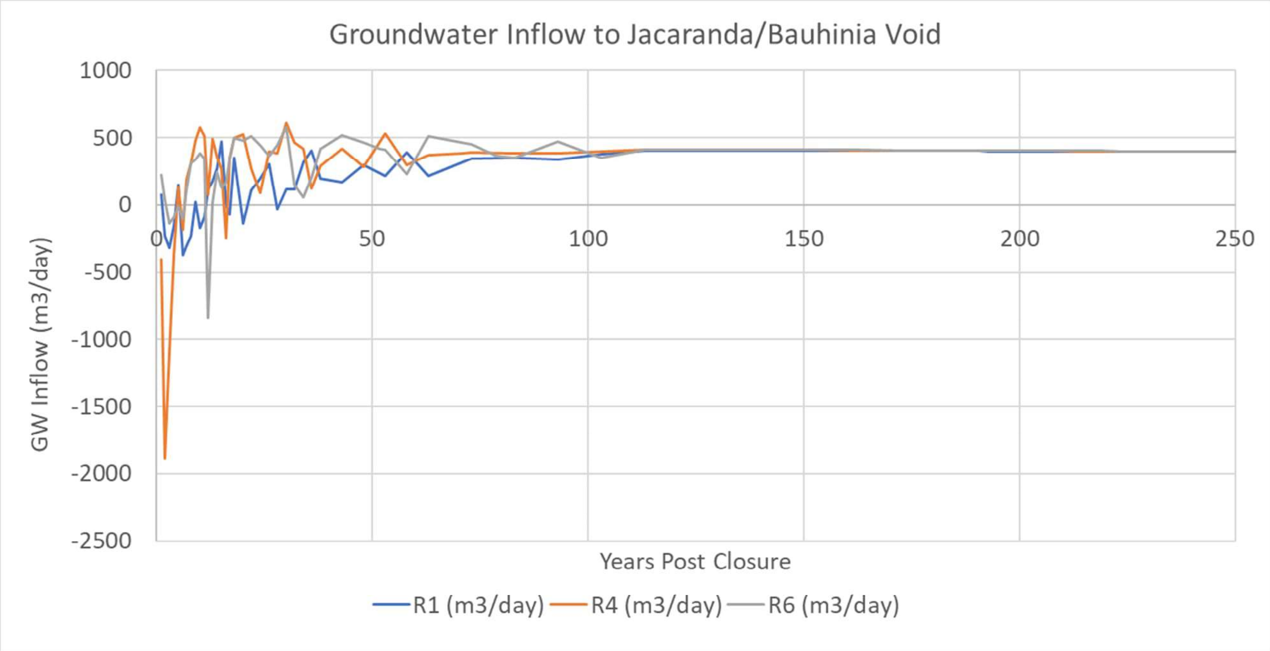


Figure 6.8 Groundwater inflows to Jacaranda/Bauhinia residual void – generated from SLR (2023)

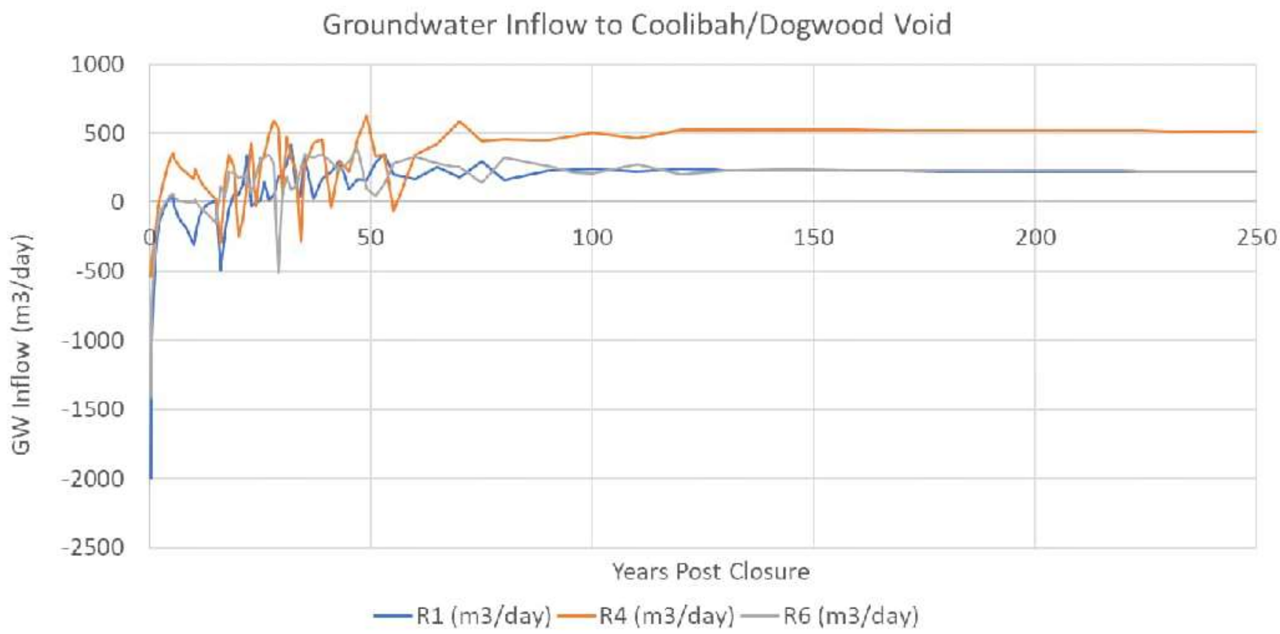


Figure 6.9 Groundwater inflows to Coolibah/Dogwood residual void – generated from SLR (2023)

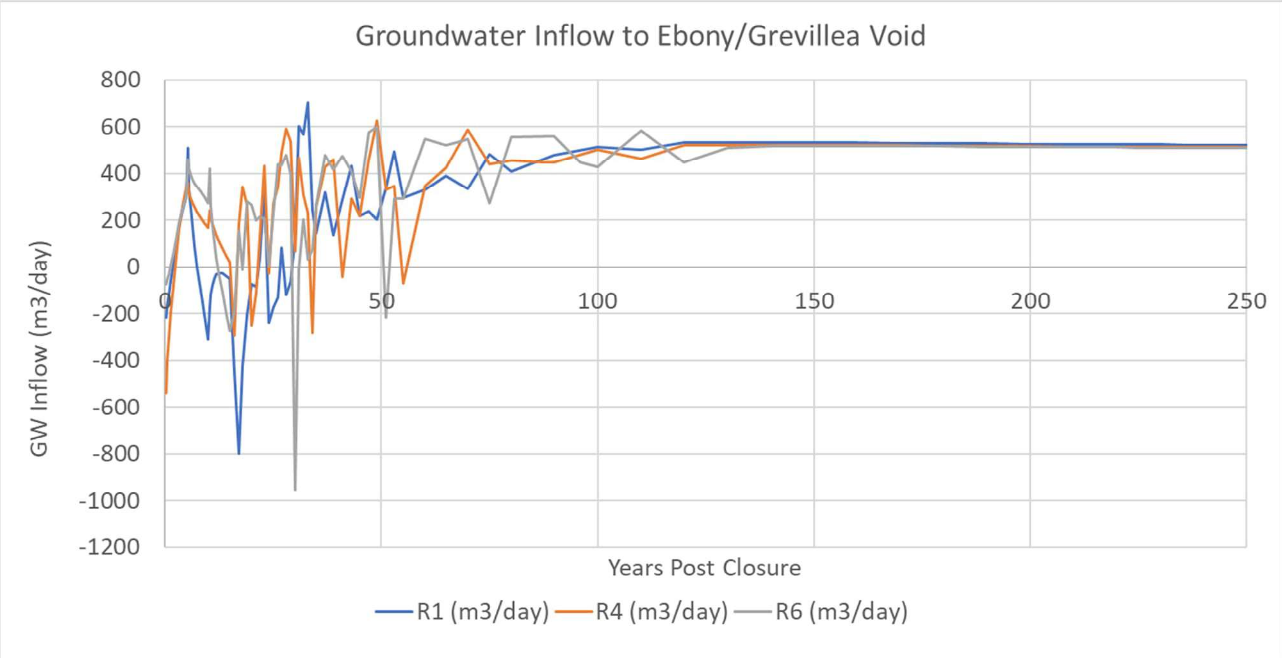


Figure 6.10 Groundwater inflows to Ebony/Grevillea residual void – generated from SLR (2023)

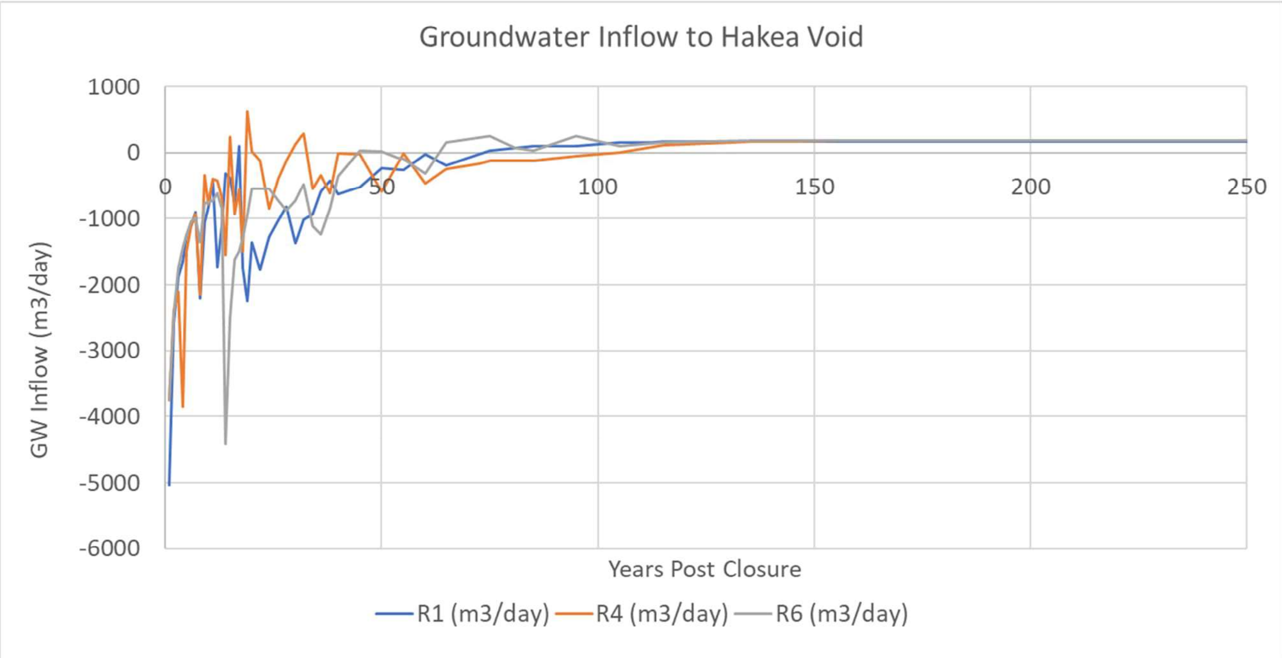


Figure 6.11 Groundwater inflows to Hakea residual void – generated from SLR (2023)

Groundwater inflows to the residual voids, as discussed in Section 4, are predicted to equate to between 11 and 15% of the total volumetric inflow. Surface water fluxes act as the dominant driver on final void water levels.

6.2 Residual void water balance outcomes

6.2.1 Jacaranda/Bauhinia residual void

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows reduce and the mean equilibrium is nearly reached. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.12. The mean (total) annual inflow to Jacaranda/Bauhinia Pit is 1,008 megalitres per year (ML/yr) for the simulation period of 2180 to 2199. The mean annual outflow for the same period is 969 ML/yr. This indicates that the mean water balance for Jacaranda/Bauhinia residual void is reaching equilibrium at the end of the simulation period. Extending the simulation period is expected to result in the water balance reaching full equilibrium without a significant change to the void water level.

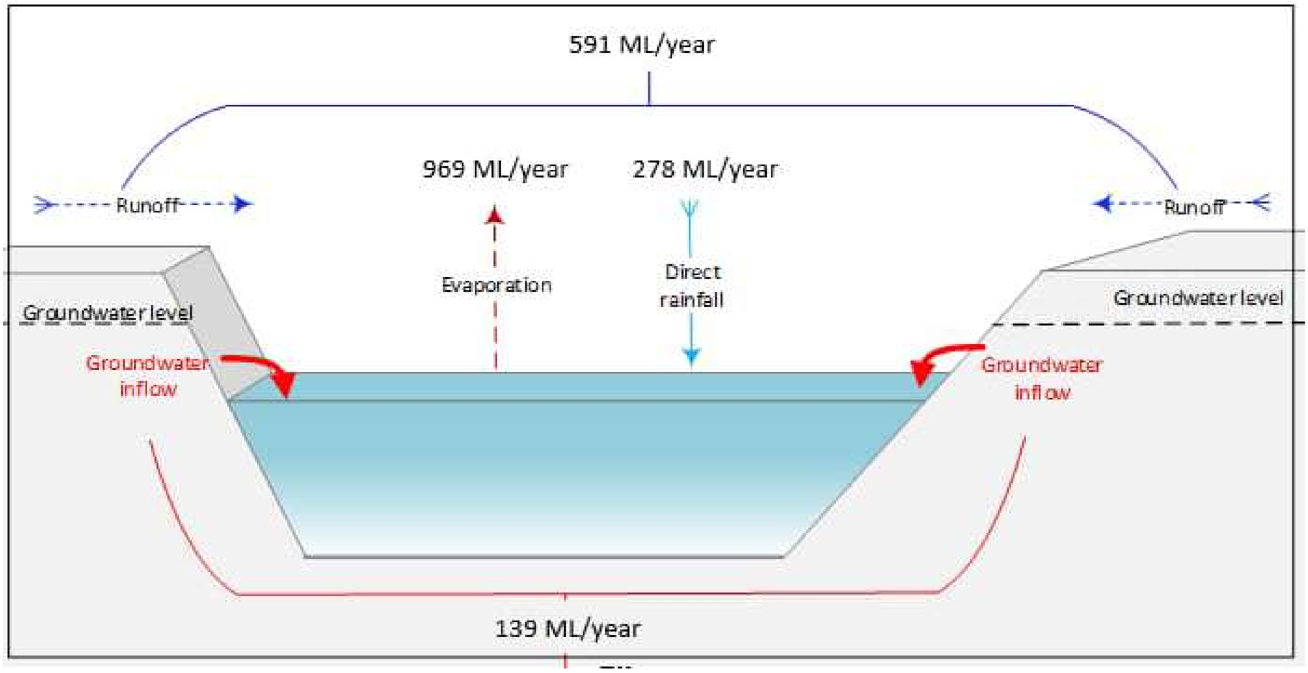


Figure 6.12 Schematic representation of average inflows/outflows simulated for the period from 2180 to 2199 – Jacaranda/Bauhinia residual void (realisations 1, 4, and 6)

The results from the WBM for Jacaranda/Bauhinia residual void indicate that, after an initial increase in void water level and volumes observed from the beginning of the simulation until the year 2140, the mean void water levels start to stabilise. The mean void water elevation reaches 3 m AHD and the mean void water volume reaches 13,103 ML by the end of the simulation across all realisations (as shown in Figure 6.13 and Figure 6.14).

The water levels remain below the pre-mining regional groundwater level (approx. 176 m AHD) (Jacobs, 2017) (Figure 6.13), and the lowest point of the base of the shallow geologic formations (weathered regolith and basalt) (around 145.5 m AHD) (SLR, 2023a) for the duration of the simulation and consequently remain below the void spill point (183 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

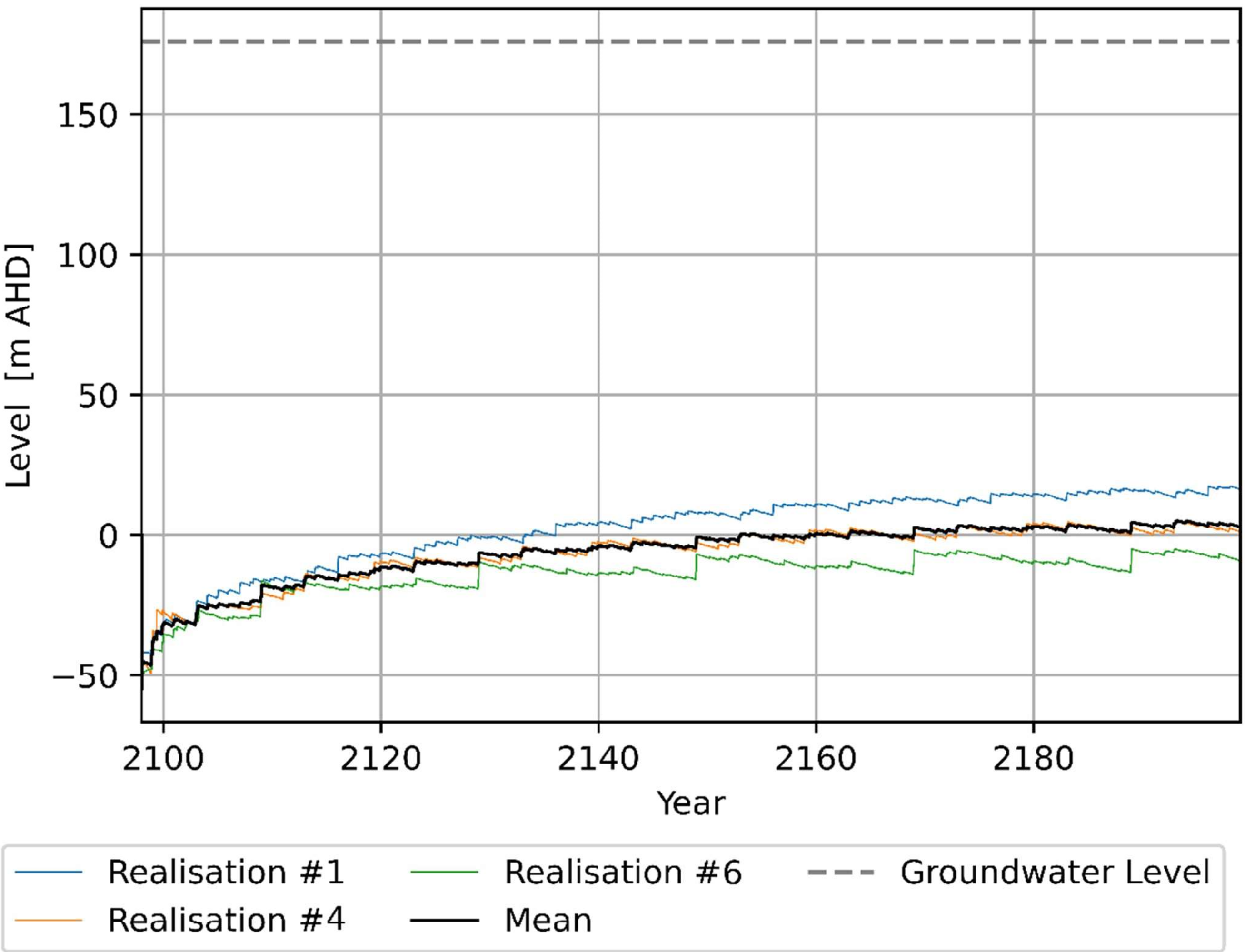


Figure 6.13 Modelled water levels in Jacaranda/Bauhinia residual void compared to surrounding groundwater levels (realisations 1, 4, and 6)

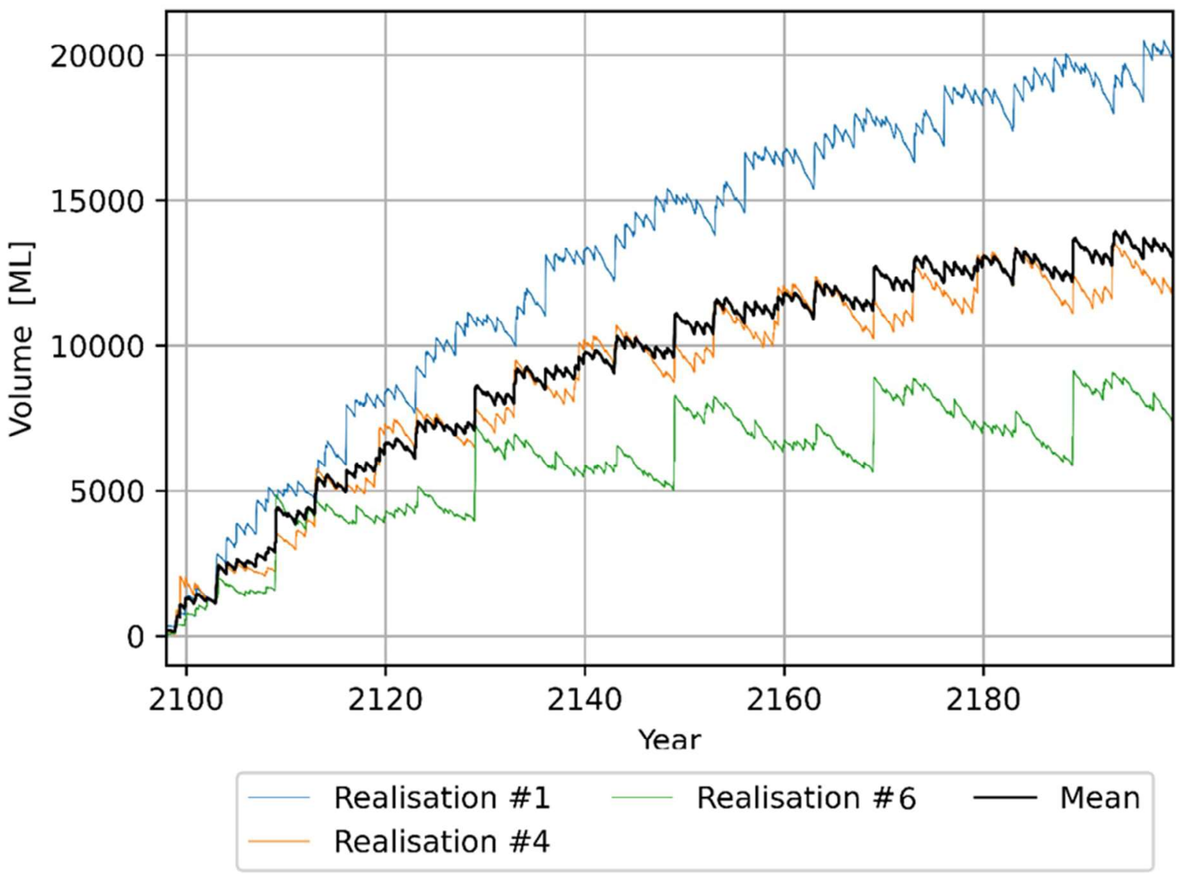


Figure 6.14 Modelled water volumes in Jacaranda/Bauhinia residual void (realisations 1, 4, and 6)

6.2.2 Coolibah/Dogwood residual void

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows reduce and the mean water balance has reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.15. The mean (total) annual inflow to Coolibah/Dogwood residual void is 768 ML/yr for the final 20-year period. The mean annual outflow for the same period is 763 ML/yr. This indicates that the mean water balance for Coolibah/Dogwood residual void can be considered to have reached equilibrium.

