Ranger Mine Closure Plan

2025

Executive Summary

Issued date: 1 October 2025

Revision number: 0.25.1

TABLE OF CONTENTS

FIGURES

TABLES

Cover: Former Ranger mine showing progress of initial capping on Pit 3 (2025).

1 INTRODUCTION

Energy Resources of Australia Ltd (ERA) produced uranium oxide for the global nuclear energy market for more than 40 years. The Ranger ore body, located on Mirarr country in the Alligator Rivers Region of the Northern Territory, was first discovered in 1969. ERA was established in February 1980, and when floated on the Australian Stock Exchange (ASX) in July 1980, was the largest public float in Australian history.

After considerable exploration and site preparation activity, mining started from Pit 1 (Photo 1), and ore processing soon followed with the plant commissioned in July 1981. The first drum of uranium oxide was produced on 13 August 1981.

Mining from Pit 1 finished in December 1994 and finished from Pit 3 in November 2012. The last processing of stockpiled ore and the final drum of uranium oxide was produced on 8 January 2021 (Photo 2) completing the mine's operational stage after producing a total of 132,000 tonnes of uranium oxide. The former Ranger mine is now in the closure phase.

Photo 1: Pit 1 in 1981

Photo 2: Final drum of Uranium Oxide

In April 2024, ERA appointed Rio Tinto to manage the Ranger Rehabilitation Project under a Management Services Agreement (MSA). The MSA took effect on 3 June 2024. Under the MSA, Rio Tinto will manage all aspects of the rehabilitation of Ranger, on ERA's behalf. Implementation of the MSA will allow Rio Tinto to build on ERA's work and combine this with Rio Tinto's technical expertise in designing, scoping and executing closure projects.

The environmental protection conditions within which ERA has operated and must now close the former mine are set out in the *Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine* (hereafter ERs). These ERs are attached to the Ranger Authority issued under Section 41 of the *Atomic Energy Act 1953*. The ERs are also given effect through the Ranger Authorisation issued under the then Northern Territory *Mining Management Act 2001*. The Mining Management Act was repealed and replaced by the *Environment Protection Act 2019* on 1 July 2024, and the rehabilitation activities at Ranger are now conducted in accordance with the Deemed Mining Licence (DML-0108-18), which comprises the Ranger Authorisation 0108-18 and the latest approved Ranger Mine Closure Plan.

The Atomic Energy Act included an end date for closure activities at Ranger of 8 January 2026. In November 2022, the *Atomic Energy Amendment (Mine Rehabilitation and Closure) Act 2022* (Cth) was passed. The amendments to the Act allow the Minister to vary or confer a new Authority for the express purposes of authorising rehabilitation, remediation and monitoring activities at Ranger to extend beyond the previously legislated deadline of 8 January 2026. The amendment also allows for a process for the progressive relinquishment (close-out) of parts of the RPA. Work continues with the Commonwealth Government, Northern Land Council (NLC) and Gundjeihmi Aboriginal Corporation (GAC) (on behalf of the Mirarr Traditional Owners), to negotiate the new Section 41 Authority for the RPA (a 'Rehabilitation Authority' as defined in Section 41CA of the Atomic Energy Act). ERA applied for a new Authority on 27 May 2024.

The ultimate objective for closing the mine is to prevent impacts to people and the environment, and to rehabilitate the site to a standard that will establish an environment similar to the adjacent Kakadu National Park. ERA has worked in close collaboration with many stakeholders over the last 40 years, generating a significant amount of information from research and monitoring. This ongoing information collection and analysis is guiding the rehabilitation activities towards a successful mine closure that achieves the above objective.

The MCP is the primary mechanism to describe the closure activities and rehabilitation. The MCP seeks to consolidate the relevant information from the last 40 years and demonstrate how the current and planned closure and rehabilitation activities will achieve the ERs. The 2025 MCP also discusses the role of the Ranger Rehabilitation Project Team in supporting the post-mining transition of Jabiru. To ensure its currency, and to incorporate lessons learnt from ongoing engineering, scientific and monitoring studies, the MCP is updated and submitted for approval annually. The 2024 MCP received Commonwealth Minister approval on 18 September 2025.

Standalone applications seeking approval to perform certain closure activities (e.g. backfilling Pit 1 and Pit 3; demolishing the Processing Plant; and creating the Final Landform) are also submitted. The activities subject to standalone approval applications, and those seeking approval via the MCP, are described in Chapter 4 of the main document.

2 LOCATION OF THE MINE AND CLOSURE DOMAINS

Ranger is located within the RPA adjacent to Jabiru, approximately 260 km east of Darwin in the Northern Territory (Figure 1). Access to the RPA is via the Arnhem Highway. The RPA occupies approximately 79 km^2 and is surrounded by, but separate from, Kakadu National Park.

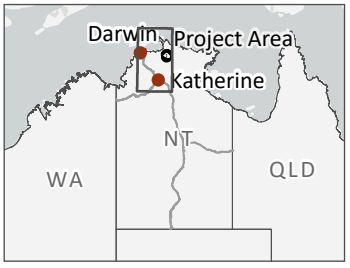
The Mirarr people are the Traditional Owners of the lands on which Ranger is located. Mirarr country encompasses the RPA, the Jabiluka Mineral Lease, the town of Jabiru, and parts of Kakadu National Park. In 1995, the Mirarr established the GAC, an incorporated body, to assist them to manage a balance between sustainable development and traditional practice on their land. The GAC represent the Mirarr Traditional Owners in discussions and negotiations regarding the Ranger Rehabilitation Project.

FIGURE 1

Location of the Ranger Project Area (RPA)

LEGEND

- Ranger Project Area
- Arnhem Land
- Kakadu National Park World Heritage Area
- National Park
- Primary Roads
- Town



0 25 50
Kilometres

Scale 1:2,000,000 at A4
GDA 1994 MGA Zone 53

Image Source: ESRI Basemap (2022); **Data source:** NT Government Data (2023)

It is common practice for spatial areas within a mine site to be identified as ‘Closure Domains’. This provides a point of reference and spatial boundary for discussions that follow. The Closure Domains for Ranger are shown in Figure 2 and comprise the following:

- Domain 1: Pit 1 (~41 ha, backfilled and rehabilitated in 2021).
- Domain 2: Pit 3 (~107 ha, being dewatered at the time of writing this MCP to dry out the tailings, allowing them to start consolidating to improve their geotechnical strength ahead of initial capping).
- Domain 3: Tailings Dam / Ranger Water Dam (RWD) (~185 ha, previously stored tailings and is now being used to store process water, hence the name change).
- Domain 4: Land application areas (total ~157 ha, used for irrigation of release water during the dry season if required).
- Domain 5: Processing plant, water treatment plant, power station, administration and maintenance facilities (~40 ha, the facilities used for processing ore have been decommissioned and are ready for demolition; some infrastructure like the water treatment and power supply facilities remain in operation).
- Domain 6: Rock stockpiles (~268 ha, will be used to backfill Pit 3 and create the final landform).
- Domain 7: Water retention ponds, water storage structures and constructed wetlands (~110 ha, used to store process water, pond water and release water).
- Domain 8: Linear infrastructure corridors supporting access roads and service tracks (~41 ha, most of these will remain throughout closure and some will remain throughout the monitoring and maintenance phase to access monitoring locations).
- Domain 9: Miscellaneous areas that include trial sites (~55 ha, will be progressively rehabilitated, with the plant nursery remaining active throughout the monitoring and maintenance phase).
- Domain 10: Jabiru Airport and offices of the Environmental Research Institute of the Supervising Scientist (ERISS) (~44 ha, future of the airport is uncertain, ERISS will likely remain throughout the monitoring and maintenance phase).
- Domain 11: Residual Ranger Project Area (RPA) (~6,852 ha). This area encompasses the balance of the RPA (i.e. all areas not included in another closure domain). It is largely undisturbed but was subject to exploration activities (e.g. historic exploration drill holes, access tracks). It also contains monitoring wells and sampling stations. Parts of this domain will be the first areas where the Ranger Rehabilitation Project team seek progressive close-out.

