Mine Closure 2024 – AB Fourie, M Tibbett & G Boggs (eds)

doi:10.36487/ACG_repo/2415_45

Three years of barrier cover field trials at Rosebery mine

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Abstract

The MMG Rosebery mine is located on the west coast of Tasmania, Australia, approximately (~) 125 km south of Burnie and ~300 km northwest of Hobart. The mine is an underground polymetallic operation (zinc, lead, copper, gold and silver) with some small-scale open cut workings. The Bobadil tailings storage facility (TSF) contains mine tailings that are potentially acid forming (PAF).

Rehabilitation of a PAF TSF to minimise environmental contamination is site specific; being a function of, among other factors, construction, the tailings deposition method and climate.

The primary design objective of the cover is to limit rainfall infiltration (percolation), with a secondary objective of limiting the ingress of oxygen into the underlying PAF tailings.

Two experimental barrier covers (the options) have been constructed in preparation for comparison to decide on a suitable cover. Both options include layers of moorland peat and glacial till; however, one option includes a geosynthetic clay liner (GCL) between the glacial till and tailings.

The results indicate that the moorland peat layer provides a perched phreatic zone that is largely anoxic. It limits the potential for deep-rooted trees, which could damage the GCL, to establish. It also provides the preferred environment for shallow-rooted native grasses. Shallow-rooted grasses enhance cover water movement and create an ecological community that is sympathetic to the surrounding landscape.

The purpose of this paper is to describe the method and results for the cover trials that are being used to assess the performance of each option.

Keywords: *cover, seepage, groundwater recharge, oxygen concentration*

1 Introduction

1.1 Location

The Rosebery mine is an underground polymetallic mine (zinc, lead, copper, gold and silver) with some small-scale open cut workings on mining lease 28M/1993. The mine, owned and operated by MMG Australia Limited (MMG), is approximately (~) 125 km) south of Burnie and ~300 km northwest of Hobart on the west coast of Tasmania, Australia.

1.2 The Bobadil tailings storage facility

The Bobadil tailings storage facility (TSF) is located ~3.5 km northwest of the town of Rosebery and has been operated since 1974. The TSF recently had an upstream embankment lift to extend its operational life until 2025, after which time it will be decommissioned and rehabilitated.

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2 Background and review

2.1 Climate

The mine has a maritime (temperate) climate. The mean annual maximum temperature is 16.4°C, with December to March being the hottest months (>20°C). The mean annual minimum temperature is 7°C, with June to September being the coolest months (<6°C).

Regional average annual rainfall is 1,953.1 mm Queensland Government 2024). There is a distinct wet season (between June and September), with less rain falling in the remaining months of the year. Average annual regional evaporation (700 mm) is significantly less than rainfall.

2.2 Cover types

Cover designs are a fundamental aspect of sustainable mining practices and mine closure because an effective cover limits percolation, reducing the potential for contaminant leaching, and physical transport to the receiving environment. Vegetation establishment is key because it removes the transport mechanism — percolation by evaporation and transpiration (evapotranspiration). It reduces the erosion potential by binding soil through root and stem establishment; improving structural and water-retaining qualities and reducing runoff potential by increasing ground cover (Supervising Scientist 1998).

The International Network for Acid Prevention's (INAP's) Global Acid Rock Drainage Guide provides a general list of criteria to be used when choosing an appropriate cover for climates ranging from arid to high rainfall and tropical to polar (INAP 2017). While there are several cover types, the cover most common to Australia is the store and release type. Other suitable covers include organic and low-permeability options.

Store and release covers are common on many mine sites. They are designed to rely on evapotranspiration to minimise percolation and the transport of contaminants to the receiving environment. Evapotranspiration covers rely on natural processes to mitigate percolation, and their performance is fundamentally linked to climate. Store and release covers perform best when potential evaporation exceeds annual rainfall by at least a factor of two, and therefore are generally not suitable where evaporation rarely exceeds rainfall (Greaser & Weinig 2022).

Organic covers are created from organic materials that have the potential to remove oxygen-limiting sulphide reduction. Like store and release covers they also prevent transport of contaminants, though this is primarily by controlling biogeochemical processes rather than limiting transport by percolation (Germain et al. 2010).

Low-permeability covers utilise natural or synthetic low-permeability materials to reduce seepage to underlying mine waste. The percolation rate of the cover is determined by the combination of the design and the materials used, which can include plastics such as polyethylene, high-density polyethylene, chlorinated polyethylene, polyvinyl chloride and linear low-density polyethylene (LLDPE), and/or a geosynthetic clay layer (GCL) and/or a bitumen geomembrane.

2.3 Cover selection

The mine ultimately designed a hybrid cover that incorporates key features from store and release, organic and low-permeability covers.

Rehabilitation of the TSF has been under investigation since 2016. At that time a phase A pre-feasibility study (PFS-A) was done by O'Kane Consulting Pty Limited. The preferred PFS-A closure design was a synthetically lined low-permeability cover using an LLDPE and compacted clay layer (CCL). The objectives were to limit oxygen and rainfall infiltration while reducing the potential for acid rock drainage (ARD).

In 2020 SRK Consulting (Global) Limited (SRK) built upon the PFS-A and did the phase B pre-feasibility study (PFS-B). They identified that the construction of a CCL on unconsolidated tailings would be difficult and recommended using a GCL as an alternative because it would remove the need for compaction.

After that time SRK and LMRS Pty Limited (LMRS) recommended that moorland peat be used as the top layer of the cover to maintain near-saturated conditions, stopping the germination of tall-growing and deep-rooting trees and thereby protecting the integrity of the GCL and glacial till (that is, till derived from the erosion and entrainment of material by the moving ice of a glacier). The resulting options (the cover trials) are shown in Figure 1.