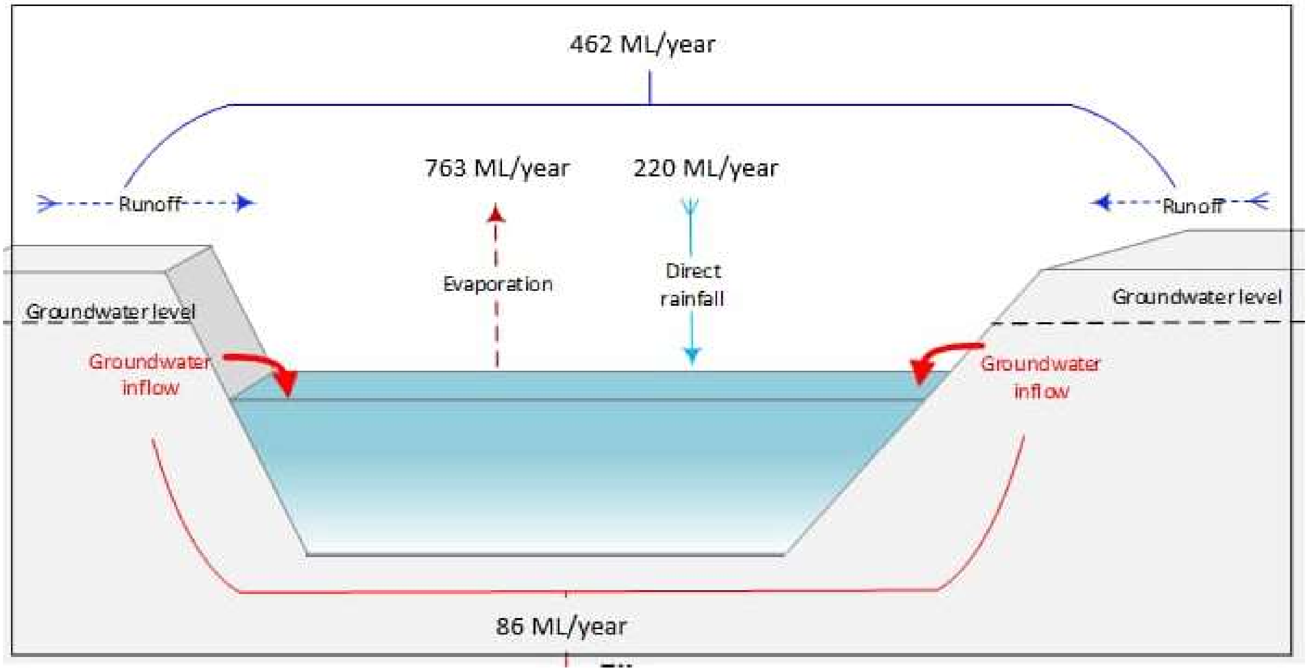


Figure 6.15 Schematic representation of average inflows/outflows simulated for period from 2180 to 2199 – Coolibah/Dogwood residual void (realisations 1, 4, and 6)

The results from the WBM for Coolibah/Dogwood residual void indicate that, after the year 2120, the mean void water levels start to stabilise, reaching a mean void water elevation of 14 m AHD and a mean void water volume of 7,256 ML by the end of the simulation (as shown in Figure 6.16 and Figure 6.17).

The water levels remain below the pre-mining regional groundwater level (approx. 176 m AHD) (Jacobs, 2017) (Figure 6.16) and the lowest point of the base of the shallow geologic formations (weathered regolith and basalt) (around 150.2 m AHD) (SLR, 2023a), for the duration of the simulation and consequently remain below the void spill point (192 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

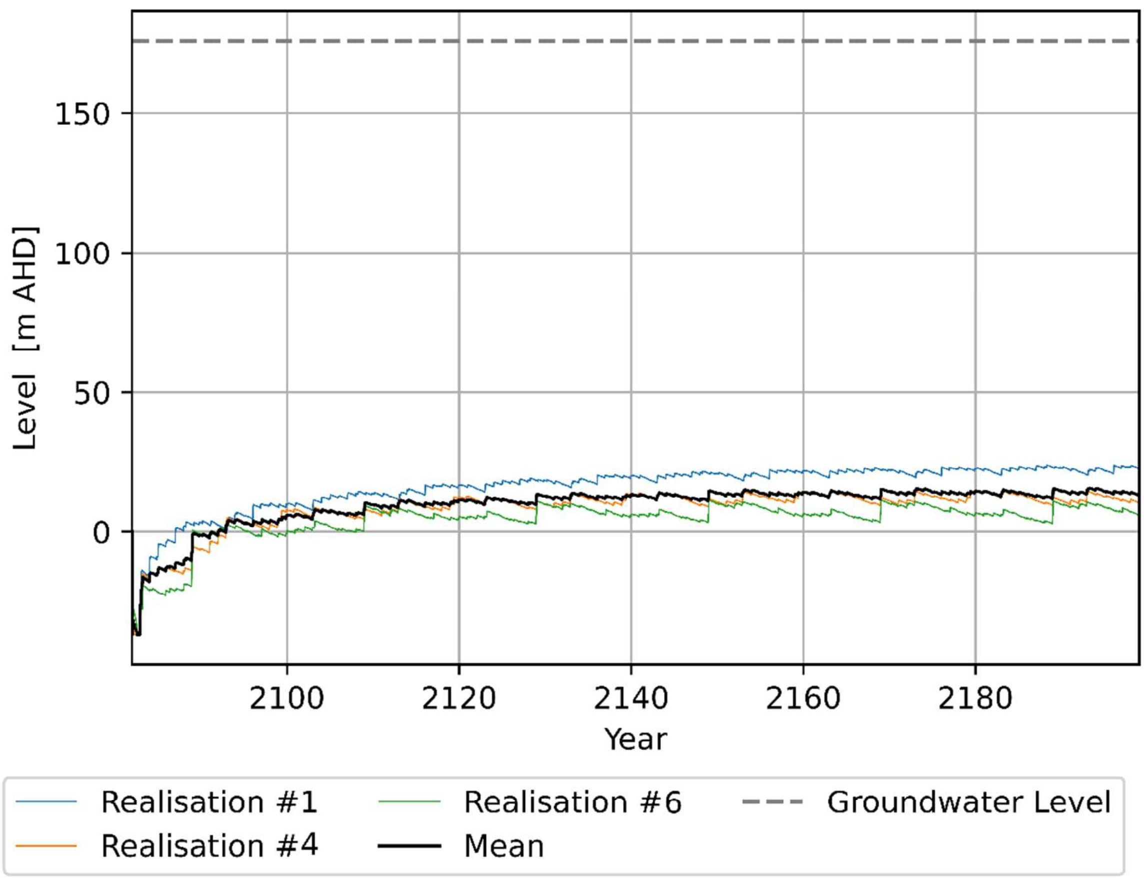


Figure 6.16 Modelled water levels in Coolibah/Dogwood residual void compared to surrounding groundwater levels (realisations 1, 4, and 6)

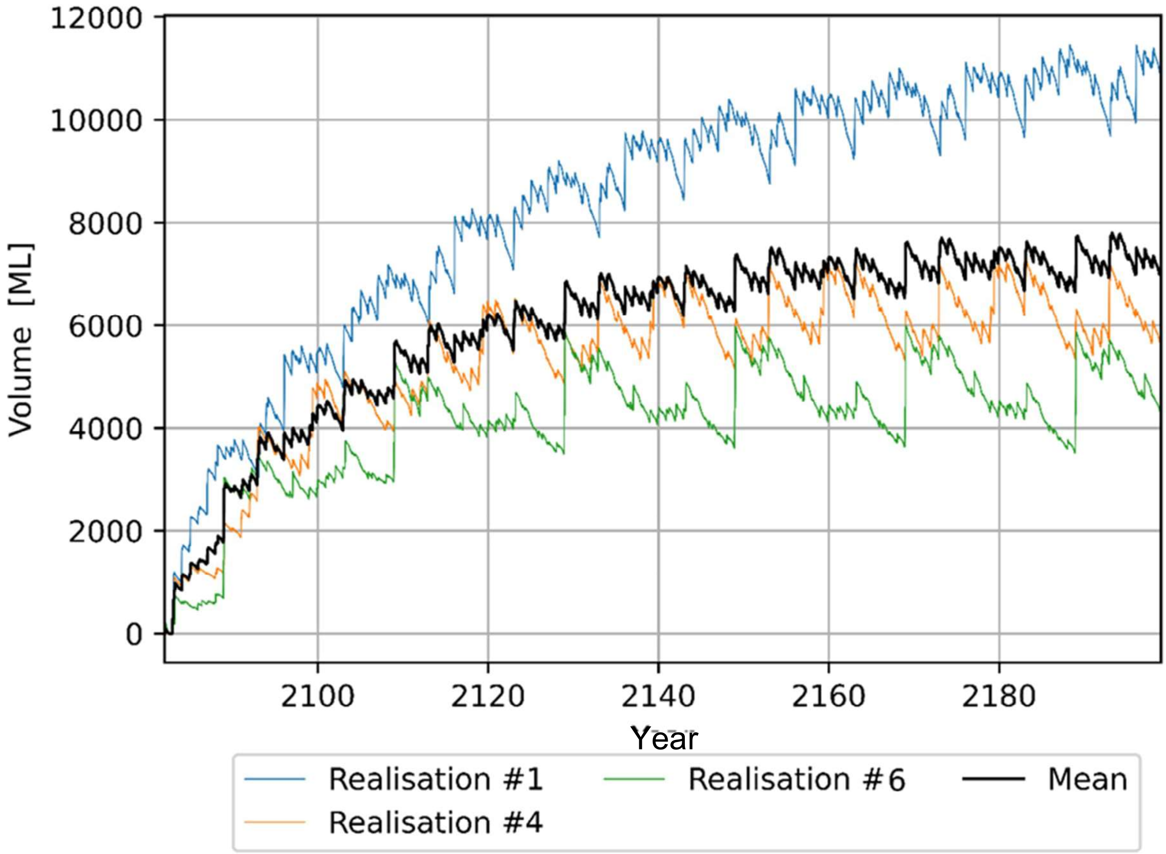


Figure 6.17 Modelled water volumes in Coolibah/Dogwood residual void (realisations 1, 4, and 6)

6.2.3 Ebony/Grevillea residual void

By 2199, the end of the simulation period, the differences between mean inflows and mean outflows reduce and the mean water balance has reached equilibrium The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2180 to 2199 and are presented in Figure 6.18. The mean (total) annual inflow to Ebony/Grevillea residual void is 1,204 ML/yr for the final 20-year period. The mean annual outflow for the same period is 1,171 ML/yr. This indicates that the mean water balance for Ebony/Grevillea residual void is reaching equilibrium at the end of the simulation period. Extending the simulation period is expected to result in the water balance reaching full equilibrium without a significant change to the void water level.

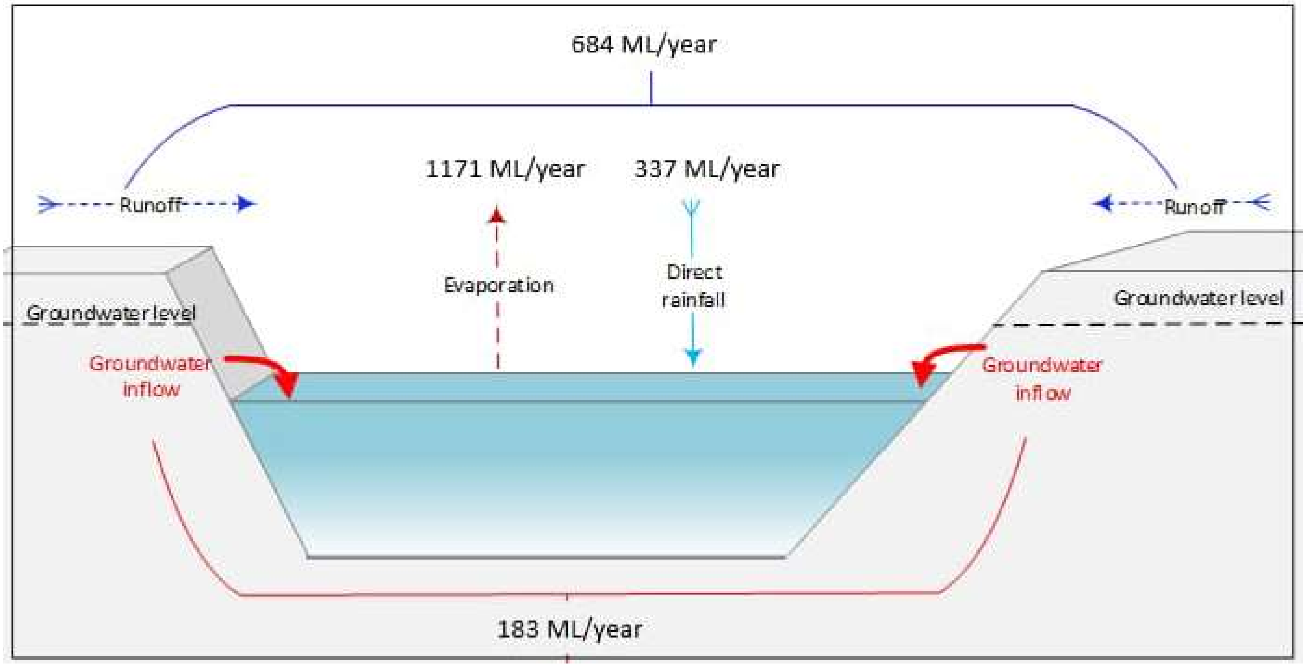


Figure 6.18 Schematic representation of average inflows/outflows simulated for period from 2180 to 2199 – Ebony/Grevillea residual void (realisations 1, 4, and 6)

The results from the WBM for Ebony/Grevillea residual void Pit indicate that, after the year 2160 the mean void water levels start to stabilise, reaching a mean void water elevation of -16 m AHD and a mean void water volume of 20,770 megalitres by the end of the simulation – as shown in Figure 6.19 and Figure 6.20.

The water levels remain below the pre-mining regional groundwater level (approx. 176 m AHD) (Jacobs, 2017) (Figure 6.19) and the lowest point of the base of the shallow geologic formations (weathered regolith and basalt) (around 165.5 m AHD) (SLR, 2023a), for the duration of the simulation and consequently remain below the void spill point (192 m AHD). Therefore, there is a low risk of the void overtopping, and the void is modelled to act as a groundwater sink for all the scenarios considered.

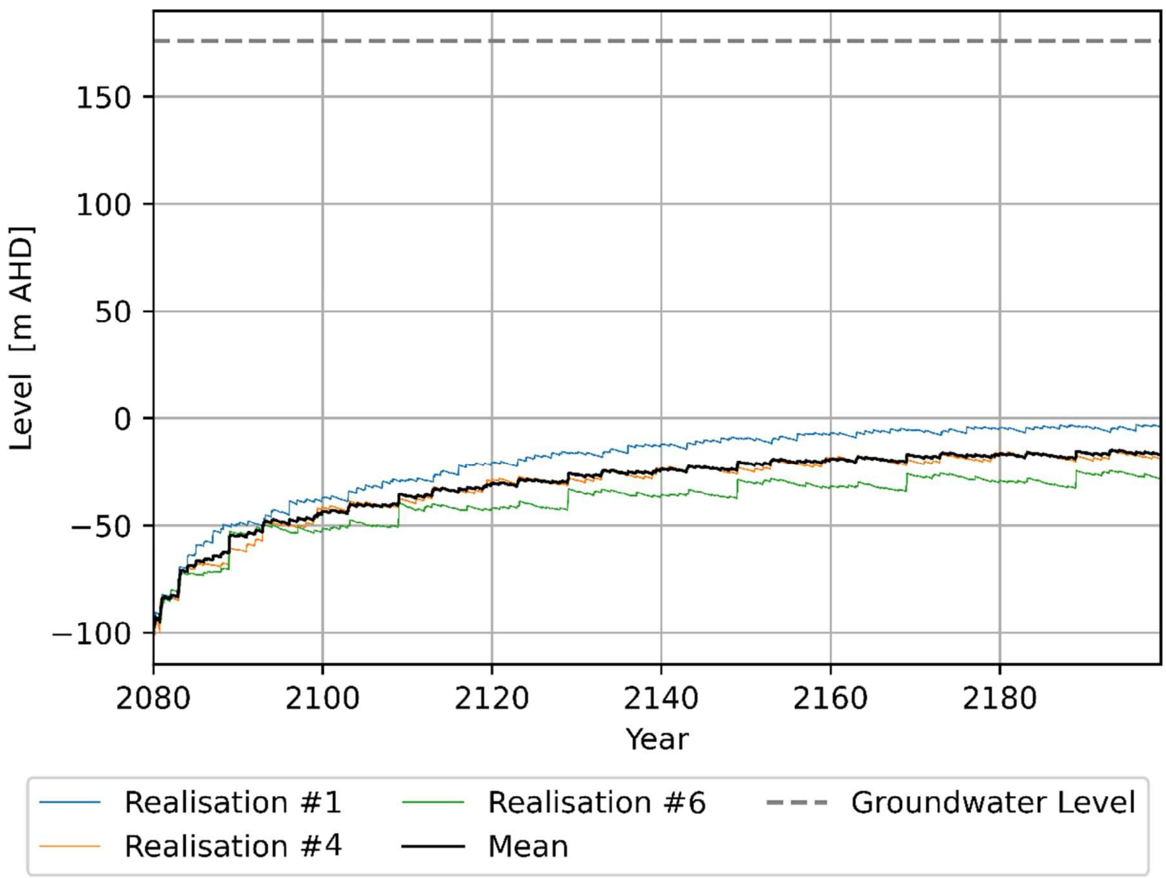


Figure 6.19 Modelled water levels in Ebony/Grevillea residual void compared to surrounding groundwater level (realisations 1, 4, and 6)