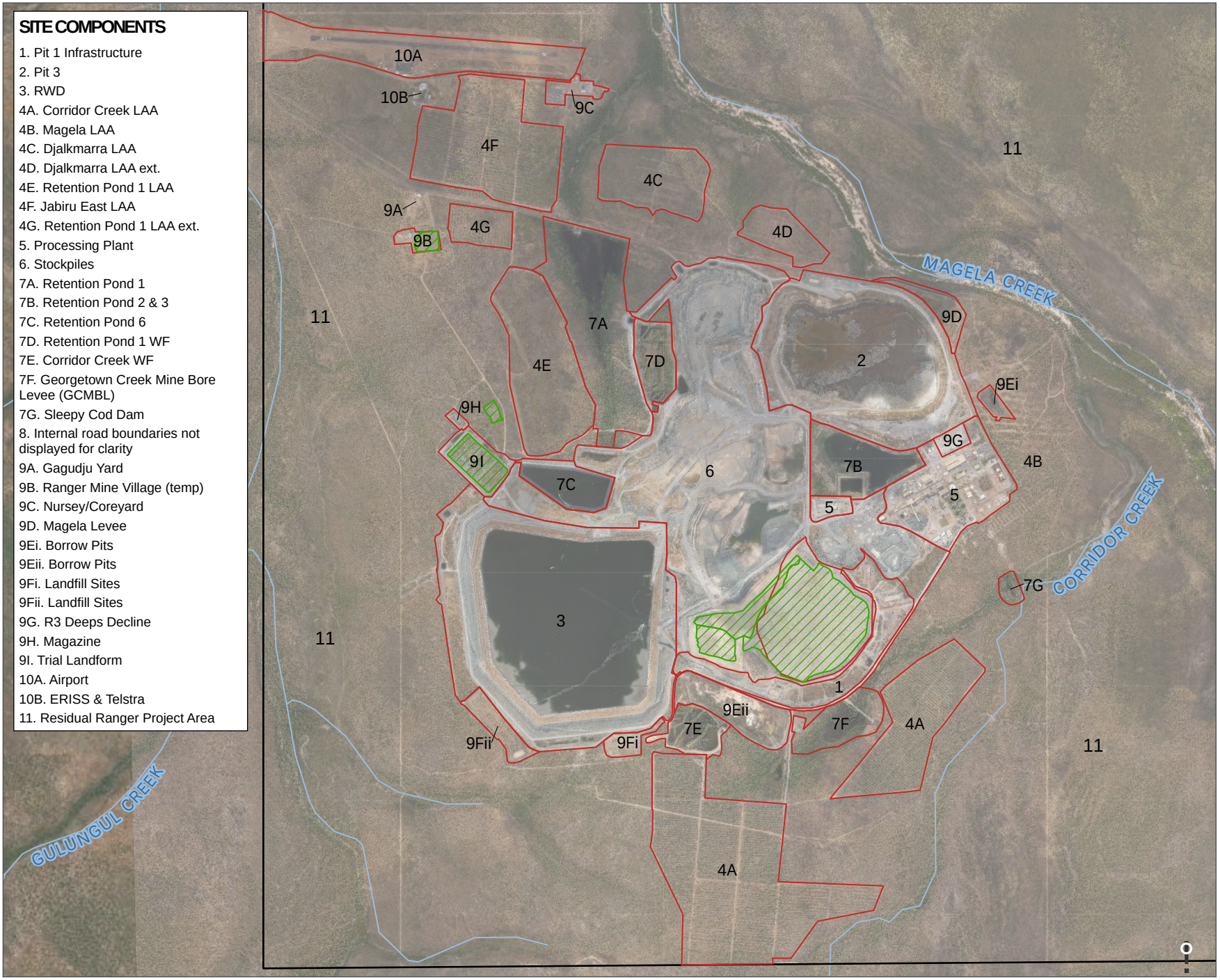
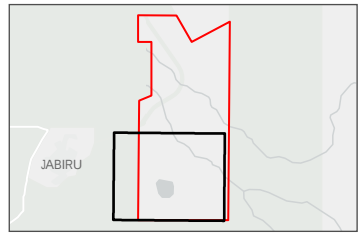


FIGURE 2

Ranger Closure Domains

LEGEND

- Mine closure domain
- Progressive rehabilitation
- Ranger Project Area



0 0.5 1

Kilometres

Scale 1:32,500 at A4
GDA 1994 MGA Zone 53

Image Source: ESRI Basemap (2024); Aerometrex (2024) **Data source:** NT Government Data (2023)

3 STAKEHOLDER ENGAGEMENT

The Ranger Rehabilitation Project Team's approach to stakeholder engagement is centred on maintaining and strengthening our relationships based on mutual respect, active partnership, transparency and long-term commitment. The team will continue to connect with and respect Mirarr culture and the aspirations of local communities as we create a positive legacy and achieve sustainable rehabilitation of the former Ranger mine.

Discussions with stakeholders are coordinated through the forums and committees listed in Table 1. These committees oversee and/or contribute to the mine's approval processes, mandatory reporting obligations, and the scientific integrity of studies, trials and projects.

In 2023, ERA undertook a range of social impact identification and social risk analysis. These processes are common best practice in the industry to support projects to identify impacts and opportunities of activities on host communities and set out clear mitigations to be monitored over the closure and post-closure phases.

ERA remains committed to its role in supporting the transition of Jabiru. In 2024, the Ranger Rehabilitation Project drafted a Community and Social Performance Plan, which outlines strategies to mitigate social impacts and social risks, and enhance opportunities identified. This has been developed in line with the Rio Tinto Communities and Social Performance Standard (2022).

Table 1: Committees and forums

Forum / Committee	Description	Members / Attendees
Minesite Technical Committee (MTC)	The MTC provides a forum for stakeholders to discuss and resolve technical environmental management matters (assessments, inspections, audits and rehabilitation activities) and regulatory matters related to the former Ranger mine and considers the views of the Mirarr and Aboriginal people.	DLPE, OSS, ERA, GAC and NLC The Commonwealth DISR is an observer
Alligator Rivers Region Technical Committee (ARRTC)	The ARRTC is an independent scientific statutory committee that oversees scientific study programs undertaken to protect the environment in the Alligator Rivers Region from effects of uranium mining. These study programs are undertaken by ERA and/or OSS and articulate the relevant knowledge and tools required to ensure protection of the environment from the potential impacts of uranium mining in the Alligator Rivers Region.	An independent chairperson, OSS, independent scientific members, NLC, representatives for DLPE, Uranium Equities Limited (current holder of the Nabarlek lease), and Parks Australia
Alligator Rivers Region Advisory Committee (ARRAC)	The ARRAC is a public, non-technical statutory committee intended to facilitate communication between government, industry and community stakeholders on matters relating to the effects of uranium mining on the environment in the Alligator Rivers Region.	An independent chairperson, representatives from several NT and Commonwealth Government departments, Office of the Administrator of the NT, NGOs, GAC, NLC, OSS, ERA, and other mining companies that operate in the region
Ranger Approvals and Studies Forum (RASF)	The RASF was established as a key collaborative forum for sharing information on Ranger project approvals and studies. It supports engagement on approval applications and study scopes, outcomes and decisions; identifies technical issues for resolution by working groups; and receives updates from those groups.	RRP Approvals and Studies teams, OSS, NLC, GAC, DLPE, DISR
Relationship Committee	The committee was established by the Mining Agreement to ensure effective information sharing and review processes between ERA and the Traditional Owners and their representatives.	Traditional Owners, GAC, NLC, ERA, and invited observers Currently paused

GAC – Gundjeihmi Aboriginal Corporation; NLC – Northern Land Council; DLPE – NT Department of Lands, Planning and Environment; OSS – Office of the Supervising Scientist; DISR – Commonwealth Department of Industry, Science and Resources; NGO – Non-Government Organisations; RRP – Ranger Rehabilitation Project.

