Ranger Mine Closure Plan 2025

Appendices

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APPENDICES

APPENDIX 1.1: 2023 AND 2024 RANGER MINE CLOSURE PLAN FEEDBACK AND RESPONSES

Table 1: Response to OSS Assessment on the 2023 MCP and Progress

Recommendation	Timing / Hold Point	Relevant Theme / Section of 2024 MCP	Section in 2025 MCP[1]
Recommendation 1 Prior to deconstructing the Magela Levee, Energy Resources of Australia (ERA) should provide an Erosion and Sediment Control Plan for approval by the Supervising Authority which identifies how turbidity risks to Magela Creek will be managed and how the groundwater monitoring network in the vicinity of the levee will be protected.	Prior to deconstructing the Magela Levee	Description of Closure Activities	Section 4.4.4.6
Recommendation 2 Future iterations of the Ranger Mine closure Plan (RMCP) should provide updated information on the activities undertaken and proposed to address the recommendations from the Supervising Scientist's assessment of the *Pit 3 Capping, Waste Disposal and Backfill Application*.	MCPs	Description of Closure Activities	Section 4.2
Recommendation 3 Future iterations of the RMCP should describe how infrastructure potentially required beyond 2035, such as the nursery and water treatment infrastructure, will be disposed of and any disturbance be rehabilitated.	MCPs	Description of Closure Activities	Section 4.4.3.1 and Section 4.4.3.7
Recommendation 4 Specific details of proposed erosion, sediment and water control structures should be included in future versions of the Final Landform design (e.g. FLv7), including at the northern boundary of the Ranger Water Dam where there is a risk that the re-establishment of Coonjimba Creek could cause significant erosion and mobilise soils contaminated by the prior storage of tailings.	Future versions of the Final Landform design (e.g. FLv7)	Landform	Defer for optimisation of FLFv7
Recommendation 5 Information on how risks to the surrounding environment, particularly from surface water runoff and dust, will be managed during the construction phase as well as a detailed **Landform Construction Monitoring Plan** and associated Trigger Action Response Plans (TARPs) should be included in the Final Landform Application.	Final Landform Application	Landform	Noted

1 whilst sections of the MCP may discuss the topic of the feedback raised, further studies are occurring or planned and therefore the cross-referenced sections may not/do not resolve the feedback raised

Recommendation	Timing / Hold Point	Relevant Theme / Section of 2024 MCP	Section in 2025 MCP[1]
Recommendation 6 A detailed quality assurance and quality control program should be included with the Final Landform Application that will be implemented to ensure the final landform is built to design, and that appropriate material is used to form the surface layer.	Final Landform Application	Landform	Noted
Recommendation 7 Information obtained from erosion and sediment control trials conducted by ERA should be included and discussed in the next RMCP.	MCPs	Landform	Section 6.3.1.4
Recommendation 8 A detailed **Post-closure Landform Monitoring Plan** and associated TARP should be included in the Final Landform Application which clearly links to monitoring objectives and allows for any issues to be quickly identified and resolved.	Final Landform Application	Landform	Noted
Recommendation 9 The surface water closure criteria for Ranger should include a site-specific Guideline Value for aluminium which is being developed by OSS.	MCPs	Water and Sediment	Section 7.1.2 to Table 7-2; Section 7.3.7
Recommendation 10 A success metric should be developed for surface water closure criteria linked to the validation of groundwater modelling predictions.	MCPs	Water and Sediment	Noted
Recommendation 11 The Ranger groundwater uncertainty analysis should be reviewed and if required updated based upon the outcomes of future groundwater studies and be included in the Final Landform Application.	Final Landform Application	Water and Sediment	Section 7.3.1, Section 7.3.3, Section 7.3.12
Recommendation 12 Prior to the finalisation of contaminated site assessments and planning of remediation activities, stakeholders should be consulted on: • the identification of potentially contaminated areas prior to further investigations • on the final Areas of Potential Concern • on the draft Remediation Action Plans prior to their implementation.	MCPs	Soils	Section 8.3.2 and Section 8.9

Recommendation	Timing / Hold Point	Relevant Theme / Section of 2024 MCP	Section in 2025 MCP[1]
Recommendation 13 The Ranger Ecosystem State and Transition Model should be completed as a priority with an update on the status of the model provided in the 2024 RMCP.	2024 MCP	Ecosystems	Section 9.8
Recommendation 14 Trials should be implemented in current revegetated areas at Ranger where deviated states are occurring to test the ability to correct deviated states. Information on these trials should be provided in future RMCP submissions.	MCPs	Ecosystems	Section 9.3.3
Recommendation 15 Should ERA propose an alternative Conceptual Reference Ecosystem (CRE) for the Ranger Water Dam area which does not satisfy ER2.1 and 2.2(a), ERA will need to conclusively demonstrate that all other options to manage groundwater contamination from the RWD, such as water treatment and landform redesign, are not viable.	MCPs	Ecosystems	Noted
Recommendation 16 An operational **Revegetation Plan**, or a similar tool, should be developed in consultation with stakeholders and be provided with the Final Landform Application.	Final Landform Application	Ecosystems	Noted
Recommendation 17 An **Ecosystem Rehabilitation Monitoring Plan** should be developed and updated annually, including: • an outline of monitoring methods, scale, locations, sampling frequency and parameters • weed monitoring methods and an assessment of weed management efforts • alignment with the Trigger, Action, Response Plan (TARP) • consideration of methodological advances as new technologies become available (e.g. AI assisted classification of remote imagery).	MCPs	Ecosystems	Section 9.6
Recommendation 18 An **Ecosystem Rehabilitation Monitoring Report** should be developed and updated annually, including: • provision and interpretation of monitoring data • identification of risks, preventative controls and corrective actions	MCPs	Ecosystems	Section 9.6

Recommendation	Timing / Hold Point	Relevant Theme / Section of 2024 MCP	Section in 2025 MCP[1]
• identification of any requirements for updates to the State and Transition Model and the **Revegetation Plan** identified in Recommendation 16 • identification of additional monitoring requirements and contents for updates to the **Ecosystem Rehabilitation Monitoring Plan** identified in Recommendation 17.			
Recommendation 19 A whole-of-site radiation dose assessment (public and non-human biota) should be completed for the Final Landform Application.	MCPs, Final Landform Application	Radiation	Chapter 10
Recommendation 20 Prior to commencement of new activities or significant changes to existing site activities, the Ranger **Radiation Management Plan** should be reviewed to ensure that it accurately reflects the radiological risks from the activity and describes fit for purpose management systems.	Prior to commencement of new activities or significant changes to existing site activities	Radiation	Reviewed and specific Module provided for Pit 3 and Phase 1 Demolition
Recommendation 21 ERA's radiation monitoring program should include the following requirements: • annual radiation monitoring of drinking water from Magela Creek during the closure phase • a systematic approach to monitoring of radon decay products for worker radiation safety during the closure phase.	MCPs	Radiation	Noted
Recommendation 22 Prior to discrimination of bulk material, ERA should undertake the following activities: • test the ability of the radiometric discriminator to distinguish between low grade 1 (<0.007% U3O8) and high grade 1 (>0.007% U3O8) waste rock	Prior to BMM	Radiation	No longer required
• specify focus and action level trigger values for material grade discrimination within the TARP.			Defer to Pit 3 BMM Plan
Recommendation 23 The Ranger post closure monitoring program should include: • a monitoring program for radon exhalation from final landform surfaces of sufficient duration to demonstrate stabilisation of exhalation flux	MCPs	Radiation	Section 10.6
• atmospheric monitoring for dust and radon (or radon decay products) as part of the post-closure radiation monitoring program.			Section 10.6

Table 2: Response to OSS Assessment on the 2024 MCP

Recommendation	Timing / Hold Point	Relevant Theme / Section of 2024 MCP	Section in 2025 MCP[2]
Recommendation 1 Estimates of total brines injection volumes should be reviewed, taking into account changes in site operations, groundwater migration, transfers of pond water to process water and the possibility of prolonged water treatment. Outcomes from this review and any future ongoing validations of brines injection volumes should be reported in future Ranger Mine Closure Plans.	MCP	Description of Closure Activities – Pit 3	Section 4.2.2
Recommendation 2 An assessment of the effects of flocculants and coagulants, used in recent erosion and sediment control trials (Stage 52) on discharge water quality, including turbidity and potential toxicities, should be included and discussed in the next Ranger Mine Closure Plan. Should flocculants and coagulants be used at a large scale, an assessment of potential risks to downstream environments, including on-site billabongs, should be included in the Erosion, Sedimentation and Water Control Plan, and provided in the Final Landform Application.	MCP	Landform	Section 6.3.1.5
Recommendation 3 ERA should undertake a first pass screening assessment of risk posed by contaminants bound to sediments (including nutrients) in runoff from the final landform. The assessment should investigate the potential risks to the values of the surrounding environments and to achieving the Magela Creek Water Quality Objectives. The outcomes of the assessment should identify if further investigations and modelling (e.g. for Key Knowledge Need WS3F and WS3H) are required in support of the Final Landform Application. The assessment should be undertaken as a priority with outcomes provided in the next Ranger Mine Closure Plan.	MCP	Landform	Noted
Recommendation 4 Human health and ecological risk assessments of per- and polyfluoroalkyl substances (PFAS) should be undertaken for both the on-site and off-site environments, with the outcome to inform the need for PFAS closure criteria.	MCP	Water and Sediment	Noted

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Recommendation	Timing / Hold Point	Relevant Theme / Section of 2024 MCP	Section in 2025 MCP[2]
Recommendation 5 Groundwater modelling being used to assess options for Ranger Water Dam rehabilitation should apply the same 100-year modelling period for all options being considered in the BPT assessment and should include the removal of exfiltrated salts from the various sources for those options involving interception of contaminants.	Final Landform Application	Water and Sediment	Noted.
Recommendation 6 A risk assessment should be undertaken for the future likelihood of Acid Sulfate Soils forming on and off the Ranger Project Area, with the outcomes provided in future Ranger Mine Closure Plans. The details of the risk assessment should be provided in the Final Landform Application.	Final Landform Application	Water and Sediment	Section 7.3.10, Section 7.3.12.6
Recommendation 7 A risk assessment should be undertaken for eutrophication on and off the Ranger Project Area, with the outcomes provided in future Ranger Mine Closure Plans. The details of the risk assessment should be provided in the Final Landform Application.	MCPs, Final Landform Application	Water and Sediment	Section 7.3.9
Recommendation 8 A Weed Risk Assessment should be undertaken with updates provided in the next Ranger Mine Closure Plan.	MCP	Ecosystems	Sections 9.3.4.1, Section 9.5.1, Section 9.9.3
Recommendation 9 The uranium concentration of surface cover material in the whole-of-site radiation dose assessment should take account of commitments for material discrimination and placement.	Final Landform Application	Radiation	Section 10.9
Recommendation 10 The focus and action trigger levels in the radiation Trigger Action Response Plan should be reviewed and information provided on how they were determined for each monitoring parameter.	MCP	Radiation	Noted

Table 3: Response to GAC/NLC Feedback

Feedback on 2024 MCP	Relevant Theme / Section of 2024 MCP	Section discussed in 2025 MCP
From the Traditional Owners' perspective, the key issue is certainty and the Traditional Owners currently expect much more certainty by late 2024. There is no certainty about the status of the application to extend the Jabiluka mineral lease, and the costly and avoidable distraction that this is causing. In 2024, uncertainty remains.	General comment	Noted.
There is limited consideration of access to the RPA as a risk – mostly just noting ERA have applied for a new Authority and are keen to work with stakeholders.	General comment	Section 2.1.2
Apparent lack of progress since 2023. There is almost no change in ERA's assessment of progress reflected in the spider diagrams.		Noted
2024 Ranger Mine Closure Plan still does not contain a detailed, costed and time bound plan of the work required to achieve compliance with the Environmental Requirements. We note that ERA's own assessment provided in the 2024 Ranger Mine Closure Plan is that there has been little progress made in completing studies to address uncertainty in the previous 12 months.	General comment	Noted
Of particular concern to the Mirarr Traditional Owners is the interpretation of ALARA in the 2024 Mine Closure Plan. ALARA is of central importance in understanding the post mining environment that will be left to the Traditional Owners. The 2024 Mine Closure Plan does not recognise the Traditional Owners' position on ALARA as it relates to onsite waterbodies, namely that the standard of rehabilitation must be as high as is technically possible and the level of contamination must be as low as technically possible. The 2024 Ranger Mine Closure Plan continues to assert that the outcome of ERA's internal Best Practicable Technology process is analogous with ALARA. We require agreement with Traditional Owners on the interpretation of ALARA as it relates to rehabilitation outcomes on the Ranger Project Area to inform technical studies and engineering design.	Standard of rehabilitation	Section 3.4
This reflects the position of the Commonwealth and the NT Ministers. Demolition is an unacceptable plan.	Jabiru East Airport	Section 4.4.4.1
ERA has not finalised a Cultural Heritage Management Agreement despite undertaking to do so in 2003, the CHMS is an internal system and is no substitute for a CHMA, it is not agreed	Cultural Heritage	Section 11.3.1
Traditional Owners have not agreed to the internal Cultural Heritage Management Plan. It is inappropriate to ignore the need for a Cultural Heritage Management Agreement.	Cultural Heritage	Section 3.3; Section 11.3.1
The Engagement Framework does not accurately reflect the role of the Stakeholders.	Stakeholder Engagement	Section 3.1

Table 4: Response to ARRTC Feedback on the 2023 MCP[3]

Feedback	Relevant Theme / Section of 2023 MCP	Section in 2025 MCP[4]
The MCP does not provide adequate information about gully erosion, options for its control, and how drainage lines and gullies on the final landform will be revegetated in a way that acknowledges the role of established vegetation in stabilising channels.	Landform	Section 6.5.5
The final landform forms the basis of the remediated site because it is the foundation on which weathering of the material (waste rock) occurs to form soil, controls surface hydrology and serves as the base for revegetation. The focus is largely on the physical characteristics of the materials, and potential for erosion. A general characterisation of the landform materials across the RPA which includes the geochemical and physical characteristics and how they vary spatially would be considered necessary. There is a good understanding of the physical characteristics, but the general geochemical characteristics and their variability is less certain, particularly with regards to the cut-to and fill areas.	Ecosystems	Section 9.9 Future iterations of the MCP
"Constructed drainage channels that will have increased water flows will be rock armoured". This can be expected to result in limited variation substrate properties and limited variation in water depths, reducing the ecological value of stream habitat onsite relative to what would be achievable by instead controlling bed elevation and allowing some lateral freedom of the channel shape. This appears to be inconsistent with ER 1.2(e) on P150 that environmental impacts should be ALARA. On the other hand, controlling all channel erosion assists achievement of the landform closure criteria related to bedload and denudation rate and suspended sediment concentrations (P112). How these two closure criteria are to be traded off and resolved is not described.	Landform	Appendix 9.1 (Table 2). Future iterations of the MCP
Although '…ERA will likely install sediment basins at the terminal point of each sub-catchment' (p. 115), it is unclear how this sediment will be removed and where it will be taken. Erosion and sedimentation are natural fluvial features in all stream systems so there will need to be some clear criteria as to what levels are acceptable, especially as these processes are likely to create riparian and in-channel microhabitats that support different plants and animals from the rest of the landform.	Landform	Section 6.6.2.2. Future iterations of the MCP
6.6.3 refers to temporary erosion and sediment control features, but permanent structures are not mentioned.	Landform	Section 6.6.2.2

[3] Table 4 presents the feedback provided by ARRTC on the 2023 MCP. Feedback on the 2024 MCP has not been received.

[4] whilst sections of the MCP may discuss the topic of the feedback raised, further studies are occurring or planned and therefore the cross-referenced sections may not/do not resolve the feedback raised

Feedback	Relevant Theme / Section of 2023 MCP	Section in 2025 MCP[4]
The Ranger Conceptual Model was developed to understand contaminant sources and transport. The conceptual model consists of three models at three difference spatial scales. I would be interested to know if the conceptual models for Ranger are nested (p166), if they are spatially related and can then be scaled from smallest scale up to the regional scale, and if there is similarity between results at different scales with only differences in resolution.	Water and Sediment	Section 7.3.1
Refinement of understanding the distribution of acid sulfate soils is ongoing. There needs to be some clarification on the processes in the description of acid sulfate soil effects (p204). Acidification events caused by oxidation of hypersulfidic soils will likely lead to increased concentrations of soluble metals, but impact on dissolved oxygen (and potential for deoxygenation) is largely the effect from mobilization and oxidation of monosulfidic materials, which are usually much younger newly formed, and less likely to be caused from hypersulfidic materials.	Water and Sediment	Section 7.3.10
Step 4 of the WQMF is to 'Determine water/sediment quality guideline values' and this is described on pp. 159-161. Although there are general claims about highly variable natural ranges (e.g. for pH), there is little explanation of the importance of 'hot spots' and 'hot moments' in the area when extremes, especially of multiple parameters, might occur as a result of the combined effects of the mine and natural phenomena.	Water and Sediment	Section 7.1.3.4. Future iterations of the MCP
It was good to see the highlighted new text added to Figure 7-6 of the conceptual model underpinning the Aquatic Pathways Risk Assessment (APRA) indicating the addition of detrital pools and microbial activity to acknowledge their potential importance. However, it is less clear what work is planned to validate these additions to the conceptual model and how they may alter the vulnerability assessment framework (VAF) described on p. 184.	Water and Sediment	Section 7.3.12.3
ASS have been observed in Coonjimba Billabong, and p. 189 goes on to say, 'The occurrences of acidification observed in Coonjimba Billabong have been linked to false start wet season events, indicating that the absence of flushing associated with a continuation of rainfall may be a driver of more significant acidification related events (e.g. lower levels of dissolved oxygen and increased concentrations of metals) being observed in these years.' Work on this KKN is still ongoing but it would be interesting to know whether false starts are more likely under predicted future climatic conditions for this area, and if so, how this might affect the potential likelihood of future episodes of acidification arising from a combination of mine-related and natural processes.	Water and Sediment	Future iterations of the MCP
Regarding the length of planned monitoring of Coonjimba Billabong, on p. 235, the MCP states 'The on-site supervision will continue throughout the remediation activities and the validation sampling. Validation sampling and 'sign-off' that remediation targets have been achieved is typically a one-off process undertaken at the completion of the remediation works. However, ERA will undertake annual sampling for a further five years after the final landform has been created in the areas of the Magela LAA and Coonjimba Billabong to ensure levels remain within acceptable limits.' I wonder whether five years will be long enough after the final landform has been created, given that there is a good chance that settlement and stabilisation of erosional processes (with their concurrent effects on infiltration and subsurface water movement) may take longer than five years. Perhaps following up for a longer period (say, a decade) sampled every two years would provide more peace of mind about the effectiveness of controls of sediment contamination after the final landform is built.	Soils	Section 8.6

Feedback	Relevant Theme / Section of 2023 MCP	Section in 2025 MCP[4]
Closure criteria (Table 9.2). Although not yet approved by the Minister, these are largely settled now following stakeholder review. Nonetheless, there are some concerns.	Ecosystems	Section 9.1, Table 9.2.
In the discussion on CREs, the following (p. 249) is stated about the riparian CRE: 'It is recognised that a distinct CRE is required for the planned drainage lines on the final landform, and the surrounding Myrtle-Pandanus Savanna / Paperbark Forest vegetation community may be used as a basis for this. I would argue that there is some urgency about deciding on this CRE which can then lead on to assessments of appropriate revegetation options for the proposed riparian species (e.g. seed viability, seedling establishment and persistence, substrate requirements, etc.) so that these plants can be introduced onto the final landform along the planned drainage lines as soon as possible and start to play a role in stabilising the channels.	Ecosystems	Section 7.3.1.2
Regarding cut-to areas (p. 254), the plan recognises that, to date, there has been little research (stage 13, of 4 ha) undertaken on restoration in cut-to areas, and that this limited research indicates poor success in plant establishment (p. 254). Given that cut-to areas will constitute 28 to 47% of the final landform (p. 254), there is a high priority for such research including on the efficacy of potential remedial approaches.	Ecosystems	Section 9.9.2 (Waste rock substrate investigation). Future iterations of the MCP
While there is mention of broader invertebrate monitoring for the conceptual S&T models only ants are considered for the closure criteria. Focusing only on ants may lead to a narrow understanding of ecosystem condition and determining the establishment of desirable invertebrate communities at the RPA. Ideally, broader monitoring which includes invertebrate functional groups, including pollinators, decomposers, and herbivores, would allow a more holistic assessment and comparison for determining trajectory towards, that of the reference ecosystem.	Ecosystems	Section 9.3.2.2
The chapter states that litter decomposition and nutrient cycling is to be monitored every five years. There are some characteristics of soils that change very slowly, and some that can potentially act as early indicators of perturbations to decomposition and nutrient cycling processes. I would suggest that monitoring should be undertaken more frequently early in the monitoring program following final landform and revegetation (suggested the first five years), which can then be stepped out to monitoring every five years after the initial five years. Microbial communities and mineralizable nitrogen are very responsive to management actions and disturbance events, whereas soil organic carbon and nitrogen are indicators which are better suited to longer term monitoring.	Ecosystems	Section 9.6.5
Future work: This section provides a summary of the considerable research effort still needed to provide the required evidence base. It would help to link it more explicitly to the KKN tabulation at Appendix 5.1. There appears to be no consideration of research needed to address some closure criteria: for example, there is no consideration of the evidence base needed to evaluate progress towards the attribute (closure criterion) of 'Composition and abundance of threatened species' or of the likely effectiveness of any potential remedial actions if there is limited progress.	Ecosystems	Section 9.9

APPENDIX 4.1: CHRONOLOGY OF COMPLETED ACTIVITIES

CHRONOLOGY OF ACTIVITIES

Date	Description of Event / Milestone
1969	Discovery of Ranger ore deposit by joint ventures Electrolytic Zinc Company of Australasia Ltd (EZ) and Peko-Wallsend Operations Limited (Peko).
1974	February: Submission of Environmental Impact Statement (and supporting material) under the Australian Government's *Environmental Protection (Impact of Proposal) Act 1974*.
1975	May: Submission of Supplements 1 and 2 to the Environmental Impact Statement.
	The Ranger Uranium Environmental Inquiry (Fox *et al.* 1976) commences.
1977	The Ranger Uranium Environmental Inquiry Reports (Fox *et al.* 1976 and 1977) recommend that uranium mining proceed.
	Much of the Alligator Rivers Region (ARR) is declared a National Park (NP) and Aboriginal people are given a major role in the management of Kakadu NP.
1978	Title to the Ranger Project Area (RPA) is granted to the Kakadu Aboriginal Land Trust, in accordance with the *Aboriginal Land Rights (Northern Territory) Act 1976* (Aboriginal Land Rights Act).
	The Commonwealth Government enter an agreement with the Northern Land Council (NLC) to permit mining to proceed.
	The role and function of the Supervising Scientist is established under the *Environment Protection (Alligator Rivers Region) Act 1978*.
1979	Section 41 Authority under the Commonwealth *Atomic Energy Act 1953* is issued.
	Construction at Ranger commences.
1980	Energy Resources of Australia Limited is established as a public company. It was the largest public float in Australian history at the time.
	May: Mining of Ranger Pit 1 orebody commences using open cut methods.
1981	13 August: The first drum of uranium oxide is produced.
1994	December: Mining of Ranger Pit 1 orebody is completed.
1995	Preparation of Pit 1 to receive tailings commences, including construction of an underdrain and a horizontal rock-filled adit from the base of the pit to intercept a vertical dewatering bore.
1996	May: Approval is granted to mine Pit 3 orebody.
	August: Tailings deposition into Pit 1 begins.
1997	July: Open cut mining of Pit 3 begins.
1999	Environmental Requirements revised to include rehabilitation conditions.
2000	August: Rio Tinto becomes a major shareholder in ERA.
2006	October: ERA announces an increase in Ranger mine's reserves due to a reduction in the cut-off grade of ores for processing, adding about six years to the predicted life of processing at Ranger to 2020.
2007	June: Approval received to deposit tailings into Pit 3.
	September: Extension of Pit 3 is announced, extending mining until 2021.

Date	Description of Event / Milestone
2008	Trial Landform (TLF) construction commences.
	November: ERA announces a significant mineral exploration target defined at Ranger 3 Deeps.
	December: Tailings deposition in Pit 1 ends.
2009	March: irrigated areas of the Trial Landform are planted with seeds and seedlings.
	April: The laterite treatment plant is commissioned to extract uranium from weathered ores (referred to as laterite ores) that are unable to be processed through the existing mill circuit.
	December: non-irrigated areas of the Trial Landform are planted with seeds and seedlings.
2011	August: The ERA Board approves the construction of an exploration decline to conduct underground exploration drilling of Ranger 3 Deeps.
2012	February: ERA approves the design, construction and commissioning of a Brine Concentrator.
	May: Phase 1 construction of the Ranger 3 Deeps exploration decline begins.
	May – September 7,554 wick drains are installed in Pit 1.
	Onsite water management capacity was expanded to beyond potential flood levels, with the completion of Retention Pond 6 and Ranger Water Dam (RWD) wall lift.
	Magela Creek levee is constructed to guard Pit 3 from a potential large flood event.
	November: Mining of Ranger Pit 3 orebody is completed.
	Pit 3 backfill activities commence in preparation for the planned transfer of tailings from the then Tailings Dam (now Ranger Water Dam) and the final repository of brine from the Brine Concentrator.
2013	January: The Ranger Mining Agreement is finalised with Mirarr Traditional Owners, the Northern Land Council, ERA, and the Commonwealth government. The Mining Agreement establishes the Relationship Committee.
	September: Completed construction of the Brine Concentrator. Commissioning tests and verification phase commences.
	October: Phase 2 construction of the R3 Deeps exploration decline begins including extending the decline and constructing a ventilation shaft.
	December: Completed the placement of approximately 70 per cent of the initial capping over Pit 1 tailings to assist in tailings consolidation and the ongoing dewatering of the pit.
2014	August: Underfill installed in Pit 3. An underdrain is constructed on top of the underfill, and five brine injection wells and an extraction pumping system installed.
	Ranger 3 Deeps underground drilling program completed.
	Construction of the purpose-built tailings dredge completed.
2015	Tailings dredge, tailings transfer and water recovery/pumping infrastructure commissioned.
	Pit 3 brine injection piping and infrastructure installed and commissioned.
	Tailings from the mill begins to be transferred directly to Pit 3.
	June: ERA announces that the R3 Deeps underground mining project would not proceed, and the R3 Deeps exploration decline is placed into care and maintenance.

Date	Description of Event / Milestone
2016	January: Completed initial capping and impervious laterite layer in Pit 1. Bulk backfilling commences.
	All production tailings directed to Pit 3 and tailings transfer from RWD into Pit 3 commences.
	Brine injection into the Pit 3 underfill begins.
2017	April: Approval granted for ERA to begin the final stages of Pit 1 backfill.
2018	January: Magazine Laydown area initial revegetation planting.
	Laterite plant ceased operation due to exhaustion of laterite ore. Laterite plant placed under care and awaiting demolition as part of the site closure project.
2019	January: Magazine Laydown area infill planting.
	Ministerial approval granted to commence decommissioning of the R3 Deeps exploration decline.
	Remnant tailings cleaning from the walls of the RWD commences.
2020	February: Ranger Mine Village area initial revegetation planting.
	19 February: Approval granted (High-Density Sludge (HDS) plant application), allowing the release of partially treated process water into the pond water circuit.
	April: Stage 13.1 Area A initial revegetation planting.
	July: Approval granted to leave the subfloor of the RWD in-situ rather than to remove and transfer into Pit 3.
	August: Final backfill and landform contouring on Pit 1 completed.
	November: Stage 13.1 Area B initial revegetation planting.
	November: Scarification of Pit 1 final landform.
2021	8 January: Production at the Ranger mine ceased, concluding processing activities on the RPA after ~40 years of operation.
	March: Planting on the backfilled surface of Pit 1 begins.
	Dredging of tailing for transfer from the then Tailings Dam (now RWD) to Pit 3 is completed.
	Processing Plant is decommissioned.
	August – September: Stage 13.1 Area C initial revegetation planting.
2022	January: Planting on the backfilled surface of Pit 1 is completed.
	Final remnant tailings are transferred from RWD to Pit 3 via truck.
	31 May: ERA sells final drum of uranium oxide.
2023	March: Directionally drilled brine injection wells completed and commissioned.
	April: Wicking in Pit 3 completed and wicking barge demobilised.
	June: Approval granted to dewater and begin drying the tailings in Pit 3.
	August: dewatering of Pit 3 commenced.
	September: Pit 3 Capping, Waste Disposal and Bulk Material Movement Application is submitted.

Date	Description of Event / Milestone
	October: Pit 1 research trials and monitoring reach 2 year milestone – average 70% survival.
	October: Outcomes and data from the 2022 Feasibility Study received.
	November: Approval granted for the brine squeezer to treat process water.
2024	The Brine Squeezer process water treatment upgrade work is completed, although performance testing with RWD feed water has not yet commenced.
	4 March: Direct release of surface water runoff from the Pit 1 landform to Corridor Creek via Corridor Road Sump (CRS).
	3 April: ERA appoints Rio Tinto to manage the Ranger Rehabilitation Project under a new Management Services Agreement.
	3 June: Rio Tinto takes responsibility for management of the Ranger site on ERA's behalf.
	June -July: Limestone added to the RWD to raise pH.
	2 and 11 August: Pit 3 Capping and Backfill Approval received from the Commonwealth and NT minister respectively.
	19 November: ERA confirmed successful completion of the renounceable entitlement offer. Following the 2024 entitlement offer, Rio Tinto (through its wholly owned subsidiary North Limited) now holds over 98% of ERA's shares.
	11 and 15 December: Geotextile placement and dry capping begin on the Pit 3 tailings surface.
2025	8 January: Pit 1 runoff first released to the environment via CRS.
	6 February & 25 March: 2023 Mine Closure Plan approval received from the Commonwealth and NT minister respectively, with some exclusions to be addressed through separate applications.
	February: OSS approve Pit 3 Settlement Tower design.
	February: Trial began in Pit 3 investigating whether blending fine ore into the tailings surface would achieve accelerated drying and consolidation cycles.
	11 April: ERA advises that its majority shareholder, Rio Tinto, has lodged a compulsory acquisition notice (Notice) in relation to compulsorily acquisition of all the remaining shares of the Company. ERA inform remaining shareholders of their right to object to the compulsory acquisition by 19 May 2025.
	20 May: Shareholders holding at least 10% of the ERA shares covered by the Notice objected to the acquisition before the end of the Objection Period, allowing it only to proceed if the Court approves the acquisition. ERA advises that Rio Tinto has applied for court approval of the proposed compulsory acquisition.
	June: Construction of Trial Landform trench to support waste rock characterisation study.
	July: Pit 1 hydraulic testing commenced.
	August: Completed push down of Pit 3 tip head material.

APPENDIX 4.2: COMPLETED BPT ASSESSMENTS

Ranger Mine Closure Plan

2025

Completed BPT Assessments

Unique Reference PLN007

Revision: 0.25.1

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FIGURES

TABLES

1 SALT TREATMENT AND DISPOSAL

The need to dispose of saline water is a common process in several industries and, as a result, 25 methods were identified as potential salt management options and were considered for the BPT assessment. Many of the options considered had fatal flaws for Ranger and were hard show-stopped prior to the workshop. A total of seven options were assessed in detail (Table 1-1).

Table 1-1: Salt treatment and disposal options

Category	Brine injection	Crystallisation	Thermal distillation
Method	pit 3 underfill underground silos pit 3 underfill with rock screening	pit 3 placement underground silos placement	pit 3 underfill injection underground silos injection

The overall outcome of the BPT assessment was that brine injection to the underfill without rock screening was the highest ranked alternative. Brine injection to underground silos scored well but concerns were identified on Occupational Health and Safety issues during both the construction and the operational phases of this option. Major problems were identified for the crystallisation and distillation options, and it is considered unlikely that either option assessed would be viable. The only uncertainty remaining for the preferred option related to the potential for reactivity between the brine and the waste rock of the underfill and possible limitation on the volume available for the storage of brine.

It was concluded that this issue required further assessment prior to a final decision on the salt management option to be implemented. For this reason, crystallisation was taken forward into the overall strategy assessment pending further testing to confirm the brine injection option.

2 BRINE SQUEEZER

Report: *Application to operate a Brine Squeezer. 2019*

Water management is an environmentally and operationally relevant aspect of Ranger. Concentration and isolation of contaminants through water management is a significant component of the Ranger closure program. In January 2019, ERA presented the results of studies into additional processing options, to the Director of Mining Operations, to support the installation of the selected option, the Brine Squeezer (ERA, 2019b).

Treatment of pond water through the water treatment plants generates brines that are added to the process water inventory. This results in 200 to 1,000 ML/year of additional process water to be treated by the Brine Concentrator. However, the Water Treatment Plant (WTP) brines are less concentrated than process water (less than 25% brine of process water concentration), and treatment options that are more cost effective than treating WTP brines as process water are available. Additional processing of WTP brines will reduce the volume added to process water, reducing the total inventory to be treated by the Brine Concentrator, and reducing overall risks to the closure schedule and costs associated with water treatment.