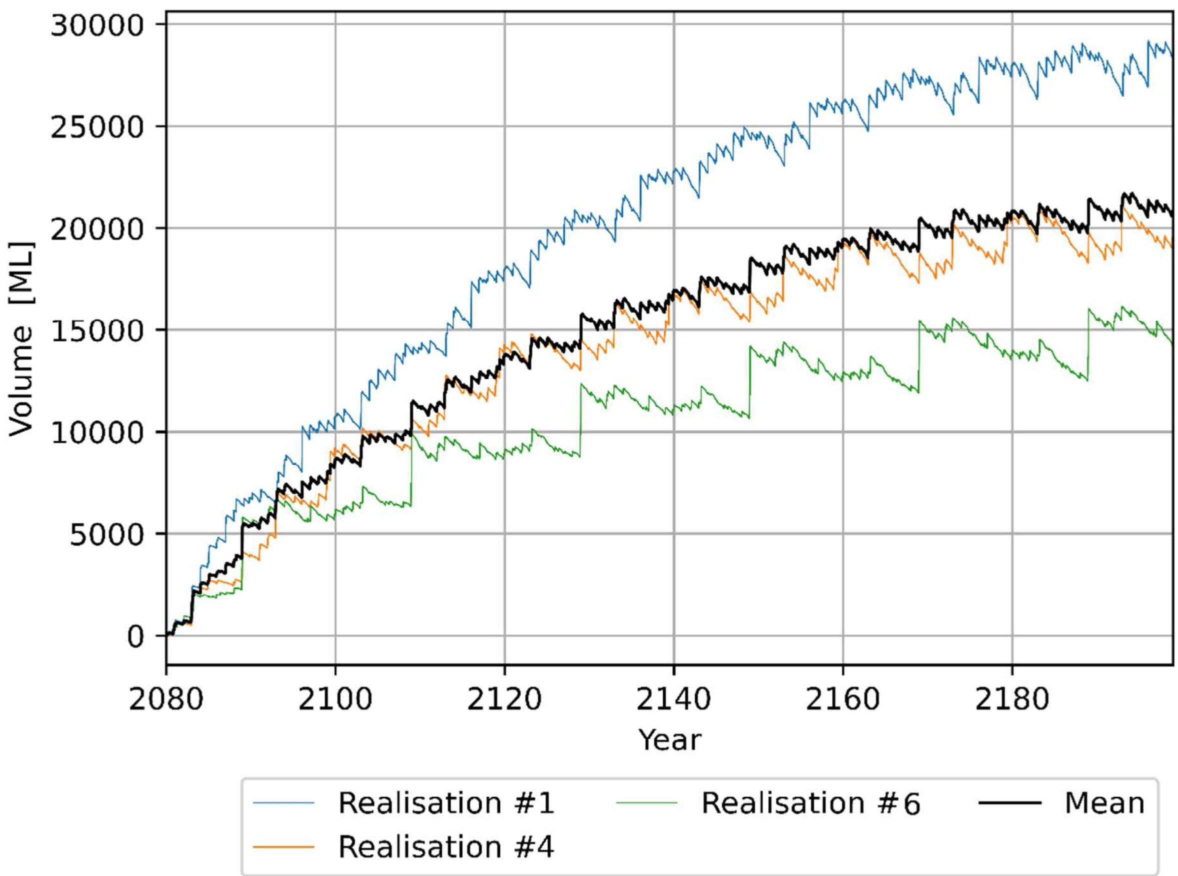


Figure 6.20 Modelled water volumes in Ebony/Grevillea residual void (realisations 1, 4, and 6)

6.2.4 *Hakea residual void*

By 2259, the end of the simulation period, the differences between mean inflows and mean outflows reduce and the mean water balance has reached equilibrium. The average annual inflows and outflows were calculated for the final 20 years of the simulation period from 2240 to 2259 and are presented in Figure 6.21. The mean (total) annual inflow to Hakea is 433 ML/yr for the final 20-year period. The mean annual outflow for the same period is 429 ML/yr. This indicates that the mean water balance for the Hakea residual void can be considered to have reached equilibrium.

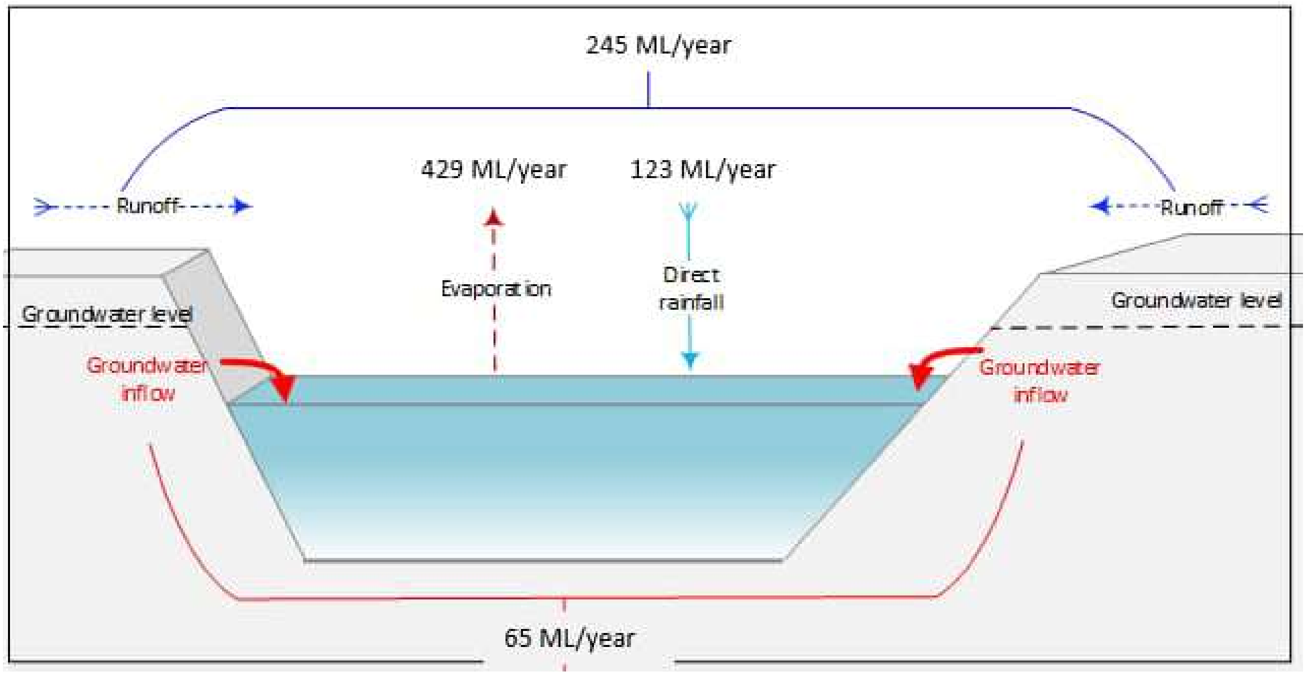


Figure 6.21 Schematic representation of average inflows/outflows simulated for period from 2240 to 2259 – Hakea residual void (realisations 1, 4, and 6)

The results from the WBM for Hakea indicate that, across all realisations, after the year 2230 the mean void water levels start to stabilise, reaching a mean void water elevation of 74 m AHD and a mean void water volume of 3,305 megalitres by the end of the simulation – as shown in Figure 6.22 and Figure 6.23.

The water levels remain below the pre-mining regional groundwater level (approx. 176 m AHD) (Jacobs, 2017) and the lowest point of the base of the shallow geologic formations (weathered regolith and basalt) (around 123.5 m AHD) (SLR, 2023a) for the duration of the simulation, and consequently below the void spill point (195 m AHD). Therefore, the void has a very low risk of overtopping and is modelled to act as a groundwater sink for all the scenarios considered.

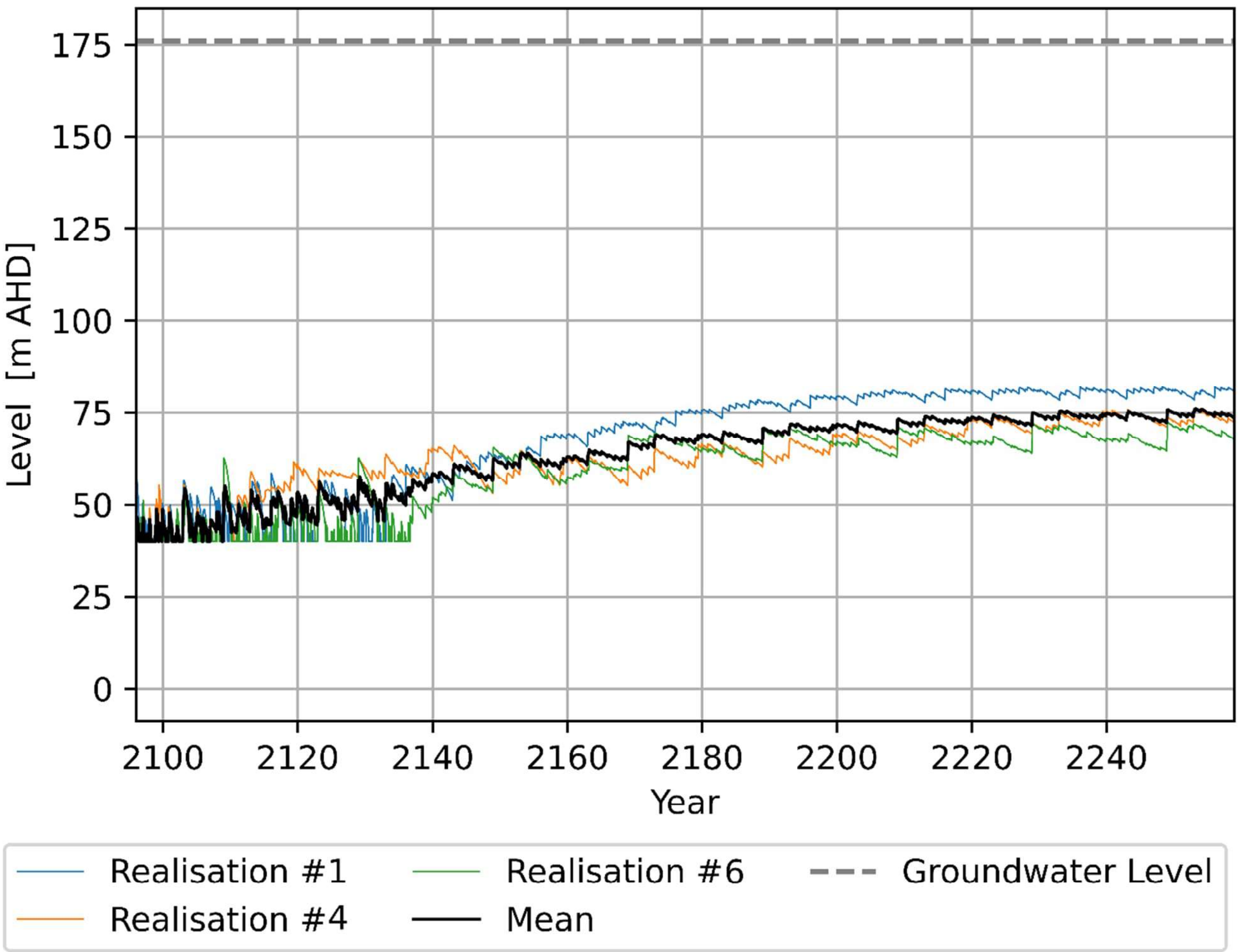


Figure 6.22 Modelled water levels in Hakea residual void compared to surrounding groundwater levels (realisations 1, 4, and 6)

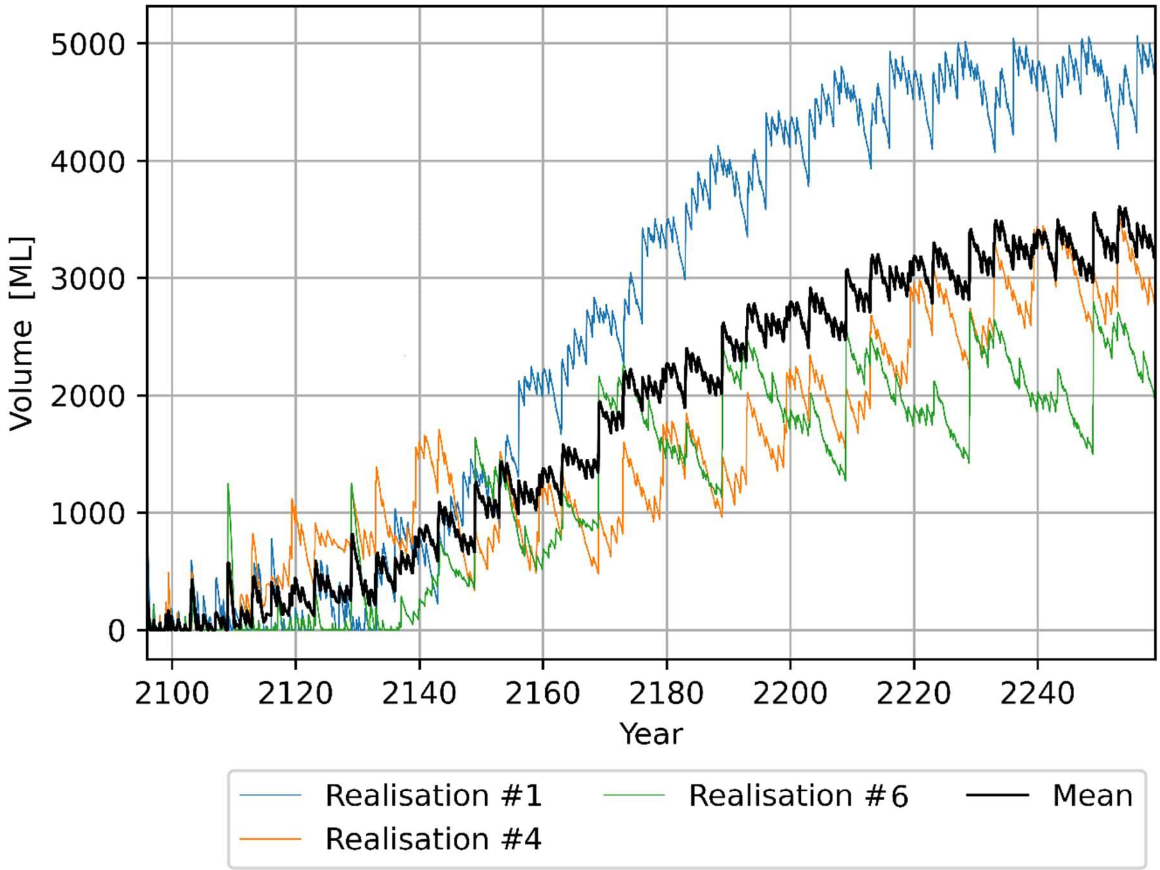


Figure 6.23 Modelled water volumes in Hakea residual void (realisations 1, 4, and 6)

7 Geotechnical stability

Geotechnical stability assessments have been completed to demonstrate that post-closure, the conceptual void high-wall, end-wall and low-wall slopes will all exhibit long-term geotechnical stability for the SRM residual voids. This section presents the assessment findings relevant to void closure at SRM.

7.1 High-wall and end-wall stability assessment

The method of limit equilibrium was selected to geotechnically assess and quantify the risk of instability for SRM residual voids' high-walls and end-walls. Limit equilibrium compares forces on a surface with (limiting) strength if the high-wall/end-wall were at the point of failing. Defects may be included explicitly as discrete strata when known, but more often they are implicit within the strengths of broader material layers. The main disadvantage of this method is that it assumes all material along the surface can realise its peak strength at the same time; the significance of any subsequent inaccuracy depends on the load-deformation behaviour of the particular materials. However, the method is generally accepted by industry as a practical industry method and has therefore been adopted for the PRC plan at SRM.

Factor of Safety (FoS) computed by limit equilibrium is essentially a ratio of the strength available to hold a slope in place divided by the loads tending to move, or destabilise, material behind the slope face. Thus, a FoS less than 1 indicates instability, and a value greater than 1 implies that the slope is stable because the capacity to resist slipping is greater than the forces promoting slipping. A FoS is a relatively coarse and simplified measure of stability that was devised to use as a design methodology. In this context, a minimum value somewhat greater than one is specified to allow for inaccuracies and uncertainties in both the method and the input data. If a constructed slope is not moving then it is obviously stable under current conditions, regardless of any computed measure. The important consideration should then be whether there is potential for those current conditions to change in a way that would then adversely affect stability.

As a design or performance criterion, the selected minimum FoS should be appropriate to the consequences if instability did occur, which in the closure context in turn relates to land use (Martin & Stacey, 2018). A minimum FoS of 1.5 is often adopted for long-term stability of civil engineering features such as road cuttings and dam walls, that is, features with broad public access. By contrast, a FoS of 1.2 is typically applied to operational design for BMA coal mine pit walls, where stability is required for a shorter time and with limited human exposure.

Pending industry research to develop observational methods and consequence assessment for long-term pit wall stability, BMA has adopted a minimum FoS of 1.5 for closure planning. However, a too conservative approach could lead to an unnecessary increase in void area and additional land disturbance at the potential expense of adjoining higher value land uses. Hence, BMA is applying the minimum FoS, not to the physical crest of the pit wall but instead:

- To a distance set back behind the crest, such that there are no environmental or third-party assets of significant value within that set-back; or
- To the final void walls, which have been located such that their computed set-back does not include any valuable assets.

This approach allows for flexibility to apply improvements in stability practice in the future and translates to both the high-walls and end-walls. At closure, all third-party assets will remain outside any identified zones of instability (i.e., a FoS equal to or less than 1.5). This constraint is illustrated in Figure 7.1. The NUMA extent will include the required set-back to achieve the minimum FoS.

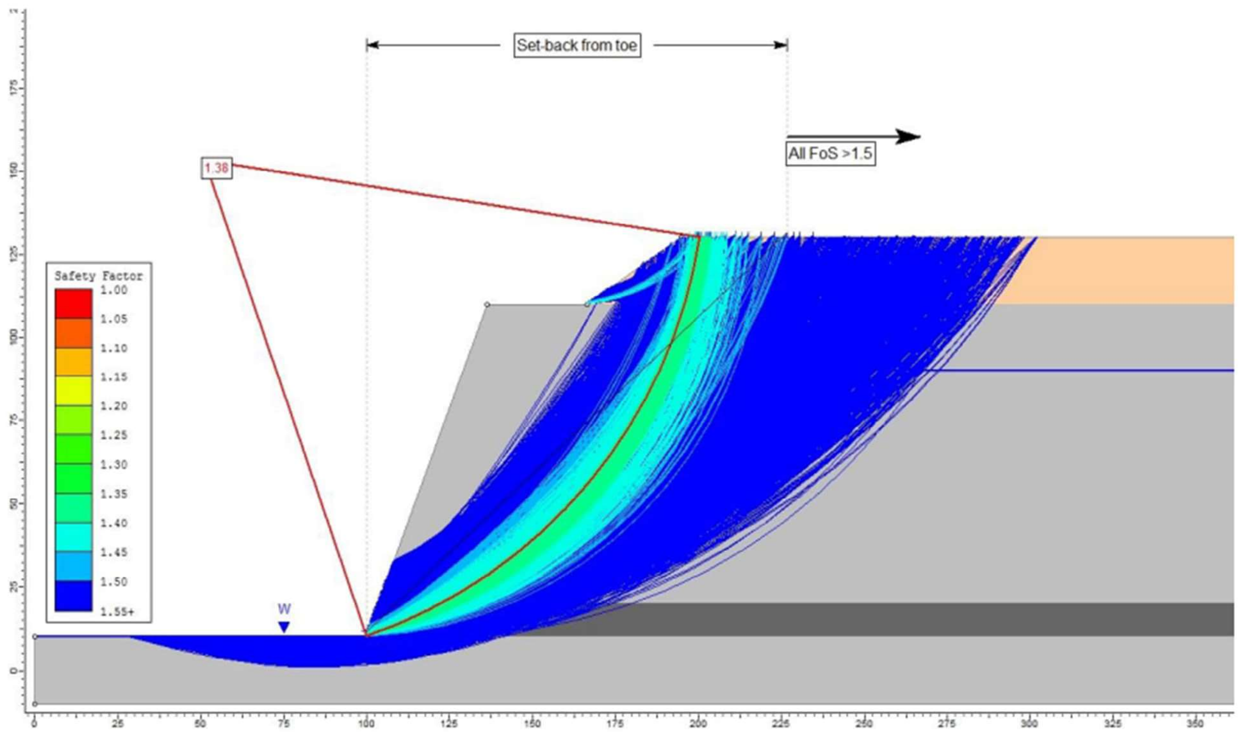


Figure 7.1 Example illustration of set-back to FoS of ≥1.5

BMA has developed a pit wall stability design tool for determining set-backs for long-term pit wall stability at BMA coal mines.

