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Mount Rawdon gold mine tailings storage facility cover system trials: commissioning case study

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Abstract

Mount Rawdon Operations (MRO), an open pit gold mine in southeast Queensland, completed mining in 2024 and is progressing rehabilitation and closure planning. As part of MRO's progressive rehabilitation and closure plan (PRCP), tailings storage facility (TSF) cover system trials were constructed in 2025 to generate field performance data and support selection of a preferred TSF cover design for final closure. The trials are designed to:

- *track the evolution of the cover system performance over time by quantifying water ingress and run-off through each cover system design*
- *build confidence in the long-term closure performance of the selected option*
- *provide practical demonstrations of the cover system designs under field conditions*
- *generate performance data to calibrate numerical models and refine the cover system design prior to full-scale implementation.*

The trials are evaluating 4 different cover system profiles, consisting of a variation of capillary break layer, reduced permeability layer (RPL), infiltration storage layer (ISL), and topsoil. Materials used include well-graded non-acid forming (NAF) waste rock from existing stockpiles, low-permeability borrow material, higher permeability poorly graded NAF waste rock, and topsoil. The cover system trials are fully instrumented to monitor infiltration, water balance, net percolation and run-off. Associated vegetation trials are also being conducted.

The paper will present the design and construction of the cover trials and key constraints during construction, including material source and compaction, and operational updates.

Keywords: *tailings, closure, cover system, trials*

1 Introduction

The Mount Rawdon Operations (MRO) is an open pit gold mine located approximately 80 km southwest of Bundaberg in Southeast Queensland, Australia. The mine is owned and operated by Evolution Mining Limited and commenced operations in 2001. Gold ore was extracted from the single open pit using conventional drill and blast, load and haul methods, and processed on site to produce gold and silver doré.

MRO includes a tailings storage facility (TSF), 2 waste rock dumps, soil stockpiles, water storage and sediment control dams, and supporting infrastructure. After mining operations at MRO were completed in 2024, remaining low-grade ore stockpiles continue to be processed. Evolution is now focused on progressive rehabilitation and closure planning to prepare the site for the post-mining landscape.

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As part of MRO's progressive rehabilitation and closure plan (PRCP), developed in accordance with Queensland statutory guidelines (DESI 2023), TSF cover system trials were constructed to reduce closure uncertainty and inform selection of a preferred final cover design.

1.1 Tailings storage facility

The TSF at MRO (Figure 1) is a valley-type landform, constructed within a natural drainage valley and formed by 3 primary embankments: northern embankment, southern embankment and western saddle embankment. Tailings from the carbon-in-leach processing plant was deposited hydraulically over the operational life of the mine, resulting in a broad, relatively flat plateau surface that is targeted for rehabilitation and closure as a final waste storage landform supporting native open-woodland vegetation. Mining ceased in 2024, and the TSF is now transitioning from operation to closure, with rehabilitation focused on placement of a store-and-release cover system on the plateau to manage water balance, limit net percolation to the underlying tailings, control capillary rise, and support long-term vegetation establishment under site-specific climatic conditions.

Figure 1 Aerial view of tailings storage facility at Mount Rawdon Operations

1.2 Purpose of cover trials

The TSF cover trials were initiated to evaluate candidate cover designs for TSF rehabilitation and closure, reduce uncertainty before full-scale implementation, and support adaptive closure decisions consistent with the Queensland PRCP framework (DESI 2023).

The trials track cover performance, water ingress, run-off and field conditions needed to calibrate numerical models and refine a final design that can support native vegetation. They also demonstrate cover functionality under field conditions, identify construction challenges before full-scale works, and are complemented by parallel vegetation trials conducted by The University of Queensland Sustainable Minerals institute (SMI) and Geotechnical Engineering Centre (GEC) that were focused on surface stability and soil moisture–plant relationships.

1.3 Proposed cover system options

The conceptual cover system design initially shortlisted 3 trial options based on prior studies and numerical modelling (SEEP/W):

- Cover D: store-and-release with an infiltration storage layer (ISL) and reduced permeability layer(RPL)
- Modified Cover D: a rainfall-shedding variant of Cover D with a more densely compacted ISL
- Cover A: store-and-release incorporating a capillary break layer beneath the RPL.

However, post construction, the ISL of Modified Cover D was found to have the same compaction profile as Cover D, and did not provide its intended hydraulic conductivity contrast. Instead, this cover configuration was adjusted by ripping the topsoil cover to a 0.5 m depth to mix it with underlying NAF rock in the ISL. This was done to assess the efficiency of deep-ripping in controlling erosion compared to profiles without this surface treatment. To preserve the trial intent of evaluating varied cover system options, an additional monolithic store-and-release cover profile was constructed and instrumented. Figure 2 presents the final cover system profiles that were constructed for the trials.

