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Optimising cover system performance with native vegetation at Mt. Whaleback mine to minimise acid and metalliferous drainage risk: a research consortium approach

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Abstract

Acid mobilisation due to net percolation (NP) through overburden storage areas poses a significant environmental risk at mine sites. BHP aims to minimise this risk at Mt. Whaleback and other Western Australia Iron Ore (WAIO) sites with the revegetated cover system program (RCSP), to improve understanding of vegetation-substrate interactions that affect transpiration and their impact on NP. The RCSP employs a cross-disciplinary approach, and includes research partners from BHP, Okane Consultants, and The University of Western Australia. The RCSP seeks to:

- *Quantify the effect of specific vegetation prescriptions and functional types on NP reduction through transpiration.*
- *Define how soil spatiotemporal processes influence evapotranspiration and NP partitioning within cover systems.*
- *Refine model parameters and test assumptions on plant traits influencing water movement.*
- *Ensure that research outcomes are practical and scalable for BHP implementation.*

Key project outcomes will be assessed through a field trial constructed at Mt. Whaleback mine. The field trial includes 18 vegetated cover trial plots, including three lysimeters. Automated monitoring collects data on weather, soil volumetric water content and matric potential, and lysimeter NP; electrical resistivity tomography arrays provide an integrated soil moisture understanding at several plots. An irrigation system allows for the simulation of ecologically informed rainfall events and ensures seedling emergence and plant establishment is maximised. The native vegetation treatments for the cover trial include specific mixes of plant species to optimise transpiration: grassland, grassland with woody shrubs and trees, and a non-vegetated control.

This paper outlines the objectives, approach, and methodology of the vegetated cover trial. The RCSP will deliver practical and scalable solutions for optimising cover system transpiration, minimising NP, and reducing acid and metalliferous drainage risk at WAIO mine sites. The project will provide valuable insights into

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vegetation-substrate interactions, refine cover system design tools, and contribute to the development of sustainable mine closure practices.

Keywords: *vegetated cover system, net percolation, evapotranspiration, mine closure, acid mine drainage*

1 Introduction

Several mines across the Pilbara region, including BHP's Mt. Whaleback mine (Whaleback), encounter ongoing environmental challenges, such as acid and metalliferous drainage (AMD) – also known as acid mine drainage or metal leaching – and acid rock drainage caused by net percolation (NP) through mine rock stockpiles (MRS). Net percolation plays a crucial role in mobilising acidity and refers to the amount of water that infiltrates through the cover system and reaches the underlying mine rock. This infiltration can mobilise acidity, leading to the generation and transportation of AMD, a significant environmental concern.

Previous studies conducted by Okane Consultants (O'Kane 2011) at Whaleback have established the crucial role of vegetation in mitigating risk of NP through transpiration. Plants act as natural pumps, drawing water from the soil and releasing it back into the atmosphere via this transpiration process (Tfwala et al. 2019). By increasing transpiration rates, vegetation cover significantly reduces the volume of NP reaching underlying mine rock (Fayer & Gee 2006; Scanlon et al. 2005), minimising the potential for AMD.

Cover systems over reclaimed MRSs commonly employ the 'store and release' concept when managing risk of AMD in arid or semi-arid regions. A store-and-release cover system stores water within the near surface where it can subsequently be removed by evaporation. An 'enhanced store-and-release' cover system builds on the principles outlined above to achieve most cover system goals, but it also incorporates extra layers that create a textural discontinuity. The main purpose of this discontinuity is to further decrease NP during short-term seasonal events when the storage capacity of a standard store-and-release cover system might be exceeded. In cover systems that include a vegetative layer, this water release also includes transpiration. Evapotranspiration (ET) is the process by which water is transferred from the land to the atmosphere through both evaporation and transpiration (Horton et al 1994). In these types of cover system, the objective is to minimise NP by maximising the amount of water released back into the atmosphere through ET (International Network for Acid Prevention2017). The effectiveness of these cover systems is linked to material texture and available water holding capacity for vegetation use, and the specific vegetation species.