A common engineering approach, when it is anticipated that designs will be required for a large number of similar scenarios, is to undertake upfront a large number of analyses to cover the range of expected scenarios and collate the results into a design tool, for example design charts or empirical formulae or lookup tables. It is important to appreciate that such tools do not omit design analyses, it is simply that all the analyses are carried out first so that when a particular scenario is considered, the result is already available. Set-backs for long-term pit wall stability at BMA coal mines clearly lends themselves to this approach – regional geology is broadly consistent; mining methods constrain the range of efficient wall geometries; and given the number of pits and different planning horizons, there will be a large number of specific scenarios to address over time.

The key features of this design tool are summarised in Sections 7.1.1 and 7.1.2. The design tool is used for initial planning. Individual assessment of each high-wall and end-wall will be undertaken as part of the final pit detailed designs as mining approaches the final pit extents.

7.1.1 Inputs to assessment – regional

7.1.1.1 Regional geology and geotechnical (strength) properties

In the Bowen Basin, predominantly Permian age coal measure sedimentary rocks are unconformably overlain by younger, mainly Tertiary age, sediments. At some locations, the latter contain laterally confined basalt that was deposited in the early Tertiary. In the context of wall stability, the important geological boundaries are base of Tertiary and base of weathering; however, for simplicity in the design tool, Tertiary and weathered Permian rocks were treated as one material, which is a conservative approach. Basalt occurs only infrequently and was not included in the study; consequently, the design tool cannot be used when significant basalt is present in the final pit wall. Stability analyses (forming the basis of the design tool) used the wall geometry summarised in Table 7.1. Assumed strength properties are presented in Table 7.2.

Table 7.1 Wall geometry covered by stability design tool

Aspect	Value range
Average wall angle in Tertiary overburden	35° (constant)
Depth of Tertiary/weathered overburden	1 m to 100 m
Bench width at base of Tertiary overburden	30 m (constant)
Average wall angle in Permian overburden	40° to 70°
Depth of Permian overburden incl. 10 m coal	50 m to 400 m

Table 7.2 Strength properties applied in stability design tool

	Cohesion (kPa)	Friction angle (°)	Unit weight (kN/m^3)
Tertiary/weathered	50	30	22
Fresh Permian	450	42	24
Coal	30	35	15

7.1.1.2 Effect of weathering

It is obvious that weathering affects the character and strength of rocks. However, weathering that has occurred over geologic time before the pit wall is excavated is automatically accounted for in the strength properties adopted for operational wall design and so has no additional geomechanical impact on rehabilitation and post-mining landforms. Hence, additional effects of weathering on long-term stability would only relate to weathering that might occur after cessation of mining.

There are two phases to weathering: physical degradation and chemical decomposition. Degradation starts almost as soon as the rock face is exposed and is essentially larger fragments or rock breaking down into smaller fragments. This breakdown, or 'slaking', is mainly caused by salt crystals adsorbing moisture and swelling, by clay minerals adsorbing moisture and swelling (although salts are usually involved as well) and less commonly by cementing minerals being dissolved in water. Rainfall and in-pit storage cause immediate slaking in susceptible materials, but humidity can produce the same result over a couple of years. Because degradation depends so heavily on water ingress, it is largely restricted to the surface of pit walls and does not penetrate far enough to cause geotechnical instability. An exception may be when particularly moisture-sensitive rock is below the long-term void water level, but this is addressed by adopting saturated strength properties and therefore does not need to be considered separately.

Chemical decomposition involves reactions of the actual rock minerals to form different minerals (ultimately, clay minerals). Because it occurs at the crystalline/molecular level and only where water and other reactants can reach, chemical weathering occurs mainly at the rock surface and along joints and bedding planes, but even there, it progresses at a very slow rate relative to other processes.

Both phases of weathering occur fastest in hot, wet climates – rainfall providing the necessary moisture, and high temperature promoting chemical reactions. The climate at SRM is hot but not wet and as such only "very slight" ongoing weathering is expected. There may be very specific situations where even a very small amount of additional weathering might affect pit wall stability, most notably where weak degradable strata underlie more resistant strata. As the degradable material ravels and falls away, the harder layer loses support and may subsequently fall. This is generally a localised scenario that may only be apparent when the pit wall is excavated. Hence it cannot generally be planned for but will be assessed and managed at the end of coal extraction at the detailed design stage for closure.

7.1.1.3 Effect of long-term erosion

Erosion is the detachment of solid particles from the soil or rock mass and the subsequent transport of those particles away from their initial location. Most commonly, detachment occurs due to mechanical means – the impact of raindrops and the energy of flowing water – and the transport is also provided by flowing water. In this scenario, the severity of erosion depends on the character of the material – how easily particles are detached – and increases with catchment size and surface slope, both of which increase the volume and velocity of runoff flow. In dispersive material, detachment can also occur by chemical means. In this case, the bonds and ionic charges within the material are such that clay particles will "disperse" into even static water that is not applying mechanical energy. However, flowing water is still required for the transport phase of erosion.

On high-walls and end-walls in the Bowen Basin, erosion in fresh rock is mainly limited to material that has already slaked because the intact rock is too strongly bound for particles to be readily detached. Above the base of weathering, particles are more easily detached. As particles are transported in water flow, erosion develops and progresses over time along flow lines. These are mainly perpendicular to the line of the wall. By contrast, slip failures involve surfaces that are at least sub-parallel to the line of the wall. Consequently, erosion rarely causes geomechanical instability. Even if an unusual arrangement of intersecting erosion gullies created the potential for a wedge-type failure, it would be addressed through surface water and erosion control measures rather than by slope stability design.

Weathering and long-term erosion will generally have little impact. This is not to say that erosion is not a rehabilitation issue in its own right, but it is generally not a significant factor in pit wall geotechnical stability. Therefore, it has not been considered further in this assessment.

7.1.1.4 Effect of significant hydrological events

In Bowen Basin coal mines, weathered overburden is generally susceptible to softening when saturated, especially materials containing significant clay. Unweathered (fresh) coal measure rocks generally do not show significant strength loss on wetting, as evidenced by the large number of inactive pits that contain water without any noticeable change in wall stability. Some particular claystones/mudstones may be more sensitive to moisture, but these tend to start slaking soon after exposure to humid air, and so are apparent during mining when wall designs can be amended to mitigate any impact on wall stability.

Water balance modelling for the proposed voids at SRM predicts average and long-term void water levels many metres below the base of weathering. Void water is only expected to contact fresh rock and so will not affect geotechnical stability of excavated pit walls. The most serious potential impact of severe rainfall events would be the inrush of floodwaters to the void. In theory, an initial inflow could scour a new channel through the ground between the void and the watercourse, thus directing more water into the void at a greater flow rate. For the final closure state landform, the pit voids will be mitigated from flooding either by: partial backfill with spoil to reduce the extent of the pit; or a flood protection landform. Spoil dumping will be conducted so that the final residual void for the NUMA will not be subject to inundation from floodwaters up to and including the 0.1% AEP climate change RCP 8.5 P90 event.

There is one other mode of instability related to water storage, namely drawdown failure. This can occur when pore water pressures in the containing earth and rock have equilibrated with the water level in the storage and that water level is then lowered quicker than the containing materials can drain, so that the pore pressures are no longer balanced out. This will not be an issue for voids which contain water passively because evaporation and small capacity pumps will not lower the water level quickly enough to establish this imbalance. Stability under drawdown would be a consideration for post-mining land uses (PMLUs) involving movement of large volumes of water, such as large-scale irrigation and pumped hydro energy storage, but such uses are not proposed for SRM residual voids.

7.1.2 Inputs to assessment – local

Long sections extracted from the current SRM geological model provided void wall profile data as summarised in Table 7.3. The boundary between Tertiary and weathered Permian overburdens can be difficult to determine due to multiple weathering periods; however, this possible inaccuracy is not critical because total depth of weathering is the input used in stability analyses.

Some igneous intrusions – sill and dykes – have been encountered during mining, although these are believed to be more widespread in the area south-east of the mine. Given their localised nature, it is not feasible to reliably map such intrusions significantly in advance of current strips but they will be addressed operationally as mining of the pits advances.

Table 7.3 Geotechnical profiles for the residual void walls at SRM

Geotechnical profile parameters		**Jacaranda/ Bauhinia**	**Coolibah/ Dogwood**	**Ebony/Grevillea**	**Hakea**
Depth of tertiary overburden (m)	Average Range 90% less than	20 8–37 32	21 4–41 36	12 6–23 19	19 14–25 23
Depth of tertiary/weathered overburden (m)	Average Range 90% less than	34 26–45 42	32 20–51 44	26 21–31 30	27 22–33 30
Thickness of base coal seam (m)	Average Range 90% less than	6.9 0–8.7 8.2	5.7 0–8.8 8.2	4.3 0–7.5 5.8	4.8 3.7–5.3 5.3
Depth of fresh overburden (m)	Average Range 90% less than	198 150–207 205	174 121–218 209	222 142–275 266	118 92–141 139
Total wall depth (m)	Average Range 90% less than	232 184–250 245	206 163–242 236	248 163–299 290	145 119–165 164

The depth ranges for Tertiary/weathered and fresh Permian overburdens are within the application limits for the design tool. Computations were made with two assumed wall angles, namely, 50° and 60°. The computed set-back from the wall toe is not very sensitive to that parameter, but steeper angles are slightly more conservative because they impose greater overburden weight on the potential slip surface. The thickness of the coal seam at the pit floor ranged up to 9 m, which is close to the assumed thickness in the design tool (10 m).

The design tool is used for initial planning only. Individual assessment of each high-wall and end-wall will be undertaken as part of the final pit detailed design stage required as part of closure works as mining approaches the final pit extents and as more geological and geotechnical data becomes available.

The procedure for estimation of set-back developed in the design tool is:

1 If D_{TW} = <47m, FoS_{TW} =1.5 and $S_{TW} = D_{TW}/\tan(35°)$

2 Otherwise $S_{TW} = 2.58*D_{TW} – 41.5$

3 $S1 = S_{TW} + 30 + D_P/\tan(A_P)$

4 $FoS_P = 1.208 + 0.0655/\sqrt{D_{TW}} + 13.87/\sqrt{D_P} – 0.0168A_P$; if FoS_P >=1.5 then $S_P = D_P/\tan(A_P) + 30 + D_{TW}/\tan(35°)$

5 Otherwise, $S_P = 0.856*D_{TW}^{1.15} + 3.727*D_P^{0.94} + 39.35\tan(A_P)^{1.09} + 35.01\ FoS_P^{2.49}$ -389

6 Required set-back from the wall toe = max(S_1, S_P)

Where:

- D_{TW} = depth of Tertiary/weathered overburden (m) 0
- D_P = depth of fresh Permian overburden (m)
- A_P = average wall angle in fresh Permian overburden (degrees)
- S_{TW} = set-back for stability in Tertiary/weathered overburden (m), measured from the toe of the weathered overburden batter
- S_1 = set-back for whole operational wall design (m), measured from the toe of the whole wall
- S_P = set-back for stability of whole wall (m), at FoS = 1.5.

7.1.3 High-wall and end-wall stability assessment results

Comparing the geotechnical profile at SRM with the design tool geometry in Table 7.1, the geotechnical profile at SRM is within the design tool limits and it is valid to use the design tool for final closure state landform planning.

The results for the SRM high-walls are summarised in Table 7.4. Note that changing average wall slope in fresh Permian overburden changed the average set-back by less than 5 m when the wall's FoS was less than 1.5, and therefore the set-back to achieve 1.5 extended behind the wall crest. When the FoS at the crest of the wall is greater than 1.5, the set-back from the toe of the wall is simply the distance from the toe to that crest; this was the case for Hakea residual void. Set-backs for end-walls will range from the value at the end of each high-wall down to the value coinciding with the excavated wall crest as the exposed wall height reduces.

Table 7.4 Setbacks for long-term high-wall stability at SRM

Geotechnical profile parameters		Jacaranda/ Bauhinia	Coolibah/ Dogwood	Ebony/ Grevillea	Hakea
D_{tw} (m)	Average	34	32	26	27
	Range	26–45	20–51	21–31	22–33
	90% less than	42	44	30	30
D_p (m)	Average	198	174	222	118
	Range	150–207	121–218	142–275	92–141
	90% less than	205	209	266	139
A_p (°) 50					
S_1 (m)	Average	195	176	208	136
	Range	154–210	137–221	137–251	100–191
	90% less than	206	202	243	191
Fos_p	Average	1.37	1.44	1.32	1.61
	Range	1.34–1.51	1.32–1.64	1.22–1.55	1.36–1.83
	90% less than	1.35	1.34	1.23	1.38
S_p (m)	Average	321	268	364	196
	Range	204–355	192–350	179–481	146–317
	90% less than	347	335	460	310
Set-back from toe of wall (m)	Average	321	268	364	196
	Range	204–355	192–350	179–481	146–317
	90% less than	347	335	460	310
A_p (°) 60					
S_1 (m)	Average	134	123	143	93
	Range	106–144	94-179	94–173	69–132
	90% less than	142	139	167	131
Fos_p	Average	1.20	1.27	1.16	1.44
	Range	1.18–1.34	1.15–1.47	1.05–1.38	1.19–1.66
	90% less than	1.18	1.17	1.06	1.21
S_p (m)	Average	325	268	368	183
	Range	219–359	175–354	182–487	122–320
	90% less than	350	338	466	312
Set-back from toe of wall (m)	Average	325	268	368	183
	Range	219–359	175–354	182–487	122–320
	90% less than	350	338	466	312

This set-back approach to long-term geotechnical stability offers several options to meet the requirements for mine closure including:

- Stop the mining pit with the toe of each pit wall at least the set-back distance away from significant permanent assets including lease boundaries, third-party infrastructure, and Matters of State Environmental Significance.
- Move the asset in question, for example to relocate a public road.
- Undertake a more detailed geotechnical investigation and wall stability analysis to remove some of the conservatism imposed by the design tool.
- Plan to partially backfill the residual void. In simple terms, this would reduce the (exposed) wall depth and depth of fresh Permian overburden, which would in turn reduce the set-back.

For SRM, the conceptual voids have been designed with the toes of each void wall at least the set-back distance away from significant permanent third-party assets. The design will be refined with detailed individual geotechnical assessment as mining of the pits approaches the final extents. The NUMA extents include the calculated set-back distance to achieve geotechnical stability within the NUMA.

7.2 Low-wall stability assessment

The geotechnical stability of low-walls has been assessed for the SRM residual voids with the purpose of demonstrating that, post-closure, void low-wall slopes will exhibit long-term geotechnical stability.

A stability analyses of the low-wall final closure state landform for the SRM residual voids was undertaken using the 2-dimensional (2D) limit equilibrium analysis software Slide2 (version 9.028). Four cross-sections were selected that represented the interpreted critical (worst case) low-wall conditions from a stability point of view, targeting areas of greatest spoil height and steepest floor dip. The section locations for the analysis are presented in Figure 7.2 and the corresponding sections are identified as:

- Section 1 (Jacaranda / Bauhinia residual void)
- Section 2 (Coolibah / Dogwood residual void)
- Section 3 (Ebony / Grevillea residual void)
- Section 4 (Hakea residual void).

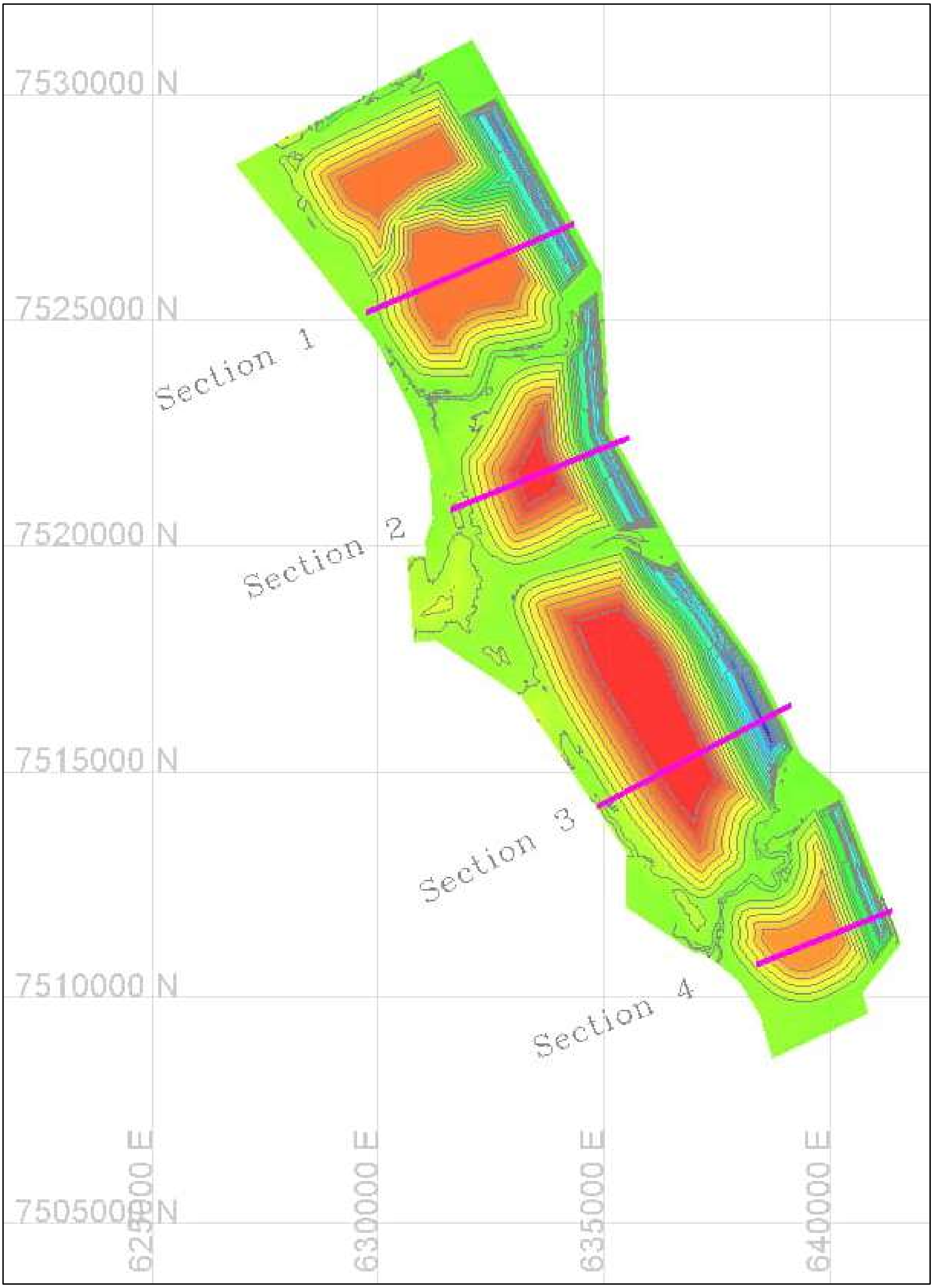


Figure 7.2 Cross-section locations for the SRM residual voids

For each of the four cross-sections, the following analysis cases were considered:

- Slope configuration based on the 3D final closure state landform and 3D final pit floor profile.
- Two alternative failure mechanisms including:
  - Circular analyses using *Morgenstern-Price*.
  - Non-circular using *Sarma* and *Morgenstern-Price*, non-vertical slices.
- Alternative cases of failure extents, including:
  - Global stability: Slip surfaces extending from the PMLU area of the low-wall slope to the spoil toe at pit floor level.
  - Local stability: Slip surfaces constrained to within the PMLU area of the low-wall slope, outside of the NUMA.
- For Ebony/Grevillea residual void, the FoS of 1.5 was not achieved on the initial analysis of the initial landform. Therefore, a modification to the initial landform in the form of including a low-wall bench at the edge of the NUMA boundary was included in the final analysis, thus achieving the required FoS.