4 MINE CLOSURE PLAN UPDATE

In 2023, the Ranger MCP was restructured to show more clearly the progress towards achieving the ERs and the current level of residual risk to the closure of Ranger. By doing so, the MCP highlights the elements of the project that require further study and design refinement to achieve the ERs and reduce residual risk. This is represented by:

1. Spider web diagrams for each of the six ER themes (Landform, Water and Sediment, Soils, Ecosystems, Radiation and Cultural) that provide a subjective per cent complete for the key metrics of Closure Criteria Approved; Relevant Studies Completed; Preventative Controls Effective; Monitoring Program Developed; and Corrective Actions Effective. The diagrams have been updated to show any change in each metric between the 2024 and 2025 MCP.
2. Bow-tie diagrams that provide on a single page a transparent way of showing progress towards achieving each ER. Within each bow-tie diagram:
    - Threats to achieving the ER and the preventative controls that have or will be implemented to manage these threats are represented on the left side of the diagram.
    - Corrective actions that will be implemented if the monitoring program identifies a deviation from the planned trajectory to achieving the ER, and the consequences and residual risk of this, are presented on the right side. The residual risk ratings reflect the current understanding and effectiveness of the controls and corrective actions. The findings of the studies that are currently underway will inform a refinement to, or addition of new, closure activities that will strengthen the effectiveness of the preventative controls and/or corrective actions, thereby reducing the level of residual risk.

5 PROGRESS OF CLOSURE ACTIVITIES

Figure 3 shows the sequence in which closure activities are planned to occur, including indicative timeframes. It is noted that the timeframes shown are subject to change as they are pending the outcomes of further studies being undertaken on matters such as water management and bulk material movement. A detailed description of closure activities is provided in Chapter 4 of the MCP.

Table 2 summarises the completed, current and future activities being undertaken within each of the closure domains as they progress towards final landform.

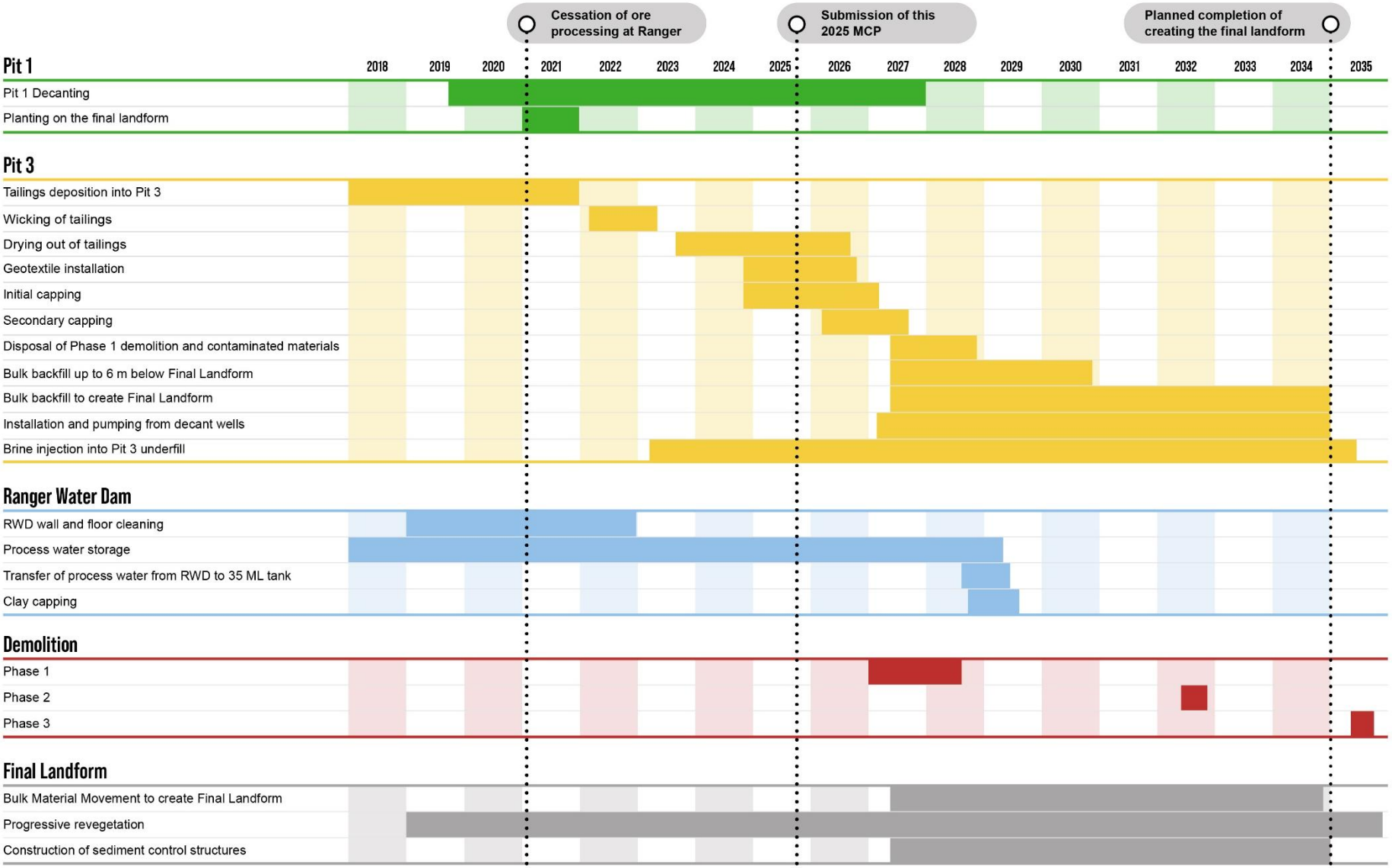


Figure 3: Indicative sequence of major closure activities

Table 2: Closure implementation work program

Domain	Completed Activity	Current Activity	Future Activity
1: Pit 1 (~41 ha)	• Mining of Pit 1 ended in December 1994 (Photo **3**). • Underdrain installed in preparation to receive tailings. • Tailings deposition began in August 1996 and ended Q4 2008 (Photo 4). • Wicking to assist dewatering and consolidation of tailings. • Installation of geotextile layer and initial capping in 2013–14. • Full backfill started in May 2019 and final landform achieved in August 2020 (Photo 5). • Scarification of the landform started in November 2020 and rehabilitation plantings started in 2021 (Photo 6). • Creation of habitat via rock features (Photo 7).	• Removal of pit tailings flux (process water) via decant wells. • Monitoring, maintenance and adaptive management activities to inform surface water runoff and ecosystem re-establishment. This work will enable the Ranger Rehabilitation Project Team to apply lessons learnt to other landforms as they are progressively established.	• Contour perimeter drain backfilled to final landform (Photo 8). • Removal of Corridor Creek road, associated bund and high voltage (HV) power. • Removal of Orica yard, trial evaporators and booster station.
2: Pit 3 (~107 ha)	• Mining started in 1997 and ended in November 2012 (Photo 9). • Underfill, underdrain and dewatering systems completed 2012–2014 (Photo 10). • Tailings deposition from mill processing started in 2015 and ended 2021 (Photo 11). • Tailings transfer from TSF started in 2016 and ended 2021. • Tailings floor transferred via truck and dozer. • Wicking to assist dewatering and consolidation of tailings (Photo 13). • Dewatering of the pit to accelerate the drying out of the tailings.	• Brine injection into the underfill zone via pit wall directional drilling (Photo 12). • Dust suppression activities and crusting the tailings surface (amphibious excavator, water spray, amphiroller). • Installation of geotextile and initial capping of the tailings (standalone approval application for Pit 3 backfill lodged September 2023 and approved August 2024)(Photo 14).	• Secondary capping (approved August 2024). • Placement of demolished plant and other infrastructure / materials into Pit 3 (standalone approval application to demolish plant was submitted 29 August 2025). • Progressive waste disposal and bulk backfill (subject to approval of additional management plans). • Final 6 m of landform and revegetation (standalone approval application for Final Landform will be submitted).