ERA investigated options to concentrate WTP brines over many years. Given the high scaling and membrane fouling potential of WTP brines, it was necessary to consider alternatives to standard reverse osmosis. The implementation of the Osmoflo Brine Squeezer was established to be a cost-effective way to treat WTP brines as it minimised unnecessary additions to the pond water and process water inventory and optimised pond and process water treatment and disposal mechanisms.

To meet regulatory requirements of the Ranger Authorisation and facilitate the incorporation of novel technology at Ranger, a thorough BPT assessment process was undertaken. This began in 2013 with a preliminary desktop screening assessment that investigated 27 options. From this assessment 15 options were hard show-stopped, whilst four options were soft show-stopped and four options scored poorly relative to the remaining four options, which were considered appropriate to progress for further assessment. A second, BPT assessment was then conducted in 2018 on:

- vibratory shear enhanced processing (VSEP);
- Brine Squeezer;
- electro dialysis reversal (EDR); and
- additional reverse osmosis.

Using a 5-level technology ranking system where a ranking of three meets industry standards, the second BPT assessment showed the Brine Squeezer (Figure 2-1) to be the highest-ranking option.

Pilot studies and test work were completed on two options: VSEP and Brine Squeezer. The results of these studies were used to inform the BPT assessment and revise the relevant criteria of the 2013 BPT assessment. The seven-month Brine Squeezer pilot study, completed in 2016, conclusively demonstrated that this technology has the capability to treat the Ranger pond water treatment brine, thus minimising the volume of brine and maximising the volume of release quality water on site.

This outcome had a significant influence on the 2018 BPT assessment scores for the Brine Squeezer, particularly against criteria such as ‘Proven technology’, ‘Technical performance’ and ‘Inherent Availability and Reliability’ compared to the other three technologies. The result is that during the 2018 BPT, the technology with the highest BPT score was the Brine Squeezer, followed by the EDR, VSEP and additional reverse osmosis (Table 2-1 and following ranking matrices).

It has been demonstrated during field trials that WTP brine can be treated at up to 94% recovery of permeate of quality equal to, or better than, current WTP permeate. The plant, installed adjacent to the sand blast yard, comprises three trains, providing for 99% availability of two trains (1 standby/cleaning). Commissioning of the Brine Squeezer commenced in June 2019, with the plant now fully operational.

Table 2-1: Comparison of final BPT scores (2013 vs 2018)

Option ID	Description	2013 BPT Results	2018 BPT Results
BM1	VSEP - Vibratory shear enhanced processing (FilTek)	18.8	13.2
BM2	Brine squeezer (Osmoflo)	21.9	23.7
BM3	EDR - electro dialysis reversal	30.0	19.4
BM6	Additional reverse osmosis	31.3	11.1

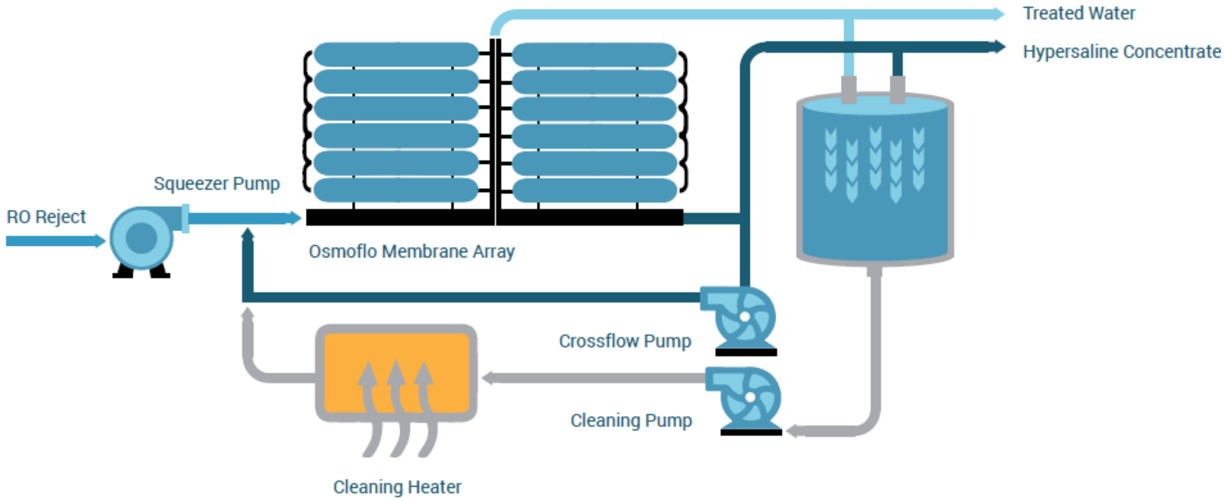

Figure 2-1: Brine Squeezer process flow diagram (source: http://www.osmoflo.com/)

BM	Brine Minimisation	Rehabilitation and Closure							Constructability		
		Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
		1	1	1	1	1	1	1	1	1	1
Option ID	Option Description	Revegetation	Radiation	Erosion	Water Quality	Tailings	Schedule	Cost	Construction Occupational Health & Safety	Construction Environmental and Cultural risks	Construction Complexity
BM1	VSEP (FilTek)	NA	NA	NA	NA	NA	3	4	4	4	3
BM2	Brine Squeezer (Osmoflo)	NA	NA	NA	NA	NA	3	4	4	4	3
BM3	EDR - Electro dialysis reversal	NA	NA	NA	NA	NA	3	4	4	4	3
BM6	Additional RO (includes pre-treatment step)	NA	NA	NA	NA	NA	3	3	4	4	3

	Inadequate	Poor	Acceptab le	Good	Excellent	Unable to evaluate	Not applicable to this option
Rank	1	2	3	4	5	UTE	NA

BM	Brine Minimisation				TO Culture & Heritage		Protection of People and the Environment				
		Show stopper column setting			Yes	Yes	Yes	No	Yes	No	Yes
				Rank weighting	1	1	1	1	1	1	1
Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture	Cultural heritage	Community Health & Safety	Socio-economic impact local community	Ecosystems of Kakadu	Ecosystems of Project Area	Long-term Protection of Environment
BM1	VSEP (FilTek)	0	0	13.2	NA	NA	4	3	4	4	NA
BM2	Brine Squeezer (Osmoflo)	0	0	23.7	NA	NA	4	3	4	4	NA
BM3	EDR - Electro dialysis reversal	0	0	19.4	NA	NA	4	3	4	4	NA
BM6	Additional RO (includes pre-treatment step)	0	0	11.1	NA	NA	4	3	4	3	NA

3 RANGER 3 DEEPS

Report: *Application Ranger 3 Deeps Exploration Decline Decommissioning. 2018*

In May 2012, phase 1 construction works of the Ranger 3 Deeps (R3D) decline began after being approved in September 2011. This allowed for underground exploration that could provide further information regarding the viability of the proposed R3D underground mine. An additional application was submitted for phase II construction works and was approved for the extension to the exploration decline, installation of a ventilation shaft, and acquisition of bulk samples on 4 June 2013.

Exploration in the decline (Figure 3-1) continued until December 2014, whilst submissions were made for the construction of the R3D underground mine at the same time. In October 2014, a draft environmental impact assessment (EIS) was submitted but, following an ERA board decision in June 2015, the statutory assessment process for the proposed R3D mine was halted and the decline was placed in long-term care and maintenance.

The primary objective of the BPT assessment was to determine which combination of options was best practice for the closure of the exploration decline. For the assessment, the decline was divided into three closure areas:

- main decline (2,710 m) – seven BPT closure options assessed;
- portal (185 m) – three BPT closure options assessed; and
- ventilation shaft (located at -260 mRL; vertical length 280 m) – nine BPT closure options assessed.

The BPT assessment rankings reflect known hydrogeological conditions obtained during decline construction and core sampling of resource holes, and subsequent hydrological modelling completed by INTERA (2018). The assessment also took into consideration ground conditions and potential heavy mobile equipment limitations (e.g. gradient, manoeuvrability). The assessed option and BPT outcomes are presented in Table 3-1 and the ranking matrices at the end of this sub-section.

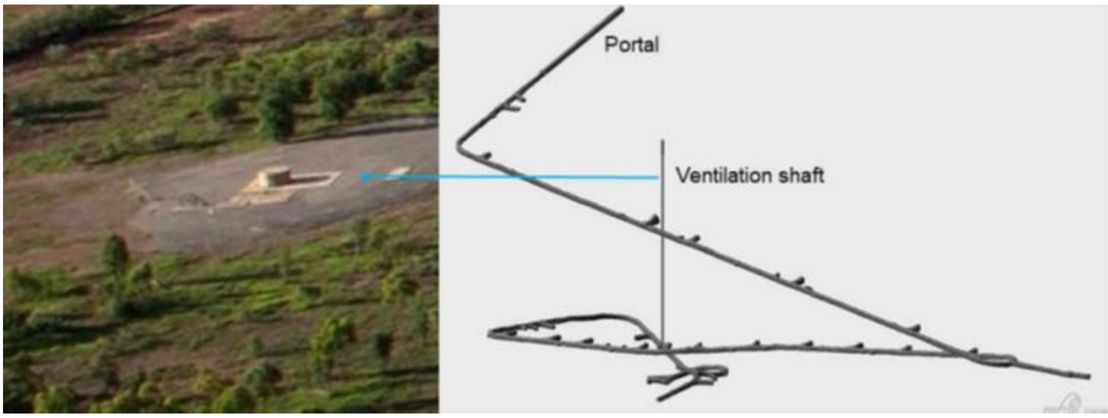

Figure 3-1: Aerial view of the ventilation shaft and underground infrastructure

Table 3-1: Decline options and best practicable technology assessment summary

Option ID	Option Description	Overall Rank
Decline closure (2,710 m)		
A1	Waste rock (full decline) and grouting of open holes	16.7
A2	A1 + bulkheads	12.5
A3	Grouting, bulkheads and waste rock placed only in the weathered zone (i.e. up to surface ~40 vertical m)	29.2
A4	A3 with cemented rock fill (CRF) instead of waste rock	25.0
A5	A3 with crushed & ground waste rock (hydraulic backfill) instead of waste rock	20.8
A6	Cut and seal portal to 10 m below surface; grout open holes and flood decline	-4.2
A7	A3 (without grouting of open holes and bulkheads)	41.7
Portal (185 m)		
B1	Remove entire steel portal, backfill portal to ground level and cover with waste rock	-11.5
B2	Partially remove portal structure to just below ground level, backfill portal to ground level and cover with waste rock	30.8
B3	Leave entire portal in situ and cover with waste rock	-10
Ventilation Shaft		
C1	Waste rock; concrete collar removed	-100
C2	Waste rock, concrete in situ	-100
C3	Crushed waste rock; concrete collar removed	31.6
C4	Crushed waste rock; concrete collar in situ	-100
C5	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar removed	21.1
C6	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar in situ	-100
C7	Steel plate; concrete collar removed and allow to flood	13.2
C8	Steel plate and allow to flood; concrete collar in situ	-100
C9	Crushed waste rock up to weathered zone, then 10 m CRF and then 10 m of crushed rock to surface; concrete collar removed	39.5

3.1 Main decline closure

For the decline, options A1 and A2 rated poorly in comparison to the other options and were soft show-stopped based on occupational health and safety (OHS) concerns, cost and operability. Three options, scoring similarly, with one of these, A5, eliminated due to cost and reliability concerns. Option A6 was eliminated due to OHS and fitness for purpose. Option A7 (waste rock placed in the weathered zone) was allocated the highest assessment score of 41.7 and selected as the preferred option.

3.2 Portal closure

For the portal closure, B1 was ranked inadequate due to difficulty and complexity. Option B3 was rejected when it became apparent that the waste rock proposed to cover the portal would not blend with the final landform and therefore at odds with the cultural criteria. Option B2 (partially remove portal structure to just below ground level, backfill portal to ground level and cover with waste rock) with a score of 30.8 and no show-stoppers, was ranked the highest and selected as the preferred option.

3.3 Ventilation shaft closure

Five of the ventilation shaft options were hard show-stopped based on fitness for purpose or cultural criteria (specifically visual amenity). Two options recorded soft show-stoppers for cultural criteria (also visual amenity) and two options, C3 and C9 scored closely on the BPT assessment. For its greater ability to mitigate potential long-term movement of groundwater to the surface via the ventilation shaft, option C9 (crushed waste rock up to weathered zone, then ten metres cemented rock fill and then ten metres of crushed rock to surface; concrete collar removed) was identified as the highest-ranking option with a score of 39.5 and selected as the preferred option.

						TO Culture & Heritage		Protection of People and the Environment			
			Show stopper column setting			Yes	Yes	Yes	No	Yes	Yes
Initial show stopper	**Option ID**	**Option Description** (Criteria from Ranger Environmental Requirements BPT explanatory material)	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture ("Location")	Cultural heritage ("Location")	Community Health & Safety ("Social factors")	Socio-economic Impact on Local Communities ("Social factors")	Ecosystems & Natural world heritage values of Kakadu National Park ("Location" & "Proven effectiveness")	Ecosystems of the Project Area ("Location")
	Decline closure (2,710 m)				0.0						
	A1	Waste rock (full decline) and grouting of open holes	0	1	16.7	NA	NA	4	3	5	3
	A2	A1 + bulkheads	0	1	12.5	NA	NA	4	3	5	3
	A3	Grouting, bulkheads and waste rock placed only in the weathered zone (i.e. up to surface ~ 40 vertical m)	0	0	29.2	NA	NA	4	3	5	3
	A4	A3 with cemented rock fill (CRF) instead of waste rock	0	0	25.0	NA	NA	4	3	5	3
	A5	A3 with crushed & ground waste rock (hydraulic backfill) instead of waste rock	0	0	20.8	NA	NA	4	3	5	3
	A6	Cut and seal portal to 10 m below surface; grout open holes and flood decline	3	0	-4.2	NA	NA	1	3	5	1
	A7	A3 (without grouting of open holes and bulkheads)	0	0	41.7	NA	NA	4	3	5	3
	Portal (185 m)				0.0						
	B1	Remove entire steel portal, backfill portal to ground level and cover with waste rock	1	0	-11.5	NA	NA	4	3	5	3
	B2	Partially remove portal structure to just below ground level, backfill portal to ground level and cover with waste rock	0	0	30.8	NA	NA	4	3	5	3
	B3	Leave entire portal in situ and cover with waste rock	2	0	-10.0	1	NA	4	3	5	1
	Vent shaft				0.0						
1	C1	Waste rock; concrete collar removed	1	0	-100.0						
1	C2	Waste rock, concrete in situ	1	0	-100.0						
	C3	Crushed waste rock; concrete collar removed	0	0	31.6	4	4	4	3	4	3
1	C4	Crushed waste rock; concrete collar in situ	2	0	-100.0	1	1				

						TO Culture & Heritage		Protection of People and the Environment			
			Show stopper column setting			Yes	Yes	Yes	No	Yes	Yes
Initial show stopper	**Option ID**	**Option Description** (Criteria from Ranger Environmental Requirements BPT explanatory material)	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture ("Location")	Cultural heritage ("Location")	Community Health & Safety ("Social factors")	Socio-economic Impact on Local Communities ("Social factors")	Ecosystems & Natural world heritage values of Kakadu National Park ("Location" & "Proven effectiveness")	Ecosystems of the Project Area ("Location")
	C5	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar removed	0	2	21.1	2	2	4	3	4	3
1	C6	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar in situ	2	0	-100.0	1	1				
	C7	Steel plate; concrete collar removed and allow to flood	0	3	13.2	2	2	4	3	4	3
1	C8	Steel plate and allow to flood; concrete collar in situ	2	0	-100.0	1	1				
	C9	Crushed waste rock up to weathered zone, then 10 m CRF and then 10 m of crushed rock to surface; concrete collar removed	0	0	39.5	5	5	4	3	4	3

						Fit for Purpose				Operational Adequacy			
			Show stopper column setting			No	No	Yes	No	Yes	No	No	No
Initial show stopper	**Option ID**	**Option Description** (Criteria from Ranger Environmental Requirements BPT explanatory material)	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Proven technology ("Age/effectiveness of equipment")	Robustness ("Age/effectiveness of equipment")	Environmental Protection ("World's best practice" & "Proven effectiveness")	CAPEX / OPEX ("Cost effectiveness")	Occupational Health & Safety	Operability	Inherent availability and reliability (e.g. crusher availability)	Maintainability
	Decline closure (2,710 m)				0.0								
	A1	Waste rock (full decline) and grouting of open holes	0	1	16.7	5	4	4	2	2	2	3	NA
	A2	A1 + bulkheads	0	1	12.5	4	4	5	1	2	2	3	NA
	A3	Grouting, bulkheads and waste rock placed only in the weathered zone (i.e. up to surface ~ 40 vertical m)	0	0	29.2	4	4	4	3	4	3	3	NA
	A4	A3 with cemented rock fill (CRF) instead of waste rock	0	0	25.0	4	4	4	2	4	3	3	NA
	A5	A3 with crushed & ground waste rock (hydraulic backfill) instead of waste rock	0	0	20.8	4	4	4	2	4	3	2	NA
	A6	Cut and seal portal to 10 m below surface; grout open holes and flood decline	3	0	-4.2	1	1	1	5	4	5	5	NA
	A7	A3 (without grouting of open holes and bulkheads)	0	0	41.7	4	4	4	4	4	4	4	NA
	Portal (185 m)				0.0								
	B1	Remove entire steel portal, backfill portal to ground level and cover with waste rock	1	0	-11.5	1	4	4	1	1	1	2	NA
	B2	Partially remove portal structure to just below ground level, backfill portal to ground level and cover with waste rock	0	0	30.8	4	4	4	3	3	3	4	NA
	B3	Leave entire portal in situ and cover with waste rock	2	0	-10.0								
	Vent shaft				0.0								
1	C1	Waste rock; concrete collar removed	1	0	-100.0	1							
1	C2	Waste rock, concrete in situ	1	0	-100.0	1							
	C3	Crushed waste rock; concrete collar removed	0	0	31.6	4	3	3	4	3	3	3	5
1	C4	Crushed waste rock; concrete collar in situ	2	0	-100.0								

						Fit for Purpose				Operational Adequacy			
			Show stopper column setting			No	No	Yes	No	Yes	No	No	No
Initial show stopper	**Option ID**	**Option Description** (Criteria from Ranger Environmental Requirements BPT explanatory material)	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Proven technology ("Age/effectiveness of equipment")	Robustness ("Age/effectiveness of equipment")	Environmental Protection ("World's best practice" & "Proven effectiveness")	CAPEX / OPEX ("Cost effectiveness")	Occupational Health & Safety	Operability	Inherent availability and reliability (e.g. crusher availability)	Maintainability
	C5	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar removed	0	2	21.1	5	3	4	2	3	3	3	5
1	C6	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar in situ	2	0	-100.0								
	C7	Steel plate; concrete collar removed and allow to flood	0	3	13.2	1	3	3	5	3	4	5	3
1	C8	Steel plate and allow to flood; concrete collar in situ	2	0	-100.0								
	C9	Crushed waste rock up to weathered zone, then 10 m CRF and then 10 m of crushed rock to surface; concrete collar removed	0	0	39.5	5	3	4	3	3	3	3	5

			Show stopper column setting			Rehabilitation and Closure				
						Yes	Yes	Yes	Yes	No
Initial show stopper	**Option ID**	**Option Description** (Criteria from Ranger Environmental Requirements BPT explanatory material)	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Revegetation ("Location")	Radiation ("Location")	Erosion ("Location")	Water ("Location")	Schedule
	Decline closure (2,710 m)				0.0					
	A1	Waste rock (full decline) and grouting of open holes	0	1	16.7	NA	NA	NA	NA	3
	A2	A1 + bulkheads	0	1	12.5	NA	NA	NA	NA	3
	A3	Grouting, bulkheads and waste rock placed only in the weathered zone (i.e. up to surface ~ 40 vertical m)	0	0	29.2	NA	NA	NA	NA	3
	A4	A3 with cemented rock fill (CRF) instead of waste rock	0	0	25.0	NA	NA	NA	NA	3
	A5	A3 with crushed & ground waste rock (hydraulic backfill) instead of waste rock	0	0	20.8	NA	NA	NA	NA	3
	A6	Cut and seal portal to 10 m below surface; grout open holes and flood decline	3	0	-4.2	NA	NA	NA	NA	3
	A7	A3 (without grouting of open holes and bulkheads)	0	0	41.7	NA	NA	NA	NA	3
	Portal (185 m)				0.0					
	B1	Remove entire steel portal, backfill portal to ground level and cover with waste rock	1	0	-11.5	4	NA	NA	NA	3
	B2	Partially remove portal structure to just below ground level, backfill portal to ground level and cover with waste rock	0	0	30.8	4	NA	NA	NA	3
	B3	Leave entire portal in situ and cover with waste rock	2	0	-10.0					
	Vent shaft				0.0					
1	C1	Waste rock; concrete collar removed	1	0	-100.0					
1	C2	Waste rock, concrete in situ	1	0	-100.0					
	C3	Crushed waste rock; concrete collar removed	0	0	31.6	4	5	3	4	3
1	C4	Crushed waste rock; concrete collar in situ	2	0	-100.0					
	C5	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar removed	0	2	21.1	4	5	3	4	3

			Show stopper column setting			Rehabilitation and Closure				
						Yes	Yes	Yes	Yes	No
Initial show stopper	**Option ID**	**Option Description** (Criteria from Ranger Environmental Requirements BPT explanatory material)	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Revegetation ("Location")	Radiation ("Location")	Erosion ("Location")	Water ("Location")	Schedule
1	C6	Crushed waste rock up to weathered zone and then CRF to surface; concrete collar in situ	2	0	-100.0					
	C7	Steel plate; concrete collar removed and allow to flood	0	3	13.2	2	5	3	4	3
1	C8	Steel plate and allow to flood; concrete collar in situ	2	0	-100.0					
	C9	Crushed waste rock up to weathered zone, then 10 m CRF and then 10 m of crushed rock to surface; concrete collar removed	0	0	39.5	4	5	3	4	3

4 PROGRESS OF PIT 1 TO FINAL LANDFORM

Report: *Application of Progress Pit 1 Landform. 2019*

To support progress of the Pit 1 final landform, additional work was undertaken to address Supervising Scientific Branch (SSB) comments (Department of the Environment and Energy 2018) on an earlier change application (ERA, 2018a). Works included:

- a risk assessment undertaken to update the 2016 risk assessment;
- solute mass balance and water balance;
- soil-vegetation-atmosphere modelling to estimate plant available water under various conditions;
- revision of the final landform cover on Pit 1 to maximise plant available water;
- review of research relevant to rehabilitation of the Ranger Mine;
- preliminary flood modelling and hydraulic design work were updated and refined from work in 2017 to create a Digital Elevation Model (DEM); and
- erosion and sediment control features were refined based on conceptual designs developed in 2017.

The digital elevation model (DEM) was also provided to the MTC for assessment and SSB feedback was included in the change application report (ERA, 2019a). The Pit 1 Progressive Rehabilitation Monitoring Framework was developed to facilitate successful rehabilitation of Pit 1 and inform ongoing rehabilitation across the RPA. These additional works supported ERAs continued backfilling of Pit 1 ahead of the initial tree planting of the Pit 1 landform surface.

An application was submitted to the Director of Mining Operations, DITT in March 2019 in accordance with the requirements of the Ranger Authorisation issued under the Mining Management Act (NT) and was approved in May 2019.

During the life of Pit 1, ERA has undertaken many studies and BPT assessments, including:

- assessment of the selected tailings deposition options for Pit 1, to ensure the long-term stability of tailings as part of the final rehabilitated landform in 1994;
- assessment of seepage limiting options in 2005; and
- closure studies undertaken as part of a 2008 PFS, 2009 feasibility study and further review and validation of the preferred Pit 1 closure option as part of the ITWC prefeasibility study in 2012.

Landform design has involved several iterations of the post-closure landscape models over the life of the mine with significant options analysis and refinement of the landscape reconstruction over several years. Through supporting investigations and thorough refinement processes, the backfilling option being implemented is optimal. In particular, bulk backfilling of Pit 1 has been completed using the selected bulk backfill methodology.

5 TAILINGS MANAGEMENT

5.1 Integrated tailings, water and closure – PFS 1

Report: *Integrated, Tailings, Water & Closure Prefeasibility Study (ITWC PFS): Analysis of Best Practicable Technology. 2013*

The focus of the ITWC PFS program was to evaluate the technology for reclamation, treatment and transfer of tailings from the TSF to the mined-out Pit 3, and salt management technology to ensure physical containment of brine (from the BC treatment of process water) within Pit 3 with no detrimental impact to the environment for a period of 10,000 years as required by the ERs.

Options were considered for the reclamation, treatment and deposition of tailings for mine closure, which are described in the sub-sections below.

5.1.1 Tailings reclamation

Three categories were considered for reclamation of tailings from the TSF: excavation, hydraulic mining and dredging. Each category had a subset of transfer options, giving a total of nine options taken into the BPT assessment (Table 5-1).

Table 5-1: Tailings reclamation options

Category	Excavation	Hydraulic Mining	Dredging
Transfer options	• dewater and truck • dewater and conveyor • slurry and pump.	• pump • thickener and pump.	• pump • thickener and pump • thickener, filtration and truck • thickener, filtration and conveyor.

Of the reclamation and transfer options, excavation rated poorly compared with hydraulic mining and dredging. The principal deficiencies identified were the sensitivity of excavation techniques to extreme rainfall events, environmental protection and OHS issues arising from dust from the disturbed tailings, the considerable operational effort that would be required, and the drainage requirements required for successful implementation of the process. Hence, excavation was rejected as a method for reclamation of tailings from the TSF.

Hydraulic mining and dredging emerged from the workshop with approximately equal BPT assessment scores. An overall assessment of the relative significance of the various advantages and disadvantages of the two options led to the conclusion that the disadvantages of the dredging option (operability, maintainability, radiation protection) are much more amenable to management than those associated with hydraulic mining (sensitivity to extreme rainfall, environmental protection, high capital costs). This is particularly the case for the issue of sensitivity to extreme rainfall events where management options are extremely limited, and the occurrence of such events could have a major impact on the rehabilitation schedule. For this reason, dredging was selected as the preferred option.

5.1.2 Tailings treatment

The principal technical advantage of filtration is the reduced time required for tailings consolidation. It was thought to have some advantages for long-term dispersal of contaminants in groundwater, but this was yet to be demonstrated and the advantage was considered to be small. Disadvantages of this option included high costs to construct, install and operate, and the high maintenance requirements. The assessment outcome of filtration at the tailings workshop was that the option should be retained for whole-of-project BPT assessment, but it appeared to be a very expensive option with limited advantages.

Cementation was considered an option to potentially reduce dispersion of solutes in groundwater if required, however, it did not emerge as a viable treatment option. The initial BPT workshop was conducted prior to the groundwater solute transport modelling from Pit 3; this option was assessed in case treatment of tailings was required in order to achieve the 10,000 year requirement for no detrimental environmental impact. Subsequent to this BPT assessment modelling has shown that additional tailings treatment is not required to mitigate solute transport.

Further trials would be required, capital costs would be high because of the need to include filtration as a preliminary step, and operational costs would be extremely high as a result of the high cement consumption implicit in the process

5.1.3 Tailings deposition

Options assessed for deposition of tailings into Pit 3 considered either subaerial or subaqueous techniques for thickened tailings and dry stacking or co-disposal with waste rock for filtered tailings.

The assessment outcome for deposition of thickened tailings was that either option would be acceptable, however subaqueous deposition was preferred principally because it rated higher on the operability and operating costs criteria and was assessed that Traditional Owners would have a distinct visual preference for tailings covered by water rather than an exposed tailings surface. Subsequently, initial BPT workshop consolidation modelling demonstrated that subaerial deposition would provide an advantage over sub aqueous deposition. Since both options were determined to be BPT, the method was changed without the need for an additional assessment.

With filtration of tailings being retained as an option, the deposition of tailings needed to be considered. Two options were considered: dry stacking, and co-disposal with waste rock. Co disposal of filter cake and waste rock led to higher maximum elevation of tailings in Pit 3, giving preference to dry stacking. There were, however, concerns expressed about the degree to which either technique had a proven track record, and it was noted that both would be sensitive to rainfall (a dry pit would be required).

The conclusions arising from the BPT workshop on tailings management were:

- dredging is the preferred tailings reclamation method;
- cementation is not currently considered viable as a treatment method; and
- tailings filtration should be retained as a potential treatment method to be considered in the overall strategic workshops but is a very expensive option that produces little benefit.

5.2 Integrated tailings, water and closure – PFS 2

The combination of the feasible tailings management options and the feasible salt management options resulting from PFS1 and the BPT assessment are provided below:

- dredged tailings, thickened and pumped to Pit 3 combined with injection of brine into the constructed base of Pit 3 (underfill);
- dredged tailings, thickened, filtered, then pumped to Pit 3 combined with injection of brine into the constructed base of Pit 3 (underfill);
- dredged tailings, thickened then pumped to Pit 3 combined with crystallisation of brine to be placed within Pit 3; or
- dredged tailings, thickened, filtered, then pumped to Pit 3 combined with crystallisation of brine to be placed within Pit 3.

These options progressed through ITWC PFS2 and were assembled into closure strategies where the preferred technical options from PFS1 were combined with two possible processing cessation dates:

- milling will cease in 2016 - these options were given a 'C' designation; or
- milling will cease at the end of 2020 consistent with the terms of the Ranger Authorisation - these options were given a 'B' designation.

This provided a total of eight closure strategies that were assessed in two stages; these are shown in Table 5-2.

Table 5-2: Initial closure strategies to be assessed

Strategy	Brine strategy	Tailings strategy	Milling end
1C	Injection	Thickened	2016
2C	Injection	Thickened and filtered	2016
3C	Crystallisation	Thickened	2016
4C	Crystallisation	Thickened and filtered	2016
1B	Injection	Thickened	2020
2B	Injection	Thickened and filtered	2020
3B	Crystallisation	Thickened	2020
4B	Crystallisation	Thickened and filtered	2020

5.2.1 Stage 1 assessment

The BPT assessment of the eight identified strategies was divided into two stages. Stage 1, or the preliminary strategic assessment, was conducted soon after completion of the individual component assessments. The intention was to eliminate strategic options that clearly did not constitute BPT, and to more clearly identify information gaps in the remaining options needing to be addressed prior to the final BPT assessment of the strategic options.

The key options that were eliminated in the stage 1 assessment were tailings filtration and brine crystallisation. The results of the stage 1 assessment are shown in Figure 5-1.

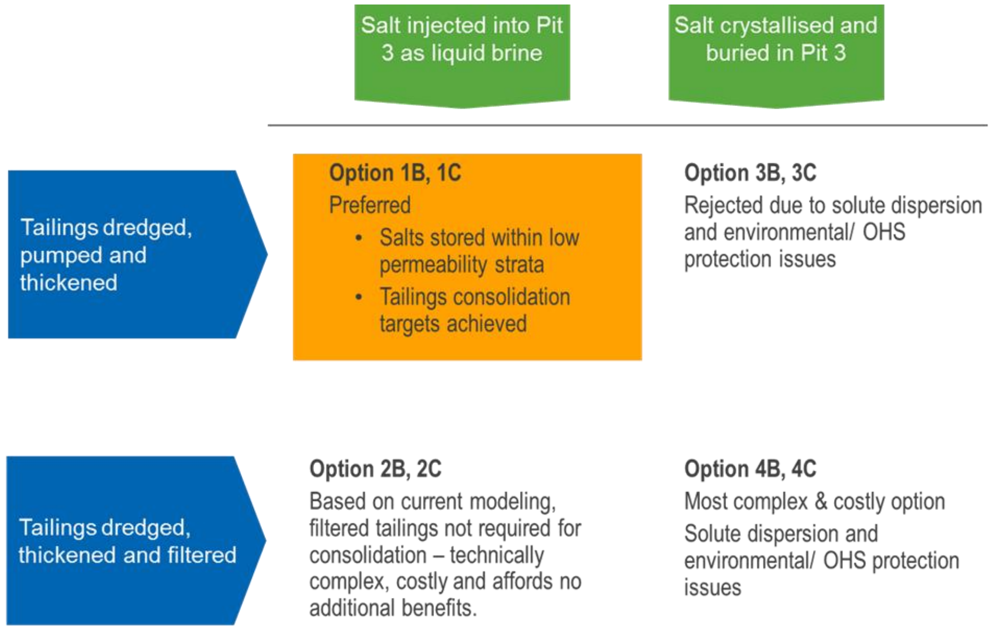

Figure 5-1: Outcomes of the Stage 1 assessment

The tailings management workshop confirmed filtration was a very expensive option with limited advantages and therefore it was decided that filtration of tailings (2C, 2B) should not be considered further in the development of the best practice strategy for rehabilitation and closure of the Ranger Mine.