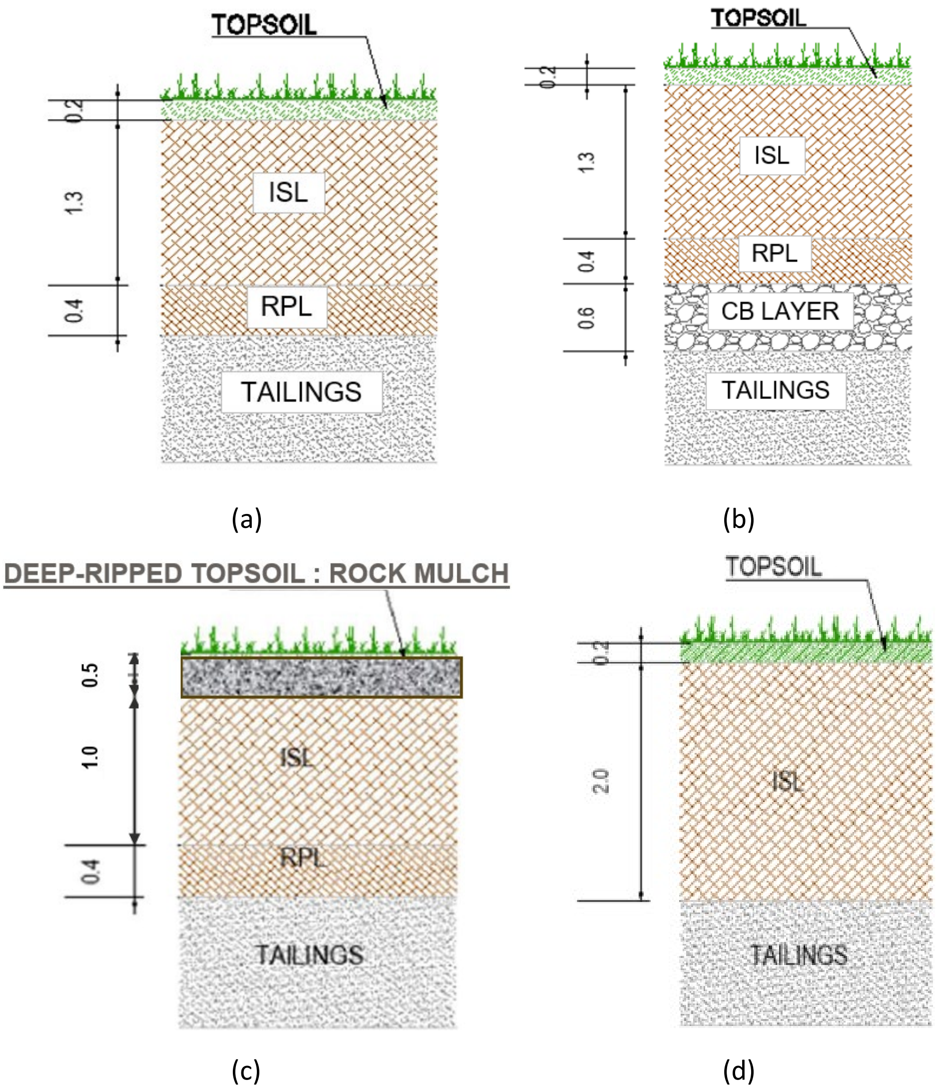


Figure 2 Cover system options for trial construction; (a) Cover D; (b) Cover A; (c) Modified (ripped) Cover D; (d) Monolithic cover

Table 1 presents cover system profile material specification following material testing.

Table 1 Summary of tailings storage facility cover system options trialled

Cover option	Layer build-up (top to bottom)	Indicative thicknesses	Key placement specifications (design)
Cover D	Topsoil + ISL + RPL + tailings	0.2 m topsoil; 1.3 m ISL; 0.4 m RPL	Topsoil: 1.45–1.55 t/m^3 (80–85% maximum dry density (MDD)). ISL: 1.39–1.56 t/m^3 (75–85% MDD). RPL: compacted to achieve saturated hydraulic conductivity (K_{sat}) <2 × 10^{-8} m/s.
Cover A	Topsoil + ISL + RPL + capillary break layer + tailings	0.2 m topsoil; 1.3 m ISL; 0.4 m RPL; 0.6 m capillary break	Topsoil: 1.45–1.55 t/m^3 (80–85% MDD). ISL: 1.39–1.56 t/m^3 (75–85% MDD). RPL: K_{sat} <2 × 10^{-8} m/s. Capillary break: coarse capillary break layer (poorly graded 5–20 mm gravel).
Modified Cover D	Topsoil + ISL + RPL + tailings	0.5 m topsoil & NAF waste rock; 1.0 m ISL; 0.4 m RPL	Ripped topsoil/NAF waste rock: 1.45–1.55 t/m^3 (80–85% MDD). ISL: 1.39–1.56 t/m^3 (75–85% MDD). RPL: compacted to achieve saturated hydraulic conductivity (K_{sat}) <2 × 10^{-8} m/s.
Monolithic cover	Topsoil + ISL + tailings	0.2 m topsoil, 2.0 m ISL	Topsoil: 1.45–1.55 t/m^3 (80–85% MDD). ISL: 1.39–1.56 t/m^3 (75–85% MDD).

1.4 Performance framework

Cover system performance is assessed against the TSF closure intent and PRCP objectives, with trial-specific indicators and nominal targets adopted to enable comparison between options.

Key indicators include:

- Limiting net percolation into the TSF (nominally <10% of total rainfall depth, mean annual rainfall of 815 mm), and fewer than 10 days per year with percolation exceeding a nominal 10 mm/day at the cover–tailings interface, consistent with internationally accepted guidance for store-and-release cover systems in similar climatic settings (INAP 2017).
- Limiting capillary rise and associated salt impacts within the root zone.
- Sustaining vegetation (nominally >30% vegetation cover, with species selection aligned to the agreed post-mining land use of open woodland and weed/pest densities no greater than reference sites).
- Erosional stability (target average annual soil loss rate <10 t/ha/yr, subject to erosion modelling and field observations/flume measurements, and minimal signs of rilling or gullying).