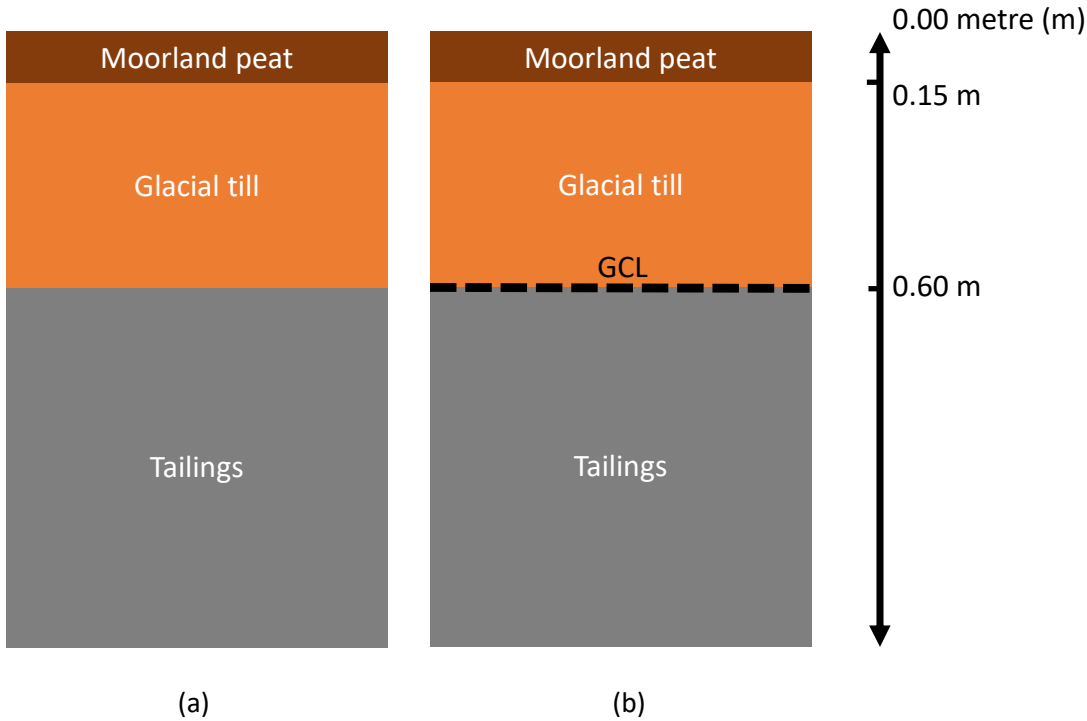


Figure 1 The cover trials: (a) Option 1 – no geosynthetic clay liner; (b) Option 2 – geosynthetic clay liner

The options have been designed to create a perched anoxic phreatic zone in the moorland peat that limits the potential for deep-rooted trees to establish. The glacial till is graded at one per cent to a perimeter drain to allow for some lateral seepage of perched water. Notwithstanding this, the compacted glacial till prevents the phreatic zone from percolating into the underlying tailings. The cover is thin (0.6 m) in comparison to other Australian covers; compacted glacial till is acting as a low-permeability barrier as an alternative to a GCL.

The cover is similar to that at Henty mine in Tasmania (Brett 2009), where it was demonstrated that the phreatic surface and ARD potential can be controlled by a 'mushy' cover, internal drainage and embankment design.

2.4 Cover performance criteria

Performance of the options is being compared to percolation (as a proxy for seepage) results from other similar Australian covers and natural groundwater recharge rates.

2.4.1 Groundwater recharge rates

Groundwater recharge rates in Australia are variable and intrinsically linked to climate and geological factors (Crosbie et al. 2010; Boas & Mallants 2022; Lee et al. 2024). Determining the groundwater recharge rate is important for understanding how a cover is performing, since cover performance is a direct function of the quality of locally sourced material (for example, well-graded compared to gap-graded glacial till), the construction method and quality control.

The average rate of groundwater recharge is generally calculated using the chloride mass balance (CMB) method for groundwater and rainfall. There are several generalised assumptions key to the CMB method (Wood 1999): chloride in groundwater is sourced from rainfall and conservative in the system, chloride flux exists as a steady system and there is no chloride recycling.

Lee et al. (2024) have used the CMB method to calculate a range of potential recharge rates for three Köppen climate classifications. The results indicate high recharge rates occur in areas with high rainfall, such as along the east coast, tropical north and northwestern regions Tasmania, whereas low recharge rates dominate inland Australia (Table 1).

Table 1 Australian groundwater recharge rates

Köppen climate classification	Recharge rate range low (millimetres per year) (mm/yr-^{1})	Recharge rate range high (mm/yr-^{1})	Mean recharge rate (mm/yr-^{1})
Arid	~0.6	~522	~6.3
Temperate	~2.6	~522	~60
Tropical	~2.6	~621	~125

2.4.2 Australian cover trials

Published results for cover performance are available for mono (water storage layer only) and duplex (a water layer underlain by a compacted low-permeability layer; similar to the mine but for drier climates) covers in Australia, including:

- Mount Whaleback and Peak gold mines, which exemplify mono layer covers as the cover is a water storage layer only (Ayres et al. 2003; O'Kane et al. 2000; O'Kane & Walters 2003; Jamson & Rohde 2019)
- Kidston, Cadia, Century, Endeavor and Mary Kathleen mines, which exemplify duplex covers as the covers use a low-permeability layer overlain by a water storage layer (Williams et al. 2000; Durham 2002; Wilson 2000; Rohde & Williams 2009; Rohde et al. 2016; Jamson & Rohde 2019; Lottermoser et al. 2003).

The ratio of evaporation to rainfall exceeds two at all of the aforementioned mines; a point of difference with a maritime (temperate) climate (Table 2). Table 2 also shows the target mean percolation rate as a percentage of cumulative rainfall: that is, mean recharge (Table 1) divided by rainfall.

Table 2 Climate summary for Australian cover trials

Location	Rainfall (mm)	Evaporation (mm)	Evaporation: rainfall	Köppen climate classification (mean percolation – % of cumulative rainfall)
Kidston mine	700	2,800	4	Arid (~0.9)
Mt Whaleback mine	320	3,000	~9	Arid (~2.0)
Cadia mine	900	2,000	~2	Temperate (~6.7)
Century mine	544	2,700	~5	Arid (~1.1)
Endeavor mine	400	1,200	3	Arid (~1.6)
Mary Kathleen mine	420	2,800	~6.5	Arid (~1.5)

Cover performance is difficult to determine from the literature. The reviewer often needs to make assumptions in order to estimate cover performance where performance relies on the estimation of percolation. Examples that have been reported in literature include (Figure 2):

- 2.0 and 4.0 m mono layer cover options from Mount Whaleback mine
- 1.5–2.0 m duplex layer cover at Kidston Gold mine
- 2.0 m (maximum) duplex layer cover at Cadia mine
- 1.5 m duplex layer cover at Mary Kathleen mine
- 0.4–0.8 m duplex layer covers at Endeavor mine
- 0.2–0.6 m mono layer cover at Peak gold mine.