Further analysis and test work completed following the initial technical options BPT workshops confirmed brine injection was the best option for management of salt. Further to this, the Stage 1 BPT confirmed brine crystallisation was not a viable option, performing poorly under several criteria. As a result, the strategies that included crystallisation (3B, 3C, 4B, 4C) of the brine stream from the water treatment plant were rejected.

5.2.2 Stage 2 assessment

Based on the Stage 1 BPT assessment, all filtration and crystallisation options were eliminated (this was further validated by programs conducted between the stage 1 BPT and the stage 2 BPT). As such, the closure strategies considered in the Stage 2 BPT workshop were limited to 1B and 1C, however, extended water treatment cases (5B and 5C) were considered as well. This was to allow for the scenario where process water volumes exceed the BC treatment capacity, allowing for longer term treatment of process water.

Table 5-3 lists the options assessed in Stage 2 (detailed ranking matrices at the end of Section 6.5).

Table 5-3: Final closure strategies assessed

Strategy	Brief description
1C	Brine injection, thickened tailings, milling until 2016
1B	Brine injection, thickened tailings, milling until 2020
5C	Strategy 1C with extended water treatment
5B	Strategy 1B with extended water treatment

The highest BPT score of 19 was recorded for Strategy 1B; the three other options scored 15. To put this result in perspective, changing the assessed score for any individual criterion by one unit would change the overall score for that option by about two units. Hence, these results imply that option 1B is the favoured option based on the BPT assessment process, but the result is marginal.

The criteria where differences were recorded were:

- socio-economic impact on Jabiru and the region: the two extended options provide additional time for community partnerships to run and continued retention of services, the 5B case also provides additional royalty income;
- technical performance: both 2020 options scored higher because the extended milling period enables the processing of lower grade ores, previously assessed as not commercially viable;
- capital expenditure: the two extended options scored higher primarily because only one BC is required for these options;
- maintainability: the 2020 milling option with extended water treatment results in the use of the BC for nine years beyond its planned lifetime;
- operating costs: the operating costs of the extended 2020 option would be higher because replacement of major BC parts would almost certainly be required; and
- schedule: both extended options scored lower than the primary options under the schedule criterion.

5.2.3 Supplementary integrated tailings, water and closure prefeasibility study

A review of the ITWC BPT assessment was conducted in August 2016. This determined, with the exception of tailings treatment, all technical options selected as BPT remained valid.

Eight options were assessed using the same assessment criteria, scoring and weighting, as used in the ITWC PFS assessment. The results are presented in Table 5-4. Of the eight options assessed, one hard show-stopper and four soft show-stoppers were identified by workshop participants.

Table 5-4: Supplementary tailings treatment assessment

Strategy	Technology	Show-stopper		Overall rank
		Hard	Soft	
A1	Thickened tailings (ITWC base case)			32.6
A2	Unthickened tailings	✓		-100
A3	Unthickened tailings, with prefabricated vertical drains (wicks)			41.3
A4	Unthickened tailings, with extended water treatment		✓	-6.5
A5	Unthickened tailings, with inline agglomeration and wicks			10.9
A6	Unthickened tailings with neutralisation and wicks		✓	17.5
A7	Thickened and filtered tailings (ITWC assessed)		✓	13.0
A8	Thickened, filtered and cemented tailings (ITWC assessed)		✓	6.8

For most of the detailed options assessed, a NA (not applicable) result was obtained for criteria in the 'Culture and Heritage', and 'Ecosystems and Natural World Heritage Values of Kakadu NP' categories. All activities associated with all options occur within the cultural heritage exemption zone. In addition, these methods do not have any impact on the surrounding ecosystems and World Heritage values of Kakadu during the operational phase. Hence, the BPT assessment of the tailings treatment options was dominated by the criteria under the 'Fit for Purpose', 'Operational Adequacy' and 'Constructability' categories.

The base case for this assessment assumed tailings would be unthickened, with three options being considered a) with wicks, b) with extended water treatment, and c) with inline agglomeration and wicks. These were assessed against the previous ITWC thickened tailings options.

The results of the BPT indicate that unthickened tailings with wicks (A3) have advantages over unthickened tailings and extended water treatment (A4) and unthickened tailings with inline agglomeration (A6). It was assessed that the use of wicks would be viewed more favourably by Traditional Owners under the 'Living Culture' criterion compared to unthickened (A2). The unthickened tailings option (A2) was hard show-stopped due to factors including: not all process water being removed during consolidation, subsidence and erosion of the landform, impacts on rehabilitation performance, impacts to water quality and the formation of visible salts in the landform surface, all of which could lead to an unwillingness for Traditional Owners to resume cultural practices on the site post-closure.

Unthickened tailings with wicks (A3) have been demonstrated as proven technology through its application in Pit 1. Prefabricated vertical drains, or wicks, present a sound technical method of achieving increased consolidation and ensuring the schedule requirements on rehabilitation on the RPA are met.

Inline agglomeration and wicks (A5) option faired less favourably across 'Fit for Purpose' and 'Operational Adequacy' categories than options A1 and A3, predominantly based on less certainty around achieving consolidation targets and potential reliability issues related to inconsistent input densities. There was also a high uncertainty around the complexity of integration with existing dredging operations, high operational expenditure and complexities associated with construction of the plant on the pit access ramp.

Unthickened with extended water treatment (A4) was soft show-stopped under category 'Construction, Environmental and Cultural risks' because of the increased number of vehicles through Kakadu National Park necessary to transport new infrastructure and the substantial increase in workforce required to construct a new water treatment plant. It emerged as the least favoured option, scoring 'inadequate to 'poor' against most categories under 'Fit for Purpose', 'Operational Adequacy' and 'Constructability'. The low ranking against these criteria was strongly influenced by high sustaining capital and operating costs associated with the existing BC, long procurement lead times required to purchase a new plant or additional infrastructure to expand the existing plant, and the complex operational nature of the plant potentially leading to a high number of interruptions and downtime.

Strategies A6 through A8 all recorded soft show-stoppers under 'Construction', 'Environmental' and 'Cultural' risks criterion, attributed to the effects of increased traffic volumes through Kakadu NP associated with new infrastructure and increased construction workforce in Jabiru. These options also recorded soft show-stoppers under OHS, attributed to increased risks of vehicle incidents during tailings transfer to Pit 3. In addition to the above, concerns identified during the ITWC PFS around strategy A8 (thickened, filtered and cemented) remain. These include the extremely high operational costs as a result of high cement consumption and uncertainty around the long-term stability of cement, which is susceptible to sulfate attack. Significantly more development work would be required before this would be considered a viable option when compared to strategies that were assessed.

5.2.4 Conclusions

The BPT assessment has considered viable thickened tailings options from the previous ITWC PFS and new, unthickened tailings treatments. Of the eight options assessed, one option was hard show-stopped (unthickened A2) and four were soft show-stopped.

Three options were considered viable; however inline agglomeration with wicks (A5) scored the lowest of the three with the assessment identifying some inherent issues around achieving consolidation targets, high operational costs and construction complexities, compared to the other two options (e.g. thickened and unthickened with wicks).

There was no material difference in the assessment scores for the thickened (A1) and unthickened with wicks (A3) options. However, ERA has extensive knowledge around strategy A3, based on the performance of the Pit 1 backfill strategy and subsequent tailings consolidation being achieved via this method.

6 TAILINGS DEPOSITION INTO PIT 3 FOR MILL TAILINGS AND DREDGE TAILINGS

Report: *Application Pit 3 Tailings Deposition. 2019*

In preparation for cessation of mining and processing activities at Ranger Mine, a further assessment of the methods for tailings deposition was undertaken. An application was submitted to the Director of Mining Operations, DPIR (now DITT) in March 2019 to change the deposition method of tailings in Pit 3 from subaerial (to a tailings beach) to subaqueous (into water) (ERA, Alan Irving & Associates 2019). The application was approved in July 2019. The change was proposed to improve deposition, specifically to:

- prevent segregation;
- prevent accumulation of fine tailings in inundated areas of the pit; and
- accelerate backfilling with consolidated tailings.

Following detailed assessment of various subaqueous deposition configurations and multi spigot subaerial deposition options for Pit 3, a BPT assessment was undertaken in January 2019 to assess the range of potentially viable deposition options (GHD, 2019). To conduct this assessment, tailings under consideration were separated into either mill tailings or dredge tailings and scored against the six major criteria. This resulted in an overall ranking calculated for each option (Table 6-1 and the ranking matrices at the end of this sub-section).

Table 6-1: Tailings deposition options and best practicable technology assessment summary

Option	Option description	Overall Rank
Mill Tailings		
M1	Subaerial deposition from the current, multiple discharge points (one at a time, infrequently changing)	41.7
M2	Subaerial deposition from multiple spigots on the east wall (one at a time, frequently changing)	35.4
M3	Subaqueous deposition	16.7
Dredge Tailings		
D1	Dredge 1 and 2 subaerial	20.8
D2	Dredge 1 and 2 subaqueous	16.7
D3	Dredge 1 subaqueous & Dredge 2 subaerial	12.5
D4	Dredge 1 subaerial & Dredge 2 subaqueous	10.4

The BPT assessment found that for mill tailings, the two subaerial options (M1 and M2) were similarly effective, and slightly better, than subaqueous discharge (M3) due to the higher cost and greater complexity of subaqueous deposition. Option M2 has the advantage of maintaining a lower, more level tailings surface. Both M1 and M2 promote overall drainage from east to west and are more cost effective than subaqueous deposition. However, M1 scored lower on schedule and both M1 and M2 will result in a slightly higher tailings level in the east of the pit.

The assessment found that for dredge tailings, the subaerial options scored more favourably on costs, constructability, operability and maintainability criteria. This is primarily due to the lower complexity of the subaerial method and because most of the subaerial facilities are already in place. However, the subaerial options scored poorly on schedule and technical performance, as the tailings surface will be more steeply sloping with a higher maximum elevation in the pit requiring additional work to even out the tailings prior to commencement of pit capping.

Conversely, the subaqueous option scored more favourably on schedule, technical performance and environmental protection, since this method promotes less tailings segregation and more rapid consolidation, and the tailings surface will be flatter with a lower maximum elevation in the pit.

Whilst relative advantages and disadvantages were identified, and all options were considered acceptable against each of the assessment criteria, a combination of options M2 (subaerial deposition from multiple spigots on the east wall) and D2 (dredge 1 and 2 subaqueous) was selected.

BPT FINAL ASSESSMENT		Rank	Inadequate 1	Poor 2	Acceptable 3	Good 4	Excellent 5	Unable to evaluate UTE	Not applicable to this option NA
ITWC Project				TO Culture & Heritage		Protection of People and the Environment			
	Show stopper column setting			Yes	Yes	Yes	No	Yes	No
			Rank weighting	1	1	1	1	1	1
Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture	Cultural heritage	Community Health & Safety	Town/Region	Ecosystems of Kakadu	Ecosystems of Project Area
Strategy 1C: Brine injection; thickened tailings; Mill to 2016	0	1	15	3	3	4	3	4	3
Strategy 5C: Brine injection; thickened tailings; Mill to 2016 Water treatment 2026 - 2030	0	1	15	3	3	4	3	4	3
Strategy 1B: Brine injection; thickened tailings; Mill to 2020	0	1	19	3	3	4	4	4	3
Strategy 5B: Brine injection; thickened tailings; Mill to 2020 Water treatment 2026 - 2034	0	1	15	3	3	4	4	4	3

BPT FINAL ASSESSMENT	Inadequate	Poor	Acceptable	Good	Excellent	Unable to evaluate	Not applicable to this option
	1	2	3	4	5	UTE	NA

ITWC Project	Fit for Purpose					Operational Adequacy				
	No	No		Yes	No	Yes	No	No	No	No
	1	1	1	1	1	1	1	1	1	1
Option Description	Proven technology	Technical performance	Robustness	Environmental Protection	CAPEX	Safety Occupational Health	Operability	Inherent availability and reliability	Maintainability	OPEX
Strategy 1C: Brine injection; thickened tailings; Mill to 2016	4	4	3	4	3	3	4	4	3	3
Strategy 5C: Brine injection; thickened tailings; Mill to 2016 Water treatment 2026 - 2030	4	4	3	4	4	3	4	4	3	3
Strategy 1B: Brine injection; thickened tailings; Mill to 2020	4	5	3	4	3	3	4	4	3	3
Strategy 5B: Brine injection; thickened tailings; Mill to 2020 Water treatment 2026 - 2034	4	5	3	4	4	3	4	4	2	2

Energy Resources Of Australia

BPT FINAL ASSESSMENT	Inadequate	Poor	Acceptable	Good	Excellent	Unable to evaluate	Not applicable to this option		
	1	2	3	4	5	UTE	NA		
ITWC Project	Rehabilitation and Closure						Constructability		
	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
	1	1	1	1	1	1	1	1	1
Option Description	Revegetation	Radiation	Erosion	Water Quality	Tailings	Schedule	Construction Occupational Health & Safety	Construction Environmental and Cultural risks	Construction Complexity
Strategy 1C: Brine injection; thickened tailings; Mill to 2016	4	3	3	UTE	2	2	3	4	3
Strategy 5C: Brine injection; thickened tailings; Mill to 2016 Water treatment 2026 - 2030	4	3	3	UTE	2	1	3	4	3
Strategy 1B: Brine injection; thickened tailings; Mill to 2020	4	3	3	UTE	2	2	3	4	3
Strategy 5B: Brine injection; thickened tailings; Mill to 2020 Water treatment 2026 - 2034	4	3	3	UTE	2	1	3	4	3

Rank	Adequate	Poor	Acceptable	Good	Excellent	Unable to evaluate	Not applicable to the option
	1	2	3	4	5	UTE	NA

					TO Culture & Heritage		Protection of People and the Environment			
		Show stopper column setting			Yes	Yes	Yes	No	Yes	Yes
Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture (Closure)	Cultural heritage	Community Health & Safety	Socio-economic Impact on Local Communities	Ecosystems & Natural world heritage values of Kakadu National Park	Ecosystems of the Project Area
A1	Thickened (ITWC base case)	0	0	32.6	4	NA	4	3	NA	3
A2	Unthickened	4	0	-100.0	1					
A3	Unthickened - wicks	0	0	41.3	3	NA	4	3	NA	4
A4	Unthickened - extended water treatment	0	1	-6.5	3	NA	4	3	NA	3
A5	Unthickened - inline agglomeration and wicks	0	0	10.9	3	NA	4	3	NA	3
A6	Unthickened - neutralisation and wicks	0	2	17.5	UTE	NA	4	4	NA	3
A7	Thickened & filtered tailings	0	3	13.0	4	NA	4	3	NA	2
A8	Thickened, filtered & cemented tailings	0	3	6.8	4	NA	4	3	NA	2

Rank	Adequate	Poor	Acceptable	Good	Excellent	Unable to evaluate	Not applicable to the option
	1	2	3	4	5	UTE	NA

					Fit for Purpose					Operational Adequacy				
		Show stopper column setting			No	No	No	Yes	No	Yes	No	No	No	No
Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Proven technology	Technical performance	Robustness (closure only)	Environmental Protection	CAPEX	Occupational Health & Safety	Operability	Inherent availability and reliability	Maintainability	OPEX
A1	Thickened (ITWC base case)	0	0	32.6	5	4	3	4	2	4	4	4	4	3
A2	Unthickened	4	0	-100.0		1								
A3	Unthickened - wicks	0	0	41.3	5	3	2	4	3	4	5	5	5	5
A4	Unthickened - extended water treatment	0	1	-6.5	5	2	2	4	1	4	1	2	2	1
A5	Unthickened - inline agglomeration and wicks	0	0	10.9	3	3	2	4	3	4	3	3	3	3
A6	Unthickened - neutralisation and wicks	0	2	17.5	5	UTE	2	4	2	2	4	4	4	1
A7	Thickened & filtered tailings	0	3	13.0	5	4	3	4	1	2	3	3	3	2
A8	Thickened, filtered & cemented tailings	0	3	6.8	4	UTE	3	5	1	2	3	3	2	1

Rank	Adequate	Poor	Acceptable	Good	Excellent	Unable to evaluate	Not applicable to the option
	1	2	3	4	5	UTE	NA

					Rehabilitation and Closure						Constructability		
		Show stopper column setting			Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Revegetation (Closure only)	Radiation (Closure only)	Erosion (Closure only)	Water (Closure only)	Tailings (Closure only)	Schedule	Construction Occupational Health & Safety	Construction Environmental and Cultural risks	Construction complexity
A1	Thickened (ITWC base case)	0	0	32.6	4	4	3	4	4	3	4	3	4
A2	Unthickened	4	0	-100.0	1		1	1					
A3	Unthickened - wicks	0	0	41.3	4	4	3	4	4	3	3	4	4
A4	Unthickened - extended water treatment	0	1	-6.5	4	4	3	4	4	2	4	2	2
A5	Unthickened - inline agglomeration and wicks	0	0	10.9	4	4	3	4	4	3	3	3	2
A6	Unthickened - neutralisation and wicks	0	2	17.5	4	4	3	4	4	3	4	2	UTE
A7	Thickened & filtered tailings	0	3	13.0	4	4	3	4	4	4	4	2	3
A8	Thickened, filtered & cemented tailings	0	3	6.8	4	4	3	4	4	4	4	2	3

						Traditional Owner Culture & Heritage		Protection of People and the Environment			
			Showstopper column setting			Yes	Yes	Yes	No	Yes	Yes
Initial Showstopper	Option #	Option Description	Showstopper 1 indicator	Showstopper 2 indicator	Overall rank	Ecosystems & the natural world heritage values of Kakadu	Ecosystems of the project area	Community Health and Safety	Socio-economic Impact on Local Communities	Ecosystems & natural world heritage values of Kakadu	Ecosystems of the Project Area
Mill Deposition											
No	M1	Sub-aerial, discharge from single point at a time - infrequent switching between two locations (current scenario)	0	0	41.7	4	3	3	3	4	3
No	M2	Sub-aerial, discharge from a single point at a time - frequent switching between multiple locations (spigots)	0	0	35.4	4	3	3	3	4	3
No	M3	Sub-aqueous	0	0	16.7	4	3	3	3	4	3
Dredge Deposition											
No	D1	Dredge 1: sub-aerial Dredge 2: sub-aerial	0	0	20.8	3	3	3	3	4	3
No	D2	Dredge 1: sub-aqueous Dredge 2: sub-aqueous	0	0	16.7	4	3	3	3	4	3
No	D3	Dredge 1: sub-aqueous Dredge 2: sub-aerial	0	0	12.5	3	3	3	3	4	3
No	D4	Dredge 1: sub-aerial Dredge 2: sub-aqueous	0	0	10.4	3	3	3	3	4	3

Best Practicable Technology Matrix continued...						Fit for Purpose					Operational Adequacy
			Showstopper column setting			No	No	No	Yes	No	Yes
Initial Showstopper	**Option #**	**Option Description**	**Showstopper 1 indicator**	**Showstopper 2 indicator**	**Overall rank**	Proven technology	Technical performance	Robustness (closure only)	Environmental protection	CAPEX	Occupational health & safety
Mill Deposition											
No	M1	Sub-aerial, discharge from single point at a time - infrequent switching between two locations (current scenario)	0	0	41.7	5	4	3	3	5	4
No	M2	Sub-aerial, discharge from a single point at a time - frequent switching between multiple locations (spigots)	0	0	35.4	5	4	3	3	4	4
No	M3	Sub-aqueous	0	0	16.7	5	3	4	4	2	3
Dredge Deposition											
No	D1	Dredge 1: sub-aerial Dredge 2: sub-aerial	0	0	20.8	5	2	3	3	4	4
No	D2	Dredge 1: sub-aqueous Dredge 2: sub-aqueous	0	0	16.7	5	4	5	4	2	3
No	D3	Dredge 1: sub-aqueous Dredge 2: sub-aerial	0	0	12.5	5	3	4	3	4	3
No	D4	Dredge 1: sub-aerial Dredge 2: sub-aqueous	0	0	10.4	5	3	4	3	3	3

Best Practicable Technology Matrix continued...						Operational Adequacy				Rehabilitation and Closure	
			Showstopper column setting			No	No	No	No	Yes	Yes
Initial Showstopper	Option #	Option Description	Showstopper 1 indicator	Showstopper 2 indicator	Overall rank	Operability	Inherent availability & reliability	Maintainability	OPEX	Revegetation (closure only)	Radiation (closure only)
Mill Deposition											
No	M1	Sub-aerial, discharge from single point at a time - infrequent switching between two locations (current scenario)	0	0	41.7	5	5	5	5	3	3
No	M2	Sub-aerial, discharge from a single point at a time - frequent switching between multiple locations (spigots)	0	0	35.4	4	5	4	4	3	3
No	M3	Sub-aqueous	0	0	16.7	3	4	3	2	3	3
Dredge Deposition											
No	D1	Dredge 1: sub-aerial Dredge 2: sub-aerial	0	0	20.8	5	3	4	4	3	3
No	D2	Dredge 1: sub-aqueous Dredge 2: sub-aqueous	0	0	16.7	2	3	3	2	3	3
No	D3	Dredge 1: sub-aqueous Dredge 2: sub-aerial	0	0	12.5	3	3	3	3	3	3
No	D4	Dredge 1: sub-aerial Dredge 2: sub-aqueous	0	0	10.4	3	3	3	3	3	3

Best Practicable Technology Matrix continued...						Rehabilitation and Closure				Constructability		
			Showstopper column setting			Yes	Yes	Yes	No	Yes	Yes	No
Initial Showstopper	**Option #**	**Option Description**	**Showstopper 1 indicator**	**Showstopper 2 indicator**	**Overall rank**	Erosion (closure only)	Water (closure only)	Tailings (closure only)	Schedule	Construction occupational health & safety	Construction environmental and cultural risks	Construction complexity
Mill Deposition												
No	M1	Sub-aerial, discharge from single point at a time - infrequent switching between two locations (current scenario)	0	0	41.7	3	NA	4	2	4	5	4
No	M2	Sub-aerial, discharge from a single point at a time - frequent switching between multiple locations (spigots)	0	0	35.4	3	NA	4	3	4	5	4
No	M3	Sub-aqueous	0	0	16.7	3	NA	4	3	3	5	3
Dredge Deposition												
No	D1	Dredge 1: sub-aerial Dredge 2: sub-aerial	0	0	20.8	3	NA	3	1	4	5	4
No	D2	Dredge 1: sub-aqueous Dredge 2: sub-aqueous	0	0	16.7	3	NA	4	3	3	5	3
No	D3	Dredge 1: sub-aqueous Dredge 2: sub-aerial	0	0	12.5	3	NA	3	2	3	5	3
No	D4	Dredge 1: sub-aerial Dredge 2: sub-aqueous	0	0	10.4	3	NA	3	2	3	5	3

7 REMNANT TAILINGS TRANSFER

The bulk of the tailings within the Tailings Storage Facility (TSF) was dredged and transferred into Pit 3 in 2020/2021. Remnant tailings, the material that remained on the TSF floor and walls after the bulk tailings transfer, also needed to be encapsulated in Pit 3 as per the ERs. This BPT investigated 10 options to determine the best method to undertake this activity.

A BPT workshop was conducted in February 2021 to assess the range of potentially viable transfer options. Each option was assessed against the relevant criteria and the resulting scores are shown in Table 7-1.

Table 7-1: BPT Overall ranking for HDS recommissioning and release

Option	Option description	Score
1	Pre-Cap Pump (base case)	2
2	Post-Cap Truck (Pit 3 west end)	6
2a	Post-Cap Truck (Pit 3 east end)	0
2b	Post-Cap Truck (temp store in Pit 3 THWS rather than TSF SE temp cell)	-6
3	Pre-Cap Truck (deposit into Pit 3 south west end, down pit wall, tailings slurried to push lower into pit)	17
3a	Pre-Cap Truck (deposit into Pit 3 south west end, down pit wall)	6
3a (i)	Pre-Cap Truck (deposit into Pit 3 south west end, down pit wall)	4
3b	Pre-Cap Truck, sucker truck ramp to north wall (below cap)	2
3c	Pre-Cap Truck, Pit 3 west ramp, barge or floating conveyor transfer to west central end of pit	0
4	Bury tailings in TSF	Hard show-stopped

Option 3 was selected as the preferred method for the transfer of remnant tailings, having the highest score of 17. Each individual criteria ranked for Option 3 received as ‘3’ or greater, indicating that the selected approach meets or exceeds current standards across all assessed fields.

The remnant tailings transfer commenced in Q2 2021, following construction of the Pit 3 tip head and upgrades to the required haul roads. Some of the remnant tailings have ‘hung up’ on the internal wall of Pit 3 and the most effective method to move these tailings deeper into the pit is the subject of current assessment.

8 HIGH DENSITY SLUDE PLANT RECOMMISSIONING

Report: *Application to release water from High Density Sludge (HDS) Plant. 2020*

The HDS plant was recommissioned on a trial basis in 2019 with the HDS product water recycled into the process water inventory. The recommissioning of the HDS plant was a planned strategy to increase the capacity of process water treatment during closure. An application was submitted to the Director of Mining Operations, DPIR (now DITT) in January 2020 to approve the release of HDS treated process water generated from the recommissioned plant by either of the following options:

- direct treatment through Water Treatment Plant 1 (WTP1) and subsequent release to the Corridor Creek Wetland Filter;
- indirect treatment by releasing HDS product into the pond water inventory, for subsequent treatment through any of the pond water treatment plants (WTPs).

Approval was granted in February 2020 with specification for discharge of water to RP2 when releasing HDS product water via indirect treatment as per the application. This approval was contingent on ERA implementing operational controls described in the revised application.

To support this application a BPT assessment was conducted to build upon the previous BPT analysis that was completed to support the original construction of the HDS plant in 2004. The recent BPT assessment evaluated twelve (12) options to address additional process water treatment capacity. The majority of options scored high (31 – 44.4) and differed marginally in the weighting of individual criteria namely ‘Robustness’, ‘Cost’, ‘Schedule’ and ‘Construction complexity’ (Table 8-1 and the ranking matrices at the end of this section).

Table 8-1: BPT Overall ranking for HDS recommissioning and release

Option	Option description	Score
5.1	Recommission the existing HDS plant, full treatment and transfer of product water direct to WTP1 (dry season only).	31.0
5.2	Recommission the existing HDS plant, full treatment and transfer product water direct to pond water inventory (year round).	33.3
5.3	Recommission the existing HDS plant, adaptive operation (full treatment) with product transfer to either WTP1 (dry season) or pond water storage (year round).	33.3
5.4	Recommission the existing HDS plant, partial treatment and transfer product water direct to WTP1 (year round).	31.0
6.1	Repurpose of mill infrastructure for large scale HDS treatment.	16.7
6.2	New build of larger HDS plant for large scale HDS treatment.	16.7
7.1	BC single train equivalent construction.	35.7
7.2	BC duplication construction.	33.3
8.1	Direct feed process water (untreated) to existing UF/RO infrastructure.	40.5
8.2	Direct feed process water (untreated) to new UF/RO infrastructure similar to current.	33.3
8.3	Discharge process water (untreated) direct to pond water inventory (untreated).	38.1
11	Do nothing.	44.4

All options exceeded current standards for environmental protection and proven technology. The options that ranked highest overall (38.1–44.4) were assessed as not feasible for current implementation on the basis that they did not align with the overarching objectives, required significantly high capital expenditure ($10M+), or would likely cause impacts to the closure schedule (i.e. construction delays or conflicts with other closure commitments).

The option identified as most suitable for implementation involved the use of the existing HDS plant under adaptive operational conditions to optimise treatment capability (option 5.3). This option received the mean overall ranking (33.3) and represents a rational approach to addressing project limitations whilst maintaining effective environmental outcomes.

Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture (Closure)	Cultural heritage	Community Health & Safety	Socio-economic Impact on Local	Ecosystems & Natural world heritage	Ecosystems of the Project Area
					TO Culture & Heritage		Protection of People and the Environment			
		Show stopper column setting				Yes	Yes	No	Yes	Yes
5.1	Recommission the existing HDS plant, product to WTP1, dry season only operation, full treatment			31.0	3	4	4	3	4	4
5.2	Recommission the existing HDS plant, product to pond water, year round operation, full treatment			33.3	3	4	4	3	4	4
5.3	Recommission the existing HDS plant, adaptive operation, full treatment			33.3	3	4	4	3	4	4
5.4	Recommission the existing HDS plant, partial treatment			31.0	3	4	4	3	4	4
6.1	Re-purpose mill infrastructure			16.7	3	4	3	3	4	4
6.2	New build HDS plant			16.7	3	4	3	3	4	4
7.1	BC single train equivalent			35.7	3	4	4	3	5	5
7.2	BC duplication			33.3	3	4	4	3	5	5
8.1	Direct feed to existing UF/RO infrastructure			40.5	3	4	4	3	4	4
8.2	Direct feed to new UF/RO infrastructure similar to current			33.3	3	4	4	3	4	4
8.3	Discharge direct to pond inventory			38.1	3	4	4	3	4	4
11	Do nothing			44.4	3	4	4	3	5	5

Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Proven technology	Technical performance	Robustness (closure only)	Environmental Protection	CAPEX	Occupational Health & Safety	Operability	Inherent availability and reliability	Maintainability	OPEX
					Fit for Purpose					Operational Adequacy				
		Show stopper column setting			No	No		Yes	No	Yes	No	No	No	No
5.1	Recommission the existing HDS plant, product to WTP1, dry season only operation, full treatment			31.0	4	4	3	4	4	4	3	3	3	3
5.2	Recommission the existing HDS plant, product to pond water, year round operation, full treatment			33.3	4	4	3	4	4	4	3	4	3	3
5.3	Recommission the existing HDS plant, adaptive operation, full treatment			33.3	4	4	3	4	4	4	3	4	3	3
5.4	Recommission the existing HDS plant, partial treatment			31.0	4	4	3	4	4	4	3	3	3	3
6.1	Re-purpose mill infrastructure			16.7	4	4	4	4	3	4	3	4	3	3
6.2	New build HDS plant			16.7	4	4	5	4	2	4	3	4	3	3
7.1	BC single train equivalent			35.7	4	5	4	5	2	4	4	4	4	3
7.2	BC duplication			33.3	4	5	5	5	1	4	4	4	4	3
8.1	Direct feed to existing UF/RO infrastructure			40.5	4	3	3	4	5	4	4	4	4	4
8.2	Direct feed to new UF/RO infrastructure similar to current			33.3	4	3	4	4	2	4	4	4	4	4
8.3	Discharge direct to pond inventory			38.1	4	3	2	4	5	4	4	4	4	4
11	Do nothing			44.4	5	4	1	4	5	4	NA	NA	NA	3

					Rehabilitation and Closure						Constructability		
		Show stopper column setting			Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Option ID	**Option Description**	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Revegetation (Closure only)	Radiation (Closure only)	Erosion (Closure only)	Water (Closure only)	Tailings (Closure only)	Schedule	Construction Occupational Health & Safety	Construction Environmental and Cultural risks	Construction complexity
5.1	Recommission the existing HDS plant, product to WTP1, dry season only operation, full treatment			31.0	NA	NA	NA	4	NA	3	4	4	4
5.2	Recommission the existing HDS plant, product to pond water, year round operation, full treatment			33.3	NA	NA	NA	4	NA	3	4	4	4
5.3	Recommission the existing HDS plant, adaptive operation, full treatment			33.3	NA	NA	NA	4	NA	3	4	4	4
5.4	Recommission the existing HDS plant, partial treatment			31.0	NA	NA	NA	4	NA	3	4	4	4
6.1	Re-purpose mill infrastructure			16.7	NA	NA	NA	3	NA	2	3	3	2
6.2	New build HDS plant			16.7	NA	NA	NA	3	NA	2	3	3	2
7.1	BC single train equivalent			35.7	NA	NA	NA	4	NA	3	3	3	2
7.2	BC duplication			33.3	NA	NA	NA	4	NA	2	3	3	2
8.1	Direct feed to existing UF/RO infrastructure			40.5	NA	NA	NA	4	NA	3	4	4	4
8.2	Direct feed to new UF/RO infrastructure similar to current			33.3	NA	NA	NA	4	NA	3	4	4	3
8.3	Discharge direct to pond inventory			38.1	NA	NA	NA	4	NA	3	4	4	4
11	Do nothing			44.4	NA	NA	NA	4	NA	1	5	5	5

9 TSF NORTH NOTCH STAGE 3

Report: *Application to reduce the certified crest height of the Ranger Mine Tailings Storage Facility North Notch Stage 3. 2020*

The water level of the TSF continued to be lowered to maximise the efficiency of the dredges during the transfer of tailings to Pit 3. As a result of the lowering water level, there was a need to create notches within the TSF walls to increase the pumping efficiency and to maintain safe access to the floating infrastructure. An application was submitted to the Director of Mining Operations, Department of Primary Industry and Resources (DPIR) (now Department of Industry, Tourism and Trade [DITT]) in April 2020 to approve reduction of the clay core crest height to Relative Level (RL) 37.8 m and to manage future raises in crest height with the construction of clay bunds across the notch if required. The DPIR (now DITT) approved the application in June 2020 and agreed to the provision of water balance modelling updates of the inventory at the beginning of each dry season to ensure sufficient capacity for the upcoming wet season.