These criteria provide a transparent basis for interpretation of monitoring data and for refining the preferred closure design.

1.5 Numerical modelling

One-dimensional unsaturated flow modelling was undertaken using SEEP/W to incorporate as-built layer thicknesses, verified material properties and material-specific soil hydraulic functions derived from laboratory and in situ testing.

Hydraulic conductivity functions and soil water characteristic curves for the ISL and RPL were updated using results from disc permeameter (tension infiltrometer) testing, laboratory falling-head permeability tests, and pressure plate/WP4C moisture retention testing. The adopted near-saturated hydraulic conductivity for the ISL was 2.3×10^{-6} m/s, based on the geometric mean of 5 in situ measurements at −50 mm suction, representing realistic near-field infiltration behaviour under natural rainfall conditions. Laboratory compaction and permeability testing of the RPL confirmed a geometric mean saturated hydraulic conductivity of approximately 2×10^{-8} m/s, more than 2 orders of magnitude lower than the ISL, supporting its function as a hydraulic break layer.

Updated long-term climate simulations incorporating as-built material properties (from the trials) and monolithic cover scenarios indicate that Cover D (store-and-release with RPL) and Cover A (store-and-release with RPL and capillary break) both limit net percolation to less than 5–8% of mean annual rainfall, with percolation events occurring infrequently and predominantly following periods of above-average climatic wetness. In contrast, monolithic store-and-release covers (without an RPL) exhibit increased sensitivity to extreme rainfall years, with modelled net percolation reaching 10–15% of annual rainfall under upper-bound climatic scenarios. The inclusion of an RPL reduces deep drainage by approximately 40–70 % relative to monolithic store-and-release systems under extreme rainfall scenarios, while having minimal impact on near-surface moisture availability for vegetation. Modelling also shows that Cover D and Cover A control capillary rise and sustain vegetation under site-specific climatic conditions. Capillary break performance in Cover A further limits upward salt migration by maintaining lower matric suctions within the root zone during prolonged dry periods.

Interpretation of modelling outcomes indicates that cover system performance is primarily governed by layer sequencing and hydraulic contrast, rather than absolute permeability values alone. These modelled results reinforce the role of the RPL in moderating deep drainage under extreme wet conditions and reducing long-term closure risk. These performance ranges are consistent with the moderate net percolation classifications defined in global cover system guidance for store-and-release designs (INAP 2017). Occasional exceedance of nominal net percolation targets during extreme wet years is not considered indicative of cover system failure, provided long-term water balance objectives are maintained.

Monitoring data from the field trials will test the modelling results and assess if the expected continued performance of the RPL is maintained when subjected to climatic cycling. Monitoring data following initial 'bedding in' of the cover system profiles will also allow to calibrate the cover system modelling and inform predicted performance.

2 Trial design

The TSF cover system trials were designed to provide field-scale data to support selection and refinement of a preferred closure cover configuration while reducing uncertainty prior to full-scale implementation. The trial design integrates representative cover system profiles, controlled construction methods, and comprehensive instrumentation to enable direct comparison of hydraulic performance, constructability, and vegetation response under construction-realistic conditions and site-specific climatic conditions. Trial layouts, material specifications and monitoring approaches were informed by prior numerical modelling, detailed design documentation and as-built constraints, with the intent of capturing realistic performance behaviour rather than idealised design conditions. The trials therefore provide a practical framework for linking material characterisation, construction outcomes and long-term water balance performance to closure decision-making.

2.1 Materials characterisation

Trial materials were sourced from existing stockpiles and borrow areas at MRO. Characterisation testing confirmed grading, plasticity, compaction response and permeability for ISL, RPL, capillary break and topsoil materials, and was used to verify design assumptions and update numerical modelling inputs. Topsoil was tested before placement but applied several weeks after initial trial construction.

Testing showed the trial materials generally aligned with design assumptions, with some site-specific characteristics relevant to performance. ISL material from the west waste rock dump is coarse-grained, gravel-dominated, non-plastic and low in fines (<10%), with Emerson class 6 behaviour indicating good structural stability and low dispersion risk. Its relatively low plant-available water capacity means performance relies mainly on layer thickness and vegetation establishment.

RPL materials are well graded but low in clay, with plasticity indices of 12–14 and Emerson class 2 behaviour, indicating possible dispersivity. However, field compaction achieved about 90–95% MDD and laboratory permeability confirmed the RPL met its intended hydraulic function. Elevated exchangeable sodium percentages are mitigated by placement at depth and erosion protection.

Topsoil is non-plastic, moderately acidic, and low in nutrients and organic carbon. Although erosion-susceptible on its own, it is suitable for rehabilitation if supported by early vegetation establishment, temporary erosion controls and amendments such as gypsum where required.

2.2 Cover trials layout

The trials comprise field-scale cover plots constructed on the TSF surface, with plot layout and monitoring locations selected to reduce edge effects and enable comparison between cover options (Figure 3). The trial location is in an area considered representative of the TSF surface at closure and with minimal likelihood of disturbance during the monitoring period. The trial area is approximately 50 × 60 m at the base and grades to the northwest at approximately 0.7%. Each trial plot includes a primary instrumentation nest (matric suction and volumetric water content sensors) and a secondary nest (volumetric water content sensors), with surface drainage controls and bunding to direct run-off to measurement points.