The results for the low-wall stability assessment for SRM residual voids are presented in Sections 7.2.1 to 7.2.4. The analyses that returned the lowest FoS are presented.

7.2.1 Jacaranda/Bauhinia residual void

The geotechnical stability assessment for Jacaranda/Bauhinia residual void (cross-section 1) concluded that, for the final closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was greater than 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results are provided in Table 7.5, Figure 7.3, and Figure 7.4.

Table 7.5 Summary of low-wall geotechnical stability analysis results for Jacaranda/Bauhinia residual void (Morgenstern-Price, non-circular)

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
1	383	1.86	2.24

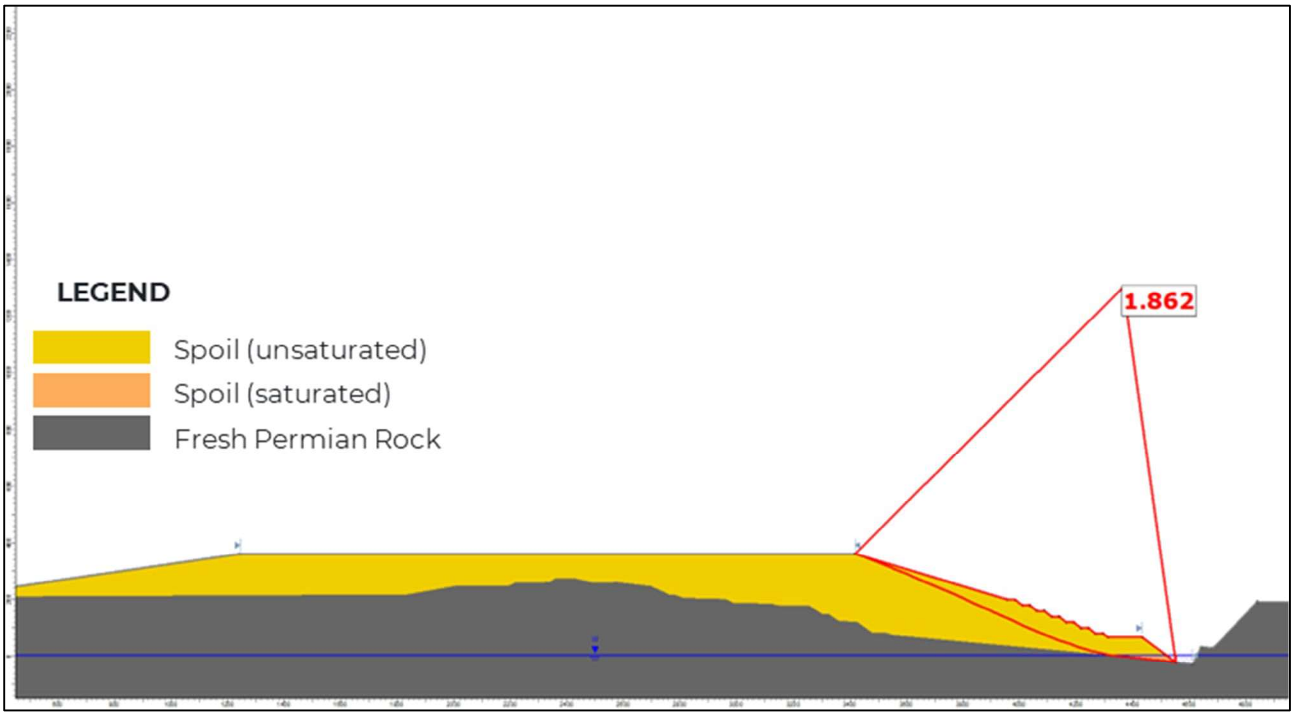


Figure 7.3 Jacaranda/Bauhinia residual void (cross-section 1) – global stability (Morgenstern-Price, non-circular)

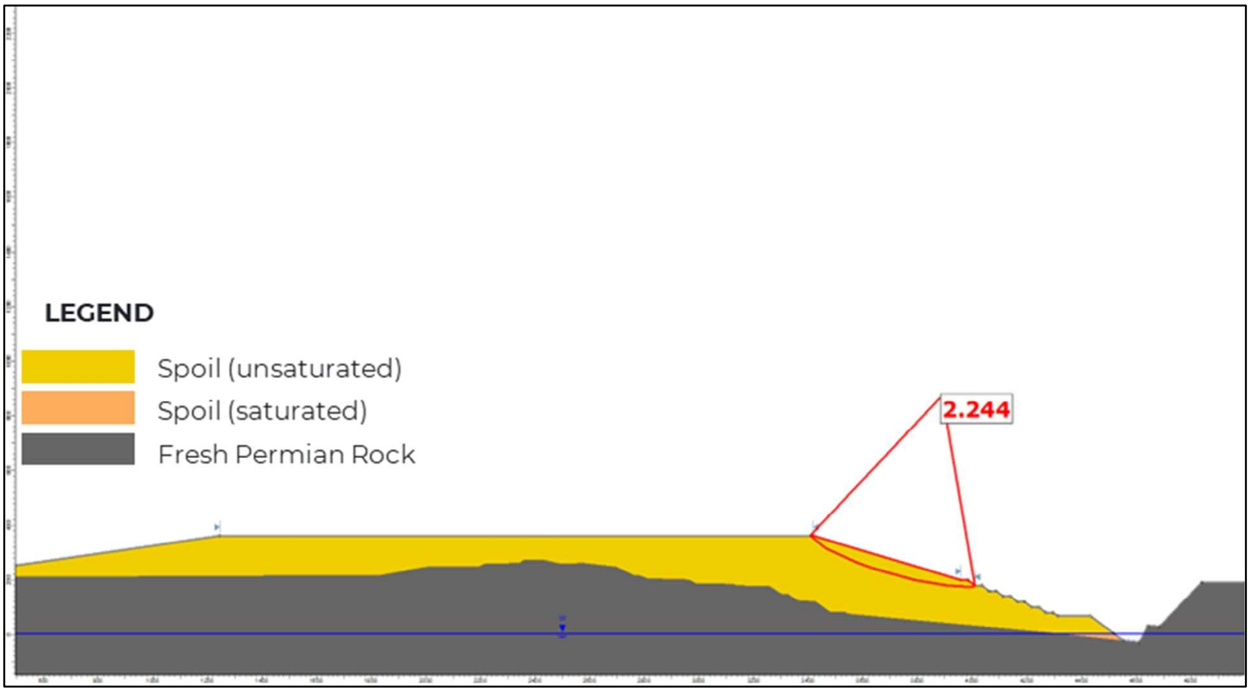


Figure 7.4 Jacaranda/Bauhinia residual void (cross-section 1) – local stability (Morgenstern-Price, non-circular)

7.2.2 Coolibah/Dogwood residual void

The geotechnical stability assessment for Coolibah/Dogwood residual void (cross-section 2) concluded that, for the final closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was greater than 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results are provided in Table 7.6, Figure 7.5, and Figure 7.6.

Table 7.6 Summary of low-wall stability analysis results for Coolibah/Dogwood residual void (Morgenstern-Price, non-circular)

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
2	410	1.93	2.20

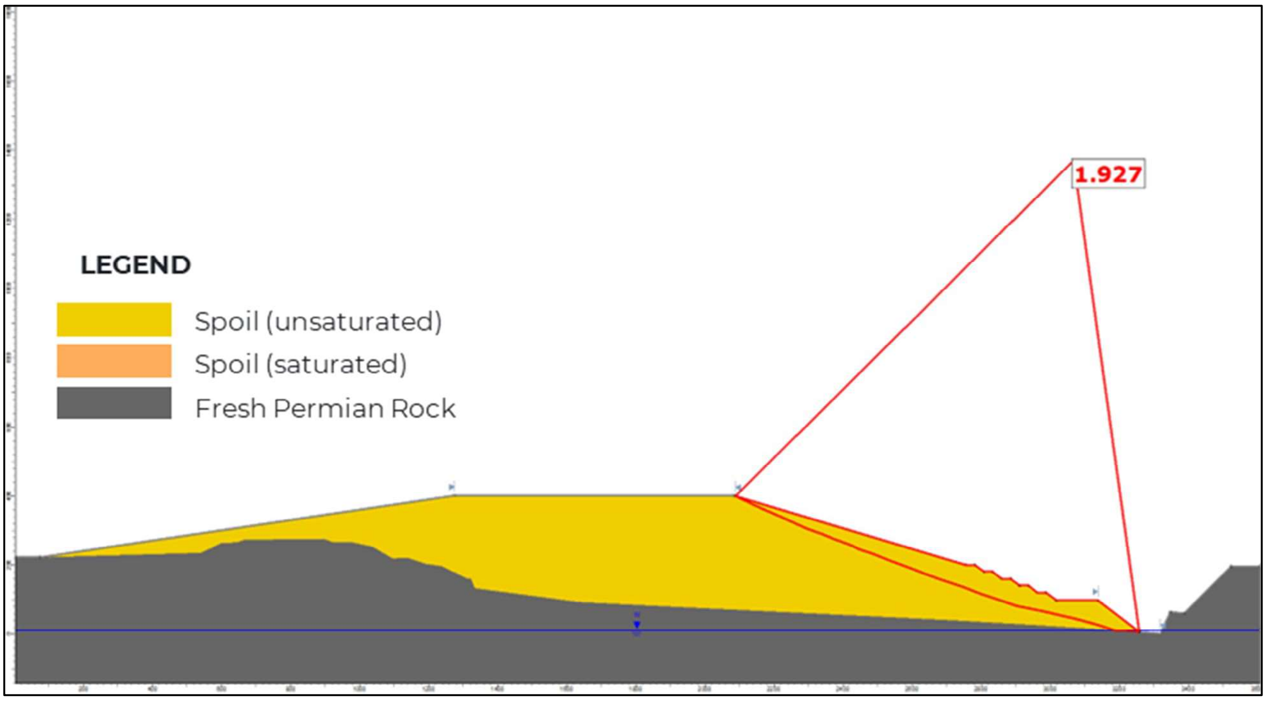


Figure 7.5 Coolibah/Dogwood residual void (cross-section 2) – global stability (Morgenstern-Price, non-circular)

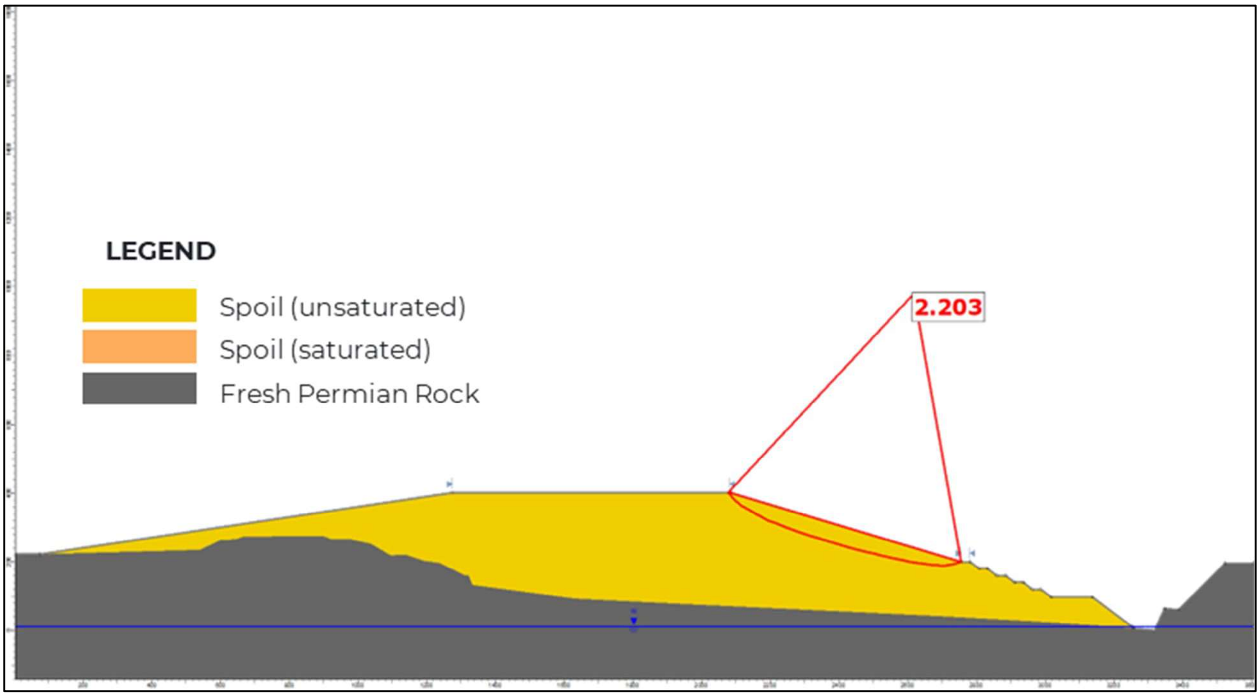


Figure 7.6 Coolibah/Dogwood residual void (cross-section 2) – local stability (Morgenstern-Price, non-circular)

7.2.3 Ebony/Grevillea residual void

The geotechnical stability assessment for the Ebony/Grevillea residual void (cross-section 3) concluded that, for the final closure state landform, closure state landform:

- The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was greater than 1.5.
- The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results are provided in Table 7.7, Figure 7.7, and Figure 7.8.

Table 7.7 Summary of low-wall stability analysis results for Ebony/Grevillea residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
3	490	1.53	2.20

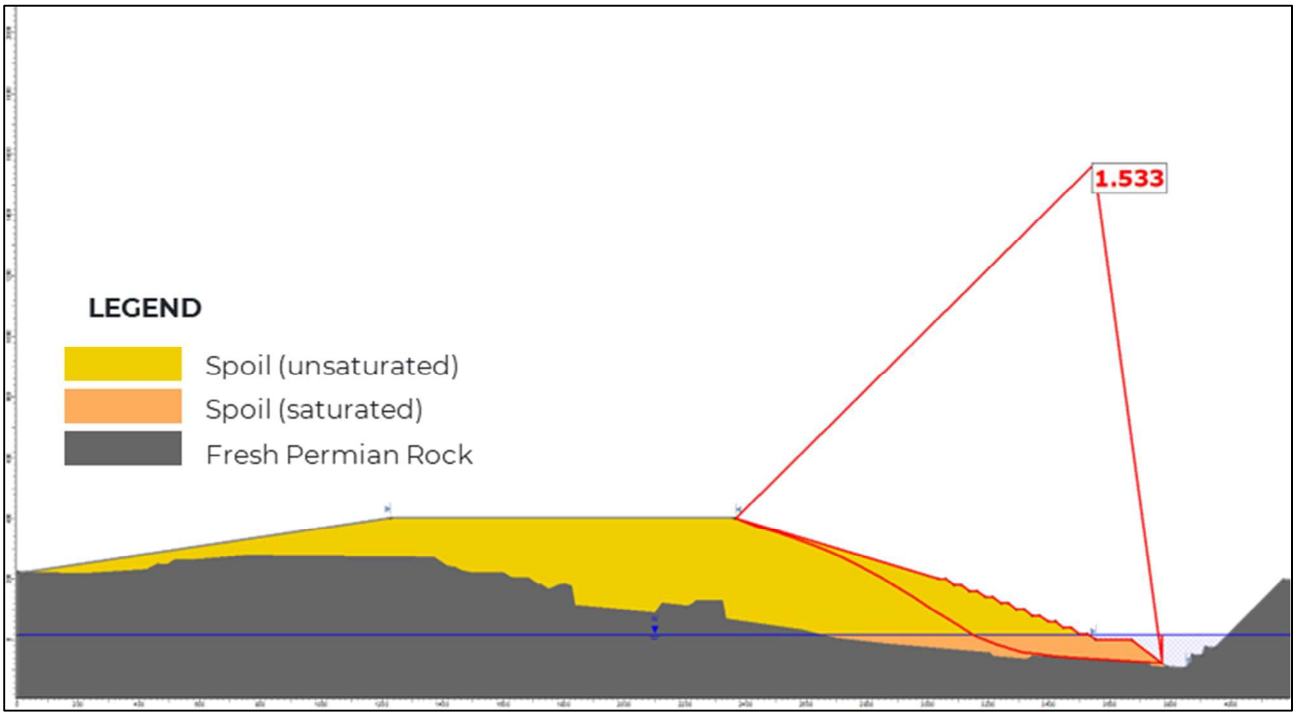


Figure 7.7 Ebony/Grevillea residual void (cross-section 3) – global stability (Sarma non-vertical slices)

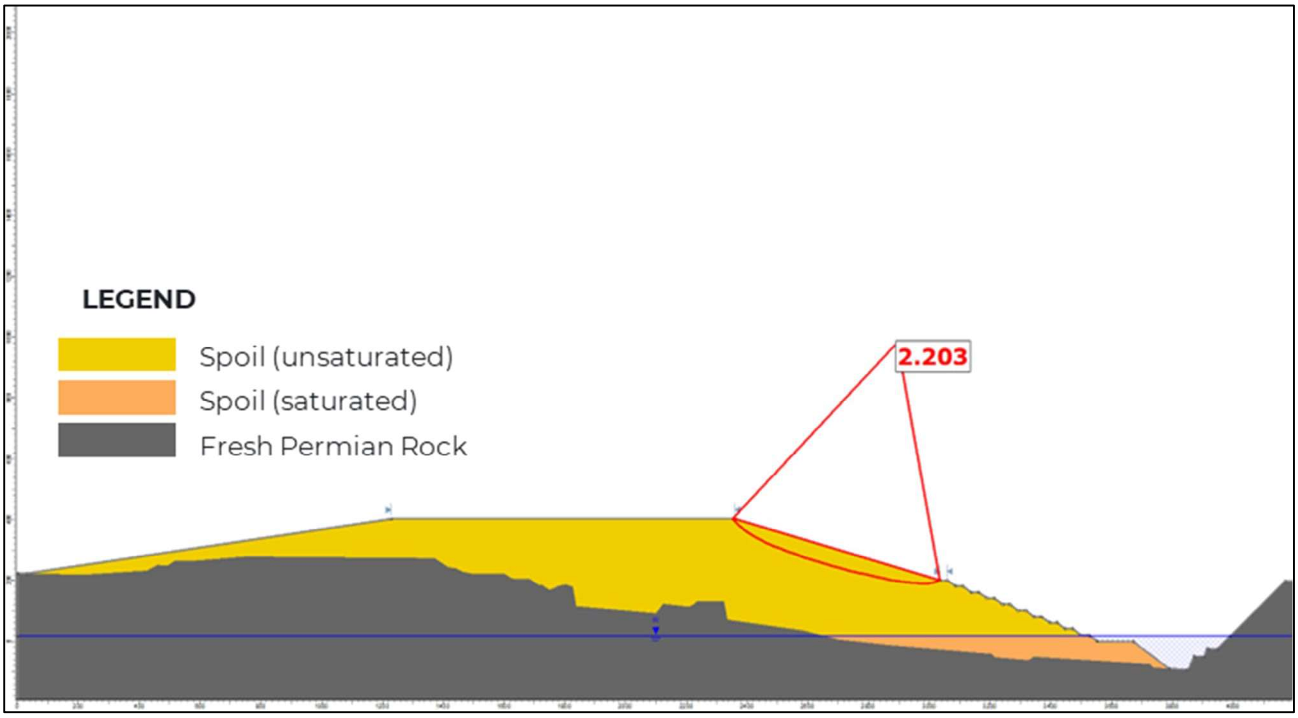


Figure 7.8 Ebony/Grevillea residual void (cross-section 3) – local stability (Morgenstern-Price, non-circular)

7.2.4 *Hakea residual void*

The geotechnical stability assessment for Hakea residual void (section 4) concluded that, for the final closure state landform, closure state landform:

— The minimum FoS for all potential slip surfaces affecting the low-wall slope outside the NUMA was greater than 1.5.

— The stability requirements of a FoS ≥1.5 for the overall slope and for slopes outside the NUMA are met.

A summary of the analysis results are provided in Table 7.8, Figure 7.9, and Figure 7.10.