The effectiveness of vegetation in controlling NP depends on root penetration depth and density. Highly compacted or cemented surface material hinders root development, limiting the effectiveness of evapotranspiration. This issue can negatively impact the system's capacity to store and release water, potentially affecting landform stability as well. Although most roots are found in the top 50 cm of soils, roots do reach much greater depths (Schenk & Jackson 2002, 2005), including arid grass species like the *Triodia* species (Reid et al. 2008). A cover system with deeper-rooted plants would likely have a greater capacity for water storage and release, leading to a more significant reduction in NP (i.e. reducing AMD seepage volume and contaminant mobilisation).

Understanding if plant diversity contributes to greater evapotranspiration is crucial. Plants with different traits and water use patterns can maximise water uptake and utilisation throughout the year, including during dry periods and after rainfall events (Ogle & Reynolds 2004). Understanding the physiology of locally native Pilbara plant species can therefore inform the optimal strategy to further decrease NP (i.e. AMD seepage volume and contaminant mobilisation) by maximising water removal from the system.

This paper describes a collaborative research program designed to investigate and quantify the role of native seeded vegetation in minimising NP within store-and-release cover systems at BHP's Whaleback mine. This knowledge will be used to optimise cover system design and minimise AMD risk, not only at Whaleback but across BHP's other operations. The RCSP, a collaborative team comprised of BHP, Okane, and The University of Western Australia, is focused on delivering practical and scalable data-driven solutions for BHP. The main research component of the RCSP is a field-based trial at an MRS plateau area of the Whaleback mine, named the study area.

The field trial focuses on four areas:

1. vegetation systems: quantifying the transpiration rates of different plant communities and their impact on NP.
2. substrate systems: understanding how soil properties and moisture dynamics influence water movement and NP partitioning within the cover system.
3. model systems: evaluating existing models used to predict NP rates by incorporating site-specific vegetation characteristics.
4. technology transfer and feedback loops: ensuring research outcomes translate into practical and scalable solutions for BHP.

2 Methodology

2.1 Study area

The study area footprint has been built up to a uniform elevation by Whaleback Mine Operations using available inert Whaleback overburden material. The Whaleback site is located in a region classified under the Köppen–Geiger climate system as BSh, characterised by hot summers and cold winters (Kottek 2006). Most rainfall occurs during the summer months (December to March), with an average annual precipitation of 321.8 mm (Bureau of Meteorology [BOM] 2023). The annual average maximum temperature is 34.3°C, with summer temperatures often exceeding 40°C. The minimum annual average temperature is 30.4°C (BOM 2023).

As part of BHP's material management program, overburden is classified in accordance with physical and geochemical properties. This overburden has been classified to be suitable for cover system material based on AMD classification and physical property classification (primarily an erosion resistance classification). The study area is composed of 18 field trial plots, 15 of these plots are vegetation plots and three are lysimeter plots (Figure 1). The 15 vegetation plots are 24 × 24 m. The three plots with lysimeters installed are 24 × 24 m in size and will be vegetated. The lysimeters themselves are 20 × 20 m, with a 2 m vegetation buffer zone that will also be seeded and monitored. The vegetation plot area was created in two 2.5 m high lifts meant to replicate full-scale cover system construction methods.

Within the large-field trial design, there are two randomised treatments (vegetation community types and simulated rainfall). There are three community types (grasslands, grasslands with shrubs, and bare soil) that are each allotted one of two rainfall treatments (yes or no rainfall pulse). The field trial at the study area was installed during mid-2024. The designed and constructed infrastructure for the project will have a long lifespan, with the life of the trials to be a minimum of 10 years.

At the time of publication, the lysimeters and trial area is anticipated to be finalising construction, and the monitoring equipment will be installed. Seeding in anticipated to be completed by early 2025.