Domain	Completed Activity	Current Activity	Future Activity
3: Tailings Dam / RWD (~185 ha)	• Tailings transfer into Pit 3 ended in 2021. • Cleaning of remnant tailings from walls and floor in 2019–21 (Photo 15 and Photo 16). • RWD wall notches installed and process water received from Pit 3 in 2022.	• Process water storage and evaporation.	• RWD deconstruction (standalone approval application or included in Final Landform application). • Final landform and revegetation (standalone approval application for Final Landform).
4: Land Application Areas (~157 ha)	• Used for disposal of release water during the dry season when required.	• Ongoing disposal of release water when required.	• Progressive removal of above ground infrastructure. • Progressive remediation of any contamination. • Progressive revegetation.
5: Process plant, water treatment plants & other infrastructure (~40 ha)	• Decommissioning of infrastructure associated with the leaching and solvent extraction circuits and areas of calcination, drying and product packing.	• Ongoing use of water treatment facilities (e.g. brine concentrator, brine squeezer, water treatment plants), fuel storage, power station and administration buildings (Photo 17).	• Demolition of plant / crusher (standalone approval application to demolish plant submitted 29 August 2025). • Treatment of water – progressively transfer sections from process water to pond water. • Revegetation (standalone approval application for Final Landform).
6: Stockpiles (~268 ha)	• Stockpiled waste rock used to backfill Pit 1 in 2020. • Stockpiled waste rock used to create Stage 13 and Stage 52 final landform. • Progressive rehabilitation of small areas.	• Weed and water management. • Initial capping of tailings.	• Secondary capping and bulk backfill of Pit 3. • Bulk material movement for RPA final landform (standalone approval application for Final Landform).
7: Water management areas (~110 ha)	• Ongoing use.	• These areas continue to support ongoing water storage, dust suppression and management, including authorised release of treated water during the wet season.	• Ongoing use ahead of progressive remediation, if required, backfill, rehabilitation of retention ponds, water storages and wetland filters.

Domain	Completed Activity	Current Activity	Future Activity
8: Linear infrastructure (~41 ha)	• Two redundant tracks (3.6 ha) and six drill pads (0.8 ha) have been rehabilitated. • Bulk of this domain is supporting ongoing activities.	• These areas continue to support ongoing activities.	• Access during monitoring phase. • Progressive removal and rehabilitation as aspects of this domain are no longer required.
9: Miscellaneous areas (~55 ha)	• Trail landform constructed in 2009 to investigate rehabilitation plantings into waste rock (Photo 18). • Closure of the Ranger 3 Deeps (R3D) approved April 2019. • Ranger mine village and adjacent workshop rehabilitated in 2020. • All explosives have been removed from the magazine area and the site has been de-registered.	• Ongoing use of the plant nursery, trial landform (Photo 19), Magela Creek levee and some landfill sites.	• Plant nursery /core yard decommissioned and rehabilitated. • Progressive rehabilitation of miscellaneous areas.
10: Airport and ERISS offices (~44 ha)	• Ongoing use.	• Ongoing use.	• Handover to a third-party operator as advised by stakeholders. • Failing handover, final decommissioning and closure to commence in accordance with approval received March 2025.
11. Residual RPA (~6,852)	• Exploration activities.	• Investigating partial relinquishment of ~3,000 ha north of Magela Creek.	• Progressive rehabilitation and/or retention and handover of some access tracks to Mirarr (to be determined as part of partial relinquishment).

Photo 3: Pit 1 (1992)

Photo 4: Pit 1 tailings deposition (2008)

Photo 5: Pit 1 being backfilled (2014)

Photo 6: Pit 1 backfilled (2022)

Photo 7: Pit 1 fauna habitat features added as boulder piles (2021)

Photo 8: Pit 1 perimeter drain with access track (left) and rock check dam (right) (2021)

Photo 9: Mining Pit 3 (2007)

Photo 10: Pit 3 underfill (2014)

Photo 11: Pit 3 tailings deposition (2016)

Photo 12: Directional drilling for brine injection into Pit 3 underfill (2022)

Photo 13: Dewatering Pit 3 (April, 2024)

Photo 14: Installation of geotextile and construction of initial capping on Pit 3 (2025)

Photo 15: Cleaning remnant tailings from walls of tailings storage facility (2020)

Photo 16: Ranger Water Dam in final stages of remnant tailings removal from floor (2021)

Photo 17: Processing plant (foreground) and Retention Pond 2 centre right (2023)

Photo 18: Trial landform constructed (2009)

Photo 19:Trial landform as of 2023, plants ~13 years old

6 CURRENT PROGRESS FOR EACH THEME

The benefit of operating a mine, collaborating with stakeholders, and conducting research and monitoring for over 40 years, is an in-depth understanding and substantial base of knowledge on which closure activities and rehabilitation can be guided. The Ranger Rehabilitation Project Team acknowledge that further work is required to improve our understanding and reduce uncertainty on several aspects of the project. Table 3 shows the subjective self-assessment of current per cent complete for the key metrics to achieving the ERs for each of the six themes. The key metrics are (these are illustrated as spider web diagrams in Chapters 6 to 11 of the MCP):

- Closure Criteria Approved: the percentage complete for this metric reflects how many of the total closure criteria for each theme have been approved. Where the percentage progress is less than 100, closure criteria are either included in this 2025 MCP for approval or still in draft and the subject of discussion.
- Relevant Studies Completed: this metric reflects the progress towards completing the studies necessary to demonstrate that the relevant ERs can be achieved.
- Preventative Controls Effective: this metric reflects progress towards the effectiveness of the controls that will be put in place between now and the creation of the final landform, or shortly thereafter, to ensure that ERs can be achieved or are on the desired trajectory to being achieved.
- Monitoring Programs Developed: this metric reflects progress towards having developed and implemented a monitoring program that will demonstrate model validation, and either the confirmation of trajectories towards closure criteria or an undesirable outcome and thus a deviated trajectory.

- Corrective Actions Effective: this metric reflects progress towards the effectiveness of corrective actions that if implemented would recover a deviated trajectory to a desired trajectory within an acceptable timeframe, and would avoid unacceptable human health, environmental and cultural impacts.

Table 3: Subjective percentage progress for each theme against key metrics

	Landform	Water and Sediment	Soils	Ecosystems	Radiation	Cultural
Closure Criteria Approved	70	70	100	80	100	100
Relevant Studies Completed	70	70	70	70	90	70
Preventative Controls Effective	80	50	60	50	80	60
Monitoring Program Developed	80	80	20	60	70	40
Corrective Actions Effective	70	60	80	60	50	60

Table 3 shows that significant progress has been made across the six themes in many of the key metrics. The sections that follow provide a brief overview of the outcomes of this work and the areas targeted for future work. Chapters 6 to 11 of the MCP describe the progress and future works program for each of the six themes in much more detail.

6.1 Landform

Landform covers the physical aspects of the final landform that will cover the disturbed footprint of the mine site (Figure 4). It includes the long-term isolation of tailings and geotechnical stability of the final landform.

The final landform is to isolate the buried tailings for a period of 10,000 years and to have similar indices of erosion and runoff distribution to the natural landscape. A Landform Evolution Model is used by OSS to assess the performance of ERA's final landform design over various rainfall scenarios and durations. The latest version of the final landform design assessed by OSS in 2020 was Final Landform Version 6.2 (FLv6.2). The key findings were:

- Potential formation of gullies after 10,000 years would be up to 7 m deep under normal rainfall conditions, and up to 9 m deep under worst case rainfall conditions and with no active management. Noting that this assessment was undertaken for a landform with no vegetation covering the surface for the entire 10,000 years. The modelling will be refined to include such factors, but even in its current state it provides comfort because the tailings buried in Pit 1 in the areas with modelled gully formation have a waste rock cover of 15 m (and substantial vegetation growth after just two years), and the tailings in Pit 3 will be covered by 27 m of waste rock. Therefore, the current conservative assessment suggests that no tailings would be exposed within 10,000 years.