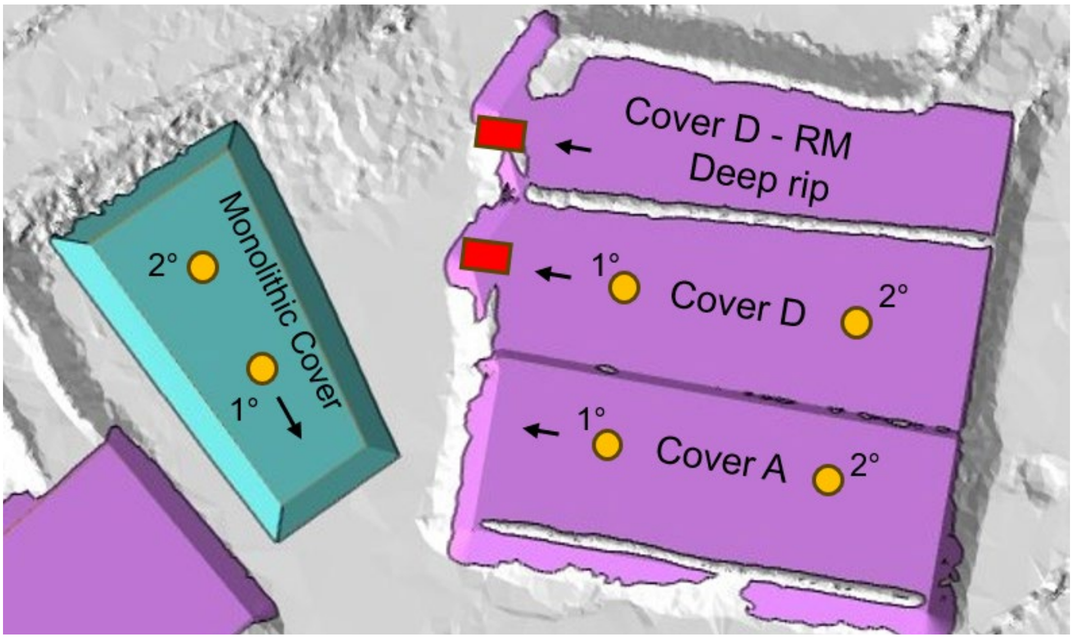


Figure 3 Layout plan of cover system trials showing locations of primary and secondary sensor nests (orange dots) and flumes (red rectangles)

2.3 Installed instrumentation

Each plot is instrumented to support estimation of the water balance and to interpret layer response during rainfall events. In-profile monitoring (Figure 4) includes matric suction sensors and volumetric water content sensors (which also record temperature and bulk electrical conductivity) installed through the topsoil, ISL and RPL, and extending into the upper tailings. A multi-element suction plate lysimeter is installed on the tailings surface adjacent to the primary nest to quantify downward flux/percolation. A pressure transducer is installed above the RPL to identify any development of positive pore pressures (saturation) within the profile.

Climate monitoring is undertaken using a dedicated weather station. Run-off monitoring is undertaken for Cover D and Modified Cover D using bunding to direct run-off to a prefabricated flume equipped with level sensors (pressure transducer and ultrasonic level sensor), with camera monitoring where practicable. Monitoring is expected to continue for several years (nominally 5–10 years) to capture vegetation establishment and evolution of as-built hydraulic behaviour.

Instrument depths were selected to capture behaviour within the topsoil and ISL, across the RPL, and into the upper tailings. Nominated sensor depths range from approximately 0.10 to 2.85 m below ground level, with the depth schedule differing between Cover D, Cover A, and the monolithic cover due to varying layer profiles.