Table 7.8 Summary of low-wall stability analysis results for Hakea residual void

Section	Low-wall spoil height (approx.) (m)	Minimum factor of safety	
		Overall slope (global stability)	Slope outside NUMA (local stability)
4	289	1.90	2.28

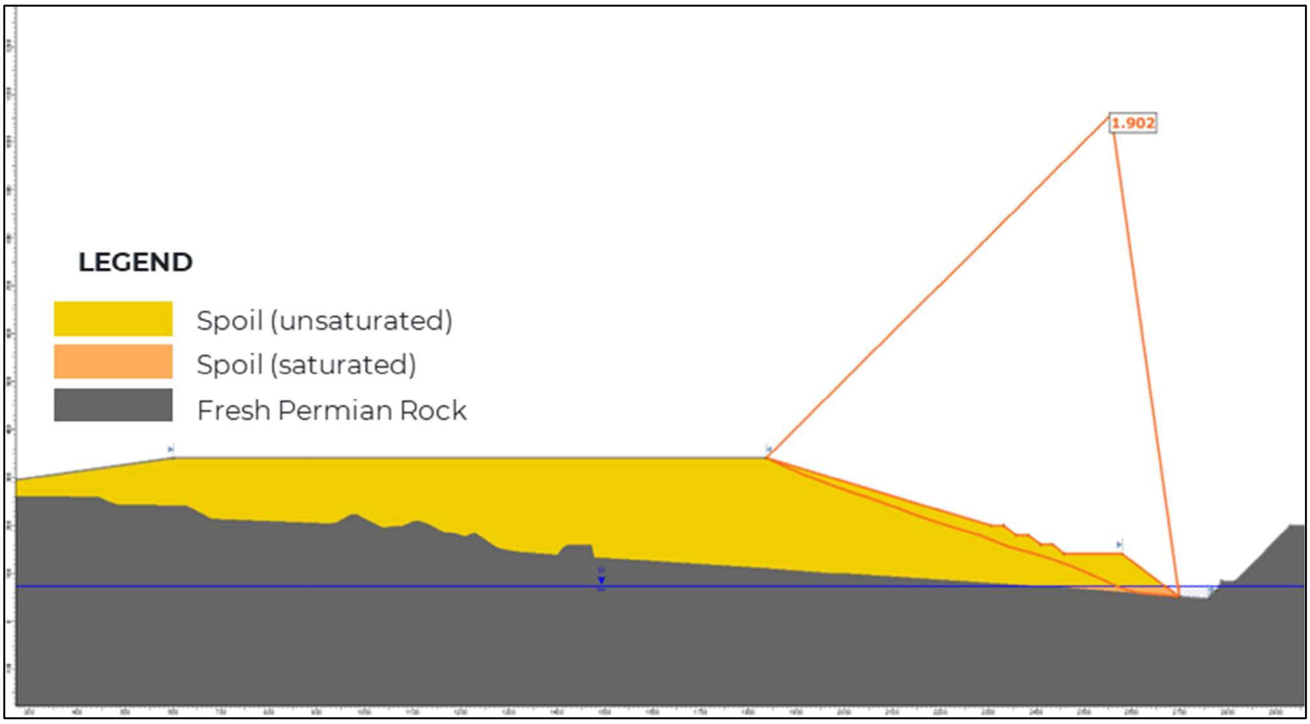


Figure 7.9 Hakea residual void (cross-section 4) – global stability (Sarma non-vertical slices)

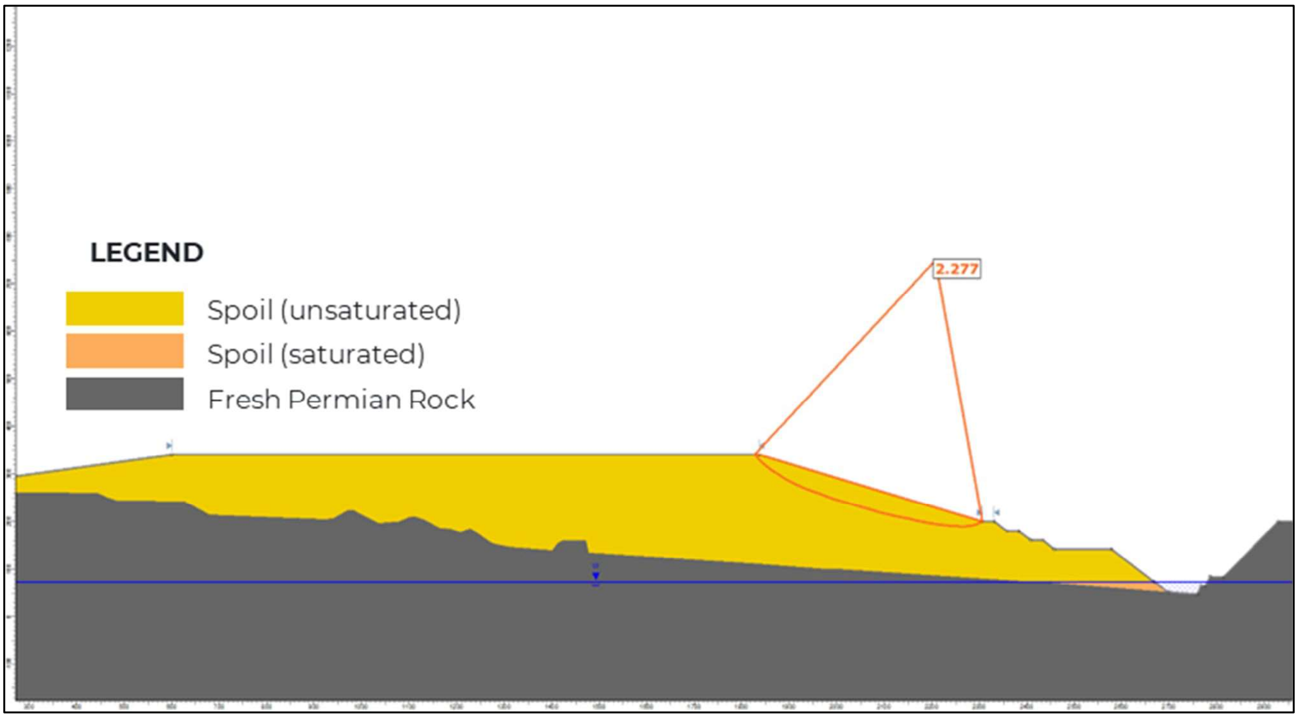


Figure 7.10 Hakea residual void (cross-section 4) – local stability (Morgenstern-Price, non-circular)

7.2.5 Assumptions

The following assumptions were made and used to inform the low-wall geotechnical stability assessments:

- The current assessment of stability of the low-wall final closure state landform at SRM is preliminary in nature. It has been based on inputs and assumptions that will be reviewed and verified as mining approaches the final void limits and more geological and geotechnical data becomes available.
- This assessment has not considered any effects of surface erosion on the stability of the low-wall spoil slopes.

- The agreed minimum FoS for any potential slip surfaces affecting low-wall slopes outside the NUMA was assigned a FoS equal to 1.5 (in accordance with EA condition E3 and Table E1).
- Based on the results of the WBM, the final void water equilibrium levels assumed for the low-wall stability analyses was 3 m AHD for Jacaranda/Bauhinia residual void, 14 m AHD for Coolibah/Dogwood residual void, 16 m AHD for Ebony/Grevillea residual void and 74 m AHD for Hakea residual void.
- Material parameters were adopted from Table 5 of the BHP Geotechnical Design, Operating and Monitoring Manual (BHP, 2020). These parameters are presented in Table 7.9 and are consistent with published values, WSP experience, and BMA practice.

Table 7.9 Adopted material parameters for the SRM low-wall geotechnical assessment (BHP, 2020)

Material	Bulk unit weight of intact rock (kN/m^3)	Cohesion (kPa)	Angle of friction (°)
Spoil (down dip, unsaturated)	18	40	30
Spoil (down dip, saturated)	20	23	25
Fresh Permian rock	24	450	42

- The spoil material was assumed to be homogeneous throughout, with all spoil above the void water equilibrium level assigned the same material parameters (spoil down dip, unsaturated), and all spoil below the void water equilibrium level assigned the same material parameters (spoil down dip, saturated).
- Any weak seams that might have been present within the sub-floor strata were assumed to have been treated by disrupting them with floor ripping or blasting, as required by BMA current operating procedures. Therefore, no such structures have been considered present in the current preliminary stability assessment of the conceptual low-wall slopes.
- No clay-rich spoil or mud will be present on the pit floor at the time when spoil is dumped there. Appropriate floor preparation was assumed to have been completed prior to placing the spoil on the pit floor, as required by BMA current operating procedures. Therefore no 'weak layer' was assumed to be present at pit floor level.

8 Geochemical stability

A geochemical assessment has been undertaken to identify the geochemical characteristics of high-wall material and mine waste materials (spoil and rejects) and model the resulting effects on long-term water quality of void lakes within the final closure state landforms for the SRM residual voids.

The objectives of the geochemical assessment were to:

- Predict the changes in water quality of SRM residual voids in a long-term closure scenario.
- Determine, at a conceptual level (by comparison to EA groundwater trigger values), whether the predicted void lake water quality may impact the surrounding environment in a closure setting.
- Determine, at a conceptual level, if stratified conditions are likely to develop within the voids.

This geochemical assessment builds directly on the void water balance assessment undertaken for the SRM residual voids (see Section 6) and covers the same timeframe: a period of 120 years post-closure (2080 through 2199) for all voids except Hakea. The Hakea void simulation period was extended by 50 years (2080 to 2259 – 180 years). Within these timeframes, the water level in the void lakes reach an equilibrium.

8.1 Water quality model

8.1.1 Geochemical materials

The geologic materials and associated mine waste materials (spoil and rejects) may react with water and release or immobilise solutes, according to their geochemical characteristics. Material interactions considered in the water quality model include:

- Highwall lithologies interacting with rainfall/runoff.
- In-pit spoil, rejects, and tailings covered with non-carbonaceous interburden interacting with rainfall/runoff (infiltration of rainfall through the spoil, rejects, and tailings was not included).
- Non-carbonaceous interburden used for covering the outside of the landform interacting with rainfall/runoff.
- Natural catchment interacting with rainfall/runoff. The natural catchment is assumed to be composed of weathered materials.

For the purposes of the geochemical assessment, the lithological materials present in the excavated walls of the SRM residual voids, and their distribution were classified into five lithological domain groupings (Table 8.1). The relative proportions of each lithological group on current and future post-closure high-walls were derived from the stratigraphic distribution (meterage) of each material within selected drill holes. Material that had no lithological classification (classified as unknown) was reallocated to carbonaceous and non-carbonaceous domains using the carbonaceous percentage in Table 8.1.

Table 8.1 Proportions of lithologies in the excavated SRM void walls (high-wall database 09/03/2022)

Lithology grouping	Excavated high-wall exposure (%)				
	SRM, all sites	Jacaranda/ Bauhinia	Coolibah/ Dogwood	Ebony/ Grevillea	Hakea
Tertiary	10.1	11.0	13.4	6.3	21.2
Non carbonaceous overburden	49.5 (76.1)	38.5 (75.7)	48.5 (70.9)	53.9 (79.6)	60.3 (68.2)
Weathered coal	0.3	0.1	0.2	0.4	0.8

Lithology grouping	Excavated high-wall exposure (%)				
	SRM, all sites	Jacaranda/ Bauhinia	Coolibah/ Dogwood	Ebony/ Grevillea	Hakea
Carbonaceous overburden	2.8 (4.3)	2.1 (4.2)	5.7 (8.1)	2.8 (4.1)	2.2 (2.0)
Coal	9.2	8.9	8.8	9.6	7.4
Unknown	28.2	39.3	23.4	26.9	8.2
Total:	**100**	**100**	**100**	**100**	**100**
Carbonaceous %	**5.3**	**5.2**	**10.5**	**4.9**	**3.5**

Note: Carbonaceous % used to redistribute 'unknown' to carbonaceous and non-carbonaceous. Rescaled results are indicated in brackets.

8.1.2 *Geochemical source terms*

The geochemical source terms were derived from the BMA environmental geochemistry databases. Drill core databases including information for the MCM were available for Caval Ridge Mine, SRM, and Peak Downs Mine. These were combined to generate one master database from which the MCM terms were derived. Comparison of short-term leach data for the spoil collected across the MCM sites displays no significant differences between sites.

For the derivation of the groundwater source term, groundwater data from 2009 to 2017 was used that included monitoring information from seven monitoring bores. Groundwater bores are screened in three main aquifers – alluvial aquifers (two bores), Tertiary and Permian aquifers (eight bores). No distinction was made between these aquifers for the derivation. The data used for the derivation of these source terms and the derived source terms are summarised in Table 8.2 and Table 8.3.

Table 8.2 Summary of data used to derive geochemical source terms for the SRM residual voids

Source term (water balance)	Comment	n	Source
Natural catchment runoff	Median of compiled MCM leach test result from weathered non-carbonaceous drill core samples	67	MCM Drill core database
Rehabilitated catchment runoff (in pit spoil runoff)	Median of compiled MCM leach test results from fresh non-carbonaceous drill core samples (Permian interburden specified as cover material for final landform)	136	MCM Drill core database
High-wall runoff	BMA's drill core databases for MCM sites were combined for statistical rigour and used to derive source terms for each lithological domain. The median of all leach test results for each domain was combined for each pit in the proportions of their high-wall exposure. Alkalinity is defined on a small subset of samples (SRM only; n~80) due to data quality.	287	MCM Drill core database
Groundwater inflow	Median water quality from SRM groundwater database; assumed pe = 4.0	112	SRM Groundwater database
Rainfall	Pure water equilibrated with atmospheric CO_2	-	-

Notes: *Surface water data from the surface water quality database were not suitable for modelling purposes due to a lack of cation data; '-' indicates not available; n= number of samples; pe = electron activity expressed in factors of 10 : pE = -log(e-)

Table 8.3 Summary of geochemical source terms (median results) derived from SRM's data sources

Parameter	Unit	MCM drill core leach test data				Groundwater	Rainfall
		Coal	Carbonaceous	Fresh non-carbonaceous	Weathered non-carbonaceous		
pH	pH units	8.8	9.0	9.1	9.0	7.80	5.5
Log of electron activity (pe) [1]		8	8	8	8	4	8
Measured Alkalinity	mg $CaCO_3$/L	42	70.5	115.5	62	557	n/a
Calculated Alkalinity [2]	mg $CaCO_3$/L	81.8	79.5	95.3	24	n/a	5.10^{-5}
Chloride (Cl) [3]	mg/L	36 (42.2)	22 (36.4)	26	130	1870 (2071)	-
Fluoride (F)	mg/L	0.28	0.55	0.7	1.15	-	-
Sulphate (SO_4)	mg/L	48	48	46	57	435	-
Nitrogen (N)	mg/L	0.045	0.055	0.045	0.105	*0.01*	-
Calcium (Ca)	mg/L	*1*	*1*	*1*	4	227	-
Magnesium (Mg)	mg/L	*1*	*1*	*1*	3	192.5	-
Sodium (Na) [3]	mg/L	66	74.5	63 (86.3)	112.5 (128.0)	1165	-
Potassium (K)	mg/L	2	4	6	6	2	-
Silver (Ag)	mg/L	*0.0005*	*0.0005*	*0.001*	*0.001*	*0.0005*	-
Aluminium (Al)	mg/L	0.05	0.07	0.12	0.03	*0.01*	-
Arsenic (As)	mg/L	0.004	0.016	0.020	0.010	*0.001*	-
Boron (B)	mg/L	*0.1*	*0.1*	*0.1*	*0.1*	-	-
Barium (Ba)	mg/L	0.024	0.01	0.017	0.1	-	-
Beryllium (Be)	mg/L	*0.001*	*0.001*	*0.001*	0.01	-	-
Bismuth (Bi)	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	-	-
Cadmium (Cd)	mg/L	*0.001*	*0.00005*	*0.001*	0.01	-	-
Cobalt (Co)	mg/L	*0.001*	*0.001*	*0.001*	0.01	-	-

Parameter	Unit	MCM drill core leach test data				Groundwater	Rainfall
		Coal	Carbonaceous	Fresh non-carbonaceous	Weathered non-carbonaceous		
Chromium (Cr)	mg/L	*0.001*	*0.001*	*0.001*	0.01	-	-
Copper (Cu)	mg/L	*0.001*	*0.001*	*0.001*	0.01	-	-
Iron (Fe)	mg/L	0.1	*0.025*	0.1	*0.025*	0.11	-
Mercury (Hg)	mg/L	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	-
Manganese (Mn)	mg/L	0.002	*0.001*	*0.001*	0.01	-	-
Molybdenum (Mo)	mg/L	0.028	0.04	0.046	*0.005*	*0.001*	-
Nickel (Ni)	mg/L	*0.001*	*0.001*	*0.001*	0.01	-	-
Phosphorous (P)	mg/L	*0.5*	*0.5*	*0.5*	*0.5*	*0.005*	-
Lead (Pb)	mg/L	*0.001*	*0.001*	*0.001*	0.01	-	-
Antimony (Sb)	mg/L	0.002	0.004	0.004	*0.001*	*0.001*	-
Selenium (Se)	mg/L	*0.01*	0.02	*0.01*	*0.01*	*0.005*	-
Tin (Sn)	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	-	-
Strontium (Sr)	mg/L	0.1	0.085	0.1	0.1	-	-
Thorium (Th)	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	-	-
Titanium (Ti)	mg/L	*0.005*	*0.005*	*0.01*	*0.005*	-	-
Thallium (Tl)	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	-	-
Uranium (U)	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	-	-
Vanadium (V)	mg/L	*0.01*	*0.01*	*0.01*	*0.01*	-	-
Tungsten (W)	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	-	-
Zinc (Zn)	mg/L	*0.005*	*0.0025*	*0.005*	0.01	-	-
Zirconium (Zr)	mg/L	*0.0025*	*0.0025*	*0.0025*	*0.0025*	-	-
Charge % error		**+15.1%**	**+2.7%**	**-5.3%**	**-6.6%**	**+3.7%**	**N/A**

Parameter	Unit	MCM drill core leach test data				Groundwater	Rainfall
		Coal	Carbonaceous	Fresh non-carbonaceous	Weathered non-carbonaceous		
Charge balance		**+ Cl**	**+ Cl**	**+ Na**	**+ Na**	**+ Cl**	**N/A**
Used to represent:		**High-wall runoff**	**High-wall runoff**	**High-wall and spoil runoff**	**High-wall and natural catchment runoff**	**Groundwater inflow**	**Direct rainfall**

Notes:

(1) Assumed value for modelling purposes

(2) Calculated alkalinity based on using carbon species to achieve charge balance.

(3) Adjusted for charge balance. Adjusted value indicated in brackets.

'-' indicates not measured; treated as a concentration of zero.

italics indicate a median result that is equal to or less than the limit of reporting (LOR), following substitution of LOR with 0.5 LOR.

8.1.3 Geochemical model approach and development

The geochemical model was run for major cations, anions, and selected metal(loid)s per the availability of data. Further discussion is focused on pH and total dissolved solids (TDS) as identified in the rehabilitation requirements of the EA (EPML00862313).

Results for each time-step were calculated using the geochemical modelling code PHREEQC (Parkhurst, 2013) with the Minteq.v4 thermodynamic database, derived from the MINTEQA2 version 4 database (US EPA, 1998).

The geochemical model contained the following features:

- Source terms were mixed for monthly timesteps, with inflow/outflow proportions calculated from the GoldSim water balance.
- Modelling was incremental, with the output for the void lake from the previous timestep being used as the input for the next time step.
- Geochemical reactions, such as mineral precipitation/dissolution, gas exchange, and sorption.

The following assumptions apply to the geochemical model:

- At all times, the void lake is fully mixed, geochemical reactions occur within the modelled timestep and are not kinetically controlled. Mineral precipitates are retained within the void lake.
- Solute release from high-wall rock and spoil does not occur below the lake water level.
- The release of coal bed methane is not a significant process and does not drive groundwater or lake chemistry towards more reducing conditions.
- There is no seepage from the void to the groundwater system as the voids act as groundwater sinks.
- There is no infiltration of rainfall or groundwater through the in-pit waste to the void lake.
- Stratification is assessed at a conceptual level based on a TDS threshold. Seasonal temperature, wind patterns and other impacts on mixing are not considered.
- The geochemical model does not account for biological processes.

A model sensitivity test was performed to highlight the role of geochemical controls on predicted water quality. The two simulations are summarised in Table 8.4 and were performed for the mean water balance scenario.