- With regards to erosion, this criterion will be achieved if the model demonstrates the long-term predictions of denudation rates from the designed landform are approaching the background denudation rate. Denudation is the measure of weathering, or erosion of a landform surface by forces such as water and wind. It is expressed in terms of millimetres per annum (mm/a). A study by Wasson and others (2021) identified a background denudation rate of 0.075 mm/a being relevant for Ranger. The 10,000 year assessment of the FLv6.2 LEM predicts a denudation rate of 0.15 mm/a over Pit 1 and 0.21 mm/a over Pit 3 under normal rainfall conditions. It is noted that a grass cover was also modelled for denudation rate from Pit 1 and this reduced the predicted 0.15 mm/a to 0.04 mm/a. Therefore, erosion of the modelled final landform is approaching the target criterion, but further refinement is required.

The findings of the OSS modelling assessment of FLv6.2 have been taken into consideration by ERA in the development of FLv7. In February 2022, an ERA landform design group was formed. This group is refining FLv7 to incorporate geomorphic principles and once completed will provide the revised design to OSS to assess the performance of the enhanced landform design.

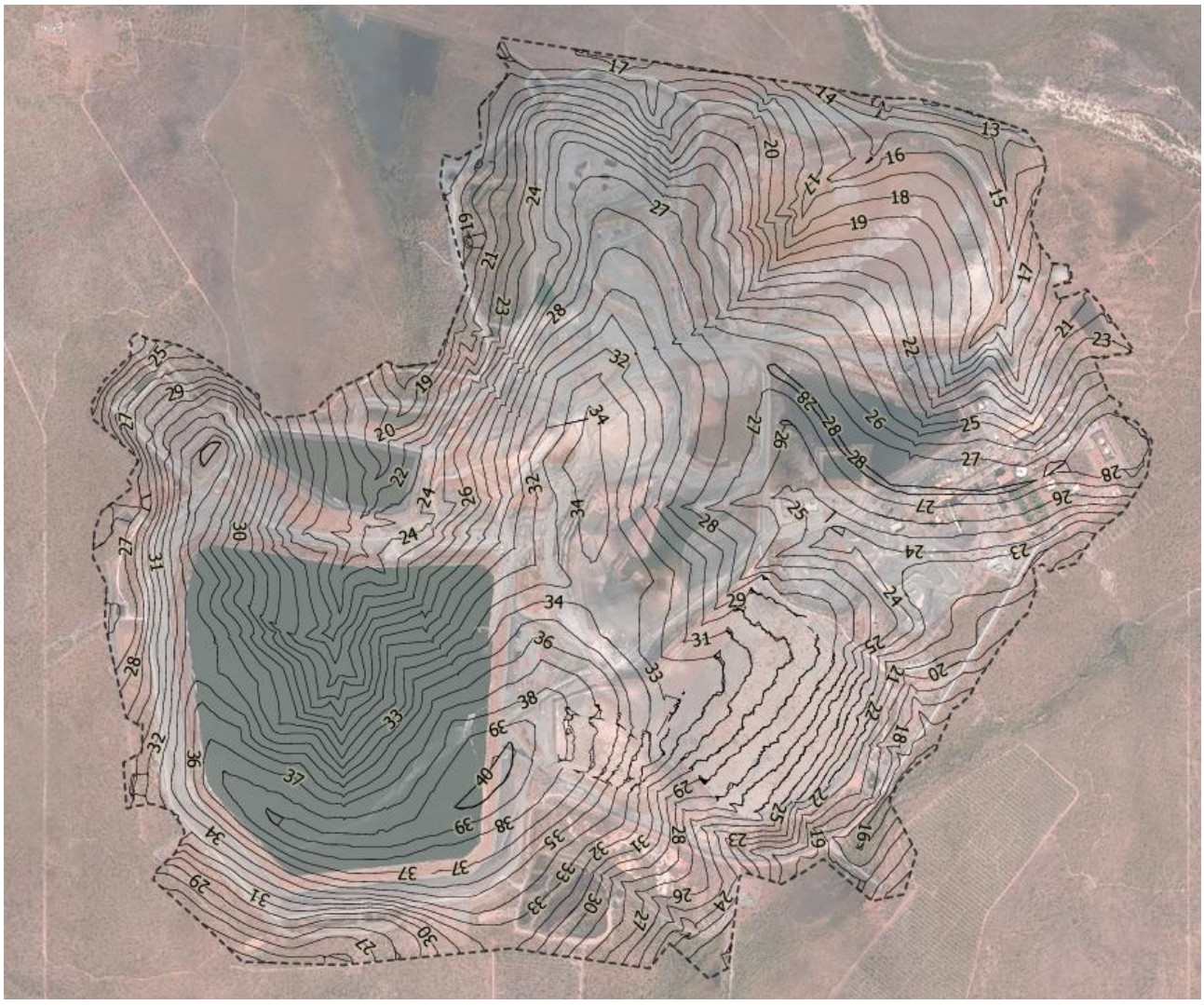


Figure 4: Final landform boundary and contours (metres reference level; mRL)

Further to the LEM development for tailings isolation and erosion rates, the Ranger Rehabilitation Project Team are undertaking a number of studies to inform a Water, Erosion and Sediment Control Plan. The objectives for the plan are to:

- in collaboration with stakeholders, determine appropriate water criteria (including turbidity) for within the RPA during the final landform construction and for the years that follow;
- design the infrastructure required to manage run-off and near surface seepage from each catchment, and across all catchments as a whole, and compare that behaviour with the agreed landform and water quality criteria;
- determine the monitoring required to support decision making and to track performance;
- develop corrective actions that would be implemented if the monitoring program detects deviation from the desired trajectory; and
- describe how the actively managed final landform will transition to long-term passive sediment management features.

6.2 Water and Sediment

Water and Sediment covers the activities undertaken to minimise the release of contaminants (i.e. radiological, chemical and physical) and prevent changes to water and sediment quality in the receiving environment that could otherwise have a detrimental impact to human health and/or ecosystems (animals and plants).

Water management is a critical aspect of the day-to-day activities at Ranger and a key driver of the timing of closure activities. It is also a key driver in achieving many of the ERs, because water is the pathway for contaminants that are present on site (largely buried in Pit 1 and Pit 3) to move off site.

Numerous studies and predictive models over the life of the mine have been developed to understand and document the often-complex hydrogeological processes. This body of work has identified Constituents of Potential Concern (CoPCs), quantified the sources of these CoPCs, and modelled the transport pathways and receptors for groundwater and surface water on and off the RPA out to 10,000 years post-closure.

There are four catchments that collect and transfer water from the mine site into Magela Creek (Figure 5). While there are hundreds of active groundwater and surface water monitoring locations on the RPA at present, the points that are particularly important to help understand the post-closure effects on Magela Creek from operating and closing the Ranger mine are shown on Figure 5. Magela Creek is an important receptor for two reasons. First, all water from the mine ultimately drains into Magela Creek. Second, the nearest resident population to the mine is located at Mudginberri Billabong, a receiving waterbody on Magela Creek approximately 5 km downstream of the point where Magela Creek crosses the boundary of the RPA (Figure 5).

The Ranger Surface Water Model (RSWM) calculates concentrations of 20 mine derived CoPCs in surface waters of the Magela Creek catchment, from Magela Creek upstream (MCUS) to Mudginberri Billabong downstream. The model is useful for estimating surface water CoPC concentrations at discrete locations as it effectively models the mixing of solutes in low concentration background loads with site loads by applying a mass balance approach. Conservation of mass was assumed for all CoPC movement within the Magela Creek system, and no allowance was made for any reactivity of CoPCs with creek flows (i.e. a conservative approach is applied).

Outputs from the model include flow exceedance values that represent the predicted solute concentration that will be exceeded for a certain percentage of the time where there is flow at that location. Concentrations taken from the model at peak loads and at 10,000 years post-closure are reported in the MCP. The values used in this assessment are a flow-weighted 3-day average of the concentration.

Development of an updated surface water solute transport model (SWSTM) is progressing that includes hydrodynamic and water quality/reactive transport modelling including the implementation of components of the Aquatic Eco-Dynamics (AED) model. The initial focus of the work is on the Coonjimba catchment, and the updated model will eventually progress to the other sub-catchments and Magela Creek. The SWSTM includes sub-daily rainfall runoff and flow dynamics as well as the capacity to model backflow and flushing in onsite billabongs. While the SWSTM is in development, the RSWM remains the current functional tool for estimating downstream water quality.