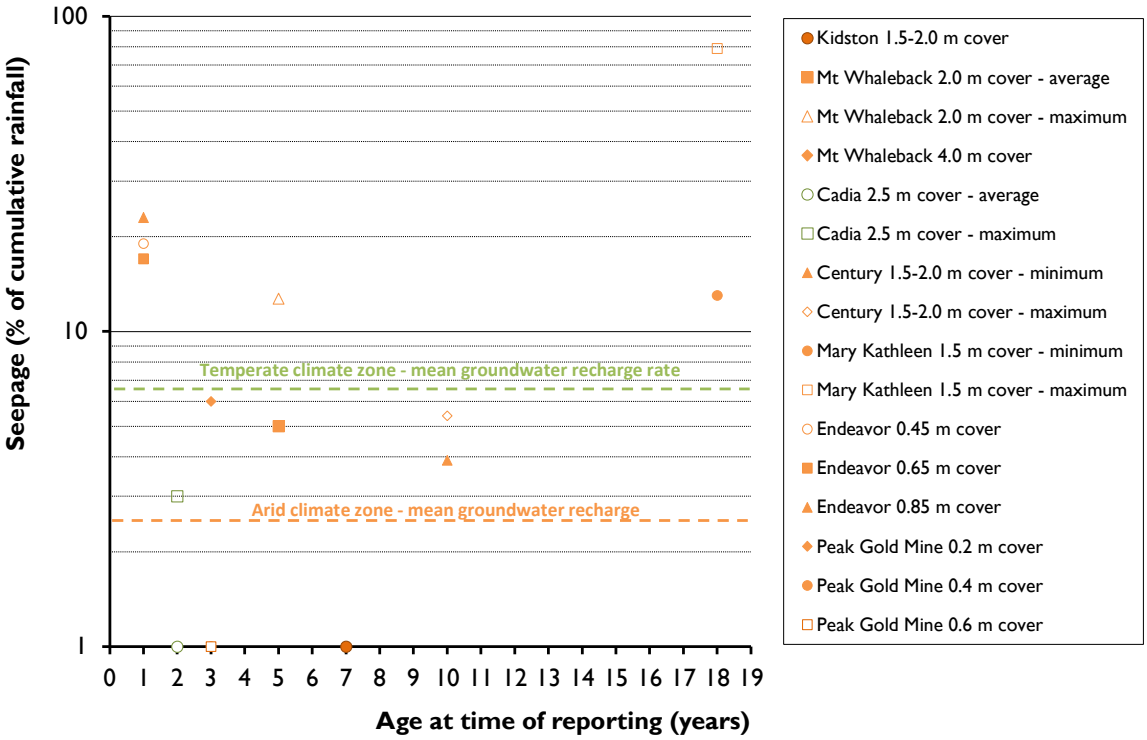


Figure 2 Percolation results for Australian cover trials

Figure 2 indicates that cover performance monitoring has typically only been reported for short periods of time. Based on the estimation of percolation, cover performance ranges from near zero for Kidston mine (duplex layer cover) to nearly 30% for Mount Whaleback mine (mono layer cover) and Mary Kathleen mine (duplex layer cover). Century mine, which is the most-reported contemporary cover, is reporting percolation of 3.2–4.8% of cumulative rainfall, which is above the mean groundwater recharge rate (Table 2 and Figure 2), but well below the high groundwater recharge rate (90% percolation equivalent). Cover performance monitoring shows that generally in Australia, cover percolation is greater than mean percolation (expressed as a percentage of cumulative rainfall (Table 2), but far less than a high rate of groundwater recharge (Table 1). The key takeaway message is that a cover cannot be expected to have zero percolation, and performance should be assessed against either regional or site-specific rates of groundwater recharge.

3 Method

In 2021 MMG commissioned two cover trials for each cover option from PFS-B on the Bobadil TSF. The cover trials are instrumented to measure their performance using:

- two lysimeters in each cover trial to measure percolation
- two monitoring stations for each cover trial that monitor volumetric water content (VWC), matric suction and oxygen concentrations
- a neighbouring weatherisation on the Bobadil TSF.

3.1 Lysimeters

3.1.1 Design

Replication of in situ conditions within and around the lysimeters is important for correct function (Bews et al. 1997; O'Kane & Barbour 2003). The vertical wall height of the lysimeter must be greater than the potential capillarity of the backfill. This condition will be satisfied where the applied flux (non-restricted percolation from the base of the cover trials) is equal to the hydraulic conductivity (measured as pressure head) internal and external to the lysimeter (Bews et al. 1997; O'Kane & Barbour 2003).

Because the lysimeters have been buried at depth it is not possible to see and evaluate their function. Interpretation of function is dependent on understanding the processes that control unsaturated flow that was evaluated using SEEP/W (GEO-SLOPE International Ltd 2012). The SEEP/W model was set up to consider a lysimeter with:

- a 2.38 m wall height
- a diameter of 3.67 m
- a buried depth of 0.1 m below the cover options
- a rock filter in the base of the lysimeter designed following Bertram and the US Army Corp of Engineers (reported in Cedegren 1977)
- the remaining volume within the lysimeter backfilled with tailings at the same density as the tailings outside of the lysimeter.

The soil water characteristic curves used in the SEEP/W model are shown in Figure 3 and have been taken from the PFS-B, with the exception of moorland peat, which comes from Walczak et al. (2002).

The saturated hydraulic conductivities have also been taken from the PFS-B, with the exception of moorland peat, which has been taken from Walczak et al. (2002) (Table 3).

Transient analysis was done to assess lysimeter function using the wettest, driest and average years of rainfall selected from the ranked annual rainfall for the past 131 years from the Department of Energy and Climate (Queensland Government 2024) (Table 4).

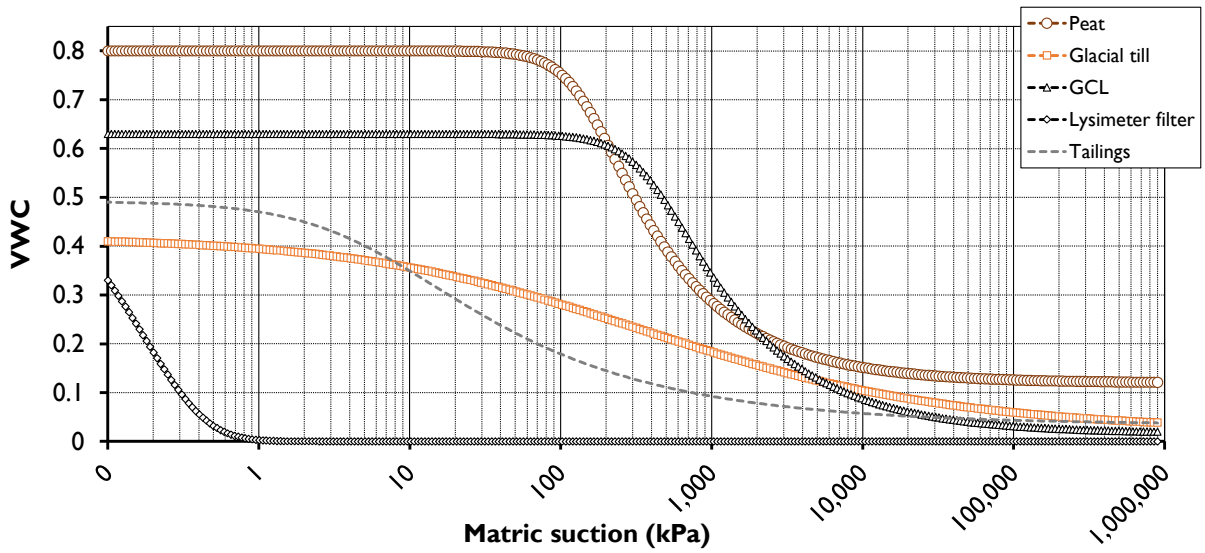


Figure 3 Bobadil tailings storage facility cover trials

Table 3 Saturated hydraulic conductivity used for lysimeter function modelling

Material	Saturated hydraulic conductivity (m/day)
Moorland peat	8.64×10^{-03}
Glacial till	6.91×10^{-04}
GCL	1.73×10^{-06}
Tailings	8.64×10^{-02}

Table 4 Transient rainfall analysis

Year	Description	Rainfall (mm)
2019	Wettest year	3,605
2015	Average year	~2,453
1950	Driest year	~1,653

The results of the analysis (Figures 4 and 5) show that the lysimeter wall height will stop percolation wicking towards/away from the lysimeters because the internal and external pressure heads are equal.