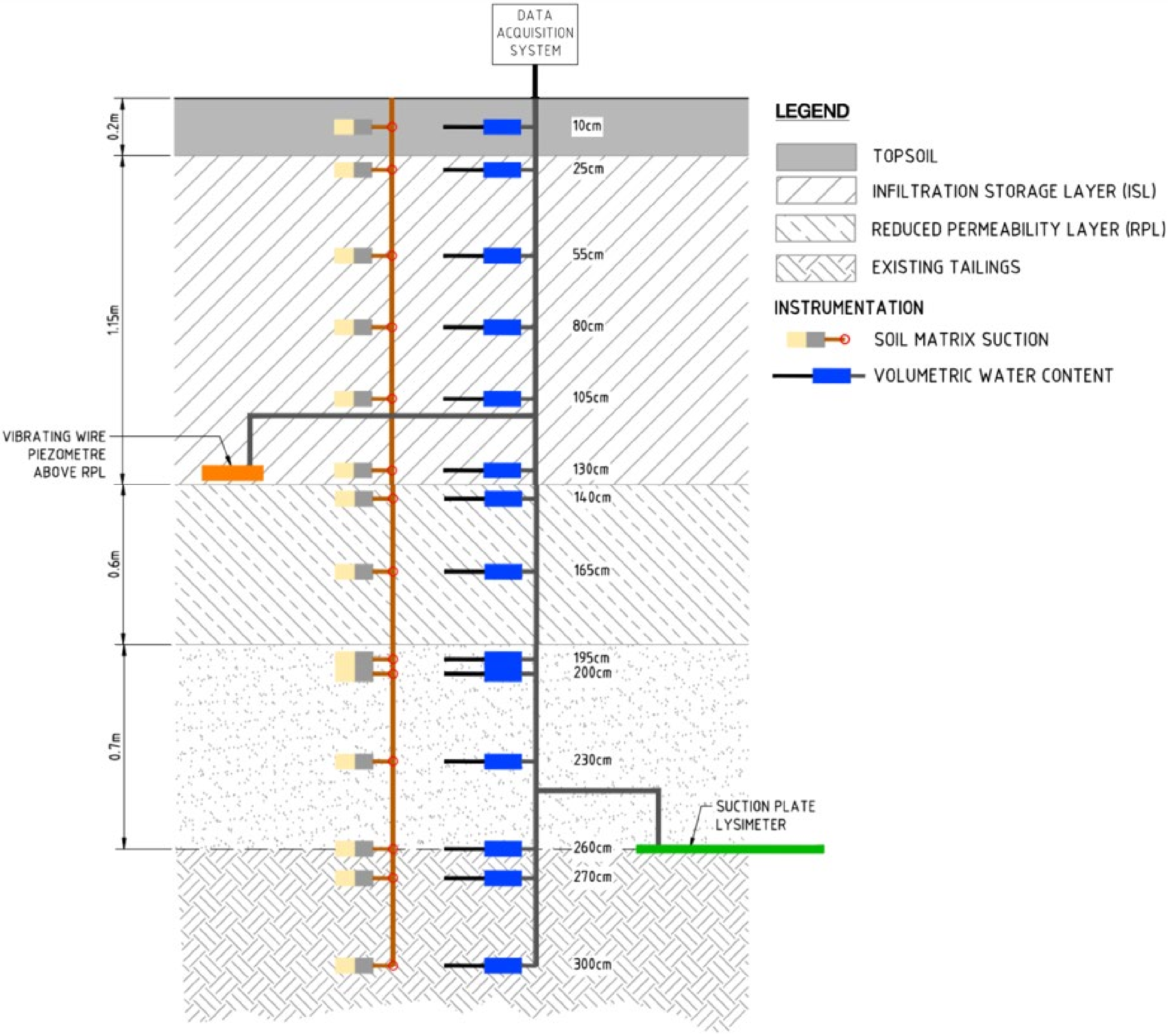


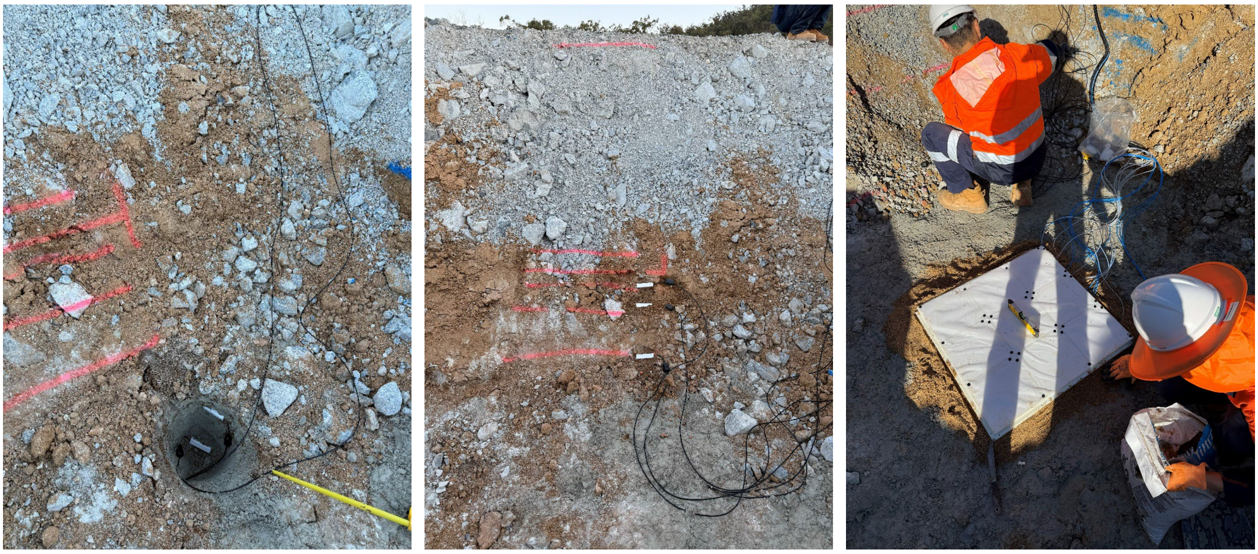
Figure 4 Typical instrumentation and sensor nests profile for primary nest

3 Construction

3.1 Earthworks and layer placement

Construction included survey and setting out, material stripping and/or hauling, placement and compaction of cover layers, and quality control/quality assurance (QC/QA). Works comprised TSF surface preparation, establishment of plot boundaries and drainage controls (bunds/diversion drains), placement of each cover layer in controlled lifts, and surface finishing to achieve design grades (Figure 5). The RPL required moisture conditioning and compaction. Trial plots were constructed to full height of the ISL prior to sensor placement and capping with the topsoil layer. The trial plots were subsequently excavated to install sensors within the profile (Figure 6).