The results provided in the 2024 MCP are a combination of the latest 2023 modelling undertaken for the submitted and approved Pit 3 application (i.e. for the Djalkmarra catchment and all source terms from contaminants to be disposed in Pit 3) and modelling undertaken in 2020 for the rest of the non-Pit 3 related sources. A Best Practicable Technology (BPT) assessment is currently underway to identify additional mitigations that would reduce solute loads from the RWD. Once completed, the modelling will be re-run to update the rest of the non-Pit 3 sources, and the outcomes of this work will be provided in standalone approval applications and future updates to the MCP.

To help understand the potential effects of the CoPC concentrations entering Magela Creek, the predicted concentrations at peak loads and 10,000 years post-closure were compared to various guideline values. The outcomes of this comparison are:

- Drinking water: the concentrations of all CoPCs are less than the guideline values – that is, there would be no risk to health from drinking the water at any of the monitoring points from predicted peak load concentrations or 10,000 years post-closure.
- Recreational water: the concentrations of all CoPCs are less than the guideline values.
- Australian livestock drinking water: the concentrations of all CoPCs are less than the guideline values.
- International wildlife / livestock drinking water: the concentrations of all CoPCs are less than the guideline values.

- Species protection level (SPL) for 99% of aquatic species: Manganese (Mn) is the only CoPC that current modelling shows an exceedance of the 99% SPL guideline value. The 99% SPL for manganese is 73 µg/L. The background manganese concentration in Magela Creek (at MCUS) is 14 µg/L. The predicted 50% exceedance at the end of RPA is 178 and 61 µg/L for the peak and 10,000 year concentrations respectively (261 and 85 µg/L for the 10% exceedance for peak and 10,000 years respectively).

Whilst not showing as an exceedance against any guideline value, the predicted loads of nutrients and sulfate are recognised as factors that require further investigation (for eutrophication and potential formation of acid sulfate soils respectively). Increased nutrient loads may contribute to eutrophication, the biological processes characterised by high levels of plant and/or algae phytoplankton that may result in the water becoming green and cloudy. Increased sulfate loads in sediments, under certain conditions and when oxidised (exposed to the air), can produce acid. Instances of acidification associated with acid sulfate soils have been observed in Coonjimba Billabong, indicating conditions suitable for the formation of acid sulfate soils are present in at least some locations on the RPA.

Therefore, whilst the planned water management activities on site are predicted to have considerable success in minimising the concentrations of most CoPCs that will enter the Magela Creek system, further work is underway to reduce the predicted concentrations of several CoPCs. This work is detailed in Chapter 7 of the MCP and includes:

- To improve modelling of likely solute concentrations in surface water, including work to reduce uncertainty in both groundwater and surface water modelling, and to better capture the spatial and temporal aspects of CoPC movement into surface waters.
- To develop the Surface Water Solute Transport Model to incorporate hydrodynamic processes and bio-geochemical phenomena to more accurately predict solute concentrations over time.
- To undertake BPT assessments of additional remediation concepts aimed at reducing the downstream concentrations of CoPCs (particularly manganese).
- The Ranger Rehabilitation Project Team will continue to monitor nitrate, ammonia, total nitrogen and total phosphorous concentrations at MCUS and MG009 to advance our understanding of eutrophication. This ongoing monitoring will provide an improved evaluation of natural background load variability, both in terms of total load as well as temporal and flow related variability.
- Potential mitigation options being considered for reducing manganese loads in the above-mentioned BPTs will also be beneficial for reducing sulfate loads.

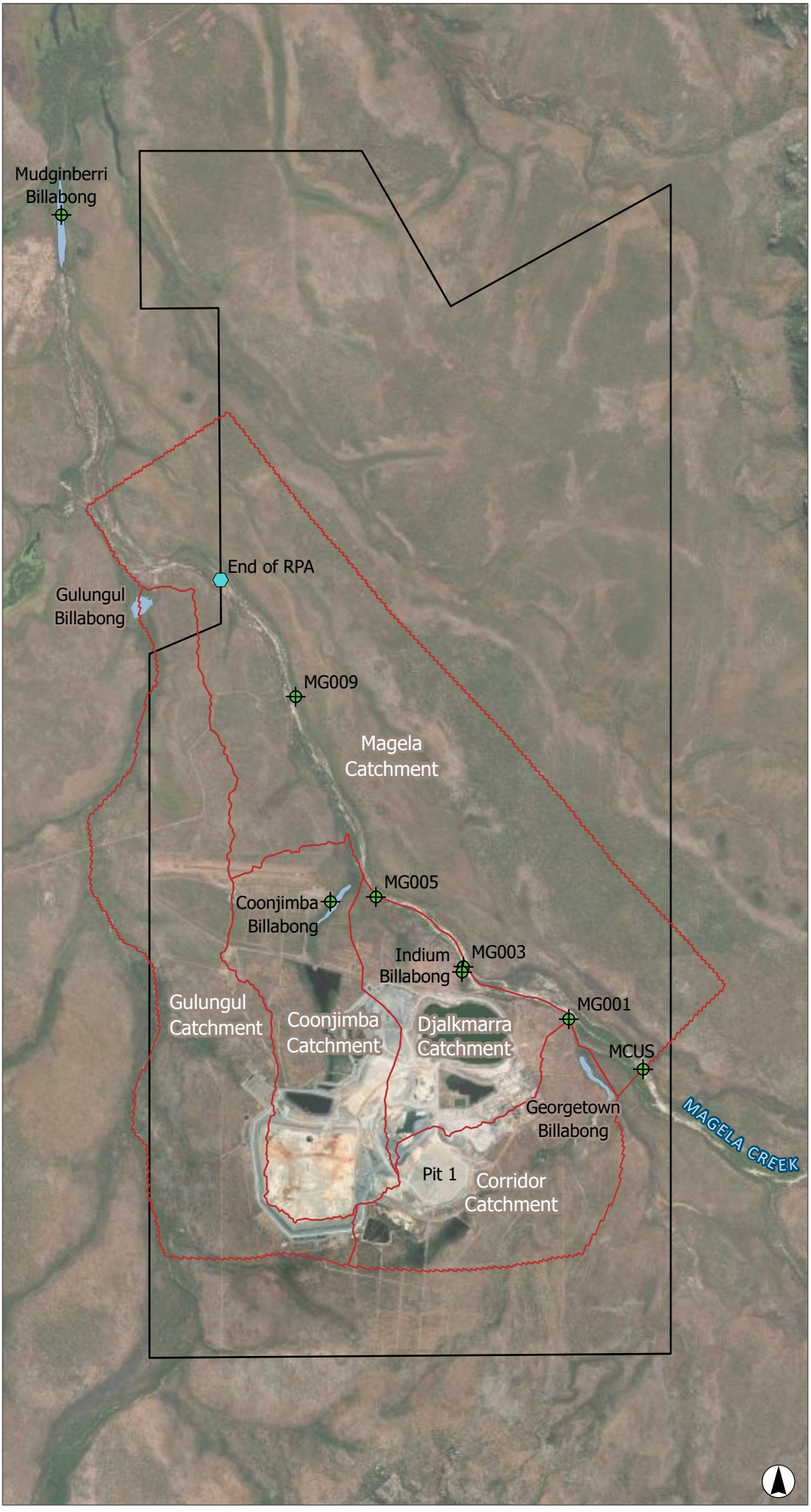
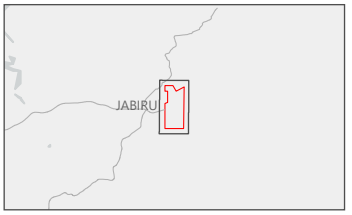


FIGURE 5

Water Catchments and Key Monitoring Locations

LEGEND

- Ranger Project Area
- Groundwater Watershed Boundary
- Waterbody
- Modelling Assessment Point
- Surface Water Monitoring Site



0 1 2
Kilometres

Scale 1:65,000 at A4
GDA 1994 MGA Zone 53

Image Source: ESRI Basemap (2022); **Data source:** NT Government Data (2023)

6.3 Soils

The theme of 'Soils' for Ranger is referring to surface or near-surface land that may have been contaminated during the operation of the mine. It includes land on the RPA that has become contaminated through treatment of pond water in wetlands and bunds, irrigation of pond water in the Land Application Areas (LAAs), and seeps and spills in areas such as the processing plant.