Notching the TSF wall proved to be fit for purpose and environmentally sound for the construction of the previous three notches. The construction of a further notch within the footprint of the North wall notch did not require a BPT assessment. However, the reduction in crest height to a level that enabled the completion of dredging presented a risk of inadequate water storage volume when considering the future needs of the TSF for process water storage facility. The purpose of this BPT assessment was to identify the most environmentally sound approach for ongoing safe access to the TSF during dredging whilst ensuring adequate crest height to meet the freeboard requirements of the Ranger Authorisation until 2024.

A total of six options were assessed as part of the BPT assessment (Table 9-1 and the ranking matrices at the end of the section).

Table 9-1: BPT options assessment for TSF notch

Option	Option description	Score
A1	Construct North Notch 3 to RL 36. (clay core RL 35.8 m) & construct clay bund in dry season if required as determined by process water inventory predictions for the following wet season.	0
A2	Construct North Notch 3 to RL 37.3 m (clay core RL 36.8 m) & construct clay bund in dry season if required as determined by process water inventory predictions for the following wet season.	0
A3	Construct North Notch 3 to RL 36.3 m RL. Infill the notch to Stage 2 level following completion of TSF cleaning operation.	0
A4	No additional notch. 1.1 Excavate progressive ramp in upstream embankment face from current North Notch 2. Relocate services and gantry into a local cutting. Crane used from Notch 2 for large lifts.	-2.8
-A5	Continue use of North Notch 2 using large crane and modified gantry.	Hard show-stopper
A6	North-East Ramp. Remove current ramp in North-East corner of TSF. Cut in new ramp, beginning from further back, in stockpile area, and notching down into TSF wall to RL36.3m. Creates notch in North-East corner. Access as per A1.	-19.4

Most of the options received scores close to zero, indicating that they meet industry standard. No option was considered to substantially exceed industry standard. This is expected given the unfamiliar activity of removing tailings from a tailings storage facility. The continued use of North Notch 2, requiring a modified gantry and an estimated 600–700 tonne crane for ongoing access to the lift workboats, was hard show-stopped at the beginning of the assessment. Gantry modification to the extent required to meet safety requirements was considered to be prohibitively expensive.

Option A2, the construction of a third notch in the North wall to a height of RL 37.3 m, was determined to be the most suitable approach. This option includes the contingency to construct a clay bund within the notch if it is required to ensure adequate freeboard during the wet seasons. It is assumed that Pit 3 remains available to receive process water from the TSF during extreme weather events to minimise the risk of overflow into the notch.

Although options A1 and A3 received the same final overall ranking, option A2, with the higher notch level, has a lower capital expenditure and construction time than A1 and A2. Capital expenditure and construction time includes clay bund and notch infill. There is a risk of overtopping the notch resulting in seepage into the dam walls in option A2. This risk is removed with the infill of the notch as proposed in option A3. Proposed risk mitigation measures, such as the construction of a clay bund and the cessation of tailings pore water transfer from Pit 3 reduce this risk to an acceptable level and justified the selection of option A2 over option A3.

						Protection of People and the Environment			Fit for Purpose				
			Show stopper column setting			Yes	No	Yes	No	No		Yes	No
Initial show stopper	Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Community health & safety	Socio-economic impact on local communities	Ecosystems & Natural world heritage values of Kakadu National Park	Proven technology	Technical performance	Robustness (closure only)	Environmental Protection	CAPEX
	A1	Construct North Notch 3 to RL36.3m & construct clay bund if required.	0	0	-3.1			3	3	3	2	3	3
	A2	Construct North Notch 3 to RL37.3m & construct clay bund if required.	0	0	-3.1			3	3	2	2	4	4
	A3	Construct North Notch 3 to RL36.3m. Infill the notch again to Stage 2 height after the TSF cleaning operation.	0	0	-3.1			3	3	3	3	4	1
	A4	Excavate progressive ramp in upstream embankment face from current North Notch 2. Relocate services & gantry into cutting. Use crane for large lifts.	0	0	-15.6			3	2	2	3	3	3
Yes	A5	Continued use of North Notch Stage 2 with large crane and modified gantry			0.0								
	A6	NE Ramp & notch - cut in new ramp from the stockpile area, notch down to RL36.3m.	0	0	-18.8			3	2	3	2	1	1

						Operational Adequacy					Rehabilitation and Closure		Constructability		
			Show stopper column setting			Yes	No	No	No	No	No	No	Yes	Yes	No
Initial show stopper	**Option ID**	**Option Description**	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Occupational Health & Safety	Operability	Inherant availability & reliability	Maintainability	OPEX	Cost (Operations only)	Schedule	Construction Occupational Health & Safety	Construction Environmental and Cultural risks	Construction complexity
	A1	Construct North Notch 3 to RL36.3m & construct clay bund if required.	0	0	-3.1	3	3	3	3	3	3	3	3	3	3
	A2	Construct North Notch 3 to RL37.3m & construct clay bund if required.	0	0	-3.1	3	2	3	3	3	3	3	3	3	3
	A3	Construct North Notch 3 to RL36.3m. Infill the notch again to Stage 2 height after the TSF cleaning operation.	0	0	-3.1	3	3	3	3	3	3	3	3	3	3
	A4	Excavate progressive ramp in upstream embankment face from current North Notch 2. Relocate services & gantry into cutting. Use crane for large lifts.	0	0	-15.6	3	2	1	3	4	3	3	3	3	2
Yes	A5	Continued use of North Notch Stage 2 with large crane and modified gantry			0.0										
	A6	NE Ramp & notch - cut in new ramp from the stockpile area, notch down to RL36.3m.	0	0	-18.8	3	3	3	3	3	3	3	3	3	3

10 TAILINGS STORAGE FACILITY SUBFLOOR MATERIAL MANAGEMENT

Report: *MTC Application Ranger Mine Tailings Storage Facility – Subfloor Material Management. 2020*

ERA undertook an assessment into the viable options for managing the TSF subfloor contaminated material as part of closure planning for the TSF and Pit 3. The assessment was aimed at assessing the environmental impact of leaving the contaminated material *in situ* rather than disposal into Pit 3. The reason for this tightly defined scope was to determine if the planning and application for the closure of Pit 3 was required to consider this subfloor material. The deconstruction of the TSF does not occur until later, and as such, this application was submitted prior to the Pit 3 application and the actual Pit 3 capping works.

Based on the outcomes of the BPT assessment, an application was submitted to the Director of Mining Operations, DITT for approval in March 2020. The application was updated in June 2020 following stakeholder feedback and the DITT approved the application in August 2020.

The BPT assessment involved comparing the option of leaving the contaminated subfloor material *in situ* against a number of methodologies for disposing the material within Pit 3 (Table 10-1 and the ranking matrices at the end of this section).

Option 1 was developed as a worst-case scenario for leaving the material *in situ*. Option 2 was omitted from further assessment, to allow for completion of the relevant supporting studies. It is intended that Option 2 will be reviewed on the basis that Option 1 demonstrates a greater ‘net environmental benefit’ than Option 3 as part of this initial assessment. A total of 12 options were reviewed for disposal of the material within Pit 3.

Table 10-1: BPT assessment options and overall ranks for TSF Contaminated Material Management

Option	Option description	Score
1a	Leave material *in situ*. TSF subfloor material left undisturbed in situ. All visible tailings removed. TSF is then used for process water storage.	38.2
2	Leave material *in situ*. TSF subfloor material left undisturbed in situ with some form of remediation which may use TSF wall material for capping or another methodology.	Initial show-stopper
3a.1	Dispose of material within Pit 3. 2 m of TSF subfloor material removed via mechanical removal, stockpiled, with transfer to Pit 3 for use as secondary cap. TSF used for process water storage.	-17.6
3a.2	Dispose of material within Pit 3. 2 m of TSF subfloor material removed via mechanical removal, intermediate stockpile, with transfer to Pit 3 for use as primary cap.	Initial show-stopper
3a.3	Dispose of material within Pit 3. 2 m of TSF subfloor material removed via mechanical removal, no stockpile, placed within south-west of Pit 3 as primary cap wedge deposit. TSF used for process water storage.	-35.3
3a.4	Dispose of material within Pit 3. 2 m of TSF subfloor material removed via dredging, not stockpiled, with transfer to Pit 3 for use as primary cap. TSF used for process water storage.	Initial show-stopper
3a.5	Dispose of material within Pit 3. 2 m of TSF subfloor material removed via mechanical removal, crush, screen and pump to Pit 3 (above tailings). TSF used for process water storage.	-41.2

Option	Option description	Score
3a.6	Dispose of material within Pit 3. 2 m of TSF subfloor material removed via mechanical removal, stockpiled, with transfer to Pit 3 and intermixed with mineralised waste rock (co-disposal). TSF used for process water storage.	-23.5
3a.7	Dispose of material within Pit 3. 2 m of TSF subfloor material removed mechanically, stockpiled, with transfer to south-west of Pit 3 as secondary cap wedge deposit. TSF used for process water storage.	-23.5
3b.1	Dispose of material within Pit 3. 20 m of TSF subfloor material removed mechanically, stockpiled, transferred to Pit 3 and use as secondary cap. TSF used for process water storage.	Initial show-stopper
3b.2	Dispose of material within Pit 3. 20 m of TSF subfloor material removed mechanically, stockpiled, partially transferred to Pit 3 and use as secondary cap with remainder to other onsite storage cell. TSF used for process water storage.	Initial show-stopper
3c.7	Dispose of material within Pit 3. 4 m of TSF subfloor material removed mechanically, stockpiled, transferred to Pit 3 and placed in south-west as secondary cap deposit. TSF used for process water storage.	-29.4
3d.6	Dispose of material within Pit 3. 2 m of TSF subfloor material removed mechanically after TSF use as water storage is complete. Schedule optimised.	-29.4
3d.7	Dispose of material within Pit 3. 2 m of TSF subfloor material removed mechanically after TSF use as water storage is complete. Solute optimised.	-29.4

To compare Options 1 and 3, an understanding of the risk of contaminants mobilising into the surrounding environment was necessary to determine how effectively the TSF subfloor could be isolated at each management location. Isolation effectiveness is assessed with regard to the likelihood of contaminants entering groundwater and surface waters, which create solute transport pathways and potentially increase exposure of contaminants to sensitive receptors. The management option that poses the lowest environmental risk and/or avoids having 'a net adverse effect' would be considered the most viable for implementation.

Option 1a (leave *in situ*) ranked highest overall and is the only option with a positive ranking of 38.2. This option scored highest overall for aspects such as 'Environmental Protection', 'Living Culture', 'Cultural Heritage', 'Ecosystems & Natural World Heritage', and 'Tailings', indicating that these aspects meet current standards and are more likely to achieve greater level of environmental and cultural protection than the other management options. This option scored lowest overall for 'Revegetation' (3) and 'Erosion' (2), indicating that this option presents greater risk to final landform management than the Pit 3 transfer options. Overall, this option had the least number of soft show-stopper aspects ('Community Health', 'Radiation' and 'Erosion') in comparison to the other options and was identified as the most viable option for contaminated material management.

						TO Culture & Heritage		Protection of People and the Environment		Fit for Purpose			
			Show stopper column setting			Yes	Yes	Yes	Yes	No	No	Yes	No
Initial show stopper	**Option ID**	**Option Description**	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture (Closure)	Cultural heritage	Community Health & Safety	Ecosystems & Natural world heritage values of Kakadu National Park	Proven technology	Robustness (closure only)	Environmental Protection	CAPEX
	Option 1a	TSF subfloor material left undisturbed in situ, post tailings clean includes all visible tailings removed from the TSF floor. Then TSF used for process water storage.	0	3	38.2	3	5	2	3	5	5	4	5
Yes	Option 2	In situ remediation. As per Option 1. then remediated.	0	0	0.0								
	Option 3a.1	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use as secondary cap. Then TSF used for process water storage.	0	4	-17.6	2	3	2	2	4	4	3	2
Yes	Option 3a.2	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use as primary cap. Then TSF used for process water storage.	0	0	0.0								
	Option 3a.3	TSF sub floor material removed to 2 m below composite floor via mechanical removal - no stockpile - move to south west of Pit 3 as primary cap wedge deposit. Then TSF used for process water storage.	0	7	-35.3	2	2	2	2	2	4	3	2
Yes	Option 3a.4	TSF sub floor material removed to 2 m below composite floor via dredging - no stockpile - move to Pit 3 and use as primary cap. Then TSF used for process water storage.	0	0	0.0								
	Option 3a.5	TSF sub floor material removed to 2 m below composite floor via mechanical removal - crush, screen & pump to Pit 3 (on top of tailings). Then TSF used for process water storage.	1	4	-41.2	2	3	2	1	2	4	3	1
	Option 3a.6	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use by co-disposal with mineralised waste rock. Then TSF used for process water storage.	0	6	-23.5	2	2	2	2	4	4	3	2
	Option 3a.7	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to south west of Pit 3 as secondary cap wedge deposit. Then TSF used for process water storage.	0	6	-23.5	2	2	2	2	4	4	3	2

						TO Culture & Heritage		Protection of People and the Environment		Fit for Purpose			
			Show stopper column setting			Yes	Yes	Yes	Yes	No	No	Yes	No
Initial show stopper	**Option ID**	**Option Description**	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Environmental Protection	CAPEX	Occupational Health & Safety	Inherent availability and reliability	Revegetation (Closure only)	Erosion (Closure only)	Water (Closure only)	Tailings (Closure only)
Yes	Option 3b.1	TSF sub floor material removed to 20 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use as secondary cap. Then TSF used for process water storage.	0	0	0.0								
Yes	Option 3b.2	TSF sub floor material removed to 20 m below composite floor via mechanical removal - stockpile - partially move to Pit 3 and use as secondary cap with remainder to other onsite storage cell. Then TSF used for process water storage.	0	0	0.0								
	Option 3c.7	TSF sub floor material removed to 4 m below composite floor via mechanical removal - stockpile - move to south west of Pit 3 as secondary cap wedge deposit. Then TSF used for process water storage.	0	6	-29.4	2	3	2	2	4	4	2	1
	Option 3d.6	TSF cleaned up then used for process water storage until required for use. TSF sub floor material removed prior to TSF deconstruction to 2 m below composite floor via mechanical removal ** schedule optimised ** Note: **It means to best maintain the closure schedule, thus the subfloor material would be near the surface of Pit 3 backfill.	0	6	-29.4	2	2	2	2	4	4	3	1
	Option 3d.7	TSF cleaned up then used for process water storage until required for use. TSF sub floor material removed prior to TSF deconstruction to 2 m below composite floor via mechanical removal ** solute optimised ** Note: **It means to stop work on Pit 3 backfill until the TSF subfloor material is available to put as low in pit as possible. Thus the closure schedule is exceeded by years.	0	6	-29.4	2	2	2	2	4	4	3	1

Initial show stopper	Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Revegetation (Closure only)	Radiation (Closure only)	Erosion (Closure only)	Water (Closure only)	Tailings (Closure only)	Schedule	Construction Occupational Health & Safety	Construction Environmental and Cultural risks	Construction complexity
						Rehabilitation and Closure						Constructability		
			Show stopper column setting			Yes	Yes	Yes	No	No	No	Yes	Yes	No
	Option 1a	TSF subfloor material left undisturbed in situ, post tailings clean includes all visible tailings removed from the TSF floor. Then TSF used for process water storage.	0	3	38.2	3	2	2	2	3	5	5	5	5
Yes	Option 2	In situ remediation. As per Option 1. then remediated.	0	0	0.0									
	Option 3a.1	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use as secondary cap. Then TSF used for process water storage.	0	4	-17.6	4	2	3	1	2	2	3	3	3
Yes	Option 3a.2	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use as primary cap. Then TSF used for process water storage.	0	0	0.0									
	Option 3a.3	TSF sub floor material removed to 2 m below composite floor via mechanical removal - no stockpile - move to south west of Pit 3 as primary cap wedge deposit. Then TSF used for process water storage.	0	7	-35.3	4	2	3	1	2	2	2	2	2
Yes	Option 3a.4	TSF sub floor material removed to 2 m below composite floor via dredging - no stockpile - move to Pit 3 and use as primary cap. Then TSF used for process water storage.	0	0	0.0									
	Option 3a.5	TSF sub floor material removed to 2 m below composite floor via mechanical removal - crush, screen & pump to Pit 3 (on top of tailings). Then TSF used for process water storage.	1	4	-41.2	4	2	3	1	1	1	2	3	2
	Option 3a.6	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use by co-disposal with mineralised waste rock. Then TSF used for process water storage.	0	6	-23.5	4	2	3	1	2	2	3	2	3
	Option 3a.7	TSF sub floor material removed to 2 m below composite floor via mechanical removal - stockpile - move to south west of Pit 3 as secondary cap wedge deposit. Then TSF used for process water storage.	0	6	-23.5	4	2	3	2	2	2	3	2	2

Initial show stopper	Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Rehabilitation and Closure						Constructability		
			Show stopper column setting			Yes	Yes	Yes	No	No	No	Yes	Yes	No
						0	0	0	0	0	0	0	0	0
Yes	Option 3b.1	TSF sub floor material removed to 20 m below composite floor via mechanical removal - stockpile - move to Pit 3 and use as secondary cap. Then TSF used for process water storage.	0	0	0.0									
Yes	Option 3b.2	TSF sub floor material removed to 20 m below composite floor via mechanical removal - stockpile - partially move to Pit 3 and use as secondary cap with remainder to other onsite storage cell. Then TSF used for process water storage.	0	0	0.0									
	Option 3c.7	TSF sub floor material removed to 4 m below composite floor via mechanical removal - stockpile - move to south west of Pit 3 as secondary cap wedge deposit. Then TSF used for process water storage.	0	6	-29.4	4	2	3	1	2	2	3	2	2
	Option 3d.6	TSF cleaned up then used for process water storage until required for use. TSF sub floor material removed prior to TSF deconstruction to 2 m below composite floor via mechanical removal ** schedule optimised ** Note: **It means to best maintain the closure schedule, thus the subfloor material would be near the surface of Pit 3 backfill.	0	6	-29.4	4	2	3	1	2	1	3	2	3
	Option 3d.7	TSF cleaned up then used for process water storage until required for use. TSF sub floor material removed prior to TSF deconstruction to 2 m below composite floor via mechanical removal ** solute optimised ** Note: **It means to stop work on Pit 3 backfill until the TSF subfloor material is available to put as low in pit as possible. Thus the closure schedule is exceeded by years.	0	6	-29.4	4	2	3	2	2	1	3	2	2

11 BLACKJACK WASTE DISPOSAL

Report: *Best Practicable Technology (BPT) Assessment Blackjack Waste Disposal. Coffey 2018*

July 2018, Coffey Services Pty Ltd (Coffey) facilitated a BPT workshop to assess options for the disposal of hydrocarbon waste generated by the Ranger Mine. As part of uranium ore processing, a hydrocarbon lubricant known as blackjack (gear oil), is injected onto the spindle of the ball mill. The inventory forecasted at closure is approximately 72 kL, which equates to approximately 10 (205 L) waste blackjack drums produced annually. There are potential risks associated with blackjack disposal.

Analysis of drummed waste blackjack concluded that the waste at Ranger is contaminated above exemption levels as set out in the National Directory for Radiation Protection (Welman, 2013). Therefore, the waste blackjack cannot be disposed of off-site at a non-radioactive waste facility. The disposal of blackjack is required to be in line with Rio Tinto and ERA policies and standards, and the Ranger ERs. Another risk includes the possibility of light-non-aqueous phase liquids to separate as free product from the blackjack and potentially leak into groundwater. As part of the BPT assessment, each option submitted for review identified and discussed the potential risks associated with the method proposed.

The BPT assessment considered five options for waste disposal including:

- Tellus ‐ National Geological Repository (A1)
  - Transport the blackjack drums in containers via road trains to the selected geological repository (multi-barrier safety case) located at Sandy Ridge (WA) to permanently isolate the waste from the biosphere. The waste will be pre-treated to immobilise contaminants prior to disposal in a bed of low permeability clay.
- Scholer ‐ Diesel fired waste incinerator (A2)
  - Design, manufacture and supply a two-stage waste oil incinerator for consecutive burning of black jack at the Ranger Mine. Overall, the two-stage incineration system ensures complete combustion, eliminating discharge of any toxic incompletely combusted compounds, including potential and actual carcinogenic combustion by-products.
- CDM Smith – Immobilisation & In-cell disposal of contained blackjack in Pit 3 (A3)
  - A proposal was submitted by CDM Smith based on a concept design to include an underground repository during the backfilling of Pit 3. The blackjack waste in this case would be pre-treated and immobilised, retained in a containment structure and buried in a multi-layered barrier system. With regards to pre-treatment, the blackjack waste will be treated physically (solidification process) and chemically (stabilisation process) then be encapsulated within a purpose-built cell in Pit 3 to provide additional layers of containment.
- In-cell disposal of contained blackjack in Pit 3 (A4)
  - Blackjack waste that is currently stored in metal drums will be placed in a containment structure and backfilled in-between waste rock and tailings in Pit 3. This excludes the pre-treatment process and immobilisation as per the CDM Smith A3 option above.

- National radioactive waste management facility (A5)
    - A national radioactive waste management facility was included as part of the original submissions of options however was removed from further consideration before the scheduled BPT assessment, as the proponents were unable to meet the closing date for submissions.

The BPT Assessment determined rankings for each of the five options (Table 11-1 and the ranking matrices at the end of this section).

Table 11-1: Blackjack disposal options and best practicable technology assessment summary

Option	Option description	Score
A1	Tellus – National Geolgoical Repositories	50.0
A2	Scholer – Waste Oil Incinerator	23.8
A3	CDM Smith – Immobilisation and in-cell disposal into Pit 3	-7.1
A4	In-cell disposal into Pit 3	-2.5
A5	National radioactive waste management facility	0.0

Tellus' National Geological Repository (Option A1) received the highest overall score, with 50 points. The second highest was Scholer's Waste Oil Incinerator, scoring 23.8 points. Tellus' National Geological Repository (Sandy Ridge) has received final approval and licencing to accept low-level radioactive waste and is the adopted option.

						TO Culture & Heritage		Protection of People and the Environment				
			Show stopper column setting			Yes	Yes	Yes	No	Yes	Yes	Yes
Initial show stopper	**Option ID**	**Option Description**	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture	Cultural heritage	Community Health & Safety	Socio-economic Impact on Local Communities	Ecosystems & Natural world heritage values of Kakadu National Park	Ecosystems of the Project Area	Long term protection of the environment (Operations only)
	A1	Tellus - National Geological Repositories	No	No	50.0	3	3	4	NA	3	5	5
	A2	Scholer - Waste Oil Incinerator	No	Yes	23.8	4	2	3	NA	3	3	5
	A3	Immobillsation and In-cell disposal into pit 3	No	Yes	-7.1	4	4	4	NA	4	4	3
	A4	In-cell disposal into pit 3	No	Yes	-2.5	3	4	4	NA	4	4	1
	A5	**National Radioactive Waste Management Facility	Yes		0.0							

						Fit for Purpose			Operational Adequacy	Rehabilitation and Closure			Constructability		
			Show stopper column setting			No	No	Yes	No	Yes	No	No	Yes	Yes	No
Initial show stopper	Option ID	**Option Description**	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Proven technology	Technical performance	Environmental Protection	OPEX	Environmental Acceptability (Operations only)	Cost (Operations only)	Schedule	Construction Occupational Health & Safety	Construction Environmental and Cultural risks	Construction complexity
	A1	Tellus - National Geological Repositories	No	No	50.0	4	3	4	5	5	5	5	NA	4	NA
	A2	Scholer - Waste Oil Incinerator	No	Yes	23.8	4	4	4	3	3	3	5	3	4	3
	A3	Immobillsation and In-cell disposal into pit 3	No	Yes	-7.1	4	2	2	3	1	3	2	2	4	2
	A4	In-cell disposal into pit 3	No	Yes	-2.5	4	2	1	4	1	3	2	2	4	3
	A5	**National Radioactive Waste Management Facility	Yes		0.0										

12 PIT 3 CAPPING

Report: Best Practicable Technology Assessment for Pit 3 Capping Methodologies. Hatch 2021.

A BPT assessment was conducted for the Pit 3 Capping options in October 2021 with a further workshop held with MTC stakeholders in November 2021. The BPT assessment considered seven options, these are summarised in **Table 12-1**.

Table 12-1: Pit 3 capping options summary of methods and assessment results

Option ID	Description	Capping methodology	Geotextile placement technique	Score
A	**Sub-aqueous capping method (base case and current plan)** Based on Golder design and proposals from 3 x vendor execution proposals.	sub-aqueous	sub-aqueous	7
B	**East platform finished with sub-aqueous capping method (Option A)** Build East platform on coarse tailings (old, beached area) to reduce capping area.	sub-aqueous	sub-aqueous	7
C.1	**Sub-aerial (passive dry out) capping method** Approx. 3 year dry out then capped (similar to Pit 1)	sub-aerial	sub-aerial	20
C.2A	**Sub-aerial (accelerated dry out by mechanical assistance) with conventional wicking through bridging layer capping method** Use mechanical assistance to accelerate dry-out, create crust, wick conventionally through initial capping layer and sub-aerially cap	sub-aerial	sub-aerial	9
C.2B	**Sub-aerial (accelerated dry out by mechanical assistance) with no wicking and sub-aerial capping method** Use mechanical assistance to accelerate dry-out, create crust, and sub-aerially cap	sub-aerial	sub-aerial	18
C.2C	**Sub-aerial (accelerated dry out by mechanical assistance) with amphibious wicking through mechanically assisted crust capping method** Use mechanical assistance to accelerate dry-out, create crust, wick amphibiously through crust and sub-aerially cap	sub-aerial	sub-aerial	16
D	**Hybrid + eastern platform** Wicking completed sub-aqueously in Zone 1, 2, & 3 only. Use C.2B method to cap (no wicks) in Zone 4 and perimeter. Use a C.1 method to cap Zone 1,2,3 after wicking.	sub-aerial	sub-aerial	23

The sub-aerial methods scored the highest, with Option D: hybrid eastern platform scoring the highest (20), followed by variants of sub-aerial capping (Options C.1, C.2B and C.2C). It is noted that all options achieved positive scores with no hard showstoppers. The ranking matrices are shown below.

						TO Culture & Heritage		Protection of People and the Environment				Fit for Purpose					Operational / Execution Adequacy			Rehabilitation and Closure						Constructability	
			Show stopper column setting			Yes	Yes	Yes	No	Yes	Yes	No	No	No	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Initial show stopper	Option ID	Option Description	Show stopper 1 Indicator	Show stopper 2 Indicator	Overall rank	Living culture (Closure) {perceived impacts are included in this, as for example leaving foreign	Cultural heritage	Community Health & Safety {Execution phase only, e.g. dust generation, additional traffic, salt dust in dry options}	Socio-economic Impact on Local Communities	Ecosystems & Natural world heritage values of Kakadu National Park	Ecosystems of the Project Area	Proven technology	Technical performance {Technical objective is the effective capping of Pit 3 and the containment of the	Sensitivity to external factors {Previously Robustness} {High rainfall, variable tailings profile/stren	Environmental Protection {The standard of what we are doing compared to what is done at other Uranium	CAPEX {RT standards}	Operability/ Constructability	Inherent availability, maintainability and reliability	OPEX {Will consider INDIRECT costs associated with keeping the closure going longer}	Revegetation	Radiation	Erosion	Water (Closure only) {Water means all other water not considered under tailings}	Tailings	Schedule {To be assessed in relation to other options}	Construction Occupational Health & Safety	Construction complexity
	A	**Sub-Aqueous Capping Method (Base case and current plan)** Based on Golder Design and proposals from 3 x vendor execution proposals	0	1	7	4	4	4	3	4	4	2	3	4	4	2	1	2	4	3	4	3	3	4	3	2	2
	B	**East platform finished with Sub-Aqueous Capping Method** Build East platform on coarse tailings (old beached area) to reduce capping area.	0	1	7	4	4	4	3	4	4	2	3	4	4	2	1	2	4	3	4	3	3	4	3	2	2
	C.1	**Sub-Aerial (passive dry out) Capping Method** Approx 3 year dry out then capped (similar to Pit 1)	0	2	20	3	4	2	4	4	2	4	5	3	4	4	4	4	2	3	4	3	3	4	2	4	3
	C.2A	**Sub-Aerial (accelerated dry out by mechanical assistance) with conventional wicking through bridging layer Capping Method** **Use amphi-roller** or similar to accelerate dry-out, create crust, wick conventionally through bridging layer and Sub-Aerially Cap	0	1	9	3	4	3	4	4	3	3	3	3	4	3	3	4	3	3	4	3	3	4	2	2	2
	C.2C	Sub-Aerial (accelerated dry out by mechanical assistance) with Amphibious wicking through mechanically assisted crust Capping Method Use amphi-roller or similar to accelerate dry-out, create crust, **wick amphibiously** through crust and Sub-Aerially Cap	0	1	18	3	4	3	4	4	3	3	5	3	4	3	4	4	3	3	4	3	3	4	2	2	3
	C.2B	Sub-Aerial (accelerated dry out by mechanical assistance) with **no wicking** and sub-aerial Capping Method Use amphi-roller or similar to accelerate dry-out, create crust, and Sub-Aerially Cap	1	1	16	3	4	3	4	4	3	3	5	3	4	4	4	4	1	3	4	3	3	4	2	2	3
	D	**Hybrid + Eastern Platform** Wicking completed sub-aqueously in Zone 1,2,3 only. (Opp: Optimise area and spacing) Use a C.2.B method to cap (no wicks) in Zone 4 and perimeter. Use a C.1 method to cap Zone 1,2,3 after wicking. Note: Approval to cap given Feb 2023.	0	1	23	3	4	2	4	4	3	4	5	3	4	3	4	4	4	3	4	3	3	4	2	3	3

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APPENDIX 5.1: CONSOLIDATED KKN LIST