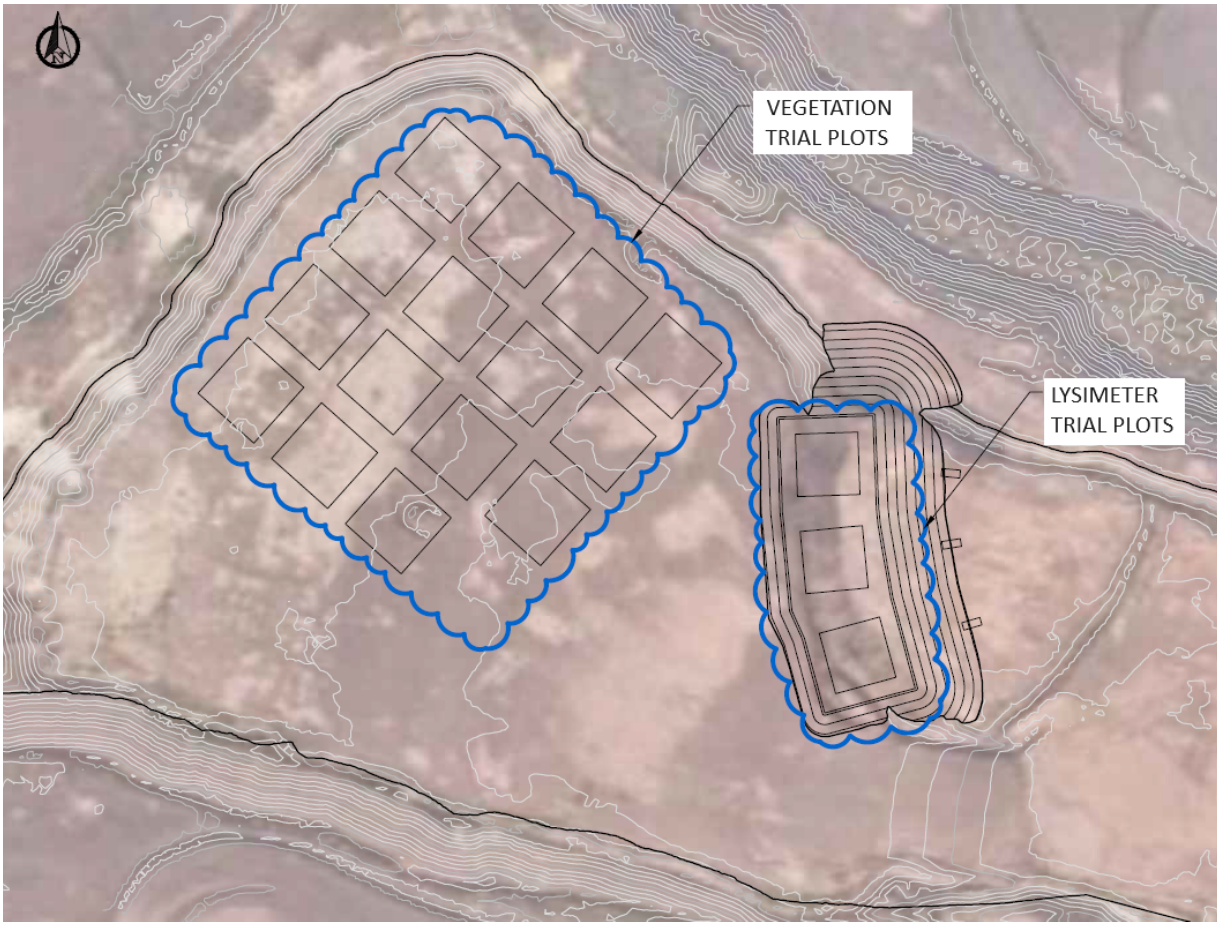

Figure 1 Whaleback revegetated cover system program field trial study area showing the location of the 15 vegetation plots (24 × 24 m each) to the west, and three lysimeter plots (20 × 20 m each) located to the east, with associated net percolation monitoring stations at the base of the slope