Figure 5 Sequence of trial pad construction



(a) (b) (c)

Figure 6 Instrumentation installation; (a) Sensors in tailings; (b) Sensors in cover profile; (c) Suction plate lysimeter

3.2 Quality assurance/quality control and as-built verification

QA/QC focused on confirming layer thicknesses and continuity, moisture and compaction outcomes (particularly for the RPL), and documenting any deviations from design intent. An as-built record (survey, construction logs and photographs) is required to support interpretation of monitoring data and to inform scale-up to full TSF closure. Prior to initiating routine monitoring, a sensor performance verification process is undertaken (calibration checks, datalogger functionality testing and, where applicable, data transmission verification).

3.3 Instrumentation installation and commissioning

Monitoring equipment and buried sensors were installed in the excavation wall to achieve target depths and protect cabling. Procurement, datalogger configuration and installation of the monitoring instrumentation were led by The University of Queensland (SMI/GEC) with ATCW's assistance, with commissioning including verification of logger configuration, sensor response checks, and establishment of baseline readings prior to major rainfall events.

3.4 Vegetation establishment and irrigation

Vegetation trials are being undertaken in parallel (led by The University of Queensland SMI/GEC) to assess the ability of the conceptual cover systems to support sustainable vegetation cover and to interpret performance in terms of soil moisture, weather, and plant water relations. In addition, vegetation surveys will be undertaken on the trial cover plots by ATC Williams to inform modelling inputs and further assess species selection. Biocondition monitoring of the vegetation ecosystem reference site will also be undertaken to enable comparisons of climatic effects on both trial and reference sites. Species selection and establishment methods are intended to be consistent across trial plots and aligned with the agreed post-mining land use (open woodland). A Japanese millet cover crop was included in the seed mix to provide rapid ground cover to reduce erosion, limit weed establishment and increase soil organic matter. The seed mix comprised a mixture of indigenous vegetation representative of the bioregion (i.e. BVG 10b), including Regional Ecosystem 12.11.6, comprising 8 tree species (e.g. *Eucalyptus* sp., *Corymbia* sp.), 15 shrub species (e.g. *Acacia* sp., *Petalostigma* sp. and *Pittosporum* sp.), 9 grass species, and a sedge and a rush. Temporary irrigation was used during the initial establishment phase, where required, to support germination (Figure 7) and reduce wind and water erosion risk.

(a) (b)

Figure 7 Vegetation establishment – (a) Millet cover crop (Monolithic cover) November 2025; (b) Dense grass cover (Cover A) February 2026

4 Initial results/commissioning

Initial commissioning observations (prior to long-term performance assessment) focus on the following:

- sensor performance and baseline readings
- early response of each cover profile to rainfall events (changes in volumetric water content and matric suction through the profile)
- behaviour of surface drainage controls and run-off measurement systems.

Particular attention is given to high-intensity rainfall events that test run-off generation, potential rilling/gullying, and any ponding or development of positive pore pressures above the RPL (as indicated by vibrating wire piezometers).

Figure 8 shows measured run-off from the flumes installed on Cover D and Cover D – Deep-rip during a high-intensity rainfall event in February 2026. The data show a very short delay between rainfall measurement and run-off reporting to the flume (Figure 9). As vegetation further establishes, this response delay may increase.

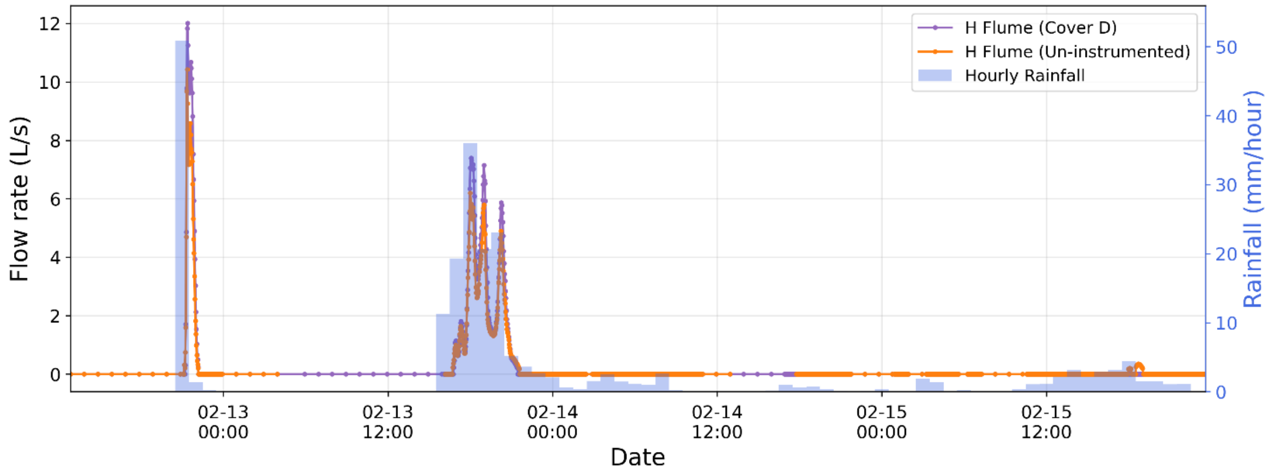


Figure 8 Flume outflow monitoring run-off

Figure 9 Flume outflow

Figures 10–12 show initial cover system monitoring data from the volumetric water content sensors installed through the trial profiles for a limited period following commissioning and including a distinct rainfall event. Water content is presented in terms of degree of saturation, thus accounting for varying material compaction though the profiles. The initial monitoring data show:

- All profiles show a clear response to rainfall events with an increase in degree of saturation moving downwards through the profile.
- The RPLs in Cover D and Cover A remain at 60% saturation following initial wetting up.
- Cover A and the monolithic covers show an increased degree of saturation in the tailings following a rainfall event compared to Cover D.
- The capillary break in Cover A remains around 30% saturation, except for a short period following rainfall event with increased saturation above the tailings interface.
- Similar increased saturation in the monolithic cover ISL above the tailings interface.
- The ISL in the monolithic cover is drier through the monitored period than Cover D and Cover A.