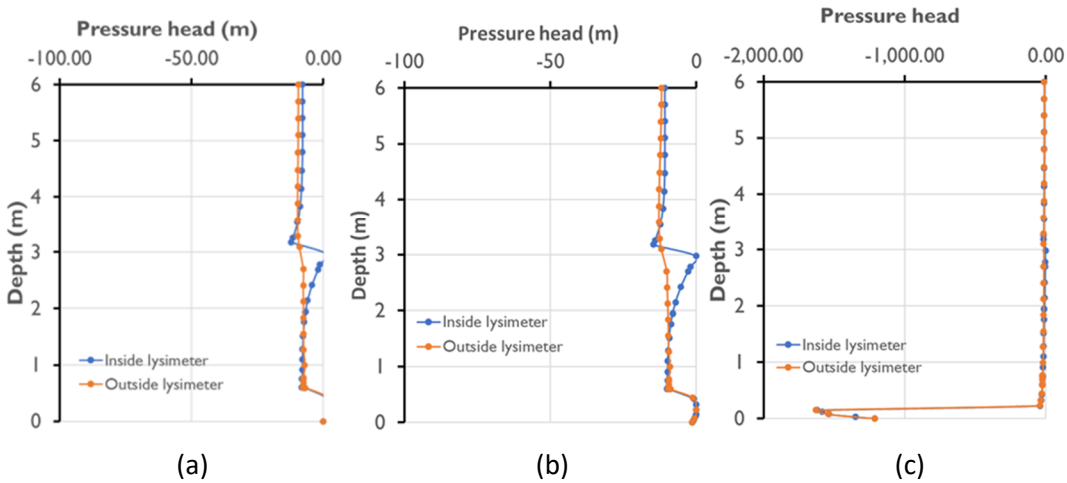


Figure 4 Lysimeter wall height performance for Option 2 (no geosynthetic clay liner cover): (a) Wettest; (b) Average; (c) Driest year

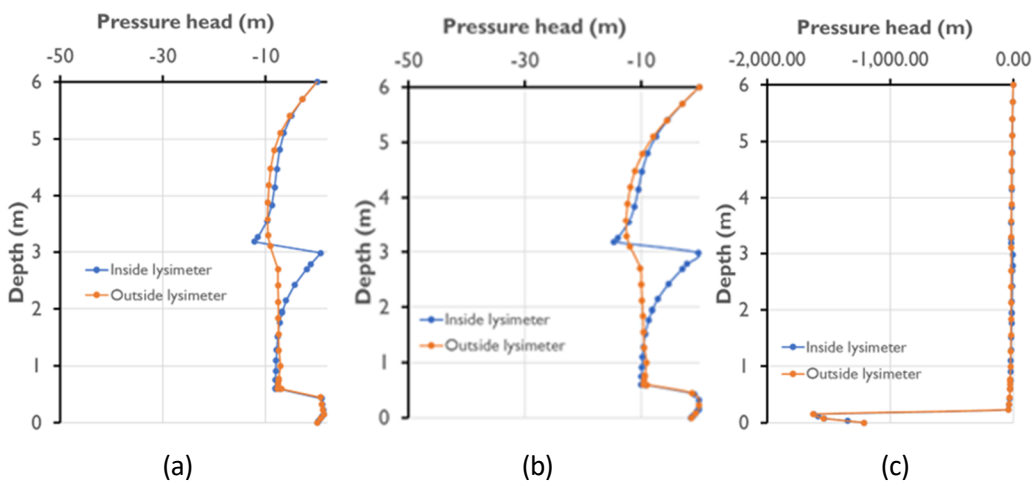


Figure 5 Lysimeter wall height performance for Option 2 (geosynthetic clay liner cover): (a) Wettest; (b) Average; (c) Driest year

3.1.2 Installation

The lysimeters are acid-resistant and reinforced water tanks that have had their tops cut off. They were installed by first excavating an installation trench (Figure 6a), lowering the lysimeter into place and attaching its 80 L seepage sump (Figure 6b), and then attaching the vertical standpipe (Figure 6c). The lysimeters are purged by automated groundwater pumps reporting to rain gauge tipping buckets triggered by a floating switch (Figure 7).

(a) (b) (c)

Figure 6 Lysimeter installation: (a) Installation trench; (b) Seepage sump; (c) Vertical standpipe

(a) (b) (c)

Figure 7 Lysimeter monitoring station: (a) Vertical standpipe at the top of the cover; (b) Monitoring station; (c) Rain gauge tipping bucket to measure seepage volume

3.2 Monitoring stations

3.2.1 Design

The cover trials and underlying tailings are monitored for VWC, matric suction and oxygen concentration. A weather station calculates evapotranspiration via the Penman-Monteith equation using a grass reference evapotranspiration method (Allen et al. 1989). The sensors have been installed into the cover options using a sensor tree designed to protect the sensors and wires from acidic conditions and damage during installation, thereby prolonging their serviceability (Figure 8).

(a) (b) (c) (d)

Figure 8 Sensor tree installation: (a) Mounting the sensor tree in the footing; (b) Backfilling with tailings; (c) Placing a geosynthetic clay liner cover; (d) Backfilling with glacial till

The matric suction sensors are recommended for use in the range of 10–1,000 kPa, however, they have been calibrated for suctions greater than 1,000 kPa, having regard for the technique used by Flint et al. (2002). The calibration functions extend up to 1,000,000 kPa, however, matric suctions of this magnitude are not expected in the field.

3.2.2 Installation

The sensors are buried vertically in the cover options and tailings at 20, 70, 320, 420, 520, 620, 1,670 and 2,670 mm below the top of the cover.

4 Results and discussion

4.1 Rainfall

Average annual rainfall is 1,875 mm (Figure 9), with a wet season (between June and September) and a period of lower rainfall (between October and May). The first year of monitoring received less-than-average annual rainfall (1,698 mm), and the second year recorded above-average rainfall (2,225 mm). The third year of monitoring has received 352 mm of rainfall to date.

Evapotranspiration at the end of the monitoring period is 1,456 mm, or about one-third of the cumulative rainfall.