2.2 Material characterisation

Prior to installation of the field trial and lysimeters, BHP assessed the borrow area as suitable rehabilitation material. Following creation of the vegetation trial plots and placement of the stockpiled material to be used for lysimeter construction, an initial characterisation spot check of the stockpiled material was carried out to create a baseline geochemical and physical (particle size distribution, Emerson aggregate testing and bulk density) profile of the material designated for the field trial. To confirm that the mine rock material conformed to expectations and predictions established during production and waste material scheduling, an initial characterisation process was employed. Five mine rock samples were collected for laboratory analysis as part of the materials characterisation scope; three samples were taken from material designated for vegetation trial plots and two samples were taken from the material staging areas (stockpile of material for backfill of the lysimeters).

Geochemical and physical analyses of the five mine rock samples indicate a high degree of similarity between the material located at the vegetation trial plots and the material stockpiled for backfill of the lysimeters. A brief summary of the geochemical and physical analyses is provided:

- The pH values (1:5 solid to liquid ratio) across all five waste rock samples ranged from 2.9 to 7.2. Samples #1 through #4 had pH values between 6.8 and 7.2, indicating neutral conditions. In contrast, Sample #5 had a pH of 2.9, indicating acidic conditions.
- The electrical conductivity (EC) of the five waste rock samples ranged from 34 µS/cm to 1,120 µS/cm. Samples #1 through #4 had EC values of their saturated extracts (ECe) below 2 dS/m,

classifying them as non-saline. In contrast, Sample #5 had an ECe of 15.68 dS/m, indicating a high level of salinity.

- Sample #2 had the lowest total sulphur content at 0.01%, while Sample #5 had the highest total sulphur content at 0.12%.
- Sample #3 had the lowest total carbon content at 0.02%, while Sample #5 had the highest at 0.16%.
- Cation exchange in the waste rock samples is primarily dominated by exchangeable magnesium (Mg) and calcium (Ca) levels.
- The exchangeable sodium percentage (ESP) values in the waste rock samples range from 2.8% to 6.0%. Sample #5 has the lowest ESP at 2.8%, classifying it as non-sodic. The highest ESP of 6.0% is found in Sample #2. Samples #1 through #4 are considered slightly sodic.
- All five waste rock samples are primarily composed of gravel-sized particles (> 2 mm). Sample #1 contained a higher proportion of cobble-sized particles (57%). Sand and clay-sized particles were present in lower proportions across all samples.
- Emerson classification values ranged from 3 to 9. Sample #1 had the lowest value of 3, indicating that the material does not disperse initially but may do so upon remodelling (where the natural structure of the soil material is altered). Sample #4 had the highest value of 9, indicating no slaking (breakdown of soil lumps upon wetting) or swelling of the waste rock material.
- The bulk density ranged from 1,810 kg/m³ (Sample #3) to 2,390 kg/m³ (Sample #2), which is considered comparable across all five waste rock samples and indicative of banded iron formation host rock types.

The overall risk of acid generation is considered minimal. This conclusion is supported by two key factors: 1) the low volume of potential acid forming material, and 2) the likely neutralisation of its slightly more reactive mineral structure by the larger volume of non-acid forming material. This neutralisation effect, consistent with the regional geology, suggests a minimal environmental risk.

Characterisation of the rehabilitation material is continuing throughout lysimeter construction. Automated sensor profiles will be installed in six of the vegetation plots, with samples collected from each. For every approximately 600 m^3 of rehabilitation material placed in the lysimeters, a bulk sample will be screened at the stockpile area with a grizzly. The grizzly reject will be assessed in the field, while passing material will be sampled for laboratory characterisation, providing an understanding of the full particle size distribution. This detailed characterisation will assist with interpretation of electrical resistivity tomography results.

2.3 Lysimeters

Infiltrated water that does not return to the atmosphere and instead reaches the groundwater is known as NP. A lysimeter, conceptualised as a buried container, is a measurement tool that directly quantifies NP. For a discussion on lysimeter design see O'Kane & Barbour (2003).