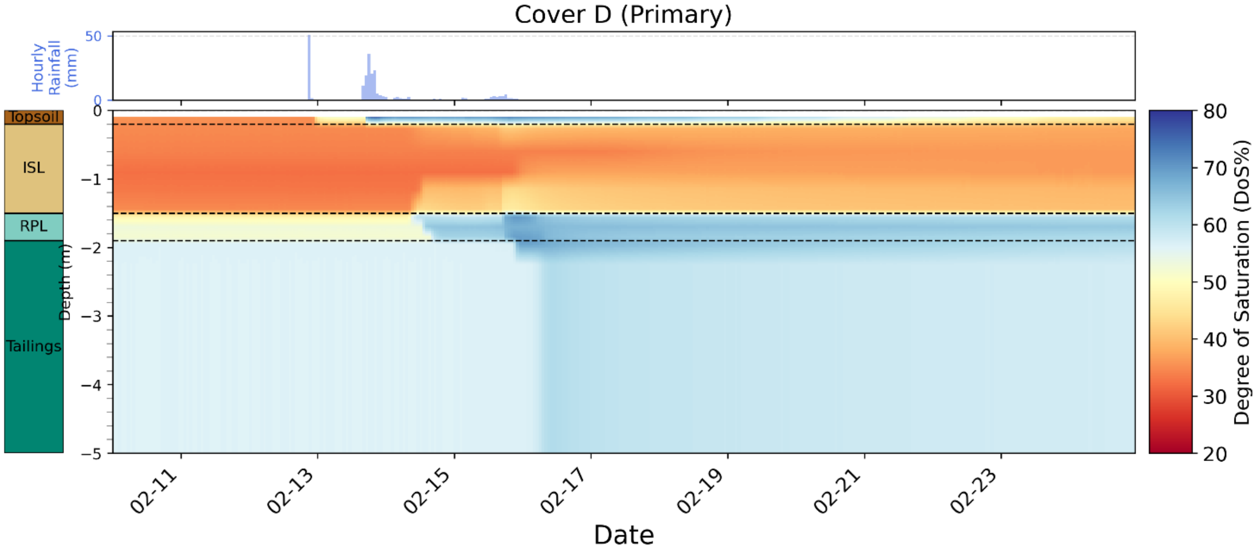


Figure 10 Cover D saturation through profile

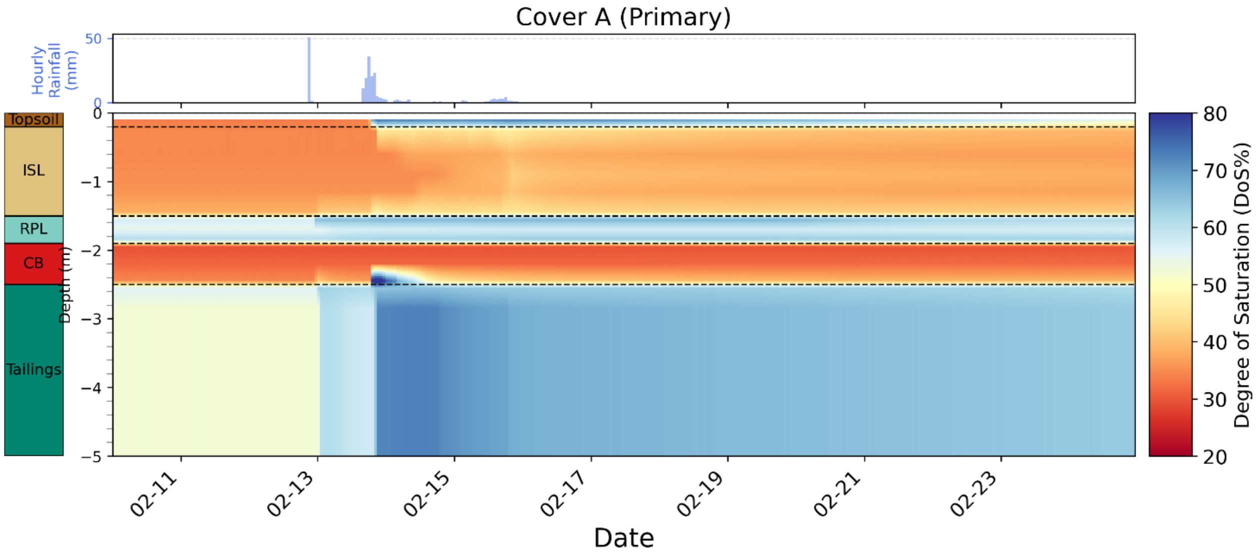


Figure 11 Cover A saturation through profile

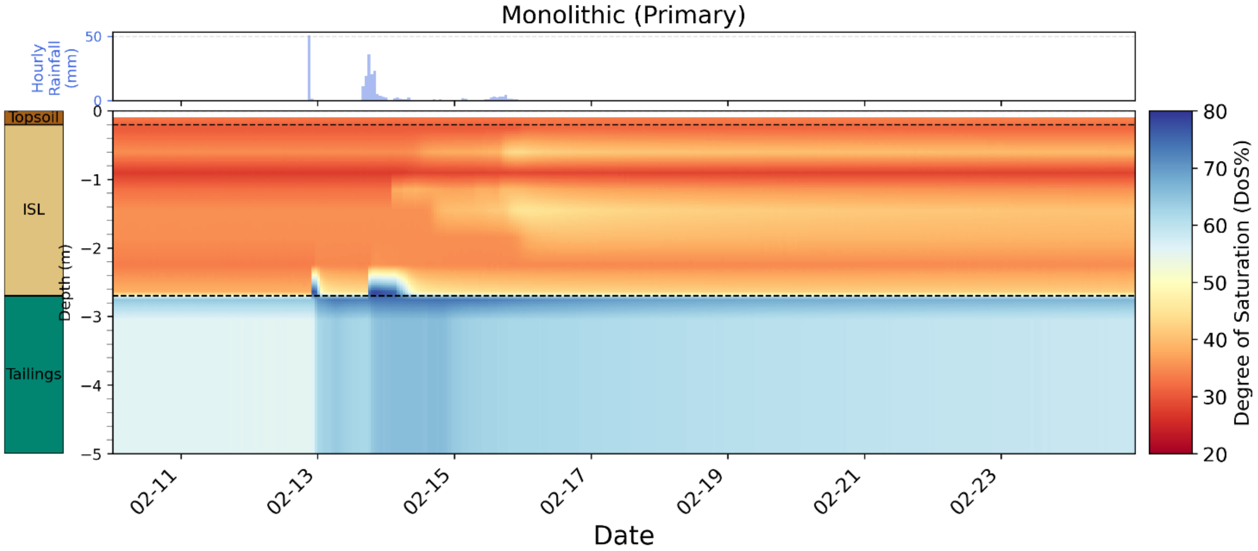


Figure 12 Monolithic cover saturation through profile

4.1 Lessons learned

Early tailings deposition adjacent to the trial footprint resulted in leachate reporting to the trial pad, with seepage observed migrating laterally into the prepared area. The seepage affected access and introduced a risk of wetting and softening of near-surface materials prior to commissioning. In response, temporary diversion channels were constructed to intercept and redirect surface run-off away from the trial area, thereby reducing the potential for continued leachate migration and ponding within the trial footprint.

Following establishment of the trial pad, upstream run-off generated on the adjacent hillside during intense storm events continued to preferentially flow toward the trial area and periodically inundated the footprint (Figure 13). Concurrent operational tailings placement and TSF expansion altered local drainage gradients and blocked the intended gravity drainage pathway, necessitating commissioning a sump-and-pump arrangement to dewater the area. During high-intensity rainfall, the available pumping capacity was exceeded, resulting in prolonged ponding. This highlighted the need to maintain pumping capacity around the trial area and to design dewatering systems for peak-event conditions.

Diversion drains should be sized for appropriate design rainfall (with freeboard), include armouring or erosion protection where velocities are high, and be configured to provide positive drainage to a stable discharge point so that exceedance flows do not report back onto the trial footprint.

The initial timeline for construction and commissioning of the cover system trials increased through the project. While instrumentation placement was initially planned to be conducted as part of trial plots construction, cover system material placement and instrumentation were conducted in 2 separate phases. Instrumentation installation and commissioning of monitoring equipment was conducted over multiple work phases.