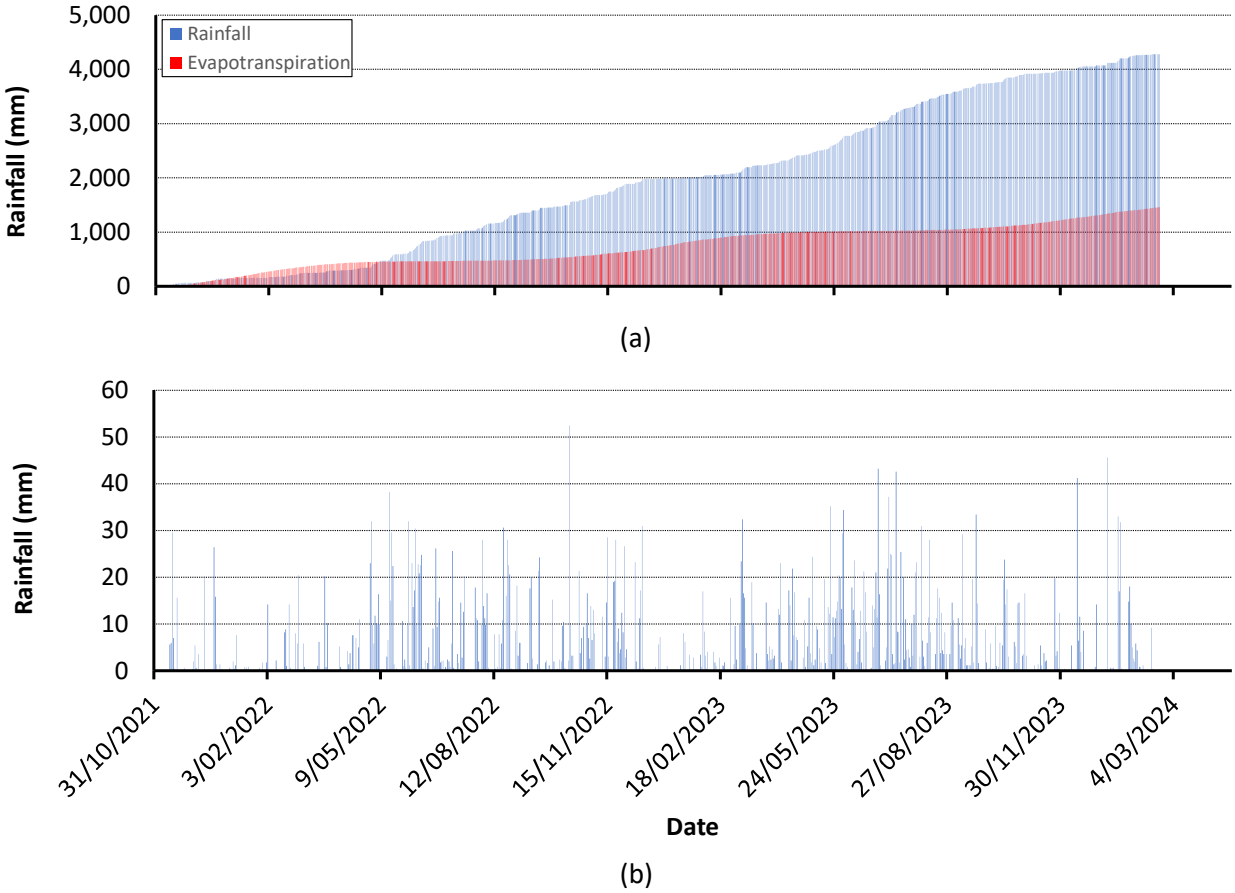


Figure 9 Climate: (a) Cumulative rainfall and evapotranspiration; (b) Daily rainfall

4.2 Stored infiltration

Stored infiltration in the cover options is calculated daily by multiplying the change in VWC by depth. The daily incremental change in stored infiltration (ΔSW) balances the infiltration budget as either wetting (+ve ΔSW) or drying (-ve ΔSW). As such, it is proportional to the rate of evaporation (Figure 10). Option 2 (GCL) consistently stores more infiltration (maximum ~240 mm) than Option 1 (no GCL) (~150 mm) and therefore maintains a higher degree of saturation.

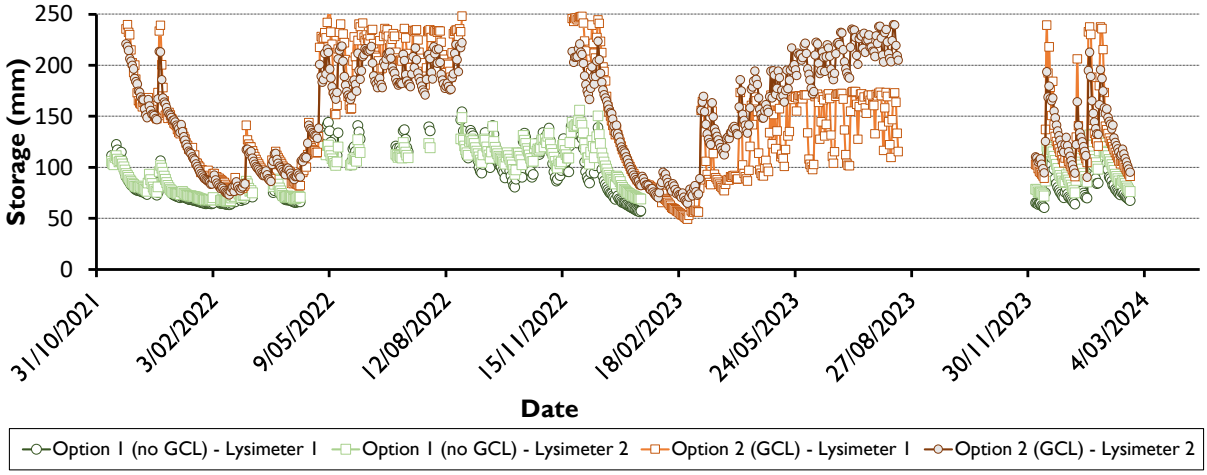


Figure 10 Stored infiltration

4.3 Percolation

Percolation results are shown in Figure 11. Option 1 (no GCL) has the highest range of percolation (13–31 mm) and Option 2 (GCL) has limited percolation to a range of 0.4–23 mm. Both cover options are less than half of the temperate climate mean groundwater recharge rate (Figure 2).

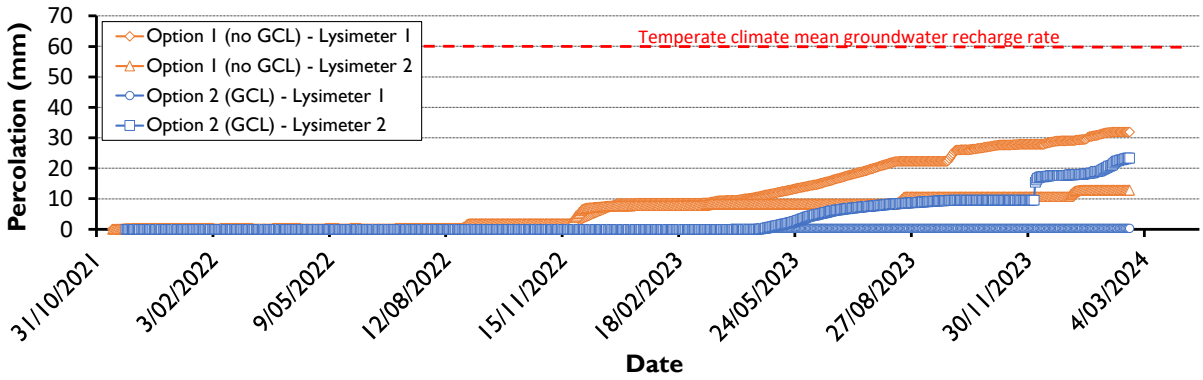


Figure 11 Percolation

4.4 Water balance and degree of saturation

The water balance for the cover options can be calculated by subtracting seepage and infiltration from total rainfall (Table 5). The results are encouraging, however, lateral seepage accounts for more than 50% of water loss from the cover. The result has been that both cover options, but particularly Option 1, have desiccated to less than a degree of saturation of 60% for substantial periods (Figures 12 and 13), the result of which has been that some tree species have started to establish.