Each of the three lysimeters to be constructed at the study area consists of a 20 × 20 m surface footprint with a high-density polyethylene (HDPE)-lined collection system, which extends to the surface through 5 m of cover system material (Figure 2). The walls will be constructed in discrete ascending lifts as the backfill is placed inside and outside the lysimeters. Each lysimeter will be backfilled with typical inert Whaleback cover system material placed within a density range representative of the planned full-scale cover system construction methodology to simulate site conditions. The lysimeters will be formed with welded geomembrane base and walls to contain infiltration/NP. A drainage system, at the base of each lysimeter, consists of a drain that transitions from the HDPE liner to pipe, which will collect and transmit NP approximately 25 m to an adjacent monitoring station where NP will be quantified with an automated system of redundant tipping buckets. The lysimeter base will be lined with a geocomposite drainage layer to assist with drainage and minimise sediment transport in NP. The liner sidewalls are protected by non-woven geotextile, and the design specifications limit the coarse content of inert mine waste placed within 0.5 m of the walls. Design features are included to avoid the HDPE liner walls from being a conduit for rapid infiltration, such as a surface bund to cap the top of the liner edge.

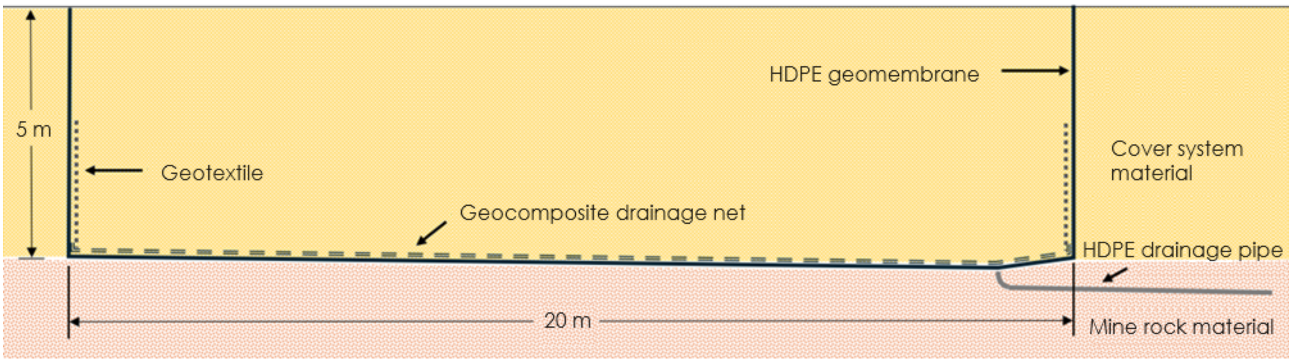

Figure 2 Schematic of lysimeter cross-section that will be constructed at Whaleback as part of the revegetated cover system program

2.4 Seeding

2.4.1 Seed mix

A diverse range of plant functional types will be established on the cover system to enhance water uptake and utilisation throughout the year. The inclusion of species with varying water use strategies will maximise water removal during both wet and dry periods, as well as following significant rainfall events. This approach capitalises on the complementary water use patterns of different vegetation functional types, ultimately promoting efficient water use within the cover system.

The locally native plant species chosen for use for this field trial were selected from the BHP Whaleback species list and were based on two factors (Table 1). First, the species were judged to be representative species of the main communities present in the Pilbara, and as such are species commonly used in mine site revegetation within the region. Secondly, the species chosen are of contrasting functional types present in the natural systems, providing a representative sample of post-restoration community function for use in this trial. Any non-native vegetation species observed growing on the study area, will be removed in accordance with the BHP Western Australia Iron Ore (WAIO) and Whaleback weed guidance (BHP 2020). Any re-seeding or planting required to achieve the required trial plant cover, as needed.