ERA Energy Resources Of Australia

CONSOLIDATED LIST OF KEY KNOWLEDGE NEEDS, OWNER AND STATUS

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
Landform					
LAN1A	What are the baseline rates of gully formation for areas surrounding the RPA?	Closed Out	Determine baseline extent, size and rate movement of gullies in undisturbed areas surrounding the mine site.	OSS	Cancelled
LAN1B	What are the baseline rates of sediment transport and deposition in creeks and billabongs?	Open	Assessment of sedimentation risk to on-site and off-site billabongs.	OSS	Completed
			What are the baseline rates of sediment transport and deposition in billabongs?	OSS	Completed
			Mapping and characterisation of geomorphology of on-site creeks in and adjacent to the mine site, including historical change.	OSS	Completed
			Determine the baseline depths of 3 Billabongs downstream of the Ranger mine site using a comparison of standard survey methods and drone based survey.	OSS	Active
LAN2A	What major landscape-scale processes could impact the stability of the rehabilitated landform (e.g. fire, extreme events, climate)?	Closed Out	Extreme natural events and the stability of tailing repositories at Ranger Uranium Mine, NT. Blong, R and Mitchell, P (1996).	ERA	Completed
			Ranger uranium mine closure first pass climate change assessment. BMT (2020).	ERA	Completed
			Evaluation of features, events and processes and safety functions for the Ranger uranium mine. Kozak, M, Sigda, J, Jones, T, Iles, M and Pugh, L (2017).	ERA	Completed
			SSB Paper: Managing for extremes: potential impacts of large geophysical events on Ranger Uranium Mine, N.T. Erskine, WD, Saynor, MJ, Jones, D, Tayler, K and Lowry, J (2012).	OSS	Completed
LAN2B	How will these landscape-scale processes impact the stability of the rehabilitated landform (e.g. mass failure, subsidence)?	Closed Out	Impact of Cyclone Monica on Gulungul Creek catchment, Ranger mine site and Nabarlek area.	OSS	Completed
			Landslips in the upper Magela catchment.	OSS	Completed
LAN3A	What is the optimal landform shape and surface (e.g.	Open	Preliminary flood modelling and hydraulic design.	ERA	Completed
			Rock Size Distribution on Pit 1 final landform.	ERA	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
	riplines, substrate characteristics) that will minimise erosion?		Water, Erosion and Sediment Control Plan.	ERA	Active
			Landform Optimisation work package.	ERA	Active
			Impact of rip lines on runoff and erosion from the Ranger trial landform.	OSS	Completed
LAN3B	Where, when and how much consolidation will occur on the landform?	Closed Out	Pit 1 Tailings consolidation modelling.	ERA	Completed
			Pit 3 Tailings consolidation modelling.	ERA	Completed
LAN3C	How can we optimise the landform evolution model to predict the erosion characteristics of the final landform (e.g. refining parameters, validation using bedload, suspended sediment and erosion measurements, quantification of uncertainty and modelling scenarios)?	Open	Ranger trial landform erosion research.	OSS	Active
			Assessing the geomorphic stability of the Ranger trial landform: calibrating model outputs.	OSS	Completed
			Determining and testing representativeness of long-term rainfall patterns for use in final landform modelling.	OSS	Completed
			Analysis of data from historical unpublished erosion studies in the ARR.	OSS	Completed
			Development of enhanced vegetation component for the CAESAR model.	OSS	Completed
			Calibrating suspended sediment outputs of the CAESAR-Lisflood LEM for application to the rehabilitated Ranger mine – Gulungul Creek scale.	OSS	Completed
			Weathering of Ranger waste rock to inform landform evolution model predictions.	OSS	Completed
			Assessment of the constructed Pit 1 landform using the CAESAR-Lisflood LEM.	OSS	Completed
			An improved method for modelling erosion and gully formation on the Ranger landform.	OSS	Completed
LAN3D	What are the erosion characteristics of the final landform under a range of modelling scenarios (e.g. location, extent, timeframe, groundwater expression and effectiveness of mitigations)?	Open	Assessing the geomorphic stability of the proposed rehabilitated Pit 1 landform.	OSS	Completed
			Model Geomorphic stability of Pit 1 landform.	OSS	Completed
			Model the geomorphic stability of the landform for up to 10,000 years – finalising longterm rainfall datasets and weathering impacts for the landform.	OSS	Completed
			Model geomorphic stability of pre-mine landform for up to 10,000 years.	OSS	Completed
			Assessing the final landform design.	OSS	Active
			Assessing the impact of groundwater discharge on landform stability.	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
			Assessment of the constructed Pit 1 landform using the CAESAR-Lisflood LEM.	OSS	Completed
			An improved method for modelling erosion and gully formation on the Ranger landform.	OSS	Completed
LAN3E	How much suspended sediment will be transported from the rehabilitated site (including land application areas) by surface water?	Closed Out	No open projects.	N/A	N/A
LAN4A	How do we optimise methods to measure gully formation on the rehabilitated landform?	Open	Development of a method for monitoring gully formation on the rehabilitated landform using stereopsis and LiDAR.	OSS	Superseded
LAN4B	What monitoring data are required for ongoing LEM validation?	Removed	N/A	N/A	N/A
LAN5A	How can we use suspended sediment in surface water (or turbidity as a surrogate) as an indicator for erosion on the final landform?	Open	Turbidity & suspended sediment relationships for Gulungul and Magela Creeks.	OSS	Active
Water and Sediment					
WS1A	What contaminants (including nutrients) are present on the rehabilitated site (e.g. contaminated soils, sediments and groundwater; tailings and waste rock)?	Open	TSF Wall Drilling program.	ERA	Completed
			Aquatic sediments (includes ASS) sampling.	ERA	Completed
			Acid sulfate sediments conceptual model.	ERA	Completed
			Soil assessments for LAA.	ERA	Completed
			Non-aquatic contaminated sites sampling.	ERA	Completed
			Processing plant contamination sampling.	ERA	Completed
			TSF floor drilling.	ERA	Completed
			Background COPC in groundwater.	ERA	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
			Stockpile drilling program.	ERA	Completed
			Solute source area/concentration conceptual model update.	ERA	Completed
			Source term updates from Groundwater Modelling Maturity and groundwater concentration maps.	ERA	Active
			Source term updates from Background COPC work package.	ERA	Active
			Source term updates from Surface Water Solute Transfer Model (Stage 4).	ERA	Active
			Incorporation of updates from Contaminated Land 2025 Assessment.	ERA	Active
WS1B	What factors are likely to be present that influence the mobilisation of contaminants from their source(s)?	Closed Out	Literature review on mobilisation of contaminants.	ERA	Completed
WS2A	What is the nature and extent of groundwater movement, now and over the long-term?	Closed out	Update groundwater solute transport modelling and conceptual model.	ERA	Completed
			Post closure solute transport modelling with uncertainty analysis.	ERA	Completed
			Distribution of groundwater sources of Ranger mine contaminants in Magela sands.	OSS	Completed
WS2B	What factors are likely to be present that influence contaminant (including nutrients) transport in the groundwater pathway?	Closed out	Literature review on mobilisation of contaminants.	ERA	Completed
			Mg:Ca input into solute transport models.	ERA	Completed
WS2C	What are predicted contaminant (including nutrients) concentrations in groundwater over time?	Open	Background CoPC in groundwater.	ERA	Completed
			Update groundwater solute transport modelling and conceptual model.	ERA	Completed
			Post closure solute transport modelling with uncertainty analysis.	ERA	Completed
			Source term updates from Groundwater Modelling Maturity and groundwater concentration maps.	ERA	Active
			Source term updates from Background COPC work package.	ERA	Active
			Groundwater Modelling Maturity – Uncertainty analysis.	ERA	Active

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
WS3A	What is the nature and extent of surface water movement, now and over the long-term?	Open	Preliminary surface water modelling.	ERA	Completed
			Surface water groundwater interaction.	ERA	Completed
			Update surface water model.	ERA	Completed
			Surface water solute transfer model.	ERA	Active
			Spectral investigation of Ranger salts.	OSS	Completed
WS3B	What concentrations of contaminants from the rehabilitated site will aquatic (surface and ground-water dependent) ecosystems be exposed to?	Open	Preliminary surface water modelling.	ERA	Completed
			Mg:Ca input into solute transport models.	ERA	Completed
			Update surface water model.	ERA	Completed
			Surface water solute transfer model	ERA	Active
			Monitoring surface water and sediment chemistry of Gulungul & Mudginberri Billabong.	OSS	Completed
WS3C	What factors are likely to be present that influence contaminant (including nutrients) transport in the surface water pathway?	Open	Update surface water model.	ERA	Completed
			Surface water solute transfer model	ERA	Active
WS3D	Where and when does groundwater discharge to surface water?	Open	Surface water groundwater interaction.	ERA	Completed
			Update conceptualisation GW/SW interface.	ERA	Active
			Monitoring surface water and sediment chemistry of Magela Creek pools	OSS	Completed
WS3E	What factors are likely to be present that influence contaminant (including nutrients) transport between groundwater and surface water?	Open	Update groundwater solute transport modelling and conceptual model.	ERA	Completed
			Post closure solute transport modelling with uncertainty analysis.	ERA	Completed
			Preliminary surface water modelling.	ERA	Completed
			Surface water groundwater interaction.	ERA	Completed
			Source term updates from Groundwater Modelling Maturity and groundwater concentration maps	ERA	Active
			Surface water solute transfer model	ERA	Active

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
			Groundwater Modelling Maturity - Uncertainty analysis	ERA	Active
			Update Conceptualisation GW/SW Interface	ERA	Active
WS3F	What are the predicted concentrations of suspended sediment and contaminants (including nutrients) bound to suspended sediments in surface waters over time?	Open	Preliminary surface water modelling.	ERA	Completed
			Optioneering and sensitivity testing for WESCP work package; Denudation rate, work program to determine sediment generated - load to creeks	ERA	Active
			Surface water solute transfer model	ERA	Active
WS3G	To what extent will the interaction of contaminants between sediment and surface water affect their respective qualities?	Closed Out	Predicting uranium accumulation in sediments.	OSS	Completed
WS3H	Where and when will suspended sediments and associated contaminants accumulate downstream?	Open	Optioneering and sensitivity testing for WESCP work package; Denudation rate, work program to determine sediment generated - load to creeks	ERA	Active
			Risk assessment on sediment deposition and bound contaminants	ERA	Active
WS4A	What are the nature and extent of baseline surface water, hyporheic and stygofauna communities, as well as other groundwater dependent ecosystems, and their associated environmental conditions?	Closed Out	Preliminary mapping of groundwater dependent ecosystems (GDEs) on the Ranger lease.	OSS	Completed
			Magela Creek sandbed water quality and subsurface fauna – pilot.	OSS	Completed
			Assess the ecological risks of mine water contaminants in the dry season, subsurface waters of Magela sand channel.	OSS	Completed
			Identification and mapping of groundwater dependent ecosystems (GDEs).	OSS	Completed
			Distribution of groundwater sources of Ranger mine contaminants in Magela sands.	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
WS5A	Will contaminants in sediments result in biological impacts, including the effects of acid sulfate sediments?	Open	Aquatic sediments (includes ASS) sampling.	ERA	Completed
			Acid sulfate sediments conceptual model.	ERA	Completed
			Acid Sulfate Soils Work Program.	ERA	Active
			The toxicity of U to sediment biota of Gulungul Billabong.	OSS	Completed
			Effects of uranium on the structure and function of bacterial sediment communities.	OSS	Completed
			Review of acid sulfate soil knowledge and development of a rehabilitation standard for sulfate.	OSS	Completed
			Impact of acid sulfate soils on aquatic ecosystems.	OSS	Completed
WS5B	What are the factors that influence the bioavailability and toxicity of contaminants in sediment?	Closed Out	Predicting uranium accumulation in sediments.	OSS	Completed
WS5C	What would be the impact of contaminated sediments to surface aquatic ecosystems?	Removed	Predicting uranium accumulation in sediments.	OSS	Completed
WS6A	What is the toxicity of ammonia to local aquatic species, considering varying local conditions (e.g. pH and temperature)?	Closed Out	Toxicity of ammonia to freshwater biota and derivation of a site-specific water quality guideline value.	OSS	Completed
			Toxicity of ammonia and other key contaminants of potential concern to freshwater mussels.	OSS	Completed
			Toxicity of ammonia to local species at a range of pHs.	OSS	Completed
WS6B	Can annual additional load limits (AALL) be used to inform ammonia closure criteria?	Removed	N/A	N/A	N/A
WS6C	What concentrations of nutrients (N and P) in waterbodies will cause eutrophication?	Open	Eutrophication risk study.	ERA	Superseded
			Monitoring surface water and sediment chemistry of Gulungul & Mudginberri Billabong.	OSS	Completed
			Nutrients thresholds defining trophic status of ARR surface waters.	OSS	Completed
			Determining eutrophication risks to Magela Creek through experimental additions of ammonia.	OSS	Active

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
WS7A	Are current guideline values appropriate given the potential for variability in toxicity due to mixtures, modifying factors and different exposure scenarios?	Closed Out	Billabong macroinvertebrates responses to mine-derived solutes.	OSS	Completed
			The effect of dissolved organic matter on the bioavailability and toxicity of metals to tropical freshwater biota (PhD project).	OSS	Completed
			Effects of Mg pulse exposures on tropical freshwater species.	OSS	Completed
			Re-analysis of existing uranium freshwater chronic toxicity data to revise the site-specific and national U trigger values.	OSS	Completed
			Effect of manganese on tropical freshwater species.	OSS	Completed
			The effect of multiple Mg pulses on tropical freshwater species with an emphasis on recovery and carry over toxicity.	OSS	Completed
			Desktop assessment of historical Direct Toxicity Assessment data to evaluate multiple single toxicant water quality limits (including the magnesium Limit).	OSS	Completed
			Assessing the toxicity of mine water mixtures for operational and closure scenarios.	OSS	Completed
			Deriving a candidate Mg guideline value based on a mesocosm study (re-analysis of 2002 PhD data).	OSS	Completed
			Deriving site specific guideline values for copper and zinc.	OSS	Completed
WS7B	What is the risk associated with emerging contaminants?	Open	Background COPC in groundwater.	ERA	Completed
			Source term updates from Background COPC work package.	ERA	Active
			Toxicity of treated process waters from Ranger uranium mine to five local freshwater species.	OSS	Completed
			Hazard and risk assessments for potential / emerging water quality contaminants and toxicity modifying factors.	OSS	Completed
			PFAS in Biota (fishes, reptiles, Eleocharis) downstream of Jabiru and Ranger.	OSS	Active
			Surface water monitoring of PFAS around Ranger mine and Jabiru.	OSS	Completed
			Development of a site-specific guideline value for aluminium.	OSS	Active

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
WS7C	Are current guideline values appropriate to protect the key groups of aquatic organisms that have not been represented in laboratory and field toxicity assessments (e.g. flow-dependent insects, hyporheic biota and stygofauna)?	Closed Out	Seasonal sensitivity (to Mg) profile for macroinvertebrates in the Magela creek channel.	OSS	Completed
WS7D	How do acidification events impact upon, or influence the toxicity of contaminants to, aquatic biota?	Removed		N/A	N/A
WS7E	How will Mg:Ca ratios influence Mg toxicity?	Closed Out	Billabong macroinvertebrates responses to mine-derived solutes.	OSS	Completed
WS7F	Can a contaminant plume in creek channels form a barrier that inhibits organism migration and connectivity (e.g. fish migration, invertebrate drift, gene flow)?	Closed Out	Effects of surface and ground water egress of mining-related solutes on stream ecological connectivity (NESP fish migration).	OSS	Completed
WS7G	What concentrations of contaminants will be detrimental to the health of (non-riparian) aquatic vegetation?	Closed Out	Evaluation of aquatic vegetation data.	OSS	Completed
WS7H	What concentrations of contaminants will be detrimental to the health of riparian vegetation?	Closed Out	Ecohydrology and sensitivity of riparian flora (NESP project).	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
WS8A	What are the physical effects of suspended sediment on aquatic biodiversity, including impacts from sedimentation and variation in sediment characteristics (e.g. particle size and shape)?	Removed		N/A	N/A
WS8B	To what extent does salinity affect suspended particulates, and what are the ecological impacts of this?	Removed		N/A	N/A
WS9A	How do we optimise methods to monitor and assess ecosystem health and surface and groundwater quality?	Open	Developing best practice and guidance documents for environmental omics in Australia.	OSS	Completed
			Developing the capacity to collect water samples from drones.	OSS	Active
			Develop a technique for automating snail egg counts for toxicity testing and monitoring.	OSS	Completed
			Developing videography-based methods for monitoring fish communities in channel billabongs.	OSS	Completed
			Building the metacode database for northern macroinvertebrate species.	OSS	Active
			Developing a short-term chronic toxicity test for the fish, Mogurnda mogurnda.	OSS	Completed
			Developing methods for monitoring fish communities in shallow lowland billabongs.	OSS	Completed
			Use of DGTs for uranium (and other metal) measurement.	OSS	Active
			Assessment of algae populations with new technologies.	OSS	Completed
			Automation of fish identification.	OSS	Completed
			Measuring river discharge from drones.	OSS	Cancelled
			Use of DNA to survey aquatic macroinvertebrate assemblages.	OSS	Active
			Acoustic Backscatter sensors for total suspended sediment monitoring.	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
			Building the DNA database of northern aquatic vertebrate species.	OSS	Completed
			Determining optimum sample volume and primers to detect fish with environmental (e)DNA.	OSS	Active
			Automating fish biomass estimated with stereo-videography and deep learning.	OSS	Completed
			Bioinformatic pipeline development for freshwater macroinvertebrate and soil microbial eDNA amplicon analysis.	OSS	Active
			Developing a method for automated detection of fish schools in channel billabongs.	OSS	Active
			Comparison between videography and eDNA for monitoring fish	OSS	Proposed
			Determining optimal subsample size for DNA extraction of macroinvertebrate samples	OSS	Proposed
Ecosystems					
ESR1A	What are the compositional and structural characteristics of the terrestrial vegetation (including seasonally-inundated savanna) in natural ecosystems adjacent to the mine site, how do they vary spatially and temporally, and what are the factors that contribute to this variation?	Open	Conceptual model of final revegetation reference ecosystem.	ERA	Superseded
			Quantifying spatial and temporal change in savanna.	OSS	Completed
			Assessment of historical vegetation reference site information for use in ecological restoration at Ranger mine site.	OSS	Completed
			Factors affecting spatial and temporal change in savanna.	OSS	Completed
			Vegetation similarity: updated data for conceptual reference ecosystem.	OSS	Completed
ESR1B	Which indicators of similarity should be used to assess revegetation success?	Closed Out	SERA standard and SSB ecosystem restoration standard.	OSS	Completed
			Vegetation similarity closure criteria: development of indicators.	OSS	Completed
ESR1C	What values should be prescribed to each indicator of similarity to demonstrate revegetation success?	Open	Deriving species composition measures and their environmental correlates to assess ecosystem restoration similarity.	OSS	Completed
			Deriving vegetation community structural attributes that inform the conceptual reference ecosystem.	OSS	Completed
			Conceptual Reference Ecosystem and Completion Criteria.	ERA	Superseded
			Ecosystem (flora and fauna) similarity and sustainability completion criteria.	ERA	Superseded

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
ESR2A	What faunal community structure (composition, relative abundance, functional groups) is present in natural ecosystems adjacent to the mine site, and what factors influence variation in these community parameters?	Open	Terrestrial fauna objectives, closure criteria and recolonisation plan.	ERA	Superseded
			Ecosystem (flora and fauna) similarity and sustainability completion criteria.	ERA	Superseded
			Invertebrate assemblages at Ranger Uranium Mine's trial revegetation sites compared with natural reference sites (CDU NESP project).	ERA	Completed
			Recommendations for faunal standards for the rehabilitation of Ranger uranium mine (NESP).	OSS	Completed
			Fauna closure criteria: development of goals.	OSS	Completed
			Fauna closure criteria: development of indicators.	OSS	Completed
			Identifying a current conceptual reference ecosystem for native vertebrate fauna	OSS	Active
ESR2B	What habitat, including enhancements, should be provided on the rehabilitated site to ensure or expedite the colonisation of fauna, including threatened species?	Open	Habitat features that influence the colonisation of fauna on the landform.	OSS	Superseded
			Nest box trials.	ERA	Completed
			Habitat features and potential enhancements for fauna colonisation.	ERA	Superseded
			Ecosystem establishment studies - Habitat Creation and Enhancement Review.	ERA	Active
ESR2C	What is the risk of introduced animals (e.g. cats and dogs) to faunal colonisation and long-term sustainability?	Closed Out	Risk assessment for feral animals impacting faunal colonisation of the landform.	OSS	Superseded
ESR3A	How do we successfully establish terrestrial vegetation, including understory (e.g. seed supply, seed treatment and timing of planting)?	Open	Species Establishment Research Program: Savanna Woodland	ERA	Active
			Species Establishment Research Program: Seasonally-inundated and Riparian	ERA	Active
			Assessment of ecosystem restoration on revegetated zones at Ranger to develop metrics to inform a long-term monitoring plan.	OSS	Superseded

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
ESR4A	What is the incidence and abundance of introduced animals and weeds in areas adjacent to the mine site, and what are the factors that will inform effective management of introduced species on the rehabilitated mine site?	Open	Determining the incidence of declared weeds and other introduced flora in areas of Kakadu National Park adjacent to the Ranger mine.	OSS	Superseded
ESR5A	What are the key sustainability indicators that should be used to measure restoration success?	Open	Conceptual model of final revegetation reference ecosystem.	ERA	Superseded
			Vegetation sustainability closure criteria: development of indicators.	OSS	Completed
			Flowering and fruiting phenology of dominant species in the reference ecosystem at Ranger mine.	OSS	Completed
ESR5B	What are possible/agreed restoration trajectories (flora and fauna) across the Ranger mine site; and which would ensure they will move to a sustainable ecosystem similar to those adjacent to the mine site, including Kakadu National Park?	Open	State and Transition model - Savanna.	ERA	Active
			State and Transition model - Seasonally inundated and other domains.	ERA	Active
			Vertebrate monitoring (including exotics).	ERA	Active
			Transitioning weeds to a desirable understorey using fire.	ERA	Active
			Invertebrate colonisation monitoring and pest management.	ERA	Active
			Review of revegetation outcomes arising from historic mine sites in the Alligator Rivers Region.	OSS	Completed
			Long-term viability of the ecosystem established on the trial landform.	OSS	Completed
			Assessing mine restoration trajectories through studies at Nabarlek.	OSS	Active
			Assessment of ecosystem restoration on revegetated zones at Ranger to develop metrics to inform a long-term monitoring plan.	OSS	Superseded
			Developing restoration trajectories to predict when the restored site will move to a sustainable ecosystem.	OSS	Completed
			Assessment of ecosystem development at Nabarlek mine site.	OSS	Cancelled
			Monitoring and assessment of vegetation and hydrology on the TLF to inform ecosystem restoration trajectories.	OSS	Superseded

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
			Ecosystem restoration trajectories for vertebrate fauna similarity indicators.	OSS	Active
			Ecosystem restoration trajectories of ant similarity indicators.	OSS	Active
			Vegetation trajectory indicator values for ecosystem similarity in the state and transition model.	OSS	Active
			Quantitative approaches to assessing progress towards, and attainment of, closure criteria in savanna ecosystems (TBC).	OSS	Proposed
ESR6A	What concentrations of contaminants from the rehabilitated site may be available for uptake by terrestrial plants?	Open	Updated radiation dose assessment.	ERA	Active
ESR6B	Based on the structure and health of vegetation on the Land Application Areas, what species appear tolerant to the cumulative impacts of contaminants and other stressors over time?	Closed Out		ERA	N/A
ESR7A	What is the potential for chemical, physical and biological processes essential to nutrient cycling to be limiting factors for sustainable ecosystems on the Ranger landform?	Open (revised wording proposed at ARRTC54)	Evaluation of key attributes of nutrient cycling in revegetated waste rock landform of Ranger uranium mine.	ERA	Completed
			Nutrient cycling indicator values for ecosystem sustainability in the state and transition model.	OSS	Active
			Soil Moisture studies work package.	ERA	Cancelled
ESR7B	Will sufficient plant available water be available in the final landform to support a mature vegetation community?	Closed Out	WAVES modelling (Plant available water balance modelling of the waste rock landform).	ERA	Completed
			Soil Moisture studies work package.	ERA	Cancelled
			Plant available water balance modelling of the waste rock landform based on Ranger trial landform (ERA-CDU project 2013-2018).	ERA	Completed
			Study of Root Mass and depth on TLF.	ERA	Completed
			A review of compaction layers in mining landforms and possible implications for Ranger uranium mine.	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
ESR7C	Will ecological processes required for vegetation sustainability (e.g. soil formation) occur on the rehabilitated landform and if not, what are the mitigation responses?	Closed Out	Evaluation of key attributes of nutrient cycling in revegetated waste rock landform of Ranger uranium mine.	ERA	Completed
			Soil formation and nutrient cycling monitoring.	ERA	Superseded
ESR7D	Are there any other properties of the rehabilitated site that could be attributed to any observed impairment of ecosystem establishment and sustainability, including vegetation and key functional groups of soil fauna?	Open	Species Establishment Research Program: Savanna Woodland.	ERA	Active
			Species Establishment Research Program: Seasonally-inundated and Riparian.	ERA	Active
			Waste rock substrate constraints to ecosystem establishment.	ERA	Active
			Evaluation of key attributes of nutrient cycling in revegetated waste rock landform of Ranger uranium mine.	ERA	Completed
ESR8A	What is the most appropriate fire management regime to ensure a fire resilient ecosystem on the rehabilitated site?	Open	Trial landform fire report.	ERA	Completed
			Fire implementation and management plan for the Ranger Final Landform.	ERA	Active
			State and Transition model - Savanna.	ERA	Active
			Collection of data to inform development of the appropriate fire regime for the Ranger rehabilitated site.	OSS	Completed
ESR9A	What parameters and measurements of revegetation and faunal community structure and sustainability on the rehabilitated site (at a range of spatial/temporal scales and relative to the areas surrounding the RPA) are optimised by ground sampling and analytical methods?	Open	Assessment of ecosystem restoration on revegetated zones at Ranger to develop metrics to inform a long-term monitoring plan.	OSS	Superseded
			Develop metrics to confirm vegetation resilience to fire events.	OSS	Superseded
			Nutrient cycling indicator values for ecosystem sustainability in the state and transition model.	OSS	Active
			Flowering and fruiting phenology of dominant species in the reference ecosystem at Ranger mine.	OSS	Completed
			Vegetation trajectory indicator values for ecosystem similarity in the state and transition model.	OSS	Active

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
ESR9B	What parameters of revegetation and faunal community structure and sustainability on the rehabilitated site (at a range of spatial/temporal scales and relative to the areas surrounding the RPA) are optimised by omics methods?	Open	Terrestrial vertebrate faunal surveys using iDNA	OSS	Completed
			Development of an omics-based method for undertaking terrestrial macroinvertebrate fauna surveys	OSS	Active
			Validating soil nutrient cycling assessments with eDNA using multi-omics approach	OSS	Active
ESR9C	What parameters of revegetation and faunal community structure and sustainability on the rehabilitated site (at a range of spatial/temporal scales and relative to the areas surrounding the RPA) are optimised by remote-sensing methods and AI approaches?	Open	Development of a low cost method for continuous monitoring of water stress in eucalypt vegetation on a rehabilitated mine site	OSS	Completed
			Developing monitoring methods for revegetation using RPAS: Jabiluka revegetation	OSS	Completed
			Spectral characterisation of overstorey vegetation species using airborne hyperspectral	OSS	Active
			Guiding ecological restoration at Ranger uranium mine with drone derived indicators of ecosystem health	OSS	Superseded
			Measuring vegetation structure at the landscape scale	OSS	Superseded
			Developing a method to measure and monitor soil microbial communities to assess nutrient cycling	OSS	Active
			Application of AI to identifying vegetation species from drone data: pipeline development	OSS	Completed
			Application of AI to identifying vegetation species from drone data: model development	OSS	Superseded
			Developing whole of site landform and ecosystem monitoring program at-scale	OSS	Cancelled
			Assessment of vegetation establishment using drone imagery	OSS	Active
			Measuring vegetation health using drone and satellite multispectral imagery	OSS	Active
			Measuring vegetation structure at the landscape scale using drone and satellite imagery	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
			Classification of tree taxa/species using AI with hybrid spectral and structural datasets	OSS	Active
			Developing a method to monitor Ranger mine surface salinity and acidity using drone and satellite imagery	OSS	Active
			Developing a method for weed mapping at Ranger mine using drone and satellite imagery	OSS	Active
			Developing a method for landscape-scale measurement of vegetation structural metrics using aerial LiDAR (TBC)	OSS	Proposed
Radiation					
RAD1A	What are the activity concentrations of uranium and actinium series radionuclides in the rehabilitated site, including waste rock, tailings and land application areas?	Open	Updated radiation dose assessment	ERA	Active
			Characterisation of contamination at land application areas at Ranger uranium mine.	OSS	Completed
RAD2A	What are the above-background activity concentrations of uranium and actinium series radionuclides in surface water and sediment?	Open	Non-aquatic contaminated sites sampling.	ERA	Completed
			Background COPC in groundwater.	ERA	Completed
			Update groundwater solute transport modelling and conceptual model.	ERA	Completed
			Preliminary surface water modelling.	ERA	Completed
			Update surface water model.	ERA	Completed
			Incorporation of updates from Contaminated Land 2025 Assessment.	ERA	Active
			Source term updates from Groundwater Modelling Maturity and groundwater concentration maps.	ERA	Active
			Source term updates from Background COPC work package.	ERA	Active
			Source term updates from Surface Water Solute Transfer Model (Stage 4).	ERA	Active
			Radionuclide fluxes from the trial landform.	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
RAD3A	What is the above-background concentration of radon and radon progeny in air from the rehabilitated site?	Closed Out	Atmospheric dispersion modelling of radon and particulate matter (consultant report: SLR 2018).	ERA	Completed
			Radon exhalation from the RUM Trial Landform.	OSS	Completed
			Radon exhalation fluxes expected from final landforms at the rehabilitated Ranger mine.	OSS	Completed
			Atmospheric dispersion of radon and radon daughters from the Ranger rehabilitated landform.	OSS	Completed
			Radon exhalation from waste rock on the Ranger trial landform.	OSS	Completed
RAD3B	If an assessment using conservative values shows a potential issue with meeting closure criteria (3A and 7A): What is the equilibrium factor between radon progeny and radon in air?	Removed	N/A	N/A	N/A
RAD3C	If an assessment using conservative values shows a potential issue with meeting closure criteria (3A and 7A): What is the unattached fraction of radon progeny in air?	Removed	N/A	N/A	N/A
RAD4A	If an assessment using conservative values shows a potential issue with meeting closure criteria (4B and 7A): What is the resuspension factor (or emission rate) of dust emitted from the final landform?	Removed	N/A	N/A	N/A
RAD4B	What is the above-background activity concentration in air of long-lived alpha-emitting radionuclides in dust emitted from the final landform?	Closed Out	Modelling the atmospheric dispersion of radionuclides in dust from the Ranger final landform.	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
RAD4C	If an assessment using conservative values shows a potential issue with meeting closure criteria (4B and 7A): What is the activity median aerodynamic diameter of long-lived alpha-emitting radionuclides in dust emitted from the final landform?	Removed	N/A	N/A	N/A
RAD5A	What are the concentration ratios of actinium-227 and protactinium-231 in bush foods?	Closed Out	Environmental fate and transport of Ac-227 and Pa-231.	OSS	Completed
RAD6A	What are the representative organism groups that should be used in wildlife dose assessments for the rehabilitated site?	Closed Out	Ranger 3 Deeps draft EIS.	ERA	Completed
			Dose rates to non-human biota.	OSS	Completed
RAD6B	What are the whole-organism concentration ratios of uranium and actinium series radionuclides in wildlife represented by the representative organism groups?	Open	Dose rates to non-human biota.	OSS	Completed
			Radionuclide uptake in small proliferators.	OSS	Completed
			Radionuclide uptake in understorey vegetation.	OSS	Completed
			Radionuclide uptake in terrestrial invertebrates.	OSS	Active
			Environmental radiation exposure of non-human biota from uranium mine rehabilitation.	OSS	Proposed
RAD6C	What are the tissue to whole organism conversion factors for uranium and actinium series radionuclides for wildlife represented by the representative organism groups?	Closed out	Dose rates to non-human biota.	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
RAD6D	What are the dose-effect relationships for wildlife represented by the representative organism groups?	Removed	Radiation dose-effect relationships for non-human biota.	OSS	Cancelled
RAD6E	What is the sensitivity of model parameters on the assessed radiation doses to wildlife?	Open	Radiological Impact Assessment.	ERA	Active
			Updated radiation dose assessment	ERA	Active
RAD7A	What is the above-background radiation dose to the public from all exposure pathways traceable to the rehabilitated site?	Open	Radiological Impact Assessment.	ERA	Active
			Radionuclide uptake in traditional Aboriginal foods.	OSS	Completed
			Pre-mining radiological analogue for Ranger.	OSS	Completed
			Gamma radiation dose rates to the public from the Ranger final landform.	OSS	Completed
RAD7B	What is the sensitivity of model parameters on the assessed doses to the public?	Open	Radiological Impact Assessment.	ERA	Active
RAD8A	Will contaminant concentrations in surface water (including creeks, billabongs and seeps) pose a risk of chronic or acute impacts to terrestrial wildlife?	Open	Maturity and application of Vulnerability Assessment Framework.	ERA	Active
			Assessing whether contaminants in surface water pose a risk of chronic or acute impacts to terrestrial wildlife.	OSS	Cancelled
RAD9A	What are the contaminants of potential concern to human health from the rehabilitated site?	Closed Out	Aquatic sediments (includes ASS) sampling.	ERA	Completed
			Soil assessments for LAA.	ERA	Completed
			Non-aquatic contaminated sites sampling.	ERA	Completed
			Background COPC in groundwater.	ERA	Completed
RAD9B	What are the concentration factors for contaminants in bush foods?	Open	Deriving site-specific concentration factors for metals in bush foods to inform human health risk assessments for the Ranger final landform.	OSS	Completed
			Environmental and Human Health Impact Work Package - Bushfoods Study	ERA	Active

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
RAD9C	What are the concentrations of contaminants in drinking water sources?	Open	Preliminary surface water modelling.	ERA	Completed
			Update surface water model.	ERA	Completed
			Surface water solute transfer model	ERA	Active
RAD9D	What is the dietary exposure of, and toxicity risk to, a member of the public associated with all contaminant sources, and is this within relevant Australian and/or international guidelines?	Open	Surface water pathway risk assessments (release pathways onsite).	ERA	Active
			Environmental and Human Health Impact Work Package – Bushfoods Study.	ERA	Active
RAD10A	How do we optimise methods to monitor and assess radionuclides?	Open	Development of a model for radium-226 uptake in *Velesunio angasi* (freshwater mussel).	OSS	Completed
			Quantifying radon retention characteristics of ERISS acrylic gamma spectroscopy containers.	OSS	Completed
			Developing drone remote sensing techniques for characterising radioactivity levels on the rehabilitated landform.	OSS	Active
Cross Theme					
CT1A	What are the cumulative risks to the success of rehabilitation on-site and to the off-site environment?	Open	Pollino, CA, Cuddy, SM & Gallant, S 2013. Ranger rehabilitation and closure risk assessment: problem formation. Canberra: CSIRO.	ERA	Completed
			Pollino, CA 2014. Ranger rehabilitation and closure risk assessment: Risk screening. Canberra Australia: CSIRO Land and Water Flagship.	ERA	Completed
			An ecological risk assessment of the major weeds on the Magela Creek Floodplain, Kakadu National Park.	OSS	Completed
			Ranger rehabilitation & closure ecological risk assessment: phase 1, problem formulation.	OSS	Completed
			Ranger rehabilitation & closure ecological risk assessment: phase 2, risk analysis.	OSS	Completed
			Cumulative risk assessment for Ranger minesite rehabilitation and closure – Phase 1 (on-site risks).	OSS	Completed