Table 5 Water balance

Cover option	1	2
Rainfall (mm)	4,275	4,275
Maximum infiltration storage (mm)	150	250
Maximum percolation (mm)	32	23
Evapotranspiration (mm)	1,456	1,456
Lateral seepage (mm)	2,637	2,546

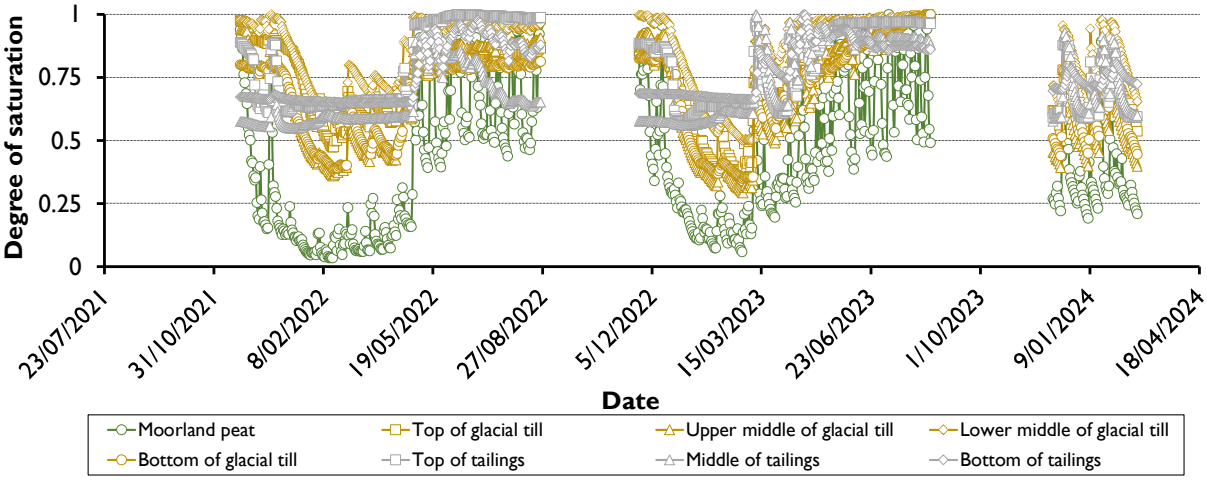


Figure 12 Degree of saturation — Option 1 (no geosynthetic composite layer)

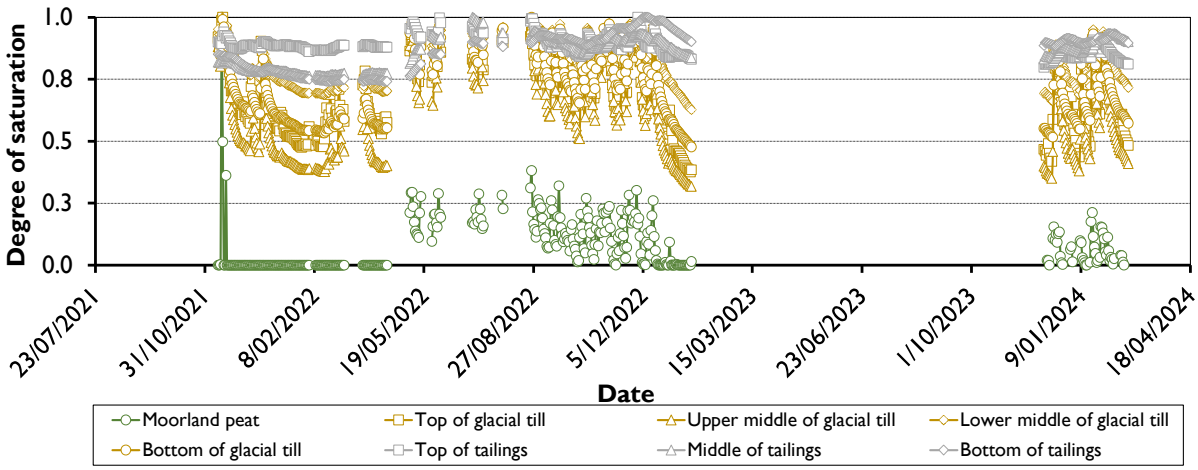
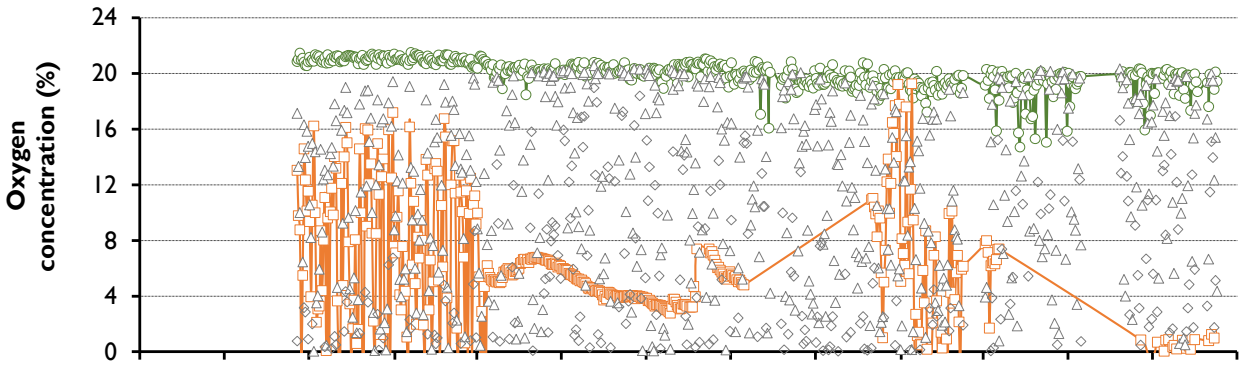


Figure 13 Degree of saturation — Option 2 (geosynthetic composite layer)

4.5 Oxygen concentration

Oxygen concentrations for each cover option are shown in Figures 14 and 15. Option 1 (no GCL) shows a decreasing oxygen gradient extending through the cover and into the underlying tailings. Notwithstanding this, the oxygen concentration in tailings is variable and, at times, close to atmospheric. Further, there does not appear to be a relationship between degree of saturation (Figure 13) and oxygen concentration. Atmospheric oxygen concentrations will allow the formation of ARD by sulphide oxidation.