Table 1 Vegetation functional groups and species composition of revegetated cover system program field trial treatments

Grassland	Grassland with woody trees and shrubs
Triodia pungens	*Triodia pungens*
	Acacia bivenosa
	Acacia inaequilatera
	Acacia ancistrocarpa
	Eucalyptus gamophylla

2.4.2 Seeding method

For the field trial surface preparation, the BHP WAIO standards have been followed, which recommend that surface scarification to a depth of 300 mm is completed as part of the seeding process. Additional guidance provided by BHP include 'deep ripping' to a depth of 1.0 m to alleviate compaction if required. Given the trial area has not experienced compaction to date, deep ripping was deemed to not be necessary.

Seeding will be carried out using suitably treated seeds (e.g. species-specific dormancy alleviation treatments applied [Erickson et al. 2017]) and sown using custom-built precision seeding machinery specifically designed for seeding native seeds in rocky soils. This method of direct seeding is now the preferred seeding apparatus used internally by BHP and will be used for this trial. The seeding machinery is 4 m wide and is attached to the back of a D7 dozer, which is used to both agitate the seedbed material profile and precision seed. The maximum depth of soil agitation from the seeding machinery is 300 mm.

2.5 Irrigation

The benefits of vegetation can only be explored if plants are successfully established on the cover system trial. Therefore, irrigation has been recommended to promote vegetation establishment in the field trial. Irrigation will be used for two purposes: promotion of germination and initial seedling emergence (Lewandrowski et al. 2017; Erickson et al. 2023), followed by simulating a range of rainfall regimes for experimental purposes on established plants. All 18 plots will require irrigation to surpass the critical germination-emergence life-stage transition. Repeat watering events over a seven-day period will achieve this in many Pilbara species (Lewandrowski et al. 2017; Erickson et al. 2023). This watering pattern will be implemented on all the 18 plots, commencing within days of seeding.

Following establishment of vegetation on the field trial, moisture dynamics and NP will be observed continuously, and in particular after large rainfall events. Moreover, in the absence of large natural events, the irrigation infrastructure allows for rainfall simulation experiments at any point in time (e.g. in summer and in winter). In these experiments, there will also be non-irrigated controls, namely nine of the vegetation plots. Rainfall simulation irrigation will be applied in a controlled manner to ensure that there is no ponding or runoff across the field trial. There will be two different rainfall treatments as part of the rainfall simulation (50 and 100 mm treatments). Care will be taken to limit the number of irrigation events to avoid excessive wetting.

- Six plots will get 50 mm rainfall treatment over two days (maximum of 40 mm per day).
- Six plots (including the three lysimeter plots) will get 100 mm rainfall treatment over three days (maximum of 40 mm per day).

The RCSP will use annual rainfall simulations to guarantee the inclusion of significant precipitation events throughout the trial period. This approach ensures the collection of site-specific data encompassing a range of rainfall volumes, leading to more robust results for the project.

2.6 Data collection and analysis

To gather data relevant to the RCSP's objectives, state-of-the-art monitoring systems will be installed to comprehensively assess the hydraulic performance of the cover system. These systems include a fully automated weather station, deployed to record rainfall data and climatic parameters essential for calculating potential evapotranspiration and for driving field response numerical modelling. Additionally, a lysimeter collection and monitoring system will be constructed to automatically quantify NP through the cover system. The lysimeter monitoring system includes automated tipping bucket flow gauges to quantify NP. Two tipping buckets installed in series for each lysimeter will be used to provide redundancy in the system.

Moisture conditions will be automatically monitored to validate NP rates measured with the lysimeter and develop a water balance for the specified monitoring area. Sensor nests are installed inside each lysimeter plot and six vegetation plots. These sensor nests consist of matric suction, temperature sensors, and volumetric water content sensors. In each of the plots, sensor nests will be placed at five depths in the soil profile: 100 mm, 250 mm, 500 mm, 1 m, and 3 m. A data acquisition system will be installed on the surface of each lysimeter and vegetation plot that is instrumented with sensors attached to automated data collection system.