Figure 13 Trial pad inundation March 2026 rain event

5 Conclusion

Field-scale cover system trials at the TSF at MRO provide a rare, integrated dataset linking construction reality, material behaviour, numerical modelling and long-term closure performance objectives. The trials demonstrate that store-and-release cover systems incorporating an RPL can be constructed using site-derived materials. Preliminary results show the effect of incorporating an RPL on the water balance of the cover system profile. Ongoing monitoring of the trials will determine which cover system option can achieve robust hydraulic performance when appropriate construction controls are applied.

Updated numerical modelling incorporating as-built conditions and verified soil hydraulic properties indicates that both Cover D and Cover A can limit long-term net percolation to low levels under site-specific climatic conditions, while monolithic store-and-release systems exhibit increased sensitivity to extreme rainfall sequences. Material characterisation testing highlights practical constraints associated with coarse-grained ISL materials and low-plasticity RPLs but confirms that these limitations can be managed through layer thickness, compaction control and profile configuration.

Initial monitoring data indicate good field response from monitoring instrumentation following distinct rainfall events. Ongoing monitoring will allow calibration and further refinement of the cover system numerical model to assess performance of cover system options.

The TSF cover trials at MRO provide defensible evidence for regulators and stakeholders supporting selection of a store-and-release cover with an RPL for final closure. Ongoing monitoring will enable calibration of model predictions, refinement of performance criteria, and translation of trial outcomes into full-scale closure design with reduced uncertainty and risk. The trials were explicitly designed to reduce uncertainty prior to full-scale closure implementation, rather than to demonstrate immediate compliance with closure criteria.

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Special mention to Dr Zicheng Zhao for always finding the time to assist, usually at the last minute.

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