KKN ID	KKN Question	KKN Status	Project Title	Project Owner	Project Status
			Cumulative risk assessment for Ranger mine site rehabilitation and closure – phase 2 (aquatic pathways).	OSS	Completed
			Cumulative risk assessment for Ranger mine site rehabilitation and closure – periodic review and update (2024).	OSS	Superseded
			Cumulative risk assessment for Ranger mine site rehabilitation and closure – periodic review and update (2026).	OSS	Superseded
			Vulnerability Assessment Framework.	ERA	Completed
			Ranger Rehabilitation and Closure Risk Assessment: Problem Formulation.	ERA	Completed
			Ranger Rehabilitation and Closure Risk Assessment: Risk Screening.	ERA	Completed
			Maturity and application of Vulnerability Assessment Framework	ERA	Active
CT2A	What World Heritage Values are found on the Ranger Project Area, and how might these influence the incorporation of the site into Kakadu National Park and World Heritage Area?	Closed Out	ERA cultural heritage management system & GIS.	ERA	Completed
			Closure criteria development – cultural.	ERA	Cancelled
			Cataloguing the natural World Heritage values on the Ranger Project Area.	OSS	Completed

APPENDIX 5.2: CONSOLIDATED LIST OF PREVENTATIVE CONTROLS

CONSOLIDATED LIST OF PREVENTATIVE CONTROLS

Unique Identifier	Description of Preventative Control	Current Effectiveness (2025)	Active or K/A[1] type of control
C1	Final landform design, construction and verification.	Marginal – Satisfactory	A
C2	Erosion control measures including preparation of final landform surface.	Marginal	A
C3	Sediment control measures including sediment basins.	Marginal – Satisfactory	A
C4	Drainage control structures including sinuous armoured drainage channels.	Marginal	A
C5	Revegetation of the final landform surface.	Marginal – Satisfactory	A
C6	Understanding final tailings elevations.	Satisfactory	K/A
C7	All tailings deposited into Pits 1 and 3.	Marginal – Strong	A
C8	Tailings buried below predicted depth of gully formation.	Satisfactory	A
C9	Legal instruments.	Weak	K/A
C10	Low grade material (2s and 3s) buried below vadose zone in Pits 1 and 3.	Satisfactory – Strong	A
C11	Pump and treat from Pits 1 and 3 until agreed criteria met or demonstrated that can be met.	Marginal – Strong	A
C12	Brine injected into Pit 3 underfill.	Marginal – Satisfactory	A
C13	No water released from mine site unless it meets defined criteria and sufficient creek flow.	Satisfactory – Strong	A
C14	Understanding source terms, groundwater loads, surface water concentrations.	Satisfactory	K/A
C15	Understanding solute transport pathways, interactions and contaminant behaviour over time.	Satisfactory	K/A
C16	Refuelling and maintenance areas are appropriately bunded.	Strong	A
C17	Clay cap over RWD floor.	Satisfactory – Strong	A
C18	Retain clay core around RWD floor.	Satisfactory – Strong	A
C19	RWD and western stockpile interception trench.	Marginal – Satisfactory	A
C20	Use of approved pesticides as per instruction.	Satisfactory	A
C21	Fertiliser use based on identified nutrient need of plants.	Satisfactory – Strong	A
C22	Containment cell for PFAS.	Satisfactory – Strong	A
C23	Excavate and dispose contaminated soil/sediments into Pit 3 and RP2.	Marginal – Strong	A
C24	Detailed understanding of soil contamination levels and location.	Satisfactory	K/A
C25	Validation sampling.	Satisfactory	K/A
C26	In situ treatment of mildly contaminated, or culturally sensitive, sites.	Marginal	A
C27	Tilling.	Satisfactory	A
C28	Post-closure monitoring.	Marginal	K/A

Unique Identifier	Description of Preventative Control	Current Effectiveness (2025)	Active or K/A[1] type of control
C29	Development of appropriate vegetation CRE.	Satisfactory	K/A
C30	Weed management in non-waste rock areas within RPA.	Satisfactory	A
C31	Weed management on waste rock rehabilitation areas.	Marginal	A
C32	Application of pre-emergent herbicide.	Strong	A
C33	Implementation of suitable ecosystem establishment strategy including appropriate species mix.	Satisfactory	A
C34	Provision of suitable irrigation.	Satisfactory	A
C35	Fire management in non-waste rock areas within RPA.	Strong	A
C36	Management of introduced fauna.	Satisfactory	A
C37	Targeted pest and disease management.	Satisfactory	A
C38	Addition of organic material from surrounds.	Marginal	A
C39	Appropriate introduction of fire to rehabilitation areas.	Satisfactory	A
C40	Development of appropriate fauna reference ecosystem.	Satisfactory	K/A
C41	Installation of appropriate habitat.	Satisfactory	A
C42	Understanding radiation emissions, exposure pathways, radionuclide concentrations and doses.	Satisfactory	K/A
C43	Understanding Traditional Owner post-closure occupancy on the RPA, dietary intake and bioaccumulation in bush foods.	Satisfactory	K//A
C44	Maintain tailings in near saturated state, and active dust control prior to capping tailings and during movement of higher grade material.	Satisfactory	A
C45	Final landform designed and constructed to meet Traditional Owner requirements.	Marginal – Satisfactory	A
C46	All sediment basins will be removed and rehabilitated.	Satisfactory	A
C47	Line of site assessment for cultural landscape features undertaken and incorporated into final landform design and execution.	Strong	K/A
C48	Management of the rehabilitated landform for weeds, exotic fauna, fire, pests and natural disturbances.	Satisfactory	A
C49	Clean-up of all existing infrastructure and rubbish.	Satisfactory	A
C50	Collaborate with Traditional Owners to understand acceptance of proposed works and outcomes.	Marginal	K/A
C51	Implement Cultural Heritage Management System.	Marginal	K/A
C52	Administrative weed education, awareness and hygiene programs.	Satisfactory	K/A

[1] - K/A = Knowledge-based / Administrative Control.

APPENDIX 5.3: CONSOLIDATED LIST OF CORRECTIVE ACTIONS

CONSOLIDATED LIST OF CORRECTIVE ACTIONS

Unique Identifier	Description of Corrective Action	Current Effectiveness (2025)	Active or K/A[1]
A1	Maintenance of erosion and sediment control measures.	Satisfactory	A
A2	Undertaking earthworks to repair significant substrate limitations, gullying or eroded areas and rectification of constructed landform.	Satisfactory	A
A3	Extension of landform monitoring and maintenance phase.	Marginal	K/A
A4	Restricting access to any exposed tailings.	Marginal	A
A5	Removing any contaminated or impacted material (e.g. water and sediment Impacted by exposed tailings).	Weak – Marginal	A
A6	Conducting health monitoring.	Satisfactory	K/A
A7	Increasing the frequency of field inspections for erosion and gully formation.	Satisfactory	K/A
A8	Planned duration of pump and treat extended to further reduce peak contaminant loads.	Satisfactory	A
A9	Additional remediation (as agreed with key stakeholders) of billabongs (e.g. sediment removal, lime treatment) if sediments do not achieve target levels.	Marginal – Satisfactory	A
A10	Short-term restrictions to land access and cultural activities.	Marginal – Satisfactory	A
A11	Infill planting and seeding to maintain suitable vegetative cover on final landform.	Satisfactory – Strong	A
A12	Additional interception system (e.g. passive reactive barrier).	Marginal	A
A13	Discontinue use/change pesticide.	Satisfactory – Strong	A
A14	Discontinue use/change fertiliser.	Strong	A
A15	Use of approved flocculant / coagulant.	Satisfactory	A
A16	Contaminated soils detected after the validation sampling will be excavated and disposed below the 2s cap in Pit 3 or into RP2.	Strong	A
A17	Tilled soils on the Magela LAA that do not reach target levels will be disposed to RP2 (or Pit 3 depending on timing) and the area will be replanted.	Strong	A
A18	Targeted weed management.	Marginal – Satisfactory	A
A19	Targeted introduced fauna management.	Satisfactory	A
A20	Addition of organic material/s and or fertiliser beyond that planned.	Marginal	A
A21	Targeted pest and disease management.	Marginal	A
A22	Supplementation of habitat features and/or migration corridors.	Marginal	A
A23	Remediation (as required) of surface radiation following construction and rehabilitation of final landform.	Satisfactory	A

Unique Identifier	Description of Corrective Action	Current Effectiveness (2025)	Active or K/A[1]
A24	Increased monitoring of radiological contaminants in impacted environments and biota.	Marginal	K/A
A25	Reshape landform.	Satisfactory	A
A26	Modified fire management.	Marginal – Satisfactory	A
A27	Remediation of surface sediment or salt deposition.	Marginal	A
A28	Early notification and consultation with Traditional Owners and implementation of agreed mitigation.	Satisfactory	K/A
A29	Initial response to prevent further damage.	Satisfactory	K/A

[1] – K/A = Knowledge-based / Administrative Corrective Action.

APPENDIX 7.1: PREDICTED PEAK COPC CONCENTRATIONS AT MG009

Table 3.3 Predicted peak CoPC concentrations (P10, P50, P90) compared to the most stringent GVs for MG009 (legend on next page)

	COPC	Mg	Ca	NO_3-N	Mn	U	NH_3-N	Cu	Pb	Cd	Fe	Zn	Cr	V	Ni	^{226}Ra > bgd	Al	Se	SO_4	Mg:Ca	Increase above No Mine scanrio (%)			
Most stringent GV for each COPC	Species protection 99% or undefined %* (µg/L)	2900	NA. See Mg:Ca column	640	73	2.8	400	0.5	1	0.06	NA	1.5	3.3* (Cr^{3+})	6*	8	NA	0.8* pH<6.5 Back-ground > GV so compare medians	5	NA	9	Cr	V	Ni	Al
	Other (^{226}Ra mBq/L; others µg/L)										300 Drinking water (aesthetic)					14 mBq/L > bgd (aquatic biota)			10000 seasonal av. (acid sulfate soils)		No GV			
Predicted peak concentrations for COMPOSITE_P10 scenario at MG009																								
Exccedance probability	1%	2060	700	200	185	0.8	73	0.3	0.1	0.01	140	0.6	0.14	0.77	0.33	0.6	106	0.1	6130	3				
	10%	1890	680	5.6	163	0.7	64	0.3	0.1	0.01	120	0.6	0.13	0.68	0.30	0.2	94	0.1	5130	3				
	25%	1760	660	5.0	157	0.7	63	0.3	0.1	0.01	110	0.6	0.13	0.51	0.30	0.3	72	0.1	4720	3				
	50%	1010	550	4.1	78	0.3	32	0.2	0.0	0.01	90	0.5	0.11	0.24	0.21	0.3	38	0.1	2580	2	12	3	38	1
	75%	650	290	3.3	18	0.1	10	0.2	0.0	0.01	80	0.4	0.10	0.10	0.14	0.3	8.7	0.1	806	2				
	90%	350	200	3.0	12	0.0	7	0.2	0.0	0.01	50	0.4	0.10	0.07	0.13	-0.1	6.0	0.1	288	1				
	99%	230	160	3.0	7	0.0	5	0.1	0.0	0.01	30	0.4	0.10	0.07	0.13	-0.1	6.0	0.0999	201	1				
Predicted peak concentrations for PIT 3 ONLY_P10 scenario at MG009																								
Exccedance probability	1%	1330	590	200	141	0.3	54	0.336	0.1	0.01	120	0.5	0.13	0.77	0.30	0.0	106	0.1	3320	2				
	10%	1290	590	3.2	125	0.2	48	0.3	0.1	0.01	110	0.5	0.12	0.67	0.28	0.0	93	0.1	2720	2				
	25%	1280	590	3.0	119	0.2	47	0.3	0.1	0.01	100	0.5	0.12	0.50	0.27	0.0	71	0.1	2480	2				
	50%	790	540	3.0	58	0.1	24	0.2	0.0	0.01	80	0.4	0.11	0.24	0.19	0.0	38	0.1	1380	2	9	1	33	1
	75%	490	270	3.0	13	0.0	7	0.2	0.0	0.01	60	0.4	0.10	0.09	0.14	-0.1	8.3	0.1	546	1				
	90%	300	190	3.0	5	0.0	5	0.2	0.0	0.01	40	0.4	0.10	0.07	0.13	-0.1	6.0	0.0999	50	1				
	99%	220	160	3.0	4	0.0	5	0.1	0.0	0.01	30	0.4	0.10	0.07	0.13	-0.2	6.0	0.0997	49.9	1				
Predicted peak concentrations for COMPOSITE_P50 scenario at MG009																								
Exccedance probability	1%	2690	780	200	304	1.1	109	0.4	0.3	0.01	180	0.8	0.17	0.78	0.61	1.7	107	0.1	9040	4				
	10%	2420	750	8.2	268	1.0	96	0.3	0.2	0.01	140	0.8	0.16	0.69	0.55	0.9	95	0.1	7600	3				
	25%	2240	720	7.1	249	1.0	93	0.3	0.2	0.01	130	0.7	0.16	0.52	0.52	0.8	73	0.1	6940	3				
	50%	1250	560	5.1	127	0.5	46	0.3	0.1	0.01	110	0.6	0.13	0.26	0.32	0.6	39	0.1	3730	3	23	9	60	5
	75%	770	310	3.5	26	0.1	13	0.2	0.0	0.01	90	0.4	0.11	0.13	0.16	0.5	12	0.1	906	2				
	90%	390	210	3.0	17	0.0	9	0.2	0.0	0.01	50	0.4	0.10	0.07	0.15	-0.1	6.1	0.1	366	2				
	99%	230	170	3.0	9	0.0	5	0.1	0.0	0.01	40	0.4	0.10	0.07	0.13	-0.1	6.0	0.0999	253	1				
Predicted peak concentrations for PIT 3 ONLY_P50 scenario at MG009																								
Exccedance probability	1%	1550	600	200	198	0.5	75	0.4	0.2	0.01	120	0.6	0.15	0.78	0.43	0.0	107	0.1	4440	3				
	10%	1500	600	3.25	176	0.4	67	0.3	0.2	0.01	110	0.6	0.14	0.68	0.39	0.0	95	0.1	3750	3				
	25%	1470	600	3.03	168	0.4	64	0.3	0.2	0.01	100	0.6	0.14	0.51	0.38	0.0	72	0.1	3510	2				
	50%	800	540	3.02	80	0.2	32	0.3	0.1	0.01	80	0.5	0.12	0.25	0.24	0.0	39	0.1	1830	2	15	4	47	3
	75%	540	270	3	14	0.0	7	0.2	0.0	0.01	60	0.4	0.10	0.11	0.14	0.0	11	0.1	622	1				
	90%	310	200	3	5	0.0	5	0.2	0.0	0.01	50	0.4	0.10	0.07	0.13	-0.1	6.0	0.1	50	1				
	99%	220	160	3	4	0.0	5	0.1	0.0	0.01	30	0.4	0.10	0.07	0.13	-0.1	6.0	0.1	50	1				

Table 3.3 continued

	COPC	Mg	Ca	NO_3-N	Mn	U	NH_3-N	Cu	Pb	Cd	Fe	Zn	Cr	V	Ni	^{226}Ra > bgd	Al	Se	SO_4	Mg:Ca	Increase above No Mine scanrio (%)			
Most stringent GV for each COPC	Species protection 99% or undefined %* (µg/L)	2900	NA. See Mg:Ca column	640	73	2.8	400	0.5	1	0.06	NA	1.5	3.3* (Cr^{3+})	6*	8	NA	0.8* pH<6.5 Back-ground > GV so compare medians	5	NA	9	Cr	V	Ni	Al
	Other (^{226}Ra mBq/L; others µg/L)										300 Drinking water (aesthetic)					14 mBq/L > bgd (aquatic biota)			10000 seasonal av. (acid sulfate soils)		No GV			
Predicted peak concentrations for COMPOSITE_P90 scenario at MG009																								
Excedance probability	1%	3000	820	200	403	1.7	140	0.4	0.6	0.01	200	1.1	0.21	0.81	0.88	2.9	112	0.1	11500	4				
	10%	2720	780	12.9	352	1.5	123	0.4	0.5	0.01	160	1.0	0.20	0.71	0.78	1.7	98	0.1	9690	4				
	25%	2530	750	10.8	326	1.5	120	0.3	0.4	0.01	140	0.9	0.19	0.53	0.72	1.4	76	0.1	8850	3				
	50%	1380	560	6.83	165	0.7	58	0.3	0.2	0.01	120	0.7	0.15	0.27	0.43	0.9	42	0.1	4670	3	31	14	70	11
	75%	790	320	3.86	28	0.1	13	0.3	0.0	0.01	100	0.4	0.11	0.16	0.17	0.6	18	0.1	996	2				
	90%	400	210	3.01	15	0.0	9	0.2	0.0	0.01	60	0.4	0.10	0.07	0.14	0.0	6.0	0.1	325	2				
	99%	230	170	3	10	0.0	5	0.1	0.0	0.01	40	0.4	0.10	0.07	0.13	-0.1	6.0	0.1	230	1				
Predicted peak concentrations for PIT 3 ONLY_P90 scenario at MG009																								
Excedance probability	1%	1860	620	200	283	1.0	105	0.4	0.3	0.01	120	0.8	0.18	0.79	0.63	0.0	110	0.1	6030	3				
	10%	1770	620	3.27	250	0.8	94	0.4	0.3	0.01	110	0.7	0.17	0.70	0.58	0.0	97	0.1	5210	3				
	25%	1740	610	3.07	240	0.8	90	0.3	0.3	0.01	100	0.7	0.16	0.52	0.56	0.0	75	0.1	4920	3				
	50%	920	540	3.05	112	0.4	44	0.3	0.1	0.01	80	0.5	0.13	0.26	0.32	0.0	41	0.1	2460	2	23	9	60	9
	75%	610	280	3	16	0.1	8	0.3	0.0	0.01	60	0.4	0.10	0.14	0.15	0.0	17	0.1	700	2				
	90%	320	200	3	5	0.0	5	0.2	0.0	0.01	50	0.4	0.10	0.07	0.13	0.0	6.0	0.1	50	1				
	99%	220	160	3	4	0.0	5	0.1	0.0	0.01	30	0.4	0.10	0.07	0.13	0.0	6.0	0.1	50	1				
Predicted peak concentrations for NO MINE scenario at MG009																					Legend			
Excedance probability	1%	810	560	194	14	0.0	6	0.3	0.0	0.01	120	0.4	0.10	0.77	0.13	-	105	0.1	893	1	Above GV			
	10%	810	560	6.8	12	0.0	5	0.3	0.0	0.01	110	0.4	0.10	0.68	0.13	-	95	0.1	763	1				
	25%	800	560	3.0	7	0.0	5	0.3	0.0	0.01	100	0.4	0.10	0.49	0.13	-	70	0.1	458	1	No mine scenario above GV			
	50%	630	440	3.0	5	0.0	5	0.2	0.0	0.01	80	0.4	0.10	0.24	0.13	-	38	0.1	69	1				
	75%	370	270	3.0	5	0.0	5	0.2	0.0	0.01	60	0.4	0.10	0.07	0.13	-	11	0.1	50	1				
	90%	270	200	3.0	5	0.0	5	0.2	0.0	0.01	50	0.4	0.10	0.07	0.13	-	6.2	0.1	50	1	Below GV			
	99%	220	160	3.0	4	0.0	5	0.2	0.0	0.01	40	0.4	0.10	0.07	0.13	-	6.0	0.1	50	1				

APPENDIX 9.1: ECOSYSTEM ESTABLISHMENT STRATEGY

Ecosystem Establishment Strategy 2025

Ranger Mine Closure Plan 2025

Unique Reference: PLN007
Revision: 0.25.1

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1 ECOSYSTEM ESTABLISHMENT STRATEGY

The sections below summarise key aspects of the current ecosystem establishment strategy on the final landform, based on a range of research trials, as outlined in the Ranger Mine Closure Plan.

The Ranger Project Team continues to partner with Kakadu Native Plant Supplies Pty Ltd (KNPS), a local Indigenous business owned and managed by Dr Peter Christophersen. KNPS specialise in cultural-led land management and have a deep understanding of local ecology and environmental conditions. KNPS have been engaged to undertake land management activities (e.g. weed and fire management) on the RPA and the adjacent Jabiluka mining lease since 2005, extending to seed collection, tubestock propagation, planting and irrigation management. KNPS also regularly provides advice on ecosystem establishment and assists with stakeholder consultations.

In collaboration with KNPS, the Ranger Project Team have developed a Species Establishment Research Program (SERP) database. The SERP is vital to the revegetation strategy and includes information on:

- seed management – including species phenology and seed collection, storage longevity, viability and germinability;
- propagation – including seed treatments, inoculation, nursery germination rates, plant growth, seasonality of propagation and alternative propagation methods; and
- establishment methods – including relevant substrates, initial tubestock planting, direct seeding, secondary introduction, natural colonisation, persistence, expected growth and development at key stages, flowering, fruiting and recruitment.

A comprehensive research project on local flora seed biology by Bellairs and McDowell (2012) provided a foundation for the SERP, which has been continuously updated with available information from published literature, ongoing revegetation trials and traditional knowledge.

The current ecosystem establishment strategy is largely based on SERP data.

1.1 Construction of the Final Landform Growth Substrate

Waste rock backfill

The surface layer of the waste rock landform is required to support the establishment of proposed vegetation communities, of which the Savanna Woodland Conceptual Reference Ecosystem (CRE) is most widespread. This CRE is characterised by a dominant overstorey of larger *Eucalyptus* trees.

An understanding of root structure in natural areas is important and has influenced waste rock backfill methodology (Figure 1). In natural systems, Hutley (2008) describes a duricrust (hard-pan) soil horizon at approximately 1–2 m depth. The bulk of tree roots occupy the upper 0.5–1 m (Werner and Murphy, 2001; Humphrey *et al.* 2009) above the duricrust layer, accessing nutrients and favouring maximum growth during the wet season (Hutley, 2008). Tap roots extend down to 5 m or 6 m below the surface, enabling access to water over the prolonged dry season (Hutley *et al.,* 2000).

Figure 2 shows approximate waste rock thickness across the final landform, above natural ground, or deeper buried waste material as is the case with backfilled pits. To facilitate plant root development, for areas of the waste rock landform with a depth of waste rock exceeding 3 m (i.e. not overlying natural ground), a 'vegetation growth layer' will be constructed. Like the methodology used in the construction of the Trial Landform (TLF) (Daws and Poole, 2010) and Pit 1, the vegetation growth layer will be constructed in two relatively thick layers, with a combined thickness of at least 6 m, using techniques known as tip-head and paddock dumping.

As illustrated in Figure 1, tip-head dumping (and compaction by heavy traffic) will be used for the lower of the two layers, to achieve a consolidated boundary layer, which mitigates potential macropores, blocks preferential flow paths, slows water percolation and improves water-holding capacity in the upper profile. Paddock dumping will be used for the upper (surface) layer and contoured in alignment with the final landform design, with an acceptable construction tolerance in the order of +/- 1 m.

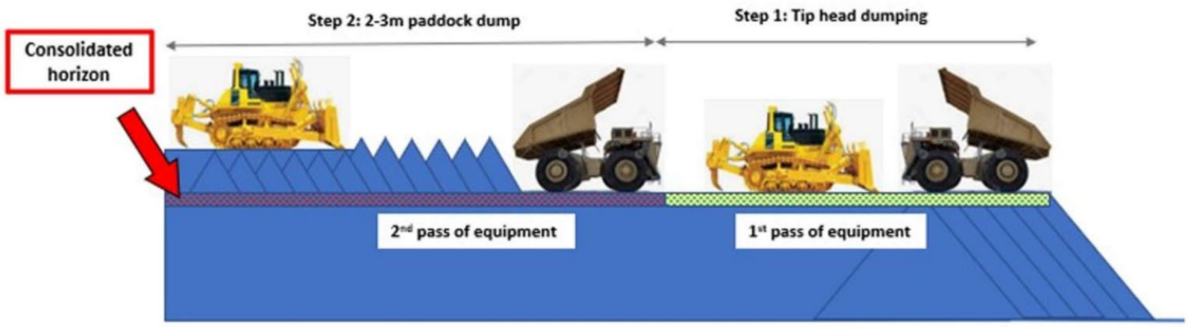

Figure 1: Construction method for final landform vegetation growth layer

Following construction of Pit 1 (completed in 2020) and initial planting, differential settlement of waste rock and the consolidation of tailings have contributed to localised depressions and variations across the Pit 1 surface, which was expected. During a visit in March 2023, Traditional Owners indicated that the areas of subsidence on Pit 1 are not a major concern at their current size and depth, and suggested certain flora species that may perform better in such conditions. It was noted however that large areas of subsidence across the landform would not be desirable. During another visit held in September 2023, there was further consultation with Traditional Owners around the acceptability of potential co-occurrence of *Melaleuca viridiflora* and *Eucalyptus sp.* on the final landform in some areas, including a visit to a representative naturally occurring ecotonal community in adjacent areas on the RPA. Species composition for several potentially relevant ecotonal reference sites is presented in Supervising Scientist (2025a).

The final landform surface, including the development of localised depressions and variations at Pit 1 and other areas, will be monitored. These features will inform the composition of any required infill planting, which may be more appropriately aligned with seasonally inundated savanna communities.

During construction of the final landform, careful planning, guidance material, and supervision will ensure that the constructed vegetation growth layer and substrate material is appropriate.

Relevant considerations and constraints are described below, as well as a description of planned additional investigations.

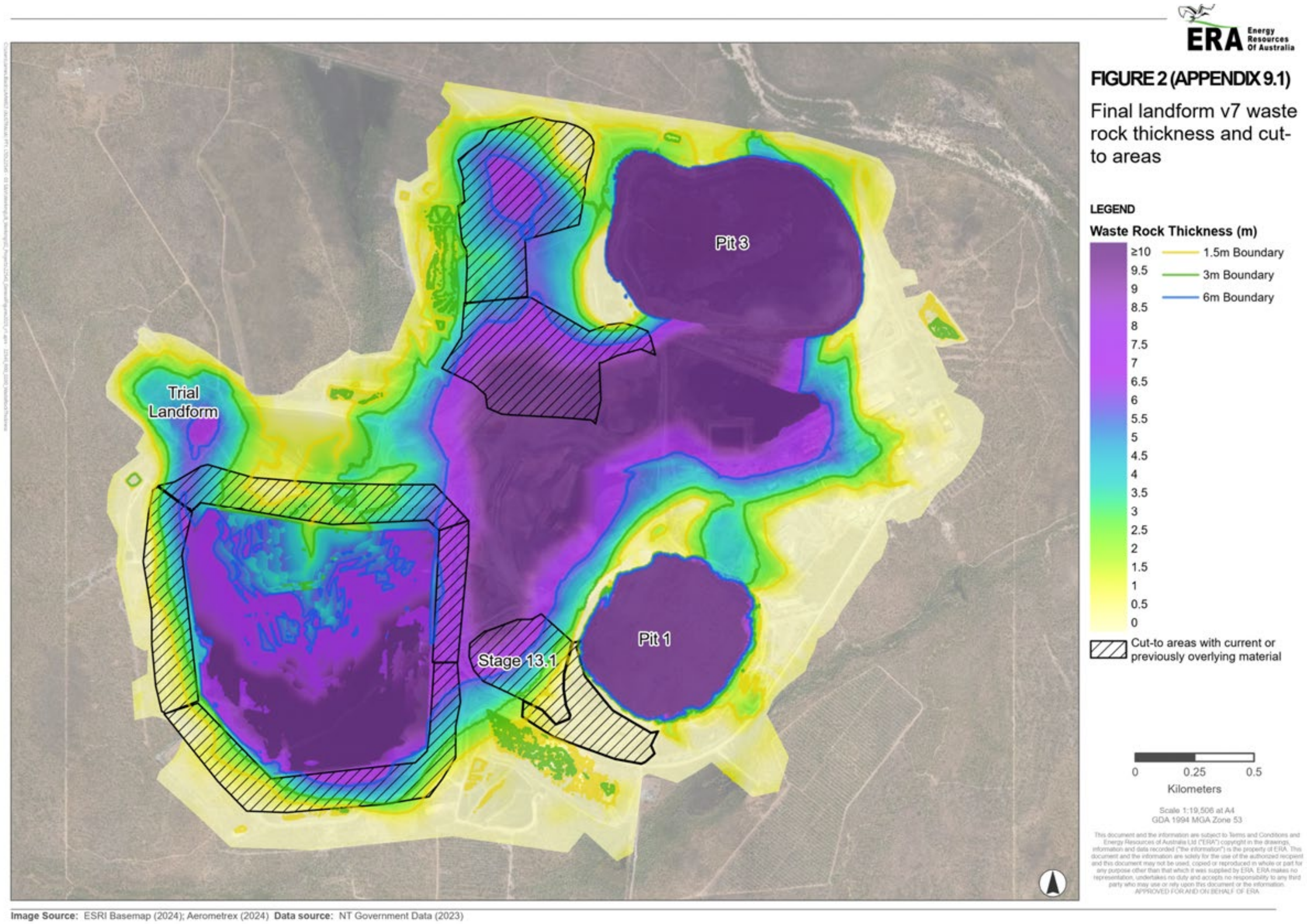

Figure 2: Proposed Final Landform (version 7) waste rock thickness and cut-to areas

Plant available water

Plant available water (PAW) can be defined as the portion of soil water that can be readily used by plants for growth and development. Several studies have been conducted since 2008 to determine if the available waste rock growth substrate (with the constructed consolidated horizon, as described above) can provide sufficient PAW to support the planned vegetation community (this was the focus of KKN ESR7B, Appendix 5.1 of the MCP). Wright (2025) provides a synthesis of studies on PAW and concludes that for a waste-rock depth of at least 6 m, a minimum of 25% of fine-grained sediments (<2 mm diameter) is sufficient to sustain the proposed Savanna Woodland CRE.

As presented in Okane (2024), even under simulated high-risk scenarios (prolonged drought and frequent fires) on an annual basis there is no modelled risk of a deficit for PAW. For a portion of days within each year, the risk profile for PAW deficit increases, although with consideration of seasonal climatic dynamics and the natural physiological adaptations of dominant savanna trees, long-lasting effects to established ecosystems are not expected.

Vegetation growth layers for the trial landform and Pit 1 contain approximately 20%-40% fine-grained material (Miller, 2020; Hancock *et al*., 2020). For subsequent areas of the final landform, particle size analysis of waste-rock stockpiles indicates a general range of between 20%–45% fines (Douglas Partners, 2019a, however rocks larger than 150 mm were excluded, meaning that actual proportions of fines may be less). Observationally, larger rocks contributed to a relatively small portion of the subject material, indicating reasonable feasibility for the sourcing of waste rock material with suitable characteristics for vegetation growth.

Consideration of retained structures

Several mine domains, such as the mill and administration block will have concrete and other compacted surfaces retained within the substrate. To support adequate drainage, water retention and sustainable root growth of established vegetation, a technical advice was developed by the Supervising Scientist (2024). The Technical advice includes the following guidelines, relevant to vegetation establishment and growth:

1. If >6 m of waste rock substrate is placed on top of retained surfaces, no limit to size or depth of retained surfaces is required.
2. If <6 m of waste rock substrate is placed on top (see Figure 3 for schematic):
    a. Linear concrete foundations up to 1 m wide may remain at unlimited length and depth.
    b. Columnar concrete foundations may be up to 3 m x 3 m in size and of unlimited depth.
    c. All concrete foundations to be separated by at least 2 m of non-compacted substrate.
    d. Horizontal surfaces must be broken up to a maximum fragment size of 3 m x 3 m and should be separated by at least 2 m of non-compacted substrate.
    e. Retained surfaces meeting the criteria above must be covered by a minimum of 1.5 m rock substrate.
    f. Retained surfaces must not interfere with surface preparation of the final landform.
    g. Toxicity of retained surfaces must be characterised and assessed prior to deposition of the final substrate.