To complement the point-source data acquired by the automated in situ sensors, electrical resistivity tomography (ERT) lines will be installed. These ERTs facilitate the monitoring of spatial and temporal variability in the water distribution of the reclamation material across each plot over time. Monthly ERT measurements will be conducted, with additional measurements before, during, and after significant rainfall events. Stable isotopic composition of rainfall, irrigation water, and soil water will be sampled regularly, as it can provide independent estimates of evaporation and track water movement through the soil profile.

Monitoring and data collection of the vegetation will occur quarterly, including monitoring of germination, species count, species richness, and establishment of weed species, plant survival and growth. Through the life of trials, research efforts are expected to increase as vegetation develops, including comparing vegetation response in nearby analogue sites and mature rehabilitation sites at Whaleback. Plant morphology and physiology measurements, while not feasible for recently emerged plants, will be progressively implemented as the vegetation becomes established. Expected physiology measurements will include leaf traits, sap flow measurements, plant water status traits, transpiration rates, and plant root distributions. Understanding the plant physiology in the field trial aims to achieve a sustainable landform while ensuring the rehabilitation project meets environmental and biodiversity criteria.

Sap flow (the movement of a water through plant stems) measurements will be employed to quantify the water use response of selected plant species to both wet and dry periods, including discrete rainfall events. These measurements will allow us to understand the differences and similarities in water use patterns (transpiration rate) and water status (tissue water potential) among the native plant species. Species with contrasting water use strategies, such as those with deeper root systems or greater water uptake during wet periods, should contribute more significantly to reducing NP by maximising water removal from the cover system (both spatially and temporally).

3 Conclusion

The lysimeters and vegetation plots of the RCSP field trials represent a unique resource for research into developing an enhanced understanding for the controls and mechanisms of AMD, specifically the role of locally native vegetation in AMD risk management. By deploying a diverse range of plant functional types within the cover system, the aim is to optimise water removal via evapotranspiration and minimise NP generation. The data collected will address key questions aligned with three of the four RCSP focus areas: vegetation systems, substrate systems, and model systems. As the field trials and monitoring equipment are in the process of being installed, data will be analysed and presented at a future date. The key vegetation Systems questions to be addressed by the trial are:

- What are the actual plant transpiration rates across different species and functional types?
- How does vegetation impact actual evapotranspiration compare to potential rates?
- How does vegetation type influence transpiration rates, ultimately leading to a decrease in NP and AMD seepage risk?
- How do plant water use, and associated water use traits respond to environmental conditions (diurnal, seasonal) and rainfall events, and how does this response affect NP?
- Define how vegetation development stage influences transpiration and NP.

These questions will provide insights into optimising plant selection and cover system design to optimise water use and NP reduction. The key substrate systems questions to be addressed by the trial are:

- Test current NP model assumptions underpinning soil-evapotranspiration relationships.
- Understand moisture movement through cover system material using a robust monitoring network.
- Quantify how transpiration and NP are influenced by soil-plant-climate interactions.

The findings from these questions will inform the development of more accurate models that account for the complex interactions between soil, vegetation and climate that determine water movement and NP generation. The key model systems question to be addressed by the trial is: which site-specific plant and soil factors can be integrated into the current NP model to enhance its accuracy?

Through addressing these questions the fourth focus area can be addressed, namely, the technology transfer and feedback loop. This research is directly targeted at providing BHP with tangible solutions for optimising their cover system design and vegetation selection for efficient water management and reduced NP generation. Focused on delivering practical and scalable data-driven solutions for BHP, this project aims to leverage science-based decisions (proven by the NP model) for selecting inputs into rehabilitation design, ultimately contributing to successful landform rehabilitation with improved biodiversity.

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4 References

BHP 2020, *BHP Environmental Weed Management in Western Australia Procedure* (Document Number 0120706, Version 4), Perth.