Table 8.4 Model sensitivity simulations

Simulation	Atmospheric CO_2 equilibrium	Mineral precipitation	Surface adsorption
Base case	Equilibrium at $10^{-3.38}$ (420 ppm)*	Equilibrium	Adsorption onto ferrihydrite
No geochemical controls	No equilibrium	No equilibrium	No sorption

Note: *420 parts per million (ppm) is representative of 2022 atmospheric CO_2 concentrations. Variation with time (i.e., geochemical climate change scenarios) is not included in current model scenarios.

A conceptual level assessment of potential chemical stratification was conducted based on the evolution of TDS, which can be used to approximate the fluid density of the fully mixed void lake. Stratification assessment is provided in Section 8.2.

8.2 Residual void water quality outcomes

The following sections present the results of the geochemical modelling for the void lakes at SRM for pH and TDS. The results are presented for scenarios with and without geochemical controls/reactions (i.e., mineral precipitation, sorption, and gas exchange).

8.2.1 Jacaranda/Bauhinia residual void

Based on the outcomes of this assessment, the void water quality in Jacaranda/Bauhinia residual void is predicted to evolve over time with TDS simulated to increase following closure due to groundwater inflows and evapoconcentration. The pH exceeds the upper EA range initially before returning to below the upper EA range around 2130 for the simulation without geochemical controls, and the end of the simulation when geochemical controls are considered. As the Jacaranda/Bauhinia residual void is considered a NUMA and current groundwater (Section 4) and water balance (Section 6) modelling indicates the residual void remains a sink after the void lake levels have reached equilibrium post-closure, exceedances should be considered in this context. The model results for pH and TDS at Jacaranda/Bauhinia residual void are presented in Figure 8.1. The results are summarised as follows:

pH:

- Acidic conditions are unlikely to form in the Jacaranda/Bauhinia residual void lake, with models indicating mildly alkaline pH. In the simulation without geochemical controls, modelled pH levels initially exceed the upper EA range up to ~2105 and subsequently decreases for the remaining model duration, falling below the upper EA range from ~2130. In the simulation with geochemical controls, modelled pH levels initially exceed the upper EA range and subsequently decreases for the remaining model duration, however, remain above the upper EA range until the end of the modelled period.
- The simulation with geochemical controls results in a higher pH than the simulation without geochemical controls. The main geochemical control is CO_2 degassing which raises pH, resulting in calcite/magnesite precipitation and dissolution that reduces and raises pH respectively. These geochemical processes are driven by the input of sources of dissolved inorganic carbon via surface runoff and groundwater to the void lake.

TDS:

- TDS concentrations increase with time, primarily driven by evapoconcentration and the input of groundwater and retained a 20-year cyclicity from the WBM with minor seasonal variation. Brackish to mildly saline conditions develop however TDS concentrations remain below the upper and lower EA-derived trigger values for the modelled period regardless of whether geochemical controls are applied or not.
- TDS concentrations are lower in simulations with geochemical controls due to the removal of calcium, magnesium and alkalinity through magnesite and calcite precipitation. Geochemical controls do not lead to an ‘equilibrium’ state for water quality (i.e., constant TDS). Other mineral phases predicted to precipitate do not significantly affect TDS, these include barite ($BaSO_4$), and ferrihydrite ($FeOH_3$).

Stratification:

- The steep sides of the void and the maximum water depth (approx. 58 m) present favourable conditions for stratification. Water of higher density (cooler or more saline) may potentially become isolated at depth. Hydrodynamic/limnological analysis is required to assess the potential for onset of thermal/chemical stratification, and the importance of seasonal mixing processes and groundwater mixing inputs. However, as the residual voids are considered NUMAs and modelled as groundwater sinks, further stratification assessment is not warranted.

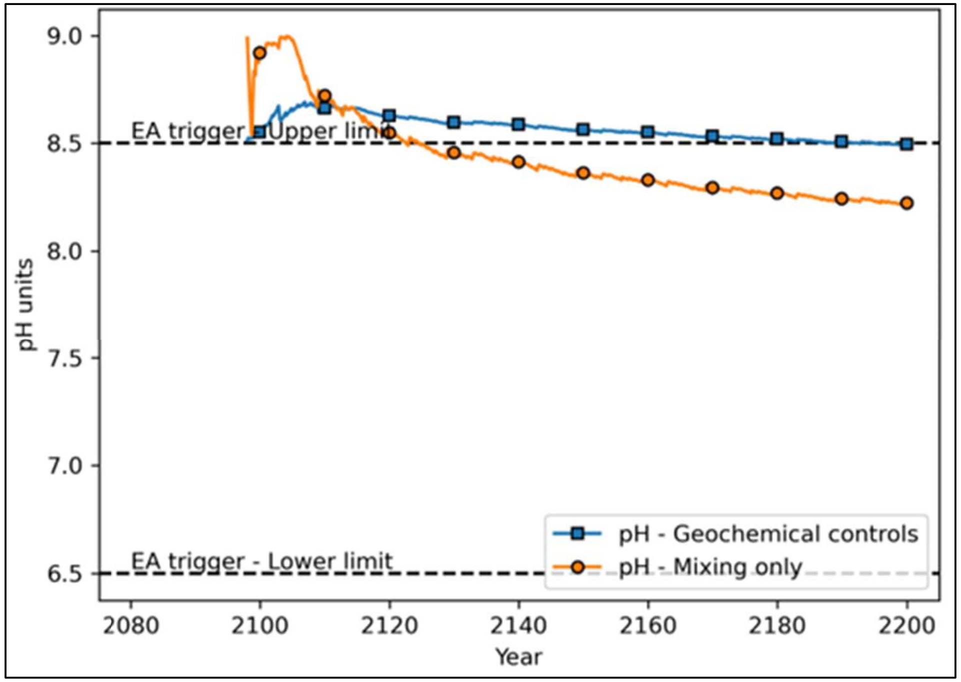
Model Quality Control (QC):

- The log of the electron activity (pe) and water mass conservation stay within a suitable range throughout the model duration.

Indicative timing for EA exceedance occurrences for Jacaranda/Bauhinia residual void is presented in Table 8.5.

Table 8.5 Jacaranda/Bauhinia residual void EA exceedance occurrence by decade

Parameter	Exceedance occurrence (by decade)			
	EA minimum trigger value		EA maximum trigger value	
	Geochemical controls	No geochemical controls	Geochemical controls	No geochemical controls
pH	2100-2160	2098-2130	2100-2160	2098-2130
TDS	N/A	N/A	N/A	N/A



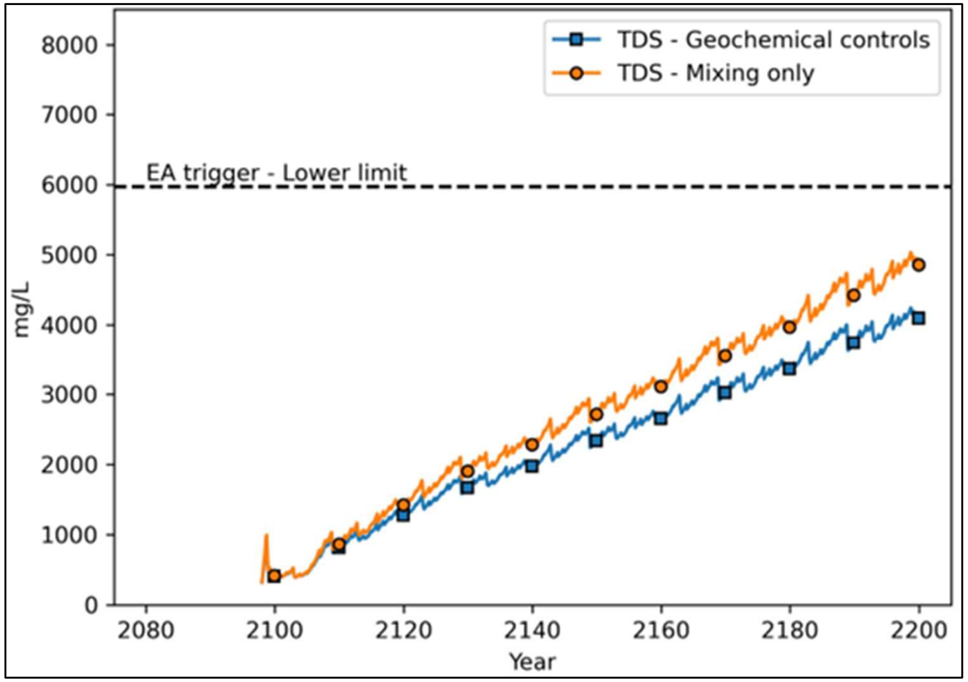


Figure 8.1 Jacaranda/Bauhinia residual void pH and TDS evolution

8.2.2 Coolibah/Dogwood residual void

Based on the outcomes of this assessment, the void water quality in Coolibah/Dogwood residual void is predicted to evolve through time with TDS simulated to increase following closure as a result of groundwater inflows and evapoconcentration. The pH exceeds the upper EA range initially before returning to below the upper EA range around 2130 for the simulation without geochemical controls. When geochemical controls are considered, pH remains above the upper EA range for the duration of the simulation. As Coolibah/Dogwood residual void is considered a NUMA and current groundwater (Section 4) and water balance (Section 6) modelling indicates the residual void remains a sink after the void lake levels have reached equilibrium post-closure, exceedances should be considered in this context. The model results for pH and TDS at Coolibah/Dogwood residual void are presented in Figure 8.2. The results are summarised as follows:

pH:

- Acidic conditions are unlikely to form in the Coolibah/Dogwood residual void lake, with models indicating mildly alkaline pH. In the simulation without geochemical controls, modelled pH levels initially exceed the upper EA range and subsequently decreases for the remaining model duration, falling below the upper EA range from ~2130. In the simulation with geochemical controls, modelled pH levels initially increase before declining from ~2110 onwards but remain above the upper EA range for the duration of the model.
- The simulation with geochemical controls results in a variable pH (and higher toward the end of the simulation period) than the simulation without geochemical controls. The main geochemical control is CO_2 degassing which raises pH, resulting in calcite/magnesite precipitation and dissolution that reduces and raises pH respectively. These geochemical processes are driven by the input of sources of dissolved inorganic carbon via surface runoff and groundwater to the void lake.

TDS:

- TDS concentrations increase systematically with time, primarily driven by evapoconcentration and the input of groundwater and retained a 20-year cyclicity from the WBM with minor seasonal variation. Brackish to mildly saline conditions develop but TDS concentrations remain below the upper EA-derived trigger values for the modelled period regardless of whether geochemical controls are applied or not. Without geochemical controls, TDS concentrations exceed the lower EA-derived trigger value by the year 2190. With geochemical controls, TDS concentrations do not exceed the lower EA-derived trigger value.
- TDS concentrations are lower in simulations with geochemical controls due to the removal of calcium, magnesium and alkalinity through magnesite and calcite precipitation. Geochemical controls do not lead to an 'equilibrium' state for water quality (i.e., constant TDS). Other mineral phases predicted to precipitate do not significantly affect TDS, these include barite ($BaSO_4$), tenorite (CuO), and ferrihydrite ($FeOH_3$).

Stratification:

- Elevated TDS, the steep sides of the void, and the maximum water depth (approx. 53 m) may all present favourable conditions for stratification. Water of higher density (cooler or more saline) may potentially become isolated at depth. Hydrodynamic/limnological analysis is required to assess the potential for onset of thermal/chemical stratification, and the importance of seasonal mixing processes and groundwater mixing inputs. However, as the residual voids are considered NUMAs and modelled as groundwater sinks, further stratification assessment is not warranted.

Model QC:

- The log of the electron activity (pe) and water mass conservation stay within a suitable range throughout the model duration.

Indicative timing for EA exceedance occurrences for Coolibah/Dogwood residual void is presented in Table 8.6.

Table 8.6 Coolibah/Dogwood residual void EA exceedance occurrence by decade

Parameter	**Exceedance occurrence (by decade)**			
	EA minimum trigger value		**EA maximum trigger value**	
	Geochemical controls	**No geochemical controls**	**Geochemical controls**	**No geochemical controls**
pH	2090	2082-2120	2090	2082-2120
TDS	N/A	2190	N/A	N/A

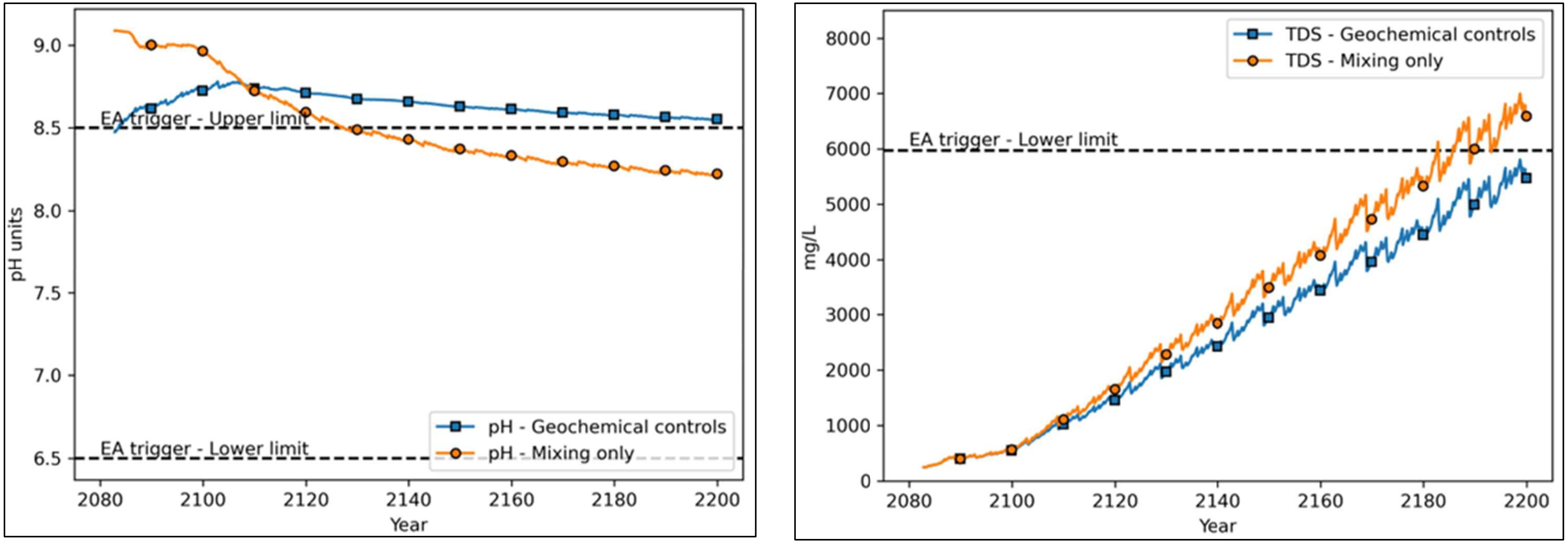


Figure 8.2 Coolibah/Dogwood residual void pH and TDS evolution

8.2.3 Ebony/Grevillea residual void

Based on the outcomes of this assessment, the void water quality in the Ebony/Grevillea residual void is predicted to evolve through time with TDS simulated to increase following closure, as a result of groundwater inflows and evapoconcentration. The pH exceeds the upper EA range initially before returning to below the upper EA range around 2140 for the simulation without geochemical controls. When geochemical controls are considered, pH remains above the upper EA range for the duration of the simulation. As the Ebony/Grevillea residual void is considered a NUMA and current groundwater (Section 4) and water balance (Section 6) modelling indicates the residual void remains a sink after the void lake levels have reached equilibrium post-closure, exceedances should be considered in this context. The model results for pH and TDS at the Ebony/Grevillea residual void are presented in Figure 8.3. The results are summarised as follows:

pH:

- Acidic conditions are unlikely to form in the Ebony/Grevillea residual void lake, with models indicating mildly alkaline pH. In the simulation without geochemical controls, modelled pH levels initially exceed the upper EA range and subsequently decreases for the remaining model duration, falling below the upper EA range from ~2140. In the simulation with geochemical controls, modelled pH levels initially increase before declining from ~2110 onwards but remain above the upper EA range for the duration of the model.
- The simulation with geochemical controls results in a variable pH (and higher toward the end of the simulation period) than the simulation without geochemical controls. The main geochemical control is CO_2 degassing which raises pH, resulting in calcite/magnesite precipitation and dissolution that reduces and raises pH respectively. These geochemical processes are driven by the input of sources of dissolved inorganic carbon via surface runoff and groundwater to the void lake.

TDS:

- TDS concentrations increase systematically with time, primarily driven by evapoconcentration and the input of groundwater and retained a 20-year cyclicity from the WBM with minor seasonal variation. Brackish to mildly saline conditions develop however TDS concentrations remain below the upper and lower EA-derived trigger values for the modelled period regardless of whether geochemical controls are applied or not.
- TDS concentrations are lower in simulations with geochemical controls due to the removal of calcium, magnesium and alkalinity through magnesite and calcite precipitation. Geochemical controls do not lead to an 'equilibrium' state for water quality (i.e., constant TDS). Other mineral phases predicted to precipitate do not significantly affect TDS, these include barite ($BaSO_4$), tenorite (CuO) and ferrihydrite ($FeOH_3$).

Stratification:

- Elevated TDS, the steep sides of the void, and the maximum water depth (approx. 86 m) may all present favourable conditions for stratification. Water of higher density (cooler or more saline) may potentially become isolated at depth. Hydrodynamic/limnological analysis is required to assess the potential for onset of thermal/chemical stratification, and the importance of seasonal mixing processes and groundwater mixing inputs. However, as the residual voids are considered NUMAs and modelled as groundwater sinks, further stratification assessment is not warranted.

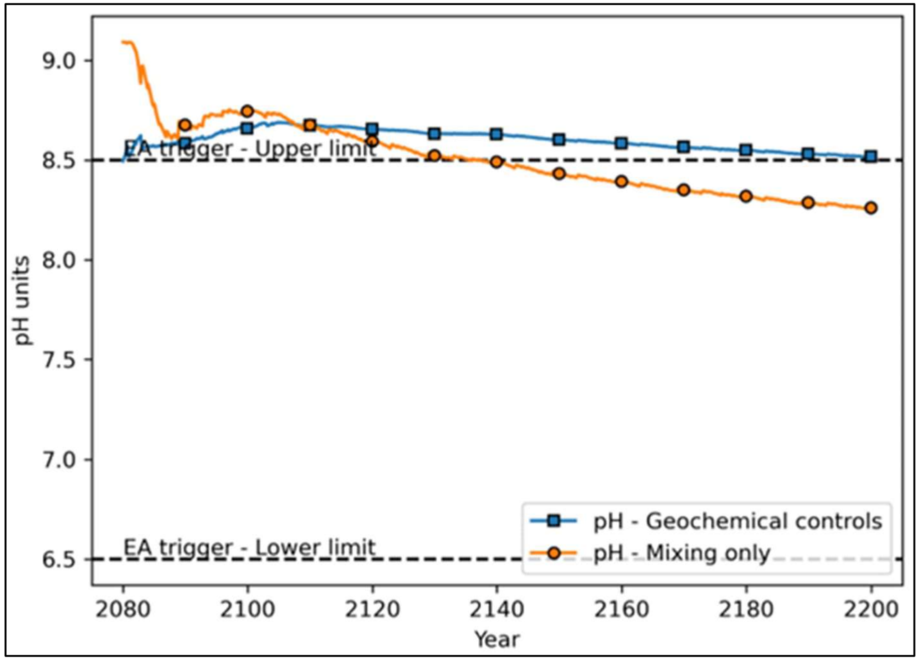
Model QC:

- The log of the electron activity (pe) and water mass conservation stay within a suitable range throughout the model duration.

Indicative timing for EA exceedance occurrences for Ebony/Grevillea residual void is presented in Table 8.7.