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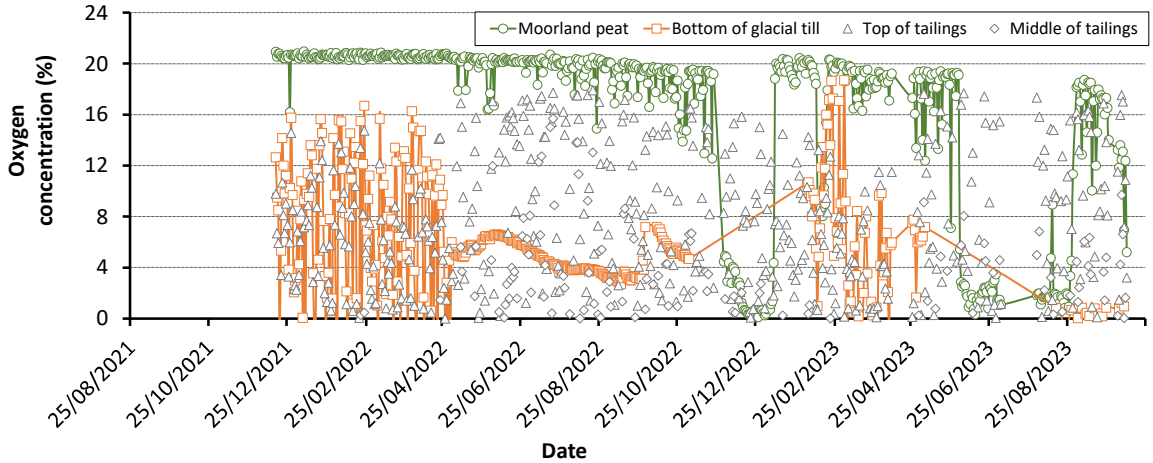
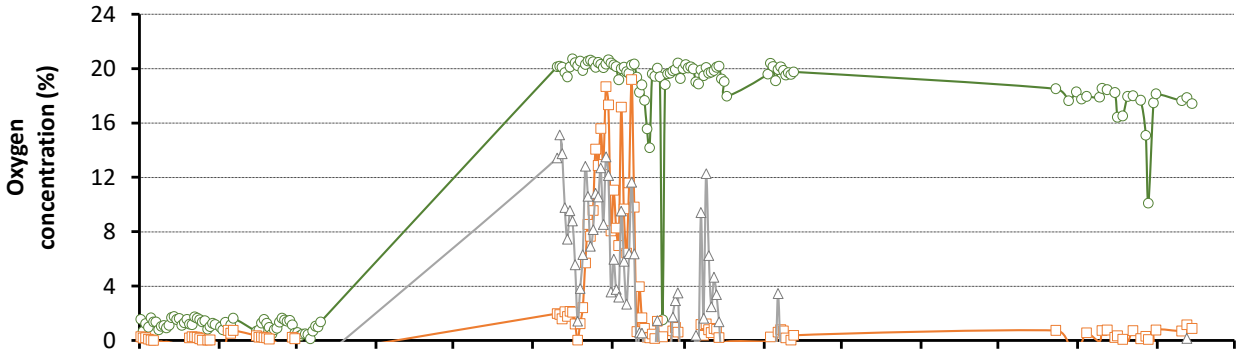


(b)

Figure 14 Oxygen concentration: (a) Option 1 (no geosynthetic composite layer) – sensor tree 1; (b) Option 1 (no geosynthetic composite layer) – sensor tree 2

Option 2 (GCL) also shows a decreasing oxygen concentration through the cover and into the underlying tailings. However, unlike Option 1 (no GCL), atmospheric oxygen concentration events in tailings is limited, even at degrees of saturation approaching 50%. While further analysis is required, early results indicate that the GCL is a physical barrier preventing oxygen advection through the cover and into the tailings.



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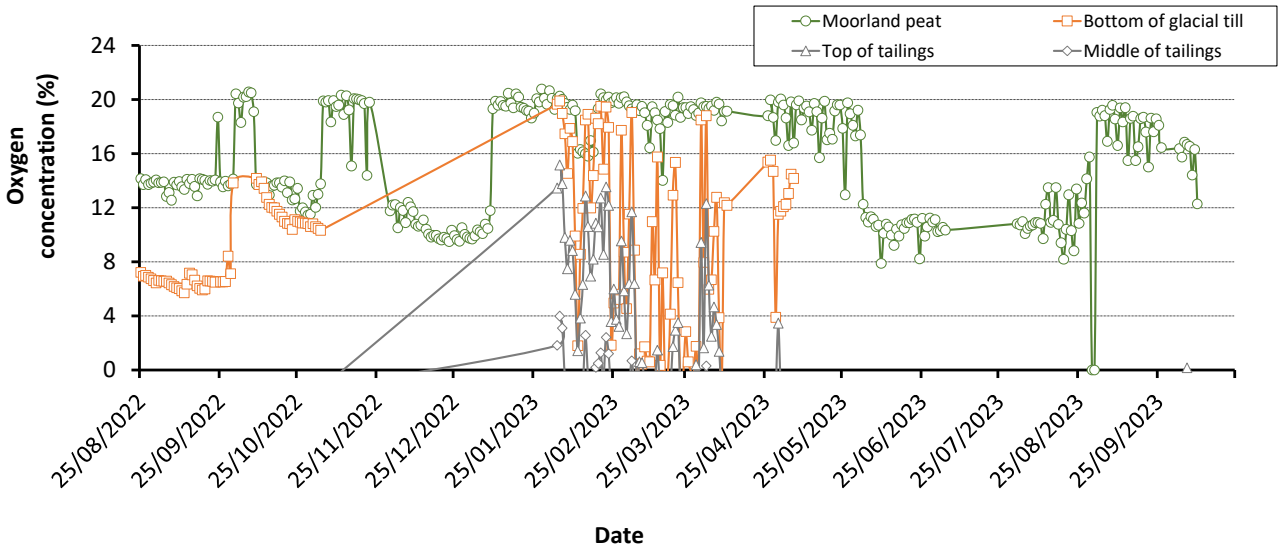

(b)

Figure 15 Oxygen concentration: (a) Option 2 (geosynthetic composite layer) – sensor tree 1; (b) Option 2 (geosynthetic composite layer) – sensor tree 2

5 Conclusion

MMG has designed a hybrid cover that incorporates key features from store and release, organic and low-permeability covers. Two cover options are being trialled: no GCL (Option 1) and GCL (Option 2). Their performance has been compared to natural groundwater recharge rates (for Köppen climate temperate climatic conditions), each other, and oxygen concentrations. Both cover options have allowed percolation but are less than the temperate climate mean groundwater recharge rate. Option 1 (no GCL) has the highest range of percolation (13–31 mm) and Option 2 (GCL) has limited percolation to a range of 0.4–23 mm. Both cover options have their glacial till layer graded at one per cent to allow sublateral seepage, which accounts for more than 50% of the total water balance and has resulted in desiccation of the trial cover. The effect of desiccation needs further assessment because desiccation may allow tree species to establish, which could lead to a reduction in performance if the GCL or compacted glacial till layer is compromised; and secondly, atmospheric oxygen conditions in the tailings could lead to ARD from sulphide oxidation. The oxygen gradient is most pronounced in Option 1 (no GCL) and it is likely that the GCL is a physical barrier that limits oxygen advection through the covers.