Bureau of Meteorology 2023, 'Climate data online', Weather Station 007176, http://www.bom.gov.au/climate/data/

Erickson, TE, Muñoz-Rojas, M, Kildisheva, OA, Stokes, BA, White, SA, Heyes, JL, ... Merritt, DJ 2017, 'Benefits of adopting seed-based technologies for rehabilitation in the mining sector: a Pilbara perspective', *Australian Journal of Botany*, vol. 65, pp. 646–660, DOI: https://doi.org/10.1071/BT17154

Erickson, TE, Dwyer, JM, Dalziell, EL, James, JJ, Muñoz-Rojas, M & Merritt, DJ 2023, 'Unpacking the recruitment potential of seeds in reconstructed soils and varying rainfall patterns', *Australian Journal of Botany*, vol. 71, no. 7, https://doi.org/10.1071/BT22141

Fayer, MJ & Gee, GW 2006, 'Multiple year water balance of soil covers in a semi-arid setting', *Journal of Environmental Quality*, vol. 35, pp. 366–377.

Horton, R, Ankeny, MD & Allmaras, RR 1994, 'Effects of compaction on soil hydraulic properties', *Developments in Agricultural Engineering*, vol. 11, pp. 141–165, https://doi.org/10.1016/B978-0-444-88286-8.50015-5

International Network for Acid Prevention 2017*, Global Cover System Design – Technical Guidance Document*.

Kottek, MJ 2006, 'World map of the Köppen-Geiger climate classification updated', *Meteorologische Zeitschrift*, vol. 15, pp. 259–263, https://doi.org/10.1127/0941-2948/2006/0130

Lewandrowski, W, Erickson, TE, Dixon, KW & Stevens, JC 2017, 'Increasing the germination envelope under water stress improves seedling emergence in two dominant grass species across different pulse rainfall events', *Journal of Applied Ecology*, vol. 54, pp. 997–1007, https://doi.org/10.1111/1365-2664.12816

O'Kane, MO & Barbour, SL 2003, 'Predicting field performance of lysimeters used to evaluate cover systems for mine waste', *Proceedings of the Sixth International Conference on Acid Rock Drainage,* Australasian Institute of Mining and Metallurgy, Melbourne.

O'Kane, M, Christensen, D, Bronstrom, K & Huys, B 2011, 'Evolution of waste rock management and cover system design', MEND MLARD Workshop.

Ogle, K & Reynolds, JF 2004, 'Plant responses to precipitation in desert ecosystems: integrating functional types, pulses, thresholds, and delays', *Oecologia*, vol. 141, pp. 282–294.

Reid, N, Hill, SM & Lewis, DM 2008, 'Spinifex biogeochemical expressions of buried gold mineralisation: the great mineral exploration penetrator of transported regolith', *Applied Geochemistry*, vol. 23, no. 1, pp. 76–84, https://doi.org/10.1016/j.apgeochem.2007.09.007

Scanlon, BR, Reedy, RC, Keese, KE & Dwyer, SF 2005, 'Evaluation of evapotranspiration covers for waste containment in arid and semi-arid regions in south-western USA', *Vadose Zone Journal*, vol. 4, pp. 55–71.

Schenk, HJ & Jackson, RB 2002, 'Rooting depths, lateral root spreads and below-ground/above-ground allometries of plants in water-limited ecosystems', *Journal of Ecology*, vol. 90, no. 3, pp. 480–494, https://www.jstor.org/stable/3072232

Schenk, HJ & Jackson RB 2005, 'Mapping the global distribution of deep roots in relation to climate and soil characteristics', *Geoderma*, vol. 126, no. 1–2, pp. 129–140, https://doi.org/10.1016/j.geoderma.2004.11.018

Tfwala, CM, van Rensburg, LD, Bello, ZA & Zietsman, PC 2019, 'Transpiration dynamics and water sources for selected indigenous trees under varying soil water content', *Agricultural and Forest Meteorology*, vol. 275, pp. 296–304, https://doi.org/10.1016/j.agrformet.2019.05.030