Table 8.7 Ebony/Grevillea residual void EA exceedance occurrence by decade

Parameter	Exceedance occurrence (by decade)			
	EA minimum trigger value		EA maximum trigger value	
	Geochemical controls	No geochemical controls	Geochemical controls	No geochemical controls
pH	2090-2170	2080-2120	2090-2170	2080-2120
TDS	N/A	N/A	N/A	N/A



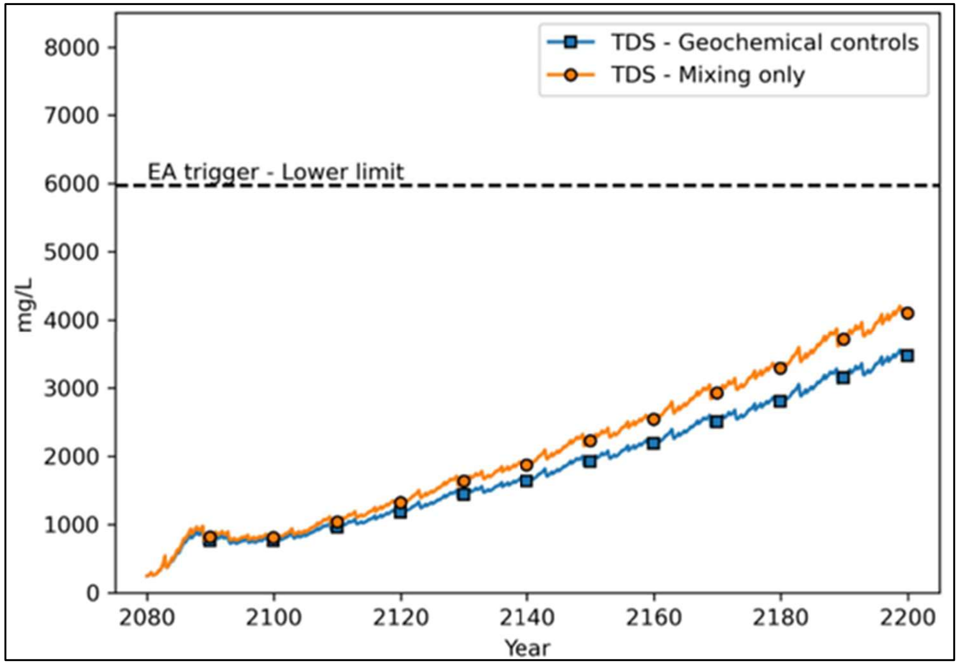


Figure 8.3 Ebony/Grevillea residual void pH and TDS evolution

8.2.4 Hakea residual void

Based on the outcomes of this assessment, the void water quality in Hakea residual void is predicted to evolve through time with TDS simulated to increase following closure, as a result of groundwater inflows and evapoconcentration. The pH generally exceeds the upper EA range initially before returning to below the upper EA range around 2190 for the simulation without geochemical controls, and the end of the simulation when geochemical controls are considered. As the Hakea residual void is considered a NUMA and current groundwater (Section 4) and water balance (Section 6) modelling indicates the residual void remains a sink after the void lake levels have reached equilibrium post-closure, exceedances should be considered in this context.

Due to model convergence issues from the initial transient lake levels between 2096 and 2108 where the lake intermittently dries out (see Section 6.2.4), this period was not modelled for the geochemical assessment. Water quality during this transient period is dominated by surface water runoff input that is subject to evapoconcentration. The water quality in this period is expected to be similar to that predicted prior to ~2160 when groundwater inputs begin to stabilise. This period includes two short duration peaks in TDS where evaporation is the dominant water output. The fluctuations in the modelled pH and TDS in the initial period of the simulation are a result of evaporation dominating the water output.

The model results for pH and TDS at the Hakea residual void are presented in Figure 8.4. The results are summarised as follows:

pH:

- Acidic conditions are unlikely to form in the Hakea residual void lake, with models indicating mildly alkaline pH. In the simulation without geochemical controls, modelled pH levels initially exceed the upper EA range and subsequently decreases for the remaining model duration, falling below the upper EA range from ~2190. In the simulation with geochemical controls, modelled pH levels initially exceed the upper EA range and subsequently decreases for the remaining model duration, falling below the upper EA criteria by the end of the modelled period.
- The simulation with geochemical controls results in a variable pH (and higher toward the end of the simulation period) than the simulation without geochemical controls. The main geochemical control is CO_2 degassing which raises pH, resulting in calcite/magnesite precipitation and dissolution that reduces and raises pH respectively. These geochemical processes are driven by the input of sources of dissolved inorganic carbon via surface runoff and groundwater to the void lake.

TDS:

- TDS concentrations increase systematically with time, primarily driven by evapoconcentration and the input of groundwater and retained a 20-year cyclicity from the WBM with minor seasonal variation. Brackish to mildly saline conditions develop however TDS concentrations remain below the upper EA-derived trigger values for the modelled period regardless of whether geochemical controls are applied or not. Without geochemical controls, TDS concentrations exceed the lower EA-derived trigger value by the year 2250. With geochemical controls, TDS concentrations exceed the lower EA-derived trigger value by the year 2260.
- TDS is lower in simulations with geochemical controls due to the removal of calcium, magnesium and alkalinity through magnesite and calcite precipitation. Geochemical controls do not lead to an ‘equilibrium’ state for water quality (i.e., constant TDS). Other mineral phases are predicted to precipitate but do not significantly affect TDS, including barite ($BaSO_4$) and ferrihydrite ($FeOH_3$).

Stratification:

- Elevated TDS, the steep sides of the void, and the maximum water depth (approx. 34 m) may all present favourable conditions for stratification. Water of higher density (cooler or more saline) may potentially become isolated at depth. Hydrodynamic/limnological analysis is required to assess the potential for onset of thermal/chemical stratification, and the importance of seasonal mixing processes and groundwater mixing inputs. However, as the residual voids are considered NUMAs and modelled as groundwater sinks, further stratification assessment is not warranted.

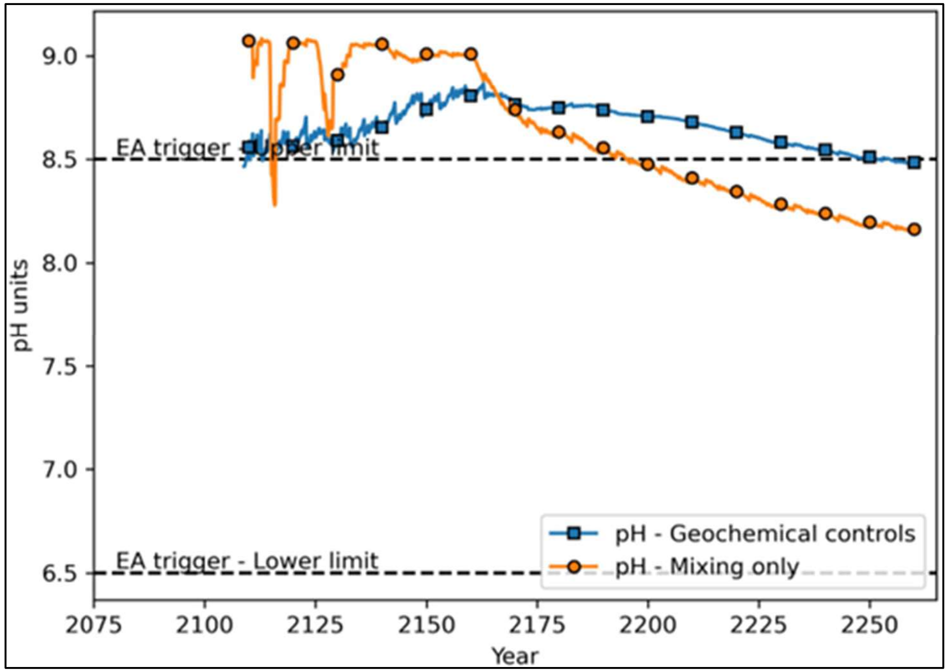
Model QC:

- The log of the electron activity (pe) and mass of water are observed to stay within a suitable range throughout the model duration.

Indicative timing for EA exceedance occurrences for Hakea residual void is presented in Table 8.8.

Table 8.8 Hakea residual void EA exceedance occurrence by decade

Parameter	Exceedance occurrence (by decade)			
	EA minimum trigger value		EA maximum trigger value	
	Geochemical controls	No geochemical controls	Geochemical controls	No geochemical controls
pH	2110-2230	2108-2190	2110-2230	2108-2190
TDS	2260	2250	n/a	n/a



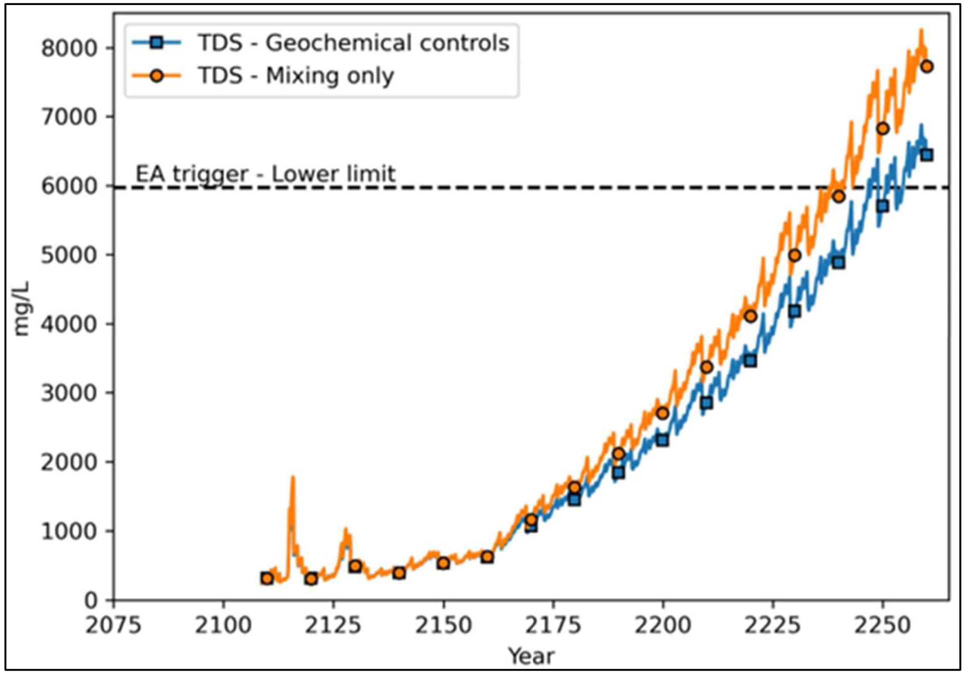


Figure 8.4 Hakea residual void pH and TDS evolution

8.2.5 Qualifications

The following caveats and limitations apply to the water quality model, in relation to the TDS and pH modelling, for the SRM residual voids:

- Available data at the time of modelling was used to represent relevant geochemical interactions. Availability of additional data in future may result in different model outputs.
- Water movements are based on complementary studies (groundwater and water balance). These studies constrain the model duration and the water sources. Most notably, it is currently not possible to quantify in-pit seepage through spoil.
- Screening was performed against EA criteria for groundwater contaminant trigger values. The criteria for TDS were derived from the EA electrical conductivity value using a 0.67 factor that is considered acceptable for freshwater.

9 Residual void management

A summary of the key findings from the technical studies (presented in Sections 4 to 8) used to inform the development of residual void management measures are presented below:

- Groundwater modelling and WBM results indicate the formation of void lakes in all four of the residual voids. Void lake levels are modelled to equilibrate below both pre-mining groundwater elevations and the base of shallow geologic formations.
- Continued evaporation from the void lakes will result in ongoing groundwater inflow to the residual voids (i.e., residual voids will act as terminal sinks). Groundwater outflows are not predicted in the long-term (i.e., >100 years post-mining), with the residual voids continuing to capture infiltration of rainfall through the in-pit spoil dumps.
- No additional impact beyond that which already exists at the end of mining is expected on surficial aquifers, including the shallow alluvium, and little to no impact on environmental or anthropogenic receptors (e.g. water extraction bores) is expected.
- WBM results predict that the voids will not overtop, with the residual voids achieving the mean void water levels and volumes in Table 9.1 at the end of the simulation; these are well below the spill elevations for the respective pits.

Table 9.1 Mean void water levels and volumes for the SRM residual voids

Residual void	Mean void water elevation (m AHD)	Mean void water volume (ML)
Jacaranda/Bauhinia	3	13,103
Coolibah/Dogwood	14.5	7,256
Ebony/Grevillea	-16	20,770
Hakea	74	3,305

- The final closure state landforms have been designed such that the geotechnical stability for the low-walls achieved a FoS ≥1.5. Therefore, the low-walls of the final closure state landforms can be considered stable for all residual voids.
- With regards to high-walls and end-walls, at closure the NUMA extents include identified set-back zones to achieve a FoS =1.5. All third-party assets will remain outside of these extents.
- At closure, the SRM residual voids will be bunded, fenced, with appropriate signage - where restricting access to the residual voids is required, to maintain safety for humans and livestock.
- For the final closure state landform, spoil dumping will be conducted so that the final residual voids associated with SRM are not subject to inundation from floodwaters up to and including the 0.1% AEP under the upper climate change rainfall intensity event.
- Monitoring and maintenance of the residual voids in accordance with the relevant section of the PRC plan is expected to be restricted to the following:
  - Monitoring and maintenance of exclusion fences/bunds to ensure these remain effective.
  - Groundwater and residual void lake level monitoring to confirm the voids are progressing towards acting as sinks.
- All four SRM residual voids will be retained as NUMAs. To support attainment of NUMA voids that are safe and do not present an unacceptable risk of off-tenure environmental harm, the management strategies presented in Table 9.2 will be implemented.

Table 9.2 SRM residual void closure context (safe, stable, non-polluting) and management considerations

Residual void closure aspect	Closure objective			Residual void closure context	Management consideration
	Safety	Stability	Non-polluting		
Geotechnical stability	✓	✓	-	— Stability outside of the NUMA extents = FoS $\geq$1.5 — Set-back distances for long-term pit wall stability have been defined by geotechnical analysis for all residual voids for high-walls, end-walls and low-walls — Setbacks are included within the NUMA extent to ensure stability and that no assets (BMA, third-party, or of significant environmental value) are retained within this boundary at closure.	— As mining approaches the final limits, re-assess the geotechnical setbacks based on the latest available data. — Review and adjust the mine plan and final closure state landform, if needed, to account for any revised set-back requirements. — Use a minimum FoS$\geq$1.5 as a guidance for ongoing void closure planning. (This may be refined over the mine life should industry research provide optimised guidance on observational methods and consequence assessment).
Void hydrology	✓	✓	✓	— All SRM final residual voids in the final closure state landform are not subject to inundation from floodwaters up to and including the 0.1% AEP event under the upper climate change rainfall intensity scenario based on rehabilitation flood modelling completed. — As the water levels remain below the groundwater levels for all SRM residual voids (and well below the voids' spill points), the voids will not overtop and environmental harm beyond that of the void itself is not expected. Therefore, no management activities required. — The long-term mean void lake levels for all SRM residual voids remain below groundwater level. This provides an available storage capacity for the void to keep acting as long-term sinks (based on average gradients).	— Residual void catchments are minimised as far as practicable and predominantly include only the low-wall areas. — At cessation of mining activities, review and update the void water balance modelling, incorporating identified changes to the voids' final closure state landforms and spill point elevations, rainfall and evaporation, surface water runoff and groundwater inflows, and climate projections. — Although not identified in current modelling, if future modelling identifies an unacceptable risk of environmental harm outside the tenure boundary, then management strategies to be implemented.

<table>
<tr><th rowspan="2">Residual void closure aspect</th><th colspan="3">Closure objective</th><th rowspan="2">Residual void closure context</th><th rowspan="2">Management consideration</th></tr>
<tr><th>Safety</th><th>Stability</th><th>Non-polluting</th></tr>
<tr><td></td><td></td><td></td><td></td><td><u>For Jacaranda/Bauhinia residual void:</u>
— After 2140 mean water levels start to stabilise, with simulated mean inflows of 1,008 ML/year being very similar to mean outflows of 969 ML/yr. This indicates that the mean water balance has reached an equilibrium.
<u>For Coolibah/Dogwood residual void:</u>
— After 2120 mean water levels start to stabilise, with simulated mean inflows of 768 ML/year being very similar to mean outflows of 763 ML/yr. This indicates that the mean water balance has reached an equilibrium.
<u>For Ebony/Grevillea residual void:</u>
— After 2140 mean water levels start to stabilise, with simulated mean inflows of 1,204 ML/year being very similar to mean outflows of 1,171 ML/yr. This indicates that the mean water balance has reached an equilibrium.
<u>For Hakea residual void:</u>
— After 2150 mean water levels start to stabilise, with simulated mean inflows of 433 ML/year being very similar to mean outflows of 429 ML/yr. This indicates that the mean water balance has reached an equilibrium.</td><td>— Obtain certification from an appropriately qualified person that the residual voids will not cause environmental harm beyond the tenure boundary.
— If necessary, identify and implement mitigation measures for appropriate protection works of landforms where floodwaters from watercourses interact with final closure state landforms.</td></tr>
</table>

Residual void closure aspect	Closure objective			Residual void closure context	Management consideration
	Safety	Stability	Non-polluting		
Void hydrogeology	-	-	✓	— Mining-related dewatering activities have lowered groundwater levels that will result in suppression of the water table centred on the SRM residual voids. — Void lakes are predicted to form in residual voids post-mining. Water levels in these void lakes are modelled to remain below the pre-mining groundwater levels and shallow geological units due to evaporative effects on the void lakes. — The SRM residual voids will act as groundwater sinks post-closure. — Modelling, including particle tracking, indicates that infiltration of rainfall from the spoil, mine industrial area, and other disturbed areas within the tenure will migrate towards and be captured within the residual voids. Groundwater flow is not expected to flow off-tenure toward the receiving environment, minimising the risk of environmental harm due to the proposed final closure state landform.	— At cessation of mining activities, review and update the groundwater modelling, incorporating updated void WBM outputs and in-field groundwater sampling data, as required. — Although not identified in current modelling, if future modelling identifies an unacceptable risk of environmental harm outside the tenure boundary, management strategies are to be developed and implemented to minimise the harm. — Obtain certification from an appropriately qualified person that, upon completion of mining, residual voids do not present an unacceptable risk of environmental harm beyond the tenure boundary.

Residual void closure aspect	Closure objective			Residual void closure context	Management consideration
	Safety	Stability	Non-polluting		
Void water quality	-	-	✓	— There are no significant sources of acid generation associated with SRM's closure-related surface water hydrology, and acidic conditions are unlikely to develop in the voids. — TDS in all SRM residual voids will continue to increase over time. — Preliminary, high-level screening base on predicted TDS levels suggest that all SRM residual voids may become chemically stratified. — All SRM residual voids do not present an unacceptable risk of environmental harm beyond that of the void itself as they stabilise as groundwater sinks over time. — Note: As all four residual voids are classified as NUMAs and are predicted to behave as terminal sinks, void water quality should be interpreted in this context.	— At cessation of mining activities, review and update the void geochemical assessment including additional or refined data from in-pit surface water samples, surface- and groundwater samples, and biochemical modelling. — Although not identified in current modelling, if future modelling identifies an unacceptable risk of environmental harm outside the tenure boundary, then management strategies to be developed and implemented. — Obtain certification from an appropriately qualified person that the residual voids will not present an unacceptable risk of environmental harm beyond the tenure boundary.
Void access control	✓	-	-	— Access to the residual void will be restricted for humans and livestock.	On cessation of mining activities: — Construct a safety bund at the geotechnical set-back distance. — Erect fencing and signage (where required) around the perimeter of the safety bund. — Obtain certification from an appropriately qualified person that the residual void is safe to humans and livestock.

Monitoring of the residual voids will be undertaken as part of monitoring of the NUMA extents (see Monitoring Section in the PRC plan). This monitoring will aim to demonstrate achievement of sufficient improvement (final NUMA management milestone) that enables certification from an appropriately qualified person that all residual voids:

- Will not present an unacceptable risk of environmental harm outside of the tenure boundary.
- Are safe to humans and livestock.

10 Conclusion

This void closure plan provides outcomes of technical studies completed to support closure planning and achievement of safe, stable and non-polluting residual voids at SRM – specifically the residual voids associated with Jacaranda/Bauhinia Pit, Coolibah/Dogwood Pit, Ebony/Grevillea Pit and Hakea Pit. This void closure plan is an appendix to the SRM PRC plan and has been complied in terms of the requirements of the *PRC Plan Guideline*.

The documented technical studies – including water balance, hydrogeological, rehabilitation flooding, geochemical and geotechnical stability modelling, have been undertaken through an iterative approach with the development of the closure state landform design. These iterations have resulted in a closure landform design that minimises the area of the voids, provides protection from flood water, and contributes to minimising environmental harm as it relates to the final residual voids.

This plan (and associated supporting technical studies) may be required to be updated should amendments to the site's PRC plan be required.

11 References

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