Studies to identify and categorise the contaminants on the RPA have been occurring for decades. The Ranger Rehabilitation Project Team maintains a contaminated sites register and updates the register routinely.

The following conservative volumes of demolished plant and contaminated soils are estimated for disposal:

- Approximately 455,000 m^3 of demolished and/or contaminated material is to be disposed to Pit 3. The total space available within the Pit 3 footprint, to the final landform surface is approximately 29,000,000 m^3.
- Approximately 117,400 m^3 of demolished and/or contaminated material is to be disposed to Retention Pond Number 2 (RP2). The total space available within the RP2 footprint, to the final landform surface is approximately 2,500,000 m^3.

The bulk of this material is contaminated soils, representing approximately 405,000 m^3 (or 89%) and 35,000 m^3 (or 30%) of the demolished and/or contaminated material to be disposed to Pit 3 and RP2 respectively. The bulk of contaminated soils will come from beneath the processing plant, with some also likely to come from wetland filters and from the retention ponds.

The Phase 1 studies generated a conservative prediction of contaminant volumes across the RPA.

Phase 2 of the soil contamination studies has been started, with sampling undertaken to identify the nature and extent of contamination within and around the processing plant area. Phase 3 of the soil contamination studies will include the development of targeted Remediation Action Plans (RAPs), on-ground execution of the remediation works, planning for appropriate validation sampling, and the reporting of performance against the agreed criteria.

The subjective 20% complete assigned to the 'Soils' monitoring program (refer Table 3) also requires attention. This reflects the considerable future work that is planned to better inform the validation sampling and post-closure monitoring program.

6.4 Ecosystems

The 'Ecosystems' theme refers to the establishment and maintenance of vegetation, habitat and fauna communities on the final landform, aiming to ensure they are sustainable and similar to those in the adjacent areas of Kakadu National Park.

Decades of relevant studies and ongoing ecosystem establishment trials have provided a substantial knowledge base for Ranger. There are two key aspects of achieving the ERs for ecosystems:

- Ecosystem similarity – which requires the flora and fauna species composition, abundance and community structure of rehabilitated areas within the RPA to be similar to Kakadu National Park. Relevant information on this aspect is provided in the MCP under the headings:

  - Vegetation reference ecosystems;
  - Fauna reference ecosystems; and
  - Ecosystem establishment strategy.
- Ecosystem sustainability – which requires rehabilitated areas to contain functioning ecosystems that are viable in the long-term and similar to those in adjacent areas of Kakadu National Park. Relevant information on this aspect is provided in the MCP under the headings:
  - Fauna reference ecosystems (where related to key vegetation dispersing fauna);
  - Ecosystem establishment strategy;
  - Weeds and other introduced flora and fauna;
  - Sustainability processes (including resilience to disturbance) and recruitment; and
  - Fire resilience.

The key drivers for the success of the ecosystems work are to understand the reference ecosystems that represent an appropriate rehabilitation target for disturbed areas of the RPA, the characteristics of the waste rock in which the plants are to grow, and the factors that will promote or hinder ecosystem establishment and long-term sustainability. Success in these areas will provide the habitat suitable for recolonisation by native fauna.

ERA, and our partner Kakadu Native Plant Supplies, have demonstrated considerable success in collecting seed and propagating local provenance plant species, establishing these species on waste rock, particularly on the TLF for over 14 years (Photo 20), Pit 1 for over 3 years (Photo 21) and more recently Stage 52 that was planted over a year ago (Photo 22).

Whilst progress to date is very promising, there is still much work to be done, including:

- Based on relevant studies and consultation with stakeholders and subject matter experts, further clarification and development of closure criteria, to be provided for Ministerial approval in future iterations of the MCP.
- Finalisation of the savanna woodland Conceptual Reference Ecosystem (CRE), particularly regarding fauna and understorey composition.
- Consideration of applicable alternative vegetation communities, including ‘seasonally inundated savanna’, with integration of these into the Species Establishment Research Program (SERP).
- Investigation into potential waste rock substrate constraints to ecosystem establishment, including any feasible mitigation and/or amelioration options.
- Consolidation of monitoring data from rehabilitation areas, which will be used to update the SERP, and to further refine the Savanna Woodland CRE and the Ecosystem Establishment Strategy.
- Continued development of a multi-year Weed Strategy to manage weeds across the RPA using a best-practice, targeted, risk-based approach.

- Further development of monitoring methodologies at-scale for vegetation establishment, fauna, habitat formation and nutrient cycling.

Photo 20: Plantings on TLF (~14 years old)

Photo 21: Plantings on Pit 1 (~3 years old)

Photo 22: Plantings on Stage 52 (~1 year old)

6.5 Radiation

There is a substantial body of knowledge that has been generated by ERA and OSS to understand and predict radiation doses to people and radiological risks to plants and animals arising from mining activities at Ranger.

A radiological impact assessment aims to quantify the impacts of radiation that originate from sources associated with a particular activity or practice, and to compare the results to existing and accepted standards. For people, the radiological impact is calculated as a potential radiation dose, where the incremental impacts above natural background levels are assessed and compared against relevant standards and limits to determine whether the impacts are acceptable.

The potential exposure pathways to radiation are:

- dust lift off leading to subsequent deposition of radionuclides in the wider environment and uptake into plants and animals that are consumed;

- dust lift off leading to radionuclides in air that can be inhaled;
- radon emission from the rehabilitated landform and the LAAs resulting in elevated radon decay product concentrations and subsequent inhalation;
- mobilisation of radionuclides into groundwater and surface water resulting in changes in concentrations and subsequent ingestion of water or uptake into plants and animals; and
- Gamma irradiation to people in the immediate vicinity of the rehabilitated landform and the LAA from potentially elevated radionuclide concentrations.

It is understood that the rehabilitated site will be used for both recreational and cultural use by the Mirarr Traditional Owners. In 2014, ERA formalised the engagement regarding post-mining land use and closure criteria through extensive consultation with Traditional Owners via the consulting linguist and anthropologist Murray Garde. His resulting report (Garde, 2015) identified occupancy intentions (1,040 hours or 43 days per year estimated to be spent on the rehabilitated Ranger mine area), use of traditional plants and animals, and the expected post-closure bush food diet.

The dose assessment method used internationally accepted processes and recognised dose factors developed by the International Commission of Radiological Protection and considered the exposure pathways listed above for a range of age groups. The assessment considered numerous scenarios, spanning from the expected occupancy intentions and bush food diet to conservative assumptions where the entire bush food diet was sourced exclusively from the rehabilitated mine area and all water consumed was based on the peak radionuclide concentrations predicted from the surface water model. In total, doses were calculated for 100 scenarios (20 different scenarios for 5 age groups; being 1, 5, 10, 15 year old and adults). For all 100 scenarios, the total radiation dose to the public is below the public dose limit of 1 millisievert per year (mSv/y).

For non-human biota (animals and plants), the changes in radionuclide concentrations due to emissions from the rehabilitated mine are calculated at relevant locations of interest. For potential radiological impacts to plants and animals, a combination of changes in soil concentrations due to dust deposition and the changes to water concentrations due to solute transfer at peak loads and at 10,000 years post closure were used.

The radiation impact assessment has demonstrated compliance with dose limits for human and non-human biota. Nevertheless, further engineering design of closure activities and additional remediation actions are planned, which are expected to lower radiation doses further. The following work is planned for radiation:

- the radiation assessment will be re-run for the whole of the final landform after the following has occurred:
    - the review of cover material radionuclide content;
    - the review of the water quality modelling regarding two radionuclides (Radium 226 (Ra226) and Polonium 210 (Po210)); and
    - the review of surface water quality CoPC concentrations including representation of any required groundwater plume management remediation.