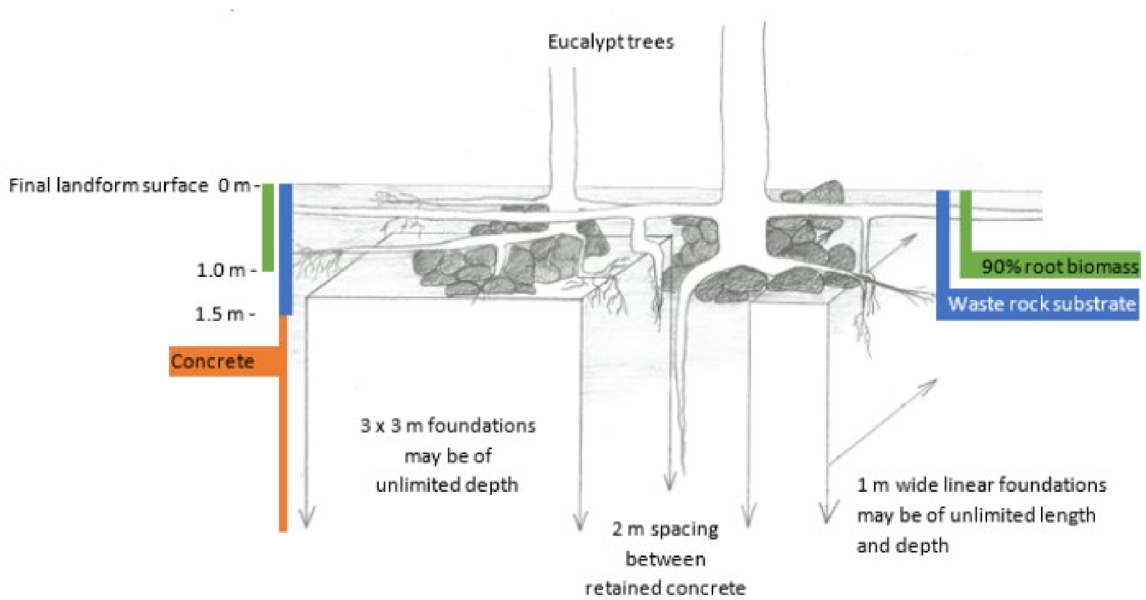

Figure 3: Dimensions and depth of retained structures relative to the root structure of vegetation

Potential chemical constraints

The waste rock material proposed for the vegetation growth layer differs from natural soils by having higher pH, electrical conductivity, cation exchange capacity, magnesium, total phosphorus and sulfate concentrations (Ashwath *et al.,* 1993).

Hutley and others (2021) suggest that elevated levels of $MgSO_4$ can be reasonably classified as a low risk to vegetation growth, however this study is focussed on riparian species only.

For Savanna woodland, earlier studies by Malden and others (1994) indicated a potential impact of $MgSO_4$ to germination from seed.

Further investigations (described below) will consider chemical-based substrate constraints, including observed surface salts, and reactions due to weathering of the constructed waste rock surface over time. Fitzpatrick and others (1989) suggest potential variations in structural development and decreases in pH due to oxidation of sulphide minerals. For non-waste rock areas, and particularly LAAs that were irrigated with mildly contaminated pond water for decades, no noticeable impacts to vegetation health have been observed (EcOz, 2022).

Cut-to areas and potential sub-stockpile compaction

Figure 1 illustrates that approximately 156 ha, or 19% of the final landform has already, or will be cut-to from existing stockpiles or embankments (noting that other minor areas (e.g. access roads, processing plant) may also be subject to a degree of compaction and subsequent reworking to achieve the planned final landform surface).

The area known as Stage 13.1 is a 4 ha section of final landform that became available for revegetation at the beginning of 2020. The area was cut down from a waste rock stockpile to the designed final landform surface level (i.e. cut-to), leaving an average 3.1 m thick layer of waste rock overlying natural ground.

Generally, the revegetation at Stage 13.1 has performed relatively poorly, which was attributed to a range of factors as described by Wright and others (2021). To investigate concerns with compaction of the Stage 13.1 rehabilitation area, dynamic cone penetrometer (DCP) testing was conducted by Douglas Partners (2019b). Results however were confounded by the presence of rocks and generally inconclusive.

Additional investigation

Under KKN ESR7D (Appendix 5.1 of the MCP) work has commenced to understand potential waste rock substrate constraints to vegetation establishment. In May 2024 several clusters of highly stressed trees were observed within Pit 1 rehabilitation. In consultation with stakeholders and subject experts, these were surveyed to understand severity, extent and potential cause. Several trees were also excavated to investigate the roots. Identified possible causes included constrained roots (due to the use of biopots) and herbicide spray drift.

To follow up on the above investigation, and conclusively investigate any chemical or physical constraints of the proposed waste rock substrate, including for cut-to areas, a detailed sampling and analysis program was commenced in October 2024 over areas of Stage 13.1 and Pit 1. The program has included sampling of substrates and plant materials over multiple seasons and analysis for a range of chemicals and nutrients. Outcomes of this investigation, and similar previous investigations, including implications for planned treatment and management of substrates, will be reported in subsequent versions of the MCP.

1.2 Surface preparation

Ripping is a common industry practice used in mine site rehabilitation to aid vegetation establishment. The process improves the success of re-vegetation by promoting infiltration of surface water and assisting in capture of organic material and finer sediments locally.

The entire TLF was ripped at 2 m intervals along the contours to a depth of approximately 50 cm (Daws and Poole, 2010, Photo 1). Over a decade later, the surface (particularly in the waste rock only areas) has a similar appearance now to what it did immediately after ripping. This has contributed to concerns by Traditional Owners around traversability and they have indicated a preference to minimise ripping wherever possible across the final landform.

As part of a trial, a similar approach was applied at Stage 13.1. This resulted in larger boulders catching the dozer tynes, leaving deep linear gouges across the surface (Wright *et al.,* 2021). The majority of the Stage 13.1 surface was subsequently graded to achieve a mostly flat surface.

Stakeholder consultation with the NLC and the GAC have indicated that deep ripping of the landform may impact traversability and should be minimised wherever possible. To address these stakeholder concerns and with lessons learnt from the TLF and Stage 13.1, a different approach was trialled on the surface of Pit 1. A grader blade was used to apply a light scarification (i.e. shallow 'ripping' using a grader blade with teeth 10 cm deep). Recent inspections suggest that the surface scarification is no longer visible and the surface is easily traversed on foot Photo 2).

At this early stage, the lesser degree of surface preparation has not had a noticeable impact on ecosystem establishment. However, this very low level of scarification does not appear sufficient to manage sediment and erosion. A water, erosion and sediment control plan is being developed that will recommend an appropriate scarification program that balances the sediment risk and benefits for revegetation success with the need for a traversable surface. Adoption of this into the current strategy is subject to further consultation with stakeholders and suitable alternatives will be carefully considered.

Photo 1: Contour ripping on trial landform trial of 2 m interval (2010)

Photo 2: Scarification of the Pit 1 surface as seen in January 2024

Rock habitat features

Nine distinct rocky habitat features were constructed on Pit 1 during 2021 (Photo 3). The rock habitat features were designed by Dr Peter Christophersen (KNPS), in consultation with the Mirarr, as documented by Brady and others (2021), to improve cultural values, landscape heterogeneity, and encourage a diversity of preferential flora and fauna.

For the broader final landform, similar rockpiles are proposed along pre-determined lines (also developed in consultation with the Traditional Owners) that will link the surrounding ecosystem to the final landform (Figure 2) and encourage the return of fauna from the surrounding areas. Excess large rocks will be recovered during bulk material movement and used for this purpose.

Discussions of the links between desired flora and fauna and people's connection to each other and to places, story and cultural practice, have also been held. The selection of plant species that may be actively established for the rocky habitat features will be determined through further engagement, to incorporate traditional ecological knowledge and cultural preferences.

With regards to the benefit of these and similar rocky habitat features for fauna colonisation; ongoing monitoring will provide valuable learning opportunities for future landform design and planning.

Photo 3: Rocky outcrop habitat feature installed on Pit 1

Figure 4: Preliminary plan for rocky habitat feature lines on the final landform

1.3 Additional supplementation of fauna habitat

A literature review is underway to identify opportunities to artificially or naturally enhance Ranger's rehabilitation areas to ensure that sufficient habitat resources exist (the focus of KKN ESR2B, Appendix 5.1 of the MCP).

A report on this is currently in draft, however key findings include:

- Unsuitable fire regimes, grazing livestock and predation by exotic fauna pose the biggest threats to native fauna populations, while controlled burning can help to promote and preserve certain habitat features;
- recolonisation barriers may include poor dispersal capability from source populations, increased competition or predation, limited foraging resources, poor breeding opportunities or absence of mature habitat features;
- important habitat components comprise species rich overstorey and understorey vegetation, with a degree of strata complexity and landscape level heterogeneity, which will provide a range of energy sources, development of natural habitat features and groundcover (including litter);
- appropriate understorey should be established as early as possible, maximising available habitat, resources and refuge from predators;
- successional fauna return is expected as vegetation is established, which may be augmented by artificial habitat structures;
- caution should be exercised with early establishment of artificial habitat structures prior to development of a mature vegetation structure (15–20 years), which may contribute to an ecological trap for returning species, where foraging resources are lacking and/or predation is favoured; and
- habitat creation and enhancement should be iterative and adaptive.

The ecosystem establishment strategy and planned preventative controls are aligned with these findings. Habitat features such as leaf litter, stag trees, coarse woody debris and hollows are expected to form naturally over varying timeframes, and will be promoted and preserved using fire. Of these, hollows are the slowest, with studies suggesting that it may take up to 100 years or more before the formation of tree hollows provides suitable habitat for some species (Taylor *et al.,* 2003; Goldingay, 2009; Goldingay, 2011). To aid relatively short-term recruitment of fauna, potential controls for habitat enhancement have been considered, including nest boxes, chainsaw hollows, and *in-situ* manufacturing of stag trees or habitat logs (i.e. using herbicide and/or chainsaw). The literature review also suggests caution in implementation of these controls until vegetation is suitably mature (15-20 years), at which point implementation would only be considered in the scenario that habitat for fauna, or indicators for habitat formation over time, are not evident in the established ecosystems.

Specifically for nest boxes, a trial was completed in 2024, with relevant outputs described in the associated project close-out documentation (RRP, 2025). Even for a relatively small-scale trial, the potential benefits of nest boxes did not seem to outweigh the effort and cost that are associated with installation and ongoing monitoring of use.

Another potential control is the transplantation of leaf litter and humus from surrounds. This could present multiple ecological and stability benefits at an early stage, including habitat for invertebrates and foraging resources for vertebrates. However, practical feasibility for a site wide strategy requires further consideration.

1.4 Seed collection and storage

The approved provenance zone for seed collection is based on assessment of environmental factors, species distributions, taxonomy, present and past gene flow, and species traits known to influence genetic variation in plants. Findings are presented in Zimmermann (2013) and Zimmermann and Lu (2015), with the GAC approved ‘conservative provenance zone’ clipped to the boundary of Kakadu National Park, as shown on Figure 5.

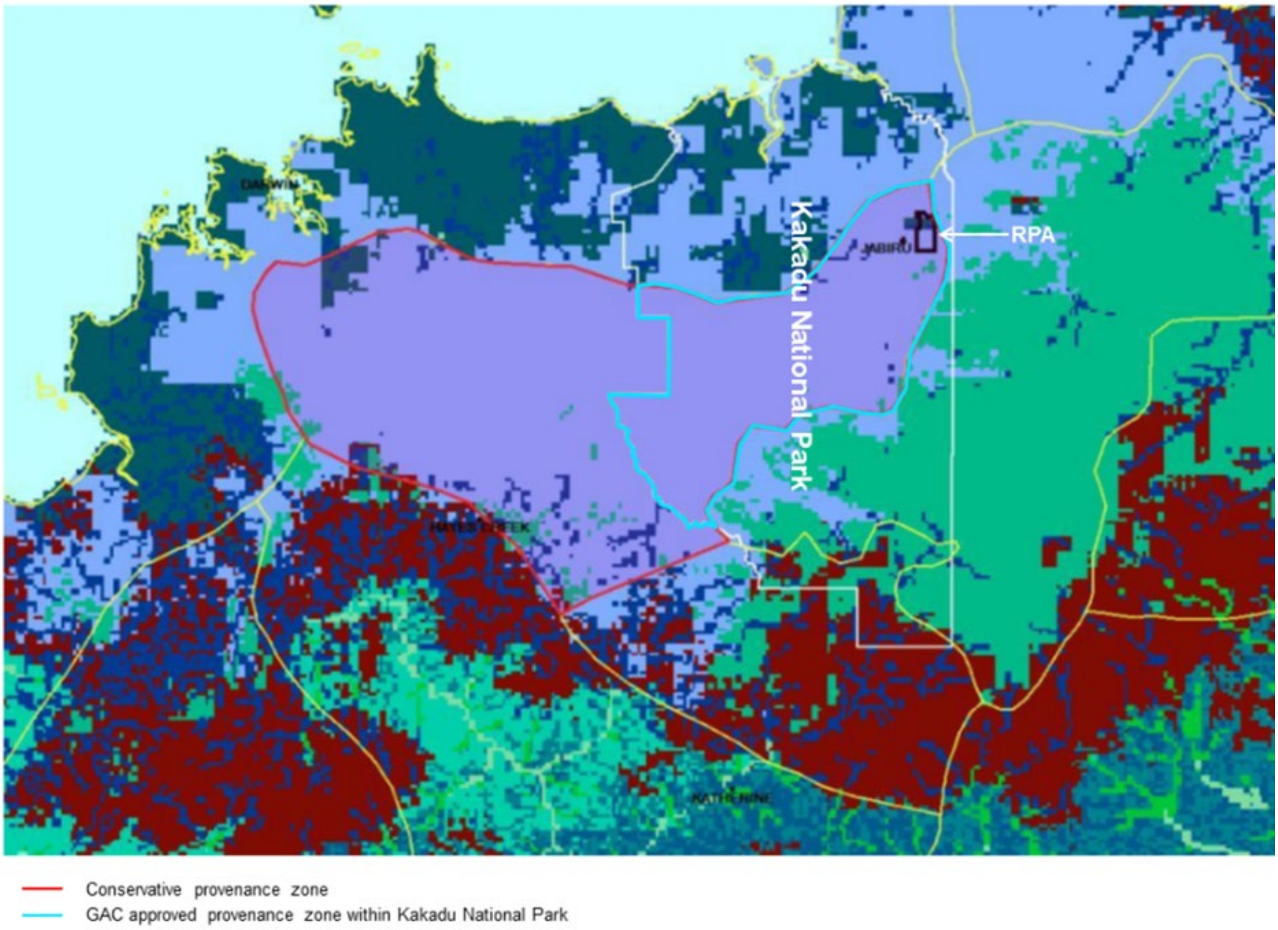

Figure 5: Proposed conservative provenance zone (bordered by the red line) and the GAC approved provenance zone within Kakadu National Park (bordered by the blue line)

KNPS collect seeds within the established provenance zone as per the terms and conditions agreed with Kakadu National Park. The permit and approved provenance zone assist in ensuring:

1. the genetic make-up of the revegetation and resilience is consistent with locally adapted populations of each species and provides a buffer for adapting to future climate change;

2. seeds collected are well adapted to the environmental conditions and promote sufficient genetic diversity to prevent inbreeding; and
3. the impact of seed collection to the natural and cultural values of Kakadu National Park are managed.

Seed availability for collection may be influenced by various environmental factors, including repeated ‘poor’ wet seasons, herbivory by fauna (e.g. cockatoos) or fire. For this reason, the collection program is designed with a degree of flexibility and allows for and encourages early collection for species with adequate storage life. Regular reconnaissance, field testing and knowledge of the landscape ensures that seed is collected at maximum viability. After collection, vegetative material is carefully processed according to industry standards and traditional knowledge for individual species, with relatively pure seed lots dried to maintain viability for long-term storage.

Seed storage principles are based on minimising temperature, moisture content and oxygen. To achieve these conditions, dried seed lots are vacuum-packed and managed for long-term storage. Vacuum-packing minimises exposure to oxygen, humidity and limits the impacts from pests. A consistent temperature of 21°C minimises the effects of condensation when seed lots are exposed to ambient temperatures in a tropical climate. Unprocessed plant material and bulk grass seed is stored separately to avoid transfer of pests.

This process has so far proven to be effective. In 2019, CDU was engaged to conduct seed viability and germination testing for 80 selected seed lots across 49 species with a range of collection dates. The results were used to validate the storage process and facilities, whilst determining acceptable storage timeframes for various species and groups. The Ranger Project Team is in the processes of setting up an ongoing, periodical seed testing campaign, which will further inform collection and storage requirements.

The majority of dominant species (e.g. Eucalypts, Corymbias and Acacias) have a proven seed longevity of at least 8-10 years, and a large portion of required seeds have already been collected and are in storage. Other species with limited storage life will require collection closer to the time of planting.

A seed management database is maintained, which includes and is progressively updated to include:

- relevant information for each seed lot, including collection details, estimated storage life, estimated viability and quantity of available seed;
- area based target planting densities, considering predicted ecosystem development and designed to achieve proposed vegetation communities; and
- a derived annual plan for seed collection, considering previous experience.

1.5 Tubestock propagation

For many rehabilitated mine sites, most flora species are established by direct seeding. Results can be variable and are often supplemented with tubestock planting, particularly in the case of hard-rock mines. At Ranger, the harsh conditions and absence of available topsoil have led to historic direct seeding trials indicating poor outcomes, particularly when assessed against environmental requirements for rehabilitation and closure criteria. For historic revegetation trials and more recently the TLF, planted tubestock areas have out-performed direct-seeded areas in terms of plant survival, growth, stem density and species composition (Daws and Gellert, 2011; additional unreported data). In addition, the increased rates of germination under nursery conditions allow a significant reduction in the volume of seed required to achieve the same densities. This is favourable considering the restricted seed collection provenance zone and permit limitations within Kakadu National Park.

Understory species have seen similar results. Parry and others (2022) found that several understorey species planted from tubestock demonstrated increased growth, persistence, recruitment and spread, compared to individuals that were directly seeded, resulting in larger, more robust plants.

With tubestock being the preferred establishment method for the majority of species, the production capacity of the Ranger plant nursery is an important consideration. The nursery has capacity for approximately 100,000 tubestock at any one time, with an average tubestock growth time for most species of around two to three months. If scheduling requires year round planting then it may be feasible to produce three rounds of propagation annually, with an annual capacity of around 300,000 tubestock. However, planting in the late wet or early dry season (typically April/May) (with provision of suitable irrigation) will be prioritised for a number of reasons, including:

- maximum availability of species with perishable seed, allowing propagation of a greater species richness;
- avoidance of dormancy issues with some species that occurs when propagated over the dry season and planted during the build-up;
- optimal access to planting areas by heavy machinery and vehicles;
- minimal impacts from wind, heavy rain and erosion;
- minimal early impacts from weeds, pests and disease in cooler weather;
- controlled conditions for irrigation; and
- relatively cooler temperatures more favourable for planters and for reducing planting shock.

For planting in other seasons, trials have indicated that variations in germination and growth for most species can be accounted for with particular techniques, including the use of a naturally heated greenhouse, longer propagation periods and increased initial planting densities.

Records are maintained for nursery production and will be used to inform nursery production for the final landform. The records include species specific details of:

- optimal propagation period for different seasons;

- optimal germination methods (e.g. seed trays or required seed quantities per pot); and
- commentary on susceptibility to fungus, influence of seed age, seasonal variations, etc.

To maintain tubestock quality, a tubestock standard has been developed for Ranger Mine Nursery, based on industry best practice, field trials, observations and local knowledge. This is presented in Table 1.

Table 1: Tubestock standard for Ranger Mine Nursery

Standard	Description
Pot type	Seedling supplied in sterilised, nursery grade plastic tube, unless otherwise directed, without significant damage.
Potting mix	Potting mix with appropriate water holding capacity, and incorporated slow-release fertiliser and microbial additives, to a level within 5 mm of pot lip.
Genetic diversity	Sufficient genetic diversity.
Size and age	Seedling is appropriate size and age as verified by reference material and/or Ranger Project Team supervisor, i.e. with multiple sets of leaves and holding potting mix without major signs of root bounding.
General health	Leaf colour and size is true to species form, without signs of active pests, disease, dieback or injury.
Seedling structure	Seedlings should be growing in accordance with natural habit (i.e. free standing where applicable without staking or tip pruning).
Stem position	The seedling stem base should be at least 10 mm from the edge of the pot.
Arrangement	Prior to planting, seedlings must be arranged into planting trays as specified by the area-specific planting plan.

Pot type

Standard plastic nursery tubes are the commercial standard and were used for all revegetation trials at Ranger prior to 2017. Biopots were used in revegetation trials between 2018 and 2022. The biopots are made from a compacted rice-hull and are a similar shape to the standard tubes. Biopots have proven to be suitably durable under irrigation regimes and provide the added benefit of allowing tubestock to be planted whilst remaining in the pots. However, when compared to standard plastic tubes, the biopots planted on Stage 13.1 and Pit 1 demonstrated poorer survival rates. In addition, the decomposition rates of biopots planted within waste-rock are uncertain and have been attributed to poor root formation and impacted plant growth in some areas of Pit 1. With consideration of these findings and potential risks related to the continued use of biopots, standard plastic nursery tubes are specified as the preferred pot type and will be sterilised for repeat use.

Seed cannot be stored for particular species (e.g. *Planchonia careya*) whilst maintaining viability. In these cases, tubestock has previously been propagated when seed is available and then held for an extended period of time before planting, with transfer into larger pots to reduce root bounding. Although this method has proven successful, larger plants are more difficult to handle during planting and require larger holes, therefore will be avoided as much as possible.

Potting mix and microorganism inoculation

Microorganism inoculation, often with commercially produced microbial additives, has become standard practice in many commercial nurseries due to the vital role that microbes perform in plant nutrient acquisition. Reddell and Zimmermann (2002) suggest that inoculation can be achieved using ectomycorrhizal fungi collected from surrounding areas. This was done for tubestock planted on the TLF and Stage 13.1.

For Stage 13.1, trial outcomes indicated that seedlings inoculated with locally sourced and/or commercial microbes were more robust than control seedlings. Furthermore, the better performing areas on Pit 1 suggest that commercially sourced microbial additives are generally suitable.

Commercial microbial additives were included in potting mixes used for Stage 52 trials and will be included in the standard potting mixes used for subsequent areas.

Promotion of genetic diversity

Sufficient genetic diversity of tubestock will improve the overall resilience to external threats and prevent issues associated with inbreeding. Each delivered seed lot is made up from several individual plants and will include a degree of genetic diversity.

Tubestock size and age

With regard to tubestock size and age, trials have indicated that tubestock with a larger ‘root to shoot’ ratio are less prone to root bounding, more resilient and have a reduced initial water demand after planting.

1.6 Provision of suitable irrigation

Due to harsh environmental conditions and unreliable rainfall, initial irrigation for up to six months has proven to be essential for successful establishment of tubestock on waste rock, as indicated by historic trials and more recently at the TLF (Daws and Gellert, 2010, Daws and Gellert, 2011), Stage 13.1 and Pit 1. These trials have included networks of raised rotational sprinklers and a travelling large-scale pivot system, both with relatively gentle application so not to displace newly planted seedlings or substantially contribute to erosion of the new landform. Georgetown Creek Median Bund Leveline (GCMBL) was used as the water source for Pit 1, Stage 13.1 and Stage 52 trials, with regular water quality testing undertaken to indicate the suitability of water for irrigation.

For the broader final landform, monitoring and maintenance of the irrigation system during plant establishment is imperative. Any damage or malfunctioning of the irrigation equipment must be recognised early to minimise impact upon vegetation. The use of pressure-based alarms and a log recording the operation of each panel will ensure that any incidents are recognised and rectified.

The optimal regime will be unique for each area and influenced by rainfall patterns, season, substrate, temperatures, wind, evaporation, and infiltration rates. Irrigation should aim to optimise survival while ensuring appropriate root development and long-term resilience to drought conditions. Ongoing irrigation regime will be informed by regular monitoring of vegetation response and may require maintenance and operation for up to six months.

Similar to what was applied at Pit 1, the following broad principles have been, and will continue to be considered for other areas:

- irrigation applied immediately prior, during (if practical) and following planting to cool surface temperatures and minimise planting shock (this may be achieved with a combination of automated irrigation and/or low pressure hoses);
- revegetation areas to receive up to 5 mm of irrigation every 12 hours immediately following planting to maintain moisture levels in the upper substrate profile;
- irrigation gradually reduced to nightly soaks over the course of a few weeks; and
- as plants begin to settle (i.e. post-planting mortality rate is stabilised with plants showing signs of new growth), less frequent, heavier soaks applied over several months, with the upper substrate profile partially drying in between.

1.7 Application of pre-emergent herbicide

For most areas of Stage 13.1 and Pit 1, Cavalier (a pre-emergent herbicide with active ingredient Oxyfluorfen at 240 g/L) was applied evenly at a rate of approximately 1.9 L/ha, either under irrigation or during the wet season, a minimum of two weeks prior to planting. The active ingredient in this herbicide kills seedlings upon germination and can be very effective in preventing colonisation of bare surfaces. To optimise effectiveness, the substrate surface was not disturbed for at least two weeks following application, and germination of the weed seeds was encouraged (via irrigation and/or seasonal rainfall). In areas where this wasn't applied, the effect has been clear, with substantially increased weed cover, competition with establishing vegetation and ongoing management required.

For Stage 52 and subsequent areas of the final landform, a similar methodology has been or will be applied during the wet season following construction of the surface layer, and prior to planting. A period of time will need to be allowed between application of a pre-emergent herbicide and planned direct seeding activities. At this stage, considering typical rates of decomposition, a conservative approach of at least four weeks is proposed.

In addition to the application of pre-emergent herbicide, emergent weeds will be treated with appropriate short acting herbicides prior to planting.

1.8 Preparation of planting holes

Preparation of planting holes will utilise a custom-designed auger (designed by KNPS) attached to a small excavator (Photo 4). This method creates a hole approximately 400 millimetres (mm) deep and 150 mm wide. Monitoring data for areas where this was previously implemented (Stage 13.1, Stage 52 and Pit 1) suggests that this approach is suitable.

Photo 4: Small excavator with auger attachment

1.9 Fertiliser application for establishment

A slow-release tabular and/or granular fertiliser (suitable for native plants) will be applied to the base of each planting hole during planting, and mixed with the backfilled substrate, which has proven to be a suitable approach.

Re-application of a similar granular fertiliser has been applied during the following wet season to the base of establishing plants, however further refinement regarding the methodology and timing for this may be conducted.

1.10 Tubestock planting

Appropriate planting zones will be clearly defined across the final landform, including a network of access tracks to support initial planting, irrigation, monitoring and maintenance. Spacing of tubestock will follow a non-uniform pattern, as with previous revegetation trials, and considering the target stems per hectare (e.g. for 1,000 tubestock per hectare, tubestock will be planted at a spacing of approximately 2–4 m).

Plants will be carefully removed from plastic pots and placed into the planting hole to minimise loss of potting mix. Holes will be backfilled manually with the surrounding loosened substrate, focusing on contact with fines and removal of large rocks. The surface of the potting mix should be just below the final surface leaving a very slight depression which will assist with collecting water for the plant (Photo 5).

Photo 5: Planting of tubestock

In non-waste rock areas, planting without irrigation has proven to be successful if it can be timed with the onset of monsoon. In the case where irrigation is not able to be installed, a small handful of pre-soaked water crystals will be added to the base of each planting hole.

If biopots are at all used, they should be lightly crushed at the bottom prior to planting to facilitate root development, and account for uncertainties with pot decomposition rates. The rims of biopots should be buried below the surface to improve thermal insulation of the root ball and prevent moisture wicking.

1.11 Direct seeding (for suitable species only)

Although establishment from tubestock is the preferred method for most species, the benefits from a resourcing and cost perspective have prompted several trials, with reasonable success for some understorey species and a few midstory species.

Key learnings, as described by Parry and others (2022) and applicable to direct seeding under a mature canopy, are described in the following points:

1. Germination and persistence from seed is generally increased with the use of surface litter, likely due to retained moisture and reduced surface temperature. The surface litter may also protect the seeds/seedlings from rain wash or uprooting, and predation.

2. Under optimal conditions, the use of fertiliser may account for waste rock nutrient deficiency and is found to increase growth, flowering and fruiting.

Further unreported trials at the TLF and Pit 1 have seen some success with direct seeding under warm and wet conditions, whilst heavy rain has been observed to wash away seed from relatively bare areas. A direct seeding approach may be adopted for select species which have proven successful.

1.12 Secondary introductions

Where they require specific environmental conditions (e.g. accumulation of organic matter, surface cover and canopy cover), identified species may be established entirely via secondary introductions. An early study included in Gellert (2014) indicated that *Xanthostemon paradoxus*, a common local tree species, may fall into this category, however more recent investigations on Stage 52 have so far indicated that this limitation may be overcome with suitable initial irrigation and improved quality of tubestock. Remaining species that fall into this category are more likely to include herbaceous forbs and vines, of which the specific methods and optimal timing will be determined with ongoing monitoring and further trials on more mature revegetation (e.g. TLF).

1.13 Proposed planting compositions

The proposed planting composition (Table 4 and Table 5) is largely based on data provided by the Supervising Scientist (2021; 2025a), and includes a range of species that are most abundant in reference sites surveyed for broadscale savanna woodland, and also seasonally inundated savanna, where this may be applicable across the rehabilitated landform. There are however several species and vegetation groups for which composition/abundance is modified (Table 2).

Table 2: Differentiation of the savanna woodland CRE from reference sites

Relevant species, growth form or vegetation community	Description of differentiations in comparison to reference sites and/or previous experience
Understorey (particularly *Sorghum spp.)*	Several regional studies, including those conducted recently by Paramjyoti and others (2024), highlight the effect of frequent fires on the dominance of *Sorghum spp.* in broadscale savanna woodland understorey. These studies suggest that most of the relevant reference sites (which include *Sorghum spp.* as dominant understorey) are influenced by an inappropriate fire regime and should not represent a direct target for a sustainable re-constructed ecosystem, at least with regards to understorey. This concept was discussed at a workshop on the 24th of June 2021, which involved relevant ERA, OSS and NLC personnel, as well as experts from Charles Darwin University and KNPS. One outcome was the adoption of a ‘functional understorey approach’ for understorey composition closure criterion. This allows for a target composition that does not necessarily include a dominance of *Sorghum spp.*, will promote a more appropriate fire regime, and improve species richness and diversity. Drawing on outcomes from a workshop in August 2023, a ‘functional’ understorey composition has been developed for the broadscale savanna woodland community and includes shrubs (legume and non-legume), grasses (perennial and annual), forbs and vines (legume and non-legume). A draft list of species is included in Table 5. It is noted that this list is not exhaustive, and some potential naturally recruiting species have only been identified to genus or family level. Proposed establishment methods and timing of introduction will be further refined with consideration of trial outcomes and ongoing monitoring, including for landform stabilisation. A ‘functional’ understorey composition for seasonally inundated savanna and drainage lines, has not yet been determined.
Acacias	As documented by Paramjyoti and others (2024), the dominance of *Acacia mimula* in surveyed reference sites is attributable to frequent fire. Whilst the proposed broadscale savanna woodland vegetation community will still have *Acacia mimula* as a dominant Acacia, there will also be increased target relative abundance for several other Acacia species which have been identified as ecologically and/or culturally important.

Relevant species, growth form or vegetation community	Description of differentiations in comparison to reference sites and/or previous experience
Dry monsoon forest sub-community	Several species that have been identified as culturally significant and do not occur in reference sites (e.g. *Allosyncarpia ternata, Ficus spp.*) are proposed for establishment in 'clusters' of forest around rockpiles and/or broad concave slopes, with relatively low average densities across the landform, and in consultation with Traditional Owners.

Table 3 provides commentary for several of the attributes presented in Table 4 and Table 5.

Table 3: Description of the attributes relevant to the savanna woodland CRE

Attribute	Description
Relevance	An indication of relevance is provided with regard to relative density in reference sites, identified cultural species, and/or functional attributes.
Target stems per hectare or percentage ground cover (minimum and maximum)	The allowable range is prescribed, which is derived from, and reflects the high degree of variability between reference sites. This will encourage a variable composition across the landform, which may be tailored to suit localised variations in the topography and structure of the waste rock landform. Default ranges are applied for species that do not occur in reference sites (OSS 2019) but have been identified culturally (Garde 2015) or experienced previous success. Target percentage ground cover for understorey is not yet confirmed and will be included in future iterations of the MCP.
Target stems per hectare or percentage ground cover (minimum average)	The minimum average target stems per hectare or percentage cover across the final landform is prescribed, which is derived from average stem densities in reference sites, however reduced proportionately to allow increased species richness without overcrowding. Relatively small minimum average densities are included by default for species that do not occur in reference sites. Target percentage ground cover for understorey is not yet confirmed and will be included in future iterations of the MCP.
Proposed establishment method	Species may be established by tubestock, direct seeding or natural recruitment, based on research outcomes. Planting methods and timing for active introduction of understorey species is not yet confirmed and will be included in future iterations of the MCP.
Initial planting density (minimum, maximum and average)	Initial planting density values are estimated based on target stems and trial performance outcomes for each species. Values will be progressively updated with consideration of ongoing monitoring outcomes, through experience and monitoring species ongoing rehabilitation performance. Planting density for understorey is not yet confirmed and will be included in future iterations of the MCP.