References

Allen, R, Jensen, M, Wright, J & Burman, R 1989, 'Operational estimates of reference evapotranspiration', *Agronomy Journal*, vol. 81, pp. 650–662.

Ayres, B, Elice, C, Christenson, D & O'Kane, M 2003, 'Development of a cover system design for potentially acid-forming tailings at Peak Gold Mine', *Proceedings of the Sixth International Conference on Acid Rock Drainage*, The Australasian Institute of Mining and Metallurgy, Melbourne, pp. 957–963.

Bews, BE, O'Kane, MA, Wilson, GW, Williams, DJ & Currey, NA 1997, 'The design of a low flux cover system including lysimeters for acid generating waste rock in semi-arid environments', *Proceedings of the Fourth International Conference on Acid Rock Drainage*, Mine Environment Neutral Drainage Program, Vancouver, pp. 747–762.

Boas, T & Mallants, D 2022, 'Episodic extreme rainfall events drive groundwater recharge in arid zone environments of central Australia', *Journal of Hydrology: Regional Studies*, vol. 40, https://doi.org/10.1016/j.ejrh.2022.101005

Brett, DM 2009, 'Water covers for tailings and waste rock — designing for perpetuity', in AB Fourie & M Tibbett (eds), *Proceedings of the Fourth International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 485–492, https://doi.org/10.36487/ACG_repo/908_37

Cedergren, H 1977, *Seepage, Drainage, and Flow Nets*, John Wiley & Sons, New York.

Crosbie, RS, Jolly, ID, Leaney, FW & Petheram, C 2010, 'Can the dataset of field-based recharge estimates in Australia be used to predict recharge in data-poor areas?', *Hydrology and Earth System Sciences*, vol. 14, no. 10, pp. 2023–2038.

Durham, A 2002, *Design and Optimisation of Waste Rock Cover System for Arid Environments*, PhD thesis, University of Saskatchewan, Saskatoon.

Flint, AL, Campbell, GC, Ellet, KM & Calissendorff, C 2002, 'Calibration and temperature correction of heat dissipation matric potential sensors', S*oil Science Society of America Journal*, vol. 66, pp. 1439–1445.

GEO-SLOPE International Ltd 2015, *Seepage Modelling with SEEP/W An Engineering Methodology*, 2015 edn, GEO-SLOPE International Ltd, Calgary, viewed 8 September 2024, https://ottegroup.com/wp-content/uploads/2021/02/seep-modeling-June2015.pdf

Germain, D, Naormand, T & Hohanne, C 2010, 'The East Sullivan mine site: merging prevention and treatment of acid mine Ddrainage', in WA Price & K Bellefontaine (eds), *Proceedings of the 16th Annual BC-MEND ML/ARD workshop*, Mine Environment Neutral Drainage Program, Vancouver.

Greaser, K & Weinig, W 2022, 'The importance of climate for evapotranspiration cover design', in M Tibbett, AB Fourie & G Boggs (eds), *Proceedings of the 15th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 1139–1152, https://doi.org/10.36487/ACG_repo/2215_84

INAP 2017, *Global Cover System Design: Technical Guidance Document*, viewed 8 September 2024, https://www.inap.com.au/wp-content/uploads/global-cover-system-design.pdf

Jamson, NP & Rohde, TK 2019, 'Tailings storage facilities store-and-release cover design for the Cobar region', in AB Fourie & M Tibett (eds), *Proceedings of the 13th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 621–634, https://doi.org/10.36487/ACG_rep/1915_50_Jamson

Lee, S, Irvine, DJ, Duvert, C, Rau, GC & Cartwright, I 2024, 'A high-resolution map of diffuse groundwater recharge rates for Australia', *Hydrology and Earth System Sciences*, vol. 28, no. 7, pp. 1771–1790, https://doi.org/10.5194/hess-28-1771-2024

Lottermoser, BG, Costelloe, MT & Ashley, PM 2003, 'Tailings dam seepage at the rehabilitated Mary Kathleen Uranium Mine', *Proceedings of the Sixth International Conference on Acid Rock Drainage*, The Australasian Institute of Mining and Metallurgy, Melbourne.

O'Kane, M and & Barbour, L 2003, 'Predicting field performance of Lysimeters used to evaluate cover systems for mine waste', *Proceedings of the Sixth International Conference on Acid Rock Drainage*, The Australasian Institute of Mining and Metallurgy, Melbourne, pp. 327-339.

O'Kane, M & Walters, M 2003, 'Dry trial covers at Mt Whaleback: A summary of overburden storage area cover system performance', *Proceedings of the Sixth International Conference on Acid Rock Drainage*, The Australasian Institute of Mining and Metallurgy, Melbourne, pp. 155–161.

O'Kane, M, Porterfield, D & Weir, A 2000, 'Cover system performance in a semi-arid climate on horizontal and sloped waste rock surfaces', *Proceedings of the Fifth International Conference on Acid Rock Drainage*, Society for Mining, Metallurgy, and Exploration, Littleron, pp. 1309–1317.

Rohde, TK & Williams, DJ 2009, 'Early hydrological monitoring of Cadia's instrumented trial waste rock dump', *Proceedings of the 8th International Conference on Acid Rock Drainage and Securing the Future: Mining, Metals & the Environment in a Sustainable Society 2009*, Curran Associates, Inc, Stockholm, pp. 987–998.

Rohde, TK, Defferrard, PL & Lord, M 2016, 'Store and release cover water balance for the south waste rock dump at Century mine', in AB Fourie & M Tibbett (eds), *Proceedings of the 11th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 47–59, https://doi.org/10.36487/ACG_rep/1608_0.6_Rohde

Queensland Government 2024, Department of Energy and Climate, Queensland Government, viewed 8 September 2024, https://www.longpaddock.qld.gov.au/silo/

Supervising Scientist 1998, *Effect of Vegetation and Surface Amelioration on Simulated Landform Evolution of the Post-Mining Landscape at ERA Ranger Mine*.

Walczak, R, Rovdan, E & Witkowska-Walczak, B 2002, 'Water retention characteristic of peat and sand mixtures', *International Agrophysics*, vol. 16, pp. 161–165.

Williams, DJ, Wilson, GW & Currey, NA 2000, 'A cover system for a potentially acid forming waste rock dump in a dry climate', *Proceedings of the Fourth International Conference on Tailings and Mine Waste*, A.A. Balkema, Rotterdam, pp. 231–235.

Wilson, GW 2000, 'Appropriate concepts and criteria for the design and construction of mine waste cover systems', in MJ Grundon & LC Bell (eds), *Proceedings of the Fourth Australian Workshop on Acid Mine Drainage*, Australian Centre for Mining Environmental Research, Brisbane, p. 81.

Wood, WW 1999, 'Use and misuse of the chloride-mass balance method in estimating ground water recharge', *Ground Water*, vol. 37, no. 1, pp. 2–3.