6.6 Cultural

In 2006, ERA and GAC (on behalf of the Mirarr Traditional Owners) developed a protocol for cultural heritage management on the RPA. Further work is proposed to improve the Cultural Heritage Management System for closure and rehabilitation via the finalisation and implementation of a formal Cultural Heritage Management Agreement.

The RPA has undergone extensive cultural heritage investigation since 2006 with approximately 75% of the lease area subject to systematic pedestrian survey. A total of 139 cultural heritage sites have been recorded on the RPA, with approximately 70 background artefact scatters also recorded.

In 2006, a ‘first pass’ closure model was provided to the Mirarr Traditional Owners. In response, a series of consultation meetings were held with the goal of understanding their expectations and concerns for closure. It was understood by the Mirarr Traditional Owners that there would be ongoing consultation over the years as the closure model was refined and more detailed information was known by ERA.

In 2012, ERA engaged Murray Garde to facilitate consultation with the Mirarr Traditional Owners to further develop the cultural closure criteria for Ranger. This consultation built on the initial discussions of the first pass closure model. To develop the criteria, the post-closure land use and the nature of the Mirarr’s interactions with the rehabilitated landscape needed to be understood. This is key to delivering a rehabilitated landform that will be accepted by the Mirarr Traditional Owners and provide them with a safe and healthy area to re-establish traditional practices.

Garde’s report (Garde, 2015) provides details of the end land use including a list of culturally important flora and fauna, the types and amount of bush foods consumed, and the nature of past and predicted future occupancy of the rehabilitated landform. Table 4 identifies the expected use of the mine area post-closure and the outcomes of preliminary assessments to understand the potential impacts to those uses based on the findings of the studies completed to date and reported in this MCP. No direct consultation with the Mirarr Traditional Owners has yet taken place as part of the preliminary assessment presented in Table 4.

Consultation with the Mirarr Traditional Owners will continue to inform the Ranger Rehabilitation Project Team of the expectations of the Mirarr Traditional Owners and the cultural monitoring program.

The Ranger Rehabilitation Project Team, NLC, GAC and the Mirarr Traditional Owners are aligned on the desire to support Traditional Owners in capacity building to undertake some of the monitoring described in this MCP. Engagement with the Traditional Owners as the post-mining landowners will be key in the planning to transition the management responsibility to the Mirarr Traditional Owners at site relinquishment. The exact nature of this support requires further discussion.

Table 4: Preliminary assessment of the potential impacts to cultural land use activities (consultation with Traditional Owners required)

Purpose of visit	Estimated time[1]	Location	Preliminary Assessment of Potential Impact / Relevant Outcome[2]	Section in MCP
Hunting and food gathering (day trips)	30 days per person per year	Magela Creek and associated riparian zones (undisturbed)	No impact to hunting and food gathering is predicted from the planned closure and rehabilitation activities. Human and animal drinking water quality all within limits, radiation doses all within limits.	7.3.5, 10.3
		Billabongs[2]	Preliminary and conservative calculations completed to date suggest that accumulation of manganese in older Mussels (bivalves) may pose a risk between Pit 3 and Mudginberri Billabong if manganese concentrations remain at predicted levels post-closure and Pit 3 is no longer acting as a groundwater sink.	7.3.11
Seasonal camping (extended camping)	20 days per person per year	Magela Creek and associated riparian zones (e.g. camp MG009)	No impact to seasonal camping (extended) predicted from the planned closure and rehabilitation activities. All CoPCs within drinking water quality guidelines, potential for minor eutrophication effects (e.g. filamentous algal growth) in early recession period (April/May) reducing visual amenity of the waterway.	7.3.5, 7.3.9
		Billabongs[2]	No impact to seasonal camping (extended) predicted from the planned closure and rehabilitation activities.	
Recreation	10 days per person per year	Magela Creek and associated riparian zones (undisturbed)	No impact to recreational visits predicted from the planned closure and rehabilitation activities. All CoPCs within drinking water quality guidelines, potential for minor eutrophication effects (e.g. filamentous algal growth) in early recession period (April/May) reducing visual amenity of the waterway.	7.3.5, 7.3.9
		Billabongs[2]		
Land management and monitoring	10 days per person per year	Magela Creek and associated riparian zones (undisturbed)	No material change to the proposed land management and monitoring.	6.6, 7.6, 8.6, 9.6, 10.6
		Billabongs[2]		
Ritual[3]	5 days per year	Magela Creek and associated riparian zones (undisturbed)	No impact predicted to ritual visits from planned closure and rehabilitation activities. However, Traditional Owner perception may impact ritual land use. Further consultation is required.	7.3.5, 10.3
		Billabongs[2]		

[1] – occupancy rates from Garde (2015).
[2] – water quality modelling uncertainty remains, and further work is being conducted to better understand potential impacts, including BPTs for additional mitigations.
[3] – Garde (2015) provides details on the type of rituals likely to be performed on the rehabilitated RPA and areas that may be utilised (including sacred sites, billabongs and camping areas).

7 CURRENT RISKS

Risk assessments for the closure of the RPA have been held since 2008 and will continue to be undertaken throughout closure as results of monitoring and technical studies become available and are used to refine the Ranger Rehabilitation Project Team's understanding of risk.

A risk matrix is used to determine the overarching risk classification for each identified risk event or threat. The risk classification is a function of the consequence and likelihood ratings determined by subject matter experts. The overarching risk classification is determined to be either Class IV (Critical), Class III (High), Class II (Moderate) or Class I (Low). The risk classification identifies the level of management action that must be taken to mitigate the risk, with:

- Class IV: Risks that significantly exceed the risk acceptance threshold and require investment in a complete suite of suitable best practice controls and detailed studies to classify uncertainty;
- Class III: Risks that exceed the risk acceptance threshold and require further investment in controls and study development, with classification of uncertainty;
- Class II: Risks that lie on the risk acceptance threshold and require some development of controls or studies to address uncertainty; and
- Class I: Risks that are within the risk acceptance threshold and do not require further controls or studies.

Table 5 provides a summary of the risks, noting that further studies aimed at improving the controls and uncertainty for Class III and Class IV risks are underway, and the progress towards reducing these risks will be discussed in future iterations of the MCP. The Class III and IV risks included in Table 5 are a consolidated list from those identified in the MCP, that is, similar risks have not been duplicated.

Table 5: Summary of current risks

Class	Risks to achieving ERs	
	No. of Risks	Description of risk event
Class IV	4	• Risk that above criteria concentrations of manganese result in health impacts. • Risk that above criteria concentrations of manganese, sulfate and/or nutrients result in environmental impacts. • Risk that the presence of weeds on the final landform is not acceptable to stakeholders. • Risk that Traditional Owners cannot resume all cultural activities (risk rating will be reduced when the first two risks are reduced).
Class III	9	• Risk that the amount of water pooling on or adjacent to the landform is not acceptable to Traditional Owners. • Risk that the amount of erosion of the final landform is not acceptable to Traditional Owners. • Risk that the view to significant cultural site/s is obscured by the final landform. • Risk of sediment from the constructed landform impacting surrounding ecosystems. • Risk that stakeholders are not satisfied with the vegetation composition, nutrient cycling or fauna returning to the revegetated landform. • Risk associated with potential tailings exposure after 10,000 years. • Risk of physical damage to cultural heritage site/s. • Risk of indirect damage to cultural heritage site/s via mine-derived altered conditions. • Risk of elevated concentrations of sulfate result in increased ASS formation and acidification processes.
Class II	14	See Chapter 12 of the MCP for details.
Class I	12	See Chapter 12 of the MCP for details.

8 REFERENCES

Garde, M. 2015. *Closure Criteria Development - Cultural*. Energy Resources of Australia Ltd (ERA) Ranger Integrated Tailings, Water & Closure Confidential report, Northern Territory, p. 160.

Rio Tinto. 2022. Communities and Social Performance Standard. Document Number: CSP-B-001.

Wasson, R.J., Saynor, M.J. & Lowry, J. 2021. The natural denudation rate of the lowlands near the Ranger mine, Australia: a target for mine site rehabilitation. Geomorphology, 389, pp. 107823.