Table 4: Proposed planting composition for midstorey and overstorey species (to be confirmed)

Species	Growth form	Reference	Target stems per ha. (min)	Target stems per ha. (max)	Target stems per ha. (ave)	Proposed Establishment Method	Initial planting density (stems/ha.) (min)	Initial planting density (stems/ha.) (max)	Initial planting density (stems/ha.) (ave)	Comment
Acacia difficilis	Shrub	Identified cultural species	0	30	15	Tubestock	0	46	23	Success with tubestock. Reduced population in reference sites possibly influenced by fire regime.
Acacia dimidiata	Shrub	Patchy coverage in reference sites, identified cultural species	0	30	15	Tubestock	0	50	25	Success with tubestock. Reduced population in reference sites possibly influenced by fire regime.
Acacia hemignosta	Tree	Sparse in reference sites	0	30	15	Tubestock	0	43	21	Success with tubestock.
Acacia lamprocarpa	Tree	Sparse in reference sites, identified cultural species	0	30	15	Tubestock	0	38	19	Success with tubestock.
Acacia latescens	Shrub	Spare in surrounding environment. High density in Ranger EIS	0	30	15	Tubestock	0	43	21	Success with tubestock. Reduced population in reference sites possibly influenced by fire regime.
Acacia mimula	Shrub	Dominant in reference sites (potentially influenced by inappropriate fire regime)	20	180	60	Tubestock	27	240	80	Success with tubestock.
Acacia oncinocarpa	Shrub	Patchy, sparse coverage in reference sites	0	50	15	Tubestock	0	77	23	Success with tubestock.
Allosyncarpia ternata	Tree	Identified cultural species	0	5	1	Transplant	0	6	1	Success with tubestock. Suitable for dry monsoon sub-community.
Alphitonia excelsa	Tree	Identified cultural species	0	5	1	Tubestock	0	10	2	Limited revegetation experience. Suitable for dry monsoon sub-community.
Antidesma ghaesembilla	Shrub	Bush food	0	1	0	Tubestock	0	1	0	Success with tubestock. Also some success with direct seeding into established vegetation. Suitable for dry monsoon sub-community.
Banksia dentata[#]	Tree	Sometimes occurs in seasonally inundated reference sites; identified cultural species	0	1425	53	Tubestock	0	300	59	Success with tubestock. Suitable for seasonally inundated areas.
Brachychiton diversifolius	Tree	identified cultural species	0	5	1	Tubestock	0	8	2	Success with tubestock.
Brachychiton megaphyllus	Tree	Patchy coverage in reference sites, identified cultural species	0	20	5	Tubestock	0	21	5	Success with tubestock. Propagation difficult in cooler months.
Breynia cernua	Shrub	Bush food	0	1	0	Tubestock	0	1	0	Success with tubestock. Requires fresh seed. Suitable for dry monsoon sub-community. Natural recruits observed.
Buchanania obovata	Tree	Sparse in reference sites, identified cultural species	0	20	5	Tubestock	0	25	6	Success with tubestock. Limited storage life.
Callitris intratropica	Tree	Identified cultural species	0	5	1	Tubestock	0	10	2	No revegetation experience. Reduced population in reference sites possibly influenced by fire regime.
Calytrix achaeta	Shrub	Sparse, patchy in reference sites	0	5	0	Tubestock	0	10	0	No revegetation experience.
Calytrix brownii	Shrub	identified cultural species	0	5	1	Tubestock	0	10	2	No revegetation experience.
Calytrix exstipulata	Shrub	Sparse in reference sites, identified cultural species	0	5	1	Tubestock	0	7	1	Success with tubestock.
Carallia brachiata	Tree	Identified cultural species	0	5	1	Tubestock	0	10	2	No revegetation experience. Suitable for dry monsoon sub-community.
Clerodendrum floribundum	Shrub	Identified cultural species	0	5	1	Tubestock	0	10	2	Success with tubestock.

Species	Growth form	Reference	Target stems per ha. (min)	Target stems per ha. (max)	Target stems per ha. (ave)	Proposed Establishment Method	Initial planting density (stems/ha.) (min)	Initial planting density (stems/ha.) (max)	Initial planting density (stems/ha.) (ave)	Comment
Cochlospermum fraseri	Shrub	Sparse in reference sites, identified cultural species	0	10	1	Tubestock	0	13	1	Waste rock coloniser and high recruitment. Will only plant sparsely in areas of finer waste rock. Also potential for direct seeding
Coelospermum reticulatum	Shrub	Identified cultural species	0	5	1	Tubestock	0	10	2	No revegetation experience.
Corymbia bleeseri	Tree	Patchy coverage (shallower soils?) in reference sites, identified cultural species	0	390	60	Tubestock	0	557	86	Success with tubestock.
Corymbia chartacea	Tree	Patchy coverage (shallower soils?) in reference sites	0	100	15	Tubestock	0	125	19	Success with tubestock.
Corymbia disjuncta	Tree	Identified cultural species	0	5	1	Tubestock	0	6	1	Success with tubestock.
Corymbia foelscheana /latifolia	Tree	Common in reference sites, identified cultural species	0	20	2	Tubestock	0	27	3	Success with tubestock.
Corymbia polycarpa	Tree	Identified cultural species	0	5	1	Tubestock	0	6	1	No tubestock experience, however some direct seeding in depressions.
Corymbia polysciada	Tree	Sparse, patchy in reference sites, identified cultural species	0	5	1	Tubestock	0	6	1	Success with tubestock.
Corymbia porrecta	Tree	Dominant in reference sites	0	220	60	Tubestock	0	314	86	Success with tubestock.
Croton arnhemicus	Shrub	Sparse in reference sites	0	10	2	Tubestock	0	20	4	No revegetation experience.
Dolichandrone filiformis	Tree	Sparse in reference sites	0	1	0	Tubestock	0	2	0	Success with tubestock.
Elaeocarpus arnhemicus	Tree	Identified cultural species	0	5	1	Tubestock	0	10	2	No revegetation experience. Suitable for dry monsoon sub-community.
Erythrophleum chlorostachys	Tree	Common in reference sites, identified cultural species	0	80	20	Tubestock	0	114	29	Success with tubestock.
Eucalyptus miniata	Tree	Dominant in reference sites, identified cultural species	10	200	70	Tubestock	15	308	108	Sensitive to waterlogging.
Eucalyptus phoenicea	Tree	Identified cultural species	0	5	1	Tubestock	0	7	1	Success with tubestock.
Eucalyptus tectifica	Tree	Sparse, patchy in reference sites	0	5	1	Tubestock	0	6	1	Success with tubestock.
Eucalyptus tetrodonta	Tree	Dominant in reference sites, identified cultural species	60	240	110	Tubestock	86	343	157	Success with tubestock.
Ficus platypoda	Tree	Identified cultural species	0	5	1	Tubestock	0	7	1	No revegetation experience. Suitable for dry monsoon sub-community.
Ficus racemosa	Tree	Identified cultural species	0	5	1	Natural	N/A	N/A	N/A	Observed natural recruitment on waste rock. Suitable for dry monsoon sub-community.
Fluggea virosa	Shrub	Bush food	0	1	0	Tubestock	0	1	0	Success with tubestock. Requires fresh seed, suitable for dry monsoon sub-community
Gardenia fucata	Tree	Identified cultural species	0	5	1	Tubestock	0	9	2	Success with tubestock.
Gardenia megasperma	Tree	Common, patchy in reference sites, identified cultural species	0	10	2	Tubestock	0	13	3	Success with tubestock. Reduced population in reference sites possibly influenced by fire regime.
Grevillea decurrens	Tree	Common in reference sites, identified cultural species	0	10	1	Tubestock	0	14	1	Success with tubestock.

Species	Growth form	Reference	Target stems per ha. (min)	Target stems per ha. (max)	Target stems per ha. (ave)	Proposed Establishment Method	Initial planting density (stems/ha.) (min)	Initial planting density (stems/ha.) (max)	Initial planting density (stems/ha.) (ave)	Comment
Grevillea pteridifolia#	Tree	Sparse in broadscale savanna but sometime occurs in seasonally inundated reference sites, identified cultural species	0	775	45	Tubestock	0	300	50	Success with tubestock. Remaining uncertainty regarding long-term suitability on waste-rock. Suitable for seasonally inundated areas.
Hakea arborescens	Tree	Low density in surrounding ecosystem	0	1	0	Tubestock	0	1	0	Success with tubestock.
Jacksonia dilatata	Shrub	Patchy abundance in surrounding ecosystem	0	1	0	Tubestock	0	1	0	Observed natural recruitment on waste rock.
Jasminum molle	Shrub	Low density in surrounding ecosystem	0	1	0	Tubestock	0	5	0	Remaining uncertainty regarding suitability on waste-rock.
Livistona humilis	Palm	Patchy coverage (fire affected?) in reference sites, identified cultural species	0	280	40	Tubestock	0	431	62	Success with tubestock.
Livistona inermis	Palm	Previous successes, present on rocky country in surrounding ecosystem	0	1	0	Tubestock	0	1	0	Success with tubestock.
Lophostemon lactifluus#	Tree	Sometimes occurs in seasonally inundated reference sites.	0	450	43	Tubestock	0	300	48	Suitable for seasonally inundated areas.
Melaleuca nervosa#	Tree	Sometimes occurs in seasonally inundated reference sites. Identified cultural species.	0	350	35	Tubestock	0	300	39	Suitable for seasonally inundated areas.
Melaleuca viridiflora#	Tree	Dominant in seasonally inundated reference sites; identified cultural species.	0	1250	165	Tubestock/ direct seeding	0	600	183	Suitable for seasonally inundated areas.
Owenia vernicosa	Tree	Sparse in reference sites, identified cultural species	0	5	1	Direct seeding	0	5	1	Direct seed in clusters near rock piles and ridgelines. Seed potentially germinated following fire.
Pandanus spiralis#	Palm	Sparse, patchy in broadscale savanna but dominant in seasonally inundated reference sites; identified cultural species	0	575	103	Direct seeding	0	600	114	Good growth on waste rock. Suitable for seasonally inundated areas.
Persoonia falcata	Shrub	Common in reference sites, identified cultural species	0	60	15	Tubestock	0	120	30	Propagation/seeding so far unsuccessful. Some limited recruitment in reveg areas.
Petalostigma pubescens	Tree	Identified cultural species	0	5	1	Tubestock	0	13	3	Success with tubestock.
Planchonella arnhemica	Tree	Sparse in reference sites, identified cultural species	0	10	5	Tubestock	0	20	10	Propagation/seeding so far unsuccessful.
Planchonia careya	Tree	Sparse in reference sites, identified cultural species	0	10	2	Tubestock	0	11	2	Success with tubestock. Requires fresh seed
Stenocarpus acacioides	Tree	Sparse, patchy in reference sites	0	5	1	Tubestock	0	13	3	Success with tubestock.
Sterculia quadrifida	Tree	Identified cultural species	0	5	1	Tubestock	0	10	2	No revegetation experience. Suitable for dry monsoon sub-community.
Syzygium eucalyptoides subsp. bleeseri	Tree	Sparse in reference sites, identified cultural species	0*	5*	1*	Tubestock	0*	6*	1*	Success with tubestock. Requires fresh seed. Suitable for seasonally inundated areas.
Syzygium eucalyptoides subsp. eucalyptoides	Tree	Sparse, patchy in reference sites, identified cultural species	0	10	1	Tubestock	0	14	1	Success with tubestock. Requires fresh seed for propagation. Suitable for dry monsoon sub-community
Syzygium suborbiculare	Tree	Sparse in reference sites, identified cultural species	0	5	1	Tubestock	0	7	1	Success with tubestock. Requires fresh seed
Terminalia carpentariae	Tree	Identified cultural species	0	5	1	Tubestock	0	7	1	Success with tubestock.

Species	Growth form	Reference	Target stems per ha. (min)	Target stems per ha. (max)	Target stems per ha. (ave)	Proposed Establishment Method	Initial planting density (stems/ha.) (min)	Initial planting density (stems/ha.) (max)	Initial planting density (stems/ha.) (ave)	Comment
Terminalia ferdinandiana	Tree	Common in reference sites, identified cultural species	10	70	30	Tubestock	13	93	40	Success with tubestock. May be suitable for direct seeding, propagation difficult in cooler months.
Terminalia pterocarya	Shrub	Common, patchy in reference sites	0	15	1	Tubestock	0	20	1	Success with tubestock.
Verticordia cunninghamii#	Shrub	Sometimes occurs in seasonally inundated reference sites	0	700	50	Tubestock	0	300	50	No revegetation experience.
Vitex glabrata	Tree	Identified cultural species	0	5	1	Tubestock	0	10	2	No revegetation experience.
Wrightia saligna	Shrub	Previous successes	0	1	0	Tubestock	0	1	0	Success with tubestock.
Xanthostemon paradoxus	Tree	Common in reference sites	0	250	50	Tubestock	0	357	71	Success with tubestock. Remaining uncertainty regarding suitability on waste-rock.

Planting densities are applicable only for seasonally inundated areas.

Note: Pre-2022, *Eucalyptus tintinnans* was included in the standard mix of species planted in Ranger rehabilitation; however, it has since been removed from planting lists as it is not considered a locally occurring species.

Table 5: Proposed understorey species planting composition for the broadscale savanna woodland vegetation community

Species	Growth form	Proposed Establishment Method	Comment
Acacia gonocarpa	Legume (shrub)	Planted	
Alloteropsis semialata	Grass (perennial)	Planted	
Alternanthera sp.	Forb	Passive	
Ampelocissus acetosa	Vine	Planted	
Amyema sanguinea	Forb	Passive	
Aristida holathera	Grass (perennial)	Mixed (planted and seeded)	May be suitable for initial landform stabilisation
Aristida hygrometrica	Grass (annual)	Passive	
Aristida inaequiglumis	Grass (perennial)	Mixed (planted and seeded)	
Aristida spp.	Grass (annual/perennial)	Passive	At least two additional species observed to recruit in multiple rehab areas
Asteraceae spp.	Forb	Passive	At least three species observed to recruit across multiple rehab areas
Austrodolichos errabundus (may actually be *Vigna vexillata)*	Legume (vine/forb)	Planted	
Blumea sp.	Forb	Passive	
Blumea tenellula	Forb	Passive	
*Boerhavia coccinea**	Vine	Passive	Common recruiter observed across all rehabilitation areas
Boerhavia sp.	Vine	Passive	
Brachyachne convergens	Grass (annual)	Passive	Common recruiter observed across all rehabilitation areas, which may be suitable for initial landform stabilisation
Buchnera linearis	Forb	Mixed (passive and seeded)	
Buchnera tetragona	Forb	Mixed (passive and seeded)	
Bulbostylis barbata	Grass (annual)	Passive	Common recruiter observed across most of the rehabilitation areas
Cartonema spicatum	Forb	Planted	low field survival - more investigation required as cultural important bushfood
Cayratia trifolia	Vine	Planted	
Chrysopogon fallax	Grass (perennial)	Mixed (planted and seeded)	
Chrysopogon latifolius	Grass (perennial)	Mixed (planted and seeded)	
*Cleome viscosa**	Forb	Passive	Common recruiter observed across all rehabilitation areas
Crotalaria brevis	Legume (vine/forb)	Passive	Common recruiter observed across all rehabilitation areas
Crotalaria montana	Legume (vine/forb)	Passive	Common recruiter observed across all rehabilitation areas
Cucumis melo	Vine	Passive	
Cymbopogon spp.	Grass (perennial)	Mixed (planted and seeded)	
Cyperus exaltatus	Grass (perennial)	Passive	
Cyperus spp.	Grass (annual/perennial)	Passive	At least four additional species observed to recruit across rehabilitated areas
Desmodium brownii	Legume (vine/forb)	Passive	
Desmodium spp.	Legume (vine/forb)	Passive	At least three additional species observed to recruit in multiple rehab areas
Desmodium triflorum	Legume (vine/forb)	Passive	
Dicanthium sp.	Grass (annual/perennial)	Mixed (passive and seeded)	
Digitaria sp.	Grass (annual/perennial)	Passive	Common recruiter observed across all rehabilitation areas
Dioscorea spp.	Vine	Planted	low field survival - more investigation required as cultural important bushfood
Ectrosia leporina	Grass (perennial)	Mixed (passive and seeded)	Common recruiter observed across all rehabilitation areas

Species	Growth form	Proposed Establishment Method	Comment
Ectrosia schultzii	Grass (annual/perennial)	Passive	
Enneapogon spp.	Grass (annual/perennial)	Passive	At least two additional species observed to recruit in multiple rehab areas
Eragrostis cumingii	Grass (annual)	Mixed (passive and seeded)	Common recruiter observed across all rehabilitation areas
Eragrostis schultzii	Grass (perennial)	Mixed (passive and seeded)	
Eragrostis spp.	Grass (annual/perennial)	Mixed (passive and seeded)	At least six additional species observed across rehabilitation areas.
Eriachne armittii	Grass (perennial)	Mixed (planted and seeded)	
Eriachne avenacea	Grass (annual)	Passive	
Eriachne ciliata	Grass (annual)	Passive	Common recruiter observed across most rehabilitation areas
Eriachne obtusa	Grass (perennial)	Mixed (planted and seeded)	May be suitable for initial landform stabilisation
Eriachne schultziana	Grass (perennial)	Mixed (planted and seeded)	
Eriachne sp.	Grass (annual/perennial)	Passive	
Eriachne triseta	Grass (perennial)	Mixed (planted and seeded)	
Euphorbia schultzii	Forb	Passive	Common recruiter observed across most rehabilitation areas
Fimbristylis spp.	Grass (annual/perennial)	Passive	At least seven additional species observed across rehabilitation areas
Fimbristylis tetragona	Grass (annual)	Passive	
Galactia megalophylla	Legume (shrub)	Planted	
Galactia tenuiflora	Legume (vine/forb)	Planted	May be suitable for initial landform stabilisation, potentially with irrigation
Geodorum densiflorum	Forb	Passive	
Gomphrena canesens	Forb	Passive	
Gomphrena sp.	Forb	Passive	At least four additional species observed across rehabilitation areas
Gonocarpus leptothecus	Forb	Passive	
Grevillea dryandri	Shrub	Planted	
Grevillea goodii	Shrub	Planted	
Grewia savannicola	Shrub	Planted	
Gymnanthera oblongata	Vine	Passive	Common recruiter observed across all rehabilitation areas
Haemodorum coccineum	Forb	Planted	low field survival - more investigation required as cultural important species
Heterachne abortiva	Grass (annual)	Passive	
Heteropogon contortus	Grass (perennial)	Passive	
Heteropogon triticeus	Grass (perennial)	Mixed (planted and seeded)	
Indigofera linifolia	Legume (vine/forb)	Passive	
Indigofera saxicola	Legume (shrub)	Planted	
Ipomea sp.	Vine	Passive	
Ludwigia spp.	Forb	Passive	At least three species observed across rehabilitation areas
Microstachys chamaelea	Forb	Passive	
Mitrasacme connata	Forb	Passive	
Mnesithea formosa	Grass (annual)	Mixed (passive and seeded)	May be suitable for initial landform stabilisation
Oldenlandia spp.	Forb	Passive	Common recruiter observed across most rehabilitation areas
Panicum sp.	Grass (annual/perennial)	Passive	
Paspalidium rarum	Grass (annual)	Passive	

Species	Growth form	Proposed Establishment Method	Comment
Petalostigma quadriloculare	Shrub	Planted	
Phyllanthus sp.	Forb	Passive	
Physalis angulata	Forb	Passive	Common recruiter observed across most rehabilitation areas
Polygala coralliformis	Forb	Passive	
Portulaca bicolor	Forb	Passive	
Portulaca spp.	Forb	Passive	At least two additional species observed across the rehabilitation areas
Pseudopogonatherum contortum	Grass (annual)	Mixed (passive and seeded)	
Pterocaulon serrulatum	Forb	Passive	Common recruiter observed across most rehabilitation areas
Ptilotus sp.	Forb	Passive	
Rhynchospora spp.	Grass (annual)	Passive	At least four species observed across the rehabilitation areas
Schizachyrium fragile	Grass (annual)	Passive	Common recruiter observed across all rehabilitation areas, which may be suitable for initial landform stabilisation
Scoparia dulcis	Forb	Passive	Common recruiter observed across most rehabilitation areas
Setaria sp.	Grass (annual/perennial)	Passive	
Sida sp.	Forb	Passive	
*Sorghum intrans**	Grass (annual)	Passive	
Spermacoce spp.	Forb	Passive	At least four species observed across the rehabilitation areas
Sphaeromorphaea littoralis	Forb	Passive	
Sporobolus australasicus	Grass (annual)	Passive	Common recruiter observed across all rehabilitation areas
Stemodia lythrifolia	Forb	Passive	Common recruiter observed across most rehabilitation areas
Stemodia sp.	Forb	Passive	
Stylidium candelabrum	Forb	Passive	
Stylidium semipartitum	Forb	Passive	
Tacca leontopetaloides	Forb	Passive	
Tephrosia oblongata	Legume (shrub)	Planted	
Tephrosia remotiflora	Legume (shrub)	Planted	
Tephrosia spp.	Legume (vine/forb)	Passive	At least four additional species observed across the rehabilitation areas
Tephrosia subpectinata	Legume (shrub)	Planted	
Triodia bitextura	Grass (perennial)	Passive	
Uraria lagopodioides	Legume (vine/forb)	Planted	May be suitable for initial landform stabilisation, potentially with irrigation
*Urochloa pubigera**	Grass (annual)	Passive	Common recruiter observed across most rehabilitation areas
Urochloa sp.	Grass (annual)	Passive	
Vigna adenantha	Legume (vine/forb)	Passive	
Vigna lanceolata var. filiformis	Legume (vine/forb)	Passive	
Vigna radiata var. sublobata	Legume (vine/forb)	Passive	
Xenostegia tridentata	Vine	Passive	

* Although considered local and native, these species will not be actively introduced, and due to their aggressive and potentially transforming nature, will be actively managed similar to other 'weed' species.

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APPENDIX 9.2: NATIVE VERTEBRATE FAUNA EXPECTED TO OCCUR ON THE REHABILITATED LANDFORM

Native Vertebrate Fauna Expected to Occur on the Rehabilitated Landform

Ranger Mine Closure Plan

2025

Unique Reference: PLN007
Revision: 0.25.1

Native mammal, bird, reptile and amphibian species from 35 savanna woodland survey sites (SLR Consulting, 2021) and additional species highlighted by Dr John Woinarski (pers. comm. Woinarski, CDU, May 2024) are listed in Table 1 to Table 4.

Threated species, and frugivorous and/or nectivorous birds, are highlighted due to their relevance to closure criteria and/or role in external exchanges and vegetation dispersal.

The listed species are not exhaustive and not all species may utilise the constructed landform. The outcomes of recent surveys by OSS (currently unpublished), further survey efforts and more advanced monitoring techniques may be used to further inform an appropriate fauna reference ecosystem and indicative trajectory towards this.

Table 1: Native mammals expected to occur on the rehabilitated landform

Scientific Name	Common Name
Antechinus bellus	Fawn Antechinus *
Canis dingo	Dingo
Dasyurus hallucatus	Northern Quoll *
Isoodon macrourus	Northern Brown Bandicoot
Melomys burtoni	Grassland Melomys
Mesembriomys gouldii gouldii	Black-footed Tree-rat (Kimberley and mainland NT) *
Notamacropus agilis	Agile Wallaby
Osphranter antilopinus	Antilopine Wallaroo
Osphranter robustus	Common Wallaroo
Petaurus ariel	Savanna Glider
Pteropus alecto	Black Flying-fox
Saccolaimus saccolaimus nudicluniatus	Bare-rumped Sheath-tailed Bat *,#
Tachyglossus aculeatus	Short-beaked Echidna
Trichosurus vulpecula arnhemensis	Northern Brushtail Possum *

***** species listed as threatened under the relevant Commonwealth and NT legislation.

[#] species highlighted by John Woinarski (pers. comm. Woinarski, CDU, May 2024) as potentially present, however not identified by SLR in 2021.

Table 2: Native birds expected to occur on the rehabilitated landform

Scientific Name	Common Name	Importance of Fruit	Importance of Nectar
Accipiter fasciatus	Brown Goshawk		
Aegotheles cristatus	Australian Owlet-nightjar		
Anhinga novaehollandiae	Australasian Darter		
Aprosmictus erythropterus	Red-winged Parrot	2	2
Artamus cinereus	Black-faced Woodswallow		2
Artamus minor	Little Woodswallow		

Scientific Name	Common Name	Importance of Fruit	Importance of Nectar
Burhinus grallarius	Bush Stone-curlew		
Cacatua galerita	Sulphur-crested Cockatoo	1	
Cacatua sanguinea	Little Corella	1	
Cacomantis variolosus	Brush Cuckoo		
Calyptorhynchus banksii	Red-tailed Black Cockatoo		
Caprimulgus macrurus	Large-tailed Nightjar		
Centropus phasianinus	Pheasant Coucal		
Chalcites minutillus	Little Bronze-cuckoo		
Chlamydera nuchalis	Great Bowerbird	2	
Circus assimilis	Spotted Harrier		
Cissomela pectoralis	Banded Honeyeater		1
Cisticola exilis	Golden-headed Cisticola		
Climacteris melanurus	Black-tailed Treecreeper		
Colluricincla harmonica	Grey Shrike-thrush		
Colluricincla megarhyncha	Little Shrike-thrush	2	
Conopophila albogularis	Rufous-banded Honeyeater		1
Conopophila rufogularis	Rufous-throated Honeyeater		
Coracina novaehollandiae	Black-faced Cuckoo-shrike		
Coracina papuensis	White-bellied Cuckoo-shrike	2	
Corvus orru	Torresian Crow		
Cracticus nigrogularis	Pied Butcherbird		
Dacelo leachii	Blue-winged Kookaburra		
Dicaeum hirundinaceum	Mistletoebird	1	
Dicrurus bracteatus	Spangled Drongo	2	
Ducula spilorrhoa	Torresian Imperial Pigeon	1	
Edolisoma tenuirostre	Cicadabird	2	
Entomyzon cyanotis	Blue-faced Honeyeater	2	1
Eolophus roseicapilla	Galah		
Ephippiorhynchus asiaticus	Black-necked Stork		
Erythrotriorchis radiatus	Red Goshawk *,#		
Eudynamys orientalis	Eastern Koel	1	
Eurostopodus argus	Spotted Nightjar		
Eurystomus orientalis	Dollarbird		
Falco berigora	Brown Falcon		
Falco cenchroides	Nankeen Kestrel		
Falco longipennis	Australian Hobby		
Geopelia cuneata	Diamond Dove		

Scientific Name	Common Name	Importance of Fruit	Importance of Nectar
Geopelia humeralis	Bar-shouldered Dove	2	
Geopelia placida	Peaceful Dove		
Geophaps smithii smithii	Partridge Pigeon *		
Gerygone chloronota	Green-backed Gerygone		
Gerygone olivacea	White-throated Gerygone		
Grallina cyanoleuca	Magpie-lark		
Haliaeetus leucogaster	White-bellied Sea-Eagle		
Haliastur sphenurus	Whistling Kite		
Hamirostra melanosternon	Black-breasted Buzzard		
Lalage leucomela	Varied Triller	1	1
Lalage tricolor	White-winged Triller		
Lichmera indistincta	Brown Honeyeater		1
Malurus melanocephalus	Red-backed Fairy-wren		
Manorina flavigula	Yellow-throated Miner		2
Megapodius reinwardt	Orange-footed Scrubfowl	1	
Melithreptus albogularis	White-throated Honeyeater		1
Merops ornatus	Rainbow Bee-eater		
Microeca flavigaster	Lemon-bellied Flycatcher		
Milvus migrans	Black Kite		
Myiagra alecto	Shining Flycatcher		
Myiagra rubecula	Leaden Flycatcher		
Myiagra ruficollis	Broad-billed Flycatcher		
Myzomela obscura	Dusky Honeyeater		
Neochmia phaeton	Crimson Finch		
Ninox boobook	Australian Boobook		
Ninox connivens	Barking Owl		
Oriolus flavocinctus	Yellow Oriole	1	
Oriolus sagittatus	Olive-backed Oriole	2	
Pachycephala rufiventris	Rufous Whistler		
Pardalotus striatus	Striated Pardalote		
Philemon argenticeps	Silver-crowned Friarbird	2	1
Philemon buceroides	Helmeted Friarbird	2	1
Philemon citreogularis	Little Friarbird	2	1
Pitta iris	Rainbow Pitta		
Platalea regia	Royal Spoonbill		
Platycercus venustus	Northern Rosella	2	
Podargus strigoides	Tawny Frogmouth		

Scientific Name	Common Name	Importance of Fruit	Importance of Nectar
Poephila acuticauda	Long-tailed Finch		
Poephila personata	Masked Finch		
Pomatostomus temporalis	Grey-crowned Babbler		
Psitteuteles versicolor	Varied Lorikeet		1
Ptilinopus regina	Rose-crowned Fruit-dove	1	
Rhipidura dryas	Arafura Fantail		
Rhipidura leucophrys	Willie Wagtail		
Rhipidura rufiventris	Northern Fantail		
Scythrops novaehollandiae	Channel-billed Cuckoo	1	
Smicrornis brevirostris	Weebill		
Sphecotheres vieilloti	Australasian Figbird	1	
Stizoptera bichenovii	Double-barred Finch		
Stomiopera unicolor	White-gaped Honeyeater	2	1
Struthidea cinerea	Apostlebird		
Synoicus ypsilophora	Brown Quail		
Taeniopygia guttata	Zebra Finch		
Threskiornis spinicollis	Straw-necked Ibis		
Todiramphus macleayii	Forest Kingfisher		
Todiramphus sanctus	Sacred Kingfisher		
Trichoglossus rubritorquis	Red-collared Lorikeet	2	1
Turnix castanotus	Chestnut-backed button-quail		
Tyto novaehollandiae kimberli	Masked Owl (Northern Mainland) *		

* species listed as threatened under the relevant Commonwealth and NT legislation.

species highlighted by John Woinarski (pers. comm. Woinarski, CDU, May 2024) as potentially present, however not identified by SLR in 2021.

1 Indicates that most of the diet is fruit, or nectar.

2 Indicates that fruit, or nectar is important, but other dietary items are more important.

Table 3: Native reptiles expected to occur on the rehabilitated landform

Scientific Name	Common Name
Amalosia rhombifer	Zigzag Velvet Gecko
Anilios spp.	Blind Snake
Anilios unguirostris	Claw-snouted Blind Snake
Antaresia childreni	Children's Python
Brachyurophis roperi	Northern Shovel-nosed Snake
Carlia amax	Two-spined Rainbow Skink
Carlia gracilis	Slender Rainbow-skink

Scientific Name	Common Name
Carlia munda	Shaded-litter Rainbow-skink
Carlia triacantha	Desert Rainbow-skink
Chlamydosaurus kingii	Frilled Lizard
Cryptoblepharus cygnatus	Swanson's Snake-eyed Skink
Cryptoblepharus metallicus	Metallic Snake-eyed Skink
Cryptophis pallidiceps	Northern Small-eyed Snake
Ctenotus essingtonii	Port Essington Ctenotus
Ctenotus robustus	Robust Ctenotus
Ctenotus storri	Storr's Ctenotus
Ctenotus vertebralis	Scant-striped Ctenotus
Delma borea	Rusty-topped Delma
Delma tincta	Excitable Delma
Dendrelaphis punctulata	Green Tree Snake
Diporiphora bilineata	Two-lined Dragon
Eremiascincus isolepis	Northern Bar-lipped Skink
Furina ornata	Orange-naped Snake
Gehyra australis	Northern Dtella
Glaphyromorphus darwiniensis	Northern Mulch-skink
Heteronotia binoei	Bynoe's Gecko
Lerista karlschmidti	Karl Schmidt's Lerista
Lialis burtonis	Burton's Snake-lizard
Liasis fuscus	Water Python
Lophognathus gilberti	Gilbert`s Dragon
Menetia greyii	Grey's Menetia
Menetia maini	Northern Dwarf Skink
Morethia storri	Storr's Snake-eyed Skink
Notoscincus ornatus	Ornate Soil-crevice Skink
Oedura marmorata	Marbled Velvet Gecko
Proablepharus tenuis	Slender Snake-eyed Skink
Tiliqua scincoides intermedia	Northern Blue-tongued Skink *,#
Varanus scalaris	Spotted Tree Monitor
Varanus tristis	Black-headed Monitor

***** species listed as threatened under the relevant Commonwealth and NT legislation.

[#] species highlighted by John Woinarski (pers. comm. Woinarski, CDU, May 2024) as potentially present, however not identified by SLR in 2021.

Table 4: Native amphibians expected to occur on the rehabilitated landform

Scientific Name	Common Name
Austrochaperina adelphe	Northern Territory Frog
Crinia bilingua	Bilingual Frog
Cyclorana australis	Giant Frog
Limnodynastes convexiusculus	Marbled Frog
Litoria bicolor	Northern Dwarf Tree Frog
Litoria caerulea	Green Tree-Frog
Litoria coplandi	Common Rock Frog
Litoria nasuta	Rocket Frog
Litoria pallida	Pale Frog
Litoria ridibunda	Western Laughing Tree Frog
Litoria tornieri	Black-shinned Rocket Frog
Notaden melanoscaphus	Northern Spadefoot
Platyplectrum ornatus	Ornate Burrowing Frog
Uperoleia lithomoda	Stonemason